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MINISTRY OF ROAD TRANSPORT & HIGHWAYS

Karnataka
Public Works, Ports &
Inland Water Transport Department

Project:

Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"

Subject:

KD-6- Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume -II: Design Report

Part II: Design of Tunnels
(A)-Proposed Tunnel Design, Standards

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Revision History

Rev.	Date	Long Description

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Introduction

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorporation of Client's observations on earlier submitted "KD5: Kucha Draft Detailed Project Report (KDDPR)" vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

The present submission is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels:

- *Proposed Tunnel Design and Standards*

- *Technical Note on Tunnel Section and System*
- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures :

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report:

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

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Volume - II: Design Report
Part- II: Design of Tunnels
(A): PROPOSED TUNNEL DESIGN AND STANDARDS

1 GENERAL

This Volume - II: Design Report- Part II: Design of Tunnels, (A) Proposed Tunnel Design and Standards, a part of “KD6: Draft Detailed Project Report for Final Approved alignment for Bypass (DDPR)” is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report -Part II: Design of Tunnels, (A) Proposed Tunnel Design and Standards of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

2 PROPOSED DESIGN BASIS, STANDARDS & SPECIFICATIONS

2.1 OBJECTIVES OF THE STUDY

Tunnels along the highways are underground engineering structures and are used for transport of traffic in hilly areas to avoid circuitous routes or to improve geometries, to avoid unstable areas and areas with unacceptably high exposure to landslides or avalanches. Safety of workers during construction, safety of traffic during construction as well as the safety of traffic after construction is the main consideration in the design of tunnels.

2.2 CONDITION SURVEY OF EXISTING RAILWAY TUNNEL

Around the project area South-Western Railway has already developed a 52km “Green Route” railway track from Sakleshpura to Kukke Subramanyan. The length of the track is 52 km and comprises 51 tunnels (out of which 26 tunnel are lined & remaining are unlined) and 109 bridges. The length of tunnels varies from a few meters i.e. 20m to around 1200m, the longest tunnel length is situated at Nagahola with a length of 1200m. The railway line crosses the highway around Ch. Km 234.5, and runs towards the valley side.

2.3 PROPOSAL FOR NEW TUNNELS

As per client’s initial requirement, a twin tube tunnel system with two driving lane and one emergency lane in each tube is proposed. Considering the present and forecast traffic load in Shiradi Ghat Hilly area, two tunnel tubes of two lanes each are required for unidirectional traffic but considering the hydro – carbon loaded tankers specially the highly explosive liquefied petroleum gas tankers travelling from MRPL refinery to Banglore & vice versa, one continuous emergency lane in each tube are proposed for safety purpose. Following tunnels are being proposed, along main road of NH-48 (Shiradi Ghat section) as given in Table 1 according to the alignment option ‘A’

Table 1: Proposed Twin tubes Tunnels for Approved Alignment “Option A”

S.No.	Tunnel No.	Section	Chainage as per km stone	Design Chainage	Length (m)	Present Road Length (Km.)	Remarks
1	T1	Main Road NH 48		2686.59 to 5581.47	2894.88 (L)		Straight, Curve 1 (1831.947 m LHC) R 2600 m Curve 2 (193.47 m LHC) R 3000
				2715.56 to 5553.19	2837.63 (R)		Curve 1(1808.147 m RHC) R 2600 m) Curve 2,(167.24m RHC) R 3000

2	T2	Main Road NH 48		5863.07 to 7920.00	2056.93 (L)		Straight, Curve 1 (203.288 m LHS) R 3000 Curve 2 (109.163 m LHC) R 500 m
				5901.33 to 7903.44	2002.11 (R)		Curve 1 (L205.605m RHS) Curve 2 (L 106.522 m RHS,) R 500 m
3	T3	Main Road NH 48		9216.58 to 11299.60	2083.22(L)		Straight,Curve(693.834 m LHC)R 2000m
				9204.84 to 11231.06	2026.22 (R)		Straight,Curve (682.113 m RHC)R 2000m
4	T4	Main Road NH 48		11603.15 to 13505.30	1902.15 (L)		Straight Curve 1(L128.175m LHC) R 1000 m Curve 2(367.041 m LHC) R 1000 M
				11539.99 to 13467.65	1927.66 (R)		Straight, Curve 1 L(161.771 m RHC,) R 1000 m.Curve 2 (354.770 m RHC) , R 1000 m
5	T5	Main Road NH 48		14804.99 to 16500.96	1695.97 (L)		Straight, Curve(L 69.881 m LHC) R 1000 m
				14770.00 to 16419.91	1649.91 (R)		Straight, Curve (27.834 m RHS) R 1000 m
6	T6	Main Road NH 48		17805.62 to 19797.17	1991.55 (L)		Straight
				18030.76 to 19636.07	1605.31 (R)		
Total					12624.50 (Left) 12048.84 (Right)		

The above proposed tunnels are lying in the area between km 236.450 to Km 259.292 of the existing road in the Shiradi Ghat area. There shall be minimum adverse impact on environment by provision of these tunnels i.e. minimum damage to trees, flora & fauna.

2.4 BENEFITS OF TUNNELS PROPOSED IN SHIRADI GHAT

The Shiradi Ghat stretch has been a serious bottleneck of the NH-48 that affects smooth movement of commuters and freight from Bangalore to Mangalore and vice versa. The existing road in the project section is characterized by difficult topographic conditions, landslides, steep gradients, multiple curves, all of which contributes to difficult working conditions for transportation of goods and is adversely affecting the economy.

Total Six (6) twin tube tunnels (each tube with two lanes plus emergency lane) of a total length of 12.611 km (based upon the chainage) are proposed between km 236.400 to km 259.292, based upon existing road chainage. The present 26km two lane road stretch shall be abandoned, and may be freely utilized for wild life and local people without any disturbance.

In case new four (4) lane highway is constructed in this area with proper geometrics in curves, the proposed road length would be approximately 44km between km 237 to km 261.45 (considering 6% gradient permissible in hill roads for difference of elevation of 725m between Maranhally to Gundya), which if constructed shall required cutting of hundreds of trees causing environmental damage to dense forest area and wild life of eco-sensitive nature. Therefore such proposal is disregarded and a proposal of a relatively straight highway with multiple tunnels with minimum disturbances to forest area and free movement of wild life is considered as beneficial. The proposal of having tunnels will enhance the freedom of wild life activities in the long run and shall create least disturbance to flora and fauna in wild life area. Large scale surface cutting and subsequent risk of erosion of the hill slopes can be avoided in mountainous terrain by construction of these six (6) twin tube tunnels.

Sharp curves and blind curves shall be abandoned and road geometrics shall be much improved through tunnels which will add to better speed, good riding quality as well as safety of traffic since this will significantly reduce the possibility of accidents on the roads. As the traffic will be mainly inside the tunnels, the disturbance to wild life of adjoining forest area is minimized and preservation of the existing natural environment is obtained. Larger sight distances help in protection of wild animals from the possibility of collision with the speeding vehicles.

Smooth flow of traffic along the project road will automatically discourage the use of horn which will not only reduce noise pollution but will also create an environment of least disturbance to wild animals. Also, the smooth flow of traffic with good riding quality resulting from better geometrics will lead to a reduction in fuel consumption and a reduction in travel time, which in turn will automatically reduce V.O.C. (Vehicle Operation Cost).

Tunnels are protected from outside impacts like seismic events or explosions of whatever kind. Worldwide many tunnels are being envisaged to be also used as civil shelters. Tunnel structures are always considered to be safer than bridge structures. Open-cuts create the risk of soil erosion and subsequent landslides and add to instability of the hill slopes in soft soils / rocky conditions where as tunnels do not affect the overall stability of the surface and slopes.

Construction of tunnels always requires special equipments and modern techniques and also needs longer time of construction as compared to bridges and open cuts (box-cuts), but even then these will prove to be economical in the long run because of the benefits of reduction in vehicle operating cost and enhancement of overall traffic safety.

Cost of tunnelling is several times more than that of open, unsupported excavation. However deep open cuts are associated with problems of land acquisition, landslides and impose maintenance problems during operation, whereas properly designed and constructed tunnels do not pose such problems.

In view of these aspects of cost and maintenance, generally for non urban tunnels, it is preferable to restrict the depth of open cuts to about 20m. Beyond this depth the mined tunnel option is economical. These consideration needs to be reviewed on the basis of local ground conditions, geology and cost benefit analysis.

2.5 SPECIFICATION AND PROVISIONS

Following provisions are being made:

1. Primary support system consisting of systematic rock bolting, sprayed concrete (reinforced either with fibres or wire mesh), lattice girders and forepoling, as per requirements.
2. Protection measures against seepage of water by using water proofing membrane system (PVC membrane plus Geotextile), combined with slotted PVC drain pipes to collect the water.
3. Groundwater drainage system to take care of seepage through the adjacent hill slopes.
4. Concrete inner lining (cast in-situ or sprayed, as per requirements), with enhanced fire resistance as per requirements by mixing in the polypropylene fibres.
5. Embankment fill, GSB, Dry lean concrete, Pavement quality concrete (PQC).
6. Cable trench / duct systems for power supply and protected installation of cables.
7. Pavement liquid drainage system with slotted gutter / intake shafts and collector pipes. This serves the collection of liquids (petroleum products e.g.) spilled on highway.
8. Sedimentation tanks to collect the pavement liquids at the portals, to separate out petroleum products
9. Tunnel ventilation system as and where required
10. Tunnel illumination
11. Fire fighting system
12. Proper layouts of traffic lanes at entry and exits.
13. Traffic safety features and road furniture.
14. Provision of safety measures during construction.
15. Provisions for maintenance and operation of tunnels.

2.6 SHAPE AND SIZE OF THE TUNNEL

2.6.1 TWIN TUBE SOLUTION – INTRODUCTION

The proposed tunnel system consists of two tubes, each tubes has geometric provision for three lanes. In both tunnels, in addition to the two driving lane (3.5m each lane) an continuous emergency lane with 3.5m width is foreseen. Due to this emergency lane no lay-by niches are required. The emergency lane will additionally allow quick access for emergency services in case of accidents in the tunnel. This requires that the use of the emergency lane is restricted to maintenance and emergency services, and broken down vehicles only.

Both tunnels are connected via cross passages at 300m spacing as per IRC SP: 91-2010; this provision is stricter than the 500m maximum distance provided in the European Guideline EC54/2004 [7]. Every cross passage is to be designed and constructed as vehicular cross passage, to allow the emergency services access every 300m. This enhanced level of safety is due to heavy traffic of hydro carbon / liquefied petroleum gas tankers from MRPL to Bangalore and vice versa. In the event of an incident / accident in one of the tube, the other tube shall be used as an escape route and alternative access route for emergency services which are allowed to enter the cross passages. Under guidance of the police or other emergency services only, light vehicles may be diverted through the vehicular cross passages to clear the incident tube (Note: this is only possible if there is no risk that smoke travels through the open cross passage into the "healthy" tube).

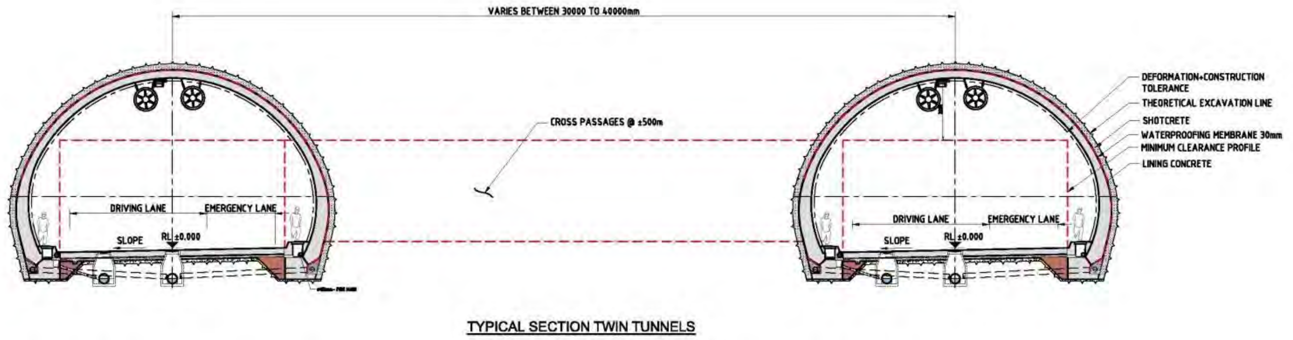

Figure 1 - Details of the tunnel system

2.6.2 TWIN TUBE SOLUTION – OVERALL SAFETY CONSIDERATIONS

Compared to any single tube solution with bi-directional traffic the proposed solution has the following advantages:

- Unidirectional traffic reduces the risk of traffic accidents
- Unidirectional traffic is also favourable for the operation of the ventilation system because the drag and piston effects support the jet fans in maintaining the proper air speed.
- The second tube is escape route as well as access route for emergency services
- In case of damages - be it caused by accidents or other man-induced incidents e.g. sabotage - in one tube the remaining tube is fully operational, at least for unidirectional

traffic (controlled at the portal areas) - an important issue for a strategic connection like the one between Bangalore and Mangalore (Port city)

The shape of the tunnel shall be such that it can resist the pressure exerted by the ground around the tunnel excavation. The pressure coming on the lining of the tunnel is both lateral as well as vertical in direction and varies with the composition of the hill material and the percentage of the moisture in the material. Some rocks have so much cohesion that they can stand vertical after cutting the material without any support, but in case of loose soil sand and mud-stones after excavation, they cannot be kept stable without a proper support. Therefore the design of the shape of tunnel shall be done properly based on the site conditions and the functional requirements as the structural cross section of the tunnel depends on type and magnitude of loadings. The most appropriate geometry for tunnels is a horse shoe shaped cross section which is used here also. Depending on the stress state and the ground condition, an invert may be introduced. All cross sections are dimensioned to provide adequate space for ventilation fans (jet fans).

The tunnel dimensions have been based on the following requirements

- 10.5m carriage way width 3 lane (Two driving lane with one emergency lane for each tube, width of each driving lane 3.5m)
- Edge strip width of 0.5m at each side of tunnel as per clause no. 2.8.2.5 (Finished section of tunnel) of SP 91: 2010 (Guidelines for Road tunnels)
- Walkways at each side of the tunnel with an width of 0.910m
- Minimum clear height over walkway: 2.30m
- Minimum vertical clearance above pavement 5.5m as per IRC guidelines.
- Forced Tunnel ventilation shall be performed by means of Jet Fans, if possible and within safety standards natural ventilation is envisaged.
- The requirements for the electromechanical installations (medium and low voltage cable need to be placed in ducts)
- Requirement of a safe placement of the fire water main
- The requirements for the permanent drainage system and connection of the side drainage to the tunnel main drainage.
- Hydro carbon liquids spilled onto the pavement as well as other potentially toxic surface liquids will be collected through slot gutters or similar arrangements and go into the pavement drain. The pavement drainage system will be designed and maintained to prevent fire and flammable and toxic liquids from spreading inside the tubes and between the tubes. The liquids from the pavement drainage will run through a sedimentation tank with skimming facility to separate out any hydrocarbon liquids.
- Construction requirements under various geological and ground water conditions
- Ground water drainage maintenance Niches: required minimum every 65 m - on both sides of each tube.

Ground water drainage maintenance niches are small openings and required for the access of cleaning pipes for the side drainage.

The external finished profile shall be uniform but the construction profile depends upon whether an invert is required or not. Invert will be required in zones of weak rocks. Twin tunnels have been provided side by side with a clear gap of 13.4 m to 23.4 m and c/c distance 30m to 40m so that the pillar between both tubes is sufficiently wide to take the additional stresses induced by tunnelling.

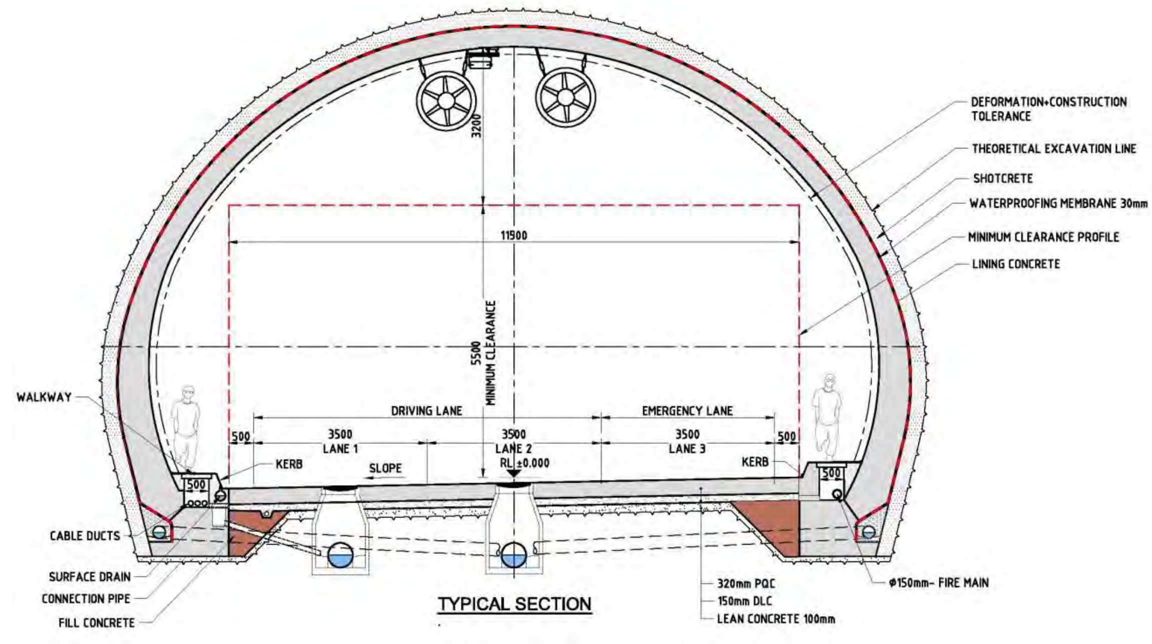

Figure 2: Typical cross section of tunnel

The advantages of this solution are:

- a defective vehicle can be removed from the driving lane to the emergency lane any where
- maintenance personal can enter the tunnel even with a vehicle carrying tools, spares etc. without disturbing the traffic
- emergency services can reach an accident location through the emergency lane very quickly
- in the case of an accident, the vehicles inside the tunnel can use the emergency lane to leave the tunnel (under guidance of the emergency services)

2.7 TUNNEL DESIGN & CONSTRUCTION

The design and execution / construction of the said tunnels shall be in accordance with NATM (New Austrian Tunnelling Method).

The NATM is an observational approach which is based on the following principle stages:

- Description of the rock mass behaviour, with stage-wise refinement as per available information
- Support design according to the requirements of the ground and the boundary conditions
- Observational approach which is reflected in the design and technical schedules and implemented during construction by employment of regular geotechnical monitoring and subsequent design adjustments

2.8 GEOLOGY ALONG PROPOSED ALIGNMENT

The location of proposed alignment is shown superimposed on the geological map (Given in volume II, part IV). The proposed alignment starts at Gundya (at the NH-48) in the western side and follows a path approximately parallel to NH-48 (and river Kempu Hole) on the southern side extends through the portions of Shiradi Ghat and finally ends at Maranhally on the eastern side. It consists of several tunnels (6 nos), bridges (6 nos) and cut & fill sections.

As can be seen the alignment passes though most sections within the peninsular gneissic complex (consisting of granite gneiss). These are some portions of tunnel (approximately between 11500 and 11800m chainage) where garnet-sillimanite-graphite schist is encountered (Sargur group).

There are other rock types in the vicinity which are currently not seen along the alignment like the numerous dolerite dykes and others like granulites, amphibolites, banded magnetite quartzites etc. These can possibly be encountered along the alignment. This would become clearer after geological mapping and geotechnical investigation study results become available, at a later stage.

There are several lineaments which are seen intersecting the alignment. These could be faults or weak zones. Some of these are encountered in the tunnel sections. There are also numerous streams in the project area which cross the alignment. These are also potential weak zones and may extend vertically to deeper levels and may be encountered in the tunnels.

The tunnel will be in general horseshoe shaped due to the advantages of a smooth geometry in respect to the sectional forces of the lining, avoidance of stress concentrations and smooth stress re-distribution in the rock mass.

There will be a primary support designed with the objective to be as economical as possible without compromising safety.

For the final stage, a cast in-situ, or alternatively sprayed concrete final lining is foreseen.

The complete project area is located in seismic zone II as per relevant Indian Standards.

2.9 TUNNEL SYSTEM AND SAFETY ISSUES

Safety in tunnels in Europe has become of great importance due to major accidents at the end of the last century. Therefore the “Directive 2004/54/EC of the European Parliament and of the Council on minimum Safety requirements for tunnels in the Trans-European road Network” dated 29.04.2004, has been published. In this Directive all necessary structural precautions and installations for tunnel longer than 500 m are stated. This directive reflects internationally the state of the art. Therefore it is recommended to utilize this Directive as design basis for the safety requirements of the system in addition to IRC codes.

Tables below showing functional requirements based on lengthwise classification of tunnel having bearing on Geometric design

● mandatory for all tunnels ❍ not mandatory
✱ mandatory with exceptions ◉ recommended

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 000 m	1 000-3 000 m	>3 000 m	
Structural Measures	2 tubes or more	§2.1						Mandatory where a 15-year forecast shows that traffic > 10 000 veh./lane.
	Gradients ≤ 5 %	§2.2	✱	✱	✱	✱	✱	Mandatory unless not geographically possible.
	Emergency walkways	§2.3.1 §2.3.2	✱	✱	✱	✱	✱	Mandatory where there is no emergency lane, unless the condition in §2.3.1 is respected. In existing tunnels where there is neither an emergency lane, nor an emergency walkway additional / reinforced measures shall be taken.
	Emergency exits at least every 500 m	§2.3.3 - §2.3.9	❍	❍	✱	✱	✱	Implementation of emergency exits in existing tunnels to be evaluated case-by-case.
	Cross-connections for emergency services at least every 1 500 m	§2.4.1	❍	❍ / ●	❍	❍ / ●	●	Mandatory in twin-tube tunnels longer than 1 500 m.
	Crossing of the central reserve outside each portal	§2.4.2	●	●	●	●	●	Mandatory outside twin- or multi-tube tunnels wherever geographically possible.
	Lay-bys at least every 1 000 m	§2.5	❍	❍	❍	❍ / ●	❍ / ●	Mandatory in new bi-directional tunnels >1 500 m without emergency lanes. In existing bi-directional tunnels >1 500 m: depending on analysis. For both new and existing tunnels, depending on extra usable tunnel width.
	Drainage for flammable and toxic liquids	§2.6	✱	✱	✱	✱	✱	Mandatory where transport of dangerous goods is allowed.
	Fire resistance of structures	§2.7	●	●	●	●	●	Mandatory where a local collapse can have catastrophic consequences.

● mandatory for all tunnels ❍ not mandatory
✱ mandatory with exceptions ◉ recommended

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 000 m	1 000-3 000 m	>3 000 m	
Lighting	Normal lighting	§2.8.1	●	●	●	●	●	
	Safety lighting	§2.8.2	●	●	●	●	●	
	Evacuation lighting	§2.8.3	●	●	●	●	●	
Ventilation	Mechanical ventilation	§2.9	❍	❍	❍	●	●	
	Special provisions for (semi-) transverse ventilation	§2.9.5	❍	❍	❍	❍	●	Mandatory in bi-directional tunnels where there is a control centre.
Emergency stations	At least every 150 m	§2.10	✱	✱	✱	✱	✱	Equipped with telephone and 2 extinguishers. A maximum interval of 250 m is allowed in existing tunnels.
Water supply	At least every 250 m	§2.11	●	●	●	●	●	If not available, mandatory to provide sufficient water otherwise.
Road signs		§2.12	●	●	●	●	●	For all safety facilities provided for tunnel users (see Annex III).
Control centre		§2.13	❍	❍	❍	❍	●	Surveillance of several tunnels may be centralised into a single control centre.
Monitoring systems	Video	§2.14	❍	❍	❍	❍	●	Mandatory where there is a control centre.
	Automatic incident detection and/or fire detection	§2.14	●	●	●	●	●	At least one of the two systems is mandatory in tunnels with a control centre.
Equipment to close the tunnel	Traffic signals before the entrances	§2.15.1	❍	●	❍	●	●	
	Traffic signals inside the tunnel at least every 1 000 m	§2.15.2	❍	❍	❍	❍	◉	Recommended if there is a control centre and the length exceeds 3 000 m.

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 00 0 m	1 000-3 000 m	>3 000 m	
Communication systems	Radio re-broadcasting for emergency services	§2.16.1	❍	❍	❍	●	●	
	Emergency radio messages for tunnel users	§2.16.2	●	●	●	●	●	Mandatory where radio is re-broadcasted for tunnel users and where there is a control centre
	Loudspeakers in shelters and exits	§2.16.3	●	●	●	●	●	Mandatory where evacuating users must wait before they can reach the outside.
Emergency power supply		§2.17	●	●	●	●	●	To ensure the functioning of indispensable safety equipment at least at during evacuation of tunnel users.
Fire resistance of equipment		§2.18	●	●	●	●	●	Shall aim to maintain the necessary safety functions.

2.10 GENERAL PRINCIPLES OF DESIGN (AS ADOPTED IN THE PRESENT CASE)

The design has been based on relevant specifications, i.e. European Guideline EC54/2004 and international recommendations (PIARC), in addition to IRC / MORT&H / BIS Guidelines and Codes. The detailed design of tunnels includes development of cross section, stress analysis, lining, support systems including rock-bolting, sprayed concrete etc, related to the structural design of the tunnel. Suitable design procedures are available for tunnel designs and accordingly, design is done based on appropriate methods. The tunnel design is based on comparable formations, already executed works in the area and test data giving properties of rocks and rock mass as required. Protection measures against seepage of water have also been provided. The tunnel systems also include ventilation systems, ventilation structures and tunnel and portal lighting.

2.10.1 LENGTH OF TUNNELS

From the psychological aspect, tunnels shall be made as short as practically possible so as to avoid feeling of confinement and magnification of unpleasant traffic noise as low as possible. However this is to be balanced with the ground conditions and other factors like gradient and beneficial portal locations; as tunnels are in general comparatively expensive structures to construct, the length of tunnels shall be optimized to by diligently choosing the locations of the portals.

2.10.2 HORIZONTAL ALIGNMENT OF TUNNEL

Horizontal alignment of tunnel shall be kept straight as far as possible considering IRC/PIARC guidelines up to a maximum 1.5 km tunnel length. Portals can have gentle curve to help in light transition. This will not only minimize the length but will also improve operating efficiency. Tunnels designed with too narrow curves may result in limited stopping site distance. Sight distances shall be examined carefully to avoid increased risk of accidents. As per IRC code straight alignment is generally preferred. However the straight stretch shall not be more than 1500 m in case of long tunnels to avoid the effect of monotony and induction of an unconscious increase in speed. For the same reason last few meters of the tunnel shall have gentle curve. The curves if provided shall be gentle and meet the minimum radius requirements for the design speed of the tunnel. Tunnel alignment at the ends and open/approach cuts shall merge smoothly with adjoining road in the open air. In case of twin tube tunnel, crossing of centre median shall be planned at suitable location at approaches of both tunnels so as to allow emergency services gain immediate access to either tube and also to send back diverted traffic to proper traffic lanes.

2.10.3 VERTICAL ALIGNMENT OF TUNNEL

Vertical alignment through the tunnel shall be such that grades in tunnels are determined primarily on the basis of driver comfort. Economic balance between construction costs & operating and maintenance expenses shall be maintained. It has to be kept in mind that tunnel lengths and gradients have direct effect on tunnel lighting and ventilation requirements. As per IRC:SP91:2010 Code "*the gradient along the tunnel length shall be very gentle. Steep gradient affects traffic capacity, resulting in additional emission by vehicles and makes ventilation more difficult. The tunnel gradients are generally limited to 4-6 percent in short tunnels and to around 3 percent if length exceeds 500m. Where steeper gradients become necessary, the design of the ventilation system shall be done taking into* *consideration the effect of steep gradients. Generally a high point somewhere in the tunnel shall be provided for efficient drainage of seepage water*". As per European Guideline EC54/2004 longitudinal gradients above 5% shall not be permitted in new tunnels, unless no other solution is geographically possible; over and above for tunnels with gradients higher than 3%, additional and/or reinforced measures shall be taken to enhance safety on the basis of a risk analysis.

2.10.4 PROVISION OF ADEQUATE LIGHTING SYSTEM

The lighting should be such that there should be minimum optical shock of travelling from natural to artificial lighting. For this purpose, number of lighting fixtures can be provided at the entrance portal, wherein upper row of lights provides supplemental daytime lighting at the entrance portal to reduce the optical shock.

Lighting requirements are highest near the portals and depend heavily on natural light and the need to make a good light transition. The lighting system should be selected properly and the resulting expenses should be included in the inherent cost of the operation.

2.10.5 VENTILATION SYSTEMS

Ventilation requirements depend on lengths, grades, available natural & vehicle induced ventilation and air quality constraints. In Shiradi Ghat tunnels, longitudinal ventilation with reversible jet fans is being proposed. The Fans are reversible i.e. the direction in which they blow the air can be changed, making it possible to create a stream of air in either direction. The increase in pollutants concentration is linear over the length of the tunnel. The longitudinal ventilation system does not require more than a dedicated area in the cross section and is therefore comparatively simple and easy to install (no further civil works required). This type of ventilation can be used economically up to 1.5km for bi-directional traffic and up to about 3.0km for unidirectional traffic, which is the case here.

2.10.6 SIGNAGE WITHIN THE TUNNEL

Large signages and cautions are provided along the road outside the tunnels and in the tunnels, only traffic lights and small signage if required shall be provided, in accordance with the overall safety concept.

2.10.7 LOCATION OF EXIT RAMPS

Exist ramps shall be located at sufficient distance down streams from the tunnel (minimum 300m) to permit needed guide signs between the tunnel and the point of exit. Traffic should not be allowed to merge, diverge or weaver within a tunnel. Therefore provisions of forks or exit & entrance ramps within the tunnels should always be avoided.

2.10.8 PROVISION OF EDGE STRIP

Edge strip width / shoulder of 0.5 m width has been provided as per IRC SP: 91: 2010; one full-width emergency lane is also provided.

2.10.9 TUNNEL DIMENSIONS

Detailed dimensions of the tunnel are presented in typical cross sections as shown in above Figure 2.

2.10.10 VERTICAL CLEARANCE

A minimum vertical clearance of 5.50m as per IRC SP 91:2010 has been provided. This vertical clearance of 5.5m will take care of ODC consignments also.

2.10.11 SIDE-WALKS

Normally, pedestrians are not permitted in freeway tunnels. However, space should be provided for emergency walking and for access by maintenance personnel. Raised side-walks 0.75m wide are desirable beyond the pavement area to serve the dual purpose of safety walk and a buffer to prevent the (frequent) overhand of vehicles from damaging the wall finish or the tunnel lighting fixtures. Walkways are also necessary for safe movement of service personnel and for free access in case of emergency. Walkways of 0.910 m width are provided in the traffic tunnels of this project.

2.10.12 SLOT GUTTERS FOR DRAINING WASTE WATER

Suitable side drains for draining waste water with spilled hydro carbon have been located below the Kerb portion.

2.10.13 REQUIREMENTS FOR FIRE FIGHTING SYSTEM

Fire fighting line with hydrants at proper spacing should be connected to water tanks located outside the tunnel (hydrant spacing preferably 60m outside the tunnel in the portal area, 250m inside the tunnel) for use in case of fire by the emergency services. The water tanks shall be preferably elevated so that the required hydraulic head can be maintained through gravity only.

2.10.14 CABLE DUCTS / TRENCHES

Cable ducts are provided to accommodate medium voltage power supply, telephone lines, lighting wires, water supply lines and other cables.

2.10.15 CROSS PASSAGES

Cross passages are provided as connections between both tunnel tubes as emergency exits from the incident tube to the “healthy” tube. In this project a spacing of 300m is provided, to cater for enhanced requirements due to the transport of dangerous goods (petroleum products). The cross passages serve also as an access of the emergency services to the incident tube. The requirement as per European Guideline EC54/2004 is to have a motorable access every 1500m. Here all cross passages are designed and constructed as vehicular cross passages, allowing the emergency services access every 300m.

The cross passages have closures at the side of either tunnel tube. These doors can be opened by authorized services to drive through; regular doors allowing persons to escape are integrated into the closures/doors.

The geometric requirements are 4.0 m high and 3.5m wide so that any fire fighting vehicles of max. height 3.5 m can pass through , with a minimum additional space provision for the sidewalks of 2.3m in height and 0.70m in width. This space provision is sufficient for the movement of emergency services. Please refer Fig.3 for cross section of cross passage.

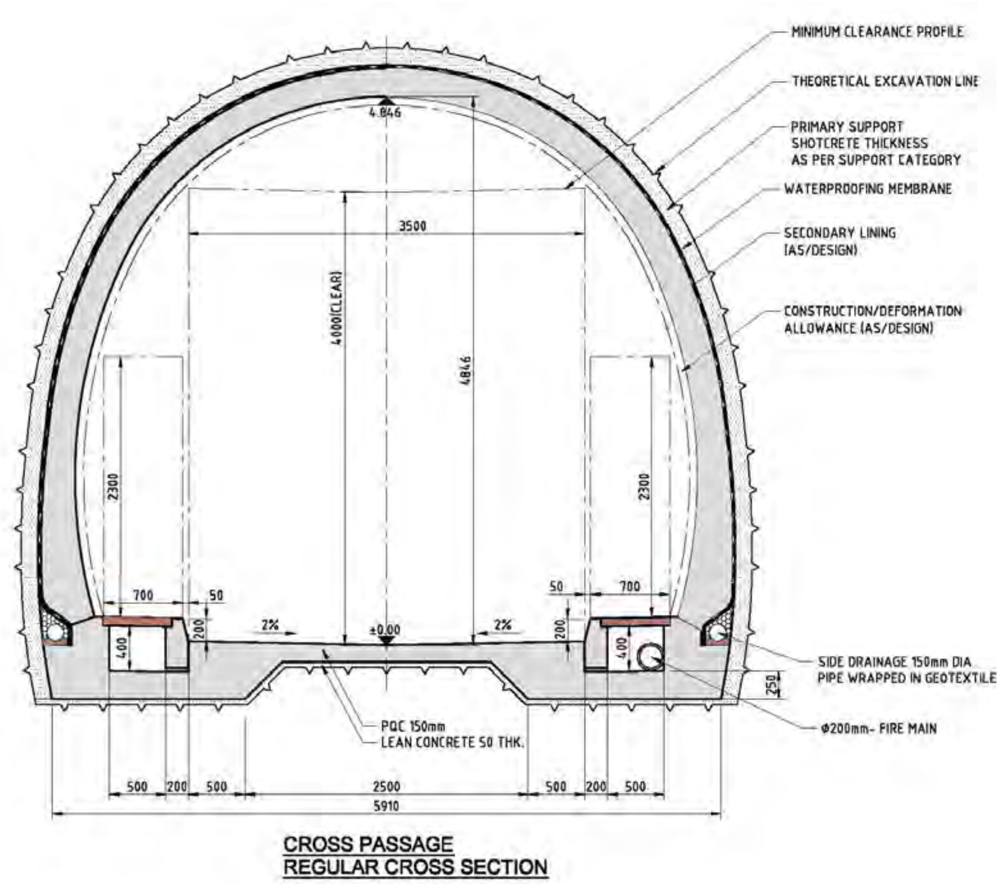

Figure 3: Cross Section of Cross passage

In the case of tunnel blockage, the police or any other authorized emergency service may, if possible, divert the light vehicles through the cross passages to clear one tube. Otherwise no vehicles except emergency services are allowed to enter the cross passages.

2.10.16 FIRE RESISTANCE OF STRUCTURES

As required by the European Guideline [7], the structural fire resistance is to be given - especially in areas where “a local collapse can have catastrophic consequences”. This is especially true in stretches where the ground is weak (soil, decomposed rock) and where the loss of the support system is causing global instability.

The fire resistance can be enhanced by various means; one is to mix polypropylene fibres into the inner lining concrete. These non-structural fibres serve the purpose to enhance the resistance against spalling in the case of fire. The heat melts the fibres, and the voids can accommodate the vapour of the water that is part of the concrete anyway. The pressure of the vapour is reduced and spalling is mitigated.

One other measure to ensure fire resistance is to increase the concrete cover for reinforced concrete members, as per relevant codes.

3 APPROACH AND METHODOLOGY TO MEET THE REQUIREMENT OF DELIVERABLES AND SERVICES

3.1 THE CONCERNS OF THE PROJECT

According to the experiences gained in the due course of similar Railway and Road Tunnel projects, the principal concerns in the Shiradi Ghat project (and in some instances, constraints) for the detailed engineering design and construction of long and deep tunnel may include:

1. The complex geological history of the Shiradi mountain range, as witnessed by the presence of complex geological formations in the longitudinal profile of the tunnel , and due to the presence of the overlaying residual laterite soils there is the risk of encountering buried faults and fault zones as well as shear zones during the tunnel excavation;

2. The geomorphology and surface processes along the open surface alignment, especially at the various tunnel portals and along the access roads, where land slide is a fact;

3. As for all construction projects there will be always time and cost constraints, but in this case, due to the complexity of the project, the definition of the optimal construction sequence and the definition of the general reference layout is fundamental;

4. Finally, one of the key aspects of road tunnel projects is the safety concept.

3.2 GENERAL CONSIDERATION REGARDING THE APPROACH

The design and construction of long and deep tunnels particularly those at more than 50 m depth, is generally associated with a high level of risks due to whole series of uncertainties involved, and the success of such tunnelling projects depends very much on the correct choice of the support sections. From the view point of risk management we strongly believe that the correct choice of the excavation methods for a given tunnel is the “first risk – mitigation measure“ or simply, the primary response to the identified principal risks. The key problem is thus clearly how to make the correct choice for a given project. A robust approach should be adopted for determining the optimal method (or combination of methods) of construction for a long tunnel, based on the principles of risk analysis and multi-criteria analysis.

In making the correct choice for a given project, the presence or absence of adverse conditions and if present, the frequency of their occurrence in a given tunnel section are of paramount importance to the choice.

The point is to recognize the risks and “to be wise a priori”, as we believe that most risks can be effectively managed through the use of a Risk Management Plan, or RMP for short, a robust, transparent and effective methodology, which can be adopted from the early design stages to the construction and operation phase, to minimize the occurrence of risks and / or mitigate their consequences.

The key elements of a typical RMP for a tunnelling project are:

1. Risk identification
2. Risk evaluation or qualification
3. Risk mitigation (i.e definition of primary responses to the identified risks including cor-

rect design – construction choices.)
4. Assessment of residual risks
5. Pre – design of counter measure for the management of residual risks during construction.

Normally a RMP is defined to manage properly the Residual Risks, the Accepted Risks, and any new risks that may arise in the subsequent stage. A RMP requires pre design of the so called “counter measures “as well as a corresponding set of Rules for the activation of each counter measure in the subsequent (especially construction) stage. Furthermore, a RMP should not be static, but dynamic, in other words, it should be constantly reviewed and updated.

From the point of view of risk assessment and according to our past experience, we are deeply convinced that:

- Tunnel design and risk assessment are mutually dependent of each other and must go hand in hand.
- A good and useful risk assessment can be obtained only through a correct understanding of the design and the construction process involved and if it is done by a multi-disciplinary team of experienced people;
- A sound and robust design of a tunnel can be achieved only if it is developed on the basis of a comprehensive risk assessment.

From the view point of risk management we strongly believe that:

- The tunnel design process itself is one of the most effective measures to reduce the initial – risk levels of a tunnelling project. Thus, time-wise , not only risk analysis should be done through the entire process of design and construction, but also it should be done in parallel with the design development or with the construction progress ; and more importantly, in the design stage the analysis of the initial risks should guide the development of tunnel design.

- The correct choice of the excavation method for a given tunnel is the “first risk mitigation measure “or simply, the primary response to the identified principal risks. The key problem is thus clearly how to make the correct choice for a given project.

4 GENERAL PRINCIPLES: OBSERVATIONAL METHOD, NATM & TUNNEL DESIGN

4.1 OBSERVATIONAL METHOD

The project alignment traverses through Western Ghat, which are full of geological surprises and continuous changes, due to the lying in the faults region. Some faults are expected along the tunnel alignment.

Especially in context like this one, it is appropriate to adopt the approach known as the 'observational method', for which the design should be reviewed during construction after the interpretation of the monitoring data.

The design developed is typically based on analyses, however analysis cannot replace judgement. Possible modes of failure – particularly those of a sudden or brittle nature, or those who could lead to progressive collapse – must be assessed carefully.

It is a fundamental element of the Observational Method to overcome the limitations of analysis by addressing actual conditions within engineering judgment. Feedback and assessment from observations (monitoring data) must be timely collected and interpreted in order to confirm predictions or to provide adequate warning of any undue trends in ground movements or loadings. There must be sufficient time to enable planned contingency measures to be implemented effectively.

The design criteria can be summarized in the following Figure 4, which describes the link between the design and the construction phases.

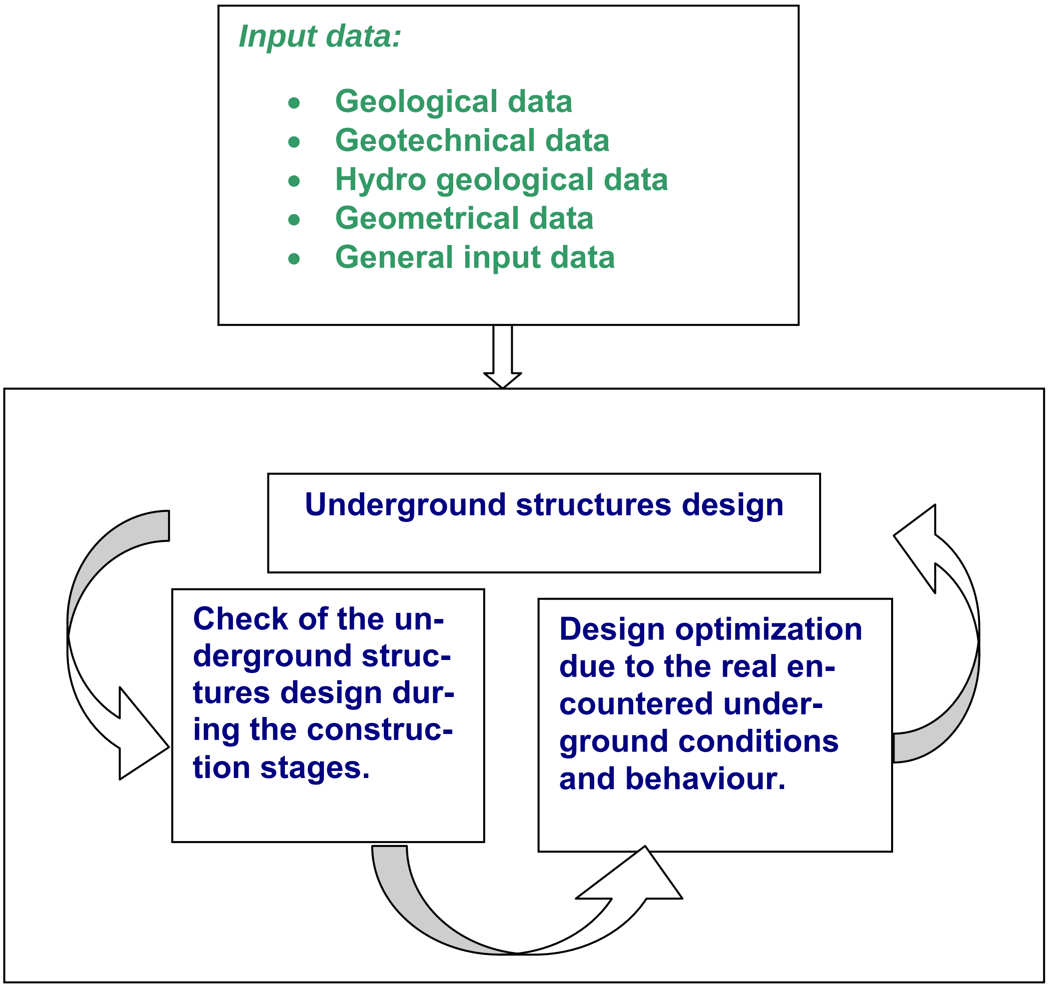

Figure 4 - Observational method

4.2 NATM – MAIN CONCEPTS

The New Austrian tunnelling method (NATM) is an observational approach to tunnelling and other underground structures and is accepted worldwide. It was introduced in India end of the seventies (Hydropower) and subsequently from 2002 onwards in Infrastructure projects (DMRC, Pir Panjal Railway Tunnel T80), and in Japan during the nineteen seventies for road and rail tunnels.

The NATM was developed by L.v. Rabzcevic as a modern approach to tunnelling and was named “New Austrian Tunnelling Method” to distinguish it from the traditional “Old Austrian Tunnelling Method” and to emphasize that it was developed mainly by Austrian Engineers and miners. NATM has evolved from practical experience and Rabcewicz called it “empirical dimensioning “. However, it has a theoretical basis involving the relationship between the stresses and deformations in the ground around tunnels. The method makes use of sophisticated in–situ instrumentation and monitoring, and interprets these measurements in a scientific manner.

The NATM is an approach or philosophy integrating the principles of the behaviour of Rock masses under load and monitoring the performance of tunnel during construction. The NATM involves a combination of many established ways of excavation and tunnelling, but the difference is the continuous monitoring of the ground behaviour and the optimization of support measures to obtain the most stable and economical lining.

The main essence of NATM is quoted as follows: “The New Austrian Tunnelling method constitutes a design where the surrounding rock – or soil – formations of a tunnel are integrated into an overall ring like support structure. Thus the formations will themselves be part of this support structure.” This definition together with the main principles was published in 1980. With a flexible primary support, a new equilibrium shall be reached after the stress redistribution due to the excavation process. This shall be controlled by in-situ (deformation) measurements. After this new equilibrium is reached (most common condition is the decrease of the convergence rate below 2mm/month) an inner lining shall be installed. In very specific cases the inner lining can be omitted.

Preferentially near – circular underground opening can be supported by relatively thin sprayed concrete membranes. With an adequate design also the subsidence on the surface can be limited to relatively small values.

Stability analyses, in which the interactions of the subsoil with the support are modelled in a realistic way, however, serve as a prerequisite for a successful tunnel construction using this method.

The design of tunnel according to the NATM is carried out stepwise with the following working steps, out of which some are to be repeated several times, if required.

- Geo-technical investigations of the ground and groundwater conditions.
- Evaluation of the soil and rock mechanical parameters, based on test results as well as experience
- Define the Ground Behaviour Type (see following paragraph)
- Design and assessment of excavation method and support measures (excavation and support classes)
- Stability analysis for both, the stability proof of the tunnel and the design of the sprayed concrete (primary support) as well as the permanent lining.
- Documentation of the actual ground conditions by Geological mapping
- Observation of system behaviour by geotechnical monitoring during construction.
- Comparison of the actual behaviour with the envisaged system behaviour
- Back analysis of the results of measurements, if required
- Design optimization based upon monitoring results

Here below the most important features, on which NATM is based, are reported :

1. <u>Mobilization of the strength of the Rock mass</u>: The Method relies on the inherent strength of the surrounding rock mass being conserved as the main component of tunnel support. Primary support is directed to enable the rock to support itself. It follows that the support must have suitable load deformation characteristics and be placed at the correct time (usually as soon as possible).
2. <u>Sprayed concrete as protection</u>: In order to preserve the load carrying capacity of the rock mass, loosening and excessive rock deformations must be avoided / minimized. This is achieved by applying a relatively thin layer of sprayed concrete, usually together with a suitable system of rock bolting, immediately after excavation. It is essential that the support system used is in full contact with the rock and deforms with it.

3. Measurements: The NATM requires the installation of instrumentation at the time the initial sprayed concrete lining is placed, to monitor the deformations of the excavation boundary, deformations inside the ground and development of loading in the support. This provides information on tunnel stability and permits optimization of the formation of a load bearing ring of rock strata.
4. Flexible support: The NATM is characterized by versatility and adaptability leading to a flexible rather than rigid tunnel support. Thus, active rather than passive support is advocated, and strengthening is not by a thicker concrete lining but by an adjustable combination of rock bolts, shotcrete with wire mesh, and steel ribs / lattice girder.
5. Closing of Invert: Since a tunnel is a thick – walled tube, the closing of the invert to form load bearing ring of the rock mass is essential. This is crucial in soft ground tunnelling, where the invert should be closed quickly to obtain a rather stiff ring, and no section of the excavated tunnel surface should be left unsupported even temporarily. However, for tunnels in rock, support needs to be flexible in order to mobilize the load-bearing capability of the rock mass. For deep rock tunnels, the rock mass must be permitted to deform sufficiently before the support is subject to excessive strains (lining stress controllers).
6. Rock mass classification determines support measures: for the main classes of rock mass behaviour the support measures are defined in advance, to be optimized in due course based upon monitoring data.

4.3 ADVANTAGES OF NATM

Applications of NATM have accelerated all over the world due to the overwhelming beneficial features it has when compared with other more conventional tunnelling methods. The main advantages have been identified as follows:

i. Can accommodate tunnels of a wide range of geometries and cross sectional areas.
ii. Low cost requirements for tunnelling equipment at the start of the project.
iii. Easy to accommodate additional support measures i.e. rock bolts, steel ribs, dowels etc. if required.
iv. Easy to install waterproof membrane.
v. Easy to install initial support system i.e. sprayed concrete.
vi. Sprayed concrete inner lining ensures good contact between support and ground.
vii. Design and installation of support system optimises costs i.e. excessive use of materials is avoided.
viii. Rigorous monitoring of deformation and stress redistribution opens opportunity for prompt implementation of precautionary / optimization measures.
ix. Can accommodate a great variety of ground conditions.

4.4 TUNNEL DESIGN CRITERIA

4.4.1 GENERAL

The tunnel design will be driven by the following design philosophy:

- Flexibility in design and contract set-up to deal with geological and geotechnical uncertainties

- Employment of State-of-the-Art materials and construction methods

Tunnel design must deal with geological uncertainties and allow for adjustments to local conditions. This is done by a sufficient number of standard excavation classes and support modifications based on geotechnical measurements.

The classification of the tunnelling behaviour during construction is of high importance.

4.4.2 DESIGN APPROACH AS PER AUSTRIAN GUIDELINE

A ground mass classification, which leads to excavation classes of underground works along the individual tunnel sections is performed.

According to Austrian Standard ÖN B 2203 [14] the main task of the geotechnical design is the economic optimization of the construction considering ground mass conditions as well as safety, stability and environmental requirements. In the design phase there are five steps to be followed:

- Determination of Ground Types describes the basic geologic architecture and defines geotechnical relevant key parameters for each ground type.
- The second step determines the Ground Behavior Types describing the potential failure mechanisms during excavation of the unsupported ground mass with the full excavation geometry without considering excavation method, excavation sequence or support.
- Determination of excavation and support takes place in a third step resulting in a system behaviour evaluating interaction between the ground behaviour and the selected excavation and support schemes.
- Based on the first three steps above the alignment is divided into sections with similar excavation and support requirements.
- In the final step of the design process the geotechnical design must be transformed into BOQ, cost and time estimate. Excavation classes are based on the evaluation of the excavation and support measures. They form the basis for compensation clauses and settlement of accounts.

4.4.3 DETERMINATION OF GROUND TYPES (GT)

A Ground Type is defined as a geo-technically relevant ground volume, including discontinuities and tectonic structures, which is similar with respect to following properties

- in rock: mechanical properties (intact rock – rock mass), discontinuity characteristics and properties, rock type, rock- and rock mass conditions hydraulic properties
- in soil: mechanical properties, grain size distribution, density, mineral composition, parameters of the soil components, matrix parameters, water content and hydraulic properties

Different Ground Types have different characteristic parameters that influence their mechanical behaviour. To determine different ground types relevant key parameters have to be evaluated and defined. Different ground masses with similar combinations of relevant parameters are distinguished as one Ground Type.

The final task in this step is to assign the Ground Types to the alignment.

The expected ground types will be given in the Geological Interpretative Baseline Report.

4.4.4 GROUND BEHAVIOUR TYPES (BT)

The ground behaviour is defined for each ground type by evaluating the effect of influencing factors on the response of the ground with the full excavation geometry without support. For evaluation following information is used.

- Ground Type (GT)
- Virgin stress conditions
- Shape and size of the underground structure (final shape and size)
- Position of underground structure in relation to surface or existing structures
- Relative orientation of the underground structure and discontinuities as a basis for kinematical analyses, and the assessment of the stress redistribution
- Boundaries between different ground types
- Ground water, seepage force, hydraulic head

After assigning all relevant properties and influencing factors along the tunnel the ground behaviour for each section of the underground structure is evaluated and categorized. Each behaviour type describes potential failure modes/mechanisms during tunnel excavation. Based on this description all ground types will be assigned to the defined behaviour types. Main ground behaviour types are generally described as follows:

(1) Stable – (2) Potential of discontinuity controlled block fall – (3) Shallow failure – (4) Voluminous stress induced failure – (5) Rock burst – (6) Buckling – (7) Crown failure – (8) Ravelling ground – (9) Flowing ground – (10) Swelling ground – (11) Ground with frequently changing deformation characteristics

The expected behaviour types will be given in the Geological Interpretative Baseline Report.

4.4.5 SELECTION OF CONSTRUCTION CONCEPT

Based on Ground Behaviour types the excavation sequence for each behaviour type and all required support measures are determined and defined in various Excavation Class Types. All types of support measures to be required for tunnel construction are explained later in more detail.

In favourable ground conditions full face excavation (if feasible from the construction logistics point of view) is considered whereas in unfavourable ground conditions top heading and bench/invert excavation will be necessary. For top heading and bench/invert excavation the maximum allowed distance between top heading and subsequent bench/invert has to be defined.

After development of the Excavation and support classes the system behaviour of the ground mass and the support measures are to be checked with calculations.

The round length is a key parameter for the selection of the excavation class. Within one excavation class the round length will vary within a certain range depending on ground condition, excavation method and time required for support installation. With skilled labour force and good equipment round length will be in the upper range which will increase the driving rate.

4.4.6 GEOLOGICAL INTERPRETATIVE BASELINE REPORT

The Geological Interpretative Baseline Report (GIR) contains the status of knowledge regarding the geological, structural and hydro-geological conditions along the alignment. In order to optimize the design the report includes a geological – geotechnical assessment, which is based upon field and desk work. The GIR summarizes subsurface and site conditions that are expected to be encountered during the tunnelling works. The subsurface and site conditions are derived from geotechnical information and data gathered from field investigations. Further the GIR includes the geological model with expected distribution of Ground Types, the expected Ground Behaviour, the description of the expected Ground Behaviour Types (orientation of discontinuities, primary stress conditions, water conditions, rock mass behaviour, and anticipated radial deformations), the assignment of ground types to Behaviour Types and the distribution of the behaviour types along the alignment.

The Geological Interpretative Baseline Report provides part of the basis for evaluating the excavation and support classes.

4.4.7 DETERMINATION OF EXCAVATION CLASSES

Following the determination of excavation and support classes the distribution of these classes along the tunnel will be assessed. This distribution of excavation and support classes is the basis for the theoretical construction time as each individual excavation and support class requires a certain amount of time for excavation and installation of support measures. It has to be emphasized that additional construction time has to be considered for exceptional incidents such as excessive water inflow, which may delay the works substantially.

For conventional tunnelling excavation class drawings according to Austrian Standard ÖN B2203-1 will be provided. An example is shown in the following sketch.

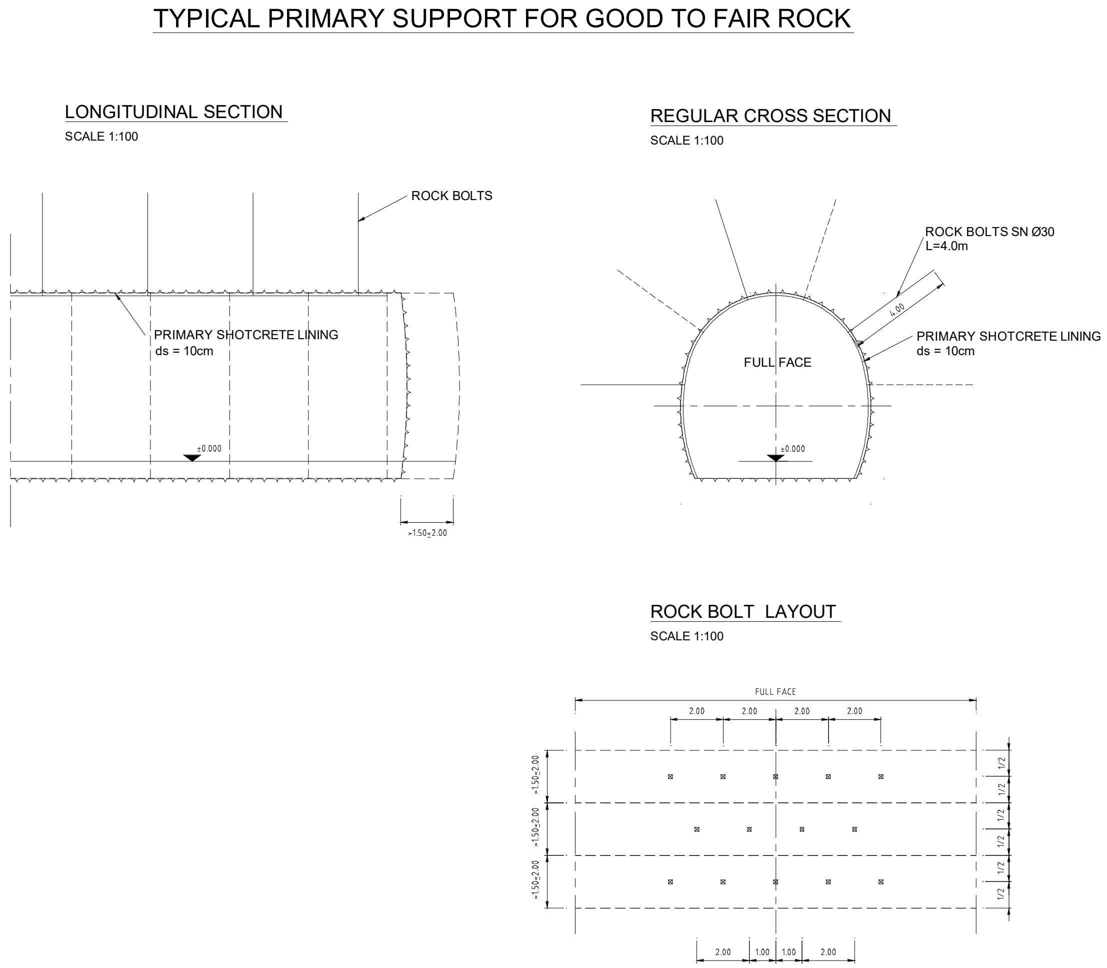

Figure 5: General Example of excavation class

Due to the inherent limitations of geotechnical investigations, excavation and support classes have to be modified on site to deal with the remaining geological uncertainties and allow for adjustments to local conditions. In this context it is emphasized to follow the principles of NATM which are described in the clause 4.2 (Page no. 26)

4.5 PORTALS

Portal cuts are required for each portal of the six tunnels (twelve tubes).

The temporary portal slopes are relatively steep and perpendicular to the alignment axis to allow easier start of the tunnel excavation.

Support measures for the portal cuts are evaluated on the basis of slope stability analysis. The safety of the portal cuts shall be verified on site by a suitable instrumentation and monitoring program.

At one portal of Tunnel T1 (first ROB side) the inclination of the cuts is 1:1 (V:H) due to presence of laterite soil. At the side slopes the angle is flattened to 1:1.25 (V:H) to minimize slope protection measures. For higher cuts, berms of 5 m width are installed for stability, water collection and maintenance purpose. The berms are situated up to 16.4 m height above final excavation level. Slope cuts over and below the berm are covered with minimum 200 mm sprayed concrete and wire mesh.

For other portals of the six tunnels (twelve tubes), the inclination of the cuts is 10:1 (V:H) , At the side slopes the angle is also 10:1 (V:H). Slopes are covered with 100 mm sprayed concrete (with one layer of wire mesh). Spot bolting by rock bolts (SN respectively SD bolts) is to be done as and where required.

Additional measures include lowering the groundwater table by drainage holes and reduction of water pressure built-up behind the sprayed concrete by weep holes. For safe conveyance of rain water, drainage ditches are installed at all slope boundaries as well as on the berms. The water collected in the drainage ditches will be collected in ditches on the slope footing and transferred towards the next drainage channel.

4.5.1 PERMANENT PORTALS

The design of the permanent slopes will be decided at a later stage after completion of topographic survey.

In general the permanent portals will need to fulfill the main objectives below:

1. Protection from minor rock falls, by providing a short stretch of tunnel covered by soil / earth
2. Aesthetic entrance to the tunnel
3. Long-term durability and stability of the tunnel entrance area

5 TUNNEL DRAINAGE AND WATERPROOFING CONCEPT

5.1 GENERAL

The twin tubes are designed as drained tunnels. This means a waterproofing system and conveyance of the water to the ground water drainage system will be provided in all parts of the tunnels.

It is requirement of MORTH / KPWD to achieve at least a "semi dry" tunnel. This means that while water inflow cannot be tolerated with regard to electrical system, local wet patches or local dripping of water can be accepted. In order to achieve a dry tunnel, a waterproofing system will be provided between the outer and inner tunnel lining.

5.2 WATER PROOFING

The water proofing system will consist of a layer of geotextile and a PVC or HDPE waterproofing membrane.

The geotextile shall act as a drainage layer and for protection of the membrane against the rough sprayed concrete surface. It requires a minimum thickness as specified in the works specifications. It will be fixed locally to the sprayed concrete surface by means of plastic discs and nails. Before installing the geotextile all sharp corners shall be removed and a final smoothening layer of 10 to 20 mm sprayed concrete shall be applied.

The waterproofing membrane is the actual water barrier and will be fixed to the plastic discs by means of thermal welding. Connection of the membrane pieces will be also by thermal welding. The waterproofing system will only be installed in the tunnel roof and the tunnel sidewalls. Minimum properties of the waterproofing membrane are defined the Work Specifications.

The water collected behind the water proofing membrane is flowing down into the lower sidewall area by gravity and is collected there in slotted pipes.

5.3 TUNNEL DRAINAGE CONCEPT

The drainage system is designed as a three part drainage concept:

- Sidewall Drainage – 200mm diameter – in both sidewalls of the tunnel
- Tunnel Main Groundwater Drainage – 300mm diameter for collection of sub surface water and draining it out (also called "main collector").
- Tunnel Main Pavement Drainage – 300mm diameter for collection of pavement water and spilled hydro – carbon liquid on surface.

The first two parts will be connected with each to form the groundwater drainage system and third one is a separate system for the purpose of tunnel safety. The vertical alignment of the twin tubes is designed as a dipping gradient profile (Refer longitudinal section of each tunnel). Therefore the water quantity over the each tunnel length shall be diverted in local drain / nala through the one portal (end portal) only.

The 200mm diameter side drainage pipes are installed in no fines concrete outside the water proofing system. Maintenance Niches minimum every 65 m at both sidewalls are intended for cleaning the sidewall drainage pipes; manholes with shafts are installed where the sidewall drainages are connected to the main collector.

The 300mm diameter Tunnel Main Pavement Drainage is designed to receive water from both lanes of the pavement (driving lanes and emergency lane). Manholes minimum every 65m are foreseen for cleaning purposes.

The minimum gradient of the drainage canals / pipes will be as per tunnel gradient.

6 DESIGN METHODOLOGY

All tunnel construction will be carried out in accordance with the principles of the New Austrian Tunnelling Method (NATM). The method is based on the concept of a cyclic sequence of excavation with subsequent installation of a primary support (outer lining) followed by the delayed installation of a secondary lining (inner lining), made either from sprayed concrete or cast – insitu concrete.

The outer lining, which consists of sprayed concrete, generally reinforced by wire mesh, lattice girder (where required) and rock bolts, will provide the immediate support and stability of the excavation. The inner lining, which is made with cast-in place concrete, will provide the long-term support and durability of the tunnel.

Tunnel excavation will generally be carried out by means of drilling & blasting with drilling jumbos or by tunnel excavator. The rock support system for excavated sections will vary from place to place, depending on rock mass quality and stress condition.

A subdivision of the tunnel cross-section into top heading and bench will be required due to the size of the cross section (available machinery). In tunnel sections of unfavorable geotechnical conditions, a temporary invert/ invert arch will be installed if and as required.

Based on the derived geological-geotechnical model, the project specific rock mass classification and the envisaged occurrence of rock classes along the tunnel sections have been developed. Specific standard support classes and their respective stabilization measures are designed to cope with all anticipated conditions.

Different excavation sequence, type and quantity of primary support elements are considered for each support class. The assignment of a tunnel section to a specific support class will be made based on the actual geotechnical conditions encountered during construction. The adjustment and refinement of the primary support, as well as its applicability for different ground conditions identified by regular face mapping, will be carried out based on the evaluation of the results of the geotechnical monitoring, which constitutes an essential element of the New Austrian Tunnelling Method.

Monitoring is carried out at instrumentation sections installed at regular and specific spacing along the tunnel.

6.1 DESIGN OF PRIMARY SUPPORT MEASURES

Based on the geological model and the geotechnical design parameters the support measurements and the excavation scheme will be designed for the different tunnel sections. The following primary support measures shall be considered in the design of the NATM structures:

6.1.1 SPRAYED CONCRETE

The primary sprayed concrete lining functions as the primary support which must provide the stability of the excavated cavity immediately at the excavation face and afterwards until the secondary lining is placed and has achieved its full load bearing capacity.

Sprayed concrete applied in the tunnels shall be of minimum quality M25 according to Indian Standard IS456:2000. Standard sprayed concrete thicknesses to be applied are currently envisaged to be between 50 mm and 300 mm. Sprayed concrete application shall be performed in layers not exceeding an individual thickness of 200 mm.

Where required due to ground conditions a sealing layer is applied, the minimum thickness of the same is included in the required structural thickness of the sprayed concrete shell.

6.1.2 LATTICE GIRDERS

Lattice girders shall be installed to provide immediate support for the exposed rock mass during excavation and to serve as template for the excavation geometry. They also serve as guidance and support for forepoling and are considered as reinforcement of the sprayed concrete lining. Lattice girders shall be of steel grade Fe500. Depending on the applied sprayed concrete thickness different types of lattice girders shall be installed.

All lattice girders shall be installed as close as possible to the actual achieved excavation line respectively sealing layer (if applicable) at a maximum distance of approximately 30cm to the top heading face.

6.1.3 ROCK BOLTS

Rock bolts shall be applied for the NATM tunnels with the following objectives:

- In good ground conditions local rock bolts may be required to secure individual blocks against rock fall (spot bolting), and
- In fair to poor ground conditions the systematic installation of rock bolts at the sidewalls increases the support pressure and thus the triaxial bearing capacity of the ground (reinforcement of the ground).

The following rock bolts shall be used in the tunnel:

SN bolts

SN bolts shall have a bar diameter of 25 mm and a steel grade Fe500. SN bolts shall have minimum yield strength of 230 kN. Installation length shall be between 4 m and 6 m for standard applications. Bolts shall be embedded in cement mortar grout or cement paste only.

Swellex bolts

Swellex bolts may be applied as required in the better rock types as alternative to SN bolts. They may be required in situations where an immediate effect of the rock bolt is required, such as securing individual blocks. Length of Swellex bolts shall be 3 m and 4 m. Swellex bolts shall have a minimum breaking load of 200 kN.

Self drilling bolts type R32N

Self drilling bolts shall be of type MAI or IBO R32N with a minimum yield strength of 230 kN. Installation length shall be between 4 m and 9 m for standard applications. If self drilling bolts are used as face bolts their length shall be 9 m to allow for a sufficient overlap between following face bolting rounds.

Bolts shall be grouted with cement mortar grout or cement paste only.

6.1.4 REINFORCEMENT STEEL

Wire mesh reinforcement and steel bars shall be of steel quality Fe 500 according to Indian Standard (IS 1786).

For all tunnel sections wire mesh 150/150/6 mm will be applied as standard. Wire mesh will be applied as outer (rock side) layer, either direct at the exposed rock surface or after application of a sprayed concrete sealing layer. Overlap of wire mesh in circumferential direction shall be 300 mm (2 mesh openings) and in longitudinal direction shall be 150 mm (1 mesh openings).

Additional reinforcement for the primary support will be installed in accordance to the structural design either as bar or wire mesh reinforcement.

6.1.5 FOREPOLING

In certain areas the installation of forepoling will be required to avoid the development of loosening rock zones in the crown area of the top heading. Forepoling will be installed each round from the current top heading face to provide safety for the following top heading excavation round. It shall be installed through the last lattice girder installed. Depending on the ground conditions encountered, forepoling will be performed with one of the following types:

- In ground conditions where the borehole stability can be guaranteed steel bars of grade Fe 500, diameter 32mm will be installed.
- In ground conditions where borehole instabilities are likely to occur self drilling bolts of type R32N with a yield strength of minimum 230 kN will be installed.

Forepoling length will be 4 m for all support classes and 6m during start sequence, and is to be installed every round, thus giving sufficient overlap between adjacent rounds. All forepoling elements must be embedded in cement mortar.

6.1.6 FACE STABILIZATION MEASURES

Face support consists of the following measures, which shall be applied individually or in combination according to the encountered conditions and requirements.

<u>Application of face sealing layer</u>

To avoid the occurrence of shallow face collapses in fractured rock masses a face sealing layer of sprayed concrete might be required to secure the top heading face during installation of support measures in the round closest to the face. If required the face sealing shall be reinforced with 1 layer of wire mesh 150/150/6mm. Face sealing layer thickness shall be between 5-10cm, while 5cm shall be unreinforced whereas a 5-10cm thick layer shall be reinforced upon requirement.

<u>Installation of face bolts</u>

In addition to sprayed concrete sealing the installation of face bolts shall be considered together with a sealing sprayed concrete layer. Face bolts shall be of type R32N with an installation length of 9 m. Overlap between following face bolt rounds shall be not less than 3 m. Face bolts shall be fully grouted with cement mortar grout or cement paste and be equipped with load distribution plates to provide a uniform support pressure onto the excavation face.

Subdivision of the top heading face in smaller "partial excavation areas"

This measure shall be taken in combination with other face support measures if face stability of the top heading cannot be maintained for the "full" face in very poor ground conditions or fault zones.

The top heading face shall be subdivided into smaller areas which are excavated and supported immediately again prior to excavation of the following top heading part.

6.2 DESIGN OF INNER CONCRETE LINING

The inner lining will vary along the route with regard to the installed primary lining and the observed system behaviour (ground-lining interaction). The secondary lining will in general consist of high-quality cast-insitu concrete or alternatively high – quality sprayed concrete. The application of sprayed concrete for the inner liner may save cost as no formwork is required, however the design at this stage will take only cast-insitu concrete into consideration.

At soft ground, very weak rock with water inflow and squeezing rock conditions an invert arch is required.

With regard to the possible options the following lining types are developed for the main tunnels:

Table 2: Inner concrete lining type

Type	Lining	Application
T1	Insitu concrete, t=300 mm, with flat invert	Good to poor/ weak rock conditions
T2	Insitu concrete, t=400 mm, with arched invert	Very poor rock condition
T3	Insitu concrete, t=300 mm, with flat invert	Portal area (good to poor/weak rock conditions)
T4	Insitu concrete, t=400 mm, with arched invert	Portal area (Laterite soil) / very poor rock condition

The concrete shall be cast using a traveling shutter. One set of tunnelling form will have one traveler and tunnel formwork of 12.5 m length.

In case of an arched invert, the invert will be cast ahead. The overt arch section will follow at some distance. For sections without invert the side foundations will be cast first and the overt arch section shall follow at a certain distance behind.

6.2.1 DESIGN OF PORTAL SLOPES

Slope stability shall be performed under consideration of the expected rock mass types at the portal and under consideration of the designed portal cuts.

The analysis of ground behaviour during excavation and after installation of the support elements for temporary slope stabilization (= sprayed concrete and bolts) shall be carried out with the calculations based on limit equilibrium and/or FEM analysis using strength reduction factors

Seismic load

The project area is situated in low seismic activity region. Following the seismic mapping as per Indian standard IS1893 (part1) – 2000, the project site is situated in seismic zone II. The zone factor for seismic zone II is 0.10 which defines the maximum value of the horizontal peak ground acceleration (kh).

Factor of Safety

The overall factor of safety for each slope is determined for two different load combinations, the normal load combination (no seismic load) and the exceptional load combination considering the seismic load case. The desired factor of safety for each load combination is given in as follows:

General combination (without seismic consideration): 1.50

Exceptional combination (with seismic consideration): 1.00

7 INSTRUMENTATION, MONITORING AND ITS EVALUATION – OBSERVATION OF TUNNEL BEHAVIOUR

The assessment of the tunnel performance, tunnel stability and proper adjustment of supporting measures and excavation sequences, is an integral part of NATM philosophy and can only be done on basis of an extensive instrumentation and monitoring program.

Geotechnical Monitoring is a vital part of NATM. The geotechnical monitoring system comprises in general the following elements:

- 3D-Targets / Monitoring points
- Instruments to do the measurement
- Software to process the data and to display the data in an appropriate way
- Extensometer
- Pressure Cells
- Strain gauges

The 3D – Targets, the total station used for the monitoring and the required software have to correspond in terms of accuracy and interfaces. To obtain accurate results both high quality 3D targets and a high precision total station are required.

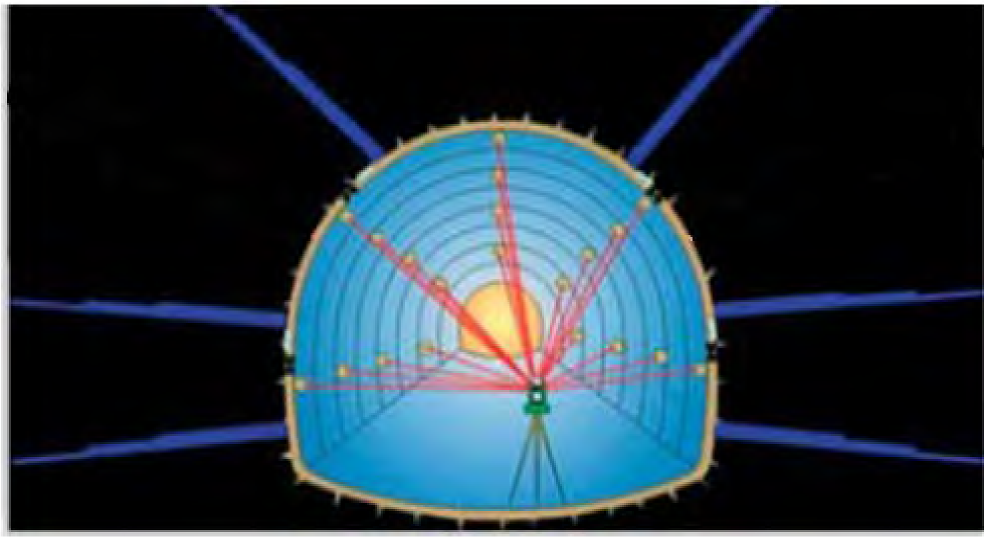

Figure 6: Typical Monitoring section with Strain meter, Extensometer and 3D Targets

The principles and procedures of Geotechnical Monitoring define the requirements for data collection. It has to be stressed that especially in tunnelling a prompt and regular data collection is the basis for interpretable and reliable information.

7.1 MONITORING ELEMENTS

The different elements foreseen for geotechnical monitoring are explained as under.

7.1.1 3D-TARGETS / MONITORING POINTS

In order to get the position of a point at the surface, bi-reflex targets are fixed on convergence bolts. The thread of the convergence bolts is protected by a protective cap during installation and periods when the target is removed from the bolt for periodic measurements. Recording distances for this kind of targets are 10-100m for desired accuracy.

7.1.2 EQUIPMENT / TOTAL STATION

The equipment for taking the measurements is given below. The equipment will be referred to as “total station”.

The required accuracy of the total station for 3D monitoring is:

- angular measurement: 1” (0,3 mgon)
- distance measurement: 1mm + 2ppm

7.1.3 SOFTWARE

The software to be used shall be able to (minimum requirements):

- import data from the total station
- organize the data as per requirements
- support analysis of the data
- Produce diagrams suitable for geotechnical interpretation and assessment of the tunnel behaviour by the Geotechnical Engineer.

7.1.4 EXTENSOMETERS

Extensometers are used for determination of ground movements outside of the excavated structure. They allow an assessment of the development of strains in the surrounding ground and of the stabilisation of movements around an excavation.

Extensometers shall be multiple rod type with anchors connected to the ground by grouting at predefined positions. Readings shall be performed by remote reading using electrical transducers. Measuring accuracy shall be ± 0.10 mm.

7.1.5 PRESSURE CELLS

7.1.6 RADIAL PRESSURE CELLS

With radial pressure cells the development of ground pressure acting on the primary support structure (sprayed concrete lining) is measured. To get reliable results the following requirements shall be met:

- Large size pressure cells, as a larger area of the cell gives more reliable results (larger area of influence)

- Possibility of Re-pressurizing; caused by thermal effects a shrinkage gap develops between the cell and the sprayed concrete lining, which has to be closed to provide accurate cell readings.

7.1.7 TANGENTIAL PRESSURE CELLS

Tangential Pressure cells are used for determination of the sprayed concrete lining stress. They shall only be installed in areas of special interest. They shall have a dimension of 100 x 200 mm, a pressure capacity of 200 bars and a measuring accuracy of ± 1 %. Readings shall be remote controlled with electrical transducers.

7.2 PRINCIPLES AND PROCEDURES

7.2.1 INSTALLATION AND INITIAL READING

The convergence bolts are to be placed and fixed provisionally before the first layer of sprayed concrete is applied. During installation the protective cap has to be there in order to avoid damage to the thread.

After the targets have been installed completely, the Zero Reading has to be taken immediately. It is good practice to do this as soon as possible, since usually the major part of the deformations takes place during and shortly after opening a round.

7.2.2 MONITORING FREQUENCY

Regular monitoring is required as per NATM concept; frequency of monitoring shall be decided based on the site conditions, geotechnical assessment and ground behaviour.

7.2.3 MONITORING SECTIONS

In principle, the various monitoring elements shall be installed in monitoring sections. Monitoring sections can be subdivided according to the elements installed.

Standard Monitoring Sections (SMS) consist of targets for absolute displacement monitoring underground. They shall be installed at regular intervals in the tunnels.

In Main Monitoring Sections (MMS) additional monitoring instruments shall be installed. They shall allow an assessment of the loading of the primary support and of ground movements outside the excavation for design verification purposes.

7.2.4 EVALUATION AND INTERPRETATION OF MONITORING RESULTS

In general, the data handling and information flow of monitoring results shall be as follows:

Upon completion of daily monitoring activities and pre-processing of monitoring raw data a preliminary evaluation of the monitoring results by a plausibility check shall be performed. Only after the results have to be found reasonable and eventual errors have been excluded and corrected, an update of the database shall be performed. Plausibility checking shall be performed by the responsible Surveyor together with the Geotechnical Expert.

When the database has been updated with the actual monitoring results, the Geotechnical Expert shall proceed with the evaluation and interpretation of the monitoring results. To guarantee a quick decision with regard to support requirements and working procedures the database must be updated with the daily measurements as early as possible.

A graphic representation of Data and Information Flow is presented in the figure below.

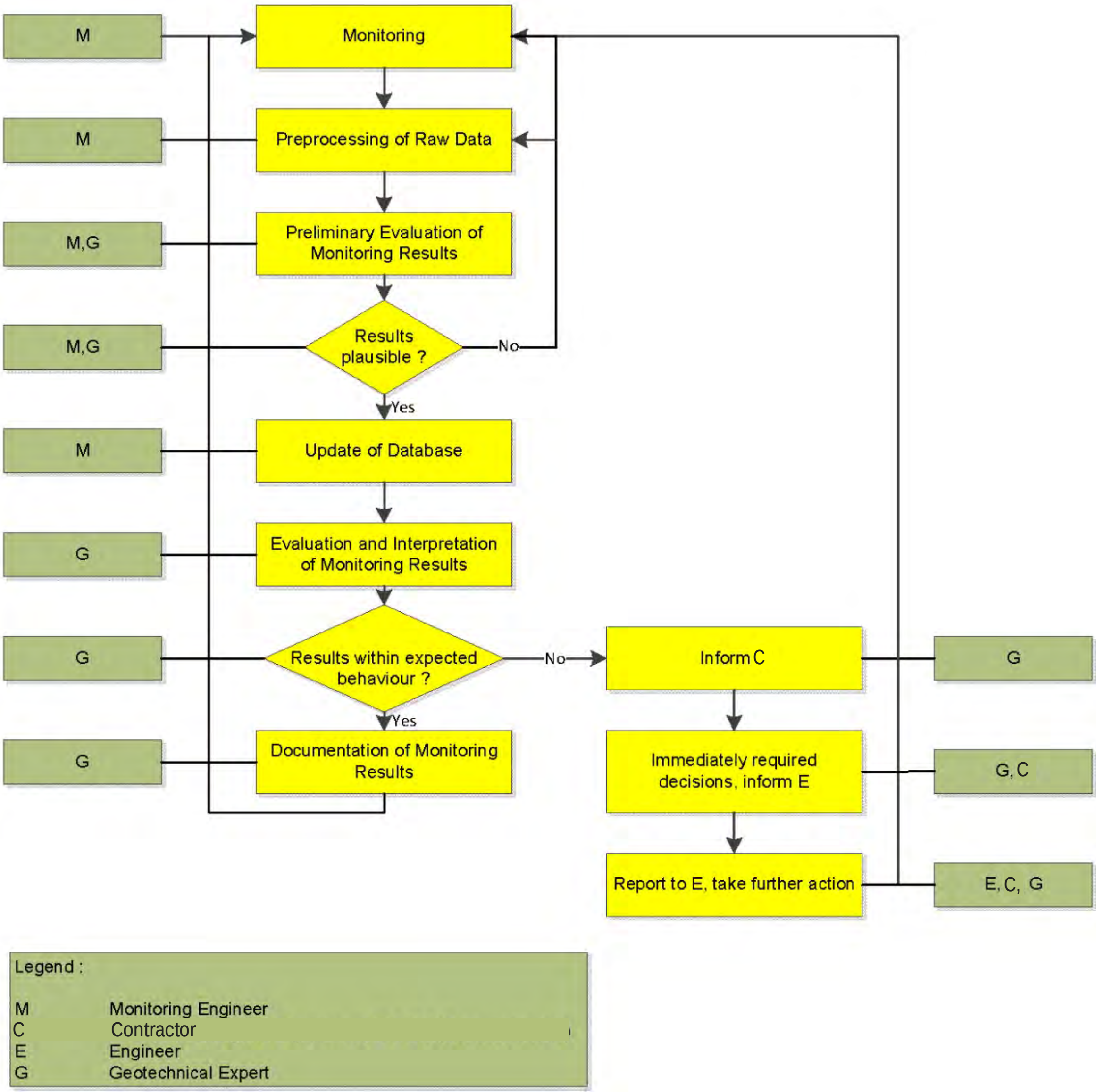

Figure 7 : Data and Information Flow for Monitoring Results

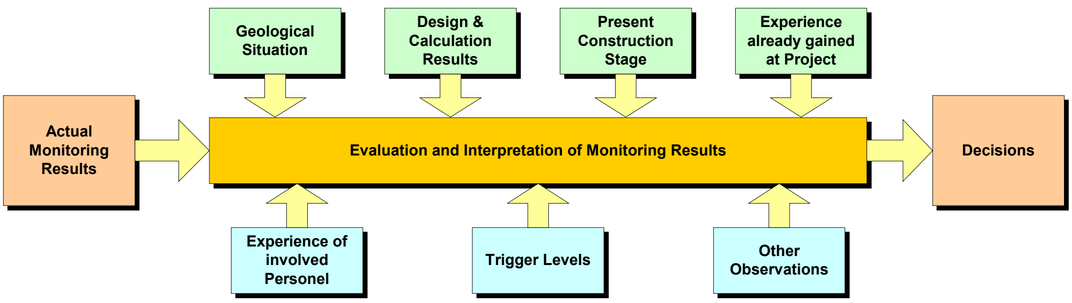

Figure 8 : Input Parameters for Evaluation and Interpretation of Monitoring Results

7.2.5 RISK MANAGEMENT THROUGH MONITORING

Geotechnical Monitoring is an effective tool in risk management for underground works. It enables the recognition of deviations from the envisaged behaviour at a very early stage, as shown below.

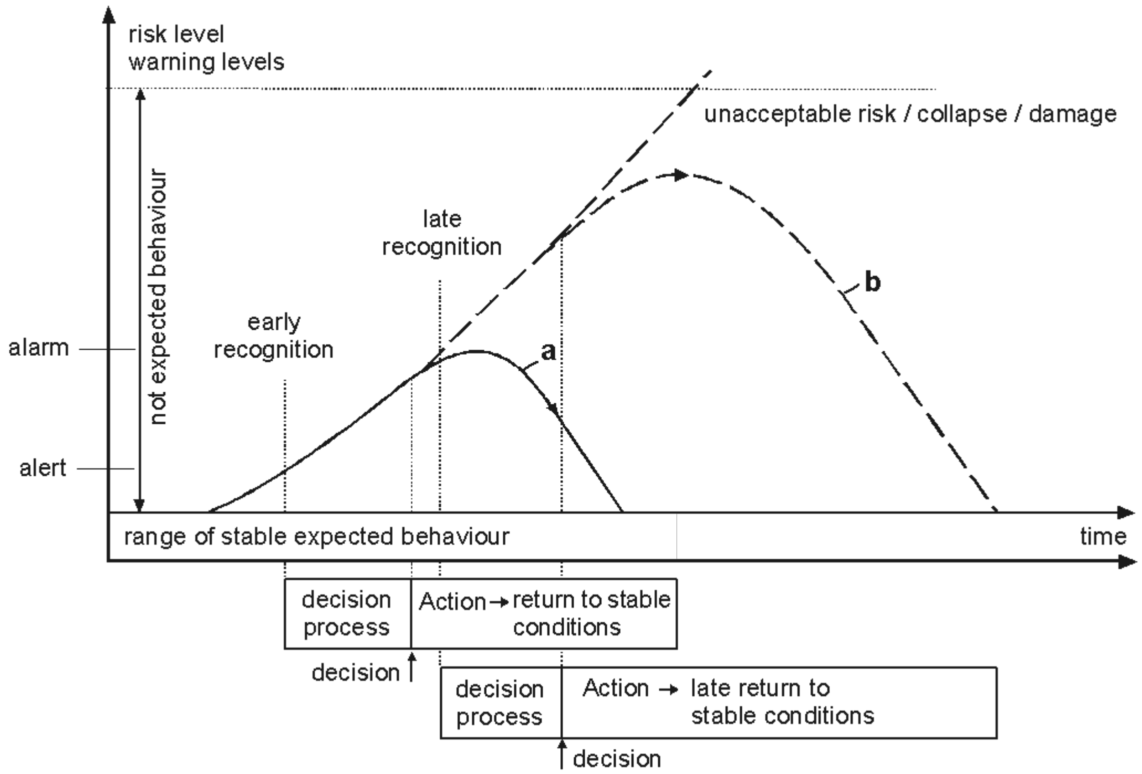

Figure 9 : Risk level versus deviation from expected behavior

Together with the observational approach through NATM, risk can be properly managed and also an optimized construction process can be achieved.

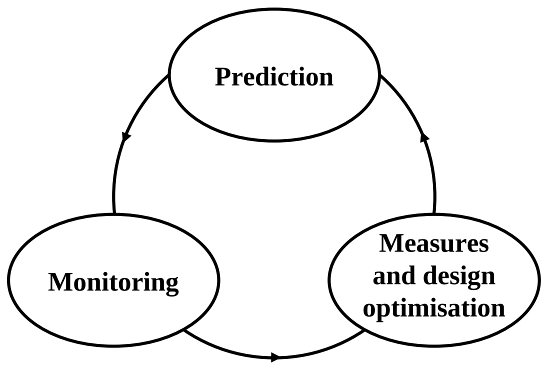

Figure 10 : Observational Approach

8 TUNNEL CONSTRUCTION

The detailed aspects of construction like number of faces, size and length of head and bench etc. will be finalized at a later stage.

Tunnel excavation will generally be carried out by means of drill & blast, except for the weathered ground sections / Laterite soil section at both portals (total length approx.500 m) of six tunnels (twin tubes) where tunnel excavators or hydraulic breakers will be used. A subdivision of the tunnel cross – section into top heading and bench will be generally applied. Along the weathered ground conditions at the portals as well as in tunnel sections of very unfavourable geo-technical conditions, an invert arch will be installed.

8.1 EXCAVATION WITH CONVENTIONAL METHOD (D&B)

Using D & B method, the studies will be driven to optimize the times and costs for the excavation considering the following aspects:

- Excavation with blasting (explosive),
- Excavation with hydraulic hammer,
- Excavation with tunnel excavator,
- Management of the crossing of fault zones
- Management of the risk of crossing of zones subject to major water inflows
- Management of the risk of excavation in the presence of natural gas.

The following figures show the sequence of Tunnel construction with D & B excavation.

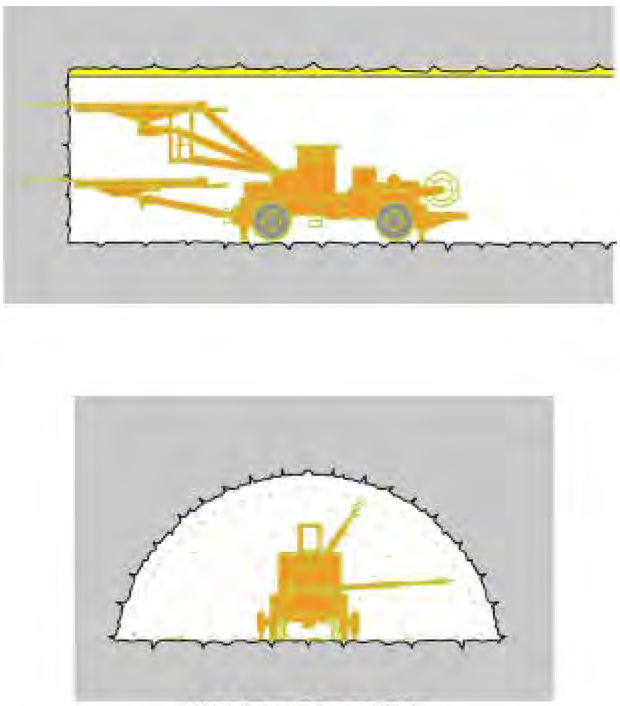

Fig.1 Tunnel face drilling

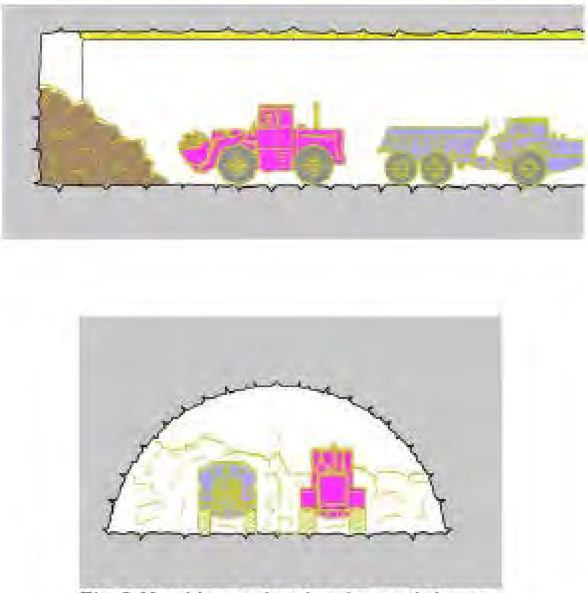

Fig.2 Mucking using loader and dumper

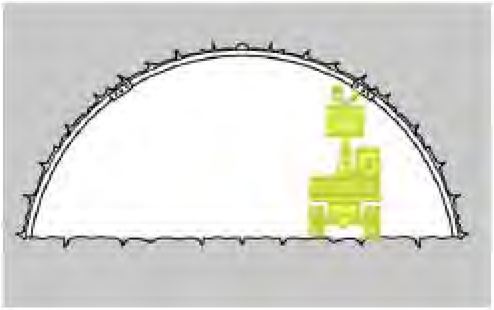

Fig. 3: Lattice Girder Installation

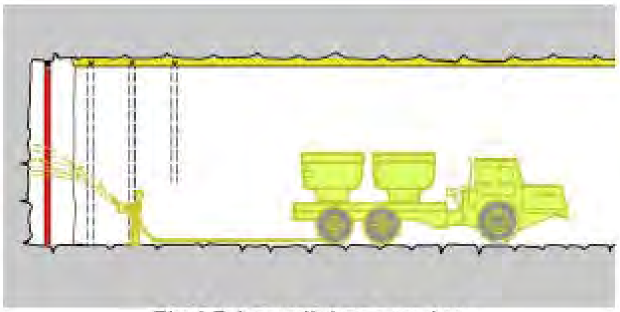

Fig.4 Primary lining spraying

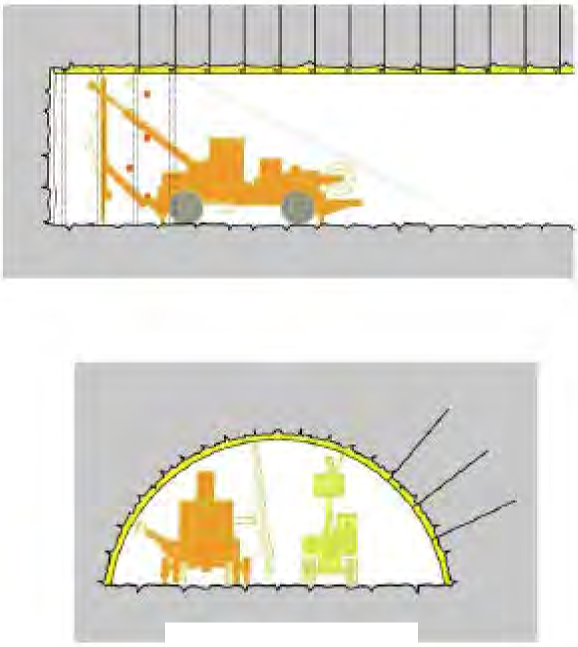

Fig. 5 Rock Bolting

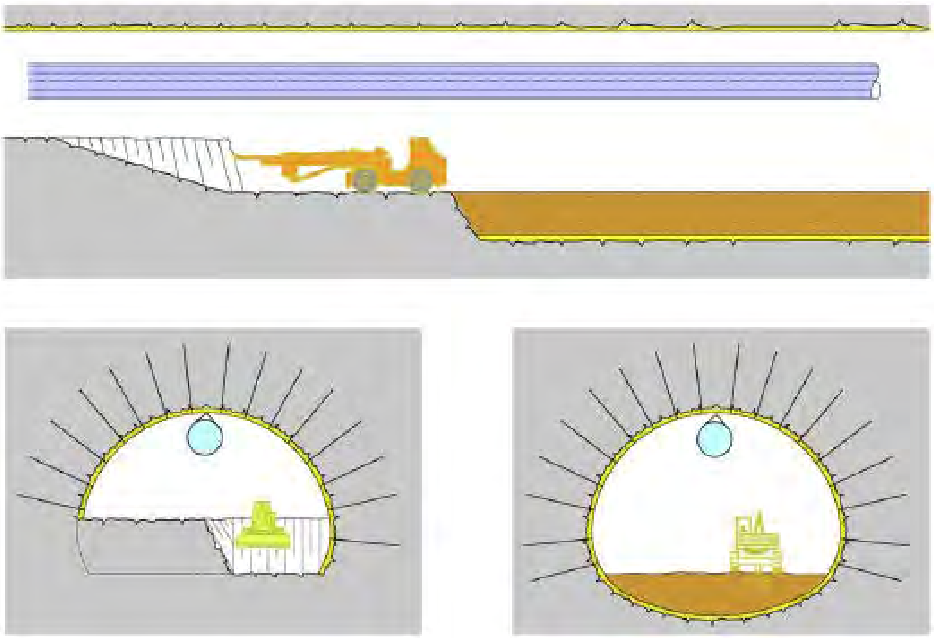

Fig. 6 Bench excavation

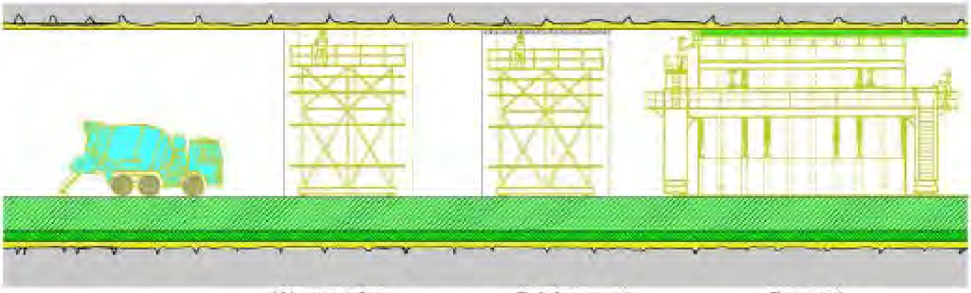

Fig.7 Secondary lining construction

9 STANDARDS & REFERENCE DOCUMENTS

[1] RFP documents for

[2] Addendum Letter No.

[3] Corrigendum Letter No.

Reports:

[4] JICA Feasibility report of tunnel construction at Shiradi ghat section in the state of Karnataka. Submitted on 07.05.2012

[5] Study on Economic Partnership projects in Developing Countries in FY 2014 – Study on Road improvement project for Shiradi Ghat Stretch in India. Submitted on January 2015.

[6] Geological Interpretative Report Shiradi Ghat tunnel project of NH 48

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[7] Directive 2004/54/EC of the European Parliament and of the Council on Minimum Safety Requirements for Tunnels in the Trans-European Road Network,2004

[8] Human Factors and Road Tunnel Safety regarding Users, World Road Association (PIARC), Report, 2008

[9] Dossier pilote des tunnels, équipements – section 4.1 Ventilation, CENTRE D'ÉTUDES DES TUNNELS (CETU), novembre 2003

[10] Vehicle emissions, air demand, environment, longitudinal ventilation, World Road Association (PIARC), Report 05.02.B, 1995

[11] Road Safety in Tunnels, World Road Association (PIARC), Report 05.04.B, 1995

[12] Guideline for geotechnical design of underground structures with conventional excavation, Austrian Society for Geomechanics, 2009

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[14] Austrian Standard Oenorm B2203 Part 1 Underground Works – Conventional Excavation, 2001.

[15] IS 456:2000 Plain and Reinforced Concrete (Fourth Revision)

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[19] EN 1992-1-1, Eurocode 2: Design of concrete structures, Part 1-1: General rules and rules for buildings

[20] EN 1997, Eurocode 7: Geotechnical design – Part 1: General rules

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[23] ZTV-Ing: 2003-01, Teil 5, Tunnelling - Tunnelbau

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[25] IS 1786-2008 High strength deformed steel bars and wires for concrete reinforcement

[26] Y.M.A.Hashash et al./Tunnelling and Underground Space Technology 16 (2001) 247-293 - "Seismic design and analysis of underground structures"

[27] IRC : SP : 91 – 2010 – Guidelines for Road Tunnels

[28] IS: 5878 (Part I) 1971 Precision Survey and setting out.

[29] IS: 4081-2013- Safety Code for Blasting and Related drilling operations.

[30] IS: 9103-1999- Admixtures for Concrete.

[31] IS: 3764-1992- Safety Code for Excavation work.

[32] IS: 4138-1977- Safety Code for Working on Compressed Air.

[33] IS: 7293-1974- Safety Code for Working with construction Machinery.

[34] IS: 823-1964- Code of procedure for manual metal Arc welding of mild steel.

[35] IS: 816-1969- Code of practice for use of Metal Arc welding for General Construction in Mild steel.

[36] IS: 1566-1982- Hard Drawn steel wise fabric for Concrete reinforcement.

[37] IS: 1200 (Part-XXV) 1971 - Methods of Measurement of Building and Civil Engineering works.

[38] IS:1905-1987-Code of Practice for Structural safety of Buildings, Masonry walls.

[39] IS: 1256-1967- Codes of Practice for Building Bylaws (First Revision).

[40] IS: 458-2003- Concrete pipes (with and without reinforcement).

[41] IS: 800-2007 – Code of Practice for use of Structural steel in General Building Construction.

[42] IS : 13365 (part I, II, III) – Quantitative classification of Rock mass

[43] IS 2339 for Aluminum Paint ready mix.

[44] IS 2062 for Structural Steel.

[45] IS 961-1975 Indian Standard Specifications for Structural Steel (High tensile) revised SR- 58-HTC grade with copper content of 0.2 to 0.35 per cent shall be used for the High Tensile steel items.

[46] IS 1149-1973 for High tensile steel rivet bars for structural purpose, with copper content of 0.2 to 0.35 per cent.

[47] IS 1148-1964 – Rivet bars (Mild Steel) for structural purpose.

[48] IS 1929-1961 and IS 2155-1962-General Dimensions of rivets.

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[52] Indian Explosive Act-1988.

[53] Indian Explosive Rules –1983.

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[59] IS 2131 (2002) Method for standard penetration test for soil.

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[61] IS 2729 (1981) Methods of test for soil.

[62] IS 5313 (1969) Guide for code drilling observation.

10 SPECIFICATIONS

The following material properties are considered in the design.

10.1 SPRAYED CONCRETE

Concrete grade (according to IS 456:2000): minimum M25

The 28-day characteristic compressive strength (fck) of sprayed concrete shall be minimum 25N/mm2. The early strength development of sprayed concrete shall conform to Class J2 according to the Austrian Guideline for Sprayed Concrete [13] (shown in Figure 10).

- Poission's Ratio ν = 0.2
- Unit weight: g = 24 kN/m³

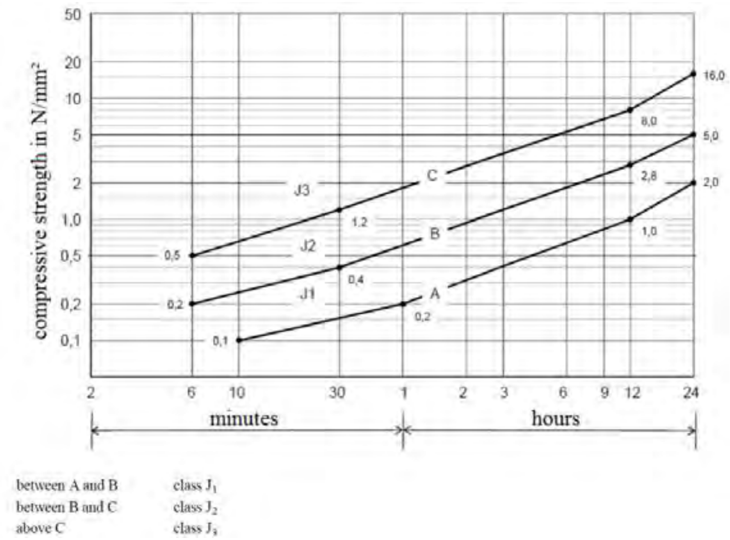

Figure11 - Early strength development of sprayed concrete

10.2 REINFORCING STEEL

Deformed steel bar mats (wire mesh) Ø6mm 150x150 according to IS 1786:2008

Grade:	Fe 500
Yield strength:	fy= 500N/mm2
Young's Modulus:	Es= 200000 N/mm2

Steel structural bars (according to IS 1786:2008)

Grade:	Fe 500
Yield strength:	fy=500N/mm2
Young's Modulus:	Es= 200000 N/mm2

10.3 STEEL FIBRES

Steel fibres for fibre reinforced sprayed concrete shall apply to the following minimum requirements.

Type:	DRAMIX RC-65/30 (or equivalent) drawn wires with end-hooks
Length of fibres:	30 mm (to guarantee pumpability)
Aspect ratio (l/d):	> 65
Tensile strength:	ftk ≥ 1000 MPa

10.4 ROCK BOLTS

SN – rock bolts min. diameter 25mm and anchor plate 200x200x12 (according to IS 1786:2008)

Steel grade:	Fe 500
Yield load:	246kN
Characteristic yield strength:	500 N/mm^2

Swellex Rockbolts

Minimum Yield load:	Fy≥180kN
Minimum breaking load:	Fu≥200kN

Self drillings bolts

Outer dia:	32mm and 38 mm
Yield load:	230kN and 400 kN
Max. Tensile Load	280kN and 500 kN

10.5 LATTICE GIRDER

Grade:	Fe 500	
Yield strength:	fy=500N/mm2	
Types:	95/20/25	130/25/32

Lattice girders shall be installed to provide immediate support for the exposed rock mass during excavation and to serve as template for the excavation geometry. They also serve as guidance and support for forepoling and are considered as reinforcement of the sprayed concrete lining. Depending on the applied sprayed concrete thickness, different types of lattice girders shall be installed.

All lattice girders shall be installed as close as possible to the actual achieved excavation line respectively sealing layer (if applicable) in a vicinity of approximately 30 cm to the top heading face.

10.6 FOREPOLING

- Steel bars with yield strength 500 N/mm2 (according to IS 1786:1985), diameter 25mm or
- Self drilling bolts of type R32N (or equivalent) with yield load 230 kN (Fy≥230kN)

All forepoling elements must be embedded in cement mortar

10.7 FINAL LINING

Concrete minimum grade (according to IS 456:2000): M35

Young's modulus: $E_C = 5000 \cdot \sqrt{f_{ck}}$ = 27400 MPa
Poisson's ratio: 0.2
Unit weight: g = 25 kN/m³ (Reinforced concrete)
= 24 kN/m³ (Plain concrete)

10.8 WATERPROOFING

The waterproofing system of the final lining shall meet the following requirements:

System: umbrella type
Type of waterproofing: PVC HDPE waterproofing membrane (or equivalent)
Thickness: 2 mm
Type of protection: protective felt (or equivalent)
Weight ≥700g/m2

10.9 LEAN CONCRETE

Concrete grade (according to IS 456:2000): M15

--------End of Main Document------------

Prepared for:

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MINISTRY OF ROAD TRANSPORT & HIGHWAYS

Karnataka
Public Works, Ports & Inland Water Transport Department

Project:

Consultancy Services for “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka”

Subject:

KD-6 - Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume - II: Design Report

Part II: Design of Tunnels (B)-Technical Note on Tunnel Section and System

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Revision History

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INTRODUCTION

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorporation of Client's observations on earlier submitted "KD5: Kucha Draft Detailed Project Report (KDDPR)" vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels :

- *Proposed Tunnel Design, Standards*
- *Technical Note on Tunnel Section and System*
- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures :

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report :

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

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PART- II: DESIGN OF TUNNELS

(B): TECHNICAL NOTE ON TUNNEL SECTION AND SYSTEM

A. General

This Volume - I: Design Report- Part II: Design of Tunnels, (B) Technical Note on Tunnel Section and System, a part of “KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)” is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report- Part II: Design of Tunnels, (B) Technical Note on Tunnel Section and System of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

1. INTRODUCTION

With the letter of acceptance LoA Ref.:NH/PIU-Tunnel/NH-48/Tender/2015-16/33-36, dated 10th July 2015, GEOCONSULT has been appointed for “Consultancy Service of feasibility-cum-geotechnical study for bypass to Shiradi Ghat from km 238.00 to 261.45 on NH-48 in the state of Karnataka”.

This report deals with the geological survey conducted till date, preliminary assessment of rock mass condition based on geological reconnaissance survey, study of available literature, maps and geotechnical/ geological model for design of the primary support measures for the tunnels in the proposed alignment for the bypass road from Maranhally to Gundya on NH-48 in Shiradi Ghat Section. It also deals with the plan for further geotechnical investigation shall be carried out. Forest clearance has been obtained so far for carrying out topographical survey, detailed engineering geological mapping and geophysical survey. However permissions are awaited for conducting geotechnical drilling, sampling, in-situ and laboratory testing from forest department

On the request of PWD Karnataka is to further elaborate the reasons for choosing the given tunnel system and cross section, which has been made by the Consultant in the above mentioned report. The reasons to propose the tunnel cross section as given in [1] are mainly economical with the background of the project boundary conditions and the safety considerations, which are based upon the European Directive 2004/54/EC [3]. This directive has been chosen as basis for the design by the Consultant, replacing the national guideline IRC84:2014 [4].

This Technical Note has been made after a meeting during a site inspection from 21st September 2015 till 24th September 2015 by the Author. Any repetitions from the subject report (Ref. [1]) will be avoided in this Technical Note.

1.1 Request for a Technical Note

The European Directive [3] came into force in 2004 and defines the minimum safety standards a tunnel has to have in Europe. The undersigning states are obliged to implement the requirements of the Directive into their national legislation. This Directive reflects the experiences with road tunnel safety from a number of countries (lead by Austria, France, Germany, Italy and Switzerland) which have long road tunnels in operations, and is also regarded by the Permanent International Association of Road Congresses (PIARC, also known as World Road Association) as the first international guideline for tunnel safety.

The Indian Road Congress has issued a Manual on Four Laning of Highways through Public Private Partnership (PPP), short IRC84:2014 [4]. As per introduction clause 1.1, “This Manual is applicable for Four Laning of Highways through Public Private Partnership (PPP) mode. The general planning aspects laid out in this manual shall be applicable for widening from 2-lane to 4-lane or new construction of 4-lane highways. The scope of the work shall be as defined in the Concession Agreement. This Manual shall be read harmoniously with the intent of the Concession Agreement. The Manual may also be used for non-PPP projects”.

The last sentence allows the Owner of a project to apply the provisions of this manual to any road projects which fall under Four Laning of Highways. Especially the tunnel section does not reflect international standards like [3].

The Consultant is of the opinion that, due to the specific circumstances under which the subject project is to be developed, the application of IRC84:2014 (which is not mandatory) is affecting the economical viability of the project without increasing the safety of the overall project.

In the light of the above the Department requested the Consultant to outline arguments to solidify the deviation from a non-mandatory national guideline by a Technical Note on the Tunnel Safety and System considerations, to be authored by one of their Tunnel Experts with international experience.

2. REFERENCES/DOCUMENTS MADE AVAILABLE

[1] Study on Road Improvement Project for Shiradi Ghat Stretch in India - Final Report, January 2015; Prepared for: Ministry of Economy, Trade and Industry, Ernst & Young Shin Nihon LLC, Japan External Trade Organization; Prepared by: CTI Engineering International Co. Ltd., CTI Engineering Co. Ltd., NIPPON STEEL & SUMITOMO METAL Corporation, East Nippon Expressway Company Limited

[2] Feasibility Cum Geo-Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH- 48 in the State of Karnataka, Field Report/ Preliminary Project Report/ Interim Progress Report (KD 4) / Part B: Preliminary Project Report, Volume – II : Design Report, GEOCONSULT India Pvt. Ltd., 16.09.2015

[3] Minimum safety requirements for tunnels in the Trans-European Road Network, DIRECTIVE 2004/54/EC of the European Parliament and of the Council of 29 April 2004

[4] IRC84:2014, Manual of Specifications & Standards for Four Laning of Highways through Public Private Partnership (First Revision), Indian Roads Congress, November 2010

[5] IRC91:2010, Guidelines for Road Tunnels, Indian Roads Congress (2010)

[6] Classification of Tunnels, Existing Guidelines and Experiences, Recommendations, PIARC Committee on Road Tunnels, 1995

[7] Cross Section Design for Unidirectional Road Tunnels, PIARC Working Group No. 4, Report 05.11.B – 2001, 2001

[8] Dossier pilote des tunnel “Ventilation”, CETU, 2004

[9] Personal Notes – Site Visit 21st September till 24th September 2015

3. RECOMMENDATIONS AND REQUIREMENTS ON TUNNELS

The recommendations for measures and also the requirements on tunnels – that means the tunnel cross section, the system layout, the installed measures and the operational plans – have been derived over a long period of time, and finally their codification was accelerated by some spectacular accidents.

3.1 Introductory Citations

The following citations are taken from the European Directive [3] and shall outline the objectives of tunnel safety and the boundary conditions which are to be taken into account.

(9) Safety in tunnels requires a number of measures relating, amongst other things, to the geometry of the tunnel and its design, safety equipment, including road signs, traffic management, training of the emergency services, incident management, the provision of information to users on how best to behave in tunnels, and better communication between the authorities in charge and emergency services such as the police, fire-brigades and rescue teams.

(11) Safety measures should enable people involved in incidents to rescue themselves, allow road users to act immediately so as to prevent more serious consequences, ensure that emergency services can act effectively and protect the environment as well as limit material damage.

(13) In order to implement a balanced approach and due to the high cost of the measures, minimum safety equipment should be defined taking into account the type and the expected traffic volume of each tunnel.

The Article 1 of the Directive [3] is putting in words what any tunnel safety guideline shall aim at:

1. This Directive aims at ensuring a minimum level of safety for road users in tunnels in the Trans-European Road Network by the prevention of critical events that may endanger human life, the environment and tunnel installations, as well as by the provision of protection in case of accidents.

That means that on the one hand the tunnel layout and cross section as well as equipment inside the tunnel shall prevent critical event and on the other hand there shall be protection / rescue facilities in case of accidents. And moreover, these provisions shall be balanced against the cost which they imply.

3.2 International practice for four-lane highways – Tunnels

For four lane highways, the usual configuration for tunnels is that the two directions are separated and the tunnels have two lanes each (twin tube system). The lane width is usually 3.5m per lane (see also [4], [5] and [7]) for highway tunnels, with maximum widths of 3.6m (AASHTO) to 3.75m (Sweden, see [7]).

The number of lanes is usually two, with lay-bys or emergency lanes. Apart from the traffic lanes and the hard clearances, which constitute the roadway, walkways are usually provided on both sides of the roadway. The space requirement for roadway and walkways defines the width of the cross section. The maintained headroom above carriageway for road tunnels is 4.5m and goes up to 5.35m (UK, [7]). The provision of 5.0m minimum vertical clearance as required in [4], leading to 5.5m vertical clearance (as per [5]) can be regarded as sufficient. It is understood from other projects in India that 5.5m vertical clearance (maintained headroom over the carriageway) is good practice and takes into account Overdimensional Consignments (ODC), which are not uncommon.

The distance of lay-bys, if no emergency lane is provided, is maximum 1000m as per [3]. As per IRC [4] it is 750m maximum distance.

As per [3], cross passages usable as emergency exits shall be provided every 500m; every 1500m cross connections suitable for the use by emergency services are to be provided (closed by fire-proof doors).

Emergency walkways (footpaths) are foreseen in nearly all international codes (ref. [7])

3.3 Comments on IRC Guidelines

The requirements stated in the IRC guidelines (ref. [4], [5]) are matching in principle the internationally required minimum standards, and in some specific area they are exceeding international requirements by far. These areas will be identified below and also discussed; for the sake of a balanced approach, keeping in view the economical and practical implications, the Consultant will propose the internationally accepted standard, i.e. [3], as design basis, with amendments wherever found appropriate for the Project. The tabular form of the requirements as per EC54/2004 is given in Annexure 1, Table 1.

The main issues identified, as can also be seen in Annexure 2, Table 2, are:

- Longitudinal gradient
- The definition of the required roadway width
- The height above the walkways
- The cross passage distance, system, cross section and layout
- Height of emergency passages
- Minor emergency equipments

3.3.1 Longitudinal Gradient

IRC:84 [4] is restricting the longitudinal gradient to 2.5% in tunnels longer than 500m, whereas the European Directive [3] is limiting the gradient to 5%, with the provision for additional / enhance safety measures based upon a risk analysis. IRC:91 [5] is asking for a maximum gradient of “around 3%”. Just the reduction of the maximum longitudinal gradient from 3% to 2.5% increases the required distance (=tunnel length) to negotiate a given elevation difference by 20%.

If put to the extreme values, IRC:84 (2.5%) would ask for double the length compared to EC54/2004 (5%). This means double the cost.

Out of reasons of economical viability, it is therefore proposed to not follow IRC:84 and take the provisions of EC54/2004 into account.

3.3.2 Required roadway width

The project is calling for a four lane bypass of a currently two lane road stretch. As per international practice the four lanes are divided into two (2) lanes for each direction. Consequently also the tunnel system would be double tube, with two lanes per tunnel tube (unidirectional two-lane tunnel).

As per 7 days traffic study conducted by Geoconsult India Pvt. Ltd in the month of Sep. 2015 shows that the 25 year projection (Year 2045 – assuming that the construction time is 5 years from now) of the total traffic in the most likely estimate is coming to around 30,995 vehicles per day (most likely case), whereas the internationally accepted threshold value is 10'000 vehicles per lane per day. That means a four lane system is being mandatory once the traffic projections are showing more than 10'000 vehicles in either direction.

As per IRC:84 [4], 14.2.5, "Tunnels shall have minimum 3-lanes carriageway for each direction of traffic" – which means that regardless of service volume the tunnels must be larger. Over and above this requirement, the hard clearance, consisting of paved shoulder of 2.0m on the left side and 0.6m edge strip on the right side, cumulates to 2.6m.

The paved shoulder of 2.0m represents the minimum requirement to park a passenger vehicle; a broken down heavy vehicle cannot park without hampering the traffic on the adjacent lane; over and above the IRC:84 asks for lay-bys each 750m of 3m width from the left most lane. That means the usual roadway width is 13.1m, with 14.1m in case of lay-bys.

Taking a two lane tunnel, where a third lane is added as an emergency lane (already an enhanced safety measure), and taking 0.50m hard clearance on both sides into account, the roadway is 11.5m wide. Due to provision of one emergency lane (third lane), no lay-bys are required. The reduction in excavation area is, under assumption of constant height, 13%. This means 13% lesser muck, or taking the 2+1 lane system as the basis, 15% more excavation volume when IRC:84 is implemented.

Since the traffic projections in [1] do not justify a three lane tunnel based upon the 25 year projection, the mandatory requirement of three traffic lanes is challengeable on grounds of viability. The same conclusion is drawn in [1], section 5.2.5.4, page 5-9.

3.3.3 Height above walkways / vertical clearance

The height above walkways is given as 1.8m in [5] and 3.0m in [4]. International guidelines, like e.g. the Austrian RVFS require 2.25m minimum vertical clearance. In railway design the vertical clearance is also 2.2m (OeBB, Austrian Federal Railways).

It is recommended to go for a clearance value within the bandwidth of what is internationally already in use, i.e. 2.3m.

3.3.4 Cross passages / emergency passages

IRC codes [4], [5] ask for motorable connections between the tunnel tubes at the angle of 30 degree every 300m (barricaded in normal conditions). These connections between the two tunnel tubes are in the light of the prescriptions of the Directive [3] a complete contradiction to the safety objectives:

- They provide a connectivity which is not providing "*Appropriate means, such as doors, shall be used to prevent smoke and heat from reaching the escape routes* *behind the emergency exit, so that the tunnel users can safely reach the outside and the emergency services can have access to the tunnel.*"

- This means there is connectivity between both tubes which may compromise the ventilation by disturbing the flow of air in the tunnel.
- "*The twin tunnels … shall be connected by a cross passage at an inclination to facilitate diversion of the traffic from one tube to other tube in the event of an incident/accident in one of the tubes at a spacing of 300 m.*" Means that traffic from two lanes is directed into the other tube in the opposite direction of the flow there, creating a bi-directional traffic scenario which increases the accident risk.
- Apart from that, the geo-mechanical implications of such a slender pillar are substantial – the stress concentration will require either disproportionate supports or a larger excavation. In this respect the layout given in both IRC codes is highly unfa

The Consultant strongly recommends to not follow this system, for the sake of safety.

The IRC:84 [4], under 14.11.2, iii) b), requests for: "*Escape Passage: These are evacuation tunnels and evacuation exits for the road users in the tunnel to a safe place. The former is built for escape, separately from the main tunnel, while the latter connects the main tunnel to an evacuation which runs in parallel with it, or two main tunnels. The evacuation tunnel may have a vertical clearance of 4.5 m. The exit for evacuation shall be shutter type of light weight and noninflammable materials. Adequate signage for direction of movement and easy opening mechanism shall be provided. Evacuation tunnel shall be used only by the evacuating persons and emergency vehicles*". This provision can be fully supported, and reflects the provision of emergency exits (cross passages) as per [3]. The vertical clearance is on the higher side (see values for maintained headroom, 2.2), and shall be reduced accordingly to internationally accepted values (minimum clearance 3.5m x 3.5m, with the provision for sidewalks of 0.7m width and 2.3m height on both sides). As per international guidelines, fireproof doors will be provided.

As the IRC:84 has no requirement for the distance between the emergency exits ("escape passages"), a maximum distance of 500m is assumed to be required. Any reduction in this distance may lead to an increase in safety, but also in cost.

3.3.5 Minor emergency equipments

The IRC:84 is requesting for handheld fire extinguishers every 50m, whereas the EC54/2004 is asking for them every 150m (emergency stations). It may be argued what happens to such minor equipment and what the cost to maintain the same is. It has to be kept in mind that fire extinguishers must be checked in certain intervals, and exchanged also. Taking a distance that is covered by international guidelines, but is three times the existing means also a third of extinguishers – a third of capital cost and maintenance / replacement cost. However it may also be advisable to have provisions against unauthorized usage / removal of the fire extinguishers – otherwise their number may decrease continuously.

IRC:84 is asking for hose reel water plugs, means hydrants with fire hoses on reels every 50m; the EC54/2004 is asking for hydrants every 250m – it is no problem for the trained emergency services to have hoses laid out in shortest time. Again – it means five times the investment in hydrants – and the investment in reels also. The installation of reels with fire hoses is always a matter of discussion, as – due to the fact that the envisaged first user of these hoses is the untrained tunnel user – their efficiency may be doubted. Over and above, the unauthorized removal is to be monitored (see above comment on fire extinguishers).

4. PROPOSED MEASURES/DESIGN BASIS FOR THE PROJECT

As this project covers a road stretch where a considerable part of the heavy goods vehicles is hazardous goods vehicles, like gas tankers, some enhancement in safety measures will be recommendable. However it is still, from the viewpoint of viability of the project, necessary to keep the balanced approach – that means starting from a basis which is internationally acceptable and yet not overloaded.

4.1 Longitudinal Gradient

Currently the design [1] is proposing a maximum longitudinal gradient of 3% in tunnels, with two exceptions – Tunnel T5 (1693m) with 3.25% and Tunnel T6 (1862m) with 3.5%. These exceptions are due to geometric requirements, and are still in the acceptable range if the IRC:91 ("around 3%") and fully covered by the EC54/2004 (less than 5%). The requirement of enhanced safety measures is covered by the use of a full emergency lane.

4.2 Cross Section

4.2.1 Roadway Width

The minimum requirement of road way width would be two lane widths (2 x 3.5m) plus 0.5m on either side as per IRC:91 [5]. This is also covered by EC54/2004 [3] and PIARC recommendations [7].

The provision of two traffic lanes would require that lay-bys are constructed, at least every 1000m. The alternative solution to lay-bys is a continuous emergency lane; as per PIARC document [7], studies show that only 40% of the vehicles reach the lay-bys to be parked there. Taking also into account the gradient, a broken HGV can block the tunnel.

Taking the gradient and the expected vehicle mix into consideration, it is therefore proposed to keep a continuous (third) lane as emergency lane, so that vehicles can be parked at anyplace in the tunnel without hampering the traffic on the two traffic lanes.

The roadway width is therefore proposed to be 11.5m, consisting of 10.5m carriageway width and two times 0.5m hard clearance.

The position of the emergency lane is the leftmost lane, away from the cross passages in the tunnel; in that configuration emergency stations must be at the side of the emergency lane and at the cross passages.

4.2.2 Walkways

The clearance for walkways shall be minimum 0.75m in width and 2.3m vertical clearance. In this area no signage or installations are allowed. The height of the walkway above the pavement is proposed to be 20cm.

4.3 Cross Passages

The distance between the cross passages and their cross section are a major factor for the tunnel safety, as it has an impact on the self-rescue and the accessibility of the incident tube from the "healthy" tube by emergency services. Fire-proof doors are to be provided, due to the possibility that emergency vehicles also use these doors; the solution to have large doors with regular doors for pedestrians integrated is a proven and practical solution.

This may increase the cross section as the space requirements of the doors have to be taken into account. The final clearance will also take into account that some comfort distance even for firefighting vehicles of maximum height of 3.5m is recommendable. The sidewalks may come on the same level as the carriageway inside the cross passages.

The minimum requirement as per [3] is a cross passage every 500m, and a cross passage usable for emergency services every 1500m.

Considering the special situation in the Project (more than 20% of the commercial vehicles carry hydrocarbon products), it is proposed to shorten the cross passage distance to 300m as per [4] and [5]. This improves the chances for self-rescue as the distance to a safe place is reduced by 40%.

Further on it is proposed to make every cross section usable for emergency services (motorable or vehicular cross passage - clearance 3.6m by 4.0m so that any fire fighting vehicle of max. height 3.5 m can pass through), with two walk way clearances on same level of 0.70m by 2.3m on either side of the clearance. This is an improvement in terms of accessibility for emergency services.

These enhanced safety measures stem mainly from the realistic threat of an accident with a tanker loaded with LPG and the need to immediately leave the affected tube.

4.4 Any other safety measures

Electromechanical installations / telecommunication installations shall be installed as per European directive [3]. The detailed choice shall be guided by practicability and maintainability. It might be advisable that gas detectors are also installed.

The EC54/2004 [3] calls for fire resistant structures “where a local collapse of the structure could have catastrophic consequences, e.g. immersed tunnels or tunnels which can cause the collapse of important neighbouring structures”. In the Project this is not the case, especially the conditions where rock is encountered are stable eve when the lining would be damaged. It is recommended to check the applicability of this provision in the portal areas / areas where the ground is requiring support; the measures can be to increase the concrete cover as per relevant standards (IS456), or to add polypropylene fibres to the concrete.

The European guideline EC54/2004 [3] requires that “Where the transport of dangerous goods is permitted, the drainage of flammable and toxic liquids shall be provided for through well-designed slot gutters or other measures within the tunnel cross sections. Additionally, the drainage system shall be designed and maintained to prevent fire and flammable and toxic liquids from spreading inside tubes and between tubes.”

The surface liquids will be collected through the slot gutter and go into the separate pavement drainage system, which is there to fulfill the requirements of the EC54/2004 is provided additionally to the ground water drainage system. The liquids from the pavement drainage will run through a sedimentation tank with skimming facility. It has to be remarked that the slot gutters have to be kept free from litter, and that in some occasions traditional pits to collect spilled liquids have only minor impact on the overall safety. However this has to be investigated in detail.

-------- End of main document --------

5. TABLE OF ANNEXURES

Annexure – 1

Table 1 – Informative summary of minimum requirements EC54/2004

ANNEXURE 1

Table 2 – Informative summary of minimum requirements EC54/2004

● mandatory for all tunnels ○ not mandatory
✱ mandatory with exceptions ◐ recommended

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 000 m	1 000-3 000 m	>3 000 m	
Structural Measures	2 tubes or more	§2.1						Mandatory where a 15-year forecast shows that traffic > 10 000 veh./lane.
	Gradients ≤ 5 %	§2.2	✱	✱	✱	✱	✱	Mandatory unless not geographically possible.
	Emergency walkways	§2.3.1 §2.3.2	✱	✱	✱	✱	✱	Mandatory where there is no emergency lane, unless the condition in §2.3.1 is respected. In existing tunnels where there is neither an emergency lane, nor an emergency walkway additional / reinforced measures shall be taken.
	Emergency exits at least every 500 m	§2.3.3 - §2.3.9	○	○	✱	✱	✱	Implementation of emergency exits in existing tunnels to be evaluated case-by-case.
	Cross-connections for emergency services at least every 1 500 m	§2.4.1	○	○ / ●	○	○ / ●	●	Mandatory in twin-tube tunnels longer than 1 500 m.
	Crossing of the central reserve outside each portal	§2.4.2	●	●	●	●	●	Mandatory outside twin- or multi-tube tunnels wherever geographically possible.
	Lay-bys at least every 1 000 m	§2.5	○	○	○	○ / ●	○ / ●	Mandatory in new bi-directional tunnels >1 500 m without emergency lanes. In existing bi-directional tunnels >1 500 m: depending on analysis. For both new and existing tunnels, depending on extra usable tunnel width.
	Drainage for flammable and toxic liquids	§2.6	✱	✱	✱	✱	✱	Mandatory where transport of dangerous goods is allowed.
	Fire resistance of structures	§2.7	●	●	●	●	●	Mandatory where a local collapse can have catastrophic consequences.

● mandatory for all tunnels ○ not mandatory
✱ mandatory with exceptions ◐ recommended

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 000 m	1 000-3 000 m	>3 000 m	
Lighting	Normal lighting	§2.8.1	●	●	●	●	●	
	Safety lighting	§2.8.2	●	●	●	●	●	
	Evacuation lighting	§2.8.3	●	●	●	●	●	
Ventilation	Mechanical ventilation	§2.9	○	○	○	●	●	
	Special provisions for (semi-) transverse ventilation	§2.9.5	○	○	○	○	●	Mandatory in bi-directional tunnels where there is a control centre.
Emergency stations	At least every 150 m	§2.10	✱	✱	✱	✱	✱	Equipped with telephone and 2 extinguishers. A maximum interval of 250 m is allowed in existing tunnels.
Water supply	At least every 250 m	§2.11	●	●	●	●	●	If not available, mandatory to provide sufficient water otherwise.
Road signs		§2.12	●	●	●	●	●	For all safety facilities provided for tunnel users (see Annex III).
Control centre		§2.13	○	○	○	○	●	Surveillance of several tunnels may be centralised into a single control centre.
Monitoring systems	Video	§2.14	○	○	○	○	●	Mandatory where there is a control centre.
	Automatic incident detection and/or fire detection	§2.14	●	●	●	●	●	At least one of the two systems is mandatory in tunnels with a control centre.
Equipment to close the tunnel	Traffic signals before the entrances	§2.15.1	○	●	○	●	●	
	Traffic signals inside the tunnel at least every 1 000 m	§2.15.2	○	○	○	○	◐	Recommended if there is a control centre and the length exceeds 3 000 m.

SUMMARY OF MINIMUM REQUIREMENTS			Traffic ≤ 2 000 veh. per lane		Traffic > 2 000 vehicles per lane			Additional conditions for implementation to be mandatory, or comments
			500-1 000 m	>1 000 m	500-1 000 m	1 000-3 000 m	>3 000 m	
Communication systems	Radio re-broadcasting for emergency services	§2.16.1	○	○	○	●	●	
	Emergency radio messages for tunnel users	§2.16.2	●	●	●	●	●	Mandatory where radio is re-broadcasted for tunnel users and where there is a control centre
	Loudspeakers in shelters and exits	§2.16.3	●	●	●	●	●	Mandatory where evacuating users must wait before they can reach the outside.
Emergency power supply		§2.17	●	●	●	●	●	To ensure the functioning of indispensable safety equipment at least at during evacuation of tunnel users.
Fire resistance of equipment		§2.18	●	●	●	●	●	Shall aim to maintain the necessary safety functions.

Annexure – 2

Table 3 - Safety installations and functions – comparison of requirements

ANNEXURE 2

Table 4 - Safety installations and functions – comparison of requirements

Technical system	European Directive EC54/2004	IRC SP:91 Guidelines	IRC SP:84:2014 four laning manual
Two separate tunnel tubes	Necessary if more than 10,000 vehicles per lane /day within a time period of 15 years.	Necessary if more than 10,000 vehicles per lane /day without specifying the time period.	Necessary without specifying traffic criteria & time period.
Maximum longitudinal gradient	More than 5% not permitted in new tunnels; more than 3% additional safety measures	4 – 6% for tunnel upto 500m and around 3% for tunnel more than 500m	Upto 6% for tunnels upto 500m and 2.5% for tunnel more than 500m
Horizontal alignment		Straight stretch shall not be more than 1500 m	Straight stretch shall not be more than 1500 m
Effective width of roadway	3.5m lane width recommended by PIARC. 3 lanes with hard clearance .5m come to 11.5m	0.5m +3.5m+3.5m + 3.5m +0.5 m = 11.5m	2.0m +3.5m +3.5m +3.5m +0.60m = 13.10m
Vertical clearance	as per national codes, minimum recommended by PIARC is 4.50m maintained headroom	5.5 m	5.0m
Minimum vertical clearance above walkway	as per national codes	1.80m	3.0m
Emergency exits maximum spacing	500m	none	none
Cross passage between both tunnel tubes	500m pedestrian / 1500m emergency services	300m, single lane motorable	300m, single lane motorable
Cross passages	To be closed by fireproof doors (emergency exits)	to be barricaded	to be barricaded
Escape Passage	see emergency exits		Vertical clearance of 4.5m. shutter type of light weight and noninflammable materials. Only to be used by persons and emergency vehicles.
Drainage system for hazarduous liquids	separate system for collection from road surface (designed for discharge of 80 l/s)	no, one system	no, one system

Technical system	European Directive EC54/2004	IRC SP:91 Guidelines	IRC SP:84:2014 four laning manual
Tunnel Lighting	to be provided	to be provided	to be provided
Safety Lighting, for minimum visibility	to be provided	no; 100% backup of regular lighting	to be provided
Evacuation Lighting	to be provided at a height not more than 1.5m	to be provided	
Ventilation	Mechanical Ventilation as per requirements (longitudinal / semi-transverse / trans-verse)	Mechanical ventilation necessary for tunnel more than 500 m.	Mechanical ventilation necessary for tunnel more than 500 m.
Emergency Stations max. distance	150m. Emergency telephone, 2 fire extinguishers.	200m telephone. 50m 2 fire extinguish-ers.	200m telephone. 50m 2 fire extinguish-ers.
Push-button alarm	-	not specified	50m
Water supply through hydrants	Spacing max. 250 m	to be provided but not specified	to be provided but not specified
Fire Plug: Hose-reel water plugs.	see hydrants.	to be provided but not specified	50m
Traffic Management central, TMC	Recommended but necessary only for tunnels with a length exceeding 3000 m. Full-time operated traffic centre for moni-toring and control.	Generally specified without any reference to applicable length of tunnel.	Nothing specified
Monitoring system	TV cameras for visual control and systems for automatic detection of incidents and acci-dents. Fire alarm sys-tem should be installed in all areas of the tun-nel.	Generally specified without any reference to applicable length of tunnel.	Use with consideration for class A & Manda-tory for class AA.
Equipment's for clo-sure of the tunnel	Signs located at tunnel entries with the possi-bility to redirect traffic to other roads. Remote controlled bars located at tunnel entries for fast closing of the tun-nel.	Generally specified without any reference to applicable length of tunnel.	Nothing specified
Communication sys-tems	Radio re-broadcasting for emergency ser-vices Emergency radio mes-sages for tunnel users. -	Generally specified without any reference to applicable length of tunnel.	Radio re-broadcasting for emergency ser-vices Emergency radio mes-sages for tunnel users. Mobile Connectivity

Technical system	European Directive EC54/2004	IRC SP:91 Guidelines	IRC SP:84:2014 four laning manual
	Loudspeakers in emergency exits and shelters.		Loudspeakers.
UPS, Interruption free power feed	Emergency power system designed for electricity feed to certain important systems and appliances in case of power failure.	Generally specified without any reference to applicable length of tunnel.	To be provided in tunnels 500 m or more in length.

Prepared for:

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Karnataka
Public Works, Ports & Inland Water Transport Department

Project:

Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"

Subject:

KD-6 - Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume- II: Design Report

Part II: Design of Tunnels (C)- Structural Analysis - Primary Lining

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Revision History

Rev.	Date	Long Description

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INTRODUCTION

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorpora tion of Client's observations on earlier submitted "KD5: Kucha Draft De tailed Project Report (KDDPR)" vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels :

- *Proposed Tunnel Design, Standards*
- *Technical Note on Tunnel Section and System*

- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures :

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report:

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

(vi) Volume - V Technical Specifications :

(vii) Volume - VI Rate Analysis :

(viii) Volume - VII Cost Estimates :

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(x) Volume - IX Drawings (A3 Size) :

a. *Location map*
b. *Layout plans*
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d. *Plan and Profile of Refined Alignment "A"*
e. *Typical Cross Sections showing Pavement details of Cut & Fill Section*
f. *Typical Cross Sections of Tunnel*
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i. *Viaducts – General Arrangement Plan and L-Section*
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k. *GAD for proposed RoB at Railway km 54+650*
l. *Standard Drawings*
m. *Miscellaneous Drawings*
n. *Indicative Land Acquisition Plans*
o. *Detailed Cross Sections @ 100m interval*

(xi) Volume - X Civil Work Contract Agreement :

(xii) Volume - XI Project Clearances :

VOLUME - II: DESIGN REPORT
PART- II: DESIGN OF TUNNELS
(C): STRUCTURAL ANALYSIS - PRIMARY LINING

1 GENERAL

This Volume - II: Design Report- Part II: Design of Tunnels, (C) Structural Analysis - Primary Lining, a part of “KD6: Draft Detailed Project Report for Final Approved alignment for Bypass (DDPR)” is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report- Part II: Design of Tunnels, (C) Structural Analysis - Primary Lining of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

2 REFERENCES

2.1 References:

[1] I6060-REP-05-KD4-PPR-Vol II-DR-A, KD 4-Field Report/Preliminary Progress Report/ Interim Progress Report: Part B: Preliminary Project Report Volume=II: Design Report

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[3] Feder G. Felsbau und Bodenmechanik Veröffentlichungen – Collected and puplished by the Institute of Rock Mechanics and Tunneling University of Graz

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[5] Austrian Standard Oenorm B2203 Part 1, Underground Works – Conventional Excavation, 2001

[6] Duddeck H. and Erdmann J.: Structural design models for tunnels

[7] Duddeck H. and Erdmann J.: Vergleich ebener und Entwicklung räumlicher-Berechnungsverfahren für Tunnel

[8] IS 456:2000 Plain and Reinforced Concrete (Fourth Revision)

[9] EN 1992-1-1 (2004) (English): Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

[10] Austrian Society for concrete and Construction Technology: Guideline Sprayed Concrete, 2013

[11] EN 1997-1 (2009): Eurocode 7: Geotechnical design

3 DESCRIPTION OF USED ANALYSIS

The following report deals with the geotechnical and structural analysis and design of the primary support measures of the main tunnel section encountered along the proposed alignment for the bypass road. These analyses correspond to a number of representative cases that cover most of the situations during tunnel construction.

The detailed geotechnical and structural design of the primary support is carried out using the closed-form solutions according to Prof. Feder (Mining University of Leoben, Austria) [3] and the analytical approach according to H. Duddeck / J. Erdmann [6]. The main variables considered in the analyses are the tunnel overburden, excavation cross-section, ground types and its properties and in-situ stress condition.

3.1 Analytical Calculations according to Prof. Feder

The method allows assessing the rock mass behaviour due to tunnel excavation by calculating the deformations of the system lining - ground as a function of rock mass properties, primary stress conditions and installed support. The analytical calculation approach after Prof. Feder is based on the closed – form solution for a circular opening in an elasto-plastic medium with a primary stress field of $K_0 = 1.0$.

This closed form solution has been extended by Prof. Feder to allow for primary stress fields different from $K_0 = 1$. Different rock strength parameters in the elastic and the plastic (fractured) zone around the tunnel and volume increase of the rock mass material in the fractured zone due to crack development is considered.

The method allows for easy and fast parameter studies regarding the determination of the stress and displacement field around a tunnel.

The bending moments are derived by assuming an eccentricity of the normal forces by 1/30 of the sprayed concrete shell thickness or 20mm whichever is higher (according to EN 1992-1-1: 2004 [9]).

3.2 Calculations according to Duddeck / Erdmann

This analytical calculation approach uses elastic, uniform soil/rock conditions and full shear bond between the elastic lining and the subsoil. Further circular shaped full-face excavation is assumed. As result of the Erdmann / Duddeck calculation normal forces N, bending moments M and shear forces V in the sprayed concrete shell at the crown, bench and invert – sections are obtained.

The analysis according to Erdmann/Duddeck is generally used for shallow tunnels with a low stress-level.

4 INPUT PARAMETERS

4.1 Geological/Geotechnical Conditions

Geological study has been undertaken for the Shiradi Ghat bypass project as per requirements given in scope of work. Maps, literature and other relevant material have been gathered (and are being gathered) for this purpose. Reconnaissance study of the project area was also carried out in July 2015 by members of the Geoconsult Team for understanding the geological aspects of the project location. According to the information gathered from these studies, eight major rock mass types are determined in and around the area of interest. The details regarding these rock mass types are mentioned in Table 1. Further detailed information about the geology is discussed in the report referenced [1].

Table 1: Rock mass types around tunnel alignment

Rock Mass Type	Description
RMT-1	Unweathered to slightly weathered Granite Gneiss/ Banded Gneiss
RMT-2	Moderately to highly weathered Granite Gneiss/ Banded Gneiss
RMT-3	Unweathered to slightly weathered Schist
RMT-4	Moderately to highly weathered Schist
RMT-5	Faulted/Sheared Rock
RMT-6	Unweathered to slightly weathered Amphibolite
RMT-7	Unweathered to slightly weathered Pegmatite
RMT-8	Laterite/ Completely weathered rock/ Residual soil

Among these eight rock mass types determined, RMT-6 is not expected anywhere along the proposed tunnel alignment and hence not included in the analysis.

4.1.1 Geotechnical Design Parameters

Several cases for different rock mass parameters and overburdens along the Tunnel alignment have been examined in the analytical calculations.

The geotechnical design parameters for different rock mass types considered for the analyses are obtained from Geological Design and Geotechnical Report [2]. Table 2 shows these parameters along with the overburden corresponding to each rock mass type. RMT 5 and RMT 7 are split into two rock mass types to represent the two different overburden encountered along the alignment.

Table 2: Preliminary Geotechnical Design Parameters

Rock Mass Type	UCS [Mpa]	GSI	ν	Φ [°]	C [Mpa]	E [GPa]	H [m]	σ_h/σ_v
RMT-1	125.0	65	0.15	43	4.50	41.0	240.0	1.0
RMT-2	70.0	45	0.15	37	4.00	8.0	20.0	0.5
RMT-3	70.0	45	0.20	29	4.00	10.0	200.0	1.0
RMT-4	35.0	30	0.2-0.25	25	2.00	1.9	20.0	0.5
RMT-5a	5.0	20	0.30	22	0.50	0.8	190.0	1.0
RMT-5b	5.0	20	0.30	22	0.50	0.8	20.0	0.5
RMT-7a	60.0	70	0.20	46	3.00	18.0	80.0	1.0
RMT-7a	60.0	70	0.20	46	3.00	18.0	30.0	0.5
RMT-8	0.5	15-20	0.40	12-15	0.05-0.1	4.5	20.0	0.5

Where:

ν	Poisson's Ratio
Φ	Angle of internal friction
C	Cohesion
E	Young's modulus
H	Overburden

4.2 Tunnel Cross Section and Support

4.2.1 Tunnel Geometry

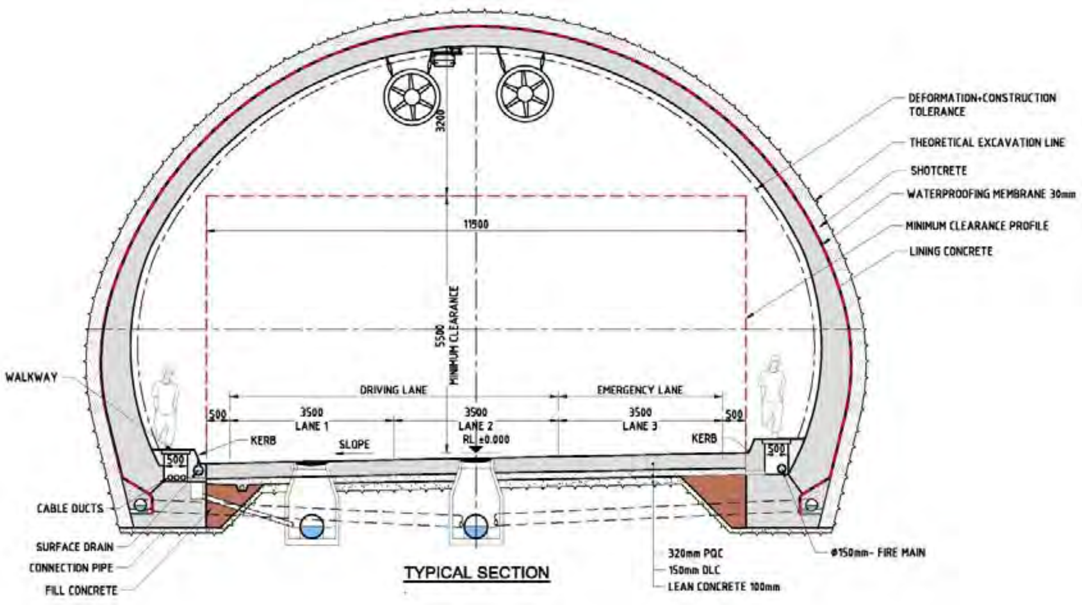


Figure 1: Typical cross section of tunnel

Considering the traffic load in the Shiradi Ghat region, the proposed tunnel system consist of two identical tunnels each having width to accommodate three lane traffic in single direction. Typical cross section of single tunnel tube is shown in Figure 1.

4.2.2 Support Types

Five support classes have been designed to negotiate all anticipated ground behaviour types. Table 3 shows the details of support measures as required for each support class.

Table 3: Support measures for designed support classes

Support Class	Excavation Stage	Round Length	Support Elements					Additional
			Sprayed concrete M25, (SFRS/Plain)	Wiremesh 150x150x6mm	Rock Bolts/ Round	Lattice Girders per Round	Forepoles per Round	Face Support (Shotcrete(M25)/+ Rock bolts) and temporary invert
SC-I	Top Heading	>3m	(Plain) Thick:100mm	1 outer layer	SW,Fy=200kN Length:3m (Spot bolting)	-	-	-
	Benching	5-6m	(Plain) Thick:100mm	1 outer layer	-	-	-	-
SC-II	Top Heading	2-2.5m	(Plain) Thick:150mm	1 outer layer	SN,Fy>230kN Length:4m Pattern: [2mX2/2.5m]	-	-	-
	Benching	4-5m	(Plain) Thick:150mm	1 outer layer	-	-	-	-
SC-III	Top Heading	1.5-2m	(Plain) Thick:200mm	1 outer layer	SN,Fy>230kN Length:4m/6m Pattern: [2mX1.5/2m]	If required	If required	50mm thick Shotcrete at face (If required)
	Benching	3-4m	(Plain) Thick:200mm	1 outer layer	SN,Fy>230kN Length: 4m Pattern: [2mX1.5/2m]	-	-	
SC-IV	Top Heading	1-1.5m	(Plain) Thick:250mm	2 layer	SN/SD,Fy>230kN Length:4m/ 6m Pattern: [2mX1/1.5m]	1 set 95/20/25	SD, ϕ32mm Length:4m Spacing 400mm/90⁰	50-100mm thick shotcrete/ Face bolts 9m long (3m overlap)-6 nos.
	Benching	2-3m	(Plain) Thick:250mm	2 layer	SN/SD,Fy>230kN Length:4m Pattern: [2mX1/1.5m]	1 set 95/20/25	-	
	Invert	4-6m	(Plain) Thick:250mm	1 outer layer	-	-	-	
SC-V	Top Heading	0.8-1m	(Plain) Thick:300mm	2 layer	SD,Fy>230kN Length:6m/ 9m Pattern: [1.5mX0.8/1m]	1 set 130/25/32	SD, ϕ32mm Length:4m Spacing 300mm/120⁰	50-100mm thick shotcrete/ Face bolts 9m long (3m overlap)-6 nos.
	Benching	1.6-2m	(Plain) Thick:300mm	2 layer	SD,Fy>230kN Length:6m Pattern: [1.5mX0.8/1m]	1 set 130/25/32	-	
	Invert	3.2-4m	(Plain) Thick:300mm	1 outer layer	-	-	-	250mm thick temporary invert with 1 layer wire mesh

4.3 Properties of Support Elements

The main material parameters of rock support elements considered are given below:

Sprayed concrete: Specified compressive strength after 28 days shall be corresponding to concrete grade M25, characteristic compressive strength f_{ck} = 25 N/mm^2, according to IS 456:2000 [8].

- Early strength Class J-II as shown in Figure 2 (according to [10])
- Young's modulus: E = 7500 MPa
- Poisson's ratio: ν = 0.2
- Unit weight: γ = 24 kN/m^3

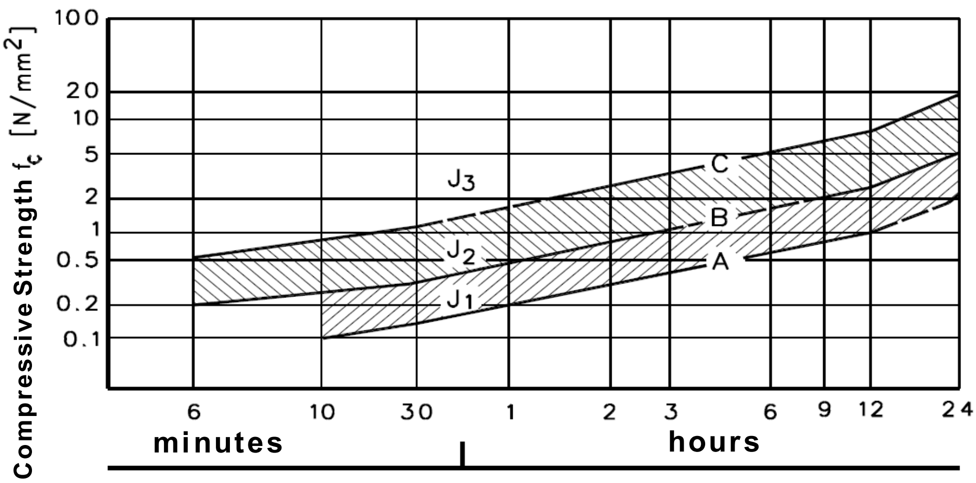


Figure 2: Early strength development of sprayed concrete

Steel reinforcement for sprayed concrete: Wire mesh (welded steel wire fabric): Grade Fe 500D, according to IS 1786:2008

- Mesh width: 150 x 150 mm; bar diameter – 6 mm
- Minimum yield strength: fy = 500.0 N/mm^2

Rock bolts:

- SN – rock bolts, Grade Fe 500D, according to IS 1786 – 2008, minimum yield strength: f_y = 500N/mm^2, bolt diameter: 25mm, minimum yield load: 200 kN
- Swellex rock bolts, ultimate load: 200 kN
- Self-drilling rock bolts, outer diameter: 32 mm, minimum yield load: 230kN

Lattice Grider:

- Steel Grade: Fe 500D according to IS 1786-2008

- Minimum yield strength: fy = 500N/mm2
- Types: 95/20/25, 130/25/32

4.4 Overview - Input parameters for the analyses

The overview of the input parameters used for the analyses is given in Table 4.

Table 4: Input parameters used for analysis

Analysis No.	Ground Type	Support Class	Radius	Over-burden	Geotechnical Parameters								
			Ro	H	γ	ϕ_{el}	ϕ_{pl}	c_{el}	c_{pl}	ν	E	K_o	α
			[m]	[m]	[KN/m^3]	[°]	[°]	[MPa]	[MPa]	[-]	[MPa]	[-]	[-]
1	RMT1	SC I/SC-II	7.50	240	26	43	43	4.50	4.50	0.15	41000	1.0	1.2
2	RMT2	SC-III	7.50	20	26	37	37	4.00	4.00	0.15	8000	0.5	1.2
3	RMT3	SC I/SC-II	7.50	200	26	29	29	4.00	4.00	0.20	10000	1.0	1.2
4	RMT4	SC-III	7.50	20	26	25	25	2.00	2.00	0.25	1900	0.5	1.2
5	RMT5a	SC-V	7.50	190	26	22	22	0.50	0.50	0.3	750	1.0	1.3
6	RMT5b	SC-V	7.50	20	26	22	22	0.50	0.50	0.3	750	0.5	1.3
7	RMT7a	SC I/SC-II	7.50	80	26	46	46	3.00	3.00	0.2	18000	1.0	1.0
8	RMT7b	SC I/SC-II	7.50	30	26	46	46	3.00	3.00	0.2	18000	0.5	1.0
9	RMT8	SC-IV/SC-V	7.50	20	26	15	15	0.1	0.1	0.4	4500	0.5	1.3

Where:
R_o Excavation Radius
H Overburden
γ Unit Weight of rock mass
ϕ_{el} Angle of friction elastic
ϕ_{pl} Angle of friction plastic
c_{el} Cohesion elastic
c_{pl} Cohesion plastic
ν Poisson's ratio
E Young's modulus
K_0 Lateral earth pressure coefficient
α Loosening factor

Installation of rock bolts provides a confinement effect to the surrounding rock, thereby improving its strength parameters which in turn help in minimizing the displacements and also in preventing wedge failure. This improvement in shear strength is conservatively ignored in the elastic state however the same has been considered to compensate the reduction in rock mass cohesion due to development of the plastic zone for rock mass of low shear strength i.e. RMT5 and RMT8. Also no significant development of plastic zone is expected in better rock mass to cause any reduction in its cohesion. Therefore the analysis considers residual cohesion same as cohesion elastic in all rock mass types.

Varying sprayed concrete thicknesses have been considered in the application of support pressure pa, which has been derived with the ring formula (based on the excavation radius, the thickness of the sprayed concrete lining) under an allowable maximum stress of the sprayed concrete lining of 15 MPa.

Support class IV & V applicable for excavation through RMT 5a, RMT 5b and RMT 8 make use of lattice girder as part of the support measures. The structural benefit of the lattice girder is kept as reserve and not considered during analysis except in case of RMT 5a (faulted/sheared rock with high overburden) which is the most critical section. Other sections prove to be safe without taking into account the structural influence of the lattice girder.

5 LOAD

5.1 Load Assumptions and Safety Factors

The following load factors have been applied for the analysis according to [11]:

- Load Factor for Normal Forces: 1.35
- Load Factor for Bending Moments: 1.0

For structural design of the primary (temporary) support, the following material factors have been applied:

- Sprayed concrete and Concrete: 1.50
- Steel: 1.15 (applied to yield strength)

5.1.1 Earth Pressure

The Earth pressure acting on the lining will be the result of the interaction between the ground surrounding the tunnel, the deformation of the ground during excavation support installation and the bending and axial stiffness of the lining. The earth pressure for the analysis is derived in consideration of overburden and soil weight.

5.1.2 Water Load

For “drained” tunnels, water pressures are not considered as design load case. Weep holes in the sprayed concrete shell and drainage holes shall ensure that no water pressure builds up.

5.1.3 Earthquake

With regard to the temporary works character of the outer lining and the experience that tunnels in rock are not subject to major seismic loading, seismic loading is not applicable here.

6 STRUCTURAL DESIGN

The structural design of the mined tunnels involve both the design of the outer sprayed concrete lining, together with associated support measures, and the design of the inner lining (reinforced/unreinforced cast-in-situ concrete) The structural design for the outer lining is carried out in general in accordance with IS 456:2000. The sprayed concrete lining will be reinforced as required by the analysis. The support classes I to III will be reinforced by one layer of wire mesh. Due to the sprayed concrete thickness and practical considerations, support classes IV and V will be reinforced with two layers of wire mesh. In view of the obtained results, it is not required to consider the additional reinforcement, which is provided by the lattice girders for all rock mass types (RMT's) except for RMT 5a. This reinforcement will provide additional safety for other RMT's as discussed in section 4.4.

6.1 Analysis Results

6.1.1 Results of the analyses according to Feder

The analysis is carried out according to Prof. Feder [3],[4] in consideration of the different overburden and the resulting in situ stress level and different rock mass parameters for various ground types which are mostly foreseen along the tunnel alignment. The results of the analysis for different cases are tabulated in the Table 5 below. The detailed calculations are given in the Annexure 1.

Table 5: Results of the analyses according to Prof. Feder.

Analysis No.	Rock Mass Type	Support Class	Crown		Side Wall		Crown / Side Wall			
			σ_{tang} [MN/m²]	σ_{rad} [MN/m²]	σ_{tang} [MN/m²]	σ_{rad} [MN/m²]	N_{max} [KN/m]	M_{max} [KNm/m]	u [mm]	r_{pl} [m]
1	RMT 1	SC I/SC-II	13.79	0.20	13.79	0.20	1500	7.5	1.4	NIL
2	RMT 2	SC-III	3.20	0.40	4.24	0.40	3000	15.0	3.6	NIL
3	RMT 3	SC I/SC-II	11.22	0.20	11.22	0.20	1500	7.5	4.7	NIL
4	RMT 4	SC-III	1.70	0.40	2.74	0.40	3000	15.0	7.4	NIL
5	RMT 5a	SC-V	7.25	0.80	7.25	0.80	6000	30.0	102.8	12.79
6	RMT 5b	SC-V	0.32	0.60	1.36	0.60	4500	22.5	6.49	NIL
7	RMT 7a	SC I/SC-II	5.66	0.20	5.66	0.20	1500	7.5	1.5	NIL
8	RMT 7b	SC I/SC-II	2.20	0.20	3.76	0.20	1500	7.5	0.8	NIL
9	RMT 8	SC-IV/SC-V	-0.17	0.60	0.87	0.60	4500	22.5	0.3	NIL

Where:

σ_{tang} tangential stress
σ_{rad} radial stress
N_{max} maximum normal force
M_{max} maximum bending moment
u deformation due to excavation
r_{pl} radius of plastic zone

6.1.2 Results of the analyses according to Duddeck / Erdmann

Analyses were done according to Duddeck-Erdmann [6],[7] for all the 9 cases as used in Feder analysis and the resulting bending moments, normal forces and shear forces are checked for structural design requirement. The results of the analyses are tabulated in the Table 6 below. The detailed calculations are given in the Annexure 2.

Table 6: Results of the analyses according to Duddeck / Erdmann.

Analysis No.	Rock Mass Type / Support Class	Crown			Side Wall			Invert		
		N_{max} [KN/m]	M_{max} [KNm/m]	V_{max} [KN/m]	N_{max} [KN/m]	M_{min} [KNm/m]	V_{max} [KN/m]	N_{max} [KN/m]	M_{max} [KNm/m]	V_{max} [KN/m]
1	**RMT 1/SC I/II**	24.38	0	0	24.38	0	0	24.38	0	0
2	**RMT 2/SC III**	19.00	0.08	0	142.48	-0.08	0.022	19.00	0.08	0
3	**RMT 3/SC I/II**	103.38	0	0	103.38	0	0	103.38	0	0
4	**RMT 4/SC III**	122.07	0.32	0	527.37	-0.32	0.085	122.07	0.32	0
5	**RMT 5a/SC V**	2983.38	0	0	2983.38	0	0	2983.38	0	0
6	**RMT 5b/SC V**	587.40	2.30	0	1401.52	-2.30	0.601	587.40	2.30	0
7	**RMT 7a/SC I/II**	57.74	0	0	57.74	0	0	57.74	0	0
8	**RMT 7b/SC I/II**	7.92	0.01	0	49.82	-0.01	0.002	7.92	0.01	0
9	**RMT 8/SC IV/V**	141.31	0.35	0	350.09	-0.35	0.091	141.31	0.35	0

Where:

N_{max} maximum normal force
M_{max} maximum bending moment
V_{max} maximum shear force

7 RESULTS STRUCTURAL DESIGN

7.1 Necessary Reinforcement

The necessary reinforcement details are provided in the Table 7 below.

Table 7: Necessary Reinforcement

Analysis No.	Support Class	Crown		Side Wall		Invert	
		$A_{s\ req}$	$A_{s\ prov}$	$A_{s\ req}$	$A_{s\ prov}$	$A_{s\ req}$	$A_{s\ prov}$
		[mm^2]	[mm^2]	[mm^2]	[mm^2]	[mm^2]	[mm^2]
1	**SC-I/II**	u.s.	188	u.s.	188	u.s.	188
2	**SC-III**	u.s.	188	u.s.	188	u.s.	188
3	**SC-I/II**	u.s.	188	u.s.	188	u.s.	188
4	**SC-III**	u.s.	188	u.s.	188	u.s.	188
5	**SC-V**	1800	2608	1800	2608	1800	2608
6	**SC-V**	u.s.	376	u.s.	376	u.s.	188
7	**SC-I/II**	u.s.	188	u.s.	188	u.s.	188
8	**SC-I/II**	u.s.	188	u.s.	188	u.s.	188
9	**SC-IV/V**	u.s.	376	u.s.	376	u.s.	188

$A_{s\ req}$....... **Required area of reinforcement per side (inner and outer side)**
$A_{s\ prov}$..... **Provided area of reinforcement per side (inner and outer side)**
u.s......... **Unreinforced sprayed concrete**

7.2 Design of Reinforcement

For the design of the reinforcement for the primary support measures of the main tunnel, the following Table 8 summarizes the results of the structural calculations.

Table 8: Applied Reinforcement

Support Class	Side of Reinforcement	Lattice Girders		Wire Mesh		Round length (RL)	Area of Lattice Girders/m	Reinforcement
		Type	Area	Type	Area			
			[mm^2/m]		[mm^2/m]	[m]	[mm^2/m]	[mm^2/m]
I	Outer	-	-	150/150/6	188	>3m	-	188
	Inner		-	-	-		-	-
II	Outer	-	-	150/150/6	188	2-2.5m	-	188
	Inner		-	-	-		-	-
III	Outer	-	-	150/150/6	188	1.5-2m	-	188
	Inner		-	-	-		-	-
IV	Outer	95/20/25	490.8	150/150/6	188	1-1.5m	490.8	678.8
	Inner		628.3	150/150/6	188		628.3	816.3
V	Outer	130/25/32	804.2	150/150/6	188	0.8-1m	1005.2	1193.2
	Inner		981.7	150/150/6	188		1227.1	1415.1

8 CONCLUSION

The analytical calculation results according to Prof. Feder show that plastic yielding occurs around the tunnel excavation and large elastic-plastic deformations develop for rock type RMT 5a which is having high overburden and low strength parameters for faulted/sheared rock mass. Duddeck-Erdmann analysis also showed the requirement for a considerable amount of reinforcement for the rock type RMT 5a under high overburden where high value of normal force can be expected. Despite this, the combined system “rock mass / support measures (SC V)” does not fail and the system behaviour remains stable. This can be attributed to the load-bearing capacity of the rock mass, which is able to take on the additional stresses, and to the properties of the modelled support system, which has sufficient ductility to accommodate the non-elastic deformations occurring. However the analysis takes into account the full overburden weight for RMT 5 (shear zone), which is a conservative assumption.

The results of the analytical calculations for the other rock mass types show stable behaviour and no development of plastic yielding is noticed.

The results of the analytical calculations according to Prof. Feder and Duddeck / Erdmann and the structural analysis show the following key results:

- considering various ground types associated with different geotechnical conditions and rock mass parameters listed in Chapter 4, the Support Classes from SC-I to SC-V designed are sufficient,
- the sprayed concrete lining requires systematic rock bolting and partly steel reinforcement, which is provided by wire mesh and lattice girders

It has to be emphasized that a comprehensive monitoring program during construction is part of the design (observational approach) to allow for a continuous assessment of the primary lining behaviour and the verification of the design assumptions. Support measures and round lengths shall be adjusted according to the actual geological conditions and the monitored displacements.

-------- End of main document --------

9 TABLE OF ANNEXURES

Annexure – 1

Calculations according to Prof. Feder

Analysis 1

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-1				
Chainage:	-				

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Excavation Radius	R_o=	7.5	[m]
Overburden	H=	240	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	43	[°]
Angle of Friction plastic	φ_{pl}=	43	[°]
Cohesion elastic	C_{el}=	4.5	[N/mm²]
Cohesion plastic	C_{pl}=	4.5	[N/mm²]
Poissons Ratio	N_y=	0.15	[-]
Youngs Modulus	E=	41000	[N/mm²]
Pressure Ratio	k_o=	1	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1.2	[-]
Support Pressure Σ pa_i	p_a=	0.20	[N/mm²]

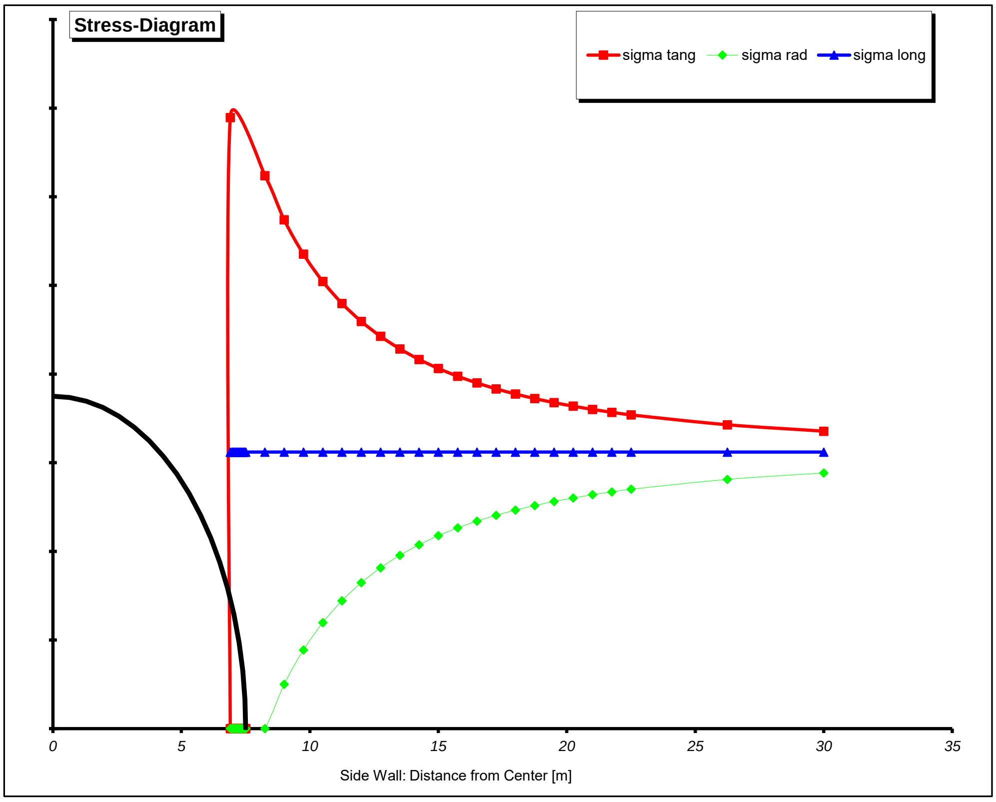
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.1	[m]
pa_1=	0.20	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

Stress-Diagram: (circular cross section)



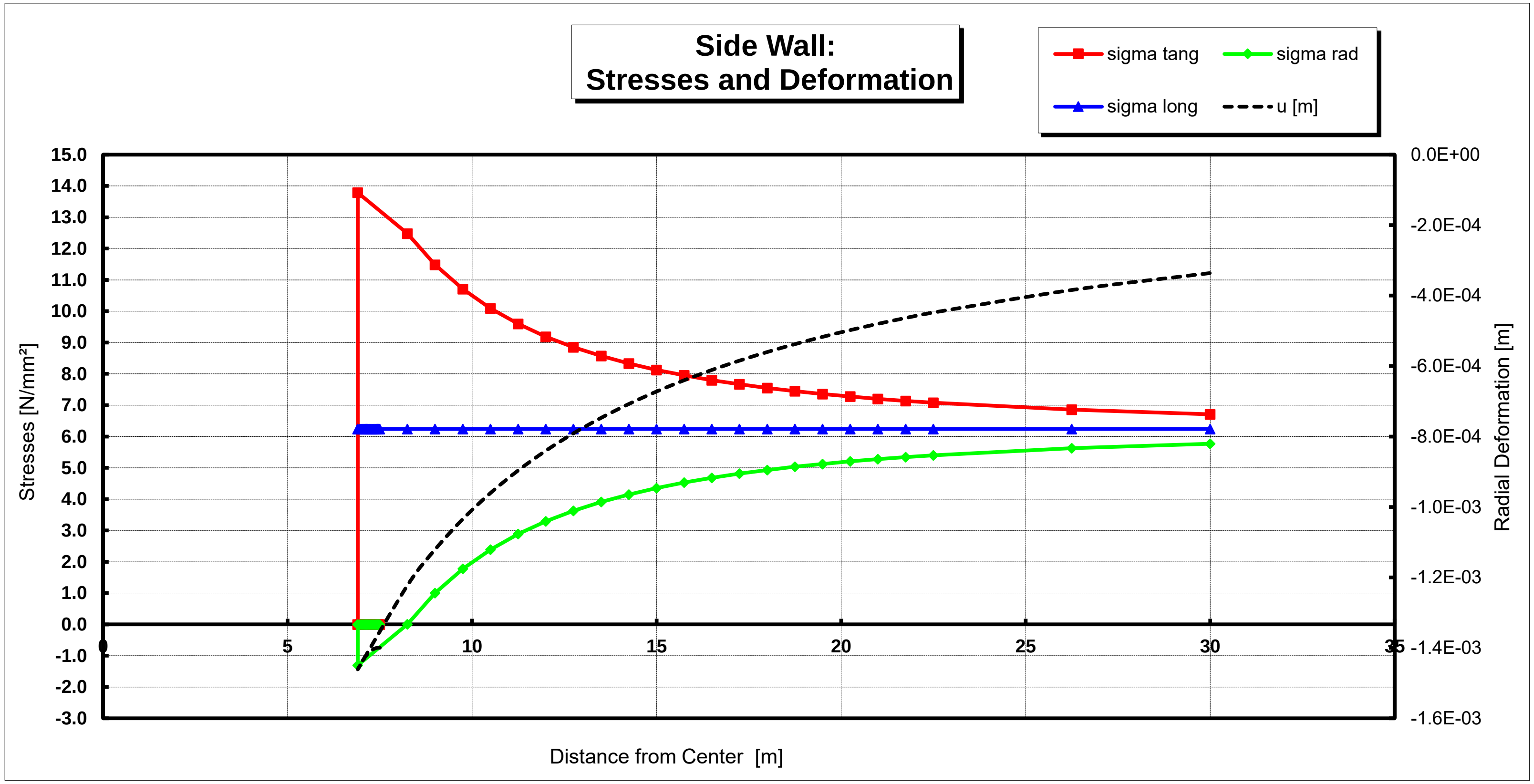
NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-1
Chainage:	-

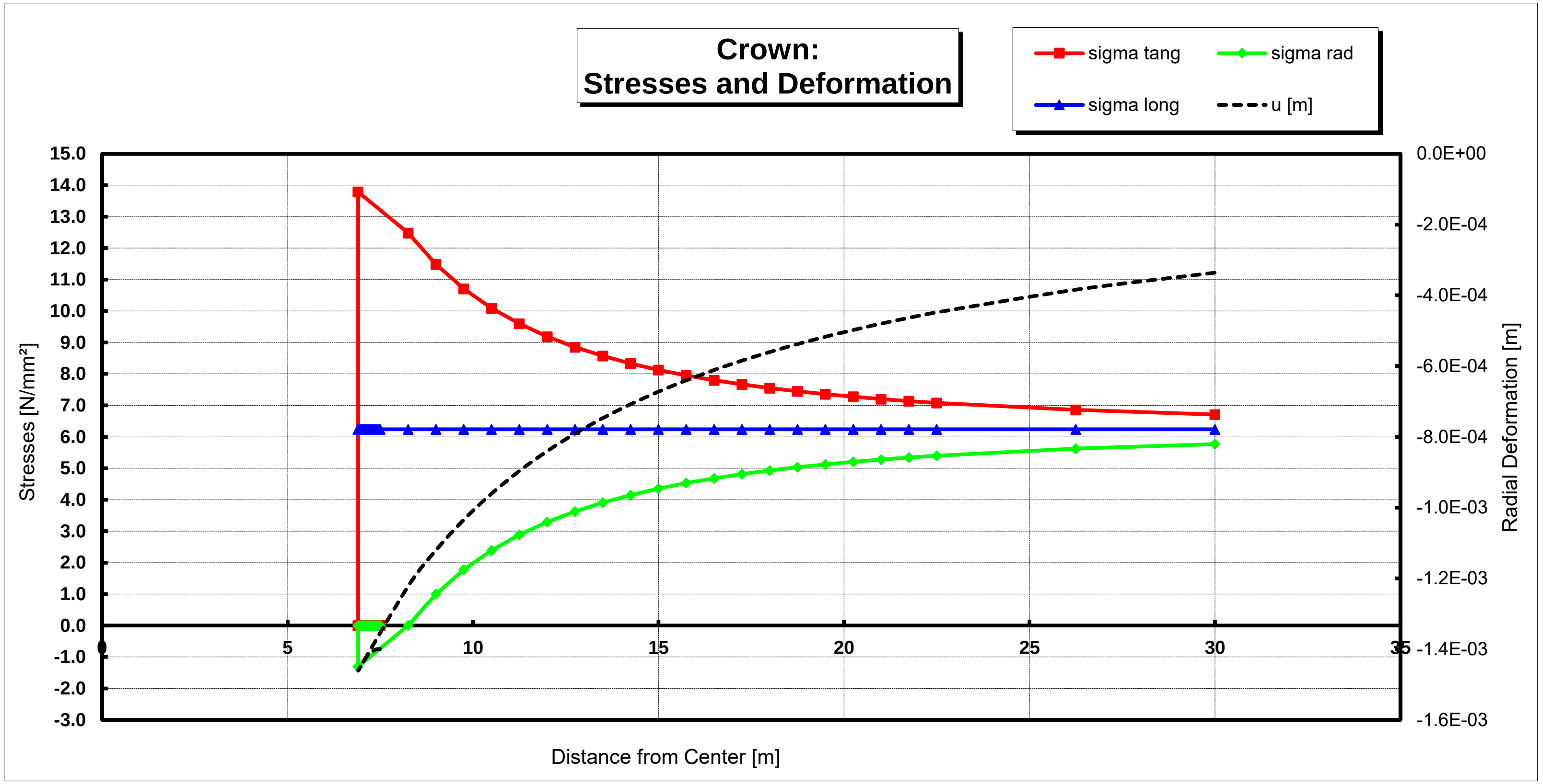
Stresses and Deformation: Side Wall



Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-1
Chainage:	-

Stresses and Deformation: Crown



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Analysis 2

Project:	Feasibility for ShiradiGhat Bypass		
Job No.: I6060	Date: 3/Dec/15	Made by: PSi	GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-2
Chainage:	-

Analyses according to Prof. Feder (MU Leoben)

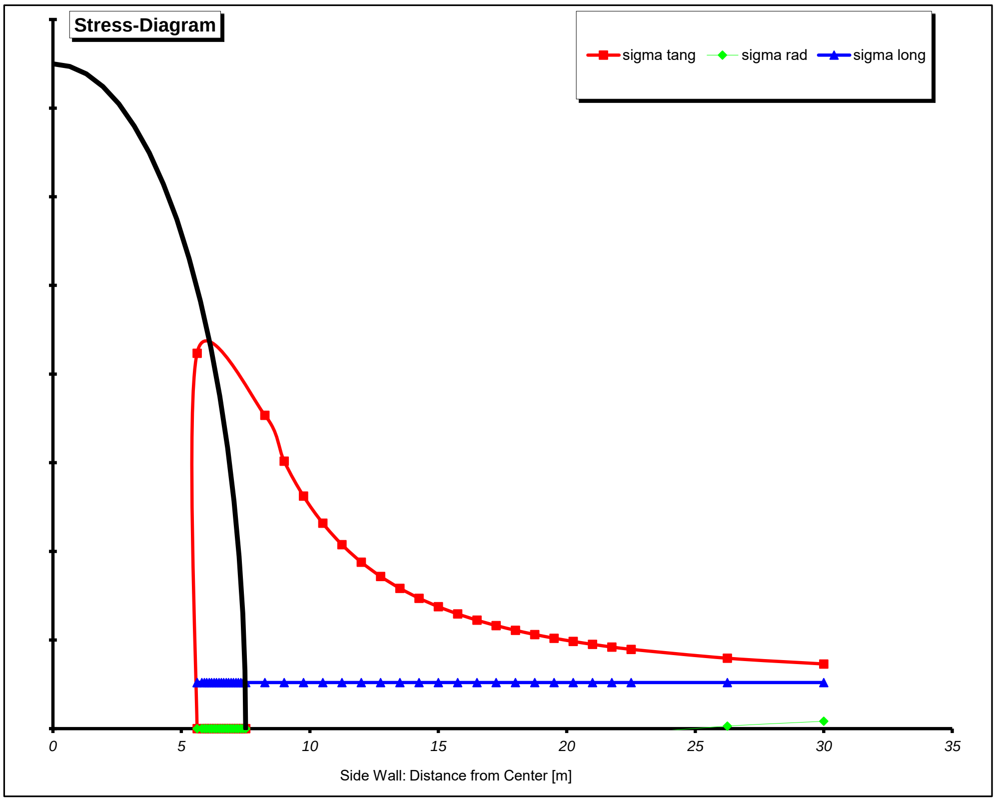
Input Parameters:

Excavation Radius	R_o=	7.5	[m]		
Overburden	H=	20	[m]		
Unit Weight of Rock	γ=	0.026	[N/mm³]		
Angle of Friction elastic	φ_{el}=	37	[°]		
Angle of Friction plastic	φ_{pl}=	37	[°]		
Cohesion elastic	C_{el}=	4	[N/mm²]		
Cohesion plastic	C_{pl}=	4	[N/mm²]		
Poissons Ratio	N_y=	0.15	[-]		
Youngs Modulus	E=	8000	[N/mm²]		
Pressure Ratio	k_o=	0.5	[-]		
Crown 0°	ψ_F=	0	[°]		
Side Wall 90°	ψ_U=	90	[°]		
Loosening factor	α=	1.2	[-]	*O.K.*	
Support Pressure Σ pa_i	p_a=	0.40	[N/mm²]	***Support pressure too high***	

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.2	[m]
pa_1=	0.40	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

Stress-Diagram: (circular cross section)



NOTE: Mind the Scale

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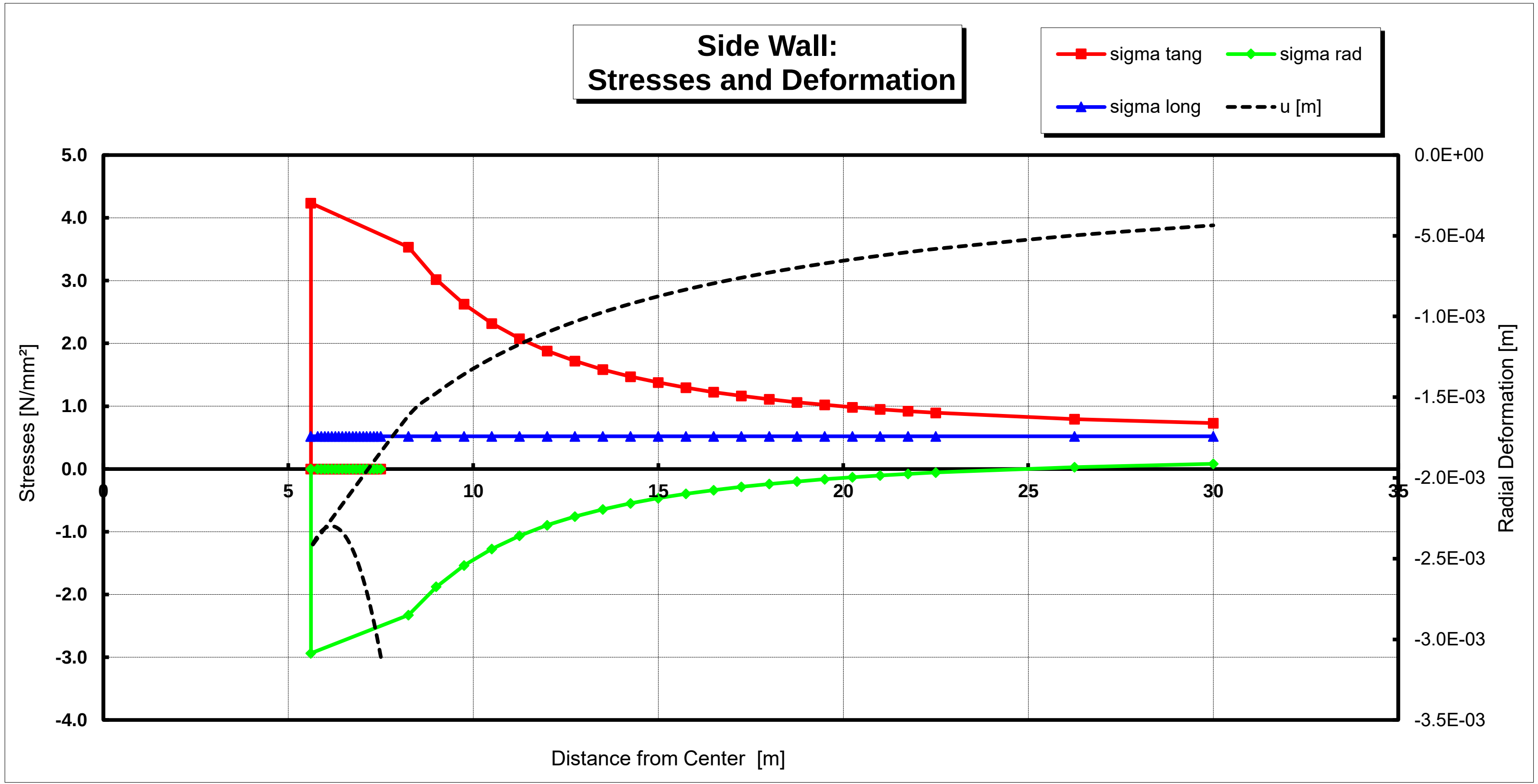
Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-2
Chainage:	-

Stresses and Deformation: Side Wall



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Project:	Feasibility for ShiradiGhat Bypass		
Job N°: I6060	Date: 3/Dec/15	Made by: PSi	

GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-2
Chainage:	-

Stresses and Deformation: Crown

Analysis 3

Project:	**Feasibility for ShiradiGhat Bypass**				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	**Tunnel 1 to 6**				
Section:	**Crown, Sidewall**				
Object:	**RMT-3**				
Chainage:	-				

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Parameter	Symbol	Value	Unit
Excavation Radius	R_o=	7.5	[m]
Overburden	H=	200	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	29	[°]
Angle of Friction plastic	φ_{pl}=	29	[°]
Cohesion elastic	C_{el}=	4	[N/mm²]
Cohesion plastic	C_{pl}=	4	[N/mm²]
Poissons Ratio	N_y=	0.2	[-]
Youngs Modulus	E=	10000	[N/mm²]
Pressure Ratio	k_o=	1	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1.2	[-]
Support Pressure Σ pa_i	p_a=	0.20	[N/mm²]

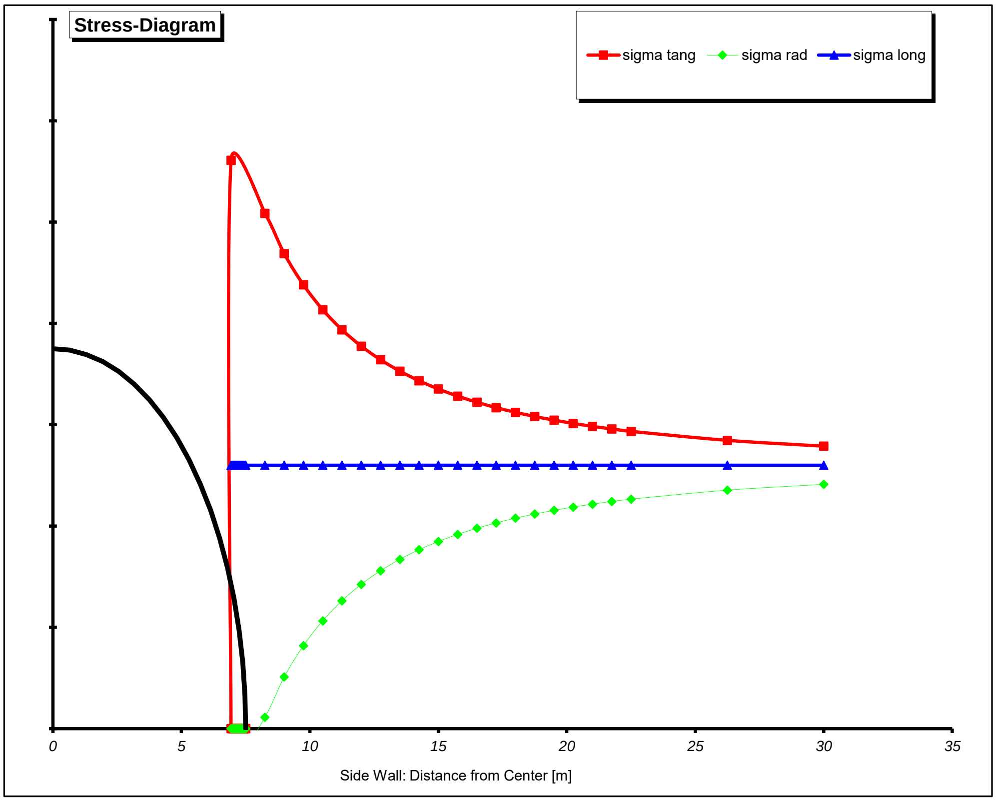
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.1	[m]
pa_1=	0.20	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

Stress-Diagram: (circular cross section)



NOTE: Mind the Scale

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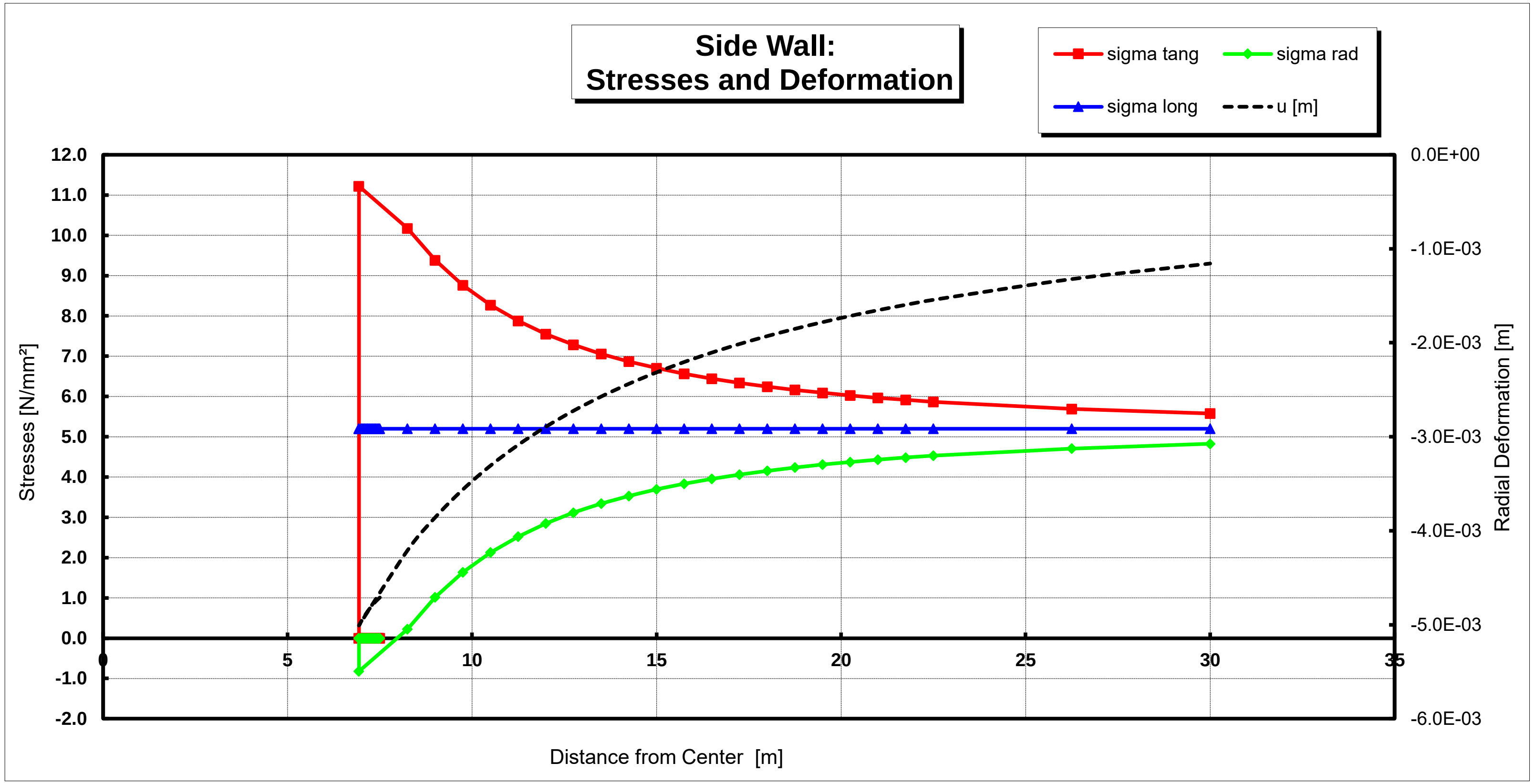
Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-3
Chainage:	-

Stresses and Deformation: Side Wall



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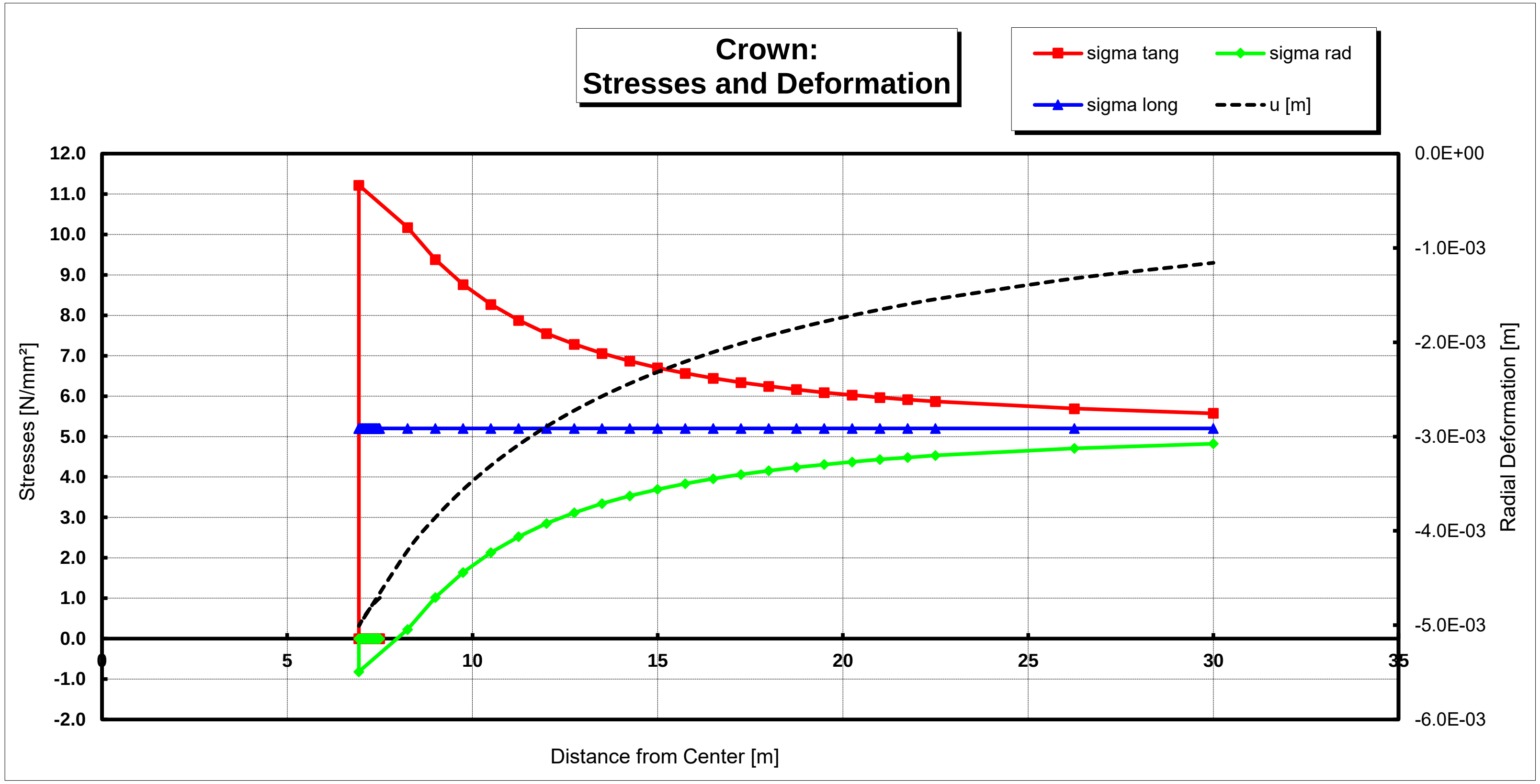
Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-3				
Chainage:	-				

GEOCONSULT

Stresses and Deformation: Crown



Analysis 4

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-4				
Chainage:	-				

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Parameter	Symbol	Value	Unit
Excavation Radius	R_o=	7.5	[m]
Overburden	H=	20	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	25	[°]
Angle of Friction plastic	φ_{pl}=	25	[°]
Cohesion elastic	C_{el}=	2	[N/mm²]
Cohesion plastic	C_{pl}=	2	[N/mm²]
Poissons Ratio	N_y=	0.25	[-]
Youngs Modulus	E=	1900	[N/mm²]
Pressure Ratio	k_o=	0.5	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1.2	[-]
Support Pressure Σ pa_i	p_a=	0.40	[N/mm²]

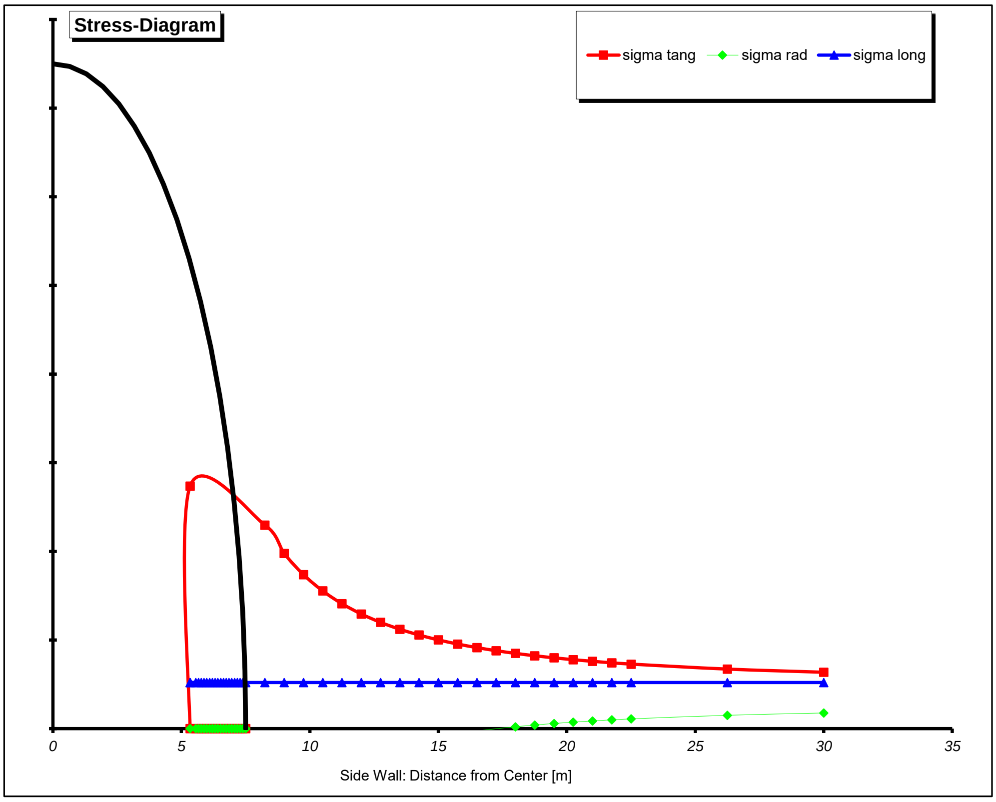
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.2	[m]
pa_1=	0.40	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

Stress-Diagram: (circular cross section)

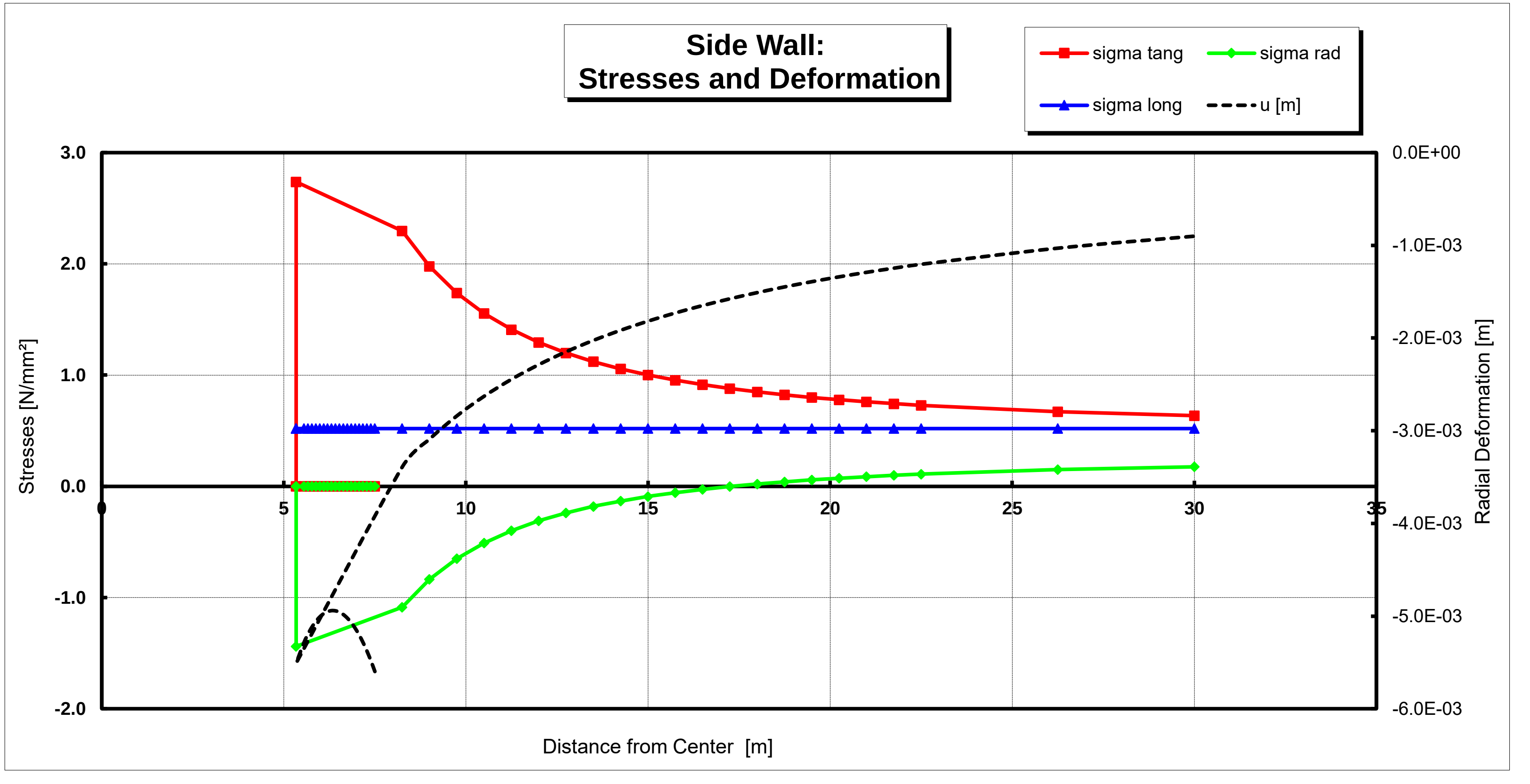


NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-4
Chainage:	-

Stresses and Deformation: Side Wall



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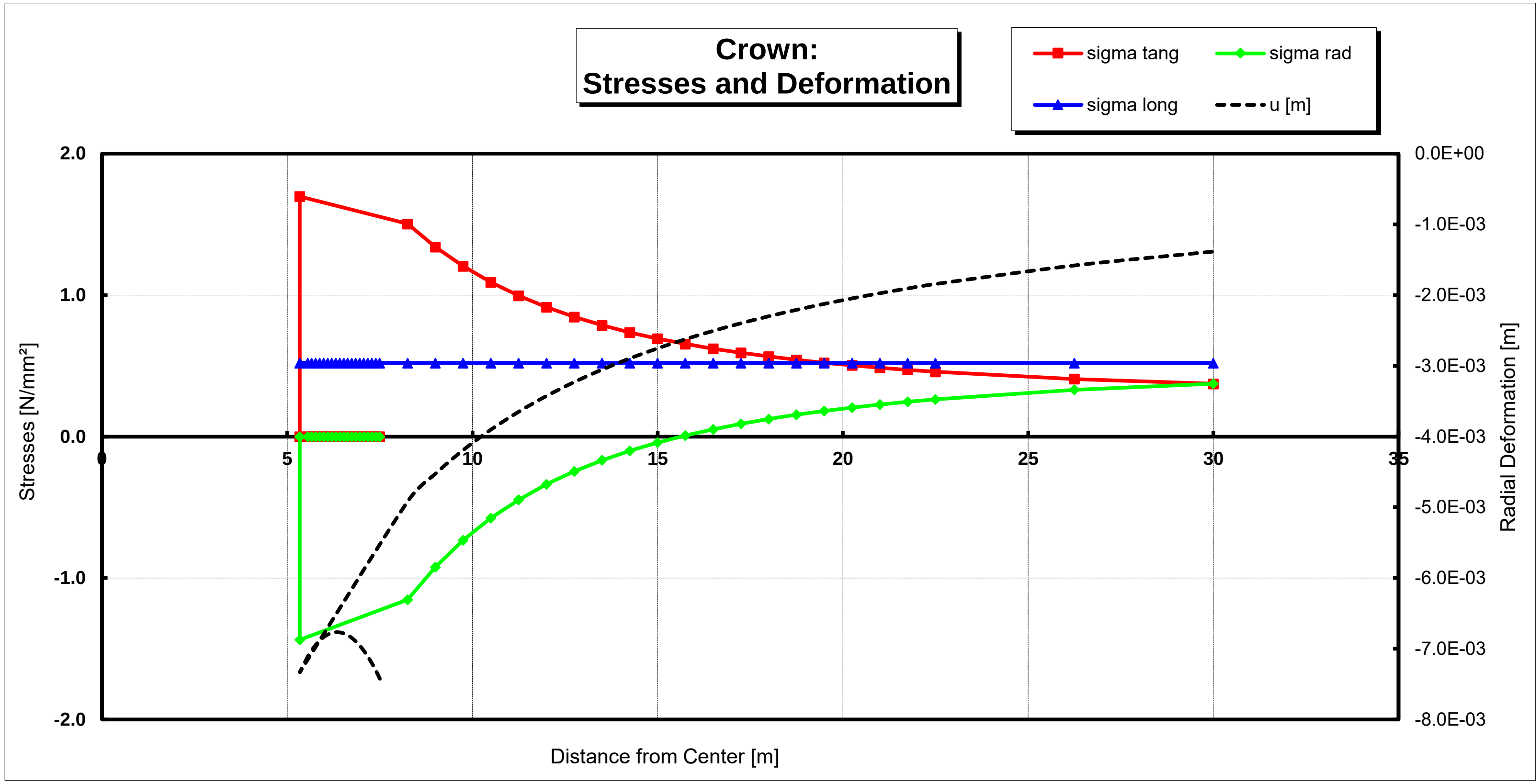
Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-4
Chainage:	-

Stresses and Deformation: Crown



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Analysis 5

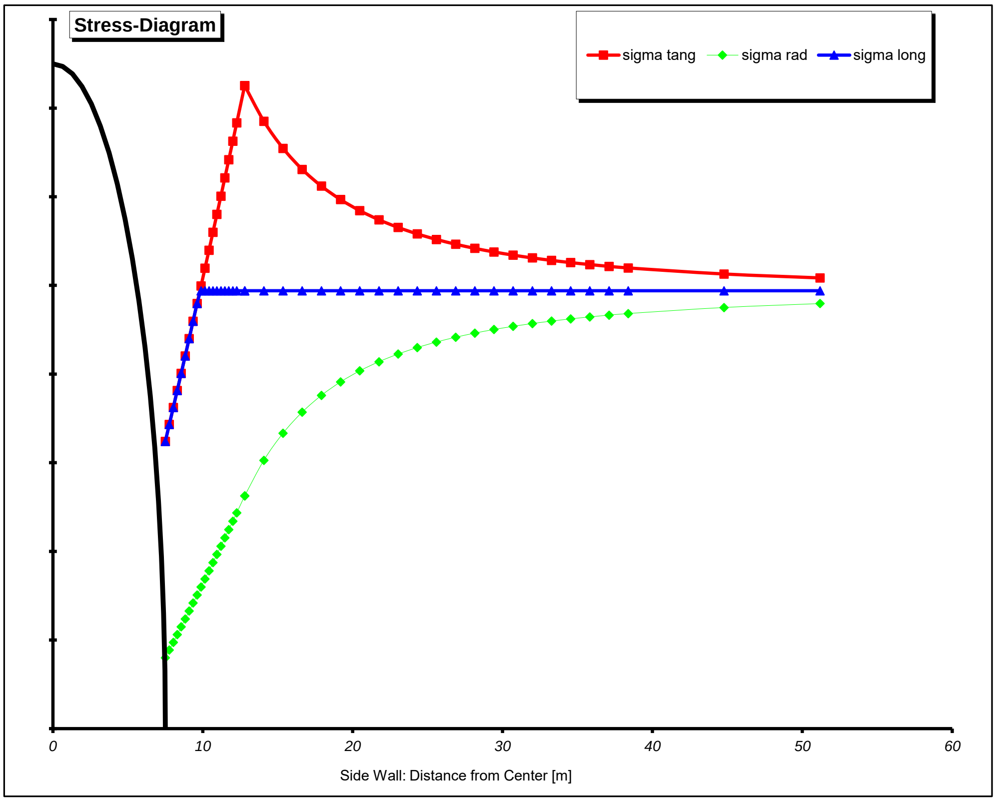
Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-5a				
Chainage:	High Overburden				

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Parameter	Symbol	Value	Unit				
Excavation Radius	R_o=	7.5	[m]		Analyses of Support Pressure		
Overburden	H=	190	[m]				
Unit Weight of Rock	γ=	0.026	[N/mm³]		Shotcrete-		
Angle of Friction elastic	φ_{el}=	22	[°]		UCS	15	[MN/m²]
Angle of Friction plastic	φ_{pl}=	22	[°]		Shotcrete-		
Cohesion elastic	C_{el}=	0.5	[N/mm²]		thickness	0.3	[m]
Cohesion plastic	C_{pl}=	0.5	[N/mm²]		pa_1=	0.60	[MN/m²]
Poissons Ratio	N_y=	0.3	[-]				
Youngs Modulus	E=	750	[N/mm²]		CP oth. support	0.2	[MN/m²]
Pressure Ratio	k_o=	1	[-]		pa_2=	0.2	[MN/m²]
Crown 0°	ψ_F=	0	[°]				
Side Wall 90°	ψ_U=	90	[°]				
Loosening factor	α=	1.3	[-]	*O.K.*			
Support Pressure Σ pa_i	p_a=	0.80	[N/mm²]	*O.K.*			

Stress-Diagram: (circular cross section)

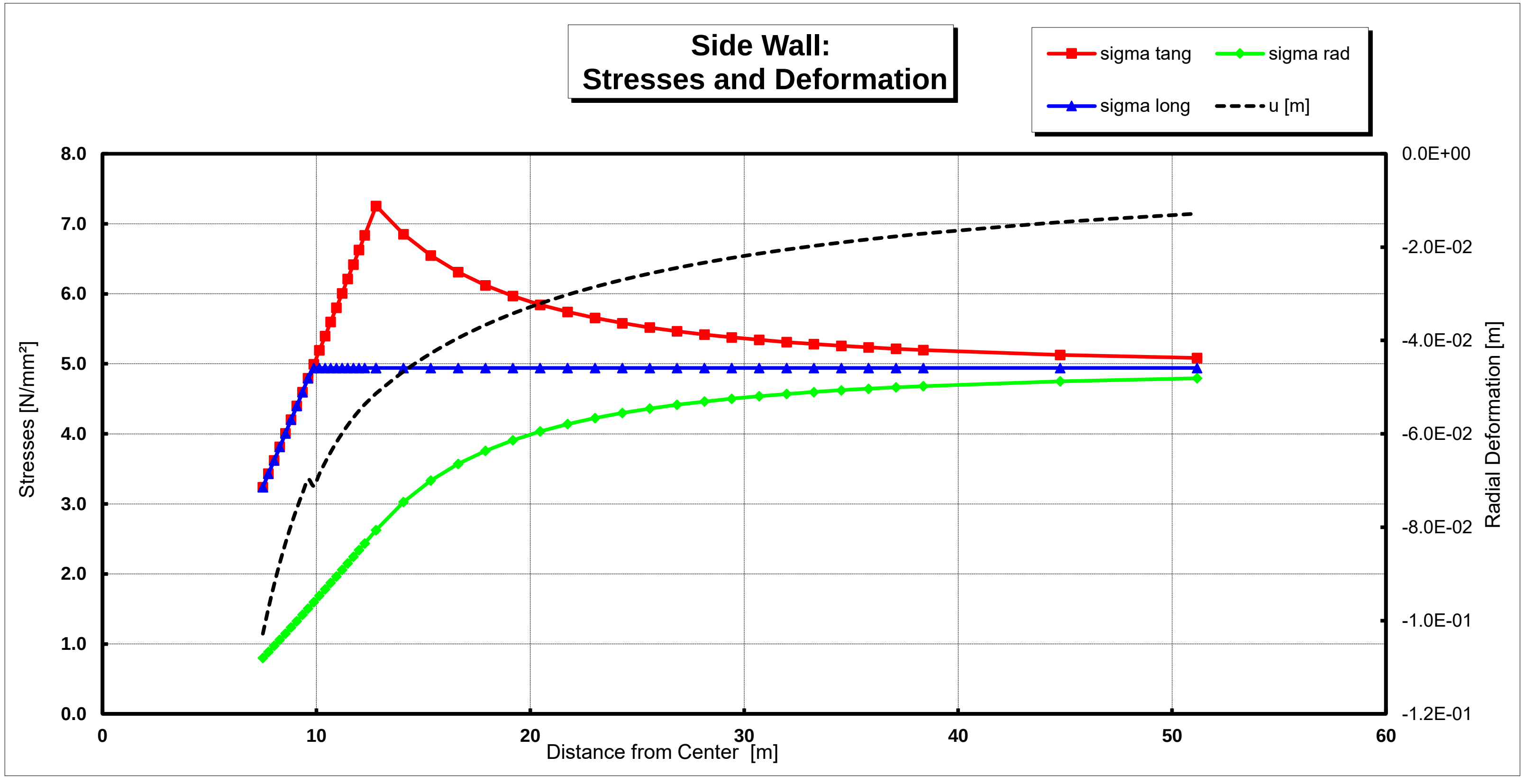


NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-5a
Chainage:	High Overburden

Stresses and Deformation: Side Wall



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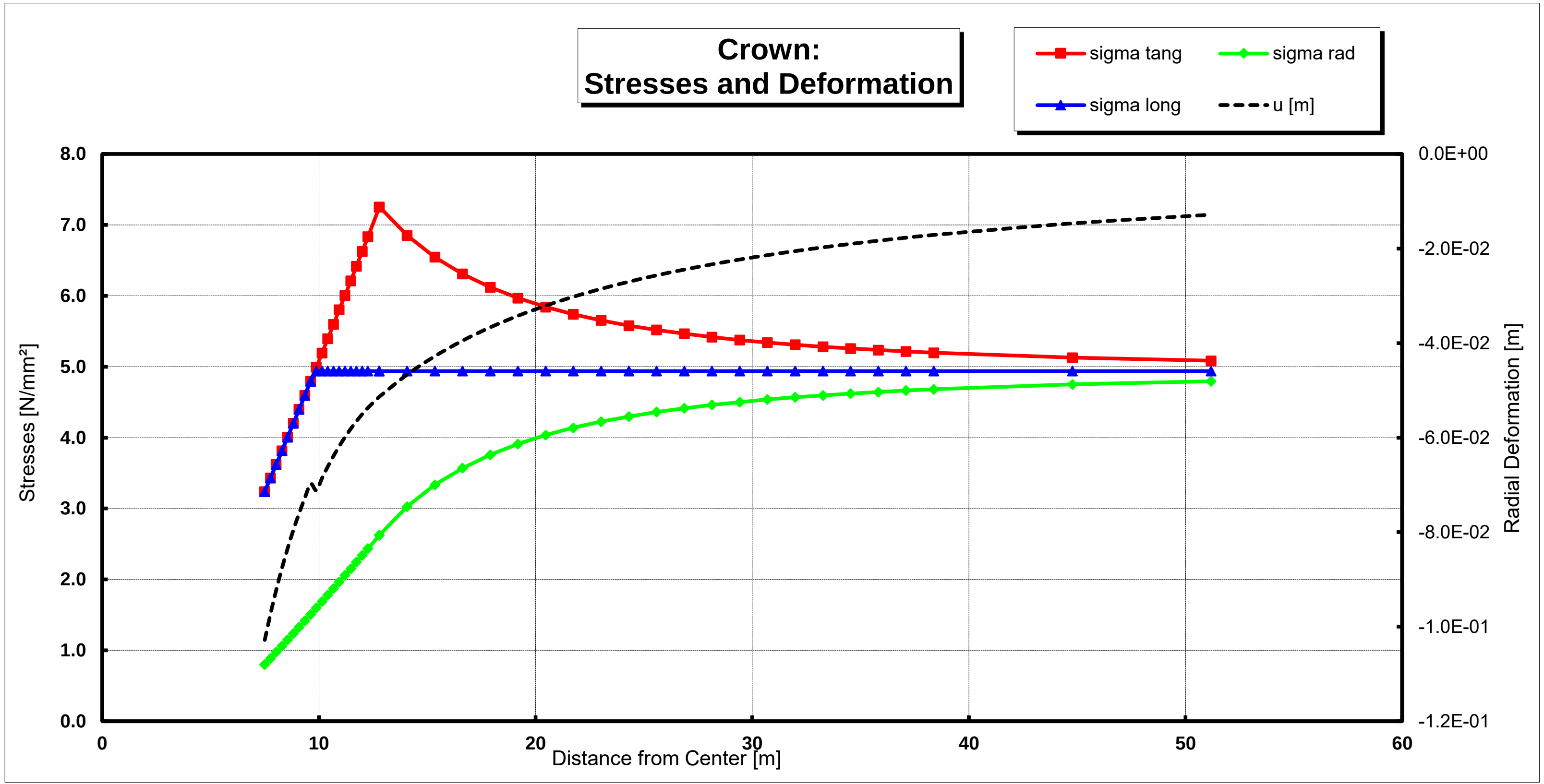
Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-5a
Chainage:	High Overburden

Stresses and Deformation: Crown



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Analysis 6

Project:	**Feasibility for ShiradiGhat Bypass**				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	**Tunnel 1 to 6**
Section:	**Crown, Sidewall**
Object:	**RMT-5b**
Chainage:	**Low Overburden**

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Excavation Radius	R_o=	7.5	[m]
Overburden	H=	20	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	22	[°]
Angle of Friction plastic	φ_{pl}=	22	[°]
Cohesion elastic	C_{el}=	0.5	[N/mm²]
Cohesion plastic	C_{pl}=	0.5	[N/mm²]
Poissons Ratio	N_y=	0.3	[-]
Youngs Modulus	E=	750	[N/mm²]
Pressure Ratio	k_o=	0.5	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1.3	[-]
Support Pressure Σ pa_i	p_a=	0.60	[N/mm²]

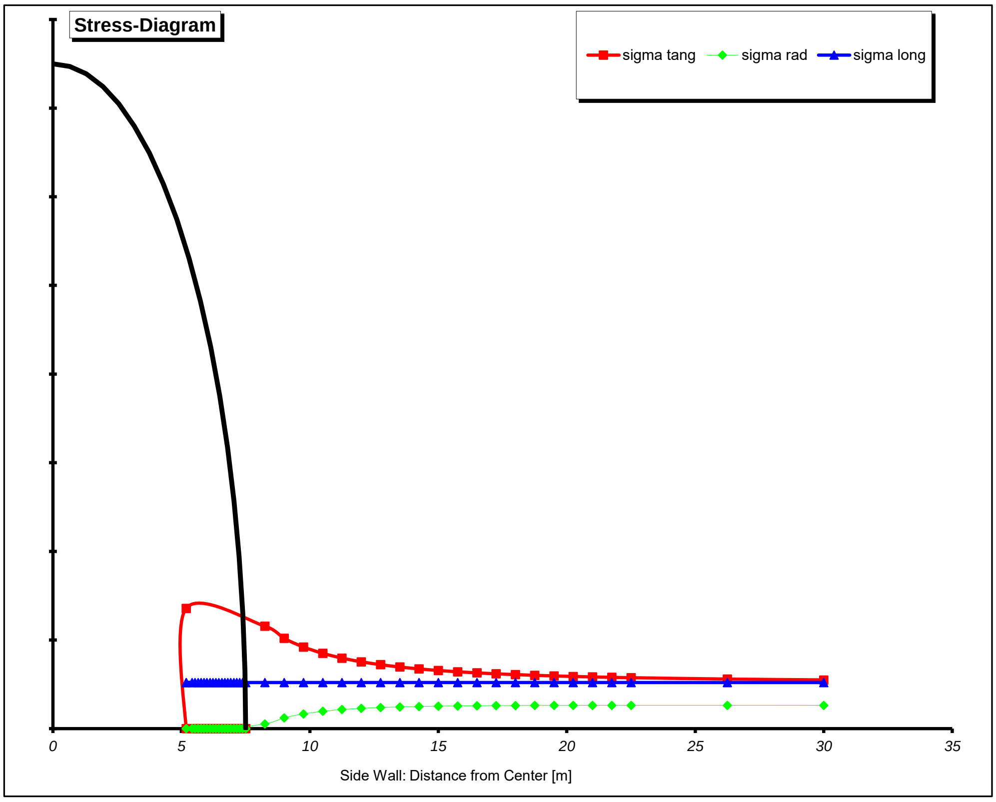
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.3	[m]
pa_1=	0.60	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

Stress-Diagram: (circular cross section)

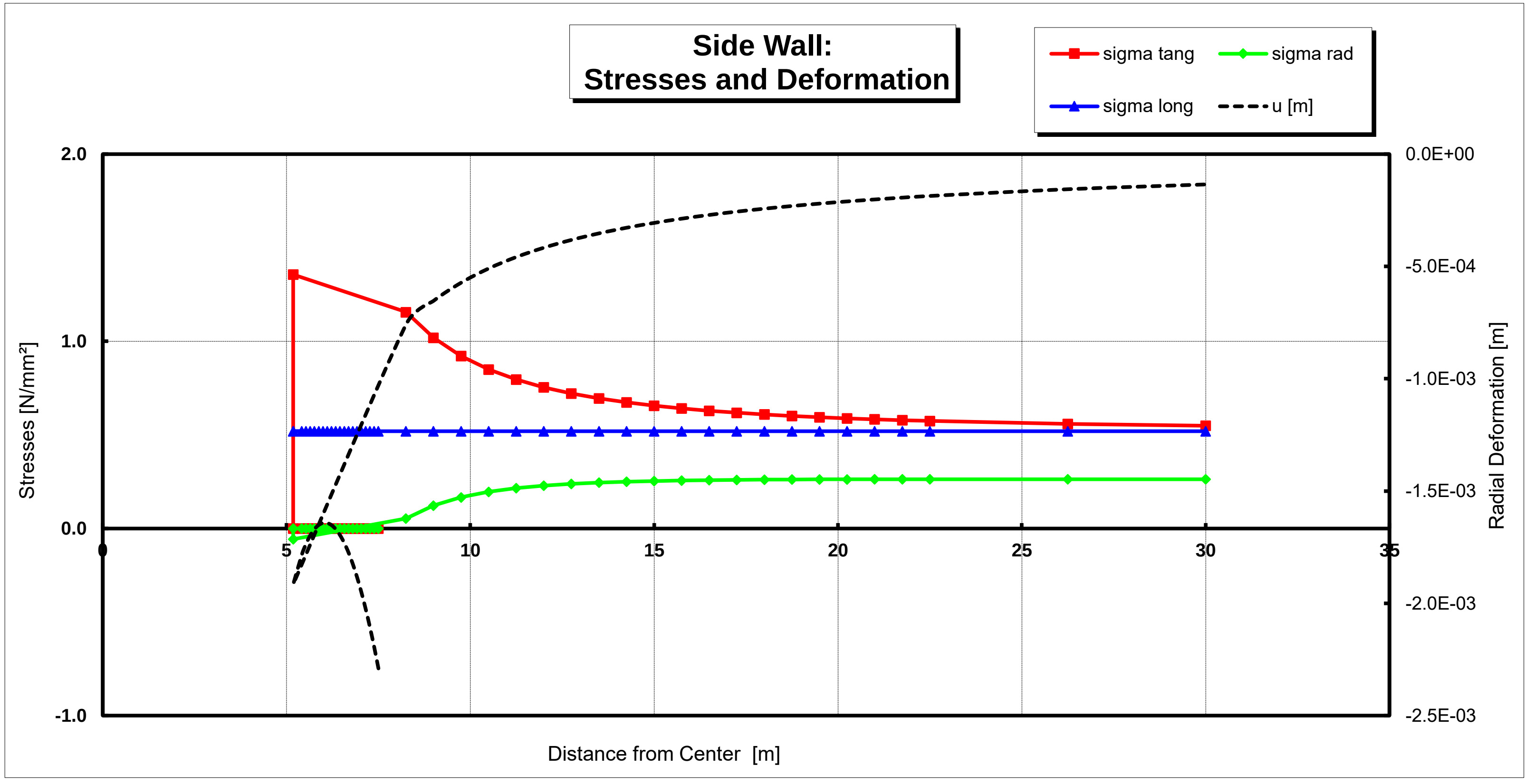


NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-5b
Chainage:	Low Overburden

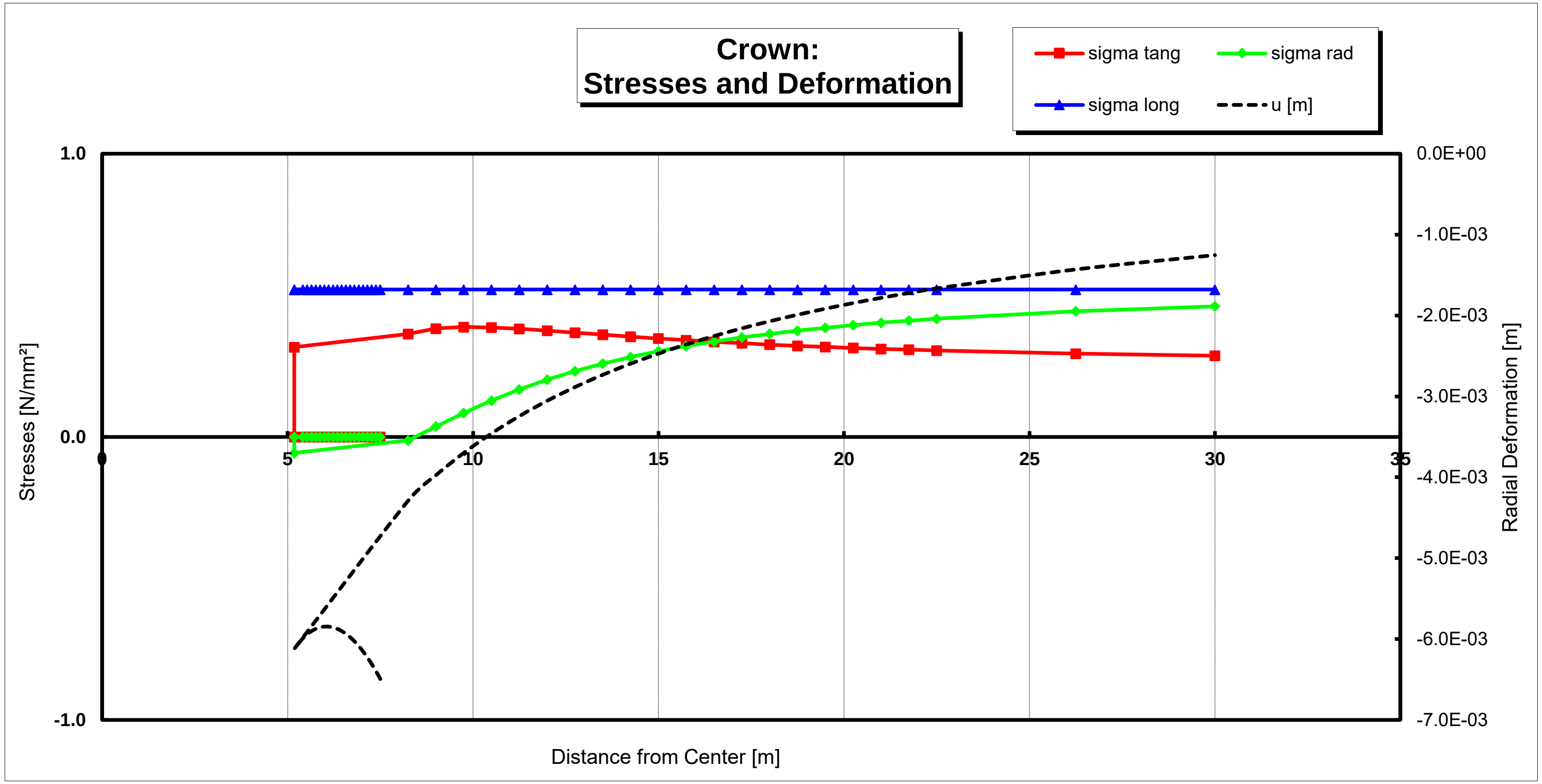
Stresses and Deformation: Side Wall



Project:	**Feasibility for ShiradiGhat Bypass**				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	**Tunnel 1 to 6**
Section:	**Crown, Sidewall**
Object:	**RMT-5b**
Chainage:	**Low Overburden**

Stresses and Deformation: Crown



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Analysis 7

Project:	**Feasibility for ShiradiGhat Bypass**				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	**Tunnel 1 to 6**				
Section:	**Crown, Sidewall**				
Object:	**RMT-7a**				
Chainage:	**High Overburden**				

GEOCONSULT

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

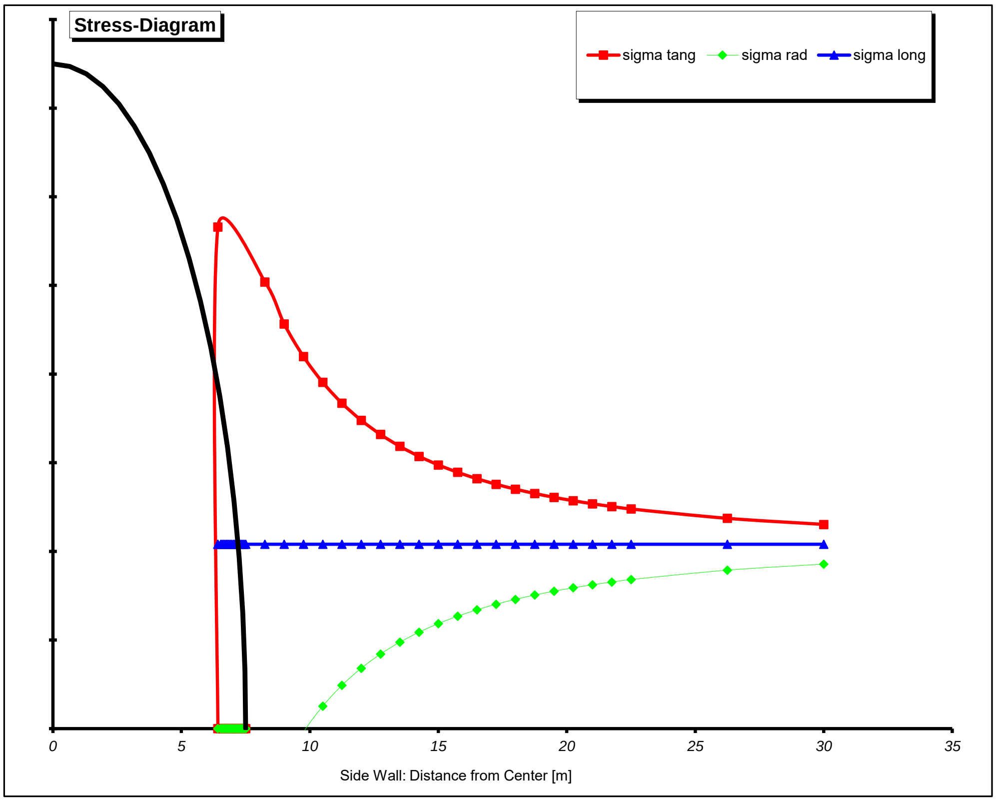
Excavation Radius	R_o=	7.5	[m]
Overburden	H=	80	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	46	[°]
Angle of Friction plastic	φ_{pl}=	46	[°]
Cohesion elastic	C_{el}=	3	[N/mm²]
Cohesion plastic	C_{pl}=	3	[N/mm²]
Poissons Ratio	N_y=	0.2	[-]
Youngs Modulus	E=	18000	[N/mm²]
Pressure Ratio	k_o=	1	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1	[-]
Support Pressure Σ pa_i	p_a=	0.20	[N/mm²]

O.K.
Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.1	[m]
pa_1=	0.20	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

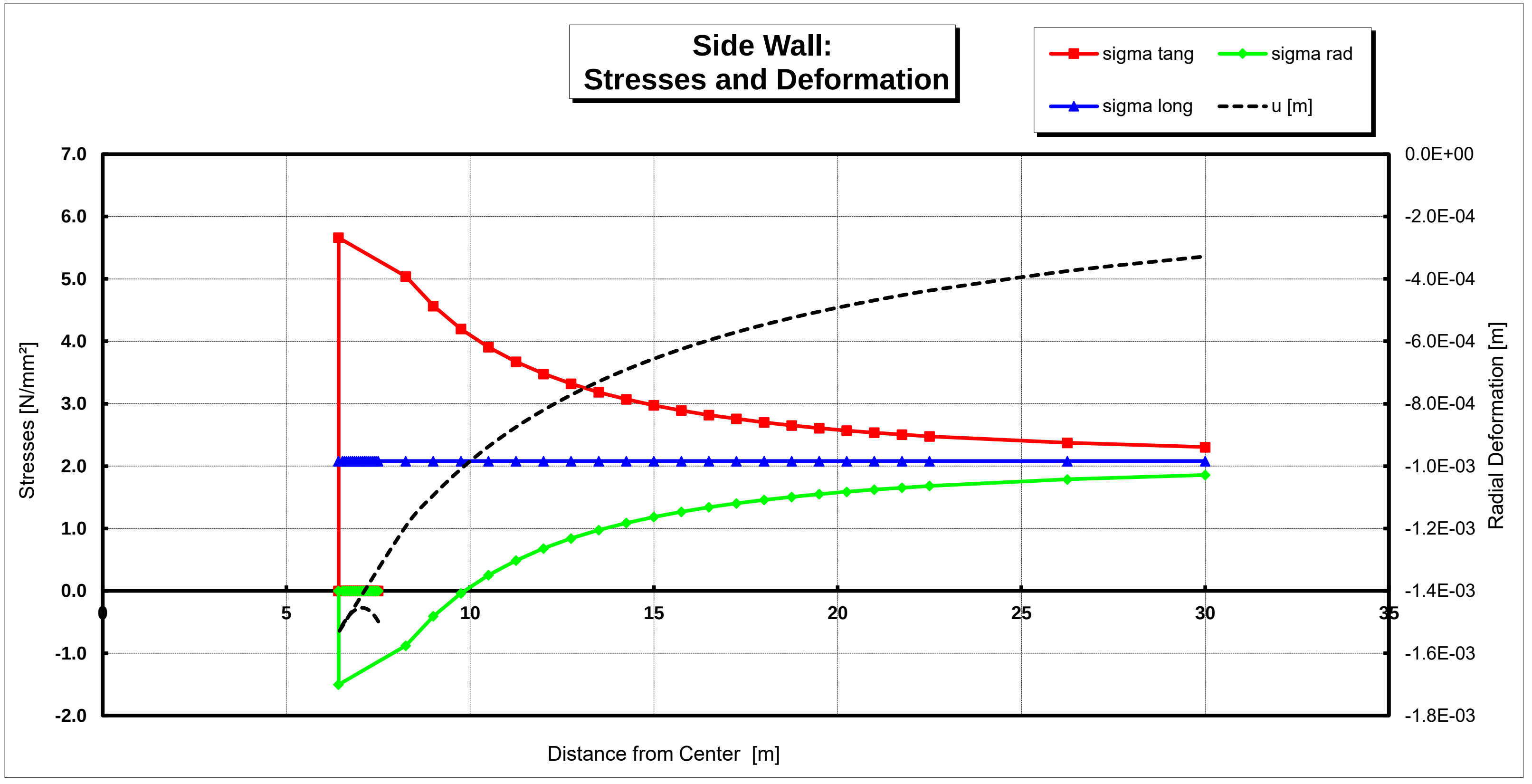
Stress-Diagram: (circular cross section)



NOTE: Mind the Scale

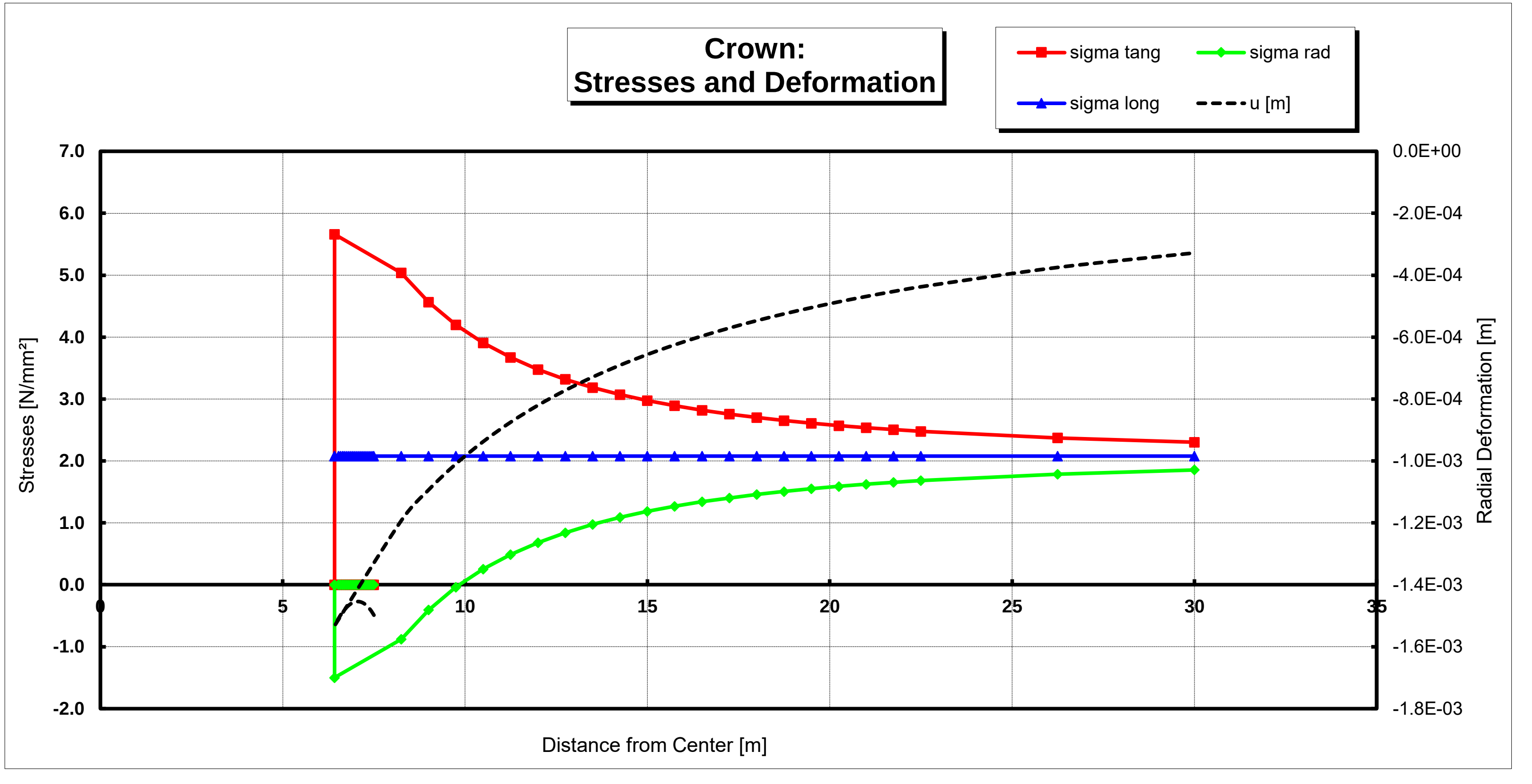
Project:	**Feasibility for ShiradiGhat Bypass**		
Job No.: I6060	Date: 3/Dec/15	Made by: PSi	GEOCONSULT
Tunnel:	**Tunnel 1 to 6**		
Section:	**Crown, Sidewall**		
Object:	**RMT-7a**		
Chainage:	**High Overburden**		

Stresses and Deformation: Side Wall



Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-7a				
Chainage:	High Overburden				

Stresses and Deformation: Crown



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Analysis 8

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

GEOCONSULT

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-7b
Chainage:	Low Overburden

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Parameter	Symbol	Value	Unit
Excavation Radius	R_o=	7.5	[m]
Overburden	H=	30	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	46	[°]
Angle of Friction plastic	φ_{pl}=	46	[°]
Cohesion elastic	C_{el}=	3	[N/mm²]
Cohesion plastic	C_{pl}=	3	[N/mm²]
Poissons Ratio	N_y=	0.2	[-]
Youngs Modulus	E=	18000	[N/mm²]
Pressure Ratio	k_o=	0.5	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1	[-]
Support Pressure Σ pa_i	p_a=	0.20	[N/mm²]

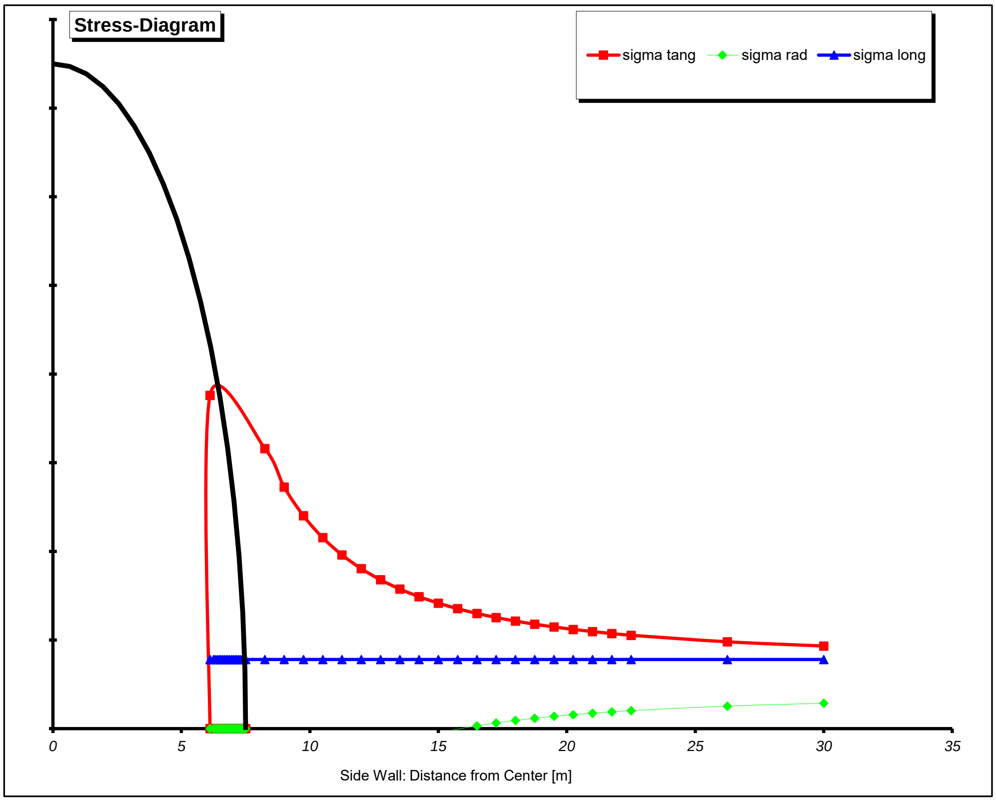
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.1	[m]
pa_1=	0.20	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

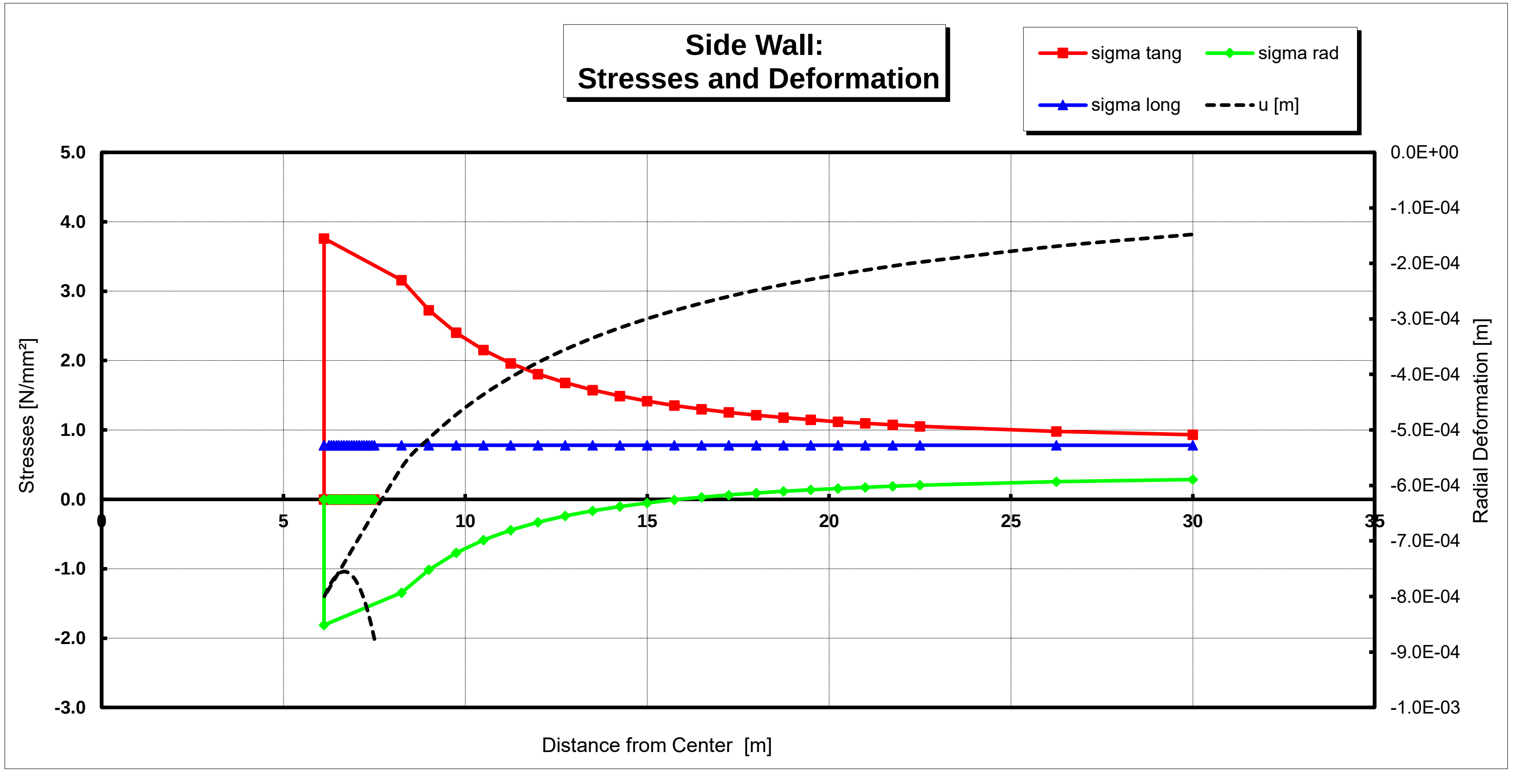
Stress-Diagram: (circular cross section)



NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-7b				
Chainage:	Low Overburden				

Stresses and Deformation: Side Wall

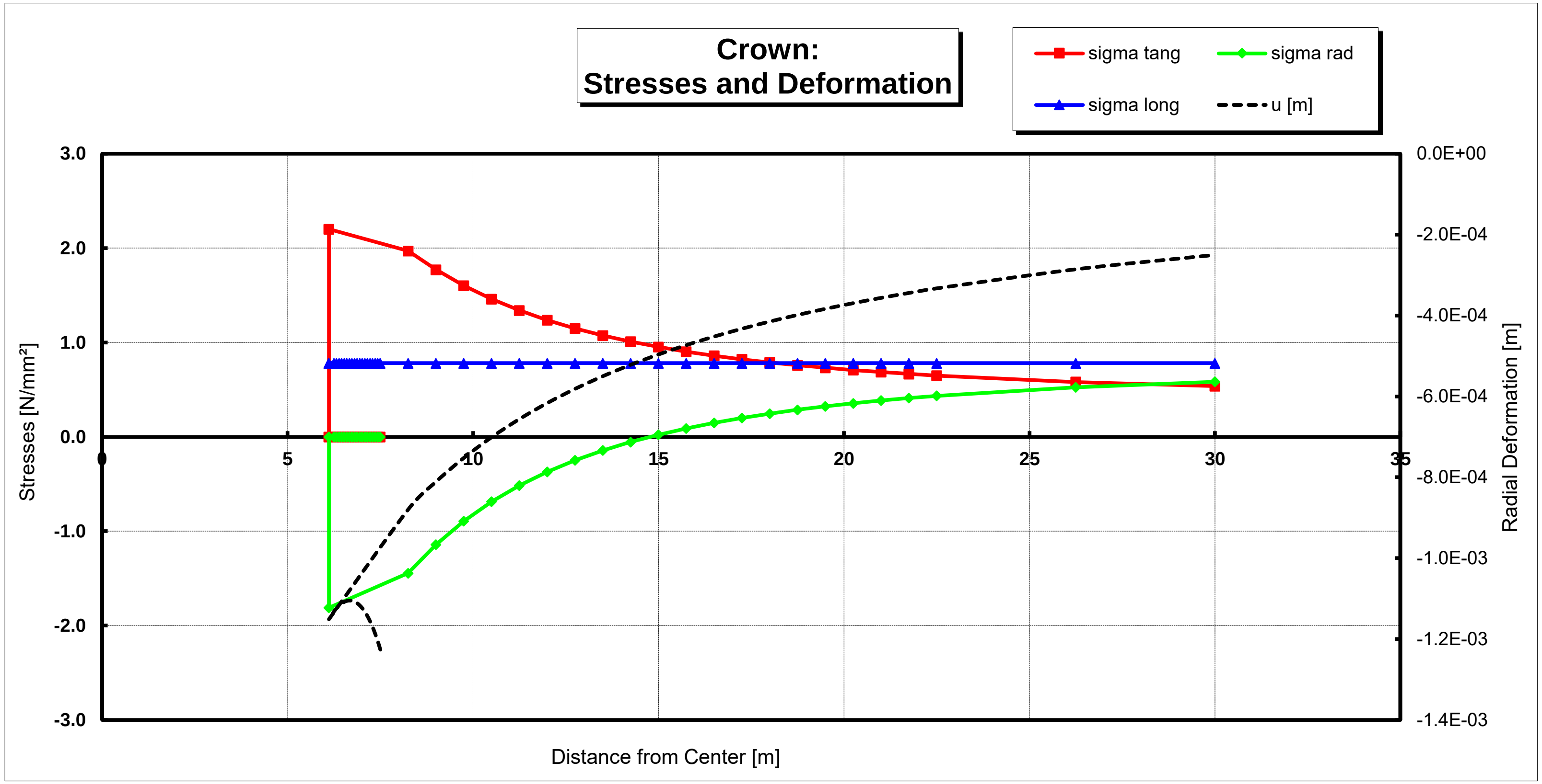


Project:	**Feasibility for ShiradiGhat Bypass**				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

GEOCONSULT

Tunnel:	**Tunnel 1 to 6**
Section:	**Crown, Sidewall**
Object:	**RMT-7b**
Chainage:	**Low Overburden**

Stresses and Deformation: Crown



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Analysis 9

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-8
Chainage:	-

Analyses according to Prof. Feder (MU Leoben)

Input Parameters:

Parameter	Symbol	Value	Unit
Excavation Radius	R_o=	7.5	[m]
Overburden	H=	20	[m]
Unit Weight of Rock	γ=	0.026	[N/mm³]
Angle of Friction elastic	φ_{el}=	15	[°]
Angle of Friction plastic	φ_{pl}=	15	[°]
Cohesion elastic	C_{el}=	0.05	[N/mm²]
Cohesion plastic	C_{pl}=	0.05	[N/mm²]
Poissons Ratio	N_y=	0.4	[-]
Youngs Modulus	E=	4500	[N/mm²]
Pressure Ratio	k_o=	0.5	[-]
Crown 0°	ψ_F=	0	[°]
Side Wall 90°	ψ_U=	90	[°]
Loosening factor	α=	1.3	[-]
Support Pressure Σ pa_i	p_a=	0.60	[N/mm²]

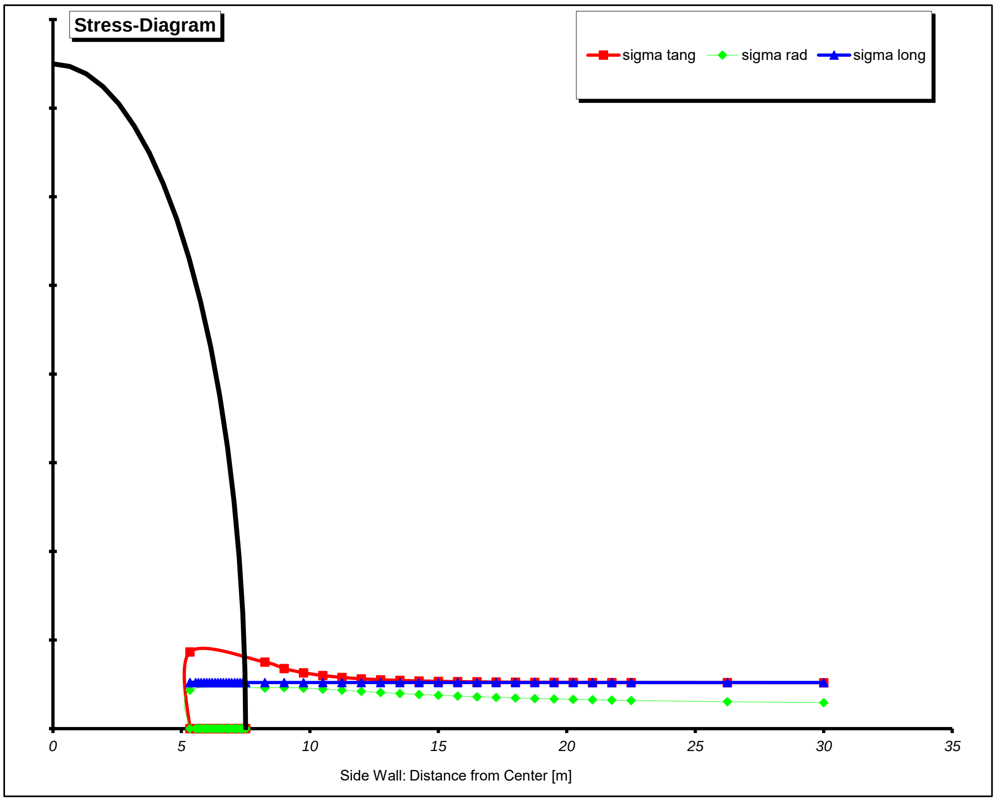
O.K.

Support pressure too high

Analyses of Support Pressure

Shotcrete-UCS	15	[MN/m²]
Shotcrete-thickness	0.3	[m]
pa_1=	0.60	[MN/m²]
CP oth. support	0	[MN/m²]
pa_2=	0	[MN/m²]

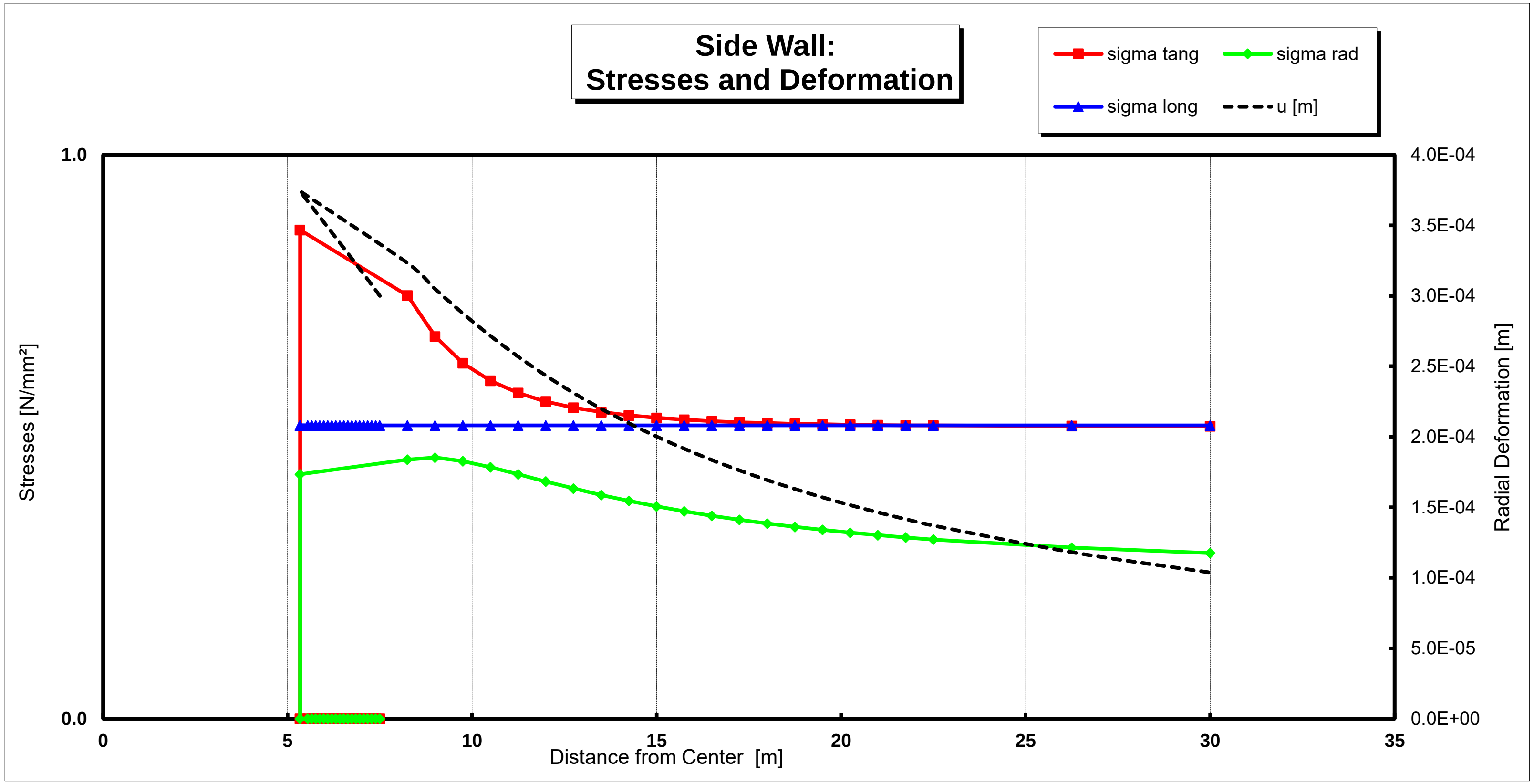
Stress-Diagram: (circular cross section)



NOTE: Mind the Scale

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	3/Dec/15	Made by:	PSi
Tunnel:	Tunnel 1 to 6				
Section:	Crown, Sidewall				
Object:	RMT-8				
Chainage:	-				

Stresses and Deformation: Side Wall



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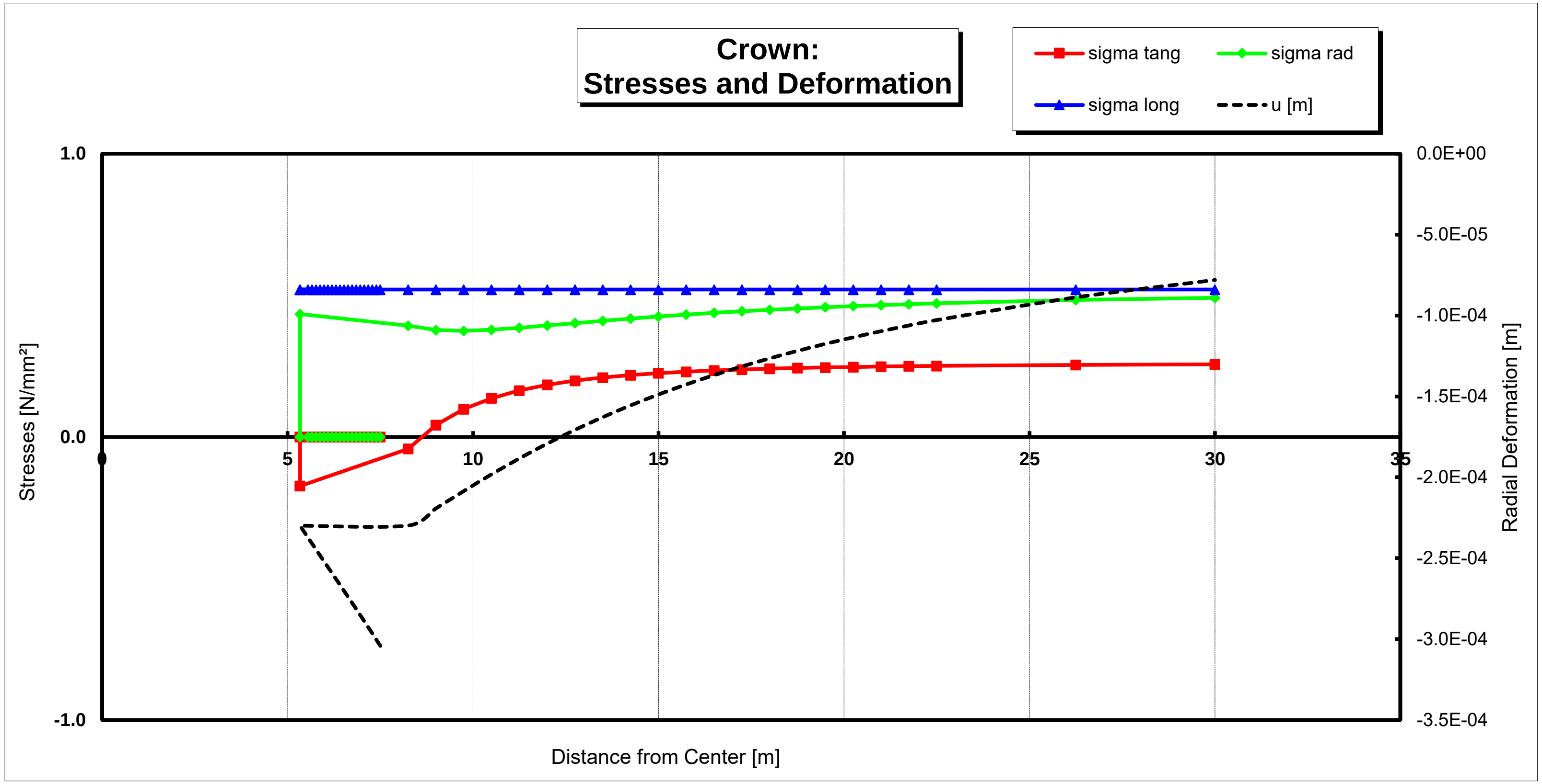
Project:	Feasibility for ShiradiGhat Bypass				
Job N°:	I6060	Date:	3/Dec/15	Made by:	PSi

Tunnel:	Tunnel 1 to 6
Section:	Crown, Sidewall
Object:	RMT-8
Chainage:	-

Stresses and Deformation: Crown



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Annexure – 2

Calculations according to Duddeck / Erdmann

Analysis 1

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-1				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	100	[mm]			
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]		
Radius	=	7.500	[m]			
Outer Radius of tunnel	=	7.6	[m]			
Overburden above tunnel axis	=	240.000	[m]			
Surcharge	=	0.00	[kPa]			
Unit Weight	=	26.00	[kN/m^3]			
Total vertical stress at tunnel axis	=	1170.00	[kPa]			
Avg. unit weight including surcharge	=	4.88	[kN/m^3]			
Young's Modulus of ground	=	41000.00	[MPa]			
Poisson's ratio of ground	=	0.15				
Horizontal earth pressure coefficient	=	1.00				
Young's Modulus of concrete lining	=	7500.00	[MPa]			
Cross-sectional area of Lining	=	0.10	[m^2]	b =	1.00	[m]
Moment of Inertia	=	0.00008	[m^4]			
Average tunnel radius	=	7.55	[m]			

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
28796825.6	415.4666667

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.003	0.007	0.000	24.38	0.000000	0.00

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
24.38	24.38	24.38	0.00	0.00	0.00

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000021	0.00000051	0.00000051	0.25	0.00	0.00

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
0.25	0.25	0.25

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-1				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	
Width of sections	=	1000	[mm]
Depth of sections	=	100	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	50	[mm]

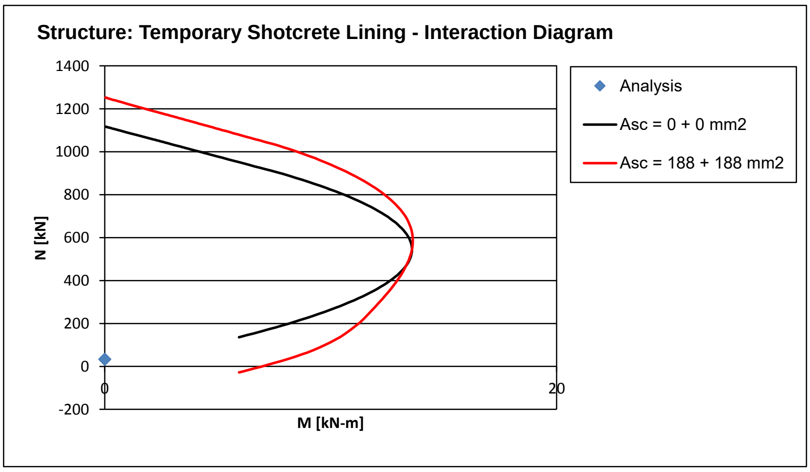
Load factor for N	1.35
Load factor for M	1

ANALYSIS

Location	N	M	N/bh	M/bh^2	To account for Load Factors N	M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	24.38	0.00	0.33	0.00	32.92	0.00
Main Tunnel - Bench	24.38	0.00	0.33	0.00	32.92	0.00
Main Tunnel - Invert	24.38	0.00	0.33	0.00	32.92	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for ...

	Reinforcement As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.19	0
Curve 3	0	188	0	0.19



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-1				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
24.38	24.38	24.38	0.00	0.00	0.00

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	0.000	0	0.000	0

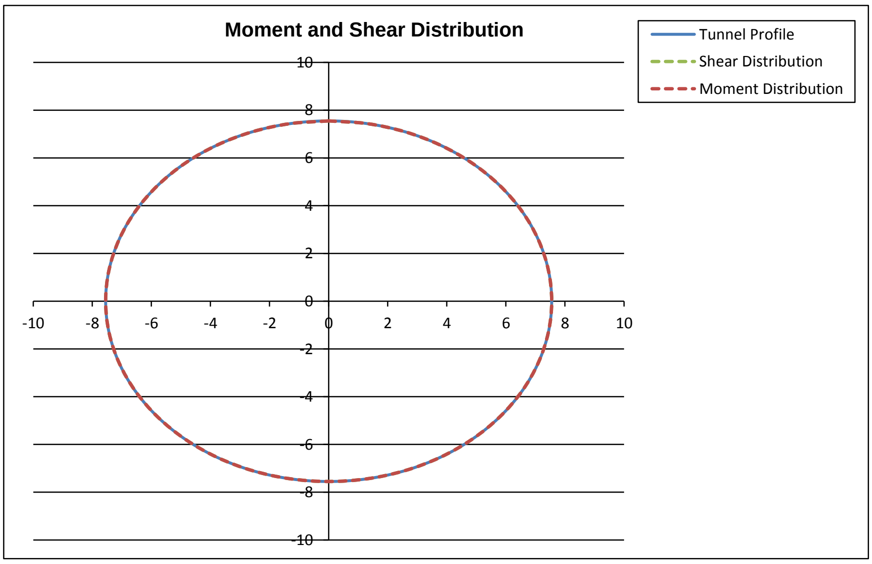
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.55 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
10	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
20	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
30	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
40	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
50	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
60	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
70	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
80	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
90	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
100	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
110	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
120	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
130	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
140	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
150	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
160	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
170	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
180	0.00	0	376	0.75	0.39	0.00	O.K.	0.00



Analysis 2

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-2				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	200	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.7	[m]	
Overburden above tunnel axis	=	20.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	520.00	[kPa]	
Avg. unit weight including surcharge	=	26.00	[kN/m^3]	
Young's Modulus of ground	=	8000.00	[MPa]	
Poisson's ratio of ground	=	0.15		
Horizontal earth pressure coefficient	=	0.50		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.20	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00067	[m^4]	
Average tunnel radius	=	7.60	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
730452.8	41.06666667

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.027	0.062	0.000	80.74	61.744084	0.08

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
19.00	142.48	19.00	0.08	-0.08	0.08

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000108	0.00000261	0.00000254	0.42	0.34	0.33

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
0.76	0.08	0.76

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-2				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	

Width of sections	=	1000	[mm]
Depth of sections	=	200	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	150	[mm]

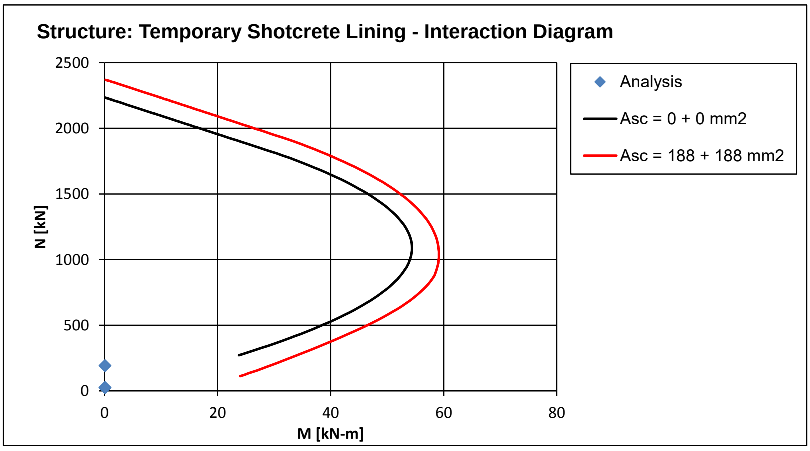
Load factor for N	1.35
Load factor for M	1

ANALYSIS

					To account for Load Factors	
Location	N	M	N/bh	M/bh^2	N	M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	19.00	0.08	0.13	0.00	25.65	0.08
Main Tunnel - Bench	142.48	-0.08	0.96	0.00	192.35	0.08
Main Tunnel - Invert	19.00	0.08	0.13	0.00	25.65	0.08
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for …

	Reinforcement			
	As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.09	0
Curve 3	0	188	0	0.09



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-2				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

GEOCONSULT

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
19.00	142.48	19.00	0.08	-0.08	0.08

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	-0.022	0	0.022	0

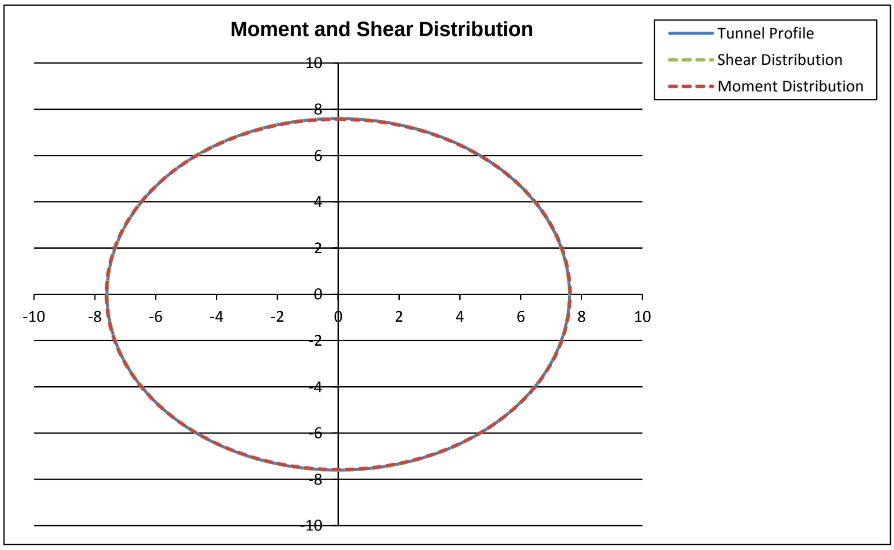
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.60 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.08	0	376	0.25	0.39	0.00	O.K.	0.00
10	0.08	-0.01	376	0.25	0.39	0.00	O.K.	0.02
20	0.06	-0.01	376	0.25	0.39	0.00	O.K.	0.03
30	0.04	-0.02	376	0.25	0.39	0.00	O.K.	0.04
40	0.01	-0.02	376	0.25	0.39	0.00	O.K.	0.05
50	-0.01	-0.02	376	0.25	0.39	0.00	O.K.	0.05
60	-0.04	-0.02	376	0.25	0.39	0.00	O.K.	0.04
70	-0.06	-0.01	376	0.25	0.39	0.00	O.K.	0.03
80	-0.08	-0.01	376	0.25	0.39	0.00	O.K.	0.02
90	-0.08	0	376	0.25	0.39	0.00	O.K.	0.00
100	-0.08	0.01	376	0.25	0.39	0.00	O.K.	0.02
110	-0.06	0.01	376	0.25	0.39	0.00	O.K.	0.03
120	-0.04	0.02	376	0.25	0.39	0.00	O.K.	0.04
130	-0.01	0.02	376	0.25	0.39	0.00	O.K.	0.05
140	0.01	0.02	376	0.25	0.39	0.00	O.K.	0.05
150	0.04	0.02	376	0.25	0.39	0.00	O.K.	0.04
160	0.06	0.01	376	0.25	0.39	0.00	O.K.	0.03
170	0.08	0.01	376	0.25	0.39	0.00	O.K.	0.02
180	0.08	0	376	0.25	0.39	0.00	O.K.	0.00



Analysis 3

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-3				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	100	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.6	[m]	
Overburden above tunnel axis	=	200.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	1170.00	[kPa]	
Avg. unit weight including surcharge	=	5.85	[kN/m^3]	
Young's Modulus of ground	=	10000.00	[MPa]	
Poisson's ratio of ground	=	0.20		
Horizontal earth pressure coefficient	=	1.00		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.10	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00008	[m^4]	
Average tunnel radius	=	7.55	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
7023616.0	101.3333333

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.012	0.025	0.000	103.38	0.000000	0.00

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
103.38	103.38	103.38	0.00	0.00	0.00

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000090	0.00000199	0.00000197	1.05	0.00	0.00

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
1.05	1.05	1.05

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-3				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	
Width of sections	=	1000	[mm]
Depth of sections	=	100	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	50	[mm]

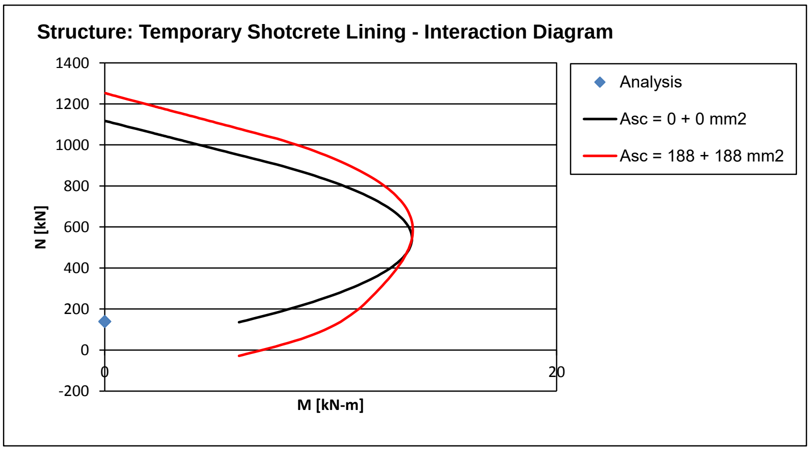
Load factor for N	1.35
Load factor for M	1

ANALYSIS

Location	N	M	N/bh	M/bh^2	To account for Load Factors N	To account for Load Factors M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	103.38	0.00	1.40	0.00	139.57	0.00
Main Tunnel - Bench	103.38	0.00	1.40	0.00	139.57	0.00
Main Tunnel - Invert	103.38	0.00	1.40	0.00	139.57	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for …

	Reinforcement			
	As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.19	0
Curve 3	0	188	0	0.19



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo

Tunnel:	**Tunnel 1 to 6**
Object:	**RMT-3**
Constr. Stage	**Final Stage / Primary Lining**
Chainage:	**High Overburden**

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
103.38	103.38	103.38	0.00	0.00	0.00

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	0.000	0	0.000	0

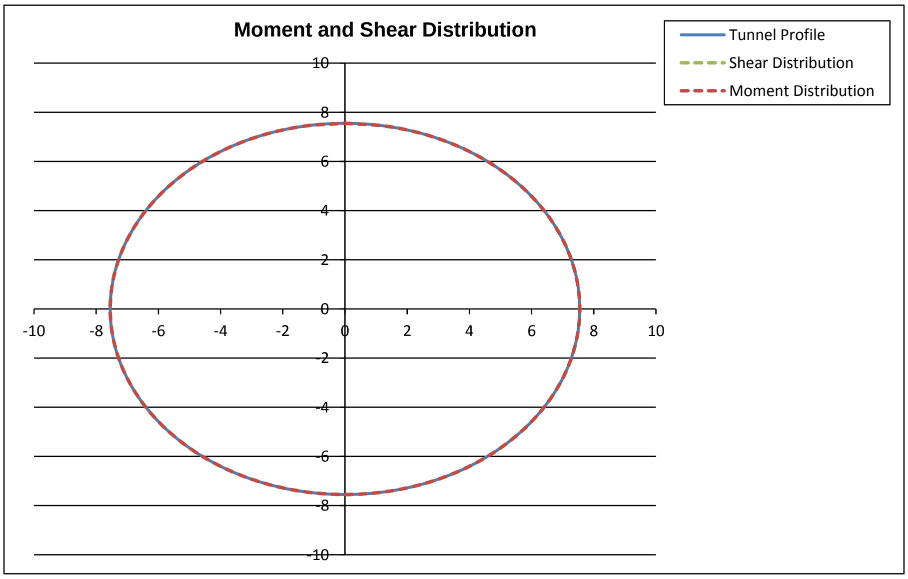
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.55 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
10	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
20	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
30	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
40	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
50	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
60	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
70	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
80	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
90	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
100	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
110	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
120	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
130	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
140	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
150	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
160	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
170	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
180	0.00	0	376	0.75	0.39	0.00	O.K.	0.00



Analysis 4

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-4				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	200	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.7	[m]	
Overburden above tunnel axis	=	20.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	520.00	[kPa]	
Avg. unit weight including surcharge	=	26.00	[kN/m^3]	
Young's Modulus of ground	=	1900.00	[MPa]	
Poisson's ratio of ground	=	0.20		
Horizontal earth pressure coefficient	=	0.50		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.20	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00067	[m^4]	
Average tunnel radius	=	7.60	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
173482.5	9.753333333

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.110	0.205	0.000	324.72	202.649624	0.32

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
122.07	527.37	122.07	0.32	-0.32	0.32

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000433	0.00001010	0.00000910	1.69	1.31	1.18

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
3.00	0.38	3.00

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-4				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	

Width of sections	=	1000	[mm]
Depth of sections	=	200	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	150	[mm]

Load factor for N	1.35
Load factor for M	1

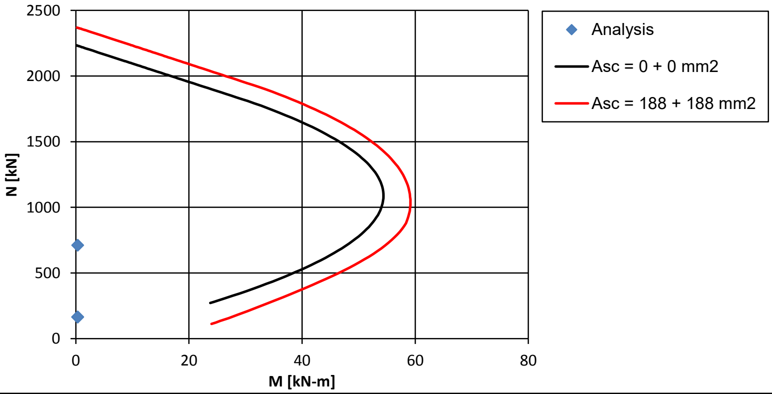
ANALYSIS

					To account for Load Factors	
Location	N	M	N/bh	M/bh^2	N	M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	122.07	0.32	0.82	0.01	164.80	0.32
Main Tunnel - Bench	527.37	-0.32	3.56	0.01	711.95	0.32
Main Tunnel - Invert	122.07	0.32	0.82	0.01	164.80	0.32
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for …

	Reinforcement			
	As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.09	0
Curve 3	0	188	0	0.09

Structure: Temporary Shotcrete Lining - Interaction Diagram



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-4				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
122.07	527.37	122.07	0.32	-0.32	0.32

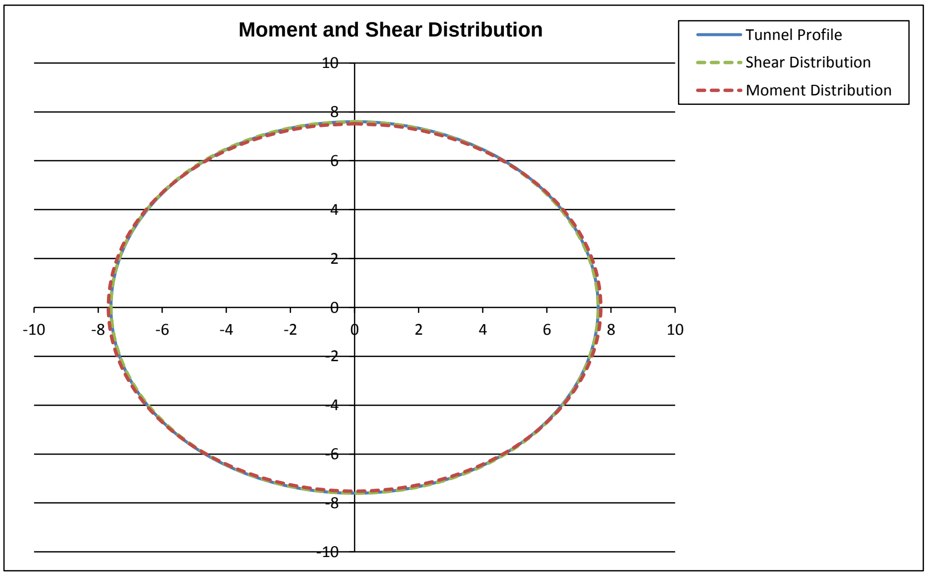
Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	-0.085	0	0.085	0

Distribution of Bending Moments and Shear Forces

Average Tunnel Radius	=	7.60	m
Load Factor	=	1.35	

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.32	0	376	0.25	0.39	0.00	O.K.	0.00
10	0.30	-0.03	376	0.25	0.39	0.00	O.K.	0.07
20	0.25	-0.05	376	0.25	0.39	0.00	O.K.	0.13
30	0.16	-0.07	376	0.25	0.39	0.00	O.K.	0.17
40	0.06	-0.08	376	0.25	0.39	0.00	O.K.	0.19
50	-0.06	-0.08	376	0.25	0.39	0.00	O.K.	0.19
60	-0.16	-0.07	376	0.25	0.39	0.00	O.K.	0.17
70	-0.25	-0.05	376	0.25	0.39	0.00	O.K.	0.13
80	-0.30	-0.03	376	0.25	0.39	0.00	O.K.	0.07
90	-0.32	0	376	0.25	0.39	0.00	O.K.	0.00
100	-0.30	0.03	376	0.25	0.39	0.00	O.K.	0.07
110	-0.25	0.05	376	0.25	0.39	0.00	O.K.	0.13
120	-0.16	0.07	376	0.25	0.39	0.00	O.K.	0.17
130	-0.06	0.08	376	0.25	0.39	0.00	O.K.	0.19
140	0.06	0.08	376	0.25	0.39	0.00	O.K.	0.19
150	0.16	0.07	376	0.25	0.39	0.00	O.K.	0.17
160	0.25	0.05	376	0.25	0.39	0.00	O.K.	0.13
170	0.30	0.03	376	0.25	0.39	0.00	O.K.	0.07
180	0.32	0	376	0.25	0.39	0.00	O.K.	0.00



Analysis 5

Project:	**Feasibility for ShiradiGhat Bypass**				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	**Tunnel 1 to 6**				
Object:	**RMT-5a**				
Constr. Stage	**Final Stage / Primary Lining**				
Chainage:	**High Overburden**				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	300	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.8	[m]	
Overburden above tunnel axis	=	190.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	1170.00	[kPa]	
Avg. unit weight including surcharge	=	6.16	[kN/m^3]	
Young's Modulus of ground	=	750.00	[MPa]	
Poisson's ratio of ground	=	0.30		
Horizontal earth pressure coefficient	=	1.00		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.30	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00225	[m^4]	
Average tunnel radius	=	7.65	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
21091.2	2.6

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.333	0.409	0.000	2983.38	0.000000	0.00

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
2983.38	2983.38	2983.38	0.00	0.00	0.00

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000901	0.00002211	0.00001659	10.55	0.00	0.00

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
10.55	10.55	10.55

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo

GEOCONSULT

Tunnel:	**Tunnel 1 to 6**
Object:	**RMT-5a**
Constr. Stage	**Final Stage / Primary Lining**
Chainage:	**High Overburden**

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm²]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm²]

Concrete

Characteristic strength of concrete	=	25	[N/mm²]
Partial safety factor for concrete	=	1.500	
Width of sections	=	1000	[mm]
Depth of sections	=	300	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	250	[mm]

Load factor for N	1.35
Load factor for M	1

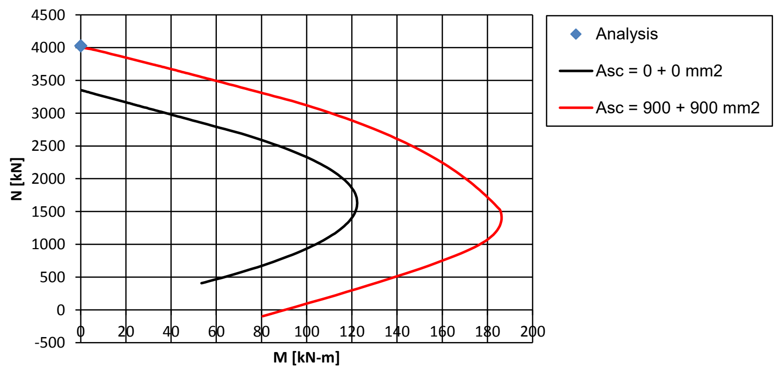
ANALYSIS

					To account for Load Factors	
Location	N	M	N/bh	M/bh²	N	M
	[kN]	[kNm]	[N/mm²]	[N/mm²]	[kN]	[kNm]
Main Tunnel - Crown	2983.38	0.00	13.43	0.00	4027.56	0.00
Main Tunnel - Bench	2983.38	0.00	13.43	0.00	4027.56	0.00
Main Tunnel - Invert	2983.38	0.00	13.43	0.00	4027.56	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for ...

	Reinforcement			
	As'	As	As'	As
	[mm²]	[mm²]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	900	0	0.30	0
Curve 3	0	900	0	0.30

Structure: Temporary Shotcrete Lining - Interaction Diagram



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-5a				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
2983.38	2983.38	2983.38	0.00	0.00	0.00

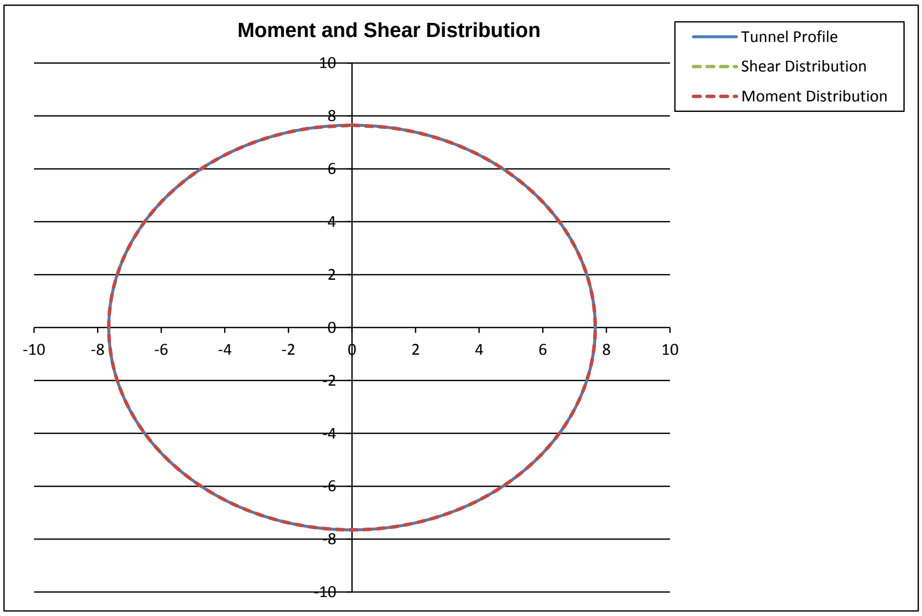
Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	0.000	0	0.000	0

Distribution of Bending Moments and Shear Forces

Average Tunnel Radius	=	7.65	m
Load Factor	=	1.35	

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.00	0	376	0.15	0.39	0.00	O.K.	0.00
10	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
20	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
30	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
40	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
50	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
60	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
70	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
80	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
90	0.00	0	376	0.15	0.39	0.00	O.K.	0.00
100	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
110	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
120	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
130	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
140	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
150	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
160	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
170	0.00	0.00	376	0.15	0.39	0.00	O.K.	0.00
180	0.00	0	376	0.15	0.39	0.00	O.K.	0.00



Analysis 6

Project:	**Feasibility for ShiradiGhat Bypass**				GEOCONSULT
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	**Tunnel 1 to 6**				
Object:	**RMT-5b**				
Constr. Stage	**Final Stage / Primary Lining**				
Chainage:	**Low Overburden**				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	300	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.8	[m]	
Overburden above tunnel axis	=	20.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	520.00	[kPa]	
Avg. unit weight including surcharge	=	26.00	[kN/m^3]	
Young's Modulus of ground	=	750.00	[MPa]	
Poisson's ratio of ground	=	0.30		
Horizontal earth pressure coefficient	=	0.50		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.30	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00225	[m^4]	
Average tunnel radius	=	7.65	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
21091.2	2.6

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.333	0.409	0.000	994.46	407.059633	2.30

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
587.40	1401.52	587.40	2.30	-2.30	2.30

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000901	0.00002211	0.00001659	3.52	2.87	2.16

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
6.39	0.64	6.39

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-5b				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm²]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm²]

Concrete

Characteristic strength of concrete	=	25	[N/mm²]
Partial safety factor for concrete	=	1.500	
Width of sections	=	1000	[mm]
Depth of sections	=	400	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	350	[mm]

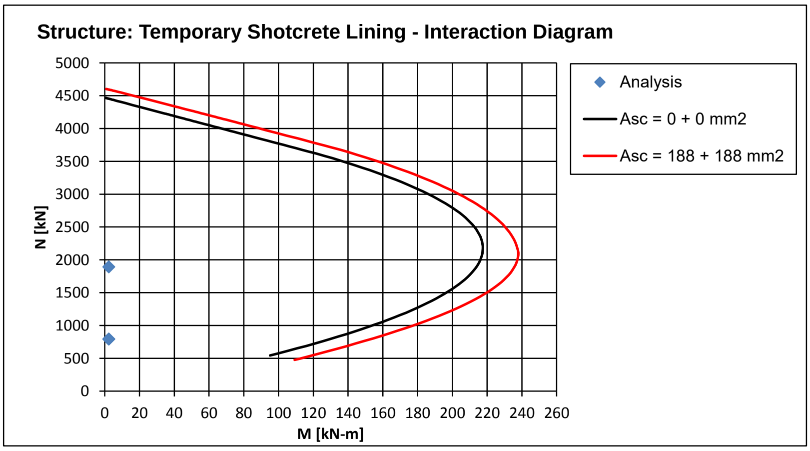
Load factor for N	1.35
Load factor for M	1

ANALYSIS

Location	N	M	N/bh	M/bh²	To account for Load Factors N	To account for Load Factors M
	[kN]	[kNm]	[N/mm²]	[N/mm²]	[kN]	[kNm]
Main Tunnel - Crown	587.40	2.30	1.98	0.01	792.99	2.30
Main Tunnel - Bench	1401.52	-2.30	4.73	0.01	1892.05	2.30
Main Tunnel - Invert	587.40	2.30	1.98	0.01	792.99	2.30
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for ...

	Reinforcement			
	As'	As	As'	As
	[mm²]	[mm²]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.05	0
Curve 3	0	188	0	0.05



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-5b				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
587.40	1401.52	587.40	2.30	-2.30	2.30

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	-0.601	0	0.601	0

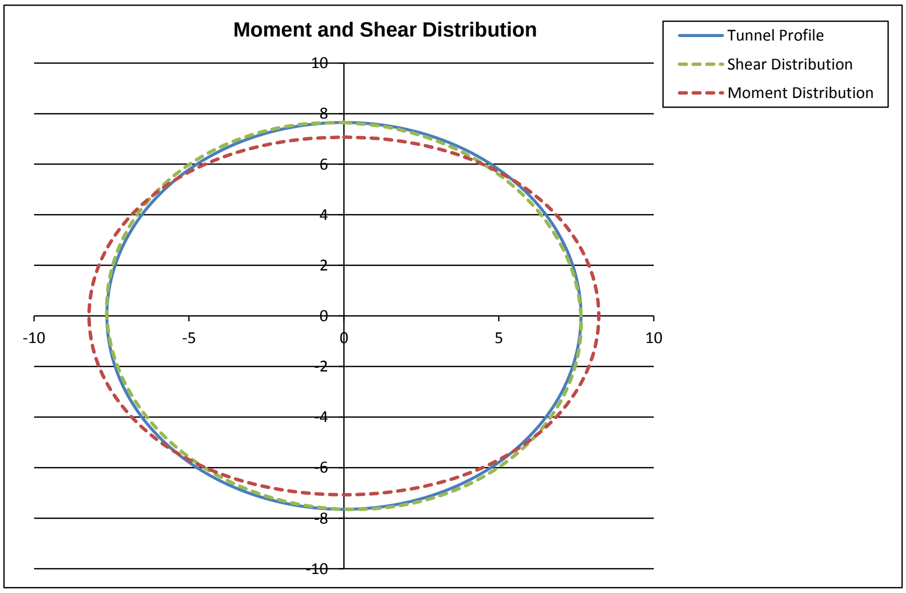
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.65 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	2.30	0	376	0.11	0.39	0.00	O.K.	0.00
10	2.16	-0.21	376	0.11	0.39	0.00	O.K.	0.20
20	1.76	-0.39	376	0.11	0.39	0.00	O.K.	0.38
30	1.15	-0.52	376	0.11	0.39	0.00	O.K.	0.51
40	0.40	-0.59	376	0.11	0.39	0.00	O.K.	0.58
50	-0.40	-0.59	376	0.11	0.39	0.00	O.K.	0.58
60	-1.15	-0.52	376	0.11	0.39	0.00	O.K.	0.51
70	-1.76	-0.39	376	0.11	0.39	0.00	O.K.	0.38
80	-2.16	-0.21	376	0.11	0.39	0.00	O.K.	0.20
90	-2.30	0	376	0.11	0.39	0.00	O.K.	0.00
100	-2.16	0.21	376	0.11	0.39	0.00	O.K.	0.20
110	-1.76	0.39	376	0.11	0.39	0.00	O.K.	0.38
120	-1.15	0.52	376	0.11	0.39	0.00	O.K.	0.51
130	-0.40	0.59	376	0.11	0.39	0.00	O.K.	0.58
140	0.40	0.59	376	0.11	0.39	0.00	O.K.	0.58
150	1.15	0.52	376	0.11	0.39	0.00	O.K.	0.51
160	1.76	0.39	376	0.11	0.39	0.00	O.K.	0.38
170	2.16	0.21	376	0.11	0.39	0.00	O.K.	0.20
180	2.30	0	376	0.11	0.39	0.00	O.K.	0.00



Analysis 7

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-7a				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

GEOCONSULT

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	100	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.6	[m]	
Overburden above tunnel axis	=	80.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	1170.00	[kPa]	
Avg. unit weight including surcharge	=	14.63	[kN/m^3]	
Young's Modulus of ground	=	18000.00	[MPa]	
Poisson's ratio of ground	=	0.20		
Horizontal earth pressure coefficient	=	1.00		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.10	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00008	[m^4]	
Average tunnel radius	=	7.55	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
12642508.8	182.4

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.007	0.014	0.000	57.74	0.000000	0.00

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
57.74	57.74	57.74	0.00	0.00	0.00

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000050	0.00000111	0.00000110	0.59	0.00	0.00

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
0.59	0.59	0.59

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-7a				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm²]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm²]

Concrete

Characteristic strength of concrete	=	25	[N/mm²]
Partial safety factor for concrete	=	1.500	
Width of sections	=	1000	[mm]
Depth of sections	=	100	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	50	[mm]

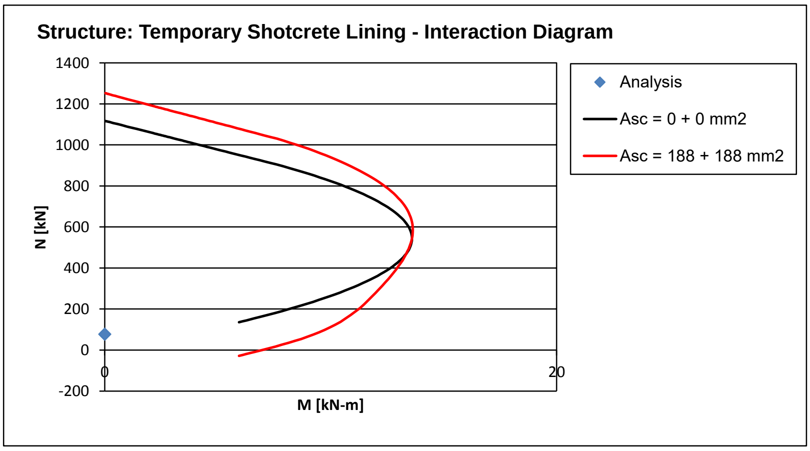
Load factor for N	1.35
Load factor for M	1

ANALYSIS

Location	N	M	N/bh	M/bh²	To account for Load Factors N	To account for Load Factors M
	[kN]	[kNm]	[N/mm²]	[N/mm²]	[kN]	[kNm]
Main Tunnel - Crown	57.74	0.00	0.78	0.00	77.94	0.00
Main Tunnel - Bench	57.74	0.00	0.78	0.00	77.94	0.00
Main Tunnel - Invert	57.74	0.00	0.78	0.00	77.94	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for ...

	Reinforcement			
	As'	As	As'	As
	[mm²]	[mm²]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.19	0
Curve 3	0	188	0	0.19



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-7a				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	High Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
57.74	57.74	57.74	0.00	0.00	0.00

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	0.000	0	0.000	0

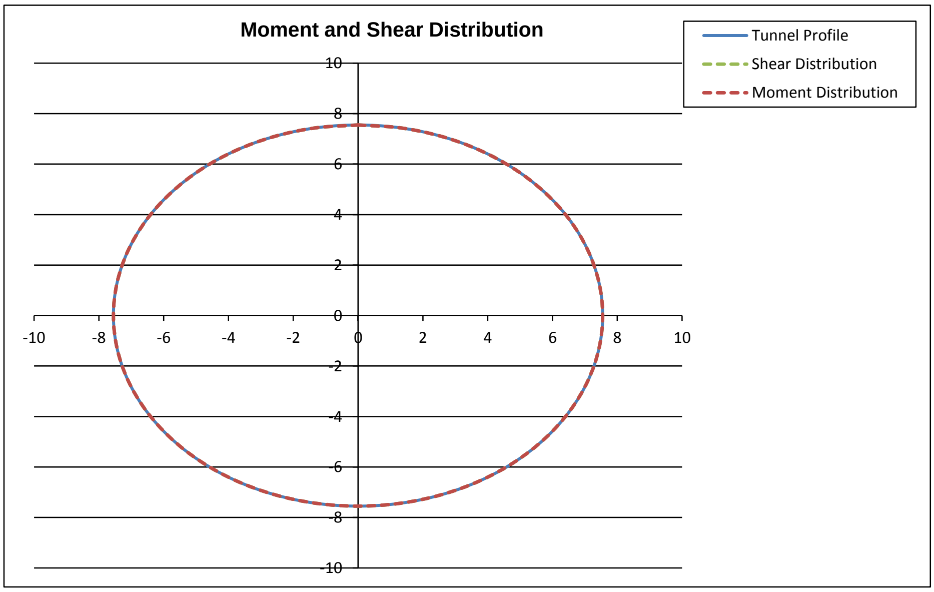
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.55 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
10	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
20	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
30	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
40	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
50	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
60	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
70	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
80	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
90	0.00	0	376	0.75	0.39	0.00	O.K.	0.00
100	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
110	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
120	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
130	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
140	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
150	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
160	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
170	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.00
180	0.00	0	376	0.75	0.39	0.00	O.K.	0.00



Analysis 8

Project:	**Feasibility for ShiradiGhat Bypass**				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	**Tunnel 1 to 6**				
Object:	**RMT-7b**				
Constr. Stage	**Final Stage / Primary Lining**				
Chainage:	**Low Overburden**				

LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	100	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.6	[m]	
Overburden above tunnel axis	=	30.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	780.00	[kPa]	
Avg. unit weight including surcharge	=	26.00	[kN/m^3]	
Young's Modulus of ground	=	18000.00	[MPa]	
Poisson's ratio of ground	=	0.20		
Horizontal earth pressure coefficient	=	0.50		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.10	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00008	[m^4]	
Average tunnel radius	=	7.55	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
12642508.8	182.4

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.007	0.014	0.000	28.87	20.951425	0.01

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
7.92	49.82	7.92	0.01	-0.01	0.01

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000050	0.00000111	0.00000110	0.29	0.22	0.22

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
0.51	0.08	0.51

NOTE: The above calculation is based on the geometry of a full circle.

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-7b				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	

Width of sections	=	1000	[mm]
Depth of sections	=	100	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	50	[mm]

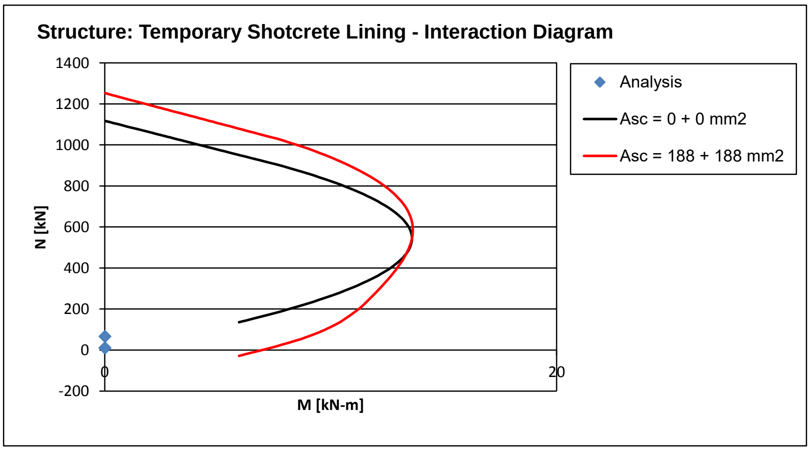
Load factor for N	1.35
Load factor for M	1

ANALYSIS

					To account for Load Factors	
Location	N	M	N/bh	M/bh^2	N	M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	7.92	0.01	0.11	0.00	10.69	0.01
Main Tunnel - Bench	49.82	-0.01	0.67	0.00	67.26	0.01
Main Tunnel - Invert	7.92	0.01	0.11	0.00	10.69	0.01
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for ...

	Reinforcement			
	As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.19	0
Curve 3	0	188	0	0.19



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-7b				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
7.92	49.82	7.92	0.01	-0.01	0.01

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	-0.002	0	0.002	0

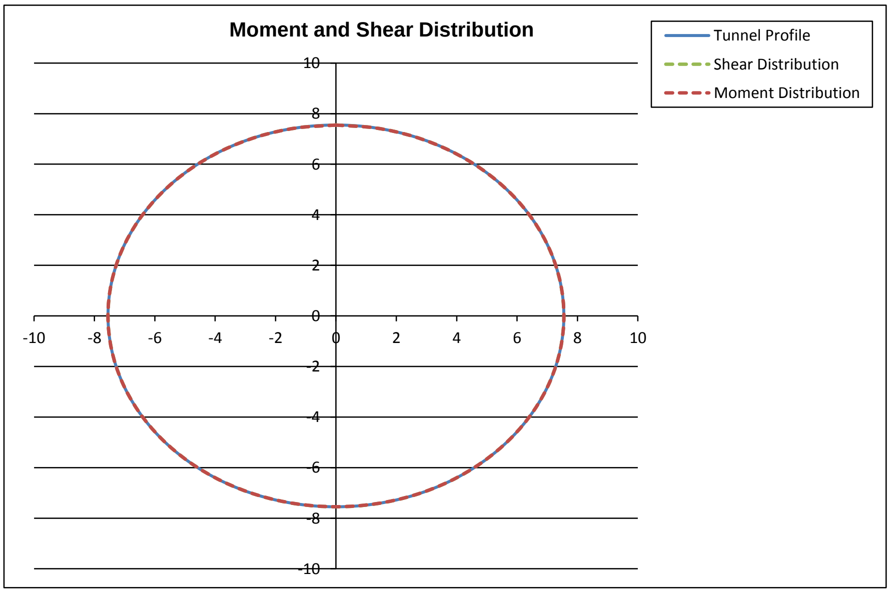
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.55 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.01	0	376	0.75	0.39	0.00	O.K.	0.00
10	0.01	0.00	376	0.75	0.39	0.00	O.K.	0.00
20	0.01	0.00	376	0.75	0.39	0.00	O.K.	0.01
30	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
40	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
50	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
60	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
70	-0.01	0.00	376	0.75	0.39	0.00	O.K.	0.01
80	-0.01	0.00	376	0.75	0.39	0.00	O.K.	0.00
90	-0.01	0	376	0.75	0.39	0.00	O.K.	0.00
100	-0.01	0.00	376	0.75	0.39	0.00	O.K.	0.00
110	-0.01	0.00	376	0.75	0.39	0.00	O.K.	0.01
120	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
130	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
140	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
150	0.00	0.00	376	0.75	0.39	0.00	O.K.	0.01
160	0.01	0.00	376	0.75	0.39	0.00	O.K.	0.01
170	0.01	0.00	376	0.75	0.39	0.00	O.K.	0.00
180	0.01	0	376	0.75	0.39	0.00	O.K.	0.00



Analysis 9

Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-8				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

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LINING CALCULATION ACCORDING TO H.DUDDECK / J.ERDMANN

Structure: *Temporary Shotcrete Lining*

Lining Thickness	=	300	[mm]	
Lining Stiffness	=	5.000	[MPa]	[J-II Class - 24 Hr Strength]
Radius	=	7.500	[m]	
Outer Radius of tunnel	=	7.8	[m]	
Overburden above tunnel axis	=	20.000	[m]	
Surcharge	=	0.00	[kPa]	
Unit Weight	=	26.00	[kN/m^3]	
Total vertical stress at tunnel axis	=	520.00	[kPa]	
Avg. unit weight including surcharge	=	26.00	[kN/m^3]	
Young's Modulus of ground	=	4500.00	[MPa]	
Poisson's ratio of ground	=	0.40		
Horizontal earth pressure coefficient	=	0.50		
Young's Modulus of concrete lining	=	7500.00	[MPa]	
Cross-sectional area of Lining	=	0.30	[m^2]	b = 1.00 [m]
Moment of Inertia	=	0.00225	[m^4]	
Average tunnel radius	=	7.65	[m]	

Stiffness ratio coefficients

Ratio of soil stiffness over the compressibility stiffness of the lining	Ratio of soil stiffness over the bending stiffness of the lining
126547.2	15.6

Shear bond between lining and ground, basic specific values for sectional forces					
n0	n2	m2	N0	N2	M2
-	-	-	[kN]	[kN]	[kN-m]
0.082	0.105	0.000	245.70	104.391432	0.35

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
141.31	350.09	141.31	0.35	-0.35	0.35

Basic Specific values for lining deformations			Basic values for lining deformations		
w0	w2	x2	W0	W2	V2
[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[m.kN^{-1}.s^2]	[mm]	[mm]	[mm]
0.00000223	0.00000335	0.00000309	0.87	0.43	0.40

Shear bond between lining and ground, Lining deformations		
rdc	rdb	rdi
[mm]	[mm]	[mm]
1.30	0.43	1.30

NOTE: The above calculation is based on the geometry of a full circle.

Project:	**Feasibility for ShiradiGhat Bypass**			
Job No.:	I6060	Date: 03-12-2015	Made by:	GMo
Tunnel:	**Tunnel 1 to 6**			
Object:	**RMT-8**			
Constr. Stage	**Final Stage / Primary Lining**			
Chainage:	**Low Overburden**			

Structure: *Temporary Shotcrete Lining*

Steel

Characteristic strength of steel	=	500	[N/mm^2]
Partial safety factor for steel	=	1.15	
E-modulus of steel	=	200000	[N/mm^2]

Concrete

Characteristic strength of concrete	=	25	[N/mm^2]
Partial safety factor for concrete	=	1.500	

Width of sections	=	1000	[mm]
Depth of sections	=	300	[mm]
Distance from compression / tension face to	=	50	[mm]
Effective depth of sections	=	250	[mm]

Load factor for N	1.35
Load factor for M	1

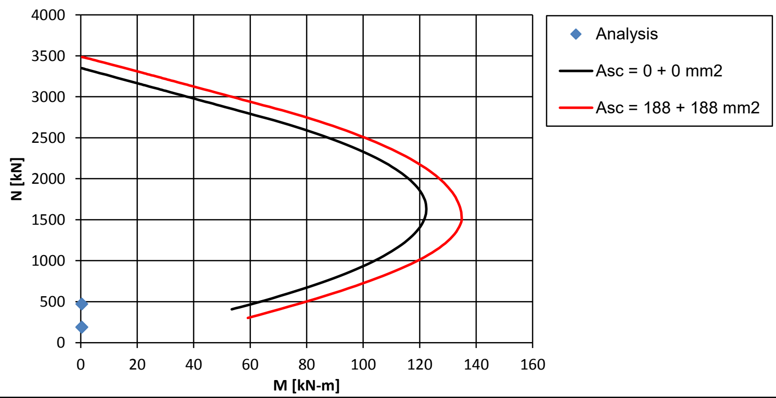
ANALYSIS

					To account for Load Factors	
Location	N	M	N/bh	M/bh^2	N	M
	[kN]	[kNm]	[N/mm^2]	[N/mm^2]	[kN]	[kNm]
Main Tunnel - Crown	141.31	0.35	0.64	0.00	190.76	0.35
Main Tunnel - Bench	350.09	-0.35	1.58	0.00	472.62	0.35
Main Tunnel - Invert	141.31	0.35	0.64	0.00	190.76	0.35
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

Draw Curves for …

	Reinforcement			
	As'	As	As'	As
	[mm^2]	[mm^2]	[%]	[%]
Curve 1	0	0	0	0
Curve 2	188	0	0.06	0
Curve 3	0	188	0	0.06

Structure: Temporary Shotcrete Lining - Interaction Diagram



Project:	Feasibility for ShiradiGhat Bypass				
Job No.:	I6060	Date:	03-12-2015	Made by:	GMo
Tunnel:	Tunnel 1 to 6				
Object:	RMT-8				
Constr. Stage	Final Stage / Primary Lining				
Chainage:	Low Overburden				

LINING CALCULATIONS - DISTRIBUTION OF MOMENTS AND SHEAR FORCES

Structure: *Temporary Shotcrete Lining*

Distribution of Shear Forces

Normal Forces due to earth pressure			Bending Moments due to earth pressure		
Crown	Bench	Invert	Crown	Bench	Invert
[kN]	[kN]	[kN]	[kN-m]	[kN-m]	[kN-m]
141.31	350.09	141.31	0.35	-0.35	0.35

Shear Forces (V) at sections				
Crown 0^0	45^o	Bench 90^0	135^o	Invert 180^0
0	-0.091	0	0.091	0

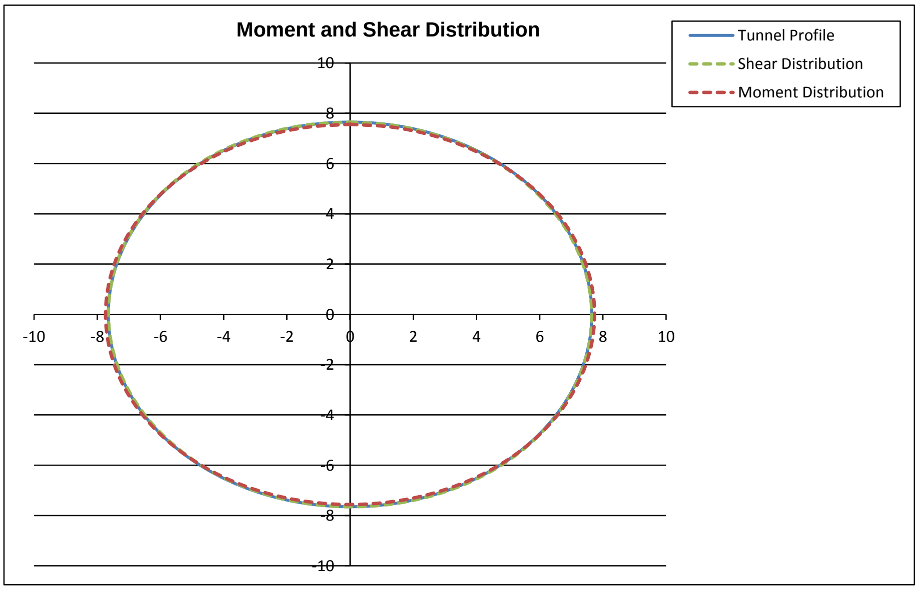
Distribution of Bending Moments and Shear Forces

Average Tunnel Radius = 7.65 m

Load Factor = 1.35

As = 376

Location	M	V	As	100 As / bd	Vc	Actual V	Check	Utilisation
[^{0}]	[kN-m/m]	[kN/m]	[mm^2]	[-]	[N/mm^2]	[N/mm^2]		[%]
0	0.35	0	376	0.15	0.39	0.00	O.K.	0.00
10	0.33	-0.03	376	0.15	0.39	0.00	O.K.	0.04
20	0.27	-0.06	376	0.15	0.39	0.00	O.K.	0.08
30	0.17	-0.08	376	0.15	0.39	0.00	O.K.	0.11
40	0.06	-0.09	376	0.15	0.39	0.00	O.K.	0.12
50	-0.06	-0.09	376	0.15	0.39	0.00	O.K.	0.12
60	-0.17	-0.08	376	0.15	0.39	0.00	O.K.	0.11
70	-0.27	-0.06	376	0.15	0.39	0.00	O.K.	0.08
80	-0.33	-0.03	376	0.15	0.39	0.00	O.K.	0.04
90	-0.35	0	376	0.15	0.39	0.00	O.K.	0.00
100	-0.33	0.03	376	0.15	0.39	0.00	O.K.	0.04
110	-0.27	0.06	376	0.15	0.39	0.00	O.K.	0.08
120	-0.17	0.08	376	0.15	0.39	0.00	O.K.	0.11
130	-0.06	0.09	376	0.15	0.39	0.00	O.K.	0.12
140	0.06	0.09	376	0.15	0.39	0.00	O.K.	0.12
150	0.17	0.08	376	0.15	0.39	0.00	O.K.	0.11
160	0.27	0.06	376	0.15	0.39	0.00	O.K.	0.08
170	0.33	0.03	376	0.15	0.39	0.00	O.K.	0.04
180	0.35	0	376	0.15	0.39	0.00	O.K.	0.00



Prepared for:

सड़क परिवहन और राजमार्ग मंत्रालय
MINISTRY OF ROAD TRANSPORT & HIGHWAYS
Government of India

Karnataka
Public Works, Ports & Inland Water Transport Department

Project:

Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"

Subject:

KD-6 - Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume - II : Design Report

Part II: Design of Tunnels (D)- Structural Analysis of Inner Lining and Design

Prepared by:

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Rev.	Date	Description	Originator	Checked	Approved
00	17.12.2015	First Issue	DSu	ADh	FKr

Document No:	I6060-REP-09-KD6-DDPR-Vol II-DR-Part II_D	Revision:	00
GCI File Path	W:\PROJECTS\I6000\60\REPORTS\R09-KD-6-Reports\I6060-REP-09-KD6-DDPR-Vol II-DR-Part II_D\I6060-REP-09-KD6-DDPR-Vol II-DR-Part II_D.docx		

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Revision History

Rev.	Date	Long Description

Table of Contents

Introduction

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorporation of Client's observations on earlier submitted "KD5: Kucha Draft Detailed Project Report (KDDPR)" vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels:

- *Proposed Tunnel Design and Standards*
- *Technical Note on Tunnel Section and System*

- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures :

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report:

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

(vi) Volume - V Technical Specifications :

(vii) Volume - VI Rate Analysis :

(viii) Volume - VII Cost Estimates :

(ix) Volume - VIII Bill of Quantities :

(x) Volume - IX Drawings (A3 Size) :

a. *Location map*
b. *Layout plans*
c. *General Drawings*
d. *Plan and Profile of Refined Alignment "A"*
e. *Typical Cross Sections showing Pavement details of Cut & Fill Section*
f. *Typical Cross Sections of Tunnel*
g. *Typical Cross Sections of Bridges*
h. *Tunnels- General Arrangement Plan and L-Sections (L&R)*
i. *Viaducts – General Arrangement Plan and L-Section*
j. *Cut & Fill and Viaducts – General Arrangement Plan and L-Section*
k. *GAD for proposed RoB at Railway km 54+650*
l. *Standard Drawings*
m. *Miscellaneous Drawings*
n. *Indicative Land Acquisition Plans*
o. *Detailed Cross Sections @ 100m interval*

(xi) Volume - X Civil Work Contract Agreement :
(xii) Volume - XI Project Clearances :

Volume - II: Design Report
Part- II: Design of Tunnels
(D): STRUCTURAL ANALYSIS OF INNER LINING AND DESIGN

1 GENERAL

This Volume - II: Design Report- Part II: Design of Tunnels, (D) Proposed Pavement Design, a part of “KD 6: Draft Detailed Project Report for Final Approved alignment for Bypass (DDPR)” is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report- Part II: Design of Tunnels, (D) Proposed Pavement Design of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

This report covers preliminary analysis and design of the inner (permanent) concrete lining and contains:

- Construction Aspects
- Geotechnical Conditions and Design Parameters
- Calculation Method and Selected Calculation Sections
- Load Cases and Load Combinations
- Structural and Reinforcement Details. (if and where required)

A summary of calculation results and reinforcement design, if and where required, is presented in this report.

2 REFERENCES

[1] I6060-REP-05-KD4-PPR-Vol II-DR-A, KD 4-Field Report/Preliminary Progress Report/ Interim Progress Report: Part B: Preliminary Project Report Volume=II: Design Report

[2] I6060-REP-02-KD5-GIR-TUNNEL, Geotechnical report-Tunnel design

[3] Austrian Society for Geomechanics: Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation, 2010

[4] Indian Railway Standard Code of Practice for Plain, Reinforced and Pre-stressed Concrete Bridge [IRS-CBC]

[5] DIN 1045 – Concrete, reinforced and pressurized concrete structures

[6] IS 1893 (Part 1) – 2002, Criteria for Earthquake Resistant Design

[7] EN 1990 : Eurocode : Basis of structural design

[8] EN 1991, Eurocode 1: Actions on structures

[9] EN 1992, Eurocode 2: Design of concrete structures, Part 1-1: General rules and rules for buildings

[10] IS 456:2000 Plain and Reinforced Concrete (Fourth Revision)

[11] IS 1893(Part-1) : 2002 Criteria for earthquake resistant design of structures

[12] STAAD Pro , programme for statically calculation for Plane frame 2D analysis

[13] Seismic design and analysis of underground structures” by YMA Hashish, JJ Hook, Birger Schmidt and John I-Chiang Yao.

3 LINING TYPE AND GEOMETRY

The following Cross Section of Inner Lining will be used as described in Figure 1.

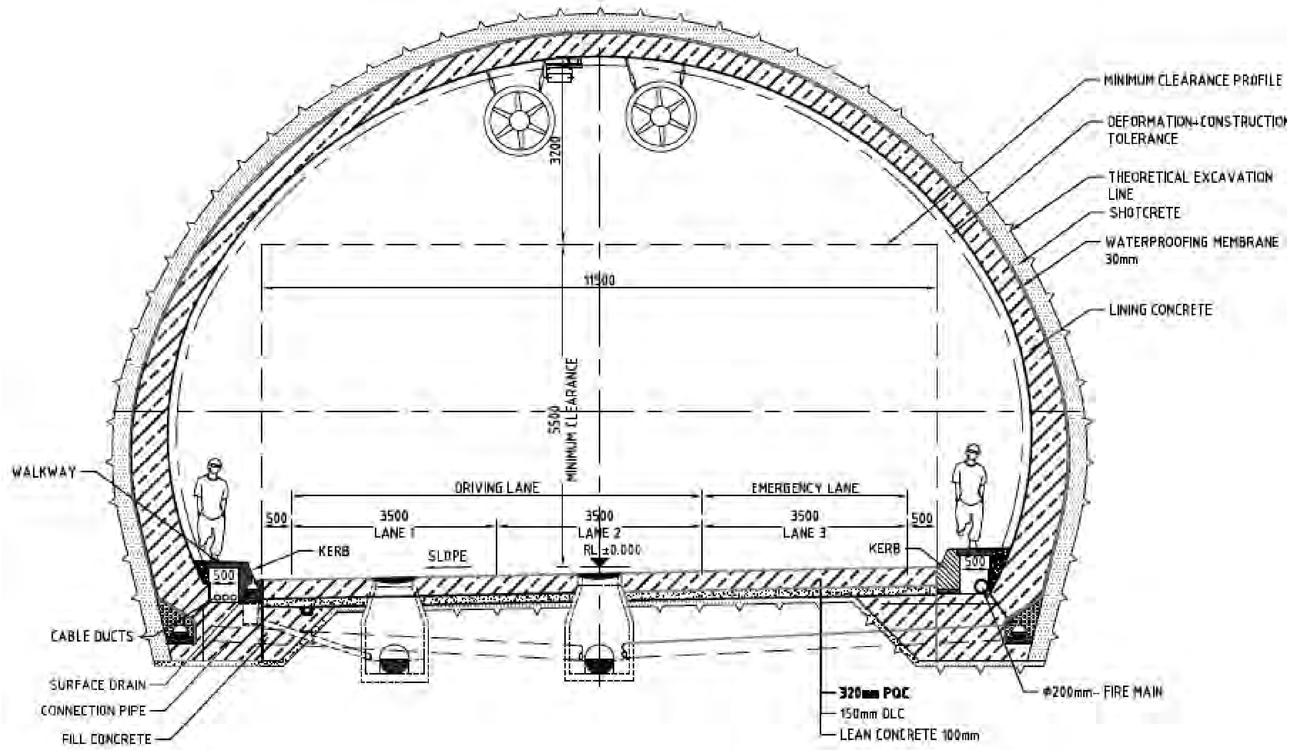


Figure 1: Tunnel Cross Section – Inner lining geometry

4 GEOTECHNICAL CONDITIONS AND SOIL PARAMETERS

4.1 Geological and geotechnical conditions

Geological study has been undertaken for the Shiradi Ghat bypass project as per requirements given in scope of work. Maps, literature and other relevant material have been gathered (and are being gathered) for this purpose. Reconnaissance study of the project area was also carried out in July 2015 by members of the Geoconsult Team for understanding the geological aspects of the project location. According to the information gathered from these studies, eight major rock mass types are determined in and around the area of interest. The details regarding these rock mass types are mentioned in Table 1**.**

4.2 Seismology

The project area is situated in region with low seismic activity. Following the seismic mapping as per Indian standard IS1893 (part1) – 2000, the project site is situated in seismic zone II.

Earthquake damage to subsurface structures is usually much less serious than to surface structures because damage decrease rapidly with increasing depth. However, an appropriate method will be selected and used to study earthquake influence on the safety of the surface and the structures.

4.3 Rock parameters

The following geotechnical parameters have been considered as given in Geotechnical Interpretation [2] .

Eight different types of Ground Types have been identified in the above report and which are shown in Table 1 **Geotechnical Input Parameters** [Note1]

Ground Type	Unit Weight	Angle of Friction [ϕ]	Cohesion [C]	Young Modulus[E]	Poisson's ratio [ν]
	kN/m3	[⁰]	MPa	GPa	---
RMT-1	26	43	4.50	41.0	0.15
RMT-2	26	37	4.00	8.0	0.15
RMT-3	26	29	4.00	10.0	0.20
RMT-4	26	25	2.00	1.9	0.2-0.25
RMT-5A	26	22	0.50	0.8	0.30
RMT-5B	26	22	0.50	0.8	0.30
RMT-7A	26	46	3.00	18.0	0.20
RMT-8	26	12-15	0.05-0.1	4.5	0.40

Table 1: **Geotechnical Input Parameters**

Note 1: The ground material parameters shall be verified during excavation works

5 MATERIALS

The relevant building materials which are concrete and reinforcement steel, confirms to the specifications given below.

5.1 Cast in place concrete

- Specified characteristic compressive strength f_{ck} = 35 N/mm^2 (Concrete Grade M35 according to IS 456:2000)
- Young's modulus: E = 29580 MPa
- Poisson's ratio: ν = 0.2
- Unit weight: γ = 25 kN/m^3

5.2 Reinforcement steel

The steel for structural reinforcement shall correspond to Fe 500 according to IS 1786-2008:

Young's modulus	E=200 Gpa
Yield strength	f_{yk}=500 MPa

6 CALCULATION METHOD AND GENERAL ASSUMPTIONS

6.1 Calculation of Cross Section

According to the defined lining types, geological conditions, overburden, etc the section as shown in Figure 1 is considered.

6.2 Calculation of Spring Constants

The lining is modeled as a beam bedded by springs. Multiple beam elements are created along centroidal axis of lining subtending angle of 5^0 to 10^0 representing linear 2D structure

Beam model spring constants are derived from modulus of sub grade reaction Ks, which is calculated from : $K_S = \frac{E}{(1+\nu)\times R}$, where:

E… Young's Modulus of soil/rock

ν… Poisson's Ratio of soil/rock mass

R…. Radius of Tunnel (with R ≤ 7 m)

The spring constant of a bedding spring representing a certain area A of sub grade is derived as: $C_r = K_S \times A$

The tangential spring constants are set as 1% of normal (radial) spring constants:

Kt = 0.01× Ks

The bending stiffness of the structural element is equal to E_c*I_g. The moment of inertia I_g is based on the modulus of inertia of gross concrete section about centroidal axis, neglecting reinforcement.

6.3 Analysis Method

A two-dimensional Plane Frame Analyses are performed using the computer program from STAAD Pro. V8i SS5. A near realistic 2Dmodel using beams bedded by radial and tangential springs has been created and loads have been applied using STAAD command. Springs have been generated by using Staad command and reference can be made to STAAD manual for further details.

The bedding is modeled in such a way that the parts of the cross-sections where inward deformation occurs, i.e. where the springs would be subject to tensions, are neglected. The material behavior of ground and lining is generally assumed as being elastic.

After applying all the forces on the frame model in STAAD Pro as detailed in Section 7. The loads are combined as per the prescribed combination of action and the Members are checked for the load combiation for for Ultimate Limit State (ULS) and Serviceability Limit State (SLS).

The Normal force, Bending moment and shear force for all members are taken from the Staad Pro and designed as per ,"*Section 12 - Plain and Lightly Reinforced Concrete Structures*" of EN1992-1-1:2004(E) suitably. The calculations can be found in the **Appendix 1**.

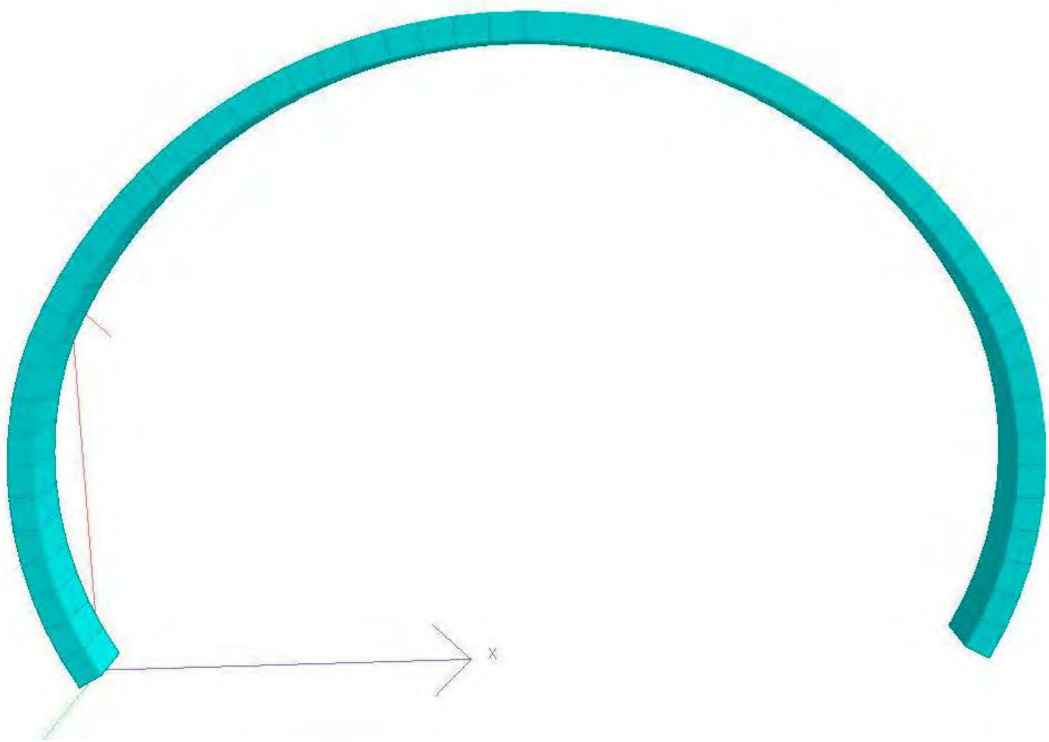


Figure 2: 3D Rendered View of Model

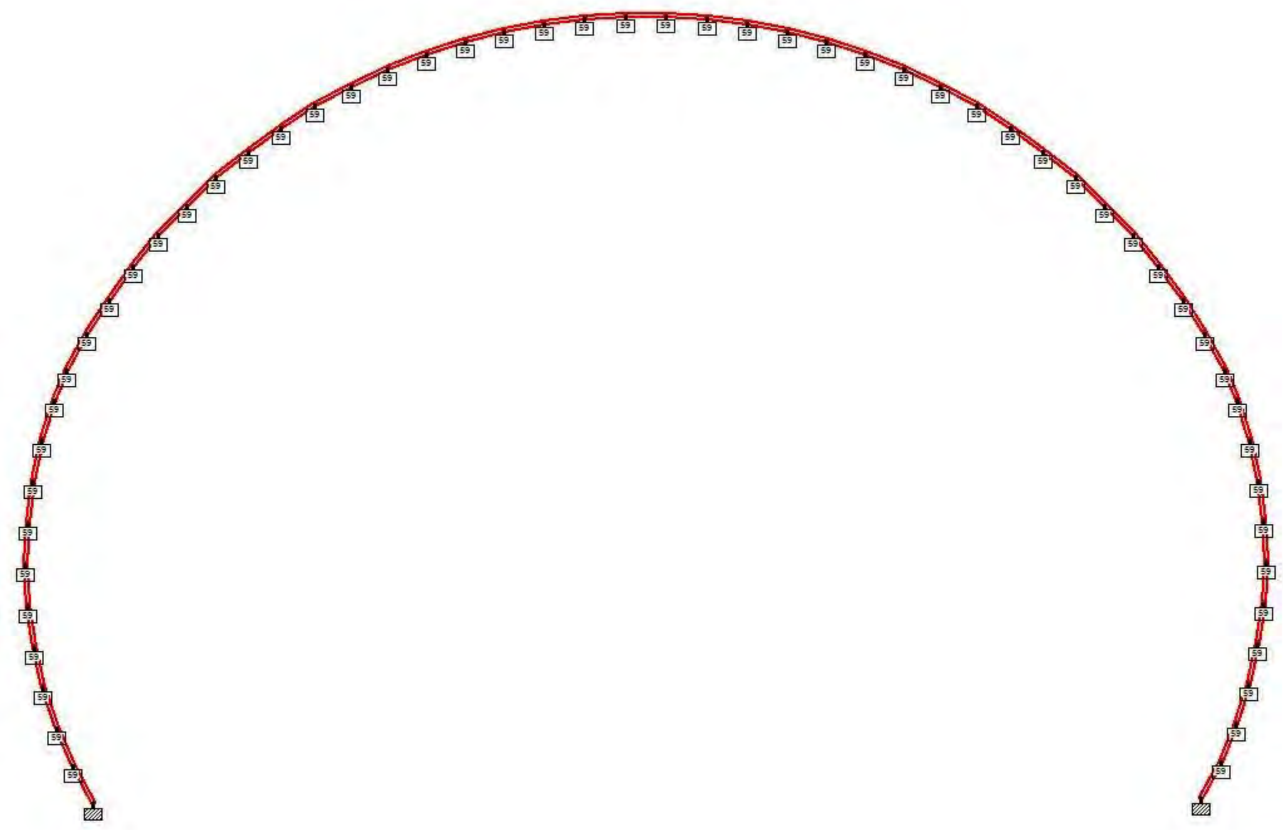


Figure 3: Idealized Model with Supports

7 LOAD CASES

7.1 Permanent Loads [G]

7.1.1 Self-Weight [G1]

The volume used for calculation of self-weight of structures is based on the nominal dimensions of the structure. Self weight of the reinforced concrete lining will be calculated with unit weight of concrete of γ_{con}=25kN/m^3.

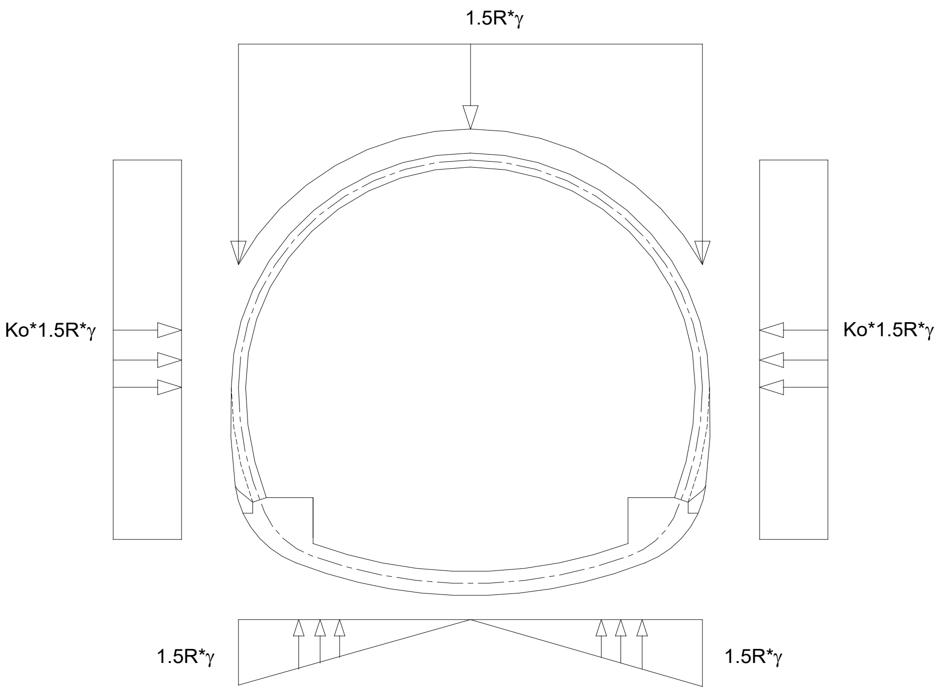
Self-Weight will be considered as dead load with partial load safety factor of 1. 5 as per IS 456.

7.1.2 Earth Pressure [G2]

With regard to vertical earth pressure actions, specifications given in German Railways – Guideline will be applied as follows:

If H>2R the vertical load is equal to weight of:

1. 1.5R depth in rock conditions and the overburden above the depth of 1.5R neglected.
2. 2.0R depth in poor rock/ soft ground and the overburden above the depth of 2.0R neglected.



The effective lateral earth pressure is equal to the product of load due to weight of overburden and coefficient of lateral earth pressure K_0. The assumed Earth Pressure Coefficient K_0 = 0.50

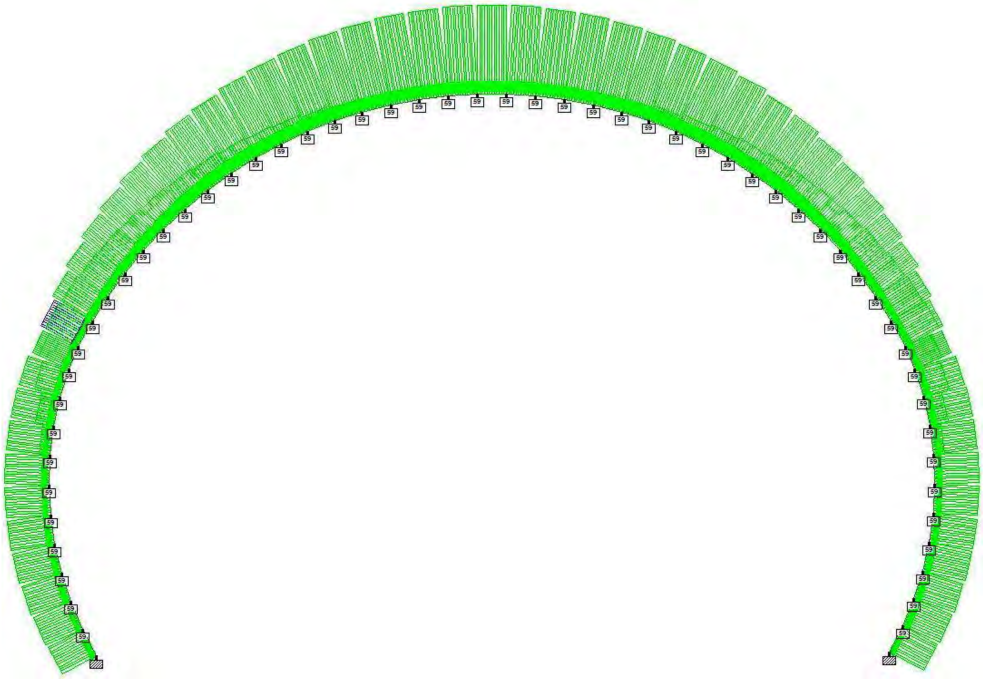


Figure 4: Tunnel Cross Section shows Earth Pressure

Earth pressure is considered with partial load safety factor of 1.50 as per IS 456.

7.1.3 Shrinkage [G3]

The self-tension of the tunnel bearing elements due to concrete shrinkage is simulated as uniform cooling of the lining. The amount of lining deformation is calculated according to IS 456 -2000 and converted into uniform cooling temperature difference of -15°C.

Since the internal forces due to shrinkage results from constraint deformation the partial load factor shall be set equal to 1.25.

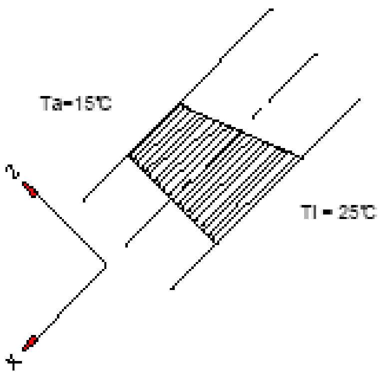
7.1.4 Water Pressure [G4]

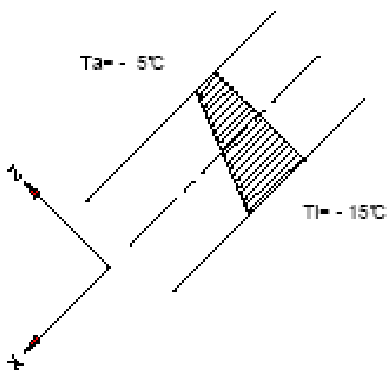
Due to the designed drainage system and the vicinity of the first blocks to the slope surface & no special provisions for water tightness have been implemented. It is not possible that water pressure will build up on portal and first tunnel blocks. Consequently, water pressure is not considered as design load case.

7.2 Live Loads [Q]

7.2.1 Temperature Load [Q1]

The temperature loads are applied only onto the tunnel arch above the construction joint. An average temperature during construction equal to tm=+11° is assumed and active temperature differences acting on the tunnel lining are taken as follows:





Since the internal forces due to temperature differences result from constraint deformation the partial load safety factor according is adopted equal to 1.15 for ULS and 0.80 for SLS.

7.3 Earthquake

In general, subsurface structures are subjected to much less stress in earthquake than buildings/structures above ground. These stresses reduce with increase in depth. So, it can be assumed that earthquake induced stress in tunnel are much lower due to earthquakes. As a rule, tunnels are not designed for earthquake forces. (Pl refer "Guide 853.9120 to 853.2001 DB directive", concerning paragraph 16).

Hence, the effect of earthquake force is not considered for structural design of tunnel inner lining.

Further, to verify this assumption, effect of seismic on tunnel evaluated as described in literature "***Seismic design and analysis of underground structures***" by YMA Hashish, JJ Hook, Birger Schmidt and John I-Chiang Yao (ref Tunneling and Underground Space Technology 16 (2001) 247-293) and provided in **Appendix 3**.

8 COMBINATIONS OF ACTIONS

8.1 Applied load cases

The applied load cases are listed in the following:

- G_1 Self weight
- G_2 Earth pressure
- G_3 Shrinkage
- Q_1 Temperature loads (winter and summer)
- E Earthquake loads

The load combinations used for the calculation are listed in the following tables.

8.2 Ultimate Limit State (ULS)

Calculations of ultimate limit state consider the following load combinations:

8.2.1 Ordinary load combinations:

I $=1.5\times G_1$
II $=1.5\times G_1+1.50\times G_2$
III $=1.5\times G_1+1.50\times G_2+1.25\times G_3$
IV $=1.5\times G_1+1.50\times G_2+1.25\times G_3+1.15\times Q_{1,summer}$
V $=1.5\times G_1+1.50\times G_2+1.25\times G_3+1.15\times Q_{1,winter}$

8.3 Serviceability Limit State (SLS)

Calculations of serviceability limit state consider the following load combinations:

I $=1.0\times G_1$
II $=1.0\times G_1+1.0\times G_2$
III $=1.0\times G_1+1.0\times G_2+1.0\times G_3$
IV $=1.0\times G_1+1.0\times G_2+1.0\times G_3+0.80\times Q_{1,summer}$
V $=1.0\times G_1+1.0\times G_2+1.0\times G_3+0.80\times Q_{1,winter}$

9 STRUCTURAL DESIGN

9.1 Structural design method

The structural design is carried out in accordance with EN 1992 as Indian codes does not provide any guidelines for design of plain cement concrete

Load combinations for the Ultimate Limit States (ULS) and the Serviceability Limit States (SLS) are considered for the reinforcement design as described in section 8 above.

Partial safety factors for materials for ultimate limit states are adopted according to Indian codes IS456- 2000.

Load Combination	***Concrete***	***Reinforcement Steel***
Ordinary Load Combination	1.5	1.15

Table 2: Partial factors for materials for ULS

9.2 Concrete cover

The minimum concrete covers to all reinforcement (main and distribution reinforcing bars) considering the exposure conditions are adopted as follows:

- Concrete exposed to earth (external face) 40 mm
- Concrete not exposed to earth (internal face) 60 mm

9.3 Crack width

A maximum crack width of 0.3 mm (moderate durability exposure) is proposed. The crack width is calculated in accordance with IS 456-2000.

10 DESIGN RESULTS

The calculation results are shown in Appendix 1 & 2.

APPENDIX 1 - CALCULATION RESULTS

Project	Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"	The Concrete Centre		
Client	Govt of Karnataka	Made by	Date	Page
Location	Tunnel Inner Lining	RMW	02-Dec-15	195
	BENDING AND AXIAL FORCE to EN 1992-1 : 2003	Checked	Revision	Job No
	Originated from TCC12.xls v 4.1 on CD © 2002-2005 TCC	chg	-	FB625

MATERIALS

fck	35	N/mm²	γs	1.15
fyk	500	N/mm²	γc	1.50

SECTION

h	400	mm
b	1000	mm

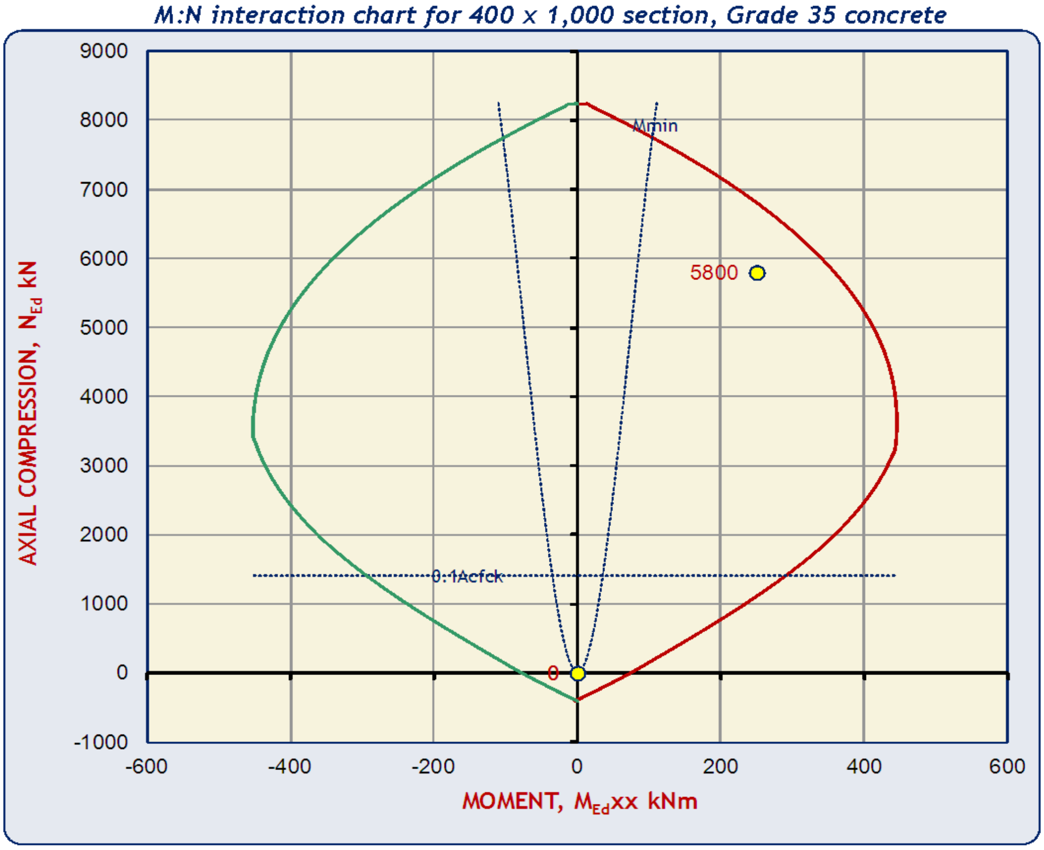
COVERS (to main steel)

TOP	40	mm
BOTTOM	60	mm
SIDES	40	mm

REINFORCEMENT

	Bar Ø	No	Area	%	Space
TOP	10	6	471	0.118	172.0
BOTTOM	10	6	471	0.118	172.0

M:N interaction chart for 400 x 1,000 section, Grade 35 concrete



LOADCASES (ULS)

CASE	N_{Ed}	M_{Ed}	CASE	N_{Ed}	M_{Ed}
1	5800	250	2		
3	0	0	4	0	0

APPENDIX 2– CALCULATION RESULTS

Based on the above calculation results, the reinforcement requirements and details are as follows and the same has been incorporated in the drawings.

S.No	Description		Reinforcement details near Invert Portion (Refer fig 5)
1.	Tunnel Inner Lining	Longitudinal Bars	16 Dia @150 mm c/c
2.		Transverse Bars	10 Dia @150 mm c/c

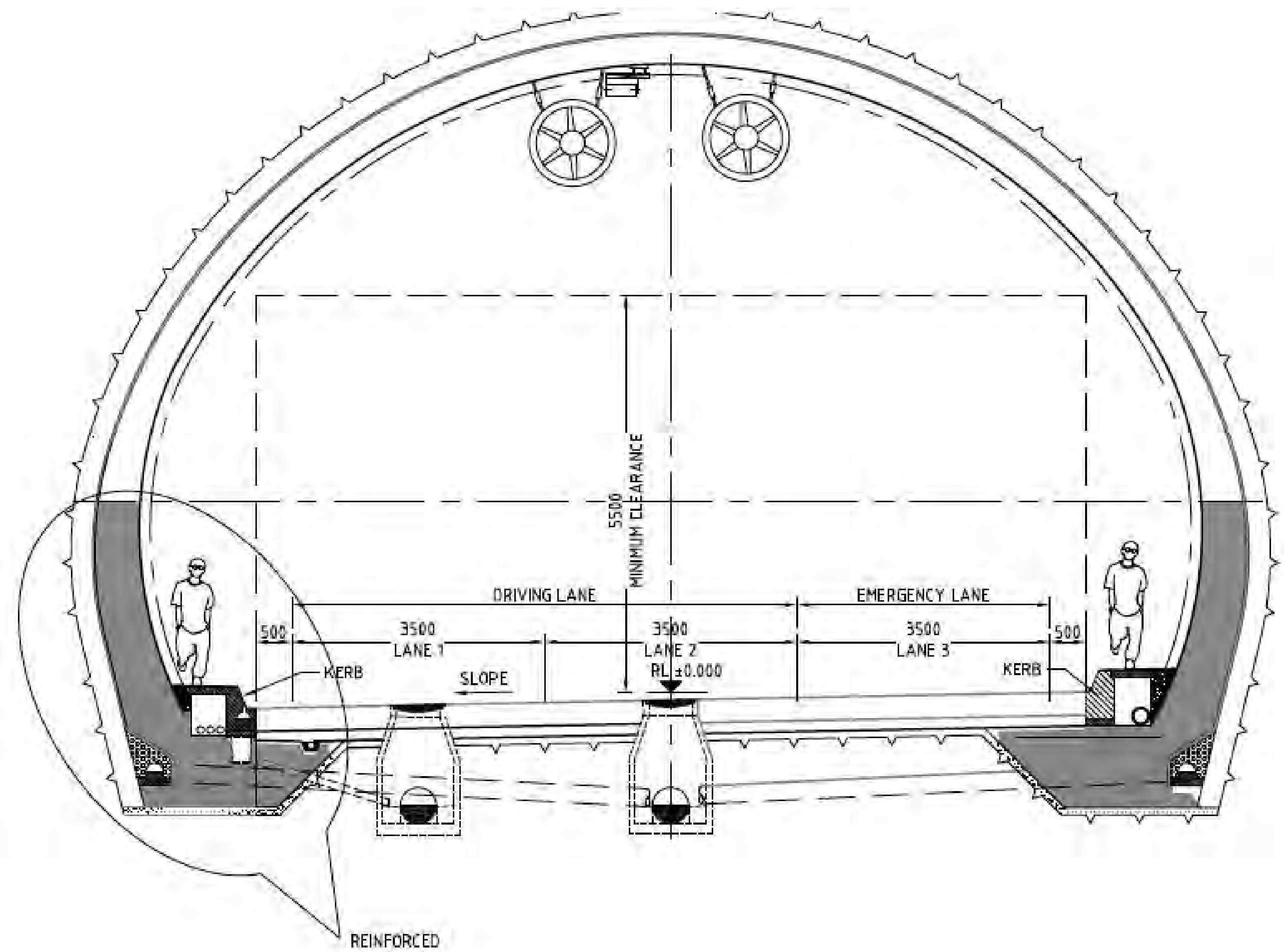


Figure 5: Reinforcement Details

Prepared for:

सड़क परिवहन और राजमार्ग मंत्रालय
MINISTRY OF ROAD TRANSPORT & HIGHWAYS

Karnataka
Public Works, Ports &
Inland Water Transport Department

Project:

Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"

Subject:

KD-6- Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume - II : Design Report

Part III : Design of Bridges and Cross Drainage Structures

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Revision History

Rev.	Date	Long Description

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INTRODUCTION

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorporation of Client's observations on earlier submitted "KD5: Kucha Draft Detailed Project Report (KDDPR)" vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels :

- *Proposed Tunnel Design and Standards*
- *Technical Note on Tunnel Section and System*
- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures:

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report:

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

(vi) Volume - V Technical Specifications :

(vii) Volume - VI Rate Analysis :

(viii) Volume - VII Cost Estimates :

(ix) Volume - VIII Bill of Quantities :

(x) Volume - IX Drawings (A3 Size) :

a. *Location map*
b. *Layout plans*
c. *General Drawings*
d. *Plan and Profile of Refined Alignment "A"*
e. *Typical Cross Sections showing Pavement details of Cut & Fill Section*
f. *Typical Cross Sections of Tunnel*
g. *Typical Cross Sections of Bridges*
h. *Tunnels- General Arrangement Plan and L-Sections (L&R)*
i. *Viaducts – General Arrangement Plan and L-Section*
j. *Cut & Fill and Viaducts – General Arrangement Plan and L-Section*
k. *GAD for proposed RoB at Railway km 54+650*
l. *Standard Drawings*
m. *Miscellaneous Drawings*
n. *Indicative Land Acquisition Plans*
o. *Detailed Cross Sections @ 100m interval*

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(xii) Volume - XI Project Clearances :

VOLUME - II: DESIGN REPORT

PART- III: DESIGN OF BRIDGES AND CROSS DRAINAGE STRUCTURES

1 GENERAL

This Volume - II: Design Report- Part III: Design of Bridges and Cross Drainage Structures, a part of KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR) is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report - Part III: Design of Bridges and Cross Drainage Structures of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

1.1 ALIGNMENT DESIGN

Alignment Option “A” proposed on the Southern side of existing NH-48 has been further re-fined minutely for better road geometry, structures connectivity, aesthetics, site suitability and construction methods. The alignment starts at Heggade (km. 236.400) traverses through Greenfields, bypassing Maranhally Kadagaravalli, Yedakumari, Gundya villages and ends at Adda Hole (km 263.400) of NH-48. The total length of alignment under this option is 23.579 Km, and the route consists of 6 tunnels (length 12.631km varying from 1660 to 2960 m), 7 bridges, 1 RoB and 1 Viaduct (total length 6.327 km, varying from 50 to 3216m), and 4.621km long cut & fill sections. The route has low gradient (roads & bridges: 0 to 3.5%, tun-nels: 3.0 to 3.5%) and gentle curves (R=500m to 2000m). The height of bridge piers in the deep valleys is restricted to 120m that makes the early implementation of the project possi-ble. Also, tunnel lengths are limited up to 3.0km that makes the scale of ventila-tion/emergency facilities ordinary in size. Only 4.621km out of total length of 23.579km is planned as “cut and fill” that requires deforestation of the construction area. Plan and Profile Drawing is given in Volume IX : Drawings.

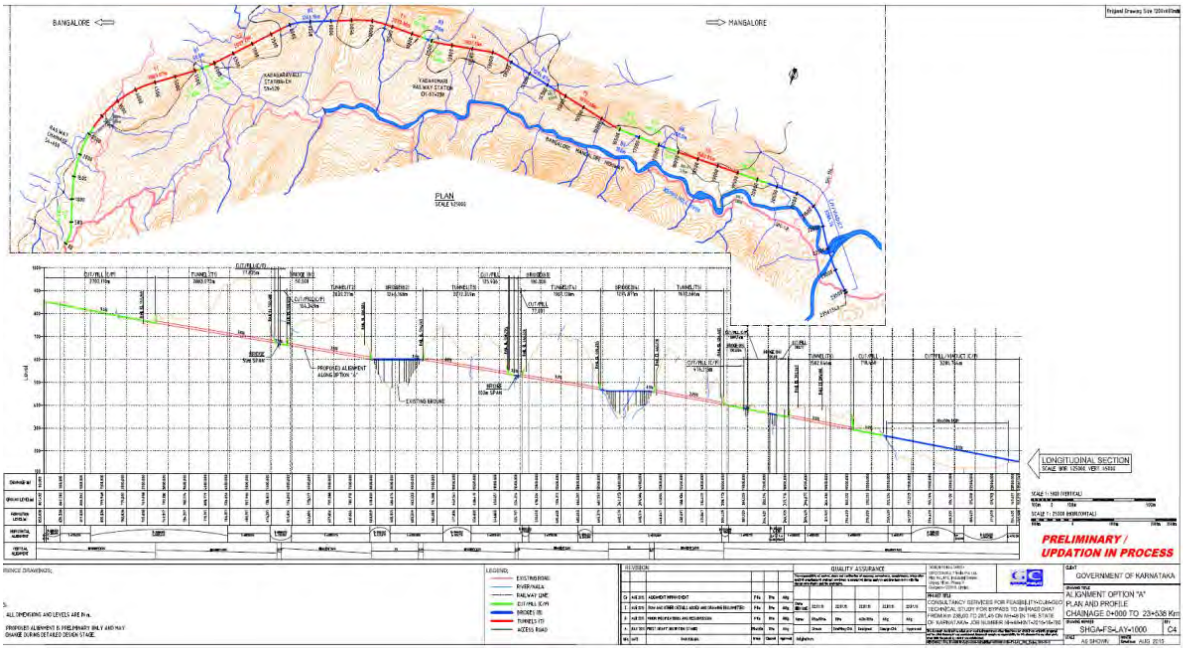


Figure 1 Proposed Alignment

Along the proposed green field alignment there are two major viaducts of nearly 1.2 Km long and one approach viaduct having length of ~3.0 Km. Among various alignment option con-sidered, the same has been chosen to obtain a relatively straight and shallowest crossing of the valley after the tunnel. For major viaduct obligatory span of ~425m long integral structure that are envisaged as an option to cross the 90-120 m deep valley. Continuous spans in the range of 100 to 150m may lead to economically viable arrangements for the superstructure. In the previous departmental study report obtained, all such major bridges have been shown in a gradient. However our detail review reveals that all these high level

Crossings are to be kept at levelled profile in order to adopt a widely accepted construction technique.

For approach Viaduct (3Km long, Gundya side) where pier height is 30-85m the superstructure is proposed in a 3.5% gradient. Bridge spans chosen for this of situation are of 50m length. There are other minor bridges of smaller (length 100-200m) where similar span length of 50m & gradient is accommodated.

1.2 Y-PIER TWIN BOX GIRDER OPTION

As per initial structural option Y-shape piers at ~190m c/c has been proposed to support 5 spans continuous integral deck with span arrangement of 70m+3x95m+70m(total length 425m). The super structure is twin box section of overall 12.3m width each carrying 2-lane geometry along with the footpath as per SP84-2014. They are proposed to be separated by 1.5m wide median. The proposed depth of box section is kept 5.5m at support & 3.0m at mid-span. However the above structural option got modified to Y- piers at 160m c/c to support 5 spans continuous integral deck with span arrangement of 65m+3x80m+65m(total length 370m). The each deck is consisting of twin box (2x6.1m) of overall depth restricted to 3.0m in order to carry the same by railway.

Hollow pier slip formed up to a height of 60-90m is proposed resting on open foundation. For the construction of Y flange of pier (27m deep,50m long), temporary stays are required until the deck continuity is established for the superstructure.

For super structure proposed construction technique envisaged is a typically balanced cantilever segmental erection with an over head launcher. The launcher can be supported on pier head etc. discussed later in this report.

Advantages of the Y-pier option

- Segmental construction method adopted for superstructure that reduces construction activities in the forest (environment friendly option) and adds overall advantages to the reduction of project duration.
- Reduced number of substructure i.e. only two major pier required for this option spaced at 160m.
- Smaller Segments size and weight due to separate carriageway. Being smaller cells used for the each separated carriageway weight of segment is within the handling and ease of handling and transportation.
- Low maintenance of deck as it devoid of joints and bearing. Thus a greater design life of structure is expected.
- Adequate comfort for the traffic user in absence of joints in the deck.

Disadvantages of Y-pier option

- The erection involves launching that required operations by overhead gantry. The gantry operations shall be carried out laterally for the two carriageways and shall not be synchronised that give rise to transverse moment for piers. However the substructure can be designed for such loading arising of out erection.
- Superstructure requiring precasting and they need to be cast in a match casting method with involves precision survey and proper casting bed setting up, handling, curing etc..
- Pier and pier caps are tall enough & need to be erected by slip forming method only. However slip forming of piers are commonly required for viaduct proposed for valley. Construction of flange of Y-pier requires temporary as well permanent stays with various precise survey and erection control.

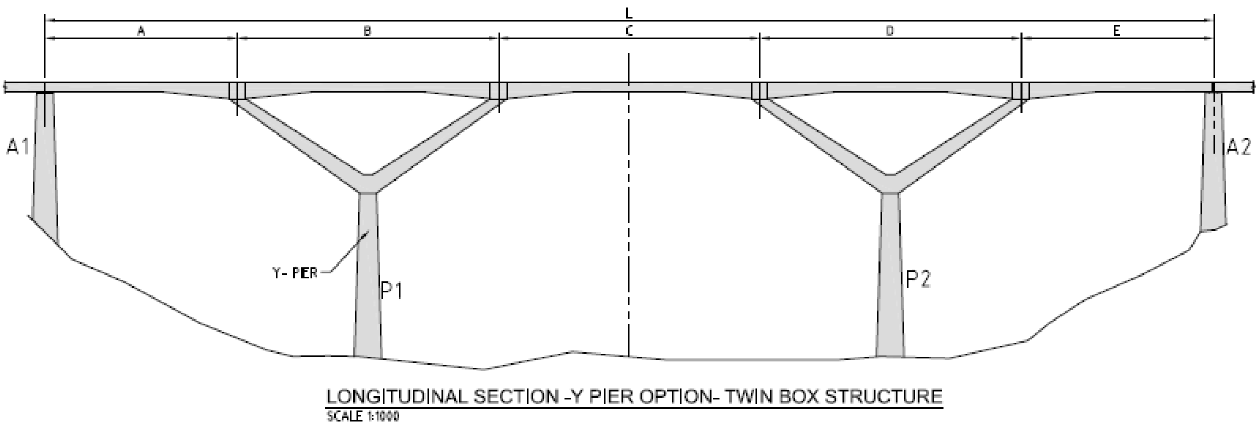


Figure 2 Longitudinal Section- Y Pier Option – Twin Box Structure

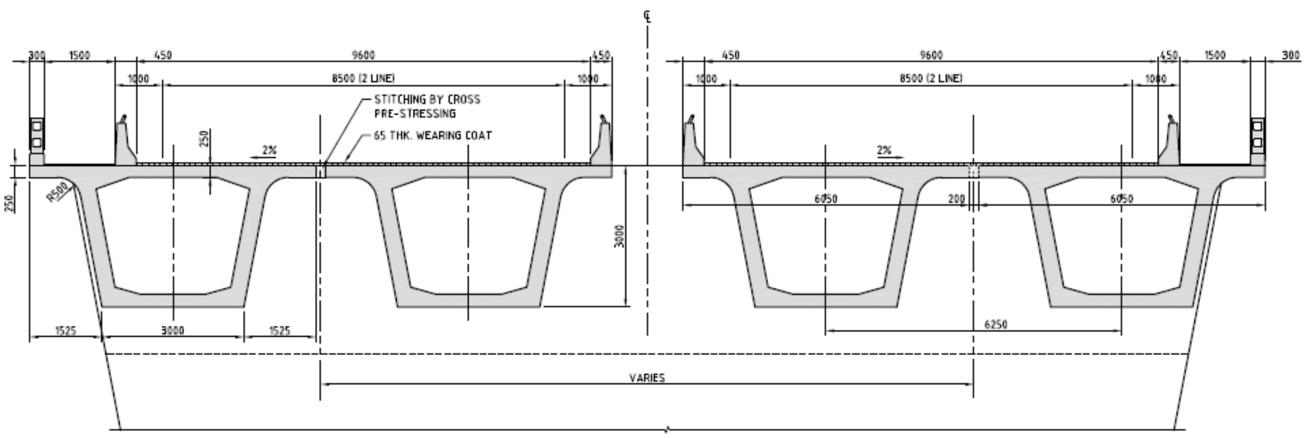


Figure 3 Twin Box Girder

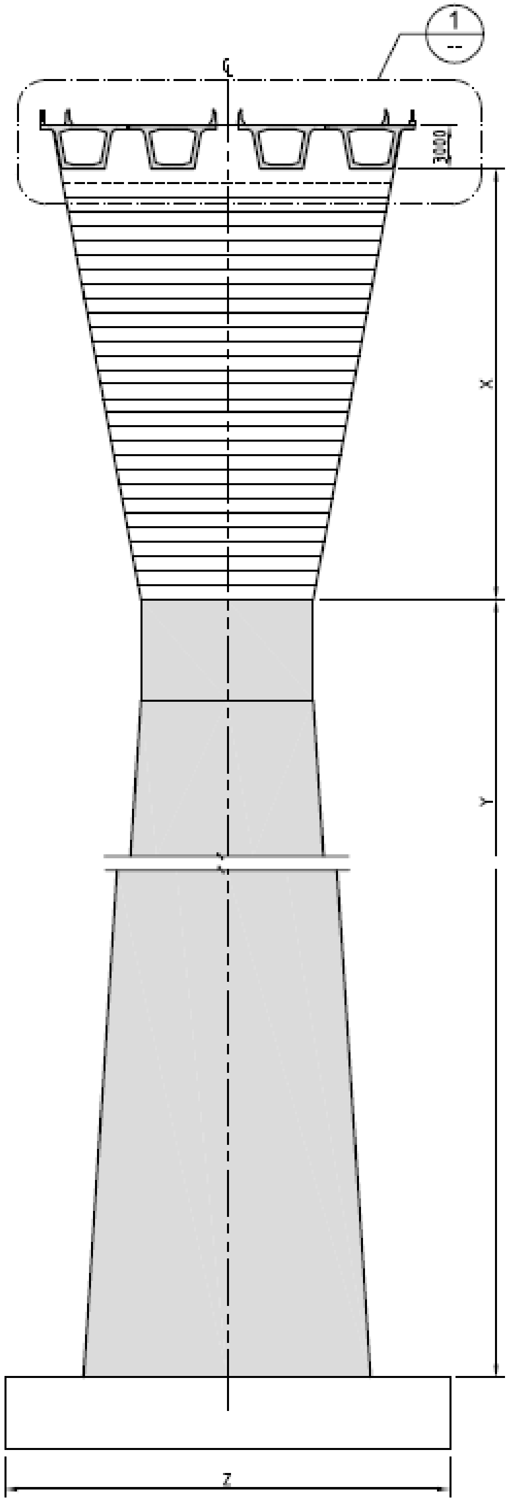


Figure 4 Cross Section

1.3 OTHER OPTION -2 EXTRA DOSED SPINE BEAM DECK

As an alternative, Extra dosed viaduct option 3 nos. piers at 140m c/c (total length 420m) has proposed to support a 3.5m deep 26.1m wide deck. The super structure is having a central spine beam and precast wings at both the sides transversely prestressed with it. Pylons are proposed at median are integral with pier cap and deck. Hollow rectangular piers constructed with slip form technique will be proposed similar to previous option up to 60-90m.

The proposed construction technique envisaged for spine beam is a typically balanced canti-lever segmental erection with over head launcher. Later precast wings will be attached to the spine beam with transverse prestressing.

Disadvantages:

- No of substructure relatively more compared to Y-pier option.
- Heavier Segments size and weight comparatively leading to heavier launcher and handling problem. This may be one of the major disadvantage for this option where there is constrains for transportation of segments to the bridge site.
- The erection involves launching operation of the spine Beam. However equal efforts are needed for the erection of wing segments.

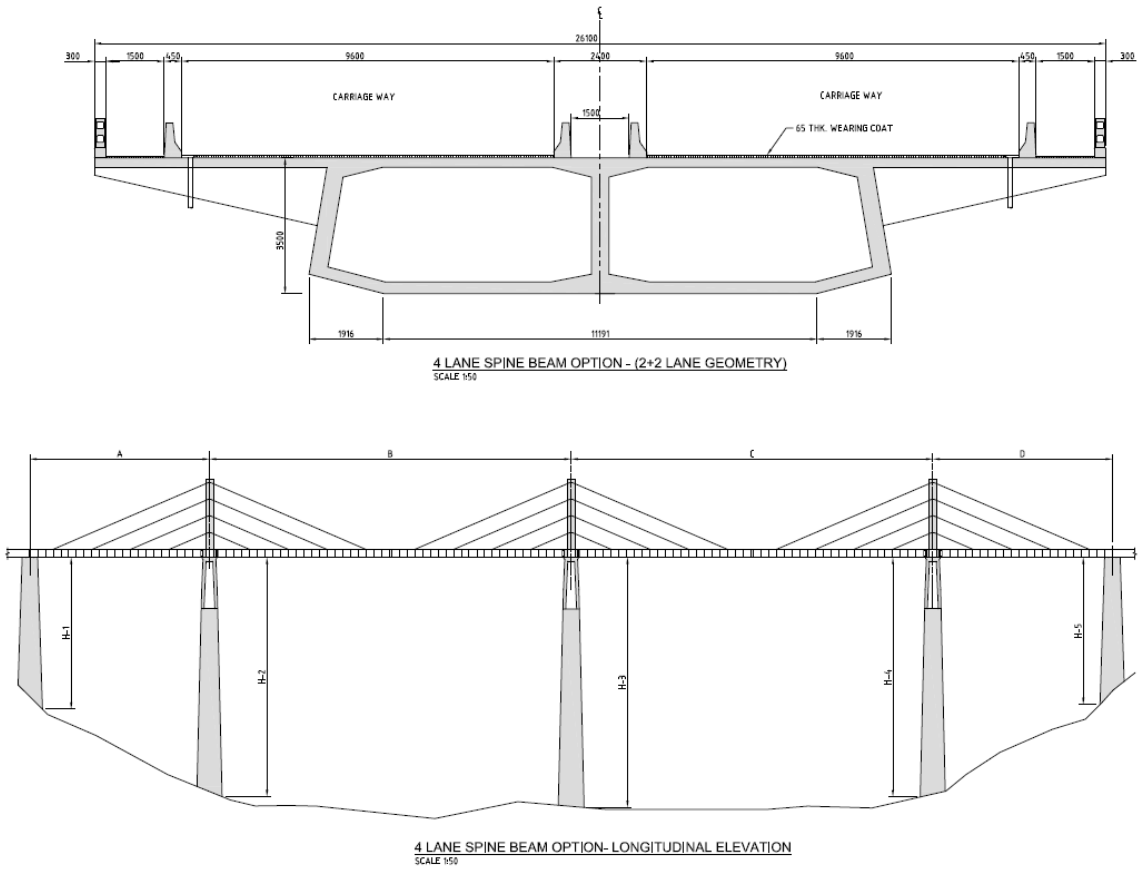


Figure 5 4-Lane Spine Beam Sections

1.4 OPTION -3 STEEL COMPOSITE GIRDER DECK

5 spans continuous composite deck having span arrangement of 70m+3x95m+70m (total length 425m). The super structure can be formed of 6 nos. 3m deep plate girders 1.98mc/c in order to facilitate the erection of girders in pairs and side shifted. Hollow pier slip formed up to a height of 90-120m is proposed resting on open foundation.

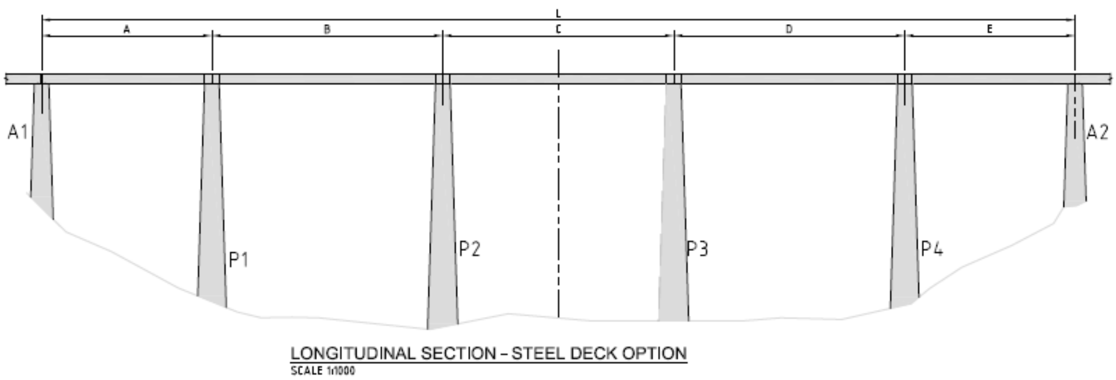


Figure 6 Longitudinal Section- Steel Deck Option

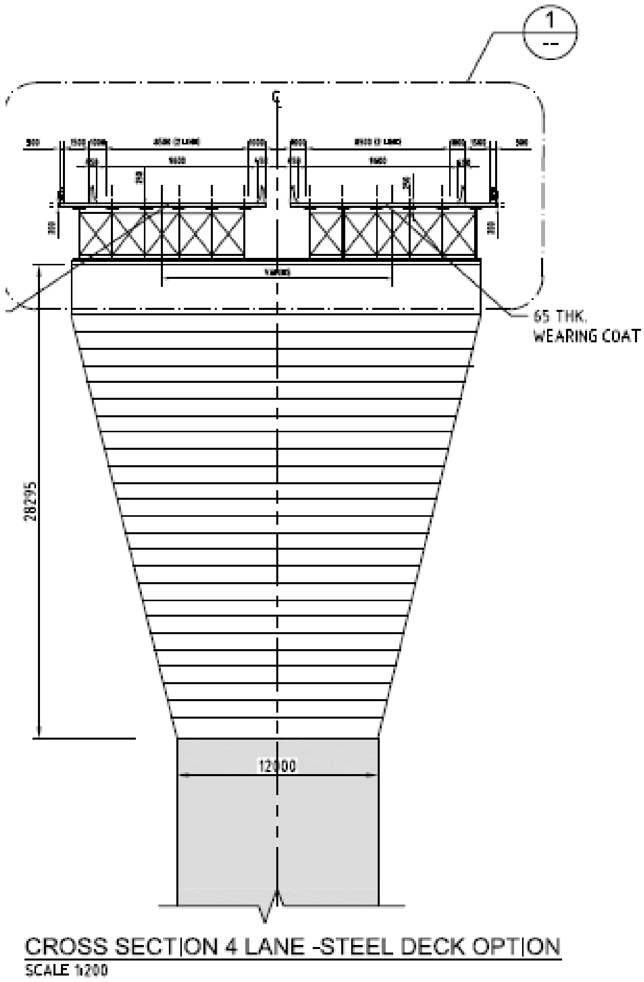


Figure 7 Cross Section- Steel Deck Option

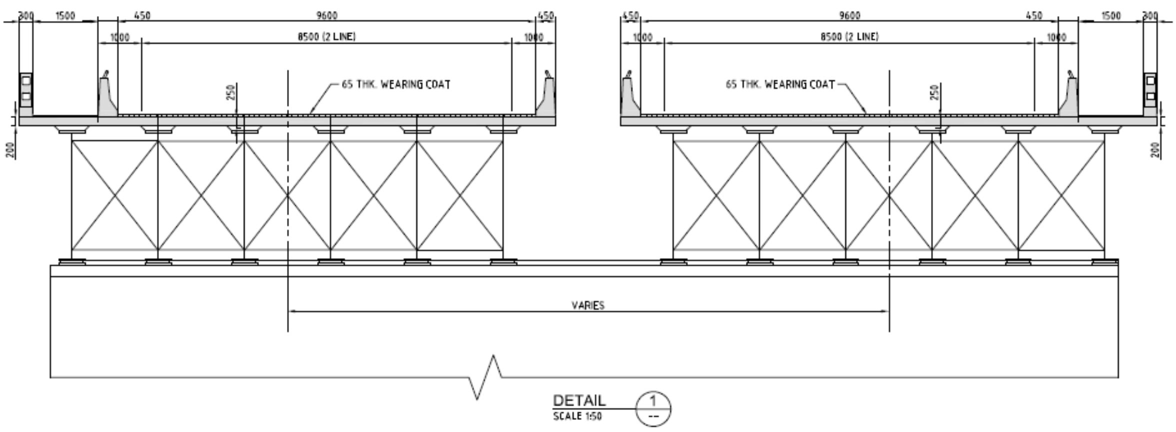


Figure 8

- No. of substructure required most compared to all options above adding to cost-disadvantage.
-

- Due to restricted depth and length, there may be multiple splices involved for prefabricated steel girders as handling and transportation of girders by railways only.
- Involves sufficiently larger construction duration. Once the composite deck is ready the next span can only be launched. Hence not efficient.
- In-situ deck construction shall lead to one of the great environmental hazards among all options.
- Steel deck option doesn't suit other bridges of the project where there is a major viaduct in gradient with tall piers ~70-80m. So in order to keep uniformity in structural scheme adopted use of composite deck may be unsuitable.

1.5 APPROACH VIADUCT

For approach/ viaduct precast segmental box girders of 50m spans are proposed. The precast segmental option is envisaged in order to reduce the impact of in-situ construction activity in the vicinity and reduction in project duration. Hollow piers nearly of a height 30-85m are proposed for the viaduct. Typically two span continuous units having deck continuity are proposed and span by span erection of decks can be adopted.

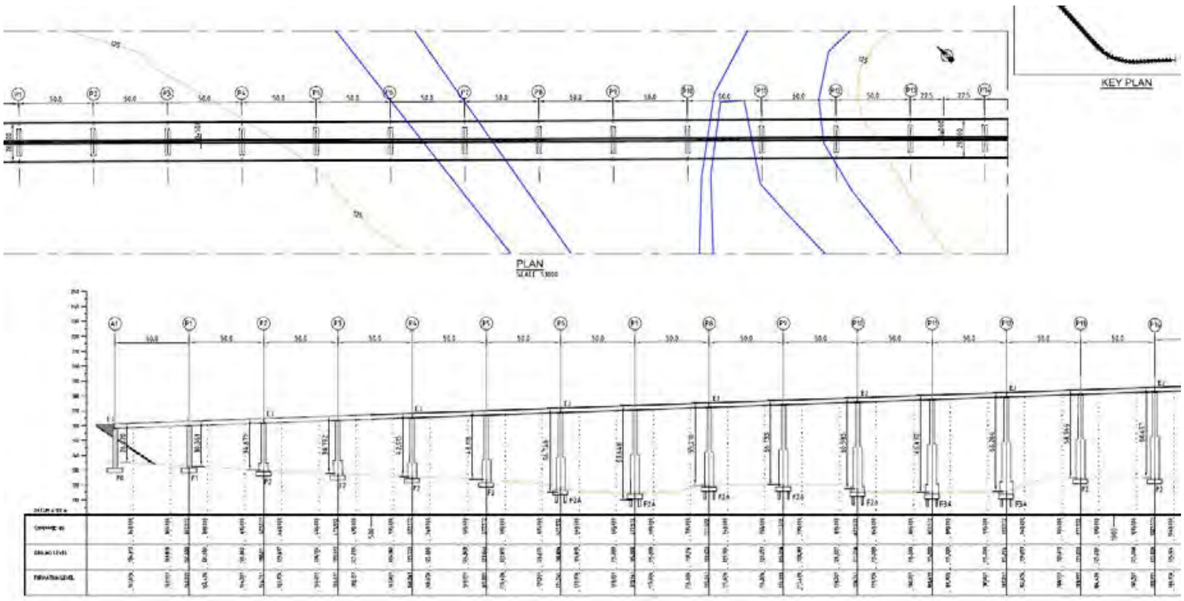


Figure 9

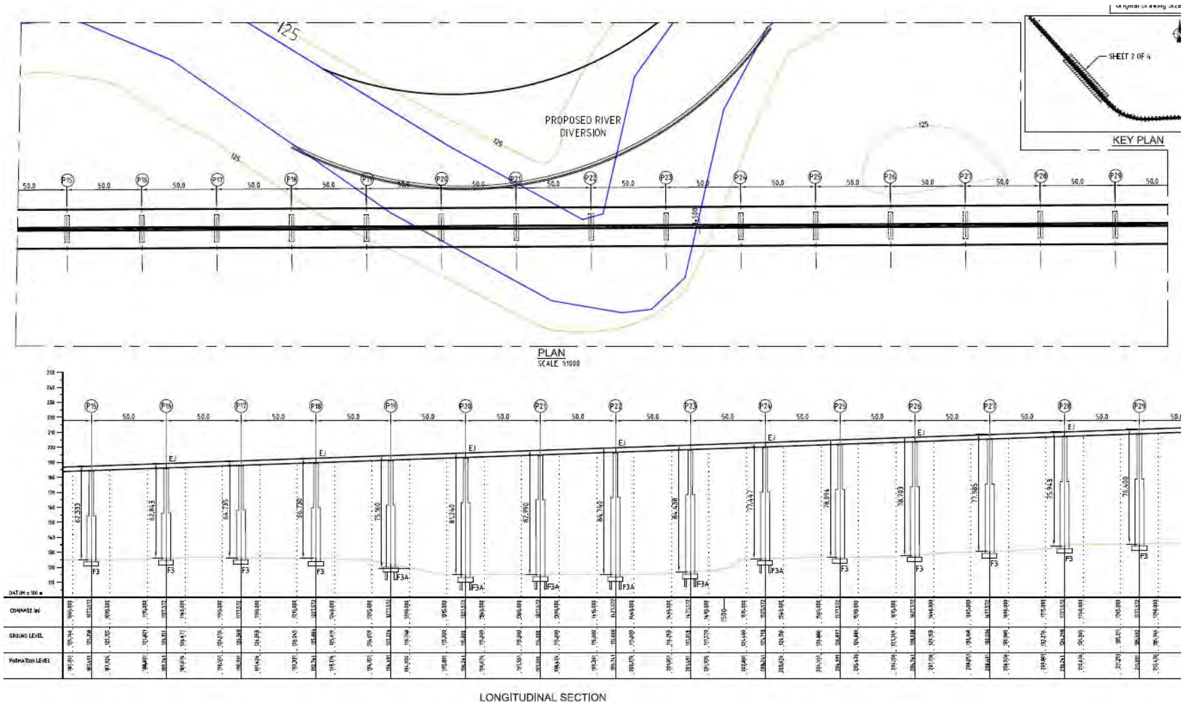


Figure 10

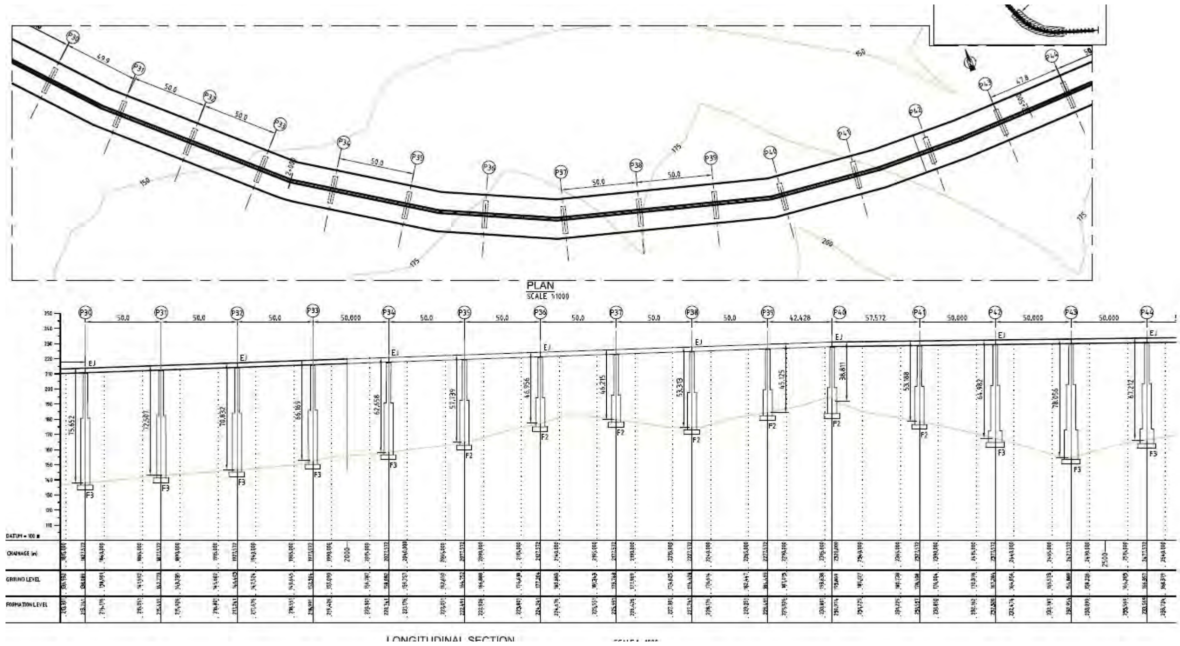


Figure 11

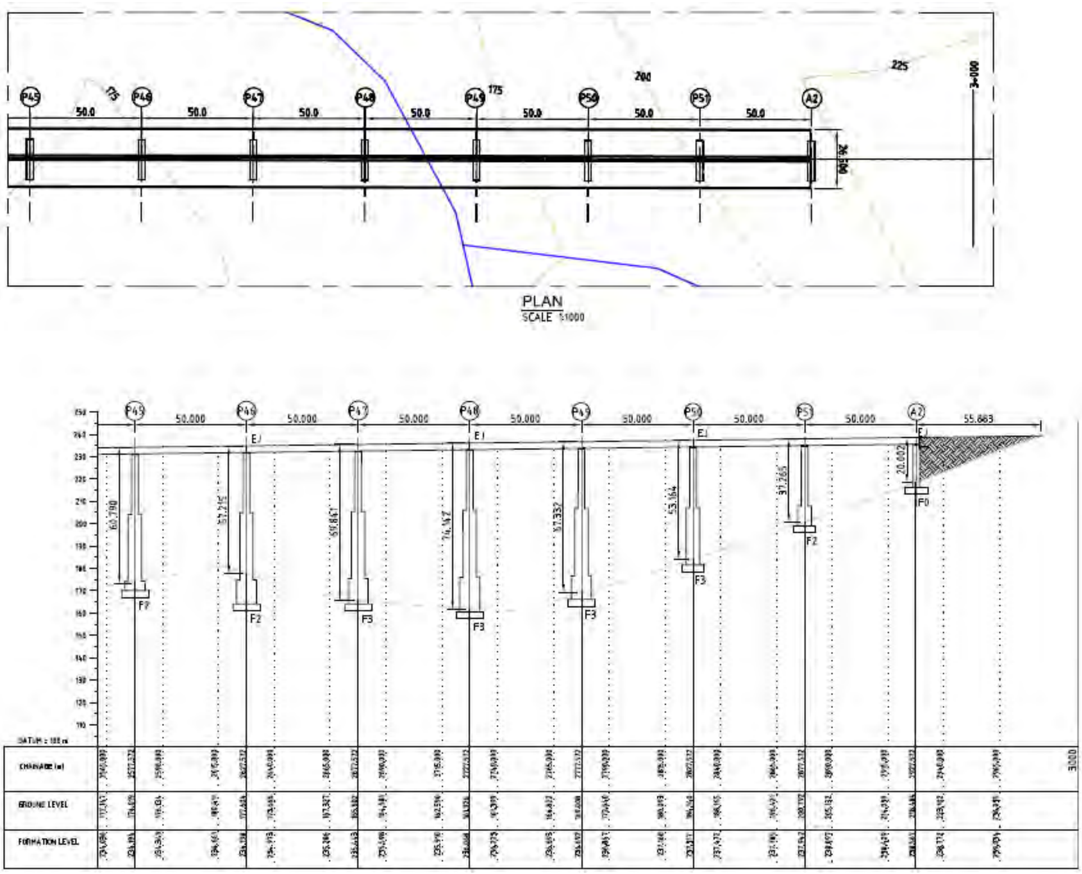
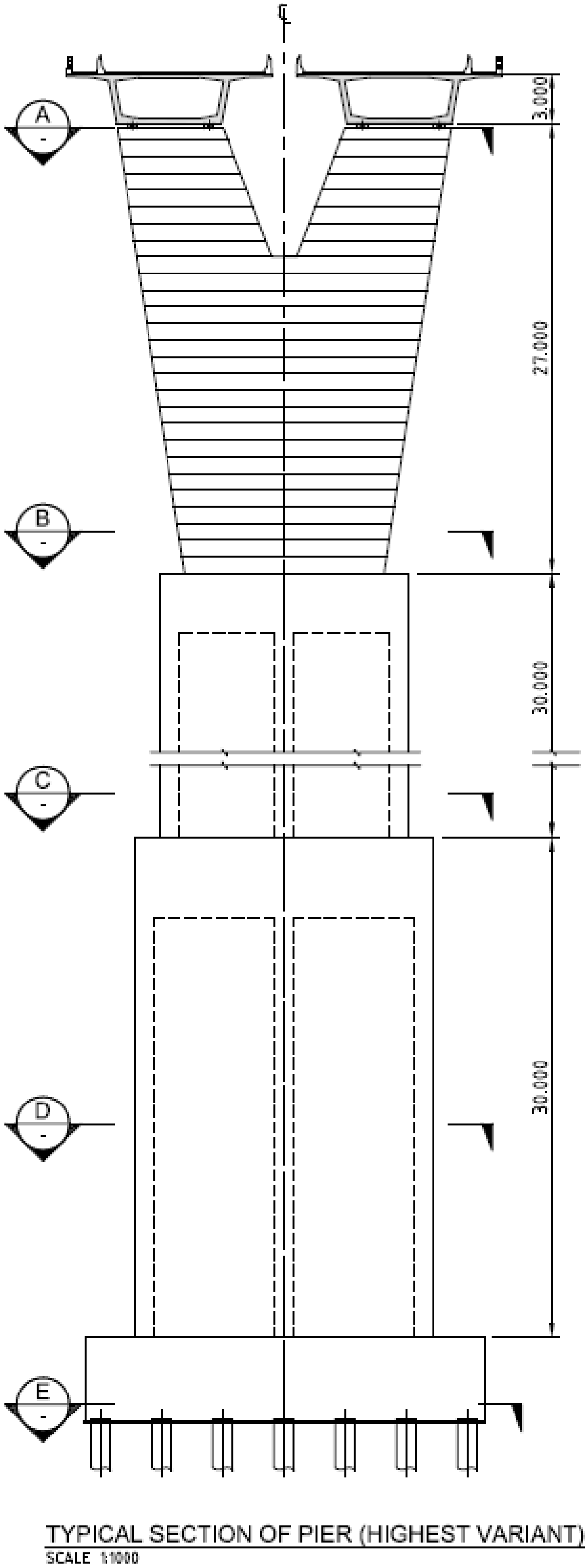

P45
P46
P47
P48
P49
P50
P51
A2
50.0
PLAN
50.000
55.883
F2
F3
F0
CHAINAGE (m)
GROUND LEVEL
FORMATION LEVEL

Figure 12



A
B
C
D
E
3.000
27.000
30.000
30.000
TYPICAL SECTION OF PIER (HIGHEST VARIANT)
SCALE 1:1000

Figure 13

2 MATERIALS

2.1 CONCRETE

Concrete made of OPC & strength, fc based on the 28 day strength of 150mm cubes shall be as follows:

Grade (kN/mm²)	f_c (MPa)	Minimum cement content (kg/m^3)	A MAXIMUM WATER CEMENT RATIO	B USE
M40	40	400	0.45	Piers, Piles,Foundation abutments, other reinforced concrete members for viaduct other than special span piers less than 45m.
M50	50	400	0.45	Piers, Piles,Foundation abutments, other reinforced concrete members for viaduct of special span and pier height more than 45m.
M45	45	400	0.45	Prestressed conc. Box decks other than special span
M60	60	400	0.45	Prestressed conc. Box decks for viaduct of special span
M40	40	400	0.45	Bridge parapet,Pedestal, Hand-rail
M30	30	360	0.45	Approach slab

Maximum cement content shall not exceed 540 kg/m^3.

Short-term modulus of elasticity of concrete has been evaluated using the expression:

Ec = 5000*sqrt(fc) MPa : Poisson's ratio=0.2

2.2 COVER TO REINFORCEMENT

Minimum clear cover to any reinforcement (increased due to high humidity in the area) shall be as follows:

Notional Cover (mm)	Locations
75	Piles, Cast In place footing in contact with soil
75	Piers, Abutments shaft & other reinforced concrete members subjected to alternate wetting & drying & in contact with earth.
45	Passive steel for precast Prestressed box girder superstructure.
50	Reinforcement cast in place superstructure
75	Prestressing steel of Box girder

2.3 REINFORCEMENT

The rebars shall conform to grade Fe500 of IS:1786. Wire fabrics conforming to IS:1566 & TMT bars conforming to IS:1786 shall be used.

fy = 500MPa & Es = 200GPa

Welding of rebars & use of mechanical couplers shall conform to IRC:21/112.

2.4 PRESTRESSING

Prestressing steel shall conform to:

Strand: 15.2mm nominal dia, 7-wire, low relaxation strand to IS:14268 (fs = 1862MPa & Ep = 195GPa)

The jacking force shall be limited to 90% of the 0.85 times Ultimate tensile strength provided that the tendon force after jack release does not exceed 70% of the braking strength.

Co-efficient of friction for corrugated HDPE duct = 0.17 /radian

Wobble factor = 0.002 /m

Pull-in = 6 mm

For all temporary prestressing & cantilever erection use stress bar(plain): fg = 872MPa

2.5 BEARINGS

Bearing shall be designed & manufactured in accordance with IRC :83 Part III

3 DESIGN LOADS & CRITERIA

3.1 CODES & STANDARD

Where applicable design, material & workmanship shall conform to latest issue of relevant Indian Standard, tender specifications and to the following standards.

IRC-5:1998	Standard Specification & Code of Practice for Road Bridges: General features of Design
IRC-6:2000 & 2010	Standard Specification & Code of Practice for Road Bridges: Loads & Stresses
IRC-24:2001 & 2010	Standard Specification & Code of Practice for Road Bridges: Steel Road Bridges
IRC-SP65:2005	Guideline for design & construction of Segmental Bridges
IRC-78:2000	Standard Specification & Code of Practice for Road Bridges: Foundation & Substructure
IRC 112:2011	Code of practice for Concrete Road Bridges
IRC SP 84:2014	Manual of specification & standards for four laning of Highways thro' PPP mode
IRC-83 Pt II:1987/2011	Standard Specification & Code of Practice for Road Bridges: Elastomeric Bearing
IRC-83 Pt III:2002	Standard Specification & Code of Practice for Road Bridges: Pot, Pot –cum-PTFE, Pin & Metallic Guide Bearing
IRC SP 51	Load testing of Bridges

3.2 ENVIRONMENT

Exposure condition: Severe; Relative Humidity: 80%

3.3 DESIGN LOADS

The bulk densities of material for Dead & super imposed dead load adopted are as follows:

Prestressed concrete	25 kN/m^3
Reinforced Concrete	24 kN/m^3
Plain cement Concrete	22 kN/m^3
Earth	18 kN/m^3
Premix	22 kN/m^3

3.4 VEHICULAR BRIDGE LIVE LOAD

The vehicular load on the bridge shall comply with the loading given at table 2 of IRC :6.

For the 9.6m wide carriageway the bridge 3 lanes of class ‘A’ load is applied with an edge distance of 0.4m from kerb face to the wheel centreline & 1.7m distance between the wheels of adjacent vehicle.

A lane of Class 70R wheeled vehicle along with a single lane class ‘A’ loading is also applied & compared for worst loading effect.

Impact factor as per clause 208 of IRC: 6 is calculated in addition to above live load effect.

A 20% reduction in live load has been considered as per cl.205 IRC: 6.

Congestion factor as per clause 204.4 shall be considered in design.

3.5 LIVE LOAD AT FOOTPATH

For the footpath of the bridge live load has been assumed as bridge may be designed for future 3-lane loading. However footpath live load as per below in addition to 9.6 m lane loading shall be considered in design.

P= (P’-260 +4800/L)x (16.5-W)/15

where, P’= 400 kg/m^2

P = the live load in kg/m^ 2

L = the effective span of the main girder or arch in m, and

W = width of the footway in m

3.6 VEHICLE COLLISION LOAD AT PARAPET

A type P1 parapet is provided at two edges of the bridge. For loading details refer table 4 of IRC :6.

3.7 LONGITUDINAL LOAD

The longitudinal horizontal load is calculated based on clause 211.2(a) of IRC :6.

3.8 LOAD DUE TO WATER CURRENT

Water current load is given by following equation:

P= 0.52KV^2 kN/m^2 where V, velocity =5.18m/s(under investigation); K=0.66; Refer cl. 210.3 to 210.5 of IRC:6. Sufficient per protection shall be suitably given along with river training works.

3.9 WIND LOAD

Basic wind speed is 33m/s as per clause 209 of IRC: 6 . Refer to table 5 in which a lateral wind load pressure has been assumed depending on the pier height.

FT = Pz x A xG x Cd

As per clause 209.3.3 G=2 Cd= 1.5 has been assumed.

3.10 SEISMIC LOAD

No special investigation shall be done for the seismic effect as per clause 219.1.2 due to span length kept below 150m. As the site is located in seismic zone II , horizontal seismic forces are calculated based on elastic seismic acceleration method given in clause 219.5 (1) of IRC: 6 -2014 for rocky strata.

Vertical Seismic force equal to half the horizontal seismic force has been considered in the design as per clause 219.3(a).

3.11 TEMPERATURE LOAD

Effective bridge temperature shall be considered as: Maxm. 37.5deg. C & Minm. 15 deg C for longitudinal design. Coefficient of thermal expansion=12E6/deg C.

Effect of temperature difference along the depth of box girder as per clause 215.3 of IRC :6 shall be considered in both longitudinal and transverse design.

3.12 LOAD DURING CANTILEVER CONSTRUCTION

A unbalance load of a segment along with a 50 kN shock load at cantilever tip equipment load of 0.5kN/m^2 & a upward wind load of 0.5kN/m^2 acting at other cantilever arm is assumed in design.

3.13 DIFFERENTIAL SETTLEMENT OF SUPPORTS

A differential settlement of 10mm for each alternate pier location has been assumed in the design. Same shall be modified due long term elastic modulus of concrete

3.14 TABLE 1: GENERAL DESIGN PHILOSOPHY

The design shall generally be done by Limit State Method as per IRC :112-2011

Item	A PHILOSOPHY	Load combinations
Foundations	Normal load capacities	Groups I to VII in table 1 of IRC:6
	Ultimate load & moment capacity for foundation elements	Groups I to 5 given in IRC:6
Reinforced concrete	Working Stress design for flexure	Groups I to VII in table 1 of IRC:6
	Check for ultimate load capacity for shear & torsion	Refer section 12 of IRC:18/112
	Check stresses in service as per cl 303.4 & appendix 1 IRC :21 in order to limit crack widths	Groups I to VII in table 1 of IRC:6
Prestressed concrete	Service load design	Groups I to VII in table 1 of IRC:6
	Check for ultimate load capacity for longitudinal flexure, shear & torsion	Refer section 12 of IRC:18/ IRC 112
Bearings	Check stresses in service in accord-ance with	Groups I to VII in table 1 of IRC:6

For those elements of the superstructure prestressed in the longitudinal direction only, the design for the longitudinal direction has been performed in accordance with the requirements for prestressed concrete members while the transverse design has been made according to the philosophy applicable to the reinforced concrete.

4 ERECTION METHOD & CONSTRUCTION SEQUENCE

On completion of the hollow/solid pier foundation, temporary pylons shall be erected on pier top in order to provide stay to Y- pier wings. The superstructure will be precast segmental type erected by cantilever method of construction from the pier flanges(refer sketch below) .Temporary launching truss is proposed to carry and hold the segments from one end during erection. The truss need to be additionally designed for the holding end span segments. After erecting cantilevers from two adjacent piers continuity is established with in-situ stitch. Foundation can be designed for eccentric loading due to one side dead load due the fact that there may not be simultaneous erection of both the deck.

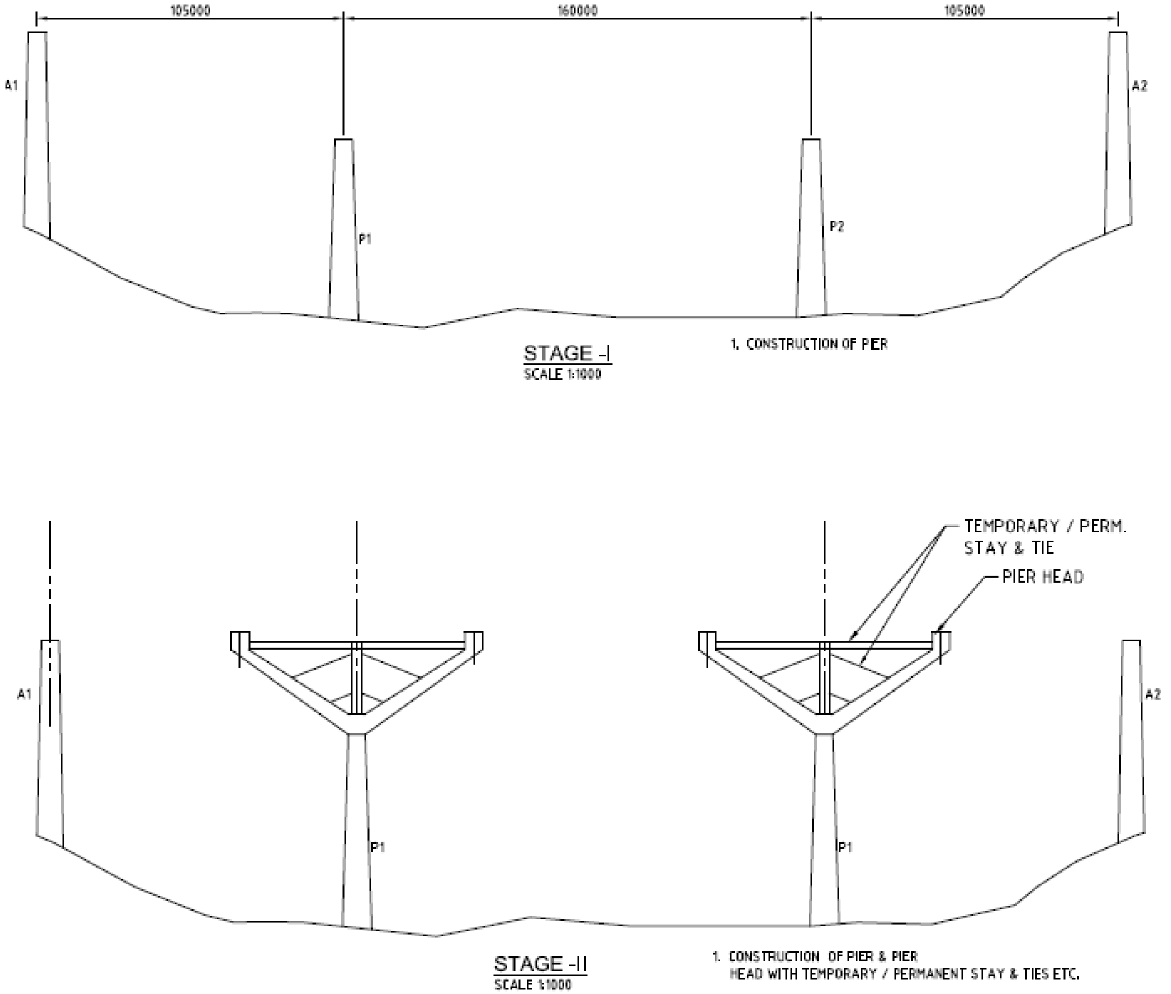
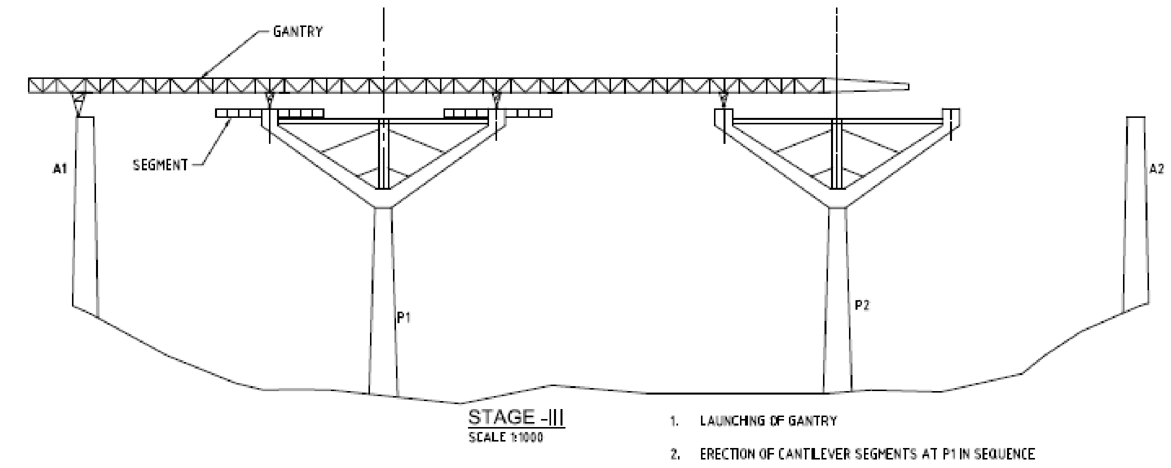


Figure 14


GANTRY
SEGMENT
A1
P1
P2
A2
STAGE -III
SCALE 1:1000
1. LAUNCHING OF GANTRY
2. ERECTION OF CANTILEVER SEGMENTS AT P1 IN SEQUENCE

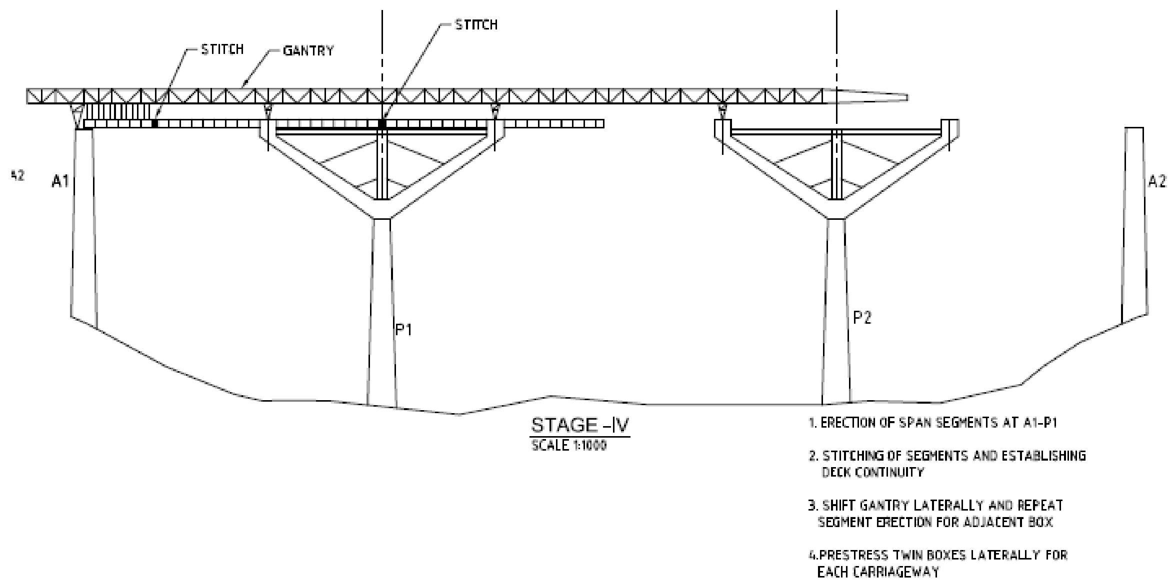
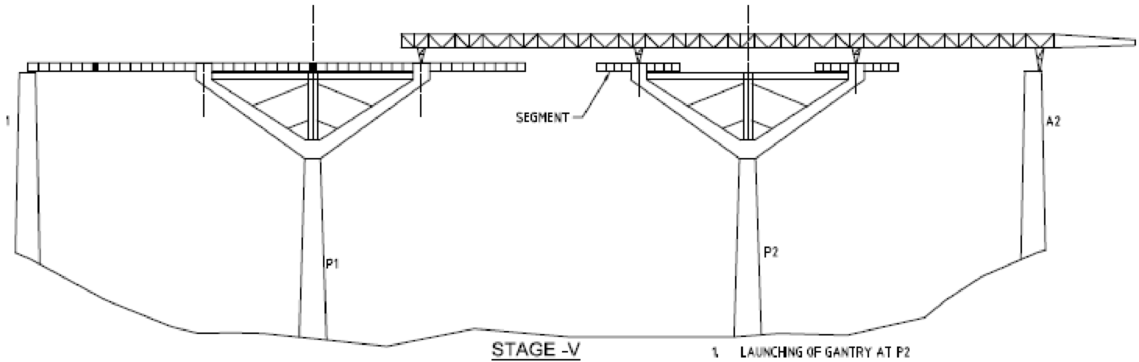
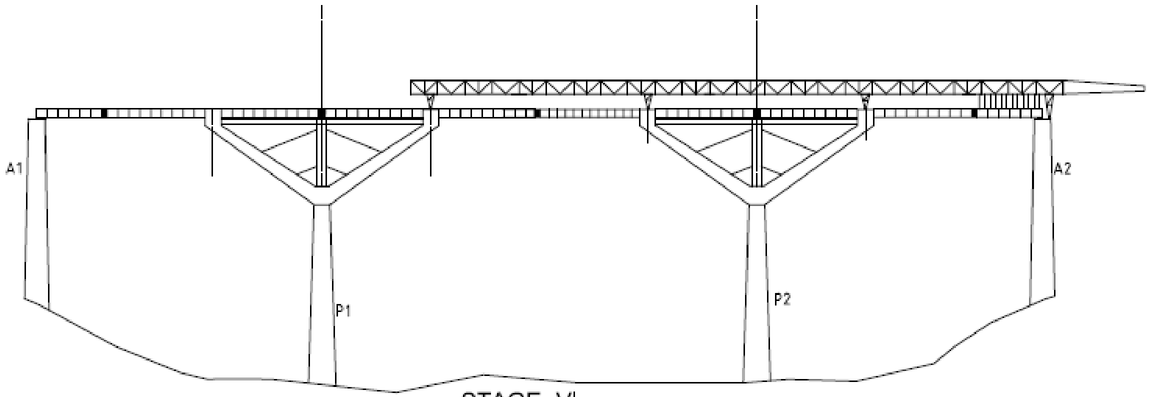

STITCH
GANTRY
STITCH
A1
P1
P2
A2
STAGE -IV
SCALE 1:1000
1. ERECTION OF SPAN SEGMENTS AT A1-P1
2. STITCHING OF SEGMENTS AND ESTABLISHING DECK CONTINUITY
3. SHIFT GANTRY LATERALLY AND REPEAT SEGMENT ERECTION FOR ADJACENT BOX
4.PRESTRESS TWIN BOXES LATERALLY FOR EACH CARRIAGEWAY

Figure 15



STAGE -V
SCALE 1:1000

1. LAUNCHNG OF GANTRY AT P2
2. ERECTION OF CANTILEVER SEGMENTS AT P2 IN SEQUENTIAL MANNER



STAGE -VI
SCALE 1:1250

1. ERECTION OF SEGMENTS AT SPAN 5 (P2-A2) AND ESTABLISHING DECK CONTINUITY & STITCHING OF SEGMENTS.
2. SHFT GANTRY LATERALLY AND REPEAT SEGMENT ERECTION FOR ADJACENT BOX .
3. RCC JOINING OF TWIN BOXES LATERALLY.

Figure 16

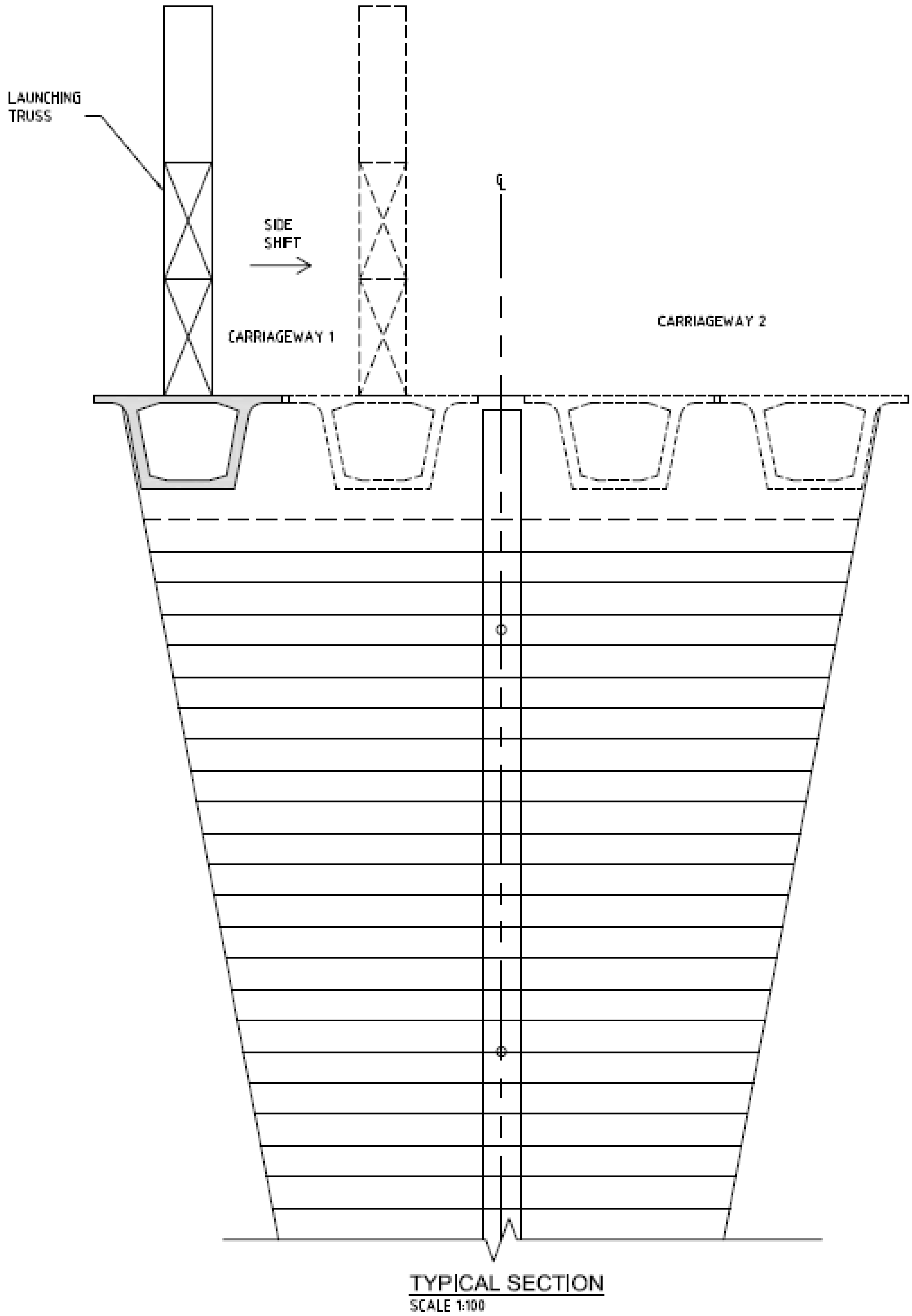

LAUNCHING TRUSS
SIDE SHIFT
CARRIAGEWAY 1
CARRIAGEWAY 2
TYPICAL SECTION
SCALE 1:100

Figure 17

4.1 FOR APPROACH VIADUCT PORTION:

Precast segmental type erected by span by span method of construction on launching truss is proposed. Since the deck is in gradient the proposed erection technique requires arrangement to lower the superstructure assembly at on end. Foundation is assumed to be designed for eccentric loading due to one side deck dead load (as erection may not be simultaneous). Structural bearing assembly will be locked & released after construction.

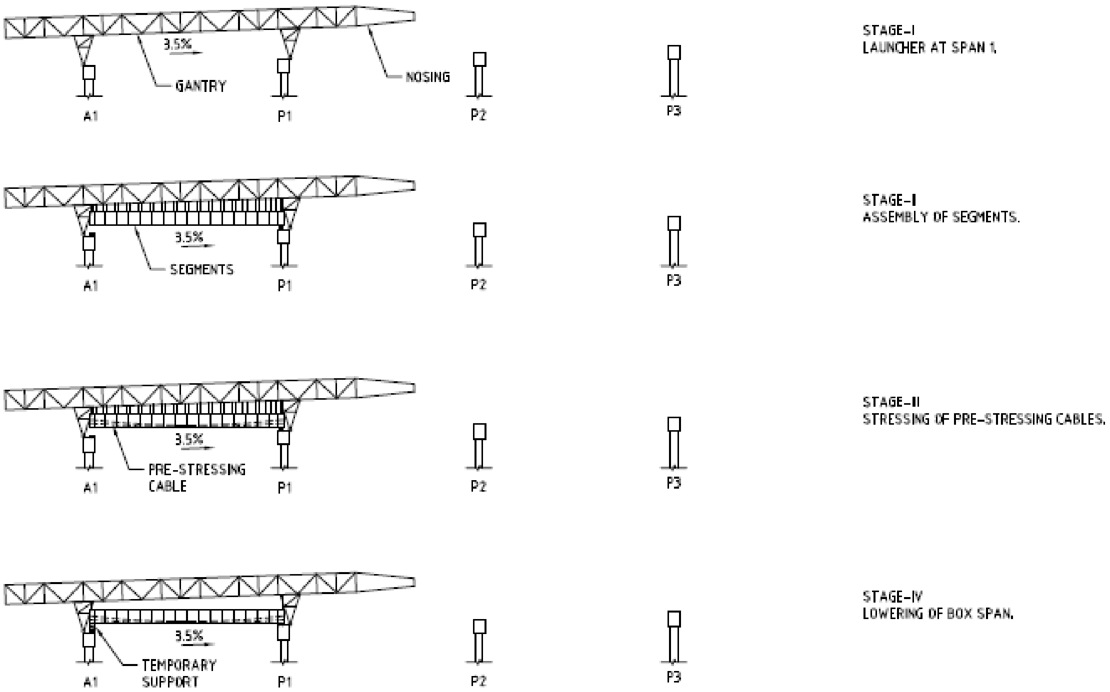


Figure 18

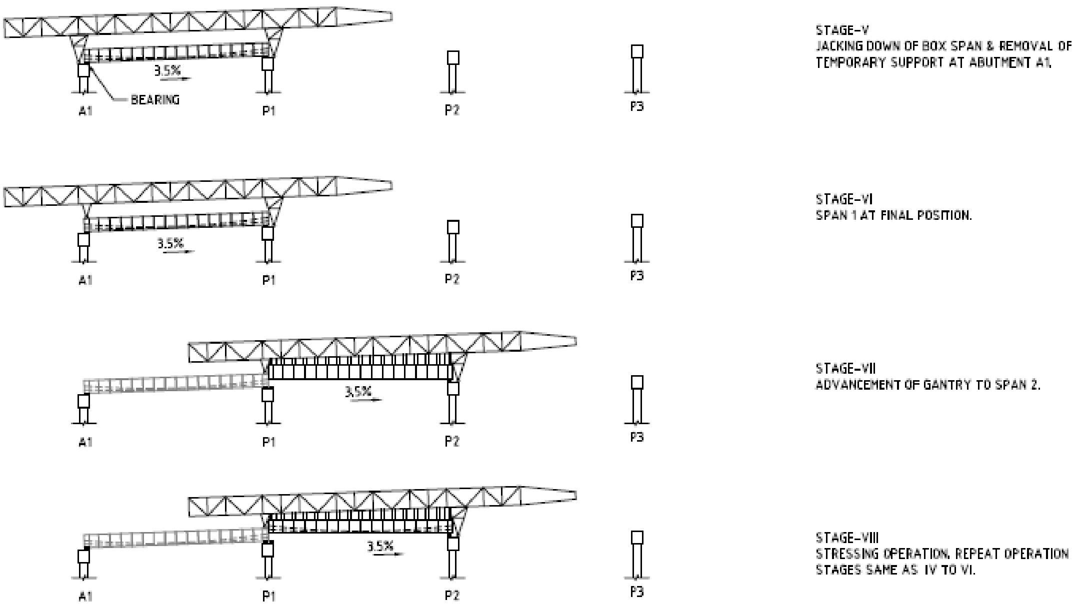


Figure 19

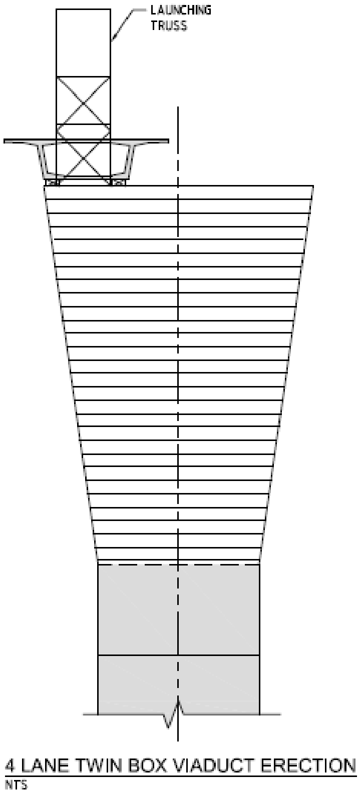


Figure 20

5 DETAILED DESIGN METHODOLOGY

The 3-D space frame model of special bridge used for stage by stage analysis in order to assess long term effects. Foundation are as supports with releases to simulate the bearing fixity.

The width of bearing support provided at girders over the pier caps have been shown on the next sheet to be more than the minimum value specified in fig 16 of the IRC :6.

6 ROCK EVALUATION

An interpolated rock profile is developed along the viaduct/special bridge portion and is presented in the Geotechnical Report.

6.1 CALCULATION OF BEARING CAPACITY

Geotechnical capacities assumed as 100 t/m^2 (under investigation and review) based on the good quality rock anticipated in the area.

6.2 CALCULATION OF PILE CAPACITY (IF ANY)

Geotechnical capacities for 1.2 m dia. piles assumed as 950 t and 1.5 m dia. pile as 1500t.

7 SOFTWARE USED

1. STAADpro by Research Engineers
2. Various Spreadsheet prepared in-house.

8 VALUE ADDITION

We propose followings as part of value addition to the project.

a. Provision of glass barrier (alternative to provision of sound absorbing panel).

It is suggested that the glass panels are to be provided at the outer parapet of the viaduct in order to protect forest inhabitants from the noise due to traffic. At the same time the road user will enjoy the scenic beauty at the end of tunnel. No barrier at the median is suggested as the road user may prefer a human interaction after they come out of the tunnel portion (subjected to acoustic study).

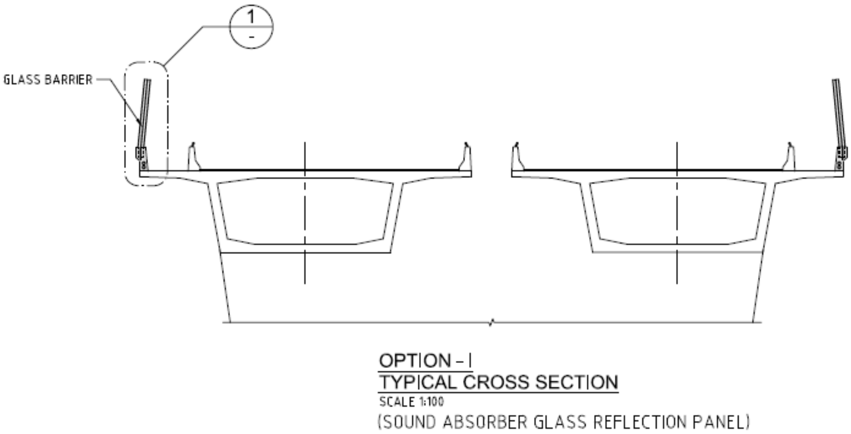


Figure 21

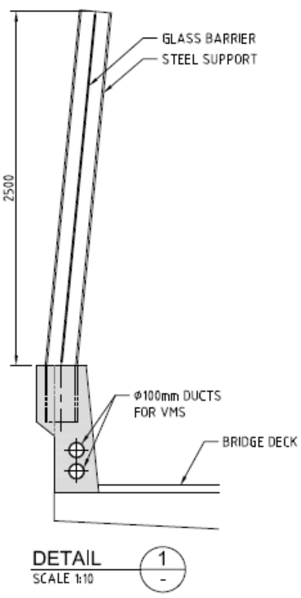


Figure 22

b. The **pedestrian parapet** shown is different than the typical IRC handrail which are prone to distress(cracking, spalls etc.) along with the noise barrier .

c. Provision of **HDPE ducts** in the parapet is recommended with proper junction box etc. as per intelligent highway design feature requirement.

d. We propose long **approach slab at the bridge embankment (refer to Typical GAD)** in order to address issue of settlement commonly occurs. More over the approach slab proposed is buried below the road matrix in order to minimize the differential settlement between flexible and rigid pavement.

-------- End of main document --------

9 TABLE OF APPENDICES

Appendix – 1

Design of Post Tensioned Twin Box Girder for Standard 50m Span Pier

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

Introduction:

1. Dimensions of the girder -	1. Center to Center of expansion joints	=	50	m
	2.Total length of segments	=	49.95	m
	3. Center to Center of Bearings (Effective Span)	=	47.95	m
	4. Depth	=	3	m
	5.Outer Diaphragm		0.5	m

2. Grade of concrete: The minimum grade of concrete M45 for girder & Diaphragm
Concrete cover 45mm

3. SIDL: Weight of Wearing Coat, parapet ,handrail and noise barrier(if any).

The design note is presented for the overall Girder. In presence of close box (torsionally rigid) the load is assumed to act on whole box. Calculation for bearing is done for both normal case and seismic case .

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

SIDL

			W (kN/m)
a.Wearing Coat	0.065 m @	22 kN/m^3	**7.87**
	0.025 m x	1.5 m	**0.00**

b. Parapet + barrier ***

	W (kN/m)
1	**10**

Total a. to b. **17.9** kN/m

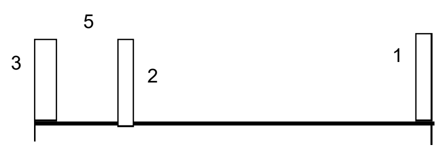
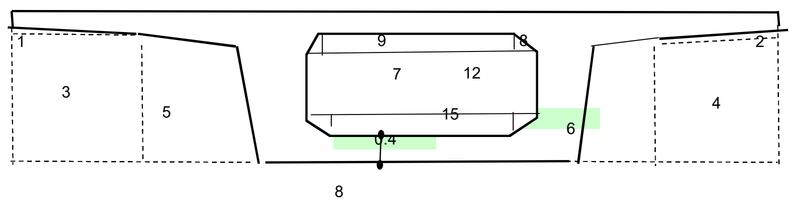


Fig.1

*** *Only Item 1 considered for live load side.*

Section just after Support location :

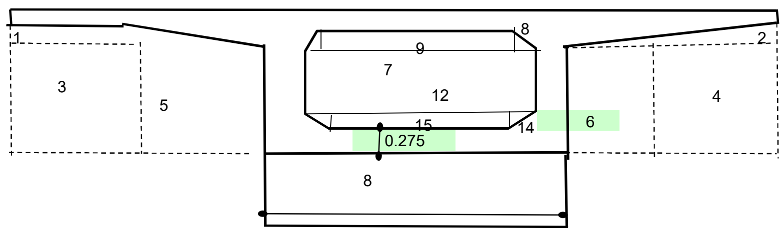


Component	w	d	Shape	A (m^2)	y (m)	A x y(m^3)	y' (m)	A x y'^2(m^4)	$I_{c.g}$(m^4)	I_{z-z}(m^4)
Whole	**6.05**	**3**	***Rectangle***	**18.15**	**1.5**	**27.23**	**0.17**	**0.51**	**13.6125**	**14.122**
1	0.00	0.00	***Triangle***	0.00	2.60	0.00	0.93	0.00	0.0000	0.00
2	0.00	0.00	***Triangle***	0.00	2.60	0.00	0.93	0.00	0.0000	0.00
3	0.85	2.75	***Rectangle***	-2.34	1.38	-3.21	0.29	-0.20	-1.4731	-1.67
4	0.85	2.75	***Rectangle***	-2.34	1.38	-3.21	0.29	-0.20	-1.4731	-1.67
5	0.18	2.60	***Rectangle***	-0.46	1.30	-0.59	0.37	-0.06	-0.2563	-0.32
6	0.18	2.60	***Rectangle***	-0.46	1.30	-0.59	0.37	-0.06	-0.2563	-0.32
5a	0.18	0.15	***Triangle***	-0.01	2.65	-0.03	0.98	-0.01	0.0000	-0.01
5b	0.50	2.60	***Triangle***	-0.65	0.87	-0.56	0.80	-0.42	-0.2441	-0.66
6a	0.18	0.15	***Triangle***	-0.01	2.65	-0.03	0.98	-0.01	0.0000	-0.01
6b	0.50	2.60	***Triangle***	-0.65	0.87	-0.56	0.80	-0.42	-0.2441	-0.66
7	2.16	2.20	***Rectangle***	-4.74	1.50	-7.11	0.17	-0.13	-1.9122	-2.05
7a	0.43	2.20	***Triangle***	-0.47	1.87	-0.87	0.20	-0.02	-0.1257	-0.14
7b	0.43	2.20	***Triangle***	-0.47	1.87	-0.87	0.20	-0.02	-0.1257	-0.14
8	0.60	0.12	***Triangle***	-0.04	2.64	-0.10	0.97	-0.03	0.0000	-0.03
9	1.80	0.12	***Rectangle***	-0.22	2.66	-0.57	0.99	-0.21	-0.0003	-0.21
10	0.60	0.12	***Triangle***	-0.04	2.64	-0.10	0.97	-0.03	0.0000	-0.03
14	0.50	0.00	***Triangle***	0.00	0.40	0.00	1.27	0.00	0.0000	0.00
15	1.35	0.00	***Rectangle***	0.00	0.40	0.00	1.27	0.00	0.0000	0.00
16	0.50	0.00	***Triangle***	0.00	0.40	0.00	1.27	0.00	0.0000	0.00
				5.2744		**8.80**				**6.177**

Properties of the Section:		
c.g of section from bottom of Girder, y_b	***1.668***	m
c.g of section from top of Girder, y_t	***1.332***	m
Moment of Inertia about c.g. of section, I_{z-z}	***6.177***	m^4
Section modulus for bottom, Z_b	***3.705***	m^3
Section modulus for top, Z_t	***4.636***	m^3
Area of section	***5.274***	m^2
Weight per meter	***13.186***	T/m

A

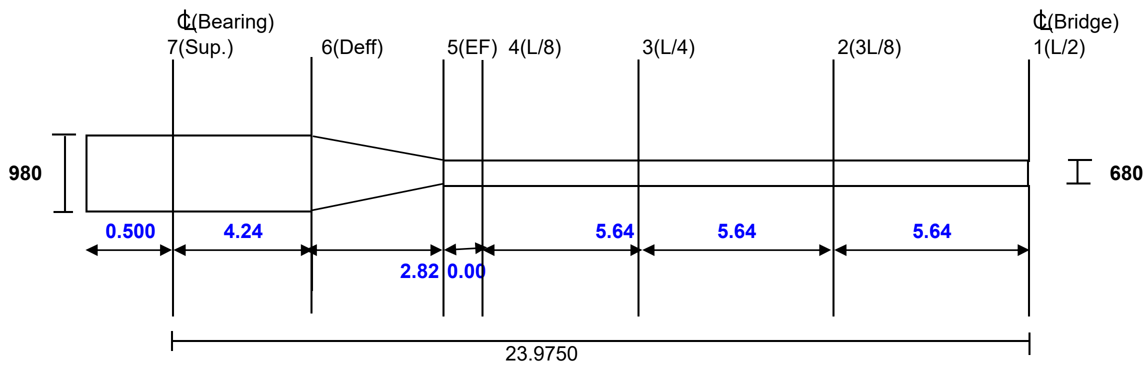
Section @ start of flaring portion :



Component	w	d	Shape	A (m^2)	y (m)	A x y(m^3)	y' (m)	A x y'^{2}(m^4)	$I_{c.g}$ (m^4)	I_{z-z} (m^4)
Whole	**6.05**	**3**	**Rectangle**	**18.15**	**1.5**	**27.23**	**0.08**	**0.11**	**13.6125**	**13.724**
1	0.00	0.05	Triangle	0.00	2.62	0.00	1.04	0.00	0.0000	0.00
2	0.00	0.05	Triangle	0.00	2.62	0.00	1.04	0.00	0.0000	0.00
3	0.85	2.75	Rectangle	-2.34	1.38	-3.21	0.20	-0.10	-1.4731	-1.57
4	0.85	2.75	Rectangle	-2.34	1.38	-3.21	0.20	-0.10	-1.4731	-1.57
5	0.18	2.60	Rectangle	-0.46	1.30	-0.59	0.28	-0.04	-0.2563	-0.29
6	0.18	2.60	Rectangle	-0.46	1.30	-0.59	0.28	-0.04	-0.2563	-0.29
5a	0.18	0.15	Triangle	-0.01	2.65	-0.03	1.07	-0.02	0.0000	-0.02
5b	0.50	2.60	Triangle	-0.65	0.87	-0.56	0.71	-0.33	-0.2441	-0.57
6a	0.18	0.15	Triangle	-0.01	2.65	-0.03	1.07	-0.02	0.0000	-0.02
6b	0.50	2.60	Triangle	-0.65	0.87	-0.56	0.71	-0.33	-0.2441	-0.57
7	2.46	2.20	Rectangle	-5.41	1.60	-8.66	0.02	0.00	-2.1828	-2.19
7a	0.42	2.20	Triangle	-0.46	1.97	-0.91	0.39	-0.07	-0.1242	-0.19
7b	0.42	2.20	Triangle	-0.46	1.97	-0.91	0.39	-0.07	-0.1242	-0.19
8	0.75	0.15	Triangle	-0.06	2.63	-0.15	1.05	-0.06	-0.0001	-0.06
9	1.80	0.15	Rectangle	-0.27	2.78	-0.75	1.20	-0.39	-0.0005	-0.39
10	0.75	0.15	Triangle	-0.06	2.75	-0.15	1.17	-0.08	-0.0001	-0.08
14	0.50	0.10	Triangle	-0.03	0.34	-0.01	1.24	-0.04	0.0000	-0.04
15	1.46	0.10	Rectangle	-0.15	0.33	-0.05	1.25	-0.23	-0.0001	-0.23
16	0.50	0.10	Triangle	-0.03	0.34	-0.01	1.24	-0.04	0.0000	-0.04
				4.3242		**6.83**				**5.419**

Properties of the Section:		
c.g of section from bottom of Girder, y_b	***1.578***	m
c.g of section from top of Girder, y_t	***1.422***	m
Moment of Inertia about c.g. of section, I_{z-z}	***5.419***	m^4
Section modulus for bottom, Z_b	***3.433***	m^3
Section modulus for top, Z_t	***3.812***	m^3
Area of section	***4.324***	m^2
Weight per meter	***10.811***	T/m

SECTIONS OF GIRDER



WEB PLAN

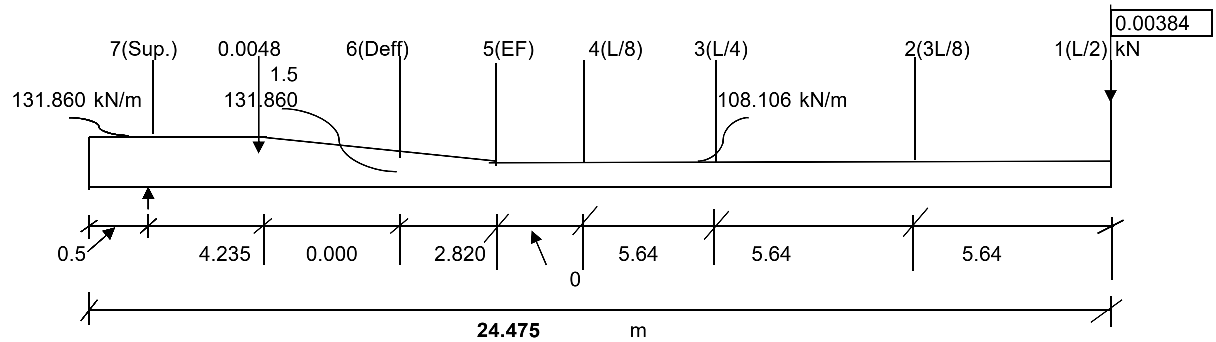
Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

CALCULATION OF BENDING MOMENTS AND SHEAR FORCES

DUE TO SELF WEIGHT OF GIRDER

Dead Load (DL)

UDL at mid span	=	4.324	x	25	=	**108.106**	kN/m
UDL at support	=	5.274	x	25	=	**131.860**	kN/m



24.475 m

Effective half span = **23.975** m

Reaction at each support	=	131.860	x	4.735			
	+	108.106	x	16.92			
	+ 0.5 x (	131.860	+	108.106) x		2.820	
		0.002	+	0.005			
	=	**2791.87**	**kN**				
Bending Moment at sec. 1 (L/2)	=	2791.87	x	23.975			
	-	131.860	x	4.735	x	22.108	
	-	108.106	x	16.920	x	8.460	
	-	119.983	x	2.820	x	18.375	
	-	0.005	x			22.475	
	=	**31440.2**	**kN-m**				
Shear at sec. 1 (L/2)	=	**0**	**kN**				
Bending Moment at sec. 2 (3L/8)	=	2791.87	x	18.335			
	-	131.860	x	4.735	x	16.468	
	-	108.106	x	11.280	x	5.640	
	-	119.983	x	2.820	x	12.735	
	-	0.005	x			16.835	
	=	**29720.8**	**kN-m**				
Shear at sec. 2 (3L/8)	=	2791.87	-	131.860	x	4.735	
	-	119.983	x	2.820			
	-	108.106	x	11.280			
	=	**609.7**	**kN**				
Bending Moment at sec. 3 (L/4)	=	2791.87	x	12.695			
	-	131.860	x	4.735	x	10.828	
	-	108.106	x	5.640	x	2.820	
	-	119.983	x	2.820	x	7.095	
	-	0.005	x			11.195	
	=	**24562.5**	**kN-m**				

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

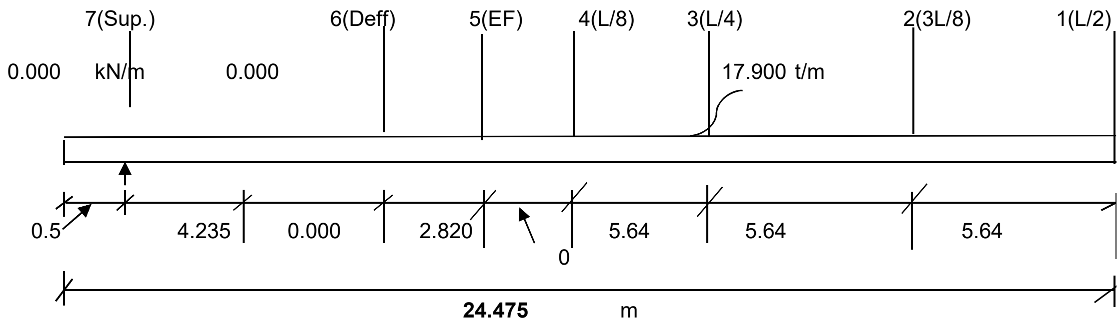
Shear at sec. 3 (L/4)	=		2791.87	-	131.860	x	4.735
	-		119.983	x	2.820		
	-		108.106	x	5.640		
	=		**1219.4**	**kN**			
Bending Moment at sec. 4 (L/8)	=		2791.87	x	7.055		
		-	131.860	x	4.735	x	5.188
		-	108.106	x	0.000	x	0.000
		-	119.983	x	2.820	x	1.455
		-	0.005	x			5.555
	=		**15965.5**	**kN-m**			
Shear at sec. 4 (L/8)	=		2791.87	-	131.860	x	4.735
	-		119.983	x	2.820		
	-		108.106	x	0.000		
	=		**1829.2**	**kN**			
Bending Moment at sec. 5 (EF)	=		2791.87	x	7.055		
		-	131.860	x	4.735	x	5.188
		-	119.983	x	2.820	x	1.455
		-	0.005	x			5.555
	=		**15965.5**	**kN-m**			
Shear at sec. 5 (EF)	=		2791.87	-	131.860	x	4.735
	-		119.983	x	2.820		
	=		**1829.2**	**kN**			
Bending Moment at sec. 6 (Deff))	=		2791.87	x	4.235		
		-	131.860	x	4.735	x	2.368
		-	131.860	x	0.000	x	0.000
		-	0.005	x			2.735
	=		**10345.4**	**kN-m**			
Shear at sec. 6 (Deff)	=		2791.87	-	131.860	x	4.735
	-		131.860	x	0.000		
	=		**2167.5**	**kN**			
Bending Moment at sec. 7 (Sup.)	=		2791.87	x	0.000		
		-	131.860	x	0.5	x	0.250
		-	131.860	x	0.000	x	0.000
	=		**-16.48**	**kN-m**			
Shear at sec. 7 (Sup.)	=		2791.87	-	131.860	x	0.5
	-		131.860	x	0.000		
	=		**2725.9**	**kN**			

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date
		2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

CALCULATION OF BENDING MOMENTS AND SHEAR FORCES

DUE TO WEIGHT OF SIDL

UDL at mid span = = **17.900** kN/m



24.475 m

Effective half span = **23.975** m

Reaction at each support = 17.900 x 24.475

= **438.10** **kN**

Bending Moment at sec. 1 (L/2) = 438.10 x 23.975
- 17.900 x 24.475 x 12.238

= **5142.2** **kN-m**

Shear at sec. 1 (L/2) = **0** **kN**

Bending Moment at sec. 2 (3L/8) = 438.10 x 18.335
- 17.900 x 18.835 x 9.418

= **4857.5** **kN-m**

Shear at sec. 2 (3L/8) = 438.10 - 17.900 x 18.835

= **101.0** **kN**

Bending Moment at sec. 3 (L/4) = 438.10 x 12.695
- 17.900 x 13.195 x 6.598

= **4003.4** **kN-m**

Shear at sec. 3 (L/4) = 438.10 - 17.900 x 13.195

= **201.9** **kN**

Bending Moment at sec. 4 (L/8)	=		438.10	x	7.055		
		-	17.900	x	7.555	x	3.778
	=		**2580.0**	**kN-m**			
Shear at sec. 4 (L/8)	=		438.10	-	17.900	x	7.555
	=		**302.9**	**kN**			
Bending Moment at sec. 5 (EF)	=		438.10	x	7.055		
		-	17.900	x	7.555	x	3.778
	=		**2580.0**	**kN-m**			
Shear at sec. 5 (EF)	=		438.10	-	17.900	x	7.555
	=		**302.9**	**kN**			
Bending Moment at sec. 6 (Deff)	=		438.10	x	4.235		
		-	17.900	x	4.735	x	2.368
	=		**1654.7**	**kN-m**			
Shear at sec. 6 (Deff)	=		438.10	-	17.900	x	4.735
	=		**353.3**	**kN**			
Bending Moment at sec. 7 (Sup.)	=		438.10	x	0.000		
		-	17.900	x	0.500	x	0.250
	=		**-2.2**	**kN-m**			
Shear at sec. 7 (Sup.)	=		438.10	-	17.900	x	0.500
	=		**429.2**	**kN**			

SUMMARY OF B.M.(kN-m) & S.F.(kN) DUE TO VARIOUS LIVE LOAD POSITIONS

Type of Loading	Support				Deff			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**-9.68**	**1262.20**	**1262.20**	**-208.46**	**3944.75**	**886.00**	**1017.90**	**3550.28**
Design Force	**-9.68**	1262.20	1262.20	**0.00**	3944.75	886.00	1017.90	3550.28

Type of Loading	End of flaring				L/8			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**6475.41**	**776.74**	**912.98**	**4833.06**	**6475.41**	**776.74**	**912.98**	**4833.06**
Design Force	6475.41	776.74	912.98	4833.06	6475.41	776.74	912.98	4833.06

Type of Loading	L/4				3L/8				L/2			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**10017.70**	**534.00**	**759.51**	**8285.25**	**12142.76**	**394.00**	**612.31**	**10356.56**	**12892.88**	**0.00**	**463.54**	**11047.00**
Design Force	10017.70	534.00	759.51	8285.25	12142.76	394.00	612.31	10356.56	12892.88	0.00	463.54	11047.00

SUMMARY OF BENDING MOMENTS (kN-m) & SHEAR FORCES FROM STAAD ANALYSIS (kN)

SECTION	Precast beam		Deck slab		Construction Live load		SIDL		Live load (LL)			
									Max. B.M. & Corr. S.f.		Max. S.F. & Corr. B.M.	
	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)
SECTION 1(L/2)	31440.17	0.00	4.17	0.00	172.37	0.00	**5142.228**	**0**	12892.88	0.00	11047.00	463.54
SECTION 2(3L/8)	29720.75	609.73	3.94	0.08	162.82	3.38	**4857.532**	**100.956**	12142.76	394.00	10356.56	612.31
SECTION 3(L/4)	24562.51	1219.45	3.25	0.16	134.19	6.77	**4003.444**	**201.912**	10017.70	534.00	8285.25	759.51
SECTION 4(L/8)	15965.46	1829.16	2.09	0.25	86.48	10.15	**2580.0**	**302.868**	6475.41	776.74	4833.06	912.98
SECTION 5(EF)	15965.46	1829.16	2.09	0.25	86.48	10.15	**2580.0**	**302.868**	6475.41	776.74	4833.06	912.98
SECTION 6(Deff)	10345.40	2167.52	1.34	0.29	55.46	11.84	**-2.2375**	**353.346**	3944.75	886.00	3550.28	1017.90
SECTION 7(Sup.)	-16.48	2725.94	0.00	0.35	-0.08	14.39	**0**	**429.1525**	-9.68	1262.20	0.00	1262.20

SUMMARY OF PRESTRESSING FORCE

CABLE IN STAGE 1 :

SECT	From Friction and Slip Loss Analysis : cable 1			From Friction and Slip Loss Analysis : Cable 2			From Friction and Slip Loss Analysis :cable 3			From Friction and Slip Loss Analysis : cable 4			TOTAL		
	HOR. P (kN)	VERT. P (kN)	cg fr soff (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)
1(L/2)	7049.00	0.00	0.3500	7049.00	0.00	0.1250	7049.00	0.00	0.1250	7049.00	0.00	0.1250	31906.0	0.000	0.1747
2(3L/8)	7049.00	0.00	0.6715	7049.00	0.00	0.4650	7049.00	0.00	0.2950	7049.00	160.64	0.1250	31906.0	263.618	0.3584
3(L/4)	7049.00	0.00	0.8111	7049.00	24.71	0.5267	7049.00	230.46	0.2955	7049.00	345.60	0.1250	31906.0	824.175	0.4030
4(L/8)	7049.00	0.00	1.0009	7049.00	295.89	0.6761	7049.00	417.34	0.3705	7049.00	489.43	0.1250	31906.0	1514.971	0.4945
5(EF)	7049.00	0.00	1.0009	7049.00	295.89	0.6761	7049.00	417.34	0.3705	7049.00	489.43	0.1250	31906.0	1514.971	0.4945
6(Deff)	7049.00	296.89	1.1474	7049.00	450.99	0.8081	7049.00	525.30	0.4765	7049.00	572.97	0.1663	31906.0	2211.286	0.5934
7(Sup.)	7049.00	530.17	1.3996	7049.00	574.52	1.0510	7049.00	611.51	0.7033	7049.00	639.62	0.1663	31906.0	2763.462	0.7529

Part of cable c3 used= 1
Part of cable c4 used= 1.000

Part of cable c5 used= 0.52632

SECT	From Friction and Slip Loss Analysis : cable 5			From Friction and Slip Loss Analysis : cable 6			From Friction and Slip Loss Analysis : 2			From Friction and Slip Loss Analysis : 2			TOTAL		
	HOR. P (kN)	VERT. P (kN)	cg fr soff (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)
1(L/2)	7049.00	0.00	0.1250	1.00	0.00	0.2607	0.00	0.00	0.4000	0.00	0.00	0.4000	0.000	0.000	0.0000
2(3L/8)	7049.00	195.67	0.1250	0.00	0.00	0.2758	0.00	0.00	0.1200	0.00	0.00	0.1200	0.000	0.000	0.0000
3(L/4)	7049.00	424.48	0.1250	0.00	0.00	0.3832	0.00	0.00	0.1340	0.00	0.00	0.1340	0.000	0.000	0.0000
4(L/8)	7049.00	593.39	0.1250	0.00	0.00	0.5942	0.00	0.00	0.2120	0.00	0.00	0.2120	0.000	0.000	0.0000
5(EF)	7049.00	593.39	0.1250	0.00	0.00	0.5942	0.00	0.00	0.2300	0.00	0.00	0.2300	0.000	0.000	0.0000
6(Deff)	7049.00	693.77	0.1663	0.00	0.00	0.7324	0.00	0.00	0.3770	0.00	0.00	0.3770	0.000	0.000	0.0000
7(Sup.)	7049.00	774.52	0.1663	0.00	0.00	0.9067	0.00	0.00	0.6440	0.00	0.00	0.6440	0.000	0.000	0.0000

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 3-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

PROGRAM FOR STRESS CHECK
and evaluation of relaxation, shrinkage creep & elastic shortening losses
(at section 1 (L/2) i.e. MID SPAN)

B. M. DUE TO DEAD LOAD(1) =	**31440.17**	kN-m	(wt. Of Girder)
B. M. DUE TO DEAD LOAD(2) =	**4.17**	kN-m	(wt. Of slab)
B. M. DUE TO Const. Live Load =	**172.37**	kN-m	
BENDING MOMENT DUE TO SIDL =	**5142.2281**	kN-m	
BENDING MOMENT DUE TO LL =	**12892.88**	kN-m	

SECTION PROPERTIES	Yt	Yb	Zt (Girder Top/ Bottom Level)	Zb (Girder Top/ Bottom Level)	A
Girder	1.422	1.578	3.8118	3.4335	4.3242

Modulus of Elasticity of cable			**2.00E+08**	kN/m^2
Nominal cross-sectional Area of each strand			**140.00**	mm^2
Cross-Sectional Area of each Tendon	**19**	T15	2660.00	mm^2
	19	T15	2660.00	mm^2
Sheathing Dia (ID)			**110.00**	mm
UTS	19	T15	5035.00	kN
	19	T15	5035.00	kN
Characteristic Strength of concrete …	f_{ck}	=	**45**	N/mm^2

	1st Stage	2nd Stage	Total
NO. OF CABLES IN	**9.05**	**0.00**	9.05
PRESTRESSING FORCE	31906.00	0.00	31906.00
CG of Cables From Bottom	0.175	0.0000	0.1747
Concrete strength at time of stressing (Mpa)	**35**	**45**	
Total vertical prestressing force(kN)	0.0		

SUMMARY OF STRESSES

DESCRIPTION	FORCE (kN)	MOMENT (kN-m)	STRESS AT TOP PART (kN / m ^{2})	STRESS AT TOP CUMMU (kN / m ^{2})	STRESS AT BOTTOM PART (kN / m ^{2})	STRESS AT BOTTOM CUMMU (kN / m ^{2})		
DEAD LOAD (1)		31440.17	8248.04	8248.04	-9157.00	-9157.00		
Ist STAGE PRESTRESS 0.9 P	28715.40		6640.55	14888.59	6640.55	-2516.45		
Ist STAGE PRESTRESS 0.9P*e		-40305.70	-10573.83	4314.76	11739.10	9222.65		
ELASTIC SHORTENING -I	-550.68	772.95	75.43	4390.19	-352.47	8870.18	<	17500
(For Loss Calculation Reffer Next Sheet)							>	-1750.0
RELAX + SHRINKAGE - I	-2739.35	3845.03	375.22	4765.41	-1753.36	7116.83		
(For Loss Calculation Reffer Next Sheet)								
CREEP - I	-496.35	696.68	67.99	4833.40	-317.69	6799.13		
(For Loss Calculation Reffer Next Sheet)								
2nd STAGE PRESTRESS P	0.00		0.00	4833.40	0.00	6799.13		
2nd STAGE PRESTRESS P*e		0.00	0.00	4833.40	0.00	6799.13	(At Day 28)	
ELASTIC SHORTENING -II	0.00	0.00	0.00	**4833.40**	0.00	**6799.13**	<	21600
(For Loss Calculation Reffer Next Sheet)							>	-2160.0
DEAD LOAD (2)		4.17	1.09	4834.49	-1.21	6797.92		
Construction LL		172.37	45.22	**4879.71**	-50.20	**6747.72**	<----Construction Stage	
Removal of CL		-172.37	-45.22	4834.49	50.20	6797.92		
SUPERIMPOSED DEAD LOAD		5142.23	1348.52	6183.02	-1497.53	5300.39		
RELAX + SHRINKAGE - II	-915.05	2728.99	504.09	6687.10	-1006.32	4294.06		
(For Loss Calculation Reffer Next Sheet)								
CREEP - II	-1070.80	1503.22	146.62	6833.72	-685.36	3608.70		
(For Loss Calculation Reffer Next Sheet)								
LIVE LOAD (75%)		9669.66	2535.82	**9369.54**	-2816.02	**792.67**		
Temp Case (Refer Temp Analysis)			-193.48	**9253.45**	-596.78	**434.61**		
60%								
Prestress Force after losses (kN)	22943.17							
% loss	28.09							

Average stress in concrete at CG of tendons av of 6684.66 and 1292.16 = 3988.41
Average stress in concrete at CG of tendons of all seven sections considered = 7394.69

ELASTIC SHORTENING LOSS FOR Ist & 2nd STAGE CABLES

2.5.1 Characteristic compressive strength :
Fckj = Fck*[2.008-1.213/(log10j)^0.5] where 'j' is in days. (As per Y.Guyon)
Elastic Modulus of concrete at j days = 5700*(Fckj)^0.5

Days	Char.Str. (MPa)	Ec (MPa)	Ec(kN/m^2)	Mod.Ratio
10	35.79	3E+04	3E+07	5.8
28	45.00	4E+04	4E+07	5.1

2.5.2 Basis of the Calculation

(a) For cables within the group:
Total Loss of prestress = 1/2*[(m*fcpa)*(n-1)*As]
where
m = Modular Ratio
n = no. of cables in the group
fcpa=average compressive stress in the concrete along the member length at cg of cables of group
fc = Increase in comp. stress in concrete due to cables of group at cg of cables of group at the section
As = C/S area of cable = 2660.00 mm^2

(b)For cables in the previous group:
Total loss of prestress= [m*fc' *n*As]
where
n=no. of cables in the previous group
fc' =increase in comp. in concrete due to cables of subsequent group at the section

	10 TO 28th DAY	**28th DAY TO INFINITY**
STRESS AT TOP	4314.76	0.00
STRESS AT BOTTOM	9222.65	0.00
STRESS AT C.G. OF Ist STAGE STEEL	8936.83	0.00
STRESS AT C.G. OF 2nd STAGE STEEL		0.00
LOSS DUE TO ELASTIC SHORTEN. IN STAGE 1 cables	550.68	0.00
LOSS DUE TO ELASTIC SHORTEN. IN STAGE 2 cables		0.00

SHRINKAGE AND RELAXATION LOSS

Loss due to Relaxation in Steel:

Basis of the Calculation (As per IRC:18 - 2000 cl.11.4 Table 4A)
(Long term loss 3 times 1000Hr. Loss)

Initial stress=fsi		% Total Loss	
0.80	U.T.S.	13.5%	
0.70	U.T.S.	7.5%	Intermediate Values can
0.50	U.T.S.	0.0%	be Interpolated

SHRINKAGE STRAIN AT BEGINING	**3.00E-04**	**1.90E-04**
(As per IRC:18-2000 cl. 11.3 Table -3)		
SHRINKAGE STRAIN AT END	**1.90E-04**	**0.00E+00**
SHRINKAGE LOSS IN STAGE 1 CABLES	529.76	915.04
SHRINKAGE LOSS IN STAGE 2 CABLES		0.01
AVERAGE FORCE IN STAGE 1 CABLES	3463.67	
AVERAGE FORCE IN STAGE 2 CABLES		0.00
AVG. FORCE/UTS FOR STAGE 1 CABLES	0.688	
AVG. FORCE/UTS FOR STAGE 2 CABLES		0.00
RELAXATION LOSS IN MPa	7.05%	0.00%
TOTAL RELAXATION LOSS (IN kN)	2209.59	0.00
TOTAL RELAXATION+SHRINKAGE LOSS	2739.35	915.05

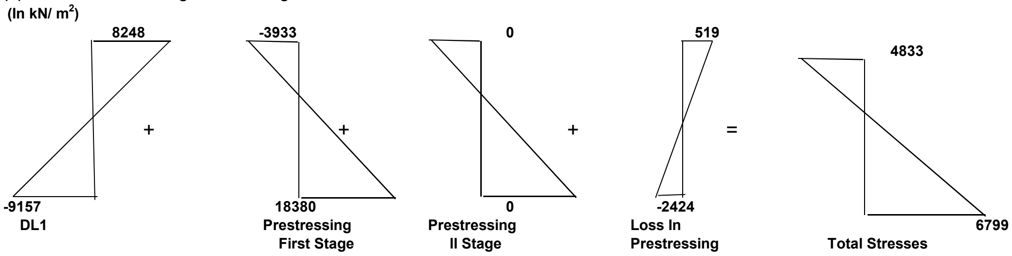
Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date
		3-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans	Rev. 0

CREEP LOSS

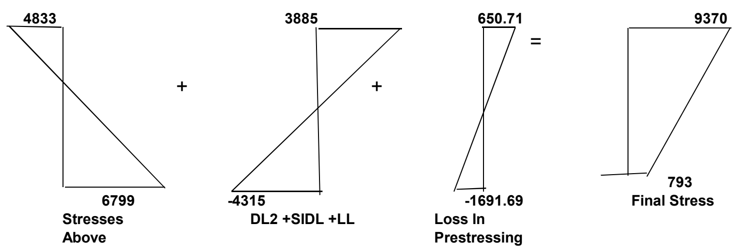
Maturity of concrete at time of stressing as % of fck (Mpa)		78		100.0
Creep strain at Maturity of concrete	70	6.10E-04	100	4.00E-04
	80	5.10E-04	110	3.60E-04
CREEP STRAIN AT BEGINING		5.32E-04		4.00E-04
(As per IRC:18-2000 cl. 11.2 Table -2)				
CREEP STRAIN AT END		4.00E-04		0.00E+00
STRESS AT TOP AT START		4390.19		4834.49
STRESS AT BOTTOM AT START		8870.18		6797.92
STRESS AT TOP AT END		4765.41		6687.10
STRESS AT BOTTOM AT END		7116.83		4294.06
AVERAGE STRESS AT TOP		4577.80		5760.80
AVERAGE STRESS AT BOTTOM		7993.50		5545.99
AVG. STRESS AT C.G. OF Ist STAGE STEEL		7794.58		5558.50
AVG. STRESS AT C.G. OF 2nd STAGE STEEL				5545.99
CREEP LOSS IN STAGE 1 CABLES		496.35		1070.79
CREEP LOSS IN STAGE 2 CABLES				0.01

Diagramatically Presentation of Stresses:

(A) At End Of Second Stage Prestressing:
(In kN/ m^2)



(B) At Service With Long Term Losses :
(At Girder Top and Bottom Level)
(In kN/ m^2)



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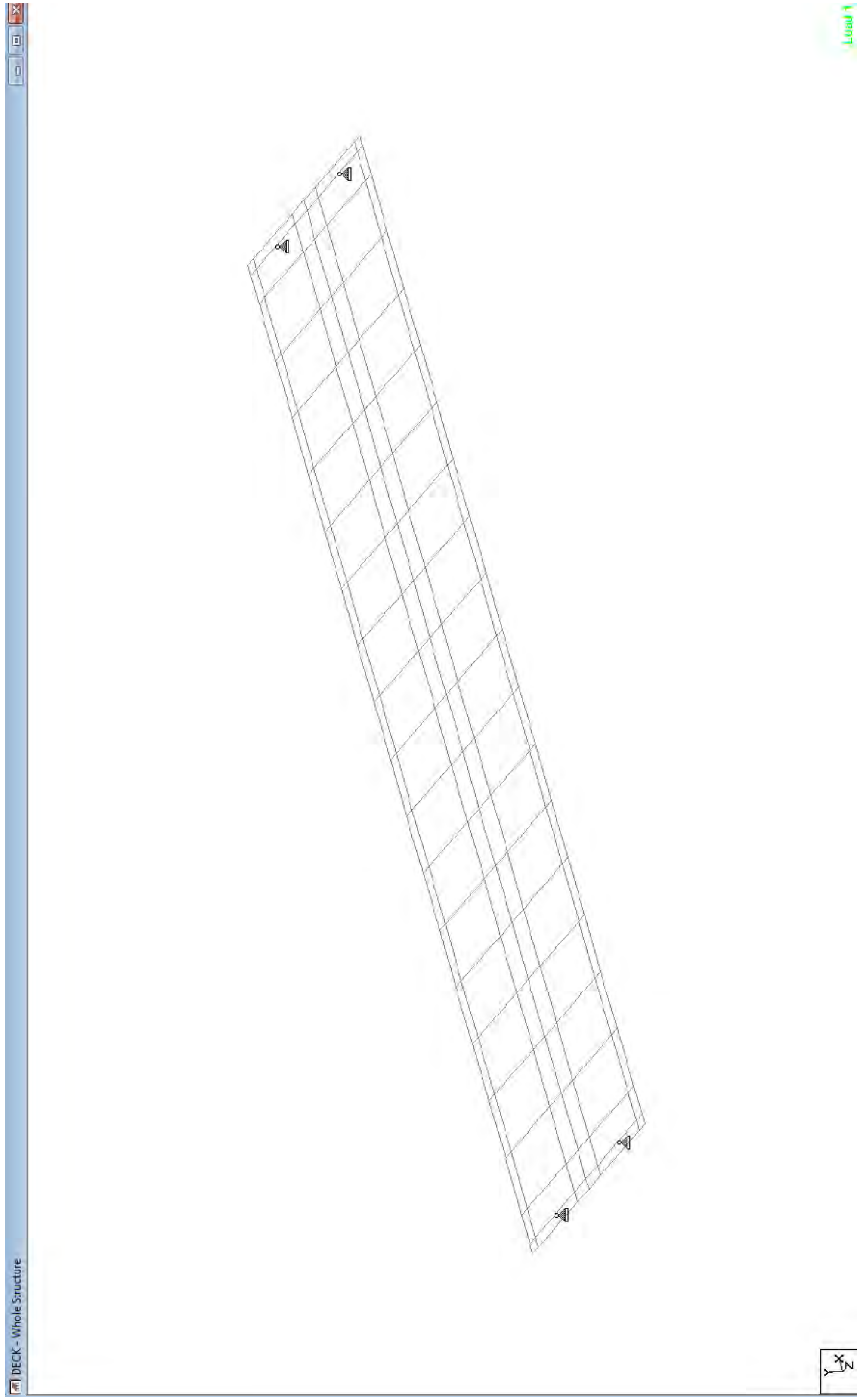

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STAAD SPACE

START JOB INFORMATION

ENGINEER DATE 14-OCT-15

END JOB INFORMATION

INPUT WIDTH 79

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UNIT METER KN

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12 27.295 0 0; 13 30.115 0 0; 14 32.935 0 0; 15 35.755 0 0; 16 38.575 0 0;

17 41.395 0 0; 18 44.215 0 0; 19 47.035 0 0; 20 48.45 0 0; 21 48.95 0 0;
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291 293 294 296 PRIS YD 0.25 ZD 2.82

292 295   PRIS AX 1.481 IX 5.535 IY 1 IZ 2.767

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298 301   PRIS AX 1.481 IX 5.535 IY 1 IZ 2.767

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304 307    PRIS AX 1.481 IX 5.535 IY 1 IZ 2.767
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321 TO 326 PRIS YD 0.1 ZD 0.1
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E 2.48e+007
DENSITY 24.5
POISSON 0.2
ISOTROPIC MATERIAL2
E 2.48e+007
POISSON 0.2
DENSITY 0
END DEFINE MATERIAL
CONSTANTS
*====================
*=====================================================
*****CONSTANTS FOR RAIL MEMBERS*****
*=====================================================
*BETA 0.00000 FX
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*G     1.0333333E7  FX
*POI   2.0000000E-01  FX
```

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*DEN   2.4500004E1  FX

*CTE   1.0800000E-05  FX

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MATERIAL MATERIAL2 MEMB 1 TO 20 61 TO 80 121 TO 140 201 TO 330

*

SUPPORTS

148 to 151 PINNED

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*CLASS A WHEEL LOAD

TYPE 1 LOAD 34 34 34 34 57 57 13.5 13.5

DIST 3 3 3 4.3 1.2 3.2 1.1 WID 1.8

*TYPE 2 LOAD 34 34 34 34 57 57 13.5 13.5

*DIST 3 3 3 4.3 1.2 3.2 1.1 WID 1.8

*CLASS 70R WHEEL LOAD

TYPE 3 LOAD 85 85 85 85 60 60 40

DIST 1.37 3.05 1.37 2.13 1.52 3.96 WID 1.93

LOAD GENERATION 150

TYPE 1 -18.8 0 9.3 XINC 0.5

*TYPE 2 -18.8 0 6.2 XINC 0.5

*TYPE 1 -18.8 0 4.2 XINC 0.5

*TYPE 2 -18.8 0 7.7 XINC 0.5

TYPE 3 -13.4 0 3.99 XINC 0.5

PERFORM ANALYSIS

PRINT MAXFORCE ENV LIST 21 to 40 41 to 60

FINISH
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Appendix – 2

Design of Post Tensioned Box Girder for Standard 50m Span Viaduct

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	**MORTH&H/ Karnataka PWD**	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

Introduction:

1. Dimensions of the girder -	1. Center to Center of expansion joints	=	50	m
	2.Total length of segments	=	49.95	m
	3. Center to Center of Bearings (Effective Span) =		47.95	m
	4. Depth	=	3	m
	5.Outer Diaphragm		0.5	m

2. Grade of concrete: The minimum grade of concrete M45 for girder & Diaphragm
   Concrete cover 45mm

3. SIDL: Weight of Wearing Coat, parapet ,handrail and noise barrier(if any).

The design note is presented for the overall Girder. In presence of close box (torsionally rigid) the load is assumed to act on whole box. Calculation for bearing is done for both normal case and seismic case .

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

SIDL Ref.

					W (kN/m)
a.Wearing Coat	0.065	m @	22	kN/m^3	**13.73**
	0.025	m x	1.5	m	**0.83**

b. Parapet + barrier

	W (kN/m)
1	**10**
2	**10**
3	**10**

Total a. to b. max. **44.6** kN/m

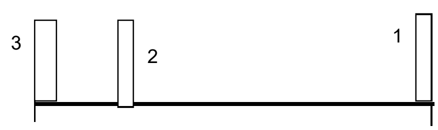
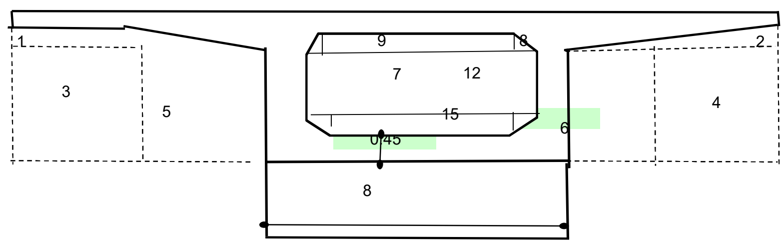


Fig.1

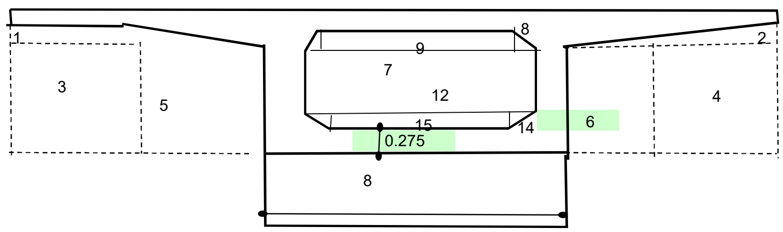
Section just after Support location :



Component	w	d	Shape	$A\ (m^2)$	y (m)	$A \times y (m^3)$	y' (m)	$A \times y'^2 (m^4)$	$I_{c.g} (m^4)$	$I_{z\text{-}z} (m^4)$
Whole	**12.3**	**3**	**Rectangle**	**36.9**	**1.5**	**55.35**	**0.18**	**1.14**	**27.6750**	**28.811**
1	1.50	0.05	Triangle	-0.04	2.57	-0.10	0.89	-0.03	0.0000	-0.03
2	1.50	0.05	Triangle	-0.04	2.57	-0.10	0.89	-0.03	0.0000	-0.03
3	1.50	2.75	Rectangle	-4.13	1.38	-5.67	0.30	-0.37	-2.5996	-2.97
4	1.50	2.75	Rectangle	-4.13	1.38	-5.67	0.30	-0.37	-2.5996	-2.97
5	1.00	2.55	Rectangle	-2.55	1.28	-3.25	0.40	-0.41	-1.3818	-1.79
6	1.00	2.55	Rectangle	-2.55	1.28	-3.25	0.40	-0.41	-1.3818	-1.79
5a	1.00	0.20	Triangle	-0.10	2.62	-0.26	0.94	-0.09	-0.0002	-0.09
5b	0.50	2.55	Triangle	-0.64	0.85	-0.54	0.83	-0.43	-0.2303	-0.66
6a	1.00	0.20	Triangle	-0.10	2.62	-0.26	0.94	-0.09	-0.0002	-0.09
6b	0.50	2.55	Triangle	-0.64	0.85	-0.54	0.83	-0.43	-0.2303	-0.66
7	5.28	2.08	Rectangle	-10.95	1.49	-16.28	0.19	-0.39	-3.9273	-4.31
7a	0.38	2.08	Triangle	-0.39	1.83	-0.71	0.16	-0.01	-0.0931	-0.10
7b	0.38	2.08	Triangle	-0.39	1.83	-0.71	0.16	-0.01	-0.0931	-0.10
8	1.25	0.18	Triangle	-0.11	2.58	-0.28	0.91	-0.09	-0.0002	-0.09
9	3.54	0.18	Rectangle	-0.62	2.61	-1.62	0.94	-0.54	-0.0016	-0.55
10	1.25	0.18	Triangle	-0.11	2.58	-0.28	0.91	-0.09	-0.0002	-0.09
14	1.20	0.00	Triangle	0.00	0.45	0.00	1.23	0.00	0.0000	0.00
15	3.38	0.00	Rectangle	0.00	0.45	0.00	1.23	0.00	0.0000	0.00
16	1.20	0.00	Triangle	0.00	0.45	0.00	1.23	0.00	0.0000	0.00
				9.4384		**15.81**				**12.474**

Properties of the Section:		
c.g of section from bottom of Girder, y_b	**1.675**	m
c.g of section from top of Girder, y_t	**1.325**	m
Moment of Inertia about c.g. of section, $I_{z\text{-}z}$	**12.474**	m^4
Section modulus for bottom, Z_b	**7.445**	m^3
Section modulus for top, Z_t	**9.417**	m^3
Area of section	**9.438**	m^2
Weight per meter	**23.596**	T/m

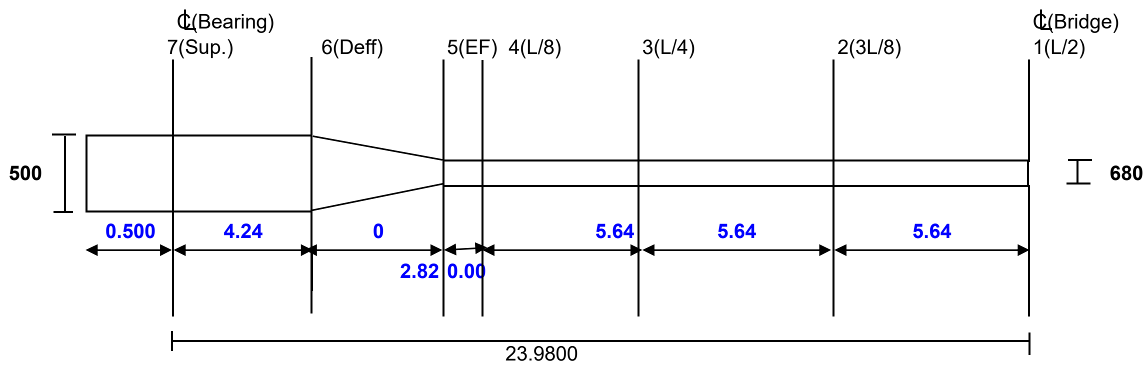
A **Section @ start of flaring portion :**



Component	w	d	Shape	A (m^2)	y (m)	A x y(m^3)	y' (m)	A x y'^2(m^4)	$I_{c.g}$(m^4)	$I_{z\text{-}z}$(m^4)
Whole	**12.3**	**3**	**Rectangle**	**36.9**	**1.5**	**55.35**	**0.31**	**3.61**	**27.6750**	**31.290**
1	1.50	0.05	Triangle	-0.04	2.57	-0.10	0.75	-0.02	0.0000	-0.02
2	1.50	0.05	Triangle	-0.04	2.57	-0.10	0.75	-0.02	0.0000	-0.02
3	1.50	2.75	Rectangle	-4.13	1.38	-5.67	0.44	-0.79	-2.5996	-3.39
4	1.50	2.75	Rectangle	-4.13	1.38	-5.67	0.44	-0.79	-2.5996	-3.39
5	1.00	2.55	Rectangle	-2.55	1.28	-3.25	0.54	-0.74	-1.3818	-2.12
6	1.00	2.55	Rectangle	-2.55	1.28	-3.25	0.54	-0.74	-1.3818	-2.12
5a	1.00	0.20	Triangle	-0.10	2.62	-0.26	0.94	-0.09	-0.0002	-0.09
5b	0.50	2.55	Triangle	-0.64	0.85	-0.54	0.83	-0.43	-0.2303	-0.66
6a	1.00	0.20	Triangle	-0.10	2.62	-0.26	0.94	-0.09	-0.0002	-0.09
6b	0.50	2.55	Triangle	-0.64	0.85	-0.54	0.83	-0.43	-0.2303	-0.66
7	5.77	2.05	Rectangle	-11.83	1.50	-17.74	0.18	-0.36	-4.1424	-4.51
7a	0.38	2.05	Triangle	-0.38	1.84	-0.71	0.16	-0.01	-0.0895	-0.10
7b	0.38	2.05	Triangle	-0.38	1.84	-0.71	0.17	-0.01	-0.0897	-0.10
8	1.50	0.20	Triangle	-0.15	2.59	-0.39	0.92	-0.13	-0.0003	-0.13
9	3.54	0.20	Rectangle	-0.71	2.63	-1.86	0.95	-0.64	-0.0024	-0.64
10	1.50	0.20	Triangle	-0.15	2.59	-0.39	0.92	-0.13	-0.0003	-0.13
14	1.20	0.20	Triangle	-0.12	0.41	-0.05	1.40	-0.24	-0.0003	-0.24
15	3.38	0.20	Rectangle	-0.68	0.38	-0.25	1.44	-1.40	-0.0023	-1.40
16	1.20	0.20	Triangle	-0.12	0.41	-0.05	1.40	-0.24	-0.0003	-0.24
				7.4811		**13.56**				**11.247**

Properties of the Section:		
c.g of section from bottom of Girder, y_b	**1.813**	m
c.g of section from top of Girder, y_t	**1.187**	m
Moment of Inertia about c.g. of section, $I_{z\text{-}z}$	**11.247**	m^4
Section modulus for bottom, Z_b	**6.204**	m^3
Section modulus for top, Z_t	**9.475**	m^3
Area of section	**7.481**	m^2
Weight per meter	**18.703**	T/m

SECTIONS OF GIRDER



WEB PLAN

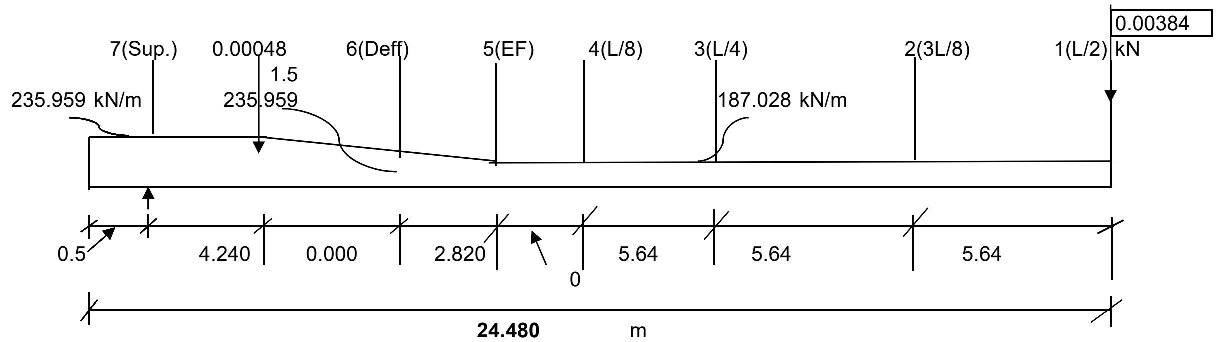
Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date 2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

CALCULATION OF BENDING MOMENTS AND SHEAR FORCES

DUE TO SELF WEIGHT OF GIRDER

Dead Load (DL)

UDL at mid span	=	7.481	x	25	=	**187.028**	kN/m
UDL at support	=	9.438	x	25	=	**235.959**	kN/m



		24.480	m	
Effective half span	=	**23.980**	m	

Reaction at each support	=	235.959	x	4.740		
	+	187.028	x	16.92		
	+ 0.5 x (	235.959	+	187.028) x		2.820
		0.002	+	0.000		
	=	**4879.37**	**kN**			
Bending Moment at sec. 1 (L/2)	=	4879.37	x	23.980		
	-	235.959	x	4.74	x	22.110
	-	187.028	x	16.920	x	8.460
	-	211.493	x	2.820	x	18.383
	-	0.000	x			22.480
	=	**54543.0**	**kN-m**			
Shear at sec. 1 (L/2)	=	**0**	**kN**			
Bending Moment at sec. 2 (3L/8)	=	4879.37	x	18.340		
	-	235.959	x	4.74	x	16.470
	-	187.028	x	11.280	x	5.640
	-	211.493	x	2.820	x	12.743
	-	0.000	x			16.840
	=	**51568.3**	**kN-m**			
Shear at sec. 2 (3L/8)	=	4879.37	-	235.959	x	4.74
	-	211.493	x	2.820		
	-	187.028	x	11.280		
	=	**1054.8**	**kN**			
Bending Moment at sec. 3 (L/4)	=	4879.37	x	12.700		
	-	235.959	x	4.74	x	10.830
	-	187.028	x	5.640	x	2.820
	-	211.493	x	2.820	x	7.103
	-	0.000	x			11.200
	=	**42644.4**	**kN-m**			

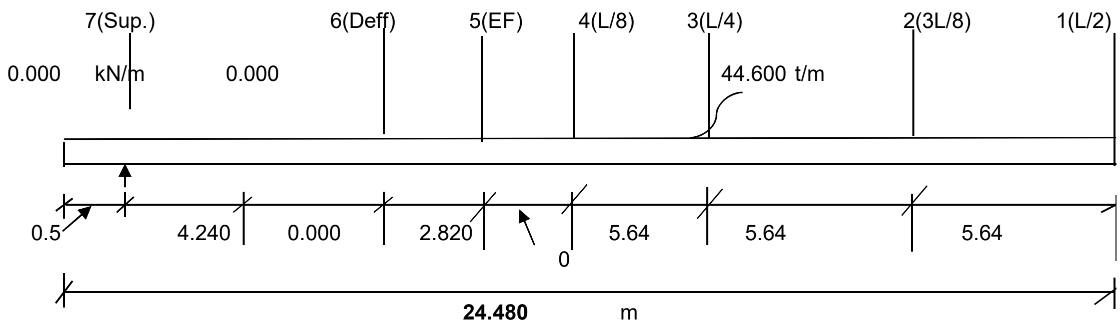
Shear at sec. 3 (L/4)	=		4879.37	-	235.959	x	4.74
	-		211.493	x	2.820		
	-		187.028	x	5.640		
	=		**2109.7**	**kN**			
Bending Moment at sec. 4 (L/8)	=		4879.37	x	7.060		
		-	235.959	x	4.74	x	5.190
		-	187.028	x	0.000	x	0.000
		-	211.493	x	2.820	x	1.463
		-	0.000	x			5.560
	=		**27771.2**	**kN-m**			
Shear at sec. 4 (L/8)	=		4879.37	-	235.959	x	4.74
	-		211.493	x	2.820		
	-		187.028	x	0.000		
	=		**3164.5**	**kN**			
Bending Moment at sec. 5 (EF)	=		4879.37	x	7.060		
		-	235.959	x	4.74	x	5.190
		-	211.493	x	2.820	x	1.463
		-	0.000	x			5.560
	=		**27771.2**	**kN-m**			
Shear at sec. 5 (EF)	=		4879.37	-	235.959	x	4.74
	-		211.493	x	2.820		
	=		**3164.5**	**kN**			
Bending Moment at sec. 6 (Deff))	=		4879.37	x	4.240		
		-	235.959	x	4.74	x	2.370
		-	235.959	x	0.000	x	0.000
		-	0.000	x			2.740
	=		**18037.8**	**kN-m**			
Shear at sec. 6 (Deff)	=		4879.37	-	235.959	x	4.74
	-		235.959	x	0.000		
	=		**3760.9**	**kN**			
Bending Moment at sec. 7 (Sup.)	=		4879.37	x	0.000		
		-	235.959	x	0.5	x	0.250
		-	235.959	x	0.000	x	0.000
	=		**-29.49**	**kN-m**			
Shear at sec. 7 (Sup.)	=		4879.37	-	235.959	x	0.5
	-		235.959	x	0.000		
	=		**4761.4**	**kN**			

Project No.	POST TENSIONED BOX GIRDER (50M SPAN)	Date
		2-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

CALCULATION OF BENDING MOMENTS AND SHEAR FORCES

DUE TO WEIGHT OF SIDL

UDL at mid span = = **44.600** kN/m



24.480 m

Effective half span = **23.980** m

Reaction at each support = 44.600 x 24.480

= **1091.81** **kN**

Bending Moment at sec. 1 (L/2) = 1091.81 x 23.980
- 44.600 x 24.480 x 12.240

= **12817.8** **kN-m**

Shear at sec. 1 (L/2) = **0** **kN**

Bending Moment at sec. 2 (3L/8) = 1091.81 x 18.340
- 44.600 x 18.840 x 9.420

= **12108.5** **kN-m**

Shear at sec. 2 (3L/8) = 1091.81 - 44.600 x 18.840

= **251.5** **kN**

Bending Moment at sec. 3 (L/4) = 1091.81 x 12.700
- 44.600 x 13.200 x 6.600

= **9980.4** **kN-m**

Shear at sec. 3 (L/4) = 1091.81 - 44.600 x 13.200

= **503.1** **kN**

Bending Moment at sec. 4 (L/8)	=		1091.81	x	7.060		
		-	44.600	x	7.560	x	3.780
	=		**6433.6**	**kN-m**			
Shear at sec. 4 (L/8)	=		1091.81	-	44.600	x	7.560
	=		**754.6**	**kN**			
Bending Moment at sec. 5 (EF)	=		1091.81	x	7.060		
		-	44.600	x	7.560	x	3.780
	=		**6433.6**	**kN-m**			
Shear at sec. 5 (EF)	=		1091.81	-	44.600	x	7.560
	=		**754.6**	**kN**			
Bending Moment at sec. 6 (Deff)	=		1091.81	x	4.240		
		-	44.600	x	4.740	x	2.370
	=		**4128.2**	**kN-m**			
Shear at sec. 6 (Deff)	=		1091.81	-	44.600	x	4.740
	=		**880.4**	**kN**			
Bending Moment at sec. 7 (Sup.)	=		1091.81	x	0.000		
		-	44.600	x	0.500	x	0.250
	=		**-5.6**	**kN-m**			
Shear at sec. 7 (Sup.)	=		1091.81	-	44.600	x	0.500
	=		**1069.5**	**kN**			

SUMMARY OF B.M.(kN-m) & S.F.(kN) DUE TO VARIOUS LIVE LOAD POSITIONS

Type of Loading	Support				Deff			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**-8.73**	**1958.25**	**1998.22**	**-407.16**	**7797.11**	**1682.01**	**1716.34**	**1513.81**
Design Force	**-8.73**	1958.25	1998.22	**0.00**	7797.11	1682.01	1716.34	1513.81

Type of Loading	End of flaring				L/8			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**12133.37**	**1526.62**	**1573.83**	**10257.14**	**12133.37**	**1526.62**	**1573.83**	**10257.14**
Design Force	12133.37	1526.62	1573.83	10257.14	12133.37	1526.62	1573.83	10257.14

Type of Loading	L/4				3L/8				L/2			
	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM	Max. BM	Corr. SF	Max. SF	Corr. BM
LL	**18920.41**	**1222.89**	**1287.25**	**17583.67**	**22992.01**	**970.65**	**1000.67**	**21979.59**	**24421.77**	**0.00**	**714.10**	**23444.90**
Design Force	18920.41	1222.89	1287.25	17583.67	22992.01	970.65	1000.67	21979.59	24421.77	0.00	714.10	23444.90

SUMMARY OF BENDING MOMENTS (kN-m) & SHEAR FORCES FROM STAAD ANALYSIS (kN)

SECTION	Precast beam		Deck slab		Construction Live load		SIDL		Live load (LL)			
									Max. B.M. &	Corr. S.f.	Max. S.F. &	Corr. B.M.
	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)	B.M. (kN-m)	S.F. (kN)
SECTION 1(L/2)	54543.00	0.00	84.84	0.00	81.91	0.00	**12817.83**	**0**	24421.77	0.00	23444.90	714.10
SECTION 2(3L/8)	51568.34	1054.84	80.14	1.66	77.37	1.61	**12108.47**	**251.544**	22992.01	970.65	21979.59	1000.67
SECTION 3(L/4)	42644.39	2109.68	66.06	3.33	63.78	3.21	**9980.41**	**503.088**	18920.41	1222.89	17583.67	1287.25
SECTION 4(L/8)	27771.16	3164.52	42.58	4.99	41.11	4.82	**6433.6**	**754.632**	12133.37	1526.62	10257.14	1573.83
SECTION 5(EF)	27771.16	3164.52	42.58	4.99	41.11	4.82	**6433.6**	**754.632**	12133.37	1526.62	10257.14	1573.83
SECTION 6(Deff)	18037.83	3760.93	27.32	5.83	26.38	5.63	**-5.575**	**880.404**	7797.11	1682.01	1513.81	1716.34
SECTION 7(Sup.)	-29.49	4761.39	-0.04	7.08	-0.04	6.83	**0**	**1069.508**	-8.73	1958.25	0.00	1998.22

SUMMARY OF PRESTRESSING FORCE

CABLE IN STAGE 1 :

SECT	From Friction and Slip Loss Analysis : cable 1			From Friction and Slip Loss Analysis : Cable 2			From Friction and Slip Loss Analysis :cable 3			From Friction and Slip Loss Analysis : cable 4 &5			TOTAL		
	HOR. P (kN)	VERT. P (kN)	cg fr soff (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)
1(L/2)	7049.00	0.00	0.5700	7049.00	0.00	0.3500	7049.00	0.00	0.1300	14098.00	0.00	0.1300	56392.0	0.000	0.2243
2(3L/8)	7049.00	0.00	0.6715	7049.00	0.00	0.4650	7049.00	0.00	0.2950	14098.00	160.64	0.1250	56392.0	356.302	0.2774
3(L/4)	7049.00	0.00	0.8111	7049.00	24.71	0.5267	7049.00	230.46	0.2955	14098.00	345.60	0.1250	56392.0	1025.245	0.3048
4(L/8)	7049.00	0.00	1.0009	7049.00	295.89	0.6761	7049.00	417.34	0.3705	14098.00	489.43	0.1250	56392.0	1796.051	0.3639
5(EF)	7049.00	0.00	1.0009	7049.00	295.89	0.6761	7049.00	417.34	0.3705	14098.00	489.43	0.1250	56392.0	1796.051	0.3639
6(Deff)	7049.00	296.89	1.1474	7049.00	450.99	0.8081	7049.00	525.30	0.4765	14098.00	572.97	0.1663	56392.0	2539.912	0.4425
7(Sup.)	7049.00	530.17	1.3996	7049.00	574.52	1.0510	7049.00	611.51	0.7033	14098.00	639.62	0.1663	56392.0	3130.337	0.5456

Part of cable c3 used= 1
Part of c4 and C5 used= 1.000

Part of c6 and C7 used= 1

SECT	From Friction and Slip Loss Analysis : cable 6 &7			From Friction and Slip Loss Analysis : cable 8			From Friction and Slip Loss Analysis : 2			From Friction and Slip Loss Analysis : 2			TOTAL		
	HOR. P (kN)	VERT. P (kN)	cg fr soff (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)	HOR. P (kN)	VERT. P (kN)	ECC. (m)
1(L/2)	14098.00	0.00	0.1300	7049.00	0.00	0.1250	0.00	0.00	0.4000	0.00	0.00	0.4000	0.000	0.000	0.0000
2(3L/8)	14098.00	195.67	0.1300	7049.00	0.00	0.1250	0.00	0.00	0.1200	0.00	0.00	0.1200	0.000	0.000	0.0000
3(L/4)	14098.00	424.48	0.1250	7049.00	0.00	0.1250	0.00	0.00	0.1340	0.00	0.00	0.1340	0.000	0.000	0.0000
4(L/8)	14098.00	593.39	0.1250	7049.00	0.00	0.1250	0.00	0.00	0.2120	0.00	0.00	0.2120	0.000	0.000	0.0000
5(EF)	14098.00	593.39	0.1250	7049.00	0.00	0.1250	0.00	0.00	0.2300	0.00	0.00	0.2300	0.000	0.000	0.0000
6(Deff)	14098.00	693.77	0.1663	7049.00	0.00	0.1663	0.00	0.00	0.3770	0.00	0.00	0.3770	0.000	0.000	0.0000
7(Sup.)	14098.00	774.52	0.1663	7049.00	0.00	0.1663	0.00	0.00	0.6440	0.00	0.00	0.6440	0.000	0.000	0.0000

Project No.	POST TENSIONED BOX GIRDER (18.3M SPAN)	Date 3-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

PROGRAM FOR STRESS CHECK
and evaluation of relaxation, shrinkage creep & elastic shortening losses
(at section 1 (L/2) i.e. MID SPAN)

B. M. DUE TO DEAD LOAD(1) =	**54543.00**	kN-m	(wt. Of Girder)
B. M. DUE TO DEAD LOAD(2) =	**84.84**	kN-m	(wt. Of slab)
B. M. DUE TO Const. Live Load =	**81.91**	kN-m	
BENDING MOMENT DUE TO SIDL =	**12817.82592**	kN-m	
BENDING MOMENT DUE TO LL =	**24421.77**	kN-m	

SECTION PROPERTIES	Yt	Yb	Zt (Girder Top/ Bottom Level)	Zb (Girder Top/ Bottom Level)	A	
Girder	1.325	1.675	9.4751	6.2036	7.4811	
Modulus of Elasticity of cable				**2.00E+08**	kN/m^2	
Nominal cross-sectional Area of each strand				**140.00**	mm^2	
Cross-Sectional Area of each Tendon		**19**	T15	2660.00	mm^2	
		19	T15	2660.00	mm^2	
Sheathing Dia (ID)				**110.00**	mm	
UTS		19	T15	5035.00	kN	
		19	T15	5035.00	kN	
Characteristic Strength of concrete ...			f_{ck} =	**45**	N/mm^2	

	1st Stage	2nd Stage	Total
NO. OF CABLES IN	**16.00**	**0.00**	16.00
PRESTRESSING FORCE	56392.00	0.00	56392.00
CG of Cables From Bottom	0.224	0.0000	0.2243
Concrete strength at time of stressing (Mpa)	**35**	**45**	
Total vertical prestressing force(kN)		0.0	

SUMMARY OF STRESSES

DESCRIPTION	FORCE (kN)	MOMENT (kN-m)	Girder Top and Bottom: STRESS AT TOP PART (kN / m^2)	STRESS AT TOP CUMMU (kN / m^2)	STRESS AT BOTTOM PART (kN / m^2)	STRESS AT BOTTOM CUMMU (kN / m^2)		
DEAD LOAD (1)		54543.00	5756.48	5756.48	-8792.21	-8792.21		
Ist STAGE PRESTRESS 0.9 P	50752.80		6784.11	12540.59	6784.11	-2008.09		
Ist STAGE PRESTRESS 0.9P*e		-73649.95	-7773.03	4767.56	11872.20	9864.11		
ELASTIC SHORTENING -I	-1088.47	1579.54	21.21	4788.77	-400.11	9464.00	<	17500
(For Loss Calculation Reffer Next Sheet)							>	-1750.0
RELAX + SHRINKAGE - I	-4803.88	6971.15	93.60	4882.37	-1765.87	7698.13		
(For Loss Calculation Reffer Next Sheet)								
CREEP - I	-934.26	1355.76	18.20	4900.58	-343.43	7354.70		
(For Loss Calculation Reffer Next Sheet)								
2nd STAGE PRESTRESS P	0.00		0.00	4900.58	0.00	7354.70		
2nd STAGE PRESTRESS P*e		0.00	0.00	4900.58	0.00	7354.70	(At Day 28)	
ELASTIC SHORTENING -II	0.00	0.00	0.00	**4900.58**	0.00	**7354.70**	<	22500
(For Loss Calculation Reffer Next Sheet)							>	-2250.0
DEAD LOAD (2)		84.84	8.95	4909.53	-13.68	7341.03		
Construction LL		81.91	8.64	**4918.18**	-13.20	**7327.82**	<----Construction Stage	
Removal of CL		-81.91	-8.64	4909.53	13.20	7341.03		
SUPERIMPOSED DEAD LOAD		12817.83	1348.50	6258.03	-2065.25	5275.78		
RELAX + SHRINKAGE - II	-1617.29	5507.82	363.62	6621.65	-1103.26	4172.52		
(For Loss Calculation Reffer Next Sheet)								
CREEP - II	-1960.30	3118.17	66.44	6688.09	-764.01	3408.51		
(For Loss Calculation Reffer Next Sheet)								
LIVE LOAD (75%)		18316.33	1926.97	**8615.06**	-2951.18	**457.33**		
Temp Case (Refer Temp Analysis) 60%			-153.23	**8523.13**	-441.41	**192.48**		
Prestress Force after losses (kN)	40348.60							
% loss	28.45							

Project No.	POST TENSIONED BOX GIRDER (18.3M SPAN)	Date 3-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

Average stress in concrete at CG of tendons av of 7171.23 and 1067.21 = 4119.22
Average stress in concrete at CG of tendons of all seven sections considered = 7101.99

ELASTIC SHORTENING LOSS FOR Ist & 2nd STAGE CABLES

2.5.1 Characteristic compressive strength :
Fckj = Fck*[2.008-1.213/(log10j)^0.5] where 'j' is in days. (As per Y.Guyon)
Elastic Modulus of concrete at j days = 5700*(Fckj)^0.5

Days	Char.Str. (MPa)	Ec (MPa)	Ec(kN/m^2)	Mod.Ratio
10	35.79	3E+04	3E+07	5.8
28	45.00	4E+04	4E+07	5.1

2.5.2 Basis of the Calculation

(a) For cables within the group:
Total Loss of prestress = 1/2*[(m*fcpa)*(n-1)*As]
where
m = Modular Ratio
n = no. of cables in the group
fcpa=average compressive stress in the concrete along the member length at cg of cables of group
fc = Increase in comp. stress in concrete due to cables of group at cg of cables of group at the section
As = C/S area of cable = 2660.00 mm^2

(b)For cables in the previous group:
Total loss of prestress= [m*fc' *n*As]
where
n=no. of cables in the previous group
fc' =increase in comp. in concrete due to cables of subsequent group at the section

	10 TO 28th DAY	28th DAY TO INFINITY
STRESS AT TOP	4767.56	0.00
STRESS AT BOTTOM	9864.11	0.00
STRESS AT C.G. OF Ist STAGE STEEL	9483.08	0.00
STRESS AT C.G. OF 2nd STAGE STEEL		0.00
LOSS DUE TO ELASTIC SHORTEN. IN STAGE 1 cables	1088.47	0.00
LOSS DUE TO ELASTIC SHORTEN. IN STAGE 2 cables		0.00

SHRINKAGE AND RELAXATION LOSS

Loss due to Relaxation in Steel:

Basis of the Calculation (As per IRC:18 - 2000 cl.11.4 Table 4A)
(Long term loss 3 times 1000Hr. Loss)

Initial stress=fsi	% Total Loss	
0.80 U.T.S.	13.5%	
0.70 U.T.S.	7.5%	Intermediate Values can
0.50 U.T.S.	0.0%	be Interpolated

SHRINKAGE STRAIN AT BEGINING	**3.00E-04**	**1.90E-04**
(As per IRC:18-2000 cl. 11.3 Table -3)		
SHRINKAGE STRAIN AT END	**1.90E-04**	**0.00E+00**
SHRINKAGE LOSS IN STAGE 1 CABLES	936.32	1617.28
SHRINKAGE LOSS IN STAGE 2 CABLES		0.01
AVERAGE FORCE IN STAGE 1 CABLES	3456.47	
AVERAGE FORCE IN STAGE 2 CABLES		0.00
AVG. FORCE/UTS FOR STAGE 1 CABLES	0.686	
AVG. FORCE/UTS FOR STAGE 2 CABLES		0.00
RELAXATION LOSS IN MPa	6.99%	0.00%
TOTAL RELAXATION LOSS (IN kN)	3867.56	0.00
TOTAL RELAXATION+SHRINKAGE LOSS	4803.88	1617.29

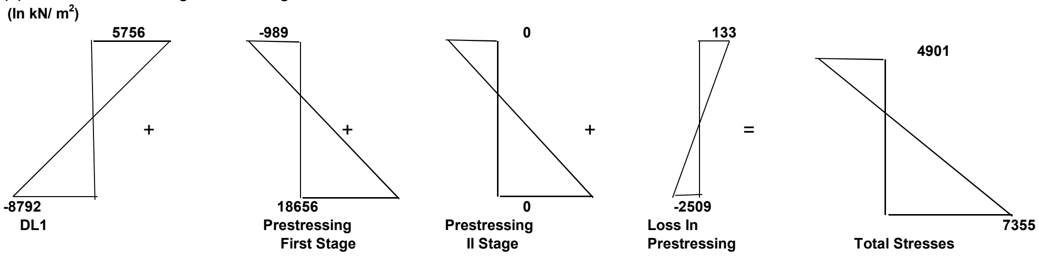
Project No.	POST TENSIONED BOX GIRDER (18.3M SPAN)	Date 3-Dec-15
16060	MORTH&H/ Karnataka PWD	DN-0xx
	Design of Standard 50m Spans for Gundya Viaduct	Rev. 0

CREEP LOSS

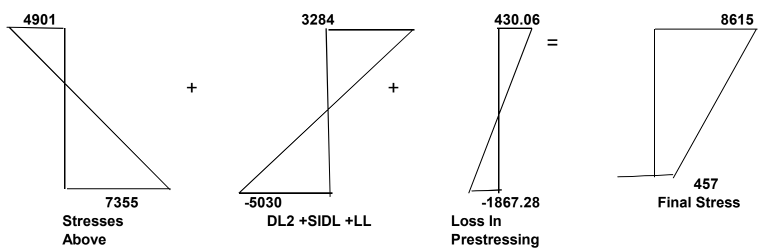
Maturity of concrete at time of stressing as % of fck (Mpa)		78		100.0
Creep strain at Maturity of concrete	70	6.10E-04	100	4.00E-04
	80	5.10E-04	110	3.60E-04
CREEP STRAIN AT BEGINING		5.32E-04		4.00E-04
(As per IRC:18-2000 cl. 11.2 Table -2)				
CREEP STRAIN AT END		4.00E-04		0.00E+00
STRESS AT TOP AT START		4788.77		4909.53
STRESS AT BOTTOM AT START		9464.00		7341.03
STRESS AT TOP AT END		4882.37		6621.65
STRESS AT BOTTOM AT END		7698.13		4172.52
AVERAGE STRESS AT TOP		4835.57		5765.59
AVERAGE STRESS AT BOTTOM		8581.06		5756.77
AVG. STRESS AT C.G. OF Ist STAGE STEEL		8301.04		5757.43
AVG. STRESS AT C.G. OF 2nd STAGE STEEL				5756.77
CREEP LOSS IN STAGE 1 CABLES		934.26		1960.29
CREEP LOSS IN STAGE 2 CABLES				0.01

Diagramatically Presentation of Stresses:

(A) At End Of Second Stage Prestressing:
(In kN/ m^2)



(B) At Service With Long Term Losses :
(At Girder Top and Bottom Level)
(In kN/ m^2)



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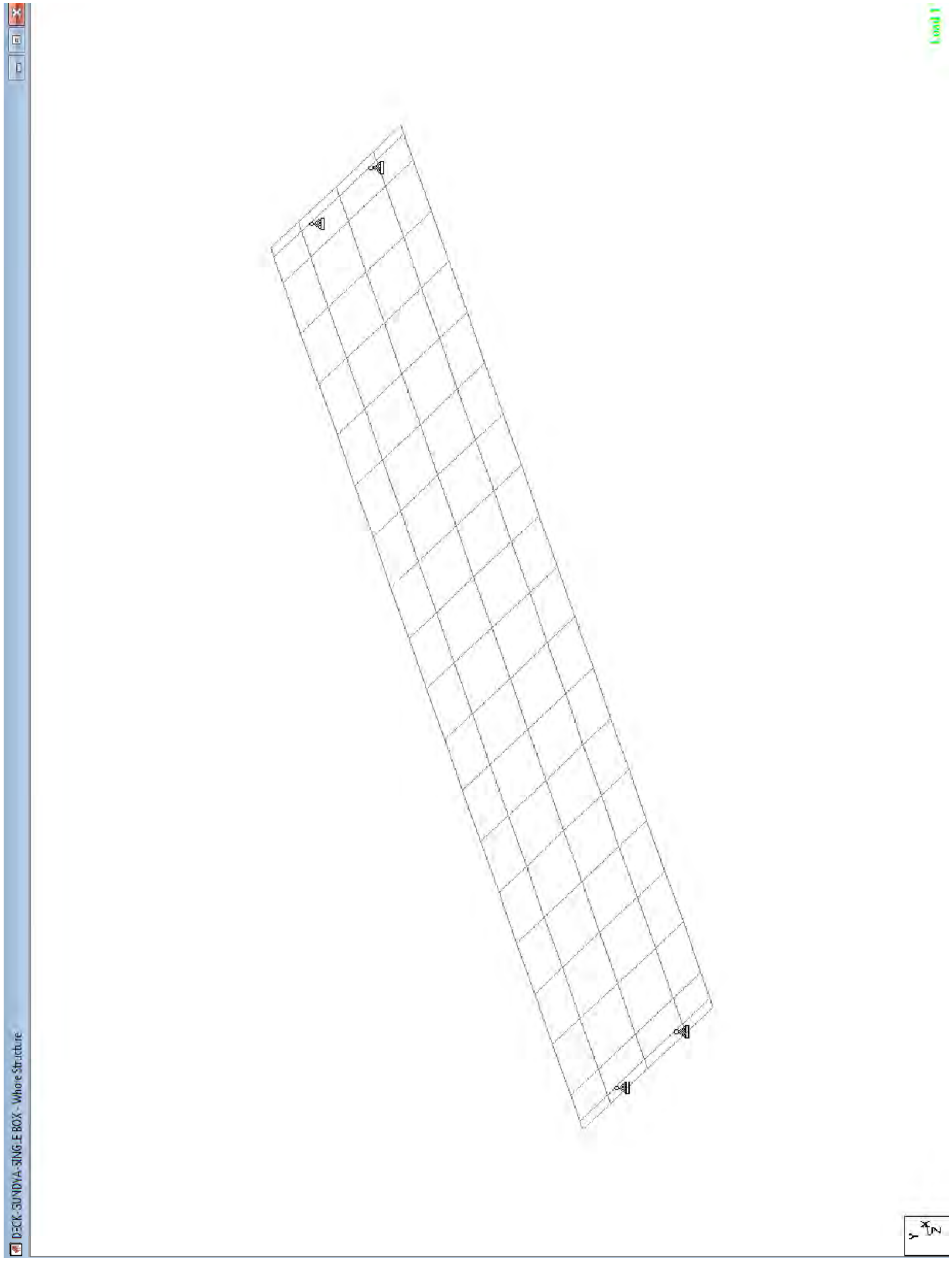

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STAAD SPACE

START JOB INFORMATION

ENGINEER DATE 14-OCT-15

END JOB INFORMATION

INPUT WIDTH 79

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UNIT METER KN

JOINT COORDINATES

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7 13.195 0 0; 8 16.015 0 0; 9 18.835 0 0; 10 21.655 0 0; 11 24.475 0 0;

12 27.295 0 0; 13 30.115 0 0; 14 32.935 0 0; 15 35.755 0 0; 16 38.575 0 0;
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17 41.395 0 0; 18 44.215 0 0; 19 47.035 0 0; 20 48.45 0 0; 21 48.95 0 0;

22 0 0 2.5; 23 0.5 0 2.5; 24 1.915 0 2.5; 25 4.735 0 2.5; 26 7.555 0 2.5;

27 10.375 0 2.5; 28 13.195 0 2.5; 29 16.015 0 2.5; 30 18.835 0 2.5;

31 21.655 0 2.5; 32 24.475 0 2.5; 33 27.295 0 2.5; 34 30.115 0 2.5;

35 32.935 0 2.5; 36 35.755 0 2.5; 37 38.575 0 2.5; 38 41.395 0 2.5;

39 44.215 0 2.5; 40 47.035 0 2.5; 41 48.45 0 2.5; 42 48.95 0 2.5; 43 0 0 5.9;

44 0.5 0 5.9; 45 1.915 0 5.9; 46 4.735 0 5.9; 47 7.555 0 5.9; 48 10.375 0 5.9;

49 13.195 0 5.9; 50 16.015 0 5.9; 51 18.835 0 5.9; 52 21.655 0 5.9;

53 24.475 0 5.9; 54 27.295 0 5.9; 55 30.115 0 5.9; 56 32.935 0 5.9;

57 35.755 0 5.9; 58 38.575 0 5.9; 59 41.395 0 5.9; 60 44.215 0 5.9;

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78 35.755 0 9.3; 79 38.575 0 9.3; 80 41.395 0 9.3; 81 44.215 0 9.3;

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95 24.475 0 11.8; 96 27.295 0 11.8; 97 30.115 0 11.8; 98 32.935 0 11.8;

99 35.755 0 11.8; 100 38.575 0 11.8; 101 41.395 0 11.8; 102 44.215 0 11.8;

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11 11 12; 12 12 13; 13 13 14; 14 14 15; 15 15 16; 16 16 17; 17 17 18; 18 18 19;
19 19 20; 20 20 21; 21 22 23; 22 23 24; 23 24 25; 24 25 26; 25 26 27; 26 27 28;
27 28 29; 28 29 30; 29 30 31; 30 31 32; 31 32 33; 32 33 34; 33 34 35; 34 35 36;
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51 53 54; 52 54 55; 53 55 56; 54 56 57; 55 57 58; 56 58 59; 57 59 60; 58 60 61;
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287 108 62; 288 109 83;

***TRANSVERSE MEMBER

MEMBER PROPERTY INDIAN

1 TO 20 PRIS YD 0.1 ZD 0.1

21 TO 40 PRIS AX 3.72 IX 8.5 IY 1 IZ 5.18

41 TO 60 PRIS YD 0.1 ZD 0.1

61 TO 80 PRIS AX 3.72 IX 8.5 IY 1 IZ 5.18

81 TO 100 PRIS YD 0.1 ZD 0.1

***TRANSVERSE MEMBER

201 TO 204 PRIS YD 0.1 ZD 0.1

205 TO 208 285 286 PRIS AX 10 IX 10 IY 10 IZ 10

209 212 PRIS YD 0.25 ZD 2.82

210 211 PRIS AX 1.4805 IX 5.53479 IY 1 IZ 2.76739

213 216 PRIS YD 0.25 ZD 2.82

214 215 PRIS AX 1.4805 IX 5.53479 IY 1 IZ 2.76739

217 220 PRIS YD 0.25 ZD 2.82

218 219 PRIS AX 1.4805 IX 5.53479 IY 1 IZ 2.76739

221 224 PRIS YD 0.25 ZD 2.82

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237 240 PRIS YD 0.25 ZD 2.82

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254 255 PRIS AX 1.4805 IX 5.534785045 IY 1 IZ 2.767392522

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269 272    PRIS YD 0.25 ZD 2.82
270 271    PRIS AX 1.4805 IX 5.534785045 IY 1 IZ 2.767392522
273 276    PRIS YD 0.25 ZD 2.82
274 275    PRIS AX 1.4805 IX 5.534785045 IY 1 IZ 2.767392522

277 TO 280 287 288 PRIS AX 10 IX 10 IY 10 IZ 10
281 TO 284 PRIS YD 0.1 ZD 0.1
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E 2.48e+007
DENSITY 24.5
POISSON 0.2
ISOTROPIC MATERIAL2
E 2.48e+007
POISSON 0.2
DENSITY 0
END DEFINE MATERIAL
constants
*====================
```

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*=======================================================
*****CONSTANTS FOR RAIL MEMBERS*****
*=======================================================
*BETA 0.00000 FX
*E     2.4800000E7  FX
*G     1.0333333E7  FX
*POI   2.0000000E-01  FX
*DEN   2.4500004E1  FX
*CTE   1.0800000E-05  FX
*
MATERIAL MATERIAL1 MEMB 21 TO 40 61 TO 80
MATERIAL MATERIAL2 MEMB 1 TO 20 41 TO 60 81 TO 100 201 TO 284 285 to 288
*
SUPPORTS
106 to 109 PINNED
DEFINE MOVING LOAD
*CLASS A WHEEL LOAD
TYPE 1 LOAD 34 34 34 34 57 57 13.5 13.5
DIST 3 3 3 4.3 1.2 3.2 1.1 WID 1.8
*TYPE 2 LOAD 34 34 34 34 57 57 13.5 13.5
*DIST 3 3 3 4.3 1.2 3.2 1.1 WID 1.8
*CLASS 70R WHEEL LOAD
TYPE 3 LOAD 85 85 85 85 60 60 40
DIST 1.37 3.05 1.37 2.13 1.52 3.96 WID 1.93
LOAD GENERATION 150
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*TYPE 1 -18.8 0 4.2 XINC 0.5

*TYPE 2 -18.8 0 7.7 XINC 0.5

TYPE 3 -13.4 0 3.99 XINC 0.5

PERFORM ANALYSIS

PRINT MAXFORCE ENV LIST 21 to 40 61 to 80

FINISH
```

Appendix – 3

Design of Common Pier P- 5

CLIENT:

GOVERNMENT OF KARNATAKA

PROJECT TITLE:

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

TITLE OF CALCULATION:

DESIGN OF PIER P5 FOR SPAN (65+80+80+80+65M)

Note No:	KG/SHIRDI GHAT/DN-203		
Revision No:	R0	No. of Sheets	1+
Date:	Oct-15		

Prepared By:	RP
Checked By:	CDS
Approved By:	AB

Date	Rev No.	Revision	By

CONSULTANT:

GEOCONSULT INDIA PVT. LTD.

PLOT NO 473, INDUSTRIAL STATE, UDYOG VIHAR PHASE V, GURGAON 122016

Tel: +91 124 4569731, +91 124 4569710; Web : www.geoconsult.co.in

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

DESIGN OF PIER P5

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

DESIGN OF PIER P5

1 GENERAL

These calclations pertain to design of Substructure and Foundation for common Pier P5. Pier P5 is conventional pier and allow longitudinal movement with guided bearings. It supports 65m span on both sides.

1.1 CODES

All the elements of the bridge shall be designed as per provisions of IRC codes. Following codes shall be used.

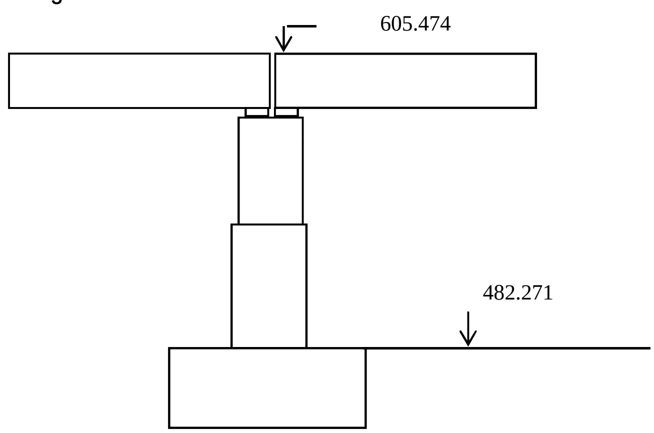
IRC - 5	Standard Specifications and code of practice for road bridges, Section I - General Features
IRC - 6	Standard Specifications and code of practice for road bridges, Section II - Load & Stresses
IRC - 112	Code of Practice for Concrete Road Bridges
IRC - 78	Standard Specifications and code of practice for road bridges, Section VII - Foundation and Substructure
IRC - 83 Part III	Standard Specifications and code of practice for road bridges, Section IX - Bearings Part III POT Bearings

Other codes (BIS, BS etc.) and specilist literature will also be refered as and when required.

1.2 Material

Concrete grade for pier and pier cap	M50	
Concrete grade for pile cap	M50	
Concrete Grade for Piles	M50	
Reiforcement	Fe500	confirming to IS: 1787

1.3 Basic Design Data



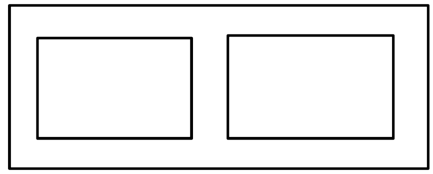
Formation Level (at control line)			605.474		m		
Ground Level			483.271		m		
top of footing			482.271		m		
Span arrangement (center to centre of Pier)			65.00	m			
effective span			65.00	m			
Depth of Superstructure			3.00	m			
CG of Mass of Superstructure from bottom			1.76	m			
CG of Mass of SIDL from soffit			3.20	m			
C/C box in trans dir			6	m			
No of boxes			4				
No of bearings for lateral loads			1				
overall width of bridge			26.1	m			
Carriageway width	2	x	9.6	m			
Brg ht			0.20	m			
W/C			0.065	m			
Camber			0.025	%			
Pier size at base			18		x	9	1.2
Pier size at 30m above base			15		x	7.5	1.2
Pier size in top varying layer			23.53		x	4	0.6

Pier size in 2nd from top varying layer	21.01	x	4	0.6
Pier size in 3rd top varying layer	17.4	x	4	0.6
Pier size in 4th top varying layer	13.8	x	4	0.6
Increament in seismic forces for checking geotech capacity	1.350			

SEISMIC COEFFICIENT for Zone II	Trans dir	Long Dir		
Z	0.10			
I	1.20			
Hor defl at Pier top due to 1 KN Load	0.01	0.035	mm, from STAAD	
Hor Load 'F' required for 1mm defl	100.000	28.571	kN	
D 'Dead +Live Load from Super'	30000	30000.00	kN	
D/(1000F)	0.300	1.050		
T=2. SQRT(D/1000F)	1.095	2.049		
Sa/g	0.91	0.49		
R for Pier	3.00	4.00	R for Bearing	3
α_h	0.020	0.010		
a_v	0.013	0.007		
Cover for Pile and Pile cap	75			
Cover for Pier	50			
Cover for Pier cap, pedestal etc	40			
Ratio of seismic force on bearing to pier	1			

2 Computation of Section Propertirs

Pier Base (Bottom 30m) Section



L	B	wall thick
18	9	1.2

S No.	L	B	A	y	Ay	Ay2	I0
1	18	1.2	21.6	8.4	181.44	1524.096	2.592
2	3.6	6.6	23.76	4.5	106.92	481.14	86.2488
3	18	1.2	21.6	0.6	12.96	7.776	2.592
		Σ	66.96		301.32	2013.01	91.43

yb=	301.32/66.96 =			4.5
Iy=	2013.01+91.43-66.96*4.5^2 =			748.500
A0	(18-1.2)*(9-1.2)			131.04
perim 'ds'	2*((18-1.2)+(9-1.2))			49.2
ds/t	41/1.2			41
Ix=	4*131.04^2/41			1675.270
Iz=	2*1.2*18^3/12	3*6.6*1.2^3/12	2*(23.76/3)*((18-1.2)/2)^2	
	1166.4	+2.85	+1117.67	=2286.92

Pier above 30m Section

L	B	wall thick
15	7.5	1.2

S No.	L	B	A	y	Ay	Ay2	I0
1	15	1.2	18	6.9	124.2	856.98	2.16
2	3.6	5.1	18.36	3.75	68.85	258.1875	39.7953
3	15	1.2	18	0.6	10.8	6.48	2.16
		Σ	54.36		203.85	1121.65	44.12

yb=	203.85/54.36 =			3.75
Iy=	1121.65+44.12-54.36*3.75^2 =			401.330
A0	(15-1.2)*(7.5-1.2)			86.94
perim 'ds'	2*((15-1.2)+(7.5-1.2))			40.2
ds/t	40.2/1.2			33.5
Ix=	4*86.94^2/33.5			902.520
Iz=	2*1.2*15^3/12	3*5.1*1.2^3/12	2*(18.36/3)*((15-1.2)/2)^2	
	675	+2.20	+582.75	=1259.95

Pier varying section (lower most)

L	B	wall thick
13.8	4	0.6

S No.	L	B	A	y	Ay	Ay2	I0
1	13.8	0.6	8.28	3.7	30.636	113.3532	0.2484
2	1.8	2.8	5.04	2	10.08	20.16	3.2928
3	13.8	0.6	8.28	0.3	2.484	0.7452	0.2484
		Σ	21.6		43.2	134.26	3.79

yb=	43.2/21.6 =	2
Iy=	134.26+3.79-21.6*2^2 =	51.650
A0	(13.8-0.6)*(4-0.6)	44.88
perim 'ds'	2*((13.8-0.6)+(4-0.6))	33.2
ds/t	33.2/0.6	55.33

Ix=	4*44.88^2/55.33			145.610
Iz=	2*0.6*13.8^3/12	3*2.8*0.6^3/12	2*(5.04/3)*((13.8-0.6)/2)^2	
	262.8072	+1.21	+133.36	=397.38

Pier varying section (2nd varying)

L	B	wall thick
17.4	4.00	0.60

S No.	L	B	A	y	Ay	Ay2	I0
1	17.4	0.6	10.44	3.7	38.628	142.9236	0.3132
2	1.8	2.8	5.04	2	10.08	20.16	3.2928
3	17.4	0.6	10.44	0.3	3.132	0.9396	0.3132
		Σ	25.92		51.84	164.02	3.92

yb=	51.84/25.92 =			2
Iy=	164.02+3.92-25.92*2^2 =			64.260
A0	(17.4-0.6)*(4-0.6)			57.12
perim 'ds'	2*((17.4-0.6)+(4-0.6))			40.4
ds/t	40.4/0.6			67.33
Ix=	4*57.12^2/67.33			193.830
Iz=	2*0.6*17.4^3/12	3*2.8*0.6^3/12	2*(5.04/3)*((17.4-0.6)/2)^2	
	526.8024	+1.21	+220.45	=748.46

Pier Fork (third segment)

L	B	wall thick
21.01	4.00	0.60

S No.	L	B	A	y	Ay	Ay2	I0
1	21.01	0.6	12.606	3.7	46.6422	172.57614	0.37818
2	1.8	2.8	5.04	2	10.08	20.16	3.2928
3	21.01	0.6	12.606	0.3	3.7818	1.13454	0.37818
		Σ	30.25		60.5	193.87	4.05

yb=	60.5/30.25 =			2
Iy=	193.87+4.05-30.25*2^2 =			76.920
A0	(21.01-0.6)*(4-0.6)			69.394
perim 'ds'	2*((21.01-0.6)+(4-0.6))			47.62
ds/t	47.62/0.6			79.37
Ix=	4*69.394^2/79.37			242.690
Iz=	2*0.6*21.01^3/12	3*2.8*0.6^3/12	2*(5.04/3)*((21.01-0.6)/2)^2	
	927.42363	+1.21	+329.65	=1258.28

Pier Fork (4th segment)

L	B	wall thick
23.53	4.00	0.60

S No.	L	B	A	y	Ay	Ay2	I0
1	23.53	0.6	14.118	3.7	52.2366	193.27542	0.42354
2	1.8	2.8	5.04	2	10.08	20.16	3.2928
3	23.53	0.6	14.118	0.3	4.2354	1.27062	0.42354
		Σ	33.28		66.55	214.71	4.14

yb=	66.55/33.28 =			2
Iy=	214.71+4.14-33.28*2^2 =			85.730
A0	(23.53-0.6)*(4-0.6)			77.962
perim 'ds'	2*((23.53-0.6)+(4-0.6))			52.66
ds/t	52.66/0.6			87.77
Ix=	4*77.962^2/87.77			277.000
Iz=	2*0.6*23.53^3/12	3*2.8*0.6^3/12	2*(5.04/3)*((23.53-0.6)/2)^2	
	1302.7641	+1.21	+418.85	=1722.82

3 COMPUTAION OF LOADS

3.1 VERTCAL LOADS

3.1.1 LOADS FROM SUPERSTRUCTURE

SPAN 1 X 65.000

Refer Superstructure design and STAAD analysis

Brg	Superstructure Rxn on Abutment				
	DL	SDL	70R Ecc	70R Conc	70RE+clA
B1	255	50	75.00	75.00	75.00
B2	255	50	75.00	75.00	75.00
B3	255	50	75.00	75.00	75.00
B4	255	50	75.00	75.00	75.00
total	1020	200	300.00	300.00	300.00
LL rxn at Free End					

Case1 70R Alone, towards median side

Case2 70R Alone, Concentric

Case3 70R +Class A, towards median side

LL Rxn tabulated above are without impact, however reduction as per clause 208 of IRC 6 has been applied.

3.1.2 LOAD FROM PIER, PIER FORK ETC.

Loads from Pier, Pier forks, tie beams, pylon etc are calculated by STAADPRO and tabulated subsequently.

3.1.3 LOAD FROM FOOTING

	L	B	H	γ	wt	ecc	Mom
S/wt	23.00	14.00	2.00	2.50	1610.00	0.00	0.00
Soil abv cap	23.00	14.00	1.00	2.00	320.00	0.00	0.00
Total cap					1930.00		0.00

3.2 HORIZONTAL LOADS

3.2.1 BEARING FRICTION

	DL	SDL	LL	TOTAL	
Reaction from one side	1020	200	300	1520	
Friction Force	1520*0.05			76.00	t

3.2.2 WIND LOAD

Basic wind speed as per figure 6 of IRC 6 2010 39 m/sec

However as per clause 209.3.7 bridge shall not be caarying any live load when wind speed is greater than 36m/sec. Hence the wind loads have been worked out for wind speed of 36m/sec at deck level considering live load and higher speed at deck level without live loads.

3.2.2.1 WIND WITH LIVE LOAD

For Basic wind speed	33	m/sec
Av Height of the bridge	100.0	m
Vz (for terrain with obstruction) in m/sec	28.20	m/sec
Pz (for terrain with obstruction) in N /m2	475.6	N/sqm

Vz for basic wind speed of 39 m/sec				33.0	m/sec
Adopt Vz with live load as				33.0	m/sec
Pz for 33 m/sec	(incl 20% extra due to funneling)			781.5	N/sqm
A1 per m length	3+0.065+0.85			3.915	m
G				2.0	
C_D	(1.5 times the CD for single box i.e. 1.5*1.5)			2.25	
d (depth of girder)				3.000	m
FT	Pz. A1. G. C_D	=781.548*3.915*2*2.25	=	13768.9	N/rm
				1.377	t/rm
Long Force	25% of Trans F			0.344	t/rm
Acting at RL	605.474-3+(3.915)/2)			604.43	m
Vert. Load	Pz. A3. G. C_L				
	where	Pz		781.5	N/sqm
		A3		26.10	m
		G		2.0	
		C_L		0.75	
		Fv		30597.6	N/rm
				3.06	t/rm
Wind on Live Load					
A1	3-(0.85)			2.15	m
G				2.0	
C_D	Refer cl 209.3.6			1.2	
FT	Pz. A1. G. C_D	=781.548*2.15*2*1.2	=	4032.79	N/rm
				0.40	t/rm
FL	25% of Trans F			0.1	t/rm
Acting at RL	605.474+0.85+2.15/2			607.40	m

Wind on Pier in Transverse Direction (9 m wide part)

A. Lower part of 9 m width

Dim 'b' (exposed to wind) of pier				9.0	m
Dim 't' of pier				18.0	m
Height 'h' of pier	605.474-3-482.271			120.20	m
t/b	18/9			2.00	
h/b	120.203/9			13.36	**consider 40**
Cd	refer table 5 (Rectangular section)			1.40	
FT (lower part)	781.548*9*1.4*2	19695	N/m	1.97	t/m
FL (lower part)				0.49	t/m

B. Middle part of 6 m width

Dim 'b' (exposed to wind) of pier				7.5	m
Dim 't' of pier				15.0	m
Height 'h' of pier	605.474-3-482.271			120.20	m
t/b	15/7.5			2.00	
h/b	120.203/7.5			16.03	**consider 40**
Cd	refer table 5 (Rectangular section)			1.30	
FT (lower part)	781.548*7.5*1.3*2	15240	N/m	1.52	t/m
FL (lower part)				0.38	t/m

C. Upper part of 4 m width

Dim 'b' (exposed to wind) of pier					4.0	m
Dim 't' of pier					18.9	m
Height 'h' of pier		605.474-3-482.271			120.20	m
t/b		18.935/4			4.73	
h/b		120.203/4			30.05	**consider 40**
Cd	refer table 5 (Rectangular section)				1.10	
FT (lower part)	781.548*4*1.1*2		6878	N/m	0.69	t/m
FL (lower part)					0.17	t/m

Wind on Pier in Longitudinal Direction (vertical Part)

A. Lower part of 18 m width

Dim 'b' (exposed to wind) of pier					18.0	m
Dim 't' of pier					9.0	m
Height 'h' of pier		605.474-3-482.271			120.20	m
t/b		9/18			0.50	
h/b		120.203/9			6.68	
Cd	refer table 5 (Rectangular section)				2.20	
FT (lower part)	781.548*18*2.2*2		61899	N/m	6.19	t/m

B. Middle part of 15 m width

Dim 'b' (exposed to wind) of pier					15.0	m
Dim 't' of pier					7.5	m
Height 'h' of pier		605.474-3-482.271			120.20	m
t/b		7.5/15			0.50	
h/b		120.203/15			8.01	
Cd	refer table 5 (Rectangular section)				2.20	
FT (lower part)	781.548*15*2.2*2		51582	N/m	5.16	t/m

C. Upper Part of varying width

Dim 'b' (exposed to wind) of pier					18.9	m
Dim 't' of pier					4.0	m
Height 'h' of pier		605.474-3-482.271			120.20	m
t/b		4/18.935			0.21	
h/b		120.203/18.935			6.35	
Cd	refer table 5 (Rectangular section)				2.10	
FT (lower part)	781.548*18.935*2.1*2		62154	N/m	6.22	t/m

4 DESIGN OF PIER

4.1 CALCULATION OF LOAD AT PIER BASE

PIER SIZE		18.00	m dia
HEIGHT OF PIER (PIER CAP TOP TO PILE CAP TOP)		123.203	M
LIVE LOAD			
CLASS 70R W		100	T
CLASS A		55.4	T
ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M
COMB ECC for 70R+A	(9.955*100+6.21*55.4)/(100+55.4)	8.620	M
ECC OF 70R W conc		0.000	M
IMPACT FACTOR	(for bed block)	1.09	
	(for pier cap)	1.04	
	(for pier base, pile cap and pile)	1.00	
DIST BETWEEN BRGS IN L DIR		0.00	M
SEISMIC COEFF.		0.02	TRANS
		0.01	LONG

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\,(m)}$	$e_{t\,m)}$	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL LEFT	1020.00			0	0	0	0
2	DL RIGHT	1020.00			0	0	0	0
3	SIDL LEFT	200.00			0	0	0	0
4	SIDL RIGHT	200.00			0	0	0	0
5	LL1	300.00			1.250	9.96	375	2987
6	LL2	300.00			1.250	0.00	375	0
7	LL3	300.00			1.250	8.62	375	2586
9	PIER	14869			0		0.0	
10	FRICTION		76.00		120.203		9135.4	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	2040.00			0	0	0.00	0.00
2	SIDL	400.00			0	0	0.00	0.00
3	LL3	300.00			0	0	375.00	2585.97
4	PIER	14869.09			0	0.00	0.00	0.00
5	FRICTION		76.00		120.203	0.00	9135	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	2040.00			120.203	120.203	0.00	0.00
2	SIDL	400.00			120.203	121.643	0.00	0.00
3	LL3	300.00			120.203	124.403	375.00	2986.50
4	PIER	14869.09			60.102	60.10	0.00	0.00
5	FRICTION		0.00		120.203	0.00	0.00	0.00
	SEISMIC (+/-) ON							
	DL	-8.16	0.0	40.8	120.203	120.203	0	4904

6	SIDL	-1.60	0.0	8.0	120.203	121.643	0	973
	LL3	-1.20	0.0	1.2	120.203	124.403	0	149
	PIER	-59.48	44.6	297.4	60.102	60.102	2681	17873
	TOTAL SEISM	-70.44	44.61	347.38			2680.96	23900

SEISMIC LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			120.203	120.203	0.00	0.00
2	SIDL	400.00			120.203	121.643	0.00	0.00
3	LL3	300.00			120.203	124.403	375.00	2986.50
4	PIER	14869.09			60.10	60.102	0.00	0.00
5	FRICTION	0.00	0.00	0.0	120.203	0.000	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-8.16		12.2	120.203	120.203	0	1471
	SIDL	-1.60		2.4	120.203	121.643	0	292
	LL3	-1.20		0.4	120.203	124.403	0	45
	PIER	-59.48	148.7	89.2	60.102	60.102	8937	5362
	TOTAL SEISM	-70.44	148.69	104.21			8937	7170

WIND TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			120.203		0.00	0.00
2	SIDL	400.00			120.203		0.00	0.00
3	LL3	300.00			120.203		375.00	2986.50
5	PIER	14869.09			60.102		0.00	0.00
6	FRICTION		76.00		120.203	0.00	9135.43	0.00
7	WIND							
	SUPER			70.0	120.203	120.203	0	8414
	PIER			150.0	60.102	60.102	0	9015
	TOTAL WIND	0.00	0.00	220.00			0.00	17429

WIND LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			120.203	0.000	0.00	0.00
2	SIDL	400.00			120.203	0.000	0.00	0.00
3	LL3	300.00			120.203	0.000	375.00	2986.50
4	PIER	14869.09			0.00	0.000	0.00	0.00
5	FRICTION		76.00	0.0	120.203	0.000	9135.43	0.00
7	WIND							
	SUPER		17.5		120.203	0.000	2104	0
	PIER		702.0		60.102	0.000	42191	0
	TOTAL WIND		719.50	0.00			44295	0

TABULATION OF LOADS AT PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL Left	16909			0	0
2	SDL Left	400.00			0	0
3	LL3	300.00			0	2987
4	FRICTION		76.00		9135	0

5	Wind Trans	0.00	0.00	220.00	0.00	17429.44
6	Wind Long	0.00	719.50	0.00	44294.81	0.00
7	SEISMIC V	-70.44				
8	SEISMIC L		148.69		8937	
9	SEISMIC T			347.38		23900

Load Factors for Various combinations

	ULS						SLS		
	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
3	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	0
4							0.6	0.6	0.5
5	0.90	1.5							
6			0.90	1.50			0.6	1	
7					0.45	0.45			
8					0.45	1.50			
9					1.50	0.45			

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	23897	0	198	0	20166		ULS 1	
Comb 2	23792	0	330	0	29579		ULS 2	
Comb 3	23897	648	0	39865	4480		ULS 3	
Comb 4	23792	1079	0	66442	3434		ULS 4	WIND LONG
Comb 5	23476	67	521	4021	36447		ULS 5	
Comb 6	23476	223	156	13405	11352		ULS 6	
Comb 7	17609	477	0	32058	2987		Rare 1	
Comb 8	17534	765	0	49776	2240		Rare 2	
Comb 9	17309	38	0	4568	0		Quasi P	

Computation of Additional Moment due to Slenderness (Refer Sec 11.2 of IRC 112)

k1	Fully rigid at bottom		0.1		
k2	AT top		100		
x	Eq. 11.3 max of	1.4	2.2		
le	MAX(1.4,2.2)*123.203		271.05		m
Area of X section			49.480		
I of section			393.3	1417.868	
rad. of gyration 'i'			2.819	5.353	
le/i			96.15	50.63	
λ_{lim}	20.A.B.C/ SQRT(n) Eq 11.1				
	20*0.978*1.274*0.7/SQRT(0.215)		37.6	38.7	
ϕ	Ref Table 6.9 for 2Ac/u=2.1 , t0=28, RH=70%		1.6	1.6	
ϕ_{ef}	1.6*(4,568/66,442)		0.110	0.000	
A=	1/(1+0.2*0.11)		0.978	1.000	
B=	SQRT(1+2ω)		1.274	1.274	
C=	$1.7-r_m$		0.7	0.7	
ω	791,679*435/(49,479,922*22.33)		0.31	0.31	
n	23,792*10000/49,479,922/22.33		0.215	0.212	
r_m	M_{o1}/M_{o2}		1	1	

Second Order Moment

$1/r_0$=	0.00063	0.00037	ε_{yd} reinforcement	0.0022	0.0022
		Radius of gyration of reinf.		3.120	5.467
		d	9/2+3.120	7.620	12.967

n_u=	$1+\omega$	1.31	1.31	
n_{bal}		0.4	0.4	
Kr	(Eq. 11.9)	1	1	
β	(Eq. 11.11)	-0.041	0.262	
$K\phi$	(Eq. 11.10)	1.000	1.000	

Wt of Pier (ULS)	20073
CG	50.47

1/r	(Eq. 11.7)	0.000634	0.00037	
c=		10	10	
e2=		4.660	2.738	m
e2 for Pier CG=		1.956	1.150	m
M2=	4.66*(23,476-20,073)+20073*1.956	57084	32400	tm

MED=	comb 4	57084+66,442	32400+3,434	123526	35834	tm
	comb 5	57084+4,021	32400+36,447	61105	68847	tm

4.2 CALCULATION OF LOAD AT 30m above Base

PIER SIZE		15.00	m dia		
HEIGHT OF PIER (PIER CAP TOP TO PILE CAP TOP)		93.203	M	Ht abv base	30
LIVE LOAD					
CLASS 70R W		100	T		
CLASS A		55.4	T		
ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M		
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M		
COMB ECC for 70R+A	(9.955*100+6.21*55.4)/(100+55.4)	8.620	M		
ECC OF 70R W conc		0.000	M		
IMPACT FACTOR	(for bed block)	1.09			
	(for pier cap)	1.04			
	(for pier base, pile cap and pile)	1.00			
DIST BETWEEN BRGS IN L DIR		0.00	M		
SEISMIC COEFF.		0.02	TRANS		
		0.01	LONG		

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\,(m)}$	$e_{t\,m)}$	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL LEFT	1020.00			0	0	0	0
2	DL RIGHT	1020.00			0	0	0	0
3	SIDL LEFT	200.00			0	0	0	0
4	SIDL RIGHT	200.00			0	0	0	0
5	LL1	300.00			1.250	9.96	375	2987
6	LL2	300.00			1.250	0.00	375	0
7	LL3	300.00			1.250	8.62	375	2586
9	PIER	9847.09			0		0.0	
10	FRICTION		76.00		90.203		6855.4	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	2040.00			0	0	0.00	0.00
2	SIDL	400.00			0	0	0.00	0.00
3	LL3	300.00			0	0	375.00	2585.97
4	PIER	9847.09			0	0.00	0.00	0.00
5	BRAKING		76.00		90.203	0.00	6855	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T (Tm)}$	$M_{L (Tm)}$
1	DL	2040.00			90.203	90.203	0.00	0.00
2	SIDL	400.00			90.203	90.203	0.00	0.00
3	LL3	300.00			90.203	1.200	375.00	2986.50
4	PIER	9847.09			45.102	45.10	0.00	0.00
5	BRAKING		0.00		90.203	0.00	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-8.16	0.0	40.8	90.203	90.203	0	3680
	SIDL	-1.60	0.0	8.0	90.203	90.203	0	722
	LL3	-1.20	0.0	1.2	90.203	1.200	0	1
	PIER	-39.39	29.5	196.9	45.102	45.102	1332	8882
	TOTAL SEISM	-50.35	29.54	246.94			1332.36	13286

SEISMIC LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T (Tm)}$	$M_{L (Tm)}$
1	DL	2040.00			90.203	90.203	0.00	0.00
2	SIDL	400.00			90.203	90.203	0.00	0.00
3	LL3	300.00			90.203	1.200	375.00	2986.50
4	PIER	9847.09			45.10	45.102	0.00	0.00
5	BRAKING	0.00	0.00	0.0	90.203	0.000	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-8.16		12.2	90.203	90.203	0	1104
	SIDL	-1.60		2.4	90.203	90.203	0	216
	LL3	-1.20		0.4	90.203	1.200	0	0
	PIER	-39.39	98.5	59.1	45.102	45.102	4441	2665
	TOTAL SEISM	-50.35	98.47	74.08			4441	3986

WIND TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T (Tm)}$	$M_{L (Tm)}$
1	DL	2040.00			90.203		0.00	0.00
2	SIDL	400.00			90.203		0.00	0.00
3	LL3	300.00			90.203		375.00	2986.50
5	PIER	9847.09			45.102		0.00	0.00
6	FRICTION		76.00		90.203	0.00	6855.43	0.00
7	WIND							
	SUPER			70.0	90.203	90.203	0	6314
	PIER			73.0	45.102	45.102	0	3292
	TOTAL WIND	0.00	0.00	143.00			0.00	9607

WIND LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T (Tm)}$	$M_{L (Tm)}$
1	DL	2040.00			90.203	0.000	0.00	0.00
2	SIDL	400.00			90.203	0.000	0.00	0.00
3	LL3	300.00			90.203	0.000	375.00	2986.50
4	PIER	9847.09			0.00	0.000	0.00	0.00
5	BRAKING		76.00	0.0	90.203	0.000	6855.43	0.00
	WIND							

7	SUPER		17.5		90.203	0.000	1579	0
	PIER		423.0		45.102	0.000	19078	0
	TOTAL WIND		440.50	0.00			20656	0

TABULATION OF LOADS AT 30m abv PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL Left	11887			0	0
2	SDL Left	400.00			0	0
3	LL3	300.00			0	2987
4	FRICTION		76.00		6855	0
5	Wind Trans	0.00	0.00	143.00	0.00	9606.62
6	Wind Long	0.00	440.50	0.00	20656.49	0.00
7	SEISMIC V	-50.35				
8	SEISMIC L		98.47		4441	
9	SEISMIC T			246.94		13286

Load Factors for Various combinations

	ULS						SLS		
	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
3	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	0
4							0.6	0.6	0.5
5	0.90	1.5							
6			0.90	1.50			0.6	1	
7					0.45	0.45			
8					0.45	1.50			
9					1.50	0.45			

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	17118	0	129	0	13126		ULS 1	
Comb 2	17013	0	215	0	17844		ULS 2	
Comb 3	17118	396	0	18591	4480		ULS 3	
Comb 4	17013	661	0	30985	3434		ULS 4	WIND LONG
Comb 5	16705	44	370	1999	20526		ULS 5	
Comb 6	16705	148	111	6662	6576		ULS 6	
Comb 7	12587	310	0	16507	2987		Rare 1	
Comb 8	12512	486	0	24770	2240		Rare 2	
Comb 9	12287	38	0	3428	0		Quasi P	

Moment including slenderness

		M_{TT}	M_{LL}	
Comb 4	30,985+42,778	73762	27714	3,434+24,280
Comb 5	1,999+42,778	44776	44806	20,526+24,280

4.3 CALCULATION OF LOAD AT 86m above Base

PIER SIZE 13.80 m dia

HEIGHT OF PIER (PIER CAP TOP TO PILE CAP TOP) 37.203 M Ht abv base 86

LIVE LOAD

CLASS 70R W 100 T

CLASS A 55.4 T

ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M
COMB ECC for 70R+A	(9.955*100+6.21*55.4)/(100+55.4)	8.620	M
ECC OF 70R W conc		0.000	M
IMPACT FACTOR	(for bed block)	1.09	
	(for pier cap)	1.04	
	(for pier base, pile cap and pile)	1.00	
DIST BETWEEN BRGS IN L DIR		0.00	M
SEISMIC COEFF.		0.02	TRANS
		0.00	LONG

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\ (m)}$	$e_{t\ m)}$	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL LEFT	1020.00			0	0	0	0
2	DL RIGHT	1020.00			0	0	0	0
3	SIDL LEFT	200.00			0	0	0	0
4	SIDL RIGHT	200.00			0	0	0	0
5	LL1	300.00			1.250	9.96	375	2987
6	LL2	300.00			1.250	0.00	375	0
7	LL3	300.00			1.250	8.62	375	2586
9	PIER	2277.05			0		0.0	
10	FRICTION		76.00		34.203		2599.4	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			0	0	0.00	0.00
2	SIDL	400.00			0	0	0.00	0.00
3	LL3	300.00			0	0	375.00	2585.97
4	PIER	2277.05			0	0.00	0.00	0.00
5	BRAKING		76.00		34.203	0.00	2599	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			34.203	34.203	0.00	0.00
2	SIDL	400.00			34.203	34.203	0.00	0.00
3	LL3	300.00			34.203	1.200	375.00	2986.50
4	PIER	2277.05			17.102	17.10	0.00	0.00
5	BRAKING		0.00		34.203	0.00	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-8.16	0.0	40.8	34.203	34.203	0	1395
	SIDL	-1.60	0.0	8.0	34.203	34.203	0	274
	LL3	-1.20	0.0	1.2	34.203	1.200	0	1
	PIER	-9.11	6.8	45.5	17.102	17.102	117	779
	TOTAL SEISM	-20.07	6.83	95.54			116.82	2449

SEISMIC LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			34.203	34.203	0.00	0.00

2	SIDL	400.00			34.203	34.203	0.00	0.00
3	LL3	300.00			34.203	1.200	375.00	2986.50
4	PIER	2277.05			17.10	17.102	0.00	0.00
5	BRAKING	0.00	0.00	0.0	34.203	0.000	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-8.16		12.2	34.203	34.203	0	419
	SIDL	-1.60		2.4	34.203	34.203	0	82
	LL3	-1.20		0.4	34.203	1.200	0	0
	PIER	-9.11	22.8	13.7	17.102	17.102	389	234
	TOTAL SEISM	-20.07	22.77	28.66			389	735

WIND TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			34.203		0.00	0.00
2	SIDL	400.00			34.203		0.00	0.00
3	LL3	300.00			34.203		375.00	2986.50
5	PIER	2277.05			17.102		0.00	0.00
6	FRICTION		76.00		34.203	0.00	2599.43	0.00
7	WIND							
	SUPER			70.0	34.203	34.203	0	2394
	PIER			23.0	17.102	17.102	0	393
	TOTAL WIND	0.00	0.00	93.00			0.00	2788

WIND LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			34.203	0.000	0.00	0.00
2	SIDL	400.00			34.203	0.000	0.00	0.00
3	LL3	300.00			34.203	0.000	375.00	2986.50
4	PIER	2277.05			0.00	0.000	0.00	0.00
5	BRAKING		76.00	0.0	34.203	0.000	2599.43	0.00
7	WIND							
	SUPER		17.5		34.203	0.000	599	0
	PIER		211.0		17.102	0.000	3608	0
	TOTAL WIND		228.50	0.00			4207	0

TABULATION OF LOADS AT 30m abv PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL Left	4317			0	0
2	SDL Left	400.00			0	0
3	LL3	300.00			0	2987
4	FRICTION		76.00		2599	0
5	Wind Trans	0.00	0.00	93.00	0.00	2787.54
6	Wind Long	0.00	228.50	0.00	4206.97	0.00
7	SEISMIC V	-20.07				
8	SEISMIC L		22.77		389	
9	SEISMIC T			95.54		2449

Load Factors for Various combinations

	ULS	SLS

	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
3	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	0
4							0.6	0.6	0.5
5	0.90	1.5							
6			0.90	1.50			0.6	1	
7					0.45	0.45			
8					0.45	1.50			
9					1.50	0.45			

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	6898	0	84	0	6989		ULS 1	
Comb 2	6793	0	140	0	7616		ULS 2	
Comb 3	6898	206	0	3786	4480		ULS 3	
Comb 4	6793	343	0	6310	3434		ULS 4	WIND LONG
Comb 5	6499	10	143	175	4271		ULS 5	
Comb 6	6499	34	43	584	1700		ULS 6	
Comb 7	5017	183	0	4084	2987		Rare 1	
Comb 8	4942	274	0	5767	2240		Rare 2	
Comb 9	4717	38	0	1300	0		Quasi P	

Moment including slenderness

		M_{TT}	M_{LL}	
Comb 4	6,310+16,072	22383	12557	3,434+9,122
Comb 5	175+16,072	16248	13394	4,271+9,122

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

5 CHECK FOR BASE PRESSURE

5.1 LOADS AT FOOTING BOTTOM

Increament in seismic for foundation	1.35
Live Load in normal case	100%
Live Load in seismic case	20%

Normal Case LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00			0	0	0.00	0.00
2	SIDL	400.00			0	0	0.00	0.00
3	LL3	300.00			0	0	375.00	2585.97
5	PIER	14869.09			0	0	0.00	0.00
7	FRICTION	0.00	76.00	0.00	122.20		9287.43	0.00
9	PILE CAP	1930.00					0.0	
TOTAL		19539.09	76.00	0.00			9662.43	2585.97

SEISMIC TRANSVERSE CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00					0.00	0.00
2	SIDL	400.00					0.00	0.00
3	LL3	60.00					75.00	517.19
5	PIER	14869.09					0.00	0.00
7	BRAKING		15.20		122.20	0.00	1857.49	0.00
8	SEISMIC (+/-)	95.09	60.22	468.97	0.00	70.80	0.00	33202.66
9	PILE CAP	1930.00					0.00	0.00
TOTAL		19394.18	75.42	468.97			1932.49	33719.85

SEISMIC LONGITUDINAL CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00					0.00	0.00
2	SIDL	400.00					0.00	0.00
3	LL3	60.00					75.00	517.19
4	PIER CAP	0.00					0.00	0.00
5	PIER	14869.09					0.00	0.00
6	0	0.00					0.00	0.00
7	BRAKING	0.00	15.20	0.0	122.203	0.000	1857.49	0.00
8	SEISMIC (+/-)	95.09	200.73	140.69	0.000	70.800	0.00	9960.80
9	PILE CAP	1930.00					0.00	0.00
TOTAL		19394.18	215.93	140.69			1932	10477.99

WIND LONGITUDINAL CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	2040.00	0.00	0.00			0.00	0.00
2	SIDL	400.00	0.00	0.00			0.00	0.00
3	LL3	300.00	0.00	0.00			375.00	2986.50
4	PIER CAP	0.00					0.00	0.00
5	PIER	14869.09	0.00	0.00			0.00	0.00
6	Wind Long	0.00	719.50	0.00			46093.56	0.00
7	BRAKING	0.00	76.00	0.0			9325.43	0.00
9	PILE CAP	1930.00					0.00	0.00
TOTAL		19539.09	795.50	0.00			55794	2986.50

SUMMARY OF LOADS ON PILE GROUP

LOAD C	V	HL	HT	MT	ML
1	19539.09	76.00	0.00	9662.43	2585.97
2	19394.18	75.42	468.97	1932.49	33719.85
3	19394.18	215.93	140.69	1932.49	10477.99
4	19539	796	0	55794	2987

FTG SIZE 23.00 14.00 AREA 322 ZLARGE 1234.333

ZSMALL 751.3333

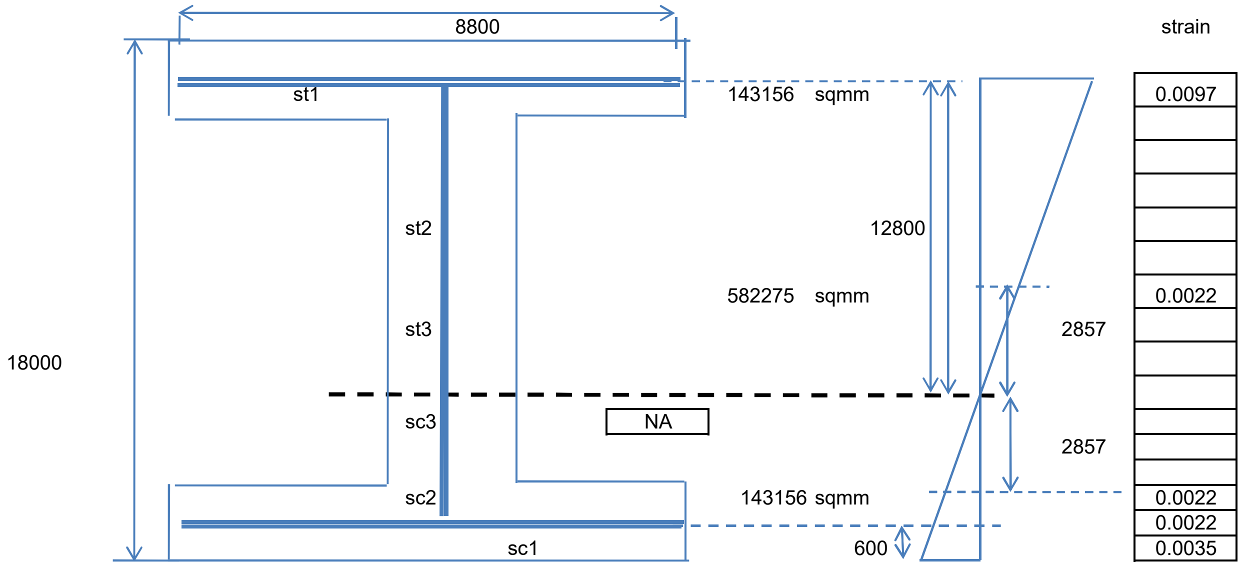
LOAD C	P/A	MT/ZL	ML/ZS	MAX	MIN
1	61	8	3	72	49
2	60	2	45	107	14
3	60	2	14	76	45
4	61	45	4	110	12

CANTILEVER		2.50	
Moment		224.8447	
ULS BM		337.267	
eff depth		1900	
Mom cap		2707.5	tm
Ast		4534.073	sqmm
Provide	40 dia bars	3.608	Numbers

6 CHECK FOR SECTION CAPACITY IN ULS FLEXURE

6.1 BASE SECTION

About Major Axis



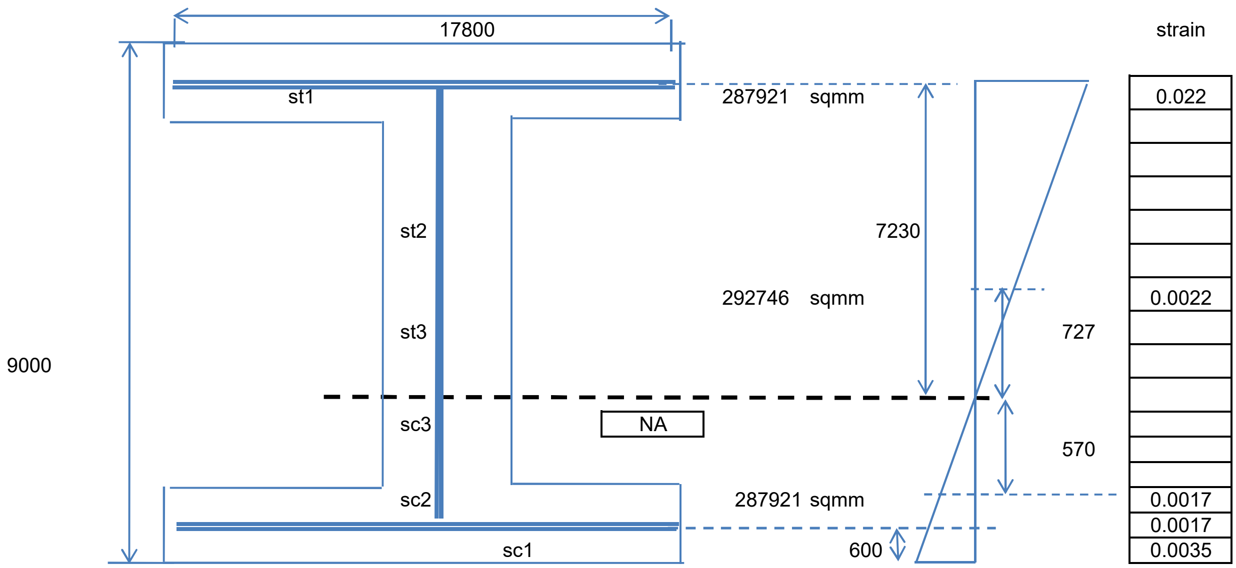
Bar Dia	32	mm			
Bar spacing	100	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	17400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	18000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	9000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	143156	sqmm	Area of comp face reinf. C1	143156	sqmm
Area of tension face reinf. T2	344612	sqmm	Area of comp face reinf. C2	39611	sqmm
Area of tension face reinf. T3	99026	sqmm	Area of comp face reinf. C3	99026	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	1.143	m	av strain	0.0022	
Length of C3 with strain $<\varepsilon_{yd}$	2.857	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	9.943	m	av strain	0.0022	
Length of T3 with strain <eyd	2.857	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	6224	t
Stress in T2	435		Force in T2	14983	t
Stress in T3 (>eyd)	217		Force in T3	2153	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	435		Force in C1	6224	t
Stress in C2	435		Force in C2	1722	t
Stress in C3	217		Force in C3	2153	t
Comp Force F1 in conc	23712	T	ttl comp F	46883	t
Comp Force F2 in conc	13072	T	ttl Tensile F	23360	t
Assume Neutral Axis	**4600**	**mm**	Net F	**23523**	t
Moment about neutral axis					
Conc F1	94847	tm	Tensile Steel T1	79669	tm

23792 t

Conc F2	43921	tm	Tensile Steel T2	117297	tm
Comp Steel C1	24897	tm	Tensile Steel T3	3075	tm
Comp Steel C2	5905	tm		**200041**	tm
Comp Steel C3	3075	tm			tm
	172645				
ttl moment	***372686***	tm	external moment	**35834**	tm

68847

About Minor Axis



Bar Dia	32	mm			
Bar spacing	100	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	8400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	9000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	18000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	287921	sqmm	Area of comp face reinf. C1	287921	sqmm
Area of tension face reinf. T2	244079	sqmm	Area of comp face reinf. C2	0	sqmm
Area of tension face reinf. T3	27274	sqmm	Area of comp face reinf. C3	21393	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0017	
Length of C2 with strain $>\varepsilon_{yd}$	0.000	m	av strain	0.0017	
Length of C3 with strain $<\varepsilon_{yd}$	0.570	m	av strain	0.0009	
strain in T1				0.0022	
Length of T2 with strain >eyd	6.503	m	av strain	0.0022	
Length of T3 with strain <eyd	0.727	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	12518	t
Stress in T2	435		Force in T2	10612	t
Stress in T3 (>eyd)	217		Force in T3	593	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	341		Force in C1	9819	t
Stress in C2	341		Force in C2	0	t
Stress in C3	171		Force in C3	365	t
Comp Force F1 in conc	37627	T	ttl comp F	47811	t
Comp Force F2 in conc	0	T	ttl Tensile F	23723	t
Assume Neutral Axis	**1170**	**mm**	Net F	**24087**	t
Moment about neutral axis					

23792 t

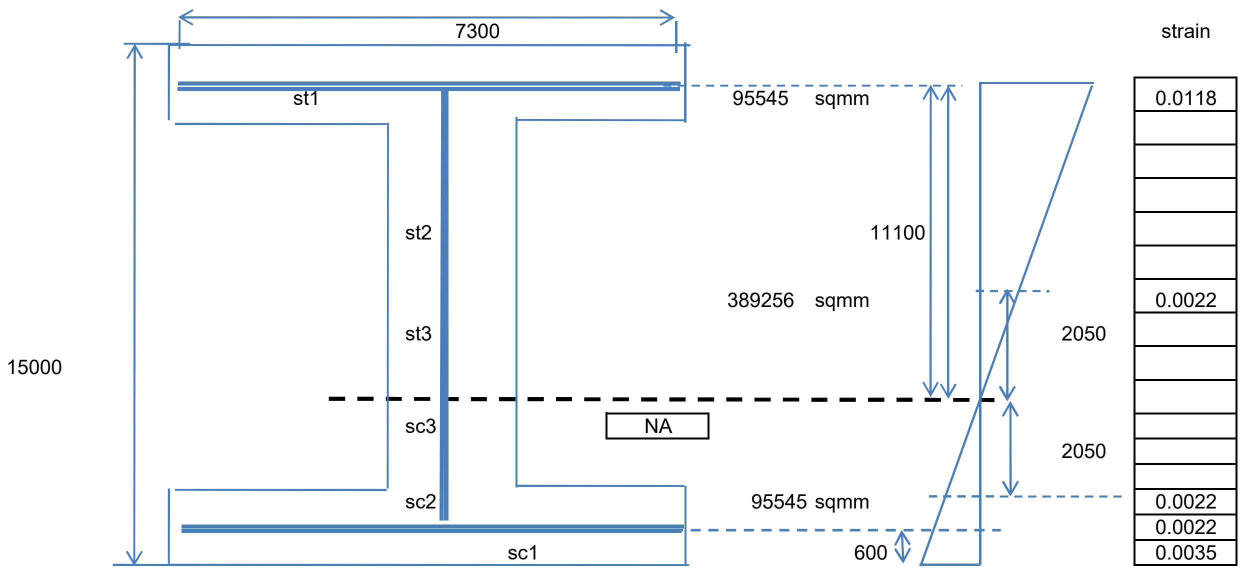
Conc F1	21448	tm	Tensile Steel T1	90507	tm
Conc F2	0	tm	Tensile Steel T2	42219	tm
Comp Steel C1	5597	tm	Tensile Steel T3	215	tm
Comp Steel C2	0	tm		**132941**	tm
Comp Steel C3	104	tm			tm
	27148				
ttl moment	***160090***	tm	external moment	**123526**	tm

61105

α		1				
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**		
0.10	+	0.77	=	0.87	< 1	OK
0.18		0.38		0.57	< 2	

6.2 SECTION AT 30M ABOVE BASE

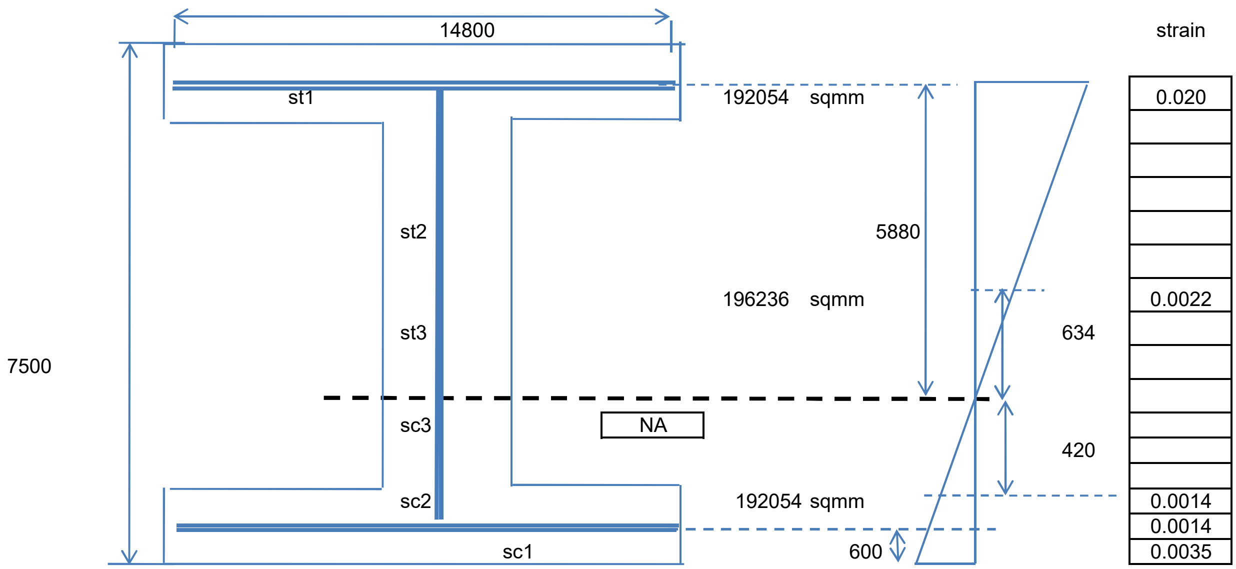
About Major Axis



Bar Dia	32	mm			
Bar spacing	125	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	14400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	15000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	7500	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	95545	sqmm	Area of comp face reinf. C1	95545	sqmm
Area of tension face reinf. T2	255282	sqmm	Area of comp face reinf. C2	18343	sqmm
Area of tension face reinf. T3	57815	sqmm	Area of comp face reinf. C3	57815	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	0.650	m	av strain	0.0022	
Length of C3 with strain $<\varepsilon_{yd}$	2.050	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	9.050	m	av strain	0.0022	
Length of T3 with strain <eyd	2.050	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	4154	t
Stress in T2	435		Force in T2	11099	t
Stress in T3 (>eyd)	217		Force in T3	1257	t
Stress in T4 (>eyd)	0		Force in T4	0	t

Stress in C1	435		Force in C1	4154	t	
Stress in C2	435		Force in C2	798	t	
Stress in C3	217		Force in C3	1257	t	
Comp Force F1 in conc	19846	T	ttl comp F	33643	t	
Comp Force F2 in conc	7589	T	ttl Tensile F	16510	t	
Assume Neutral Axis	**3300**	**mm**	Net F	**17133**	t	17013 t
Moment about neutral axis						
Conc F1	53583	tm	Tensile Steel T1	46111	tm	
Conc F2	19580	tm	Tensile Steel T2	72976	tm	
Comp Steel C1	11216	tm	Tensile Steel T3	1288	tm	
Comp Steel C2	1894	tm		**120374**	tm	
Comp Steel C3	1288	tm			tm	
	87562					
ttl moment	***207936***	tm	external moment	**27714**	tm	44806

About Minor Axis



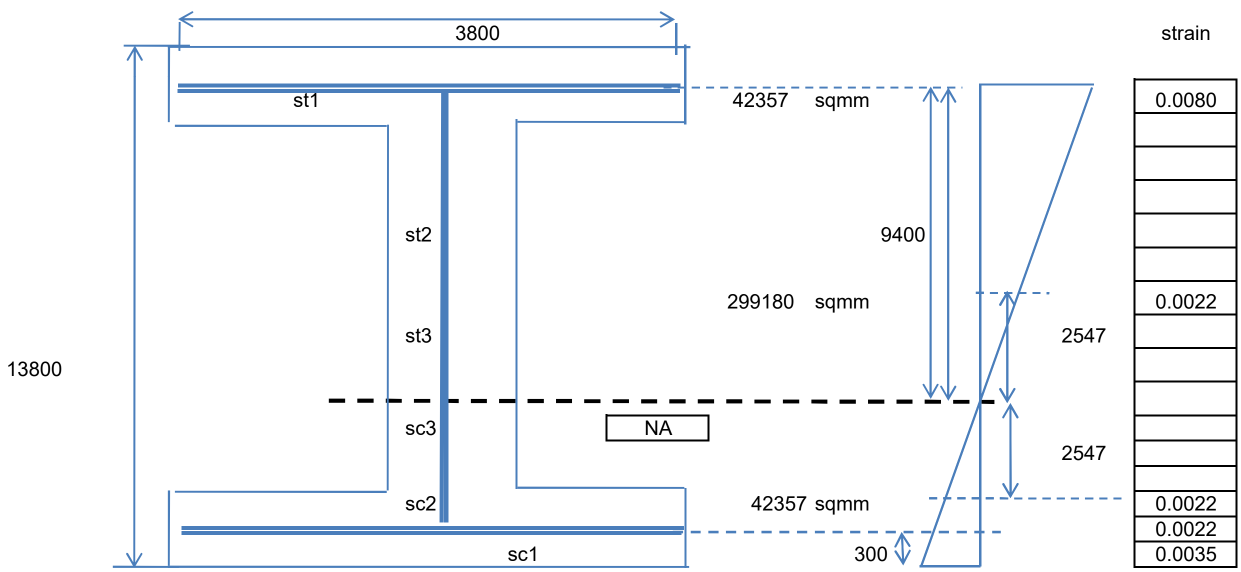
Bar Dia	32	mm			
Bar spacing	125	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	6900	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	7500	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	15000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	192054	sqmm	Area of comp face reinf. C1	192054	sqmm
Area of tension face reinf. T2	163420	sqmm	Area of comp face reinf. C2	0	sqmm
Area of tension face reinf. T3	19734	sqmm	Area of comp face reinf. C3	13082	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0014	
Length of C2 with strain $>\varepsilon_{yd}$	0.000	m	av strain	0.0014	
Length of C3 with strain $<\varepsilon_{yd}$	0.420	m	av strain	0.0007	
strain in T1				0.0022	
Length of T2 with strain >eyd	5.246	m	av strain	0.0022	
Length of T3 with strain <eyd	0.634	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	8350	t
Stress in T2	435		Force in T2	7105	t
Stress in T3 (>eyd)	217		Force in T3	429	t

Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	288		Force in C1	5536	t
Stress in C2	288		Force in C2	0	t
Stress in C3	144		Force in C3	189	t
Comp Force F1 in conc	27336	T	ttl comp F	33060	t
Comp Force F2 in conc	0	T	ttl Tensile F	15884	t
Assume Neutral Axis	**1020**	**mm**	Net F	**17176**	t 17013 t
Moment about neutral axis					
Conc F1	11481	tm	Tensile Steel T1	49099	tm
Conc F2	0	tm	Tensile Steel T2	23140	tm
Comp Steel C1	2325	tm	Tensile Steel T3	136	tm
Comp Steel C2	0	tm		**72375**	tm
Comp Steel C3	40	tm			tm
	13846				
ttl moment	***86221***	tm	external moment	**73762**	tm 44776

α			1			
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**		
0.13	+	0.86	=	0.99	< 1	OK
0.22		0.52		0.73	< 1	

6.3 SECTION 86 M ABOVE BASE

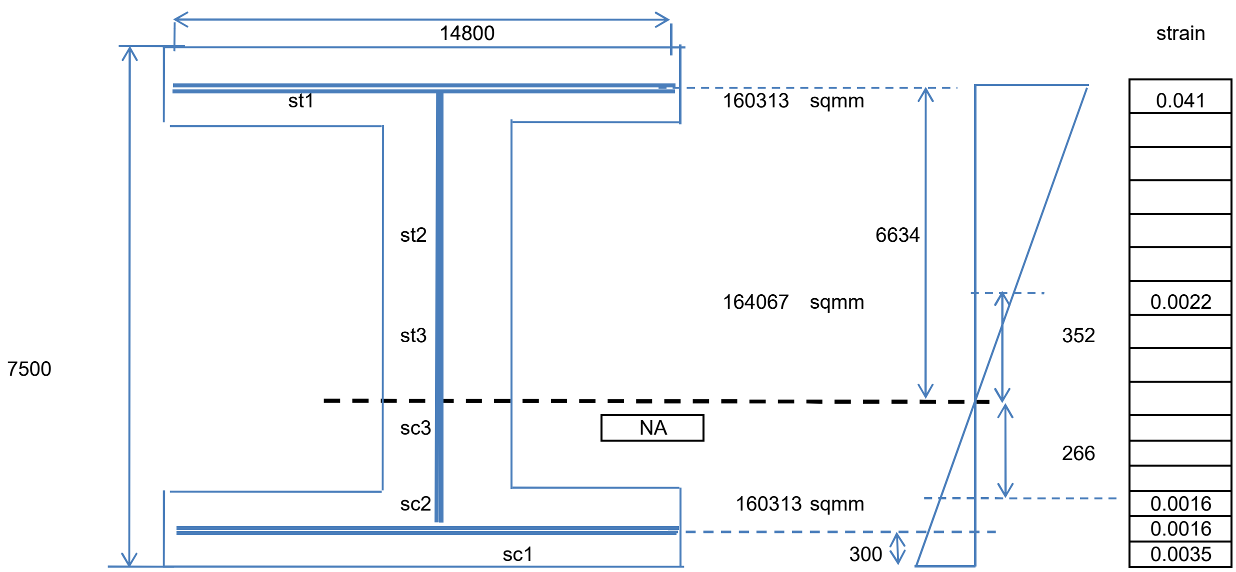
About Major Axis



Bar Dia	32	mm			
Bar spacing	150	mm	d' for comp reinf	300	
d' for tension reinf	300	mm	Effective depth 'd'	13500	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	13800	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	4000	mm	fcd	22.333	mpa
Wall thickness	600	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	42357	sqmm	Area of comp face reinf. C1	42357	sqmm
Area of tension face reinf. T2	155334	sqmm	Area of comp face reinf. C2	28409	sqmm
Area of tension face reinf. T3	57719	sqmm	Area of comp face reinf. C3	57719	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	1.253	m	av strain	0.0022	

Length of C3 with strain <ε_{yd}	2.547	m	av strain	0.0011			
strain in T1				0.0022			
Length of T2 with strain >eyd	6.853	m	av strain	0.0022			
Length of T3 with strain <eyd	2.547	m	av strain	0.0011			
Length of T4 with strain <eyd	0.000	m	av strain	0.0000			
Stress in T1	435		Force in T1	1842	t		
Stress in T2	435		Force in T2	6754	t		
Stress in T3 (>eyd)	217		Force in T3	1255	t		
Stress in T4 (>eyd)	0		Force in T4	0	t		
Stress in C1	435		Force in C1	1842	t		
Stress in C2	435		Force in C2	1235	t		
Stress in C3	217		Force in C3	1255	t		
Comp Force F1 in conc	5202	T	ttl comp F	16587	t		
Comp Force F2 in conc	7053	T	ttl Tensile F	9850	t		
Assume Neutral Axis	**4100**	**mm**	Net F	**6737**	t	6793	t
Moment about neutral axis							
Conc F1	19767	tm	Tensile Steel T1	17311	tm		
Conc F2	19468	tm	Tensile Steel T2	40342	tm		
Comp Steel C1	6998	tm	Tensile Steel T3	1598	tm		
Comp Steel C2	3920	tm		**59250**	tm		
Comp Steel C3	1598	tm			tm		
	51750						
ttl moment	***111001***	tm	external moment	**12557**	tm	13394	

About Minor Axis

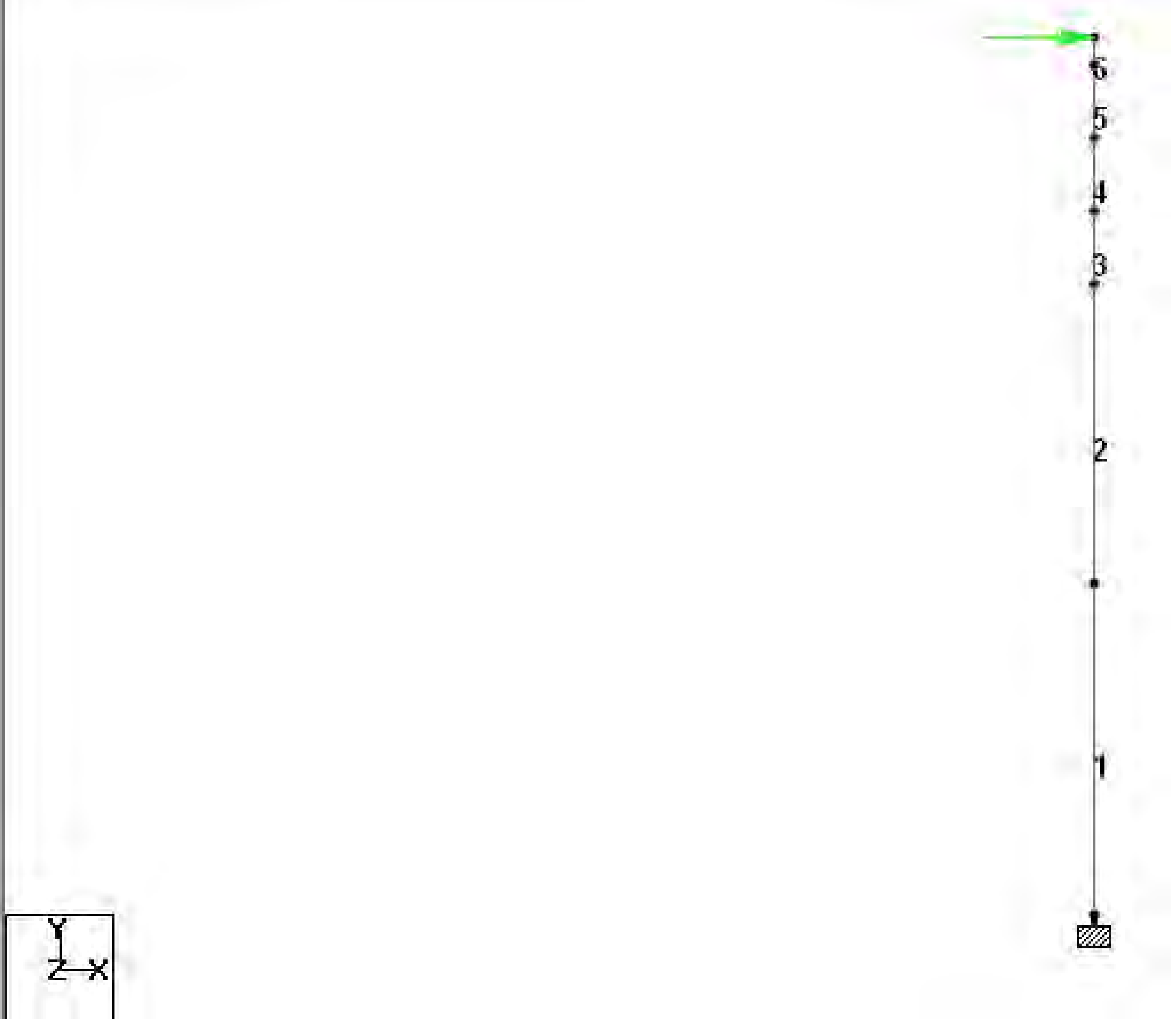


Bar Dia	32	mm			
Bar spacing	150	mm	d' for comp reinf	300	
d' for tension reinf	300	mm	Effective depth 'd'	7200	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	7500	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	15000	mm	fcd	22.333	mpa
Wall thickness	600	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	160313	sqmm	Area of comp face reinf. C1	160313	sqmm
Area of tension face reinf. T2	149383	sqmm	Area of comp face reinf. C2	0	sqmm
Area of tension face reinf. T3	8359	sqmm	Area of comp face reinf. C3	6325	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0016	

Length of C2 with strain $>\varepsilon_{yd}$	0.000	m	av strain	0.0016			
Length of C3 with strain $<\varepsilon_{yd}$	0.266	m	av strain	0.0008			
strain in T1				0.0022			
Length of T2 with strain >eyd	6.282	m	av strain	0.0022			
Length of T3 with strain <eyd	0.352	m	av strain	0.0011			
Length of T4 with strain <eyd	0.000	m	av strain	0.0000			
Stress in T1	435		Force in T1	6970	t		
Stress in T2	435		Force in T2	6495	t		
Stress in T3 (>eyd)	217		Force in T3	182	t		
Stress in T4 (>eyd)	0		Force in T4	0	t		
Stress in C1	329		Force in C1	5274	t		
Stress in C2	329		Force in C2	0	t		
Stress in C3	164		Force in C3	104	t		
Comp Force F1 in conc	15169	T	ttl comp F	20547	t		
Comp Force F2 in conc	0	T	ttl Tensile F	13647	t		
Assume Neutral Axis	**566**	**mm**	Net F	**6900**	t	6793	t
Moment about neutral axis							
Conc F1	4035	tm	Tensile Steel T1	46240	tm		
Conc F2	0	tm	Tensile Steel T2	22685	tm		
Comp Steel C1	1403	tm	Tensile Steel T3	32	tm		
Comp Steel C2	0	tm		**68957**	tm		
Comp Steel C3	14	tm			tm		
	5452						
ttl moment	***74409***	tm	external moment	**22383**	tm	16248	

α			1			
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**		
0.11	+	0.30	=	0.41	< 1	OK
0.12		0.22		0.34	< 1	

APPENDIX A
STAAD INPUT FILES


6
5
4
3
2
1
Y
Z
X
Load 1

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STAAD SPACE 120M TALL PIER P2
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ENGINEER DATE 07-Aug-13
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER KN
JOINT COORDINATES
1 0 0 0
2 0 45 0
3 0 86 0
4 0 96 0
5 0 106 0
6 0 116 0
7 0 120 0
MEMBER INCIDENCES
1 1 2 6
MEMBER PROPERTY CANADIAN
1 PRIS AX 66.96 IX 1675.27 IY 2286.92 IZ 748.5
2 PRIS AX 54.36 IX 902.52 IY 1259.95 IZ 401.33
3 PRIS AX 21.6 IX 145.61 IY 397.38 IZ 51.65
4 PRIS AX 25.92 IX 193.82 IY 748.46 IZ 64.26
5 PRIS AX 30.25 IX 242.7 IY 1258.28 IZ 76.92
6 PRIS AX 33.28 IX 277.01 IY 1722.82 IZ 85.73
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.2e+007
POISSON 0.17
DENSITY 25
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
SUPPORTS
1 FIXED
LOAD 1 UNIT LOAD
JOINT LOAD
7 FX 1
LOAD 2 UNIT LOAD
JOINT LOAD
7 FZ 1
LOAD 3 Self Wt
self y -1
load 4 wind trans
member load
1 uni Z -19.7
2 uni Z -12.2
3 to 6 uni Z -6.9
load 5 wind Long
member load
1 uni y -61.9
2 uni y -51.6
3 to 6 uni y -62.2
load 6 seismic trans
self z 0.02
load 7 seismic long
self x 0.01
PERFORM ANALYSIS
PRINT MEMBER FORCES
print support reaCTIONS
PRINT JOINT DISPLACEMENTS
FINISH
```

Appendix – 4

Design of Common Pier P- 4

CLIENT:

GOVERNMENT OF KARNATAKA

PROJECT TITLE:

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

TITLE OF CALCULATION:

DESIGN OF Y PIER P4 FOR SPAN (65+80+80+80+65M)

Note No:	KG/SHIRDI GHAT/DN-202		
Revision No:	R0	No. of Sheets	1+
Date:	Oct-15		

Prepared By:	RP
Checked By:	CDS
Approved By:	AKG

Date	Rev No.	Revision	By

CONSULTANT:

GEOCONSULT INDIA PVT. LTD.

PLOT NO 473, INDUSTRIAL STATE, UDYOG VIHAR PHASE V, GURGAON 122016

Tel: +91 124 4569731, +91 124 4569710; Web : www.geoconsult.co.in

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

DESIGN OF PIER P4

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48
DESIGN OF PIER P4

1 GENERAL

These calclations pertain to design of Substructure and Foundation for Pier P4 and P3. The piers P3 & P4 are Y shape and monolithic with superstructure where as P2 and P5 are conventional pier and allow longitudinal movement with guided bearings.

1.1 CODES

All the elements of the bridge shall be designed as per provisions of IRC codes. Following codes shall be used.

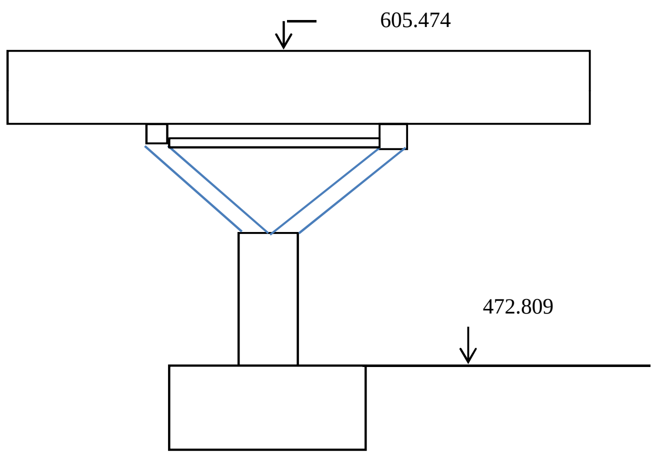
IRC - 5	Standard Specifications and code of practice for road bridges, Section I - General Features
IRC - 6	Standard Specifications and code of practice for road bridges, Section II - Load & Stresses
IRC - 112	Code of Practice for Concrete Road Bridges
IRC - 78	Standard Specifications and code of practice for road bridges, Section VII - Foundation and Substructure
IRC - 83 Part III	Standard Specifications and code of practice for road bridges, Section IX - Bearings Part III POT Bearings

Other codes (BIS, BS etc.) and specilist literature will also be refered as and when required.

1.2 Material

Concrete grade for pier and pier cap	M50	
Concrete grade for pile cap	M50	
Concrete Grade for Piles	M50	
Reiforcement	Fe500	confirming to IS: 1787

1.3 Basic Design Data



Formation Level (at control line)			605.474	m
Ground Level			474.809	m
top of footing			472.809	m
Span arrangement (center to centre of Pier)			160.00	m
effective span			160.00	m
Depth of Superstructure			3.00	m
CG of Mass of Superstructure from bottom			1.76	m
CG of Mass of SIDL from soffit			3.20	m
C/C box in trans dir			6	m
No of boxes			4	
No of bearings for lateral loads			1	
overall width of bridge			26.1	m
Carriageway width	2	x	9.6	m
Brg ht			0.20	m

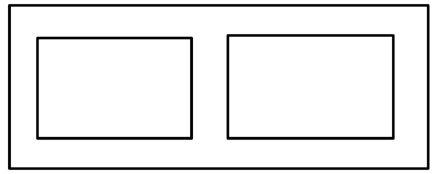
W/C	0.065	m		
Camber	0.025	%		
Pier size at base	18	x	9	1.2
Pier size at 30m above base	15	x	7.5	
Pier size in top varying layer	23.71	x	6	0.615
Pier size in 2nd from top varying layer	21.8	x	6	0.666
Pier size in 3rd top varying layer	19.08	x	6	0.740
Pier size in 4th top varying layer	16.36	x	6	0.813
Increament in seismic forces for checking geotech capacity	1.350			

1.4 SEISMIC COEFFICIENT for Zone II

	Long Dir	Trans Dir	
Z	0.10	0.10	
I	1.20	1.20	
Hor defl at Pier top due to 1 KN Load	0.36	0.13	mm, from STAAD
Hor Load 'F' required for 1mm defl	2.778	7.692	kN
D 'Dead +Live Load from Super'	80000	80000	kN
D/(1000F)	28.800	10.400	
T=2. SQRT(D/1000F)	10.733	6.450	
Sa/g	0.25	0.25	
R for Pier	3.00	3.00	R for Bearing
α_h	0.005	0.005	
a_v	0.003	0.003	
Cover for Pile and Pile cap	75		
Cover for Pier	50		
Cover for Pier cap, pedestal etc	40		

2 Computation of Section Propertirs

Pier Base Section



L	B	wall thick
18	9	1.2

S No.	L	B	A	y	Ay	Ay2	I0
1	18	1.2	21.6	8.4	181.44	1524.096	2.592
2	3.6	6.6	23.76	4.5	106.92	481.14	86.2488
3	18	1.2	21.6	0.6	12.96	7.776	2.592
		Σ	66.96		301.32	2013.012	91.433

yb=	301.32/66.96 =	4.5
Iz=	2013.012+91.433-66.96*4.5^2 =	748.510
A0	(18-1.2)*(9-1.2)	131.04
perim 'ds'	2*((18-1.2)+(9-1.2))	49.2
ds/t	41/1.2	41
Ix=	4*131.04^2/41	1675.266

Iy=	2*1.2*18^3/12	3*6.6*1.2^3/12	2*(23.76/3)*((18-1.2)/2)^2	
	1166.4	+2.85	+1117.67	=2286.92

Pier top Section

L	B	wall thick
15	7.5	1.2

S No.	L	B	A	y	Ay	Ay2	I0
1	15	1.2	18	6.9	124.2	856.98	2.16
2	3.6	5.1	18.36	3.75	68.85	258.1875	39.7953
3	15	1.2	18	0.6	10.8	6.48	2.16
		Σ	54.36		203.85	1121.6475	44.115

yb=	203.85/54.36 =	3.75
Iz=	1121.6475+44.115-54.36*3.75^2 =	401.330
A0	(15-1.2)*(7.5-1.2)	86.94
perim 'ds'	2*((15-1.2)+(7.5-1.2))	40.2
ds/t	40.2/1.2	33.5
Ix=	4*86.94^2/33.5	902.515

Iy=	2*1.2*15^3/12	3*5.1*1.2^3/12	2*(18.36/3)*((15-1.2)/2)^2	
	675	+2.20	+582.75	=1259.95

Pier Fork (first segment, lower most)

L	B	wall thick
16.36	6	0.813

S No.	L	B	A	y	Ay	Ay2	I0
1	16.36	0.813	13.301	5.594	74.397	416.142	0.733
2	2.439	4.374	10.668	3.387	36.133	122.383	17.009
3	16.36	0.813	13.301	0.600	7.980	4.788	0.733
		Σ	37.27		118.511	543.313	18.474

yb=	118.511/37.27 =	3.18
Iz=	543.313+18.474-37.27*3.18^2 =	184.900
A0	(16.36-0.813)*(6-0.813)	80.642289
perim 'ds'	2*((16.36-0.813)+(6-0.813))	41.468

ds/t	41.468/0.813			51.006
Ix=	4*80.642289^2/51.006			509.993
Iy=	2*0.813*16.36^3/12	3*4.374*1.2^3/12	2*(10.668186/3)*((16.36-1.2)/2)^2	
	593.32028	+1.89	+408.64	=1003.85

Pier Fork (2nd segment)

L	B	wall thick
19.08	6	0.74

S No.	L	B	A	y	Ay	Ay2	I0
1	19.08	0.74	14.1192	5.63	79.491096	447.53487	0.64430616
2	2.22	4.52	10.0344	3.46	34.719024	120.127823	17.0839005
3	19.08	0.74	14.1192	0.6	8.47152	5.082912	0.64430616
		∑	38.273		122.682	572.746	18.373

yb=	122.682/38.273 =			3.205
Iz=	572.746+18.373-38.273*3.205^2 =			197.980
A0	(19.08-0.74)*(6-0.74)			96.4684
perim 'ds'	2*((19.08-0.74)+(6-0.74))			47.2
ds/t	47.2/0.74			63.784
Ix=	4*96.4684^2/63.784			583.604
Iy=	2*0.74*19.08^3/12	3*4.52*1.2^3/12	2*(10.0344/3)*((19.08-1.2)/2)^2	
	856.673988	+1.95	+534.66	=1393.28

Pier Fork (third segment)

L	B	wall thick
21.8	6	0.666

S No.	L	B	A	y	Ay	Ay2	I0
1	21.8	0.666	14.5188	5.667	82.2780396	466.26965	0.5366584
2	1.998	4.668	9.326664	3.534	32.9604306	116.482162	16.9358415
3	21.8	0.666	14.5188	0.6	8.71128	5.226768	0.5366584
		∑	38.364		123.95	587.979	18.009

yb=	123.95/38.364 =			3.231
Iz=	587.979+18.009-38.364*3.231^2 =			205.490
A0	(21.8-0.666)*(6-0.666)			112.728756
perim 'ds'	2*((21.8-0.666)+(6-0.666))			52.936
ds/t	52.936/0.666			79.483
Ix=	4*112.728756^2/79.483			639.522
Iy=	2*0.666*21.8^3/12	3*4.668*1.2^3/12	2*(9.326664/3)*((21.8-1.2)/2)^2	
	1149.98575	+2.02	+659.64	=1811.65

Pier Fork (4th segment, top most)

L	B	wall thick
23.71	6	0.615

S No.	L	B	A	y	Ay	Ay2	I0
1	23.71	0.615	14.58165	5.6925	83.0060426	472.511898	0.45959538
2	1.845	4.77	8.80065	3.585	31.5503303	113.107934	16.6866924
3	23.71	0.615	14.58165	0.6	8.74899	5.249394	0.45959538
		∑	37.964		123.305	590.869	17.606

yb=	123.305/37.964 =	3.248
Iz=	590.869+17.606-37.964*3.248^2 =	207.970
A0	(23.71-0.615)*(6-0.615)	124.366575
perim 'ds'	2*((23.71-0.615)+(6-0.615))	56.96
ds/t	56.96/0.615	92.618

Ix=	4*124.366575^2/92.618			667.993
Iy=	2*0.615*23.71^3/12	3*4.77*1.2^3/12	2*(8.80065/3)*((23.71-1.2)/2)^2	
	1366.21336	+2.06	+743.22	=2111.49

PYLON

L	B	wall thick
12	2.5	0.3

S No.	L	B	A	y	Ay	Ay2	I0
1	12	0.3	3.6	2.35	8.46	19.881	0.027
2	0.9	1.9	1.71	2.15	3.6765	7.904475	0.514425
3	12	0.3	3.6	0.6	2.16	1.296	0.027
		Σ	8.91		14.297	29.081	0.568

yb=	14.297/8.91 =			1.605
Iz=	29.081+0.568-8.91*1.605^2 =			6.700
A0	(12-0.3)*(2.5-0.3)			25.74
perim 'ds'	2*((12-0.3)+(2.5-0.3))			27.8
ds/t	27.8/0.3			92.667
Ix=	4*25.74^2/92.667			28.599
Iy=	2*0.3*12^3/12	3*1.9*1.2^3/12	2*(1.71/3)*((12-1.2)/2)^2	
	86.4	+0.82	+33.24	=120.46

3 COMPUTAION OF LOADS

3.1 VERTCAL LOADS

3.1.1 LOADS FROM SUPERSTRUCTURE

SPAN 1 X 160.000

Refer Superstructure design and STAAD analysis

Brg	Superstructure Rxn on Abutment				
	DL	SDL	70R Ecc	70R Conc	70RE+clA
B1	1900	325	218.00	218.00	218.00
B2	1900	325	218.00	218.00	218.00
B3	1900	325	218.00	218.00	218.00
B4	1900	325	218.00	218.00	218.00
total	7600	1300	872.00	872.00	872.00
LL rxn at Free End					

Case1 70R Alone, towards median side

Case2 70R Alone, Concentric

Case3 70R +Class A, towards median side

LL Rxn tabulated above are without impact, however reduction as per clause 208 of IRC 6 has been applied.

3.1.3 LOAD FROM PIER, PIER FORK ETC.

Loads from Pier, Pier forks, tie beams, pylon etc are calculated by STAADPRO and tabulated subsequently.

3.1.4 LOAD FROM PILE CAP

	L	B	H	γ	wt	ecc	Mom
S/wt	28.00	20.00	2.50	2.50	3500.00	0.00	0.00
Soil abv cap	28.00	20.00	2.00	2.00	1592.00	0.00	0.00
Total cap					5092.00		0.00

3.3 HORIZONTAL LOADS

3.3.1 BRAKING FORCE

Total length						370	m
No fo 70R wheel Loads		8.00	of 100 T and	1.00	of	92.00	t
No fo Class A Loads		10.00	of 55.4 T				
70RW (First train)	100.00	x	0.20=	20.00	t		
70RW (Succeding train)	792.00	x	0.10=	79.20	t		
Cl A	554.00	x	0.05=	27.70	t		
Normal Case				126.90	t		
Seismic Case (20%)				25.38	t		

3.3.3 WIND LOAD

Basic wind speed as per figure 6 of IRC 6 2010 39 m/sec

However as per clause 209.3.7 bridge shall not be caarying any live load when wind speed is greater than 36m/sec. Hence the wind loads have been worked out for wind speed of 36m/sec at deck level considering live load and higher speed at deck level without live loads.

3.3.3.1 WIND WITH LIVE LOAD

For Basic wind speed					33	m/sec
Av Height of the bridge					100.0	m
Vz (for terrain with obstruction) in m/sec					28.20	m/sec
Pz (for terrain with obstruction) in N /m2					475.6	N/sqm
Vz for basic wind speed of 39 m/sec					33.0	m/sec
Adopt Vz with live load as					33.0	m/sec
Pz for 33 m/sec	(incl 20% extra due to funneling)				781.5	N/sqm
A1 per m length	3+0.065+0.85				3.915	m
G					2.0	
C_D	(1.5 times the CD for single box i.e. 1.5*1.5)				2.25	
d (depth of girder)					3.000	m
FT	Pz. A1. G. C_D	=781.548*3.915*2*2.25		=	13768.9	N/rm
					1.377	t/rm
Long Force	25% of Trans F				0.344	t/rm
Acting at RL	605.474-3+(3.915)/2)				604.43	m
Vert. Load	Pz. A3. G. C_L					
	where	Pz			781.5	N/sqm
		A3			26.10	m
		G			2.0	
		C_L			0.75	
		Fv			30597.6	N/rm
					3.06	t/rm
Wind on Live Load						
A1	3-(0.85)				2.15	m
G					2.0	
C_D	Refer cl 209.3.6				1.2	
FT	Pz. A1. G. C_D	=781.548*2.15*2*1.2		=	4032.79	N/rm
					0.40	t/rm
FL	25% of Trans F				0.1	t/rm
Acting at RL	605.474+0.85+2.15/2				607.40	m
Wind on Pier in Transverse Direction (vertical Part)						
Dim 'b' (exposed to wind) of pier		(9+7.5)/2			8.3	m
Dim 't' of pier		(18+15)/2			16.5	m
Height 'h' of pier		605.474-3-472.809			129.67	m
t/b		16.5/8.25			2.00	
h/b		129.665/8.25			15.72	
Cd	refer table 5 (Rectangular section)				1.00	
FT (lower part)	781.548*9*1*2		14068	N/m	1.41	t/m
FT (upper part)	781.548*7.5*1*2		11723	N/m	1.17	t/m
FL (lower part)					0.35	t/m
FL (upper part)					0.29	t/m

Wind on Pier (Inclined Fork)

Dim 'b' (exposed to wind) of pier	21.8	m
Dim 't' of pier	6.0	m
Height 'h' of pier	129.67	m

t/b	6/21.8			0.28	
h/b	129.665/21.8			5.95	
Cd	refer table 5 (Rectangular section)			1.20	
FT	781.548*6*1.2*2	11254	N/m	1.13	t/m
FL				0.28	t/m

Wind on Pier in Longitudinal Direction (vertical Part)

Dim 't' (exposed to wind) of pier	(9+7.5)/2			8.3	m
Dim 'b' of pier	(18+15)/2			16.5	m
Height 'h' of pier	605.474-3-472.809			129.67	m
t/b	8.25/16.5			0.50	
h/b	129.665/16.5			7.86	
Cd	refer table 5 (Rectangular section)			1.70	
FT (lower part)	781.548*18*1.7*2	47831	N/m	4.78	t/m
FT (upper part)	781.548*15*1.7*2	39859	N/m	3.99	t/m

Wind on Pier (Inclined Fork)

Dim 'b' (exposed to wind) of pier				21.8	m
Dim 't' of pier				6.0	m
Height 'h' of pier				129.67	m
t/b	6/21.8			0.28	
h/b	129.665/21.8			5.95	
Cd	refer table 5 (Rectangular section)			1.70	
FT	781.548*21.8*1.7*2	57928	N/m	5.79	t/m

4 DESIGN OF PIER FORK

TABULATION OF STAGE WISE BENDING MOMENT DUE TO PIER/PIER FORK DEAD LOAD (Self weight)

Refer appendix A for diagram showing member numbers

Member	As Built			Creep		
	Axial	Shear	Bending	Axial	Shear	Bending
122	-454	449	-894	-1066	-902	5248
123	-1376	1546	-15796	-1066	-902	18727
124	-2457	2291	-41850	-982	-717	29446
125	-3481	3060	-79600	-912	-553	37708
133	-19282	0	0	0	0	0
134	-24304	0	0	0	0	0

Member	As Built +Creep		
	Axial	Shear	Bending
122	-1520	-453	4354
123	-2442	644	2931
124	-3439	1574	-12404
125	-4393	2507	-41892
133	-19282	0	0
134	-24304	0	0

DUE TO STRESSING OF STAY CABLES

Member	As Built			Creep		
	Axial	Shear	Bending	Axial	Shear	Bending
122	488	415	-2376	761	648	-3707
123	488	415	-8578	761	648	-13382
124	-623	-2033	21794	704	521	-21164
125	-1686	-4513	89226	653	402	-27174
133	0	0	0	0	0	0
134	0	0	0	0	0	0

Member	As Built +Creep		
	Axial	Shear	Bending
122	1249	1063	-6083
123	1249	1063	-21961
124	81	-1512	630
125	-1033	-4111	62052
133	0	0	0
134	0	0	0

TABULATION OF STAGE WISE BENDING MOMENT DUE TO SUPERSTRUCTURE

DEAD LOAD DUE TO 4 BOX GIRDERS

Taken from Superstructure designs

Member	As Built			Creep		
	Axial	Shear	Bending	Axial	Shear	Bending
122	-4364	-1469	-4539	-106	67	4181
123	-4364	-1469	-26790	-106	67	5196
124	-4446	-1347	-47186	-87	39	5788
125	-4488	-1285	-66080	-78	25	6155
133	-7652	17	-18341	207	3	12784
134	-7650	-17	18473	205	-3	-12537

Member	As Built +Creep		
	Axial	Shear	Bending
122	-4470	-1402	-357
123	-4470	-1402	-21594
124	-4533	-1308	-41398
125	-4566	-1260	-59925
133	-7445	20	-5558
134	-7445	-20	5936

PRESTRESSING OF ALL 4 BOX GIRDERS

Member	As Built			Creep		
	Axial	Shear	Bending	Axial	Shear	Bending
122	-258	163	7858	-634	421	10835
123	-257	163	10328	-634	421	17212
124	-227	118	12108	-599	369	22801
125	-211	94	13491	-580	341	27819
133	-271	-185	5938	-602	-431	10297
134	-271	-185	6577	-602	-431	11785

Member	As Built +Creep		
	Axial	Shear	Bending
122	-891	584	18693
123	-891	584	27540
124	-826	487	34909
125	-791	435	41310
133	-873	-617	16235
134	-873	-617	18362

TABULATION OF LOADS AT JUNCTION OF PIER FORK AND PIER

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL OF FORK	-3481				-79600
2	DL BOX	-4488				-66080
3	SDL	-988				-940

4	PRESTRESS	-1897				102717
5	LL	-872				-10953
6	BRAKING	-6				-404
7	Wind Trans			137.53	6569.00	
8	Wind Long		223.85			3235.00
9	SEISMIC V	-59.71				
10	SEISMIC L		27.00			311.00
11	SEISMIC T			118.00	3108.00	0
12	CREEP	-1049.84				51843

Load Factors for Various combinations

	ULS							SLS		
	ULS 1	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.35	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
3	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
4	1	1.00	1.00	1.00	1.00	1.00	1.00	1	1	1
5	1.5	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	
6	1.5	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	
7		0.90	1.50							
8				-0.90	-1.50			0.6	1	
9						0.45	0.45			
10						-1.50	0.45			
11						0.45	1.50			
12										

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	-15504	0	0	0	-112442		ULS 1	
Comb 2	-15504	0	124	5912	-112442		ULS 2	
Comb 3	-15197	0	206	9854	-108467		ULS 3	
Comb 4	-15504	-201	0	0	-115354		ULS 4	WIND LONG
Comb 5	-15197	-336	0	0	-113320		ULS 5	
Comb 6	-14389	-41	53	1399	-98145		ULS 6	
Comb 7	-14389	12	177	4662	-97539		ULS 7	
Comb 8	-11732	134	0	0	-53318		Rare 1	
Comb 9	-11513	224	0	0	-49185		Rare 2	
Comb 10	-10854	0	0	0	-43903		Quasi P	

5 DESIGN OF PIER

5.1 CALCULATION OF LOAD AT PIER BASE

PIER SIZE		18.00	m dia
HEIGHT OF PIER (PIER CAP TOP TO PILE CAP TOP)		132.665	M
LIVE LOAD			
CLASS 70R W		100	T
CLASS A		50	T
ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M
COMB ECC for 3 lane load	(9.955*100+6.21*50)/(100+50)	8.707	M
ECC OF 70R W conc		0.000	M
IMPACT FACTOR	(for bed block)	1.09	
	(for pier cap)	1.04	
	(for pier base, pile cap and pile)	1.00	
DIST BETWEEN BRGS IN L DIR		0.00	M
SEISMIC COEFF.		0.005	Long direction
		0.005	Trans Direction

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\,(m)}$	$e_{t\,m)}$	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL LEFT	0.00			0	0	0	0
2	DL RIGHT	7600.00			0	0	0	0
3	SIDL LEFT	0.00			0	0	0	0
4	SIDL RIGHT	1300.00			0	0	0	0
5	LL1	872.00			1.250	9.96	1090	8681
6	LL2	872.00			1.250	0.00	1090	0
7	LL3	872.00			1.250	8.71	1090	7592
8	PIER CAP	0.00			0.000	0.000	0.0	0
9	PIER	20332.55			0		0.0	
10	Dirt Wall							
11	BRAKING		76.14		132.665		10101.1	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			0	0	0.00	0.00
2	SIDL	1300.00			0	0	0.00	0.00
3	LL3	872.00			0	0	1090.00	7592.21
4	PIER CAP	0.00			0.00	0	0.00	0.00
5	PIER	20332.55			0	0.00	0.00	0.00
6	Dirt Wall	0.00			0.00	0.00	0.00	0.00
7	BRAKING		76.14		132.665	0.00	10101	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			132.665	132.665	0.00	0.00
2	SIDL	1300.00			132.665	134.105	0.00	0.00
3	LL3	872.00			132.665	133.865	1090.00	8680.76

4	PIER CAP	0.00					0.00	0.00
5	PIER	20332.55			66.333	66.33	0.00	0.00
6	Dirt Wall	0.00						
7	BRAKING		15.23		132.665	0.00	2020.22	0.00
8	SEISMIC (+/-) ON							
	DL	-7.60	11.4	38.0	132.665	132.665	1512	5041
	SIDL	-1.30	2.0	6.5	132.665	134.105	259	872
	LL3	-0.87	0.0	0.9	132.665	133.865	0	117
	PIER CAP	0.00	0.0	0.0	0.000	0.000	0	0
	PIER	-20.33	30.5	101.7	66.333	66.333	2023	6744
	Dirt Wall	0.00	0.0	0.0	0.000	0.000	0	0
	TOTAL SEISM	-30.10	43.85	147.03			3794.14	12773

SEISMIC LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			132.665	132.665	0.00	0.00
2	SIDL	1300.00			132.665	134.105	0.00	0.00
3	LL3	872.00			132.665	133.865	1090.00	8680.76
4	PIER CAP	0.00			0.000	0.000	0.00	0.00
5	PIER	20332.55			66.33	66.333	0.00	0.00
6	Dirt Wall	0.00			0.00	0.000	0.00	0.00
7	BRAKING	0.00	15.23	0.0	132.665	0.000	2020.22	0.00
8	SEISMIC (+/-) ON							
	DL	-7.60	38.0	11.4	132.665	132.665	5041	1512
	SIDL	-1.30	6.5	2.0	132.665	134.105	862	262
	LL3	-0.87	0.0	0.3	132.665	133.865	0	35
	PIER CAP	0.00	0.0	0.0	0.000	0.000	0	0
	PIER	-20.33	101.7	30.5	66.333	66.333	6744	2023
	Dirt Wall	0.00	0.0	0.0	0.000	0.000	0	0
	TOTAL SEISM	-30.10	146.16	44.11			12647.14	3831.97

TABULATION OF LOADS AT PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL Left	7600.00			0	0
2	DL Right				0	0
3	SDL Left	1300.00			0	0
4	SDL Right				0	0
5	LL3	872.00			0	8681
6	PIER CAP					
7	PIER+Dwall	20333			0	0
8	BRAKING		76.14		10101	0
9	Centrif.					
10	Wind Long	0.00	325.00	0.00	43116	0.00
11	Shear rating					
12	Water C					
13	SEISMIC V	-30.10				
14	SEISMIC L		146.16		12647	
15	SEISMIC T			147.03		12773

Load Factors for Various combinations

	ULS					SLS		
	Basic	EQ. Long	EQ. Trans	WIND_AC	WIND_LD	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.35	1.35	1.35	1.35	1.35	1	1	1
3	1.55	1.55	1.55	1.55	1.55	1	1	1
4	1.55	1.55	1.55	1.55	1.55	1	1	1
5	1.50	0.20	0.20	1.50	1.15	1	0.75	0
6	1.35	1.35	1.35	1.35	1.35	1	1	1
7	1.35	1.35	1.35	1.35	1.35	1	1	1
8	1.50	0.2	0.2	1.50	1.15	1	0.75	0
9	1.50	0.2	0.2	1.50	1.15	1	0.75	0
10	0.00	0	0	0.90	1.50	0.6	1	
11						1	0.75	0.5
12	1.00	0	0	1.00	1.00	1	1	0
13	0.00	0.45	0.45	0.00	0.00	0	0	0
14	0.00	1.5	0.45	0.00	0.00	0	0	0
15	0.00	0.45	1.5	0.00	0.00	0	0	0

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}	M_{RES}	
Comb 1	41032	114	0	15152	13021		ULS 1
Comb 2	39885	234	66	20991	7484		ULS 2
Comb 3	39885	81	221	7711	20896		ULS 3
Comb 4	41032	407	0	53956	13021		ULS 4
Comb 5	40727	575	0	76290	9983		ULS 5
Comb 6	30105	271	0	35971	8681		Rare 1
Comb 7	29887	382	0	50692	6511		Rare 2
Comb 8	29233	0	0	0	0		Quasi P

Computation of Additional Moment due to Slenderness (Refer Sec 11.2 of IRC 112)

				Trans Dir	Long Dir	
k1	Fully rigid at bottom			0.1		
k2	AT top			100		
x	Eq. 11.3	max of	1.4	2.2		
le	MAX(1.4,2.2)* 132.66			291.86	198.9975	132.66 x 1.5 in long dir
Area of X section				52.972	52.972	
I of section				1558.1	428.3169	
rad. of gyration 'i'	SQRT(1558.05366585375/52.97174466767			5.423	2.844	
le/i				53.82	102.62	
λ_{lim}	20.A.B.C/ SQRT(n) Eq 11.1					
	20*1*1.274*0.7/SQRT(0.337)			30.7	30.4	
ϕ	Ref Table 6.9 for 2Ac/u=2.17 , t0=28, RH=70%			1.7	1.7	
ϕ_{ef}	1.7*(0/20,896)			0.000	0	
A=	1/(1+0.2*0)			1.000	1.000	
B=	SQRT(1+2ω)			1.274	1.274	
C=	1.7-r_m			0.7	0.7	
ω	847,548*435/(52,971,745*22.33)			0.31	0.31	
n	39,885*10000/52,971,745/22.33			0.337	0.344	
r_m	M_{o1}/M_{o2}			1	1	

Second Order Moment

$1/r_0$=	0.0003	0.00064	ε_{yd} reinforcement	0.0022	0.0022
		Radius of gyration of reinf.		5.372	3.065147
		d	18/2+5.372	14.372	7.565

n_u=	$1+\omega$	1.31	1.31
n_{bal}		0.4	0.4
Kr	(Eq. 11.9)	1	1
β	(Eq. 11.11)	0.241	-0.084
$K\phi$	(Eq. 11.10)	1.000	1.000

Wt of Pier (ULS)	27449
CG	66.60

1/r	(Eq. 11.7)	0.000336	0.000639	
c=		10	10	
e2=		2.865	2.530	m
e2 for Pier CG=		1.438	1.270	m
M2=	2.865*(39,885-27,449)+27449*1.438	75100	68453	tm

MED=	Max Trans M	75100+20,896	68453+7,711	95996	76164	tm
	Max Long Mom	75100+35,971	68453+8,681	85083	144743	

5.2 CALCULATION OF LOAD AT 30m above Base

PIER SIZE		15.00	x	7.5		
HEIGHT OF PIER (PIER CAP TOP TO SEC CONSIDERED)		102.665	M	Ht abv base		30
LIVE LOAD						
CLASS 70R W		100	T			
CLASS A		55.4	T			
ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M			
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M			
COMB ECC for 70R+A	(9.955*100+6.21*50)/(100+50)	8.707	M			
ECC OF 70R W conc		0.000	M			
IMPACT FACTOR	(for bed block)	1.09				
	(for pier cap)	1.04				
	(for pier base, pile cap and pile)	1.00				
DIST BETWEEN BRGS IN L DIR		0.00	M			
SEISMIC COEFF.		0.01	TRANS			
		0.02	LONG			

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\,(m)}$	$e_{t\,m)}$	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL LEFT	0.00			0	0	0	0
2	DL RIGHT	7600.00			0	0	0	0
3	SIDL LEFT	0.00			0	0	0	0
4	SIDL RIGHT	1300.00			0	0	0	0
5	LL1	872.00			12.000	9.96	10464	8681
6	LL2	872.00			12.000	0.00	10464	0
7	LL3	872.00			12.000	8.71	10464	7592
9	PIER	15310.55			0		0.0	
10	FRICTION		82.00		99.665		8172.5	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			0	0	0.00	0.00

2	SIDL	1300.00			0	0	0.00	0.00
3	LL3	872.00			0	0	1090.00	7592.21
4	PIER	15310.55			0	0.00	0.00	0.00
5	BRAKING		82.00		99.665	0.00	8173	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			99.665	99.665	0.00	0.00
2	SIDL	1300.00			99.665	99.665	0.00	0.00
3	LL3	872.00			99.665	1.200	1090.00	8680.76
4	PIER	15310.55			49.833	49.83	0.00	0.00
5	BRAKING		0.00		99.665	0.00	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-7.60	0.0	38.0	99.665	99.665	0	3787
5	BRAKING	0.00	0.00	0.0	99.665	0.000	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-7.60		11.4	99.665	99.665	0	1136
	SIDL	-1.30		2.0	99.665	99.665	0	194
	LL3	-0.87		0.3	99.665	1.200	0	0
	PIER	-15.31	76.6	23.0	49.833	49.833	3815	1144
	TOTAL SEISM	-25.08	76.55	36.58			3815	2475

WIND TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			99.665		0.00	0.00
2	SIDL	1300.00			99.665		0.00	0.00
3	LL3	872.00			99.665		1090.00	8680.76
5	PIER	15310.55			49.833		0.00	0.00
6	FRICTION		82.00		99.665	0.00	8172.53	0.00
7	WIND							
	SUPER			70.0	99.665	99.665	0	6977
	PIER			73.0	49.833	49.833	0	3638
	TOTAL WIND	0.00	0.00	143.00			0.00	10614

WIND LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			99.665	0.000	0.00	0.00
2	SIDL	1300.00			99.665	0.000	0.00	0.00
3	LL3	872.00			99.665	0.000	1090.00	8680.76
4	PIER	15310.55			0.00	0.000	0.00	0.00
5	BRAKING		82.00	0.0	99.665	0.000	8172.53	0.00
7	WIND							
	SUPER		17.5		99.665	0.000	1744	0
	PIER		423.0		49.833	0.000	21079	0
	TOTAL WIND		440.50	0.00			22823	0

TABULATION OF LOADS AT 30m abv PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$

1	DL Left	22911			0	0
2	SDL Left	1300.00			0	0
3	LL3	872.00			0	8681
4	FRICTION		82.00		8173	0
5	Wind Trans	0.00	0.00	143.00	0.00	10614.32
6	Wind Long	0.00	440.50	0.00	22823.29	0.00
7	SEISMIC V	-25.08				
8	SEISMIC L		76.55		3815	
9	SEISMIC T			121.92		8251

Load Factors for Various combinations

	ULS						SLS		
	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
3	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	0
4							0.6	0.6	0.5
5	0.90	1.5							
6			0.90	1.50			0.6	1	
7					0.45	0.45			
8					0.45	1.50			
9					1.50	0.45			

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	37298	200	215	16074	27641		ULS 1	
Comb 2	7514	16	83	1635	17555		ULS 2	
Comb 3	7514	16	83	1635	17555		ULS 3	
Comb 4	37298	596	215	36615	27641		ULS 4	WIND LONG
Comb 5	29279	832	164	47448	23925		ULS 5	
Comb 6	25057	423	143	25681	19295		ULS 6	
Comb 7	19336	579	107	32767	16642		Rare 1	
Comb 8	2159	0	0	0	8681		Rare 2	
Comb 9	0	0	0	0	0		Quasi P	

5.3 CALCULATION OF LOAD AT 86 above Base

PIER SIZE		0.00	m dia		
HEIGHT OF PIER (PIER CAP TOP TO PILE CAP TOP)		46.665	M	Ht abv base	86
LIVE LOAD					
CLASS 70R W		100	T		
CLASS A		55.4	T		
ECC OF 70R W ecc	26.1/2-1.7-2.79/2	9.955	M		
ECC OF ASSOC CL A	9.955-2.79/2-1.2-0.25-1.8/2	6.210	M		
COMB ECC for 70R+A	(9.955*100+6.21*50)/(100+50)	8.707	M		
ECC OF 70R W conc		0.000	M		
IMPACT FACTOR	(for bed block)	1.09			
	(for pier cap)	1.04			
	(for pier base, pile cap and pile)	1.00			
DIST BETWEEN BRGS IN L DIR		0.00	M		
SEISMIC COEFF.		0.01	TRANS		

0.00 LONG

SUMMARY OF LOAD ON PIER

S No.	Particular	V(t)	HL	HT	$e_{l\,(m)}$	$e_{t\,m)}$	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL LEFT	0.00			0	0	0	0
2	DL RIGHT	7600.00			0	0	0	0
3	SIDL LEFT	0.00			0	0	0	0
4	SIDL RIGHT	1300.00			0	0	0	0
5	LL1	872.00			1.250	9.96	1090	8681
6	LL2	872.00			1.250	0.00	1090	0
7	LL3	872.00			1.250	8.71	1090	7592
9	PIER	14554.30			0		0.0	
10	FRICTION		82.00		43.665		3580.5	

Normal Case LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			0	0	0.00	0.00
2	SIDL	1300.00			0	0	0.00	0.00
3	LL3	872.00			0	0	1090.00	7592.21
4	PIER	14554.30			0	0.00	0.00	0.00
5	BRAKING		82.00		43.665	0.00	3581	0.0

SEISMIC TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			43.665	43.665	0.00	0.00
2	SIDL	1300.00			43.665	43.665	0.00	0.00
3	LL3	872.00			43.665	1.200	1090.00	8680.76
4	PIER	14554.30			21.833	21.83	0.00	0.00
5	BRAKING		0.00		43.665	0.00	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-7.60	11.4	38.0	43.665	43.665	498	1659
	SIDL	-1.30	2.0	6.5	43.665	43.665	85	284
	LL3	-0.87	0.0	0.9	43.665	1.200	0	1
	PIER	-14.55	21.8	72.8	21.833	21.833	477	1589
	TOTAL SEISM	-24.33	35.18	118.14			1059.56	3533

SEISMIC LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			43.665	43.665	0.00	0.00
2	SIDL	1300.00			43.665	43.665	0.00	0.00
3	LL3	872.00			43.665	1.200	1090.00	8680.76
4	PIER	14554.30			21.83	21.833	0.00	0.00
5	BRAKING	0.00	0.00	0.0	43.665	0.000	0.00	0.00
6	SEISMIC (+/-) ON							
	DL	-7.60	38.0	11.4	43.665	43.665	1659	498
	SIDL	-1.30	6.5	2.0	43.665	43.665	284	85
	LL3	-0.87	0.0	0.3	43.665	1.200	0	0
	PIER	-14.55	72.8	21.8	21.833	21.833	1589	477
	TOTAL SEISM	-24.33	117.27	35.44			3532	1060

WIND TRANSVERSE CASE LL3 CONSIDERED (Live Load for 3 Lane)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			43.665		0.00	0.00
2	SIDL	1300.00			43.665		0.00	0.00
3	LL3	872.00			43.665		1090.00	8680.76
5	PIER	14554.30			21.833		0.00	0.00
6	FRICTION		82.00		43.665	0.00	3580.53	0.00
7	WIND							
	SUPER			70.0	43.665	43.665	0	3057
	PIER			23.0	21.833	21.833	0	502
	TOTAL WIND	0.00	0.00	93.00			0.00	3559

WIND LONGITUDINAL CASE LL3 CONSIDERED (Live Load for 3 Lane) (Full seismic due to Superst on one pier)

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\ (Tm)}$	$M_{L\ (Tm)}$
1	DL	7600.00			43.665	0.000	0.00	0.00
2	SIDL	1300.00			43.665	0.000	0.00	0.00
3	LL3	872.00			43.665	0.000	1090.00	8680.76
4	PIER	14554.30			0.00	0.000	0.00	0.00
5	BRAKING		82.00	0.0	43.665	0.000	3580.53	0.00
7	WIND							
	SUPER		17.5		43.665	0.000	764	0
	PIER		211.0		21.833	0.000	4607	0
	TOTAL WIND		228.50	0.00			5371	0

TABULATION OF LOADS AT 30m abv PIER BASE (CONSIDERING LL1 CASE)

S No.	Particular	V(t)	HL	HT	$M_{TT\ (Tm)}$	$M_{LL\ (Tm)}$
1	DL Left	22154			0	0
2	SDL Left	1300.00			0	0
3	LL3	872.00			0	8681
4	FRICTION		82.00		3581	0
5	Wind Trans	0.00	0.00	93.00	0.00	3558.70
6	Wind Long	0.00	228.50	0.00	5370.80	0.00
7	SEISMIC V	-24.33				
8	SEISMIC L		117.27		3532	
9	SEISMIC T			118.14		3533

Load Factors for Various combinations

	ULS						SLS		
	W_T_AC	W_T_LD	W_L_AC	W_L_LD	EQ_T	EQ_L	RARE 1	RARE 2	QUASI P
1	1.35	1.35	1.35	1.35	1.35	1.35	1	1	1
2	1.55	1.55	1.55	1.55	1.55	1.55	1	1	1
3	1.50	1.15	1.50	1.15	0.20	0.20	1	0.75	0
4							0.6	0.6	0.5
5	0.90	1.5							
6			0.90	1.50			0.6	1	
7					0.45	0.45			
8					0.45	1.50			
9					1.50	0.45			

Factored Loads in Various Combinations

	V	H_L	H_T	M_{TT}	M_{LL}			
Comb 1	36164	240	140	8903	17057		ULS 1	
Comb 2	7363	16	72	716	14021		ULS 2	
Comb 3	7363	16	72	716	14021		ULS 3	
Comb 4	36164	446	140	13736	17057		ULS 4	WIND LONG
Comb 5	28410	554	107	15706	15812		ULS 5	
Comb 6	24302	336	93	10335	12239		ULS 6	
Comb 7	18769	407	70	11588	11350		Rare 1	
Comb 8	2160	0	0	0	8681		Rare 2	
Comb 9	0	0	0	0	0		Quasi P	

6 DESIGN OF PILE LAYOUT

6.1 LOADS AT FTG BOTTOM

Increament in seismic for foundation	1.35
Live Load in normal case	100%
Live Load in seismic case	20%

Normal Case LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00			0	0	0.00	0.00
2	SIDL	1300.00			0	0	0.00	0.00
3	LL3	872.00			0	0	1090.00	7592.21
4	PIER CAP	0.00			0	0	0.00	0.00
5	PIER	20332.55			0	0	0.00	0.00
6	Dirt Wall	0	0	0	0	0	0.00	0.00
7	BRAKING	0.00	76.14	0.00	135.17		10291.46	0.00
9	FTG	5092.00					0.0	
TOTAL		35196.55	76.14	0.00			11381.46	7592.21

SEISMIC TRANSVERSE CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00					0.00	0.00
2	SIDL	1300.00					0.00	0.00
3	LL3	174.40					218.00	1518.44
4	PIER CAP	0.00					0.00	0.00
5	PIER	20332.55					0.00	0.00
6	Dirt Wall	0.00					0.00	0.00
7	BRAKING		15.23		135.17	0.00	2058.29	0.00
8	SEISMIC (+/-)	40.64	59.20	198.50	89.03	89.37	5270.08	17740.10
9	FTG	5092.00					0.00	0.00
TOTAL		34539.59	74.42	198.50			7546.37	19258.54

SEISMIC LONGITUDINAL CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$
1	DL	7600.00					0.00	0.00
2	SIDL	1300.00					0.00	0.00
3	LL3	174.40					218.00	1518.44
4	PIER CAP	0.00					0.00	0.00
5	PIER	20332.55					0.00	0.00
6	Dirt Wall	0.00					0.00	0.00
7	BRAKING	0.00	15.23	0.0	135.165	0.000	2058.29	0.00
8	SEISMIC (+/-)	40.64	197.32	59.55	89.028	89.372	17566.94	5322.03
9	FTG	5092.00					0.00	0.00
TOTAL		34539.59	212.55	59.55			19843	6840.47

WIND LONG CASE LL3 ONLY CONSIDERED

S No.	Particular	V(t)	HL	HT	la (for H_L)	la (for H_T)	$M_{T\,(Tm)}$	$M_{L\,(Tm)}$

1	DL	7600.00					0.00	0.00
2	SIDL	1300.00					0.00	0.00
3	LL3	174.40					218.00	1518.44
4	PIER CAP	0.00					0.00	0.00
5	PIER	20332.55					0.00	0.00
6	Dirt Wall	0.00					0.00	0.00
7	BRAKING	0.00	76.14	0.0	135.165	0.000	10291.46	0.00
8	Wind	0.00	325.00	0.00	135.165		43928.63	0.00
9	FTG	5092.00					0.00	0.00
TOTAL		34498.95	401.14	0.00			54438	1518.44

6.2 SUMMARY OF LOADS ON PILE GROUP

LOAD C	V	HL	HT	MT	ML
1	35197	76	0	11381	7592
2	34540	74	198	7546	19259
3	34540	213	60	19843	6840
4	34499	401	0	54438	1518

6.3 CHECK FOR BASE PRESSURE

FTG SIZE 28.00 20.00 AREA 560 ZLARGE 2613.333

ZSMALL 1866.667

LOAD C	P/A	MT/ZL	ML/ZS	MAX	MIN
1	63	4	4	71	54
2	62	3	10	75	48
3	62	8	4	73	50
4	62	21	1	83	40

6.4 CHECK FOR FTG SECTION

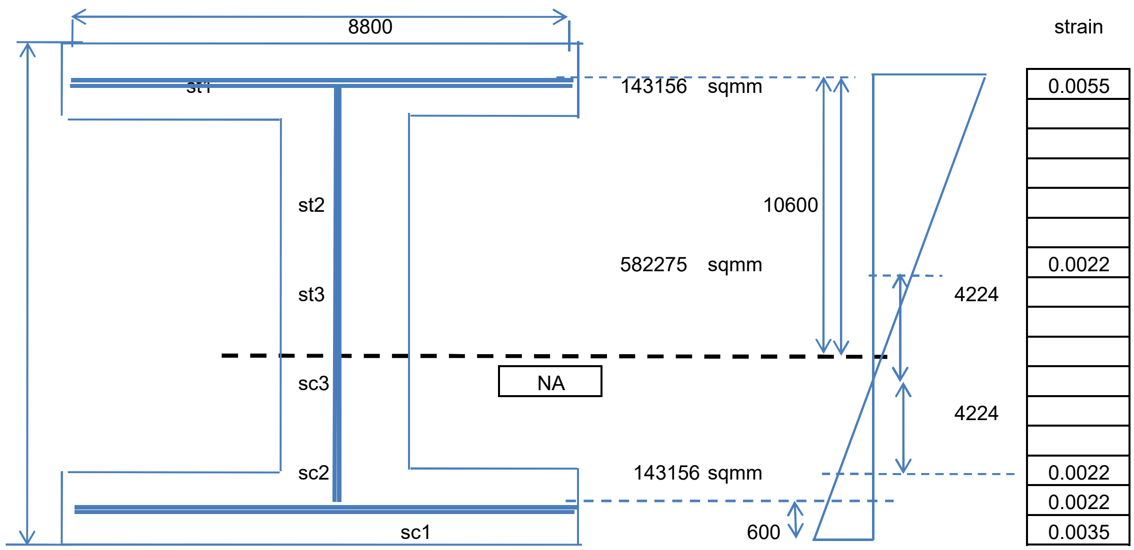
CANTILEVER	(20-9)/2	5.50	
Moment	83.25*5.5^2/2	1259	
ULS BM	1259.15625*1.5	1889	
eff depth		2400	
Mom cap		4320	tm
Ast		20101	sqmm/m
Provide 40	dia bars	16.0	Numbers

Provide in two layers

7 ULS FLEXURE CHECK

7.1 AT PIER BASE

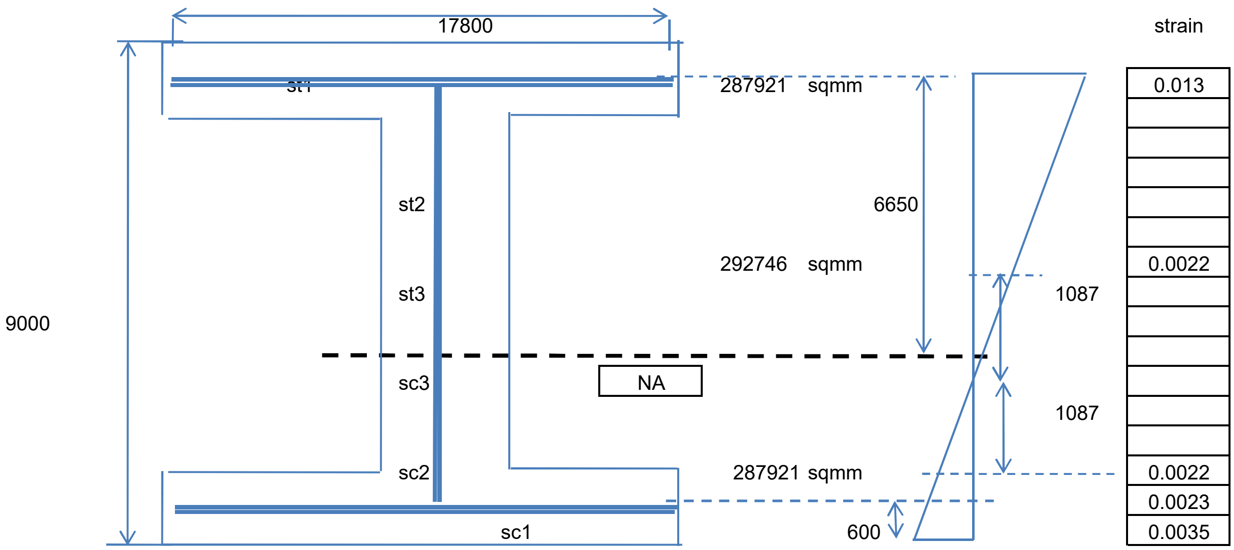
About Major Axis



Bar Dia	32	mm			
Bar spacing	100	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	17400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	18000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	9000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	143156	sqmm	Area of comp face reinf. C1	143156	sqmm
Area of tension face reinf. T2	221001	sqmm	Area of comp face reinf. C2	68500	sqmm
Area of tension face reinf. T3	146387	sqmm	Area of comp face reinf. C3	146387	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	1.976	m	av strain	0.0022	
Length of C3 with strain $<\varepsilon_{yd}$	4.224	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	6.376	m	av strain	0.0022	
Length of T3 with strain <eyd	4.224	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	6224	t
Stress in T2	435		Force in T2	9609	t
Stress in T3 (>eyd)	217		Force in T3	3182	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	435		Force in C1	6224	t
Stress in C2	435		Force in C2	2978	t
Stress in C3	217		Force in C3	3182	t
Comp Force F1 in conc	23647	T	ttl comp F	58432	t

Comp Force F2 in conc	22399	T	ttl Tensile F	19015	t		
Assume Neutral Axis	**6800**	**mm**	Net F	**39416**	t	39885	t
Moment about neutral axis							
Conc F1	146613	tm	Tensile Steel T1	65976	tm		
Conc F2	104830	tm	Tensile Steel T2	71218	tm		
Comp Steel C1	38590	tm	Tensile Steel T3	6720	tm		
Comp Steel C2	15522	tm		**143915**	tm		
Comp Steel C3	6720	tm			tm		
	312275						
ttl moment	***456190***	tm	external moment	**95996**	tm	85083	

About Minor Axis



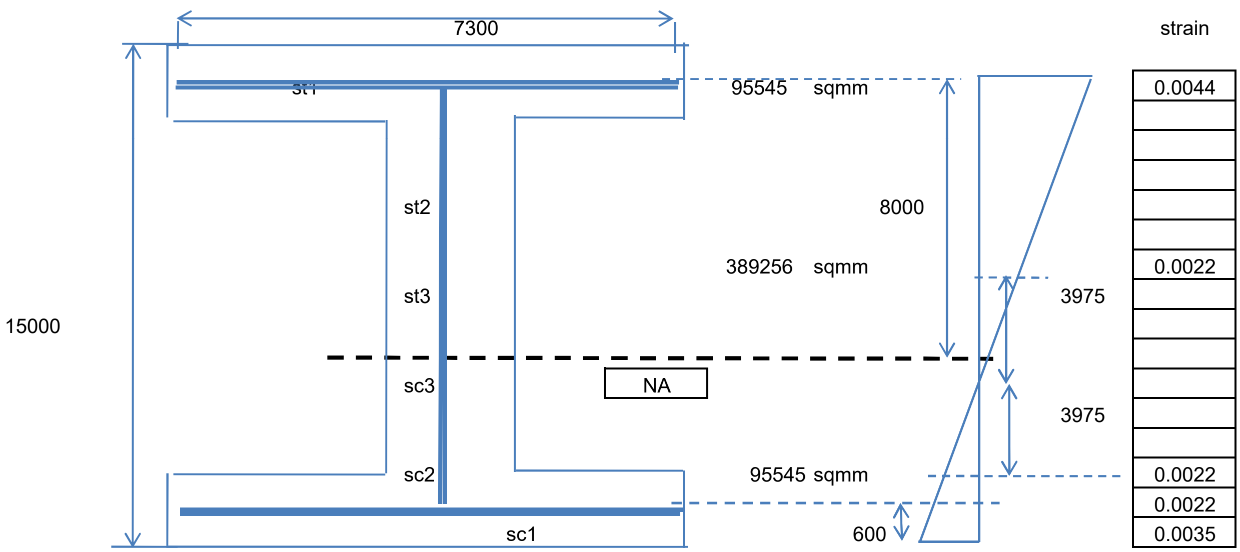
Bar Dia	32	mm			
Bar spacing	100	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	8400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	9000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	18000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	287921	sqmm	Area of comp face reinf. C1	287921	sqmm
Area of tension face reinf. T2	208790	sqmm	Area of comp face reinf. C2	2366	sqmm
Area of tension face reinf. T3	40795	sqmm	Area of comp face reinf. C3	40795	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	0.063	m	av strain	0.0022	
Length of C3 with strain $<\varepsilon_{yd}$	1.087	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	5.563	m	av strain	0.0022	
Length of T3 with strain <eyd	1.087	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	12518	t
Stress in T2	435		Force in T2	9078	t
Stress in T3 (>eyd)	217		Force in T3	887	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	435		Force in C1	12518	t

Stress in C2	435		Force in C2	103	t		
Stress in C3	217		Force in C3	887	t		
Comp Force F1 in conc	47592	T	ttl comp F	62081	t		
Comp Force F2 in conc	981	T	ttl Tensile F	22483	t		
Assume Neutral Axis	**1750**	**mm**	Net F	**39598**	t	39885	t
Moment about neutral axis							
Conc F1	54730	tm	Tensile Steel T1	83247	tm		
Conc F2	1618	tm	Tensile Steel T2	35117	tm		
Comp Steel C1	14396	tm	Tensile Steel T3	482	tm		
Comp Steel C2	115	tm		**118846**	tm		
Comp Steel C3	482	tm			tm		
	71342						
ttl moment	***190188***	tm	external moment	**76164**	tm	144743	

α			1			
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**		
0.21	+	0.40	=	0.61	< 1	OK
0.19		0.76		0.95	< 1	

7.2 AT FIRST CHANGE OF SECTION (30M ABOVE BASE)

About Major Axis



Bar Dia	32	mm			
Bar spacing	125	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	14400	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	15000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	7500	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	95545	sqmm	Area of comp face reinf. C1	95545	sqmm
Area of tension face reinf. T2	113529	sqmm	Area of comp face reinf. C2	51473	sqmm
Area of tension face reinf. T3	112127	sqmm	Area of comp face reinf. C3	112127	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain $>\varepsilon_{yd}$	1.825	m	av strain	0.0022	
Length of C3 with strain $<\varepsilon_{yd}$	3.975	m	av strain	0.0011	

strain in T1				0.0022	
Length of T2 with strain >eyd	4.025	m	av strain	0.0022	
Length of T3 with strain <eyd	3.975	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	

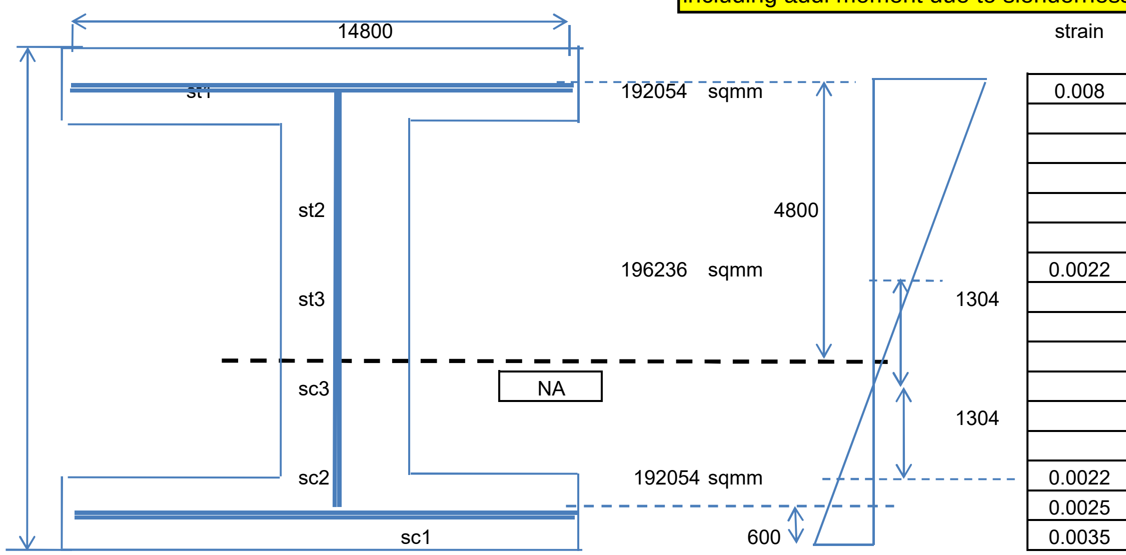
Stress in T1	435		Force in T1	4154	t
Stress in T2	435		Force in T2	4936	t
Stress in T3 (>eyd)	217		Force in T3	2438	t
Stress in T4 (>eyd)	0		Force in T4	0	t

Stress in C1	435		Force in C1	4154	t
Stress in C2	435		Force in C2	2238	t
Stress in C3	217		Force in C3	2438	t

Comp Force F1 in conc	19772	T	ttl comp F	49362	t		
Comp Force F2 in conc	20761	T	ttl Tensile F	11528	t		
Assume Neutral Axis	**6400**	**mm**	Net F	**37834**	t	37298	t
Moment about neutral axis							
Conc F1	114676	tm	Tensile Steel T1	33233	tm		
Conc F2	92178	tm	Tensile Steel T2	29555	tm		
Comp Steel C1	24094	tm	Tensile Steel T3	4845	tm		
Comp Steel C2	10938	tm		**67633**	tm		
Comp Steel C3	4845	tm			tm		
	246730						
ttl moment	***314363***	tm	external moment	**94272**	tm	105105	

About Minor Axis

including addl moment due to slenderness



Bar Dia	32	mm			
Bar spacing	125	mm	d' for comp reinf	600	
d' for tension reinf	600	mm	Effective depth 'd'	6900	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	7500	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	15000	mm	fcd	22.333	mpa
Wall thickness	1200	mm	Strain in concrete	0.0035	mm
					mpa

Area of tension face reinf. T1	192054	sqmm	Area of comp face reinf. C1	192054	sqmm
Area of tension face reinf. T2	108885	sqmm	Area of comp face reinf. C2	6094	sqmm
Area of tension face reinf. T3	40629	sqmm	Area of comp face reinf. C3	40629	sqmm
Area of tension face reinf. T4	0	sqmm			

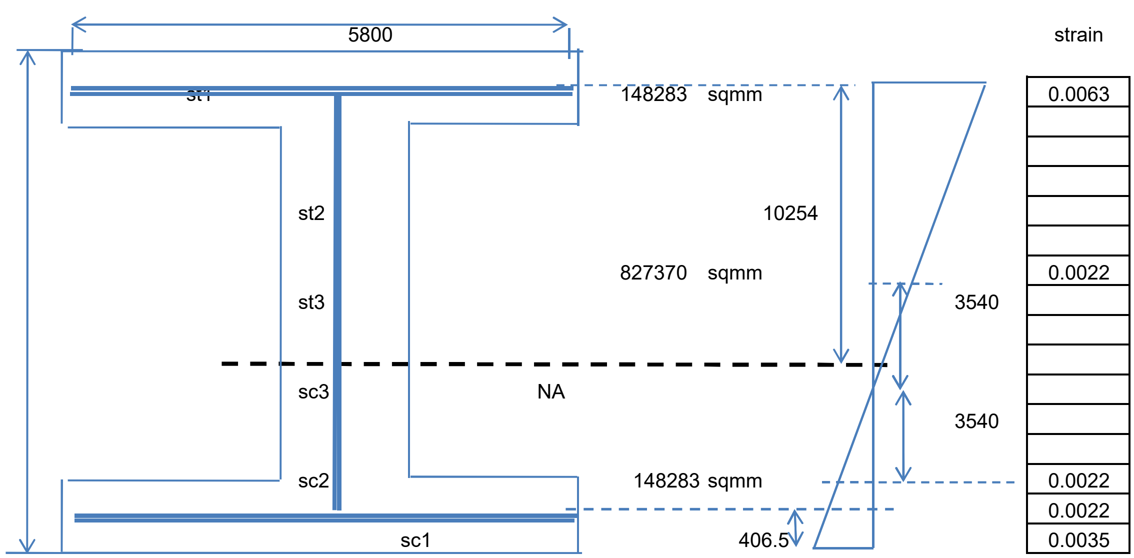
strain in C1				0.0022			
Length of C2 with strain $>\varepsilon_{yd}$	0.196	m	av strain	0.0022			
Length of C3 with strain $<\varepsilon_{yd}$	1.304	m	av strain	0.0011			
strain in T1				0.0022			
Length of T2 with strain >eyd	3.496	m	av strain	0.0022			
Length of T3 with strain <eyd	1.304	m	av strain	0.0011			
Length of T4 with strain <eyd	0.000	m	av strain	0.0000			
Stress in T1	435		Force in T1	8350	t		
Stress in T2	435		Force in T2	4734	t		
Stress in T3 (>eyd)	217		Force in T3	883	t		
Stress in T4 (>eyd)	0		Force in T4	0	t		
Stress in C1	435		Force in C1	8350	t		
Stress in C2	435		Force in C2	265	t		
Stress in C3	217		Force in C3	883	t		
Comp Force F1 in conc	39757	T	ttl comp F	51738	t		
Comp Force F2 in conc	2482	T	ttl Tensile F	13968	t		
Assume Neutral Axis	**2100**	**mm**	Net F	**37770**	t	37298	t
Moment about neutral axis							
Conc F1	59636	tm	Tensile Steel T1	40081	tm		
Conc F2	4617	tm	Tensile Steel T2	14449	tm		
Comp Steel C1	12525	tm	Tensile Steel T3	576	tm		
Comp Steel C2	372	tm		**55106**	tm		
Comp Steel C3	576	tm			tm		
	77726						
ttl moment	***132832***	tm	external moment	**80195**	tm	76480	

including addl moment due to slenderness

α			1				
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**			
0.30	+	0.60	=	0.90	< 1	OK	
0.33		0.58		0.91	< 1		

7.3 FORK SECTION AT JUNCTION

About Major Axis

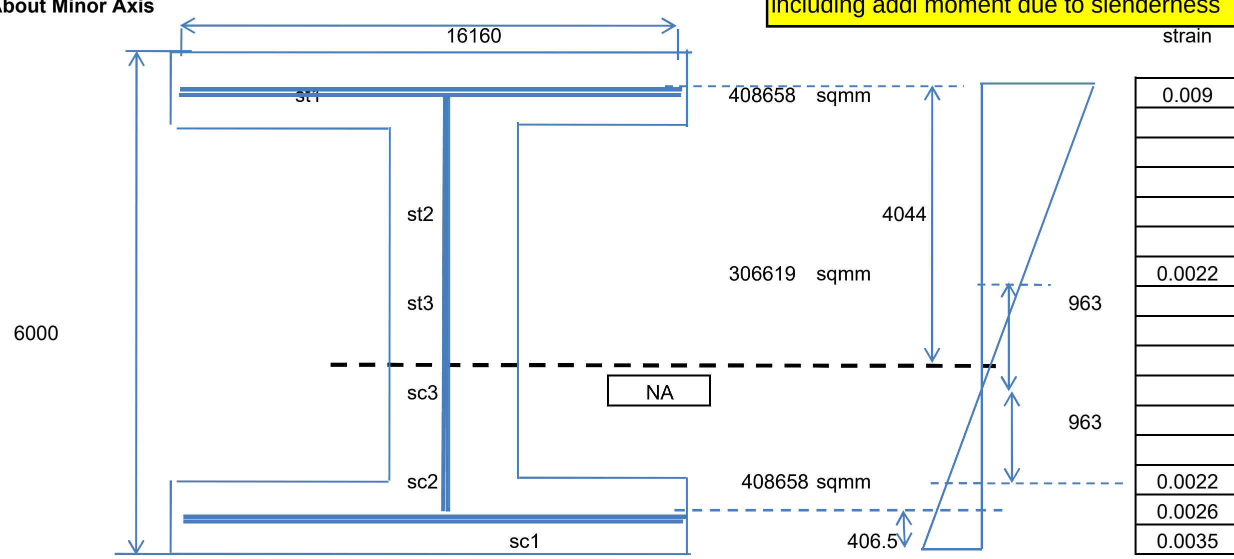


Bar Dia	40	mm			
Bar spacing	100	mm	d' for comp reinf	406.5	

d' for tension reinf	406.5	mm	Effective depth 'd'	15953.5	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	16360	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	6000	mm	fcd	22.333	mpa
Wall thickness	813	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	148283	sqmm	Area of comp face reinf. C1	148283	sqmm
Area of tension face reinf. T2	357255	sqmm	Area of comp face reinf. C2	93297	sqmm
Area of tension face reinf. T3	188409	sqmm	Area of comp face reinf. C3	188409	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain >ε_{yd}	1.753	m	av strain	0.0022	
Length of C3 with strain <ε_{yd}	3.540	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	6.713	m	av strain	0.0022	
Length of T3 with strain <eyd	3.540	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	6447	t
Stress in T2	435		Force in T2	15533	t
Stress in T3 (>eyd)	217		Force in T3	4096	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	435		Force in C1	6447	t
Stress in C2	435		Force in C2	4056	t
Stress in C3	217		Force in C3	4096	t
Comp Force F1 in conc	10355	T	ttl comp F	38140	t
Comp Force F2 in conc	13186	T	ttl Tensile F	26076	t
Assume Neutral Axis	**5700**	**mm**	Net F	**12064**	t 15504 t
Moment about neutral axis					
Conc F1	54812	tm	Tensile Steel T1	66105	tm
Conc F2	50457	tm	Tensile Steel T2	107129	tm
Comp Steel C1	34128	tm	Tensile Steel T3	7250	tm
Comp Steel C2	17917	tm		**180485**	tm
Comp Steel C3	7250	tm			tm
	164564				
ttl moment	***345048***	tm	external moment	**19769**	tm 19769

including addl moment due to slenderness

About Minor Axis

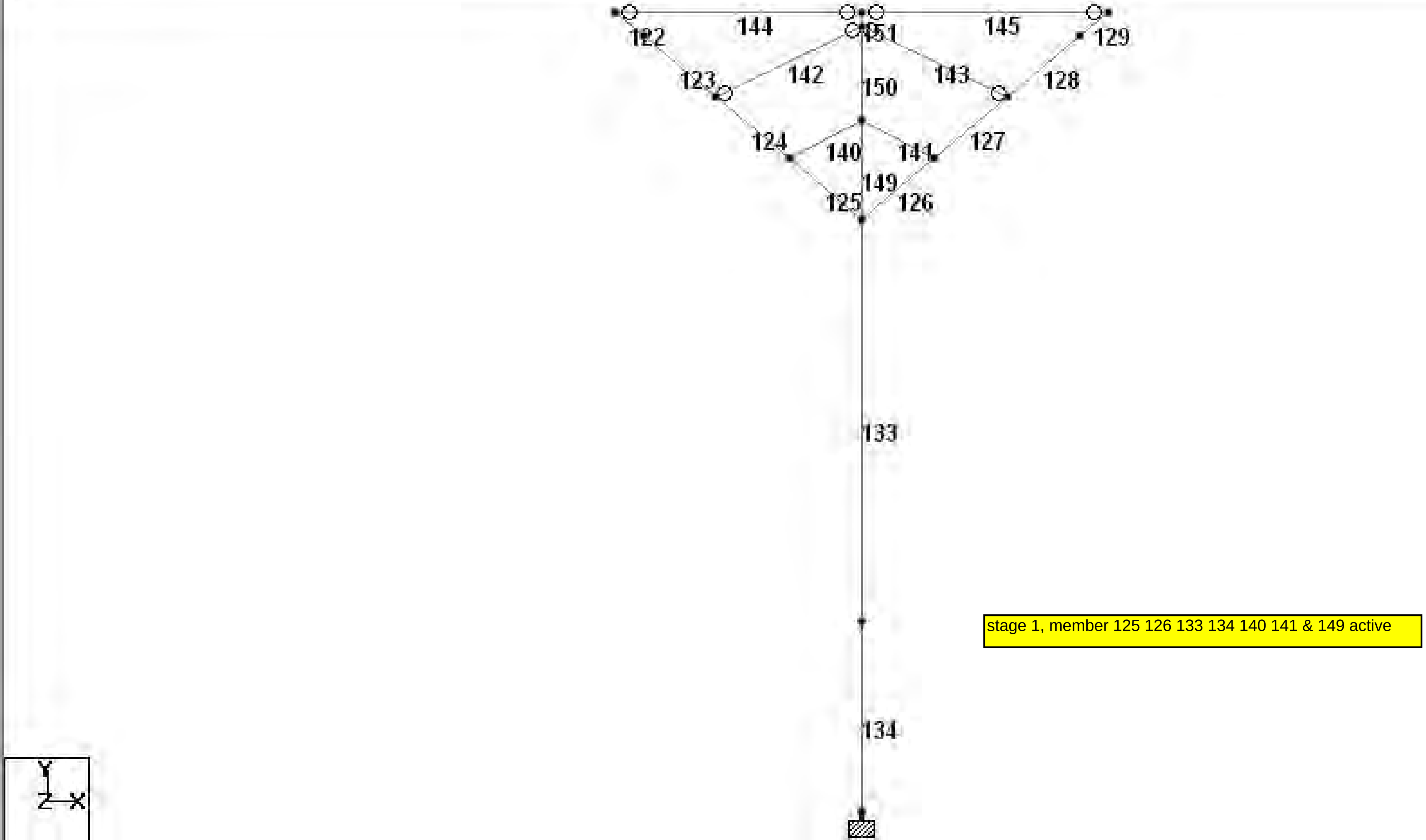


Bar Dia	40	mm			
Bar spacing	100	mm	d' for comp reinf	406.5	
d' for tension reinf	406.5	mm	Effective depth 'd'	5593.5	mm
		mm	fyd	435	mm
Dia of stirrups	16	mm	Young' modulus of reinf	200000	mm
Larger Pier dim	6000	mm	ε_{yd} reinforcement	0.0022	mpa
Shorter Pier Dim	16360	mm	fcd	22.333	mpa
Wall thickness	813	mm	Strain in concrete	0.0035	mm
					mpa
Area of tension face reinf. T1	408658	sqmm	Area of comp face reinf. C1	408658	sqmm
Area of tension face reinf. T2	182114	sqmm	Area of comp face reinf. C2	10686	sqmm
Area of tension face reinf. T3	56910	sqmm	Area of comp face reinf. C3	56910	sqmm
Area of tension face reinf. T4	0	sqmm			
strain in C1				0.0022	
Length of C2 with strain >ε_{yd}	0.181	m	av strain	0.0022	
Length of C3 with strain <ε_{yd}	0.963	m	av strain	0.0011	
strain in T1				0.0022	
Length of T2 with strain >eyd	3.081	m	av strain	0.0022	
Length of T3 with strain <eyd	0.963	m	av strain	0.0011	
Length of T4 with strain <eyd	0.000	m	av strain	0.0000	
Stress in T1	435		Force in T1	17768	t
Stress in T2	435		Force in T2	7918	t
Stress in T3 (>eyd)	217		Force in T3	1237	t
Stress in T4 (>eyd)	0		Force in T4	0	t
Stress in C1	435		Force in C1	17768	t
Stress in C2	435		Force in C2	465	t
Stress in C3	217		Force in C3	1237	t
Comp Force F1 in conc	28768	T	ttl comp F	49661	t
Comp Force F2 in conc	1424	T	ttl Tensile F	26923	t
Assume Neutral Axis	**1550**	**mm**	Net F	**22738**	t 15504 t
Moment about neutral axis					
Conc F1	32897	tm	Tensile Steel T1	71844	tm
Conc F2	1903	tm	Tensile Steel T2	19820	tm
Comp Steel C1	20317	tm	Tensile Steel T3	596	tm
Comp Steel C2	489	tm		**92259**	tm
Comp Steel C3	596	tm			
	56201				
ttl moment	***148460***	tm	external moment	**133372**	tm 131339

including addl moment due to slenderness

α		1				
$(M_{EDx}/M_{RDx})^{\alpha}$		$+(M_{EDy}/M_{RDy})^{\alpha}$		**Eq. 8.3**		
0.06	+	0.90	=	0.96	< 1	OK
0.06		0.88		0.94	< 1	

APPENDIX A
STAAD INPUT FILES


144
145
122
151
129
123
142
150
143
128
124
140
141
127
149
125
126
133
134
stage 1, member 125 126 133 134 140 141 & 149 active
Y
Z
X

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STAAD SPACE DL STAGE 1
START JOB INFORMATION
ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
JOINT COORDINATES
121 225.439 126.0 0; 122 229.951 122.204 0; 123 241.384 112.586 0;
124 252.817 102.968 0; 125 264.25 93.35 0; 126 275.683 102.968 0;
127 287.116 112.586 0; 128 298.549 122.204 0; 129 303.061 126 0;
132 264.25 30 0; 133 264.25 0 0; 136 264.25 108.725 0;
137 264.25 123.5 0; 138 264.25 126 0;
MEMBER INCIDENCES
122 121 122; 123 122 123; 124 123 124; 125 124 125; 126 125 126;
127 126 127; 128 127 128; 129 128 129; 133 125 132; 134 132 133;
140 124 136; 141 136 126; 142 123 137; 143 137 127; 144 121 138;
145 138 129; 149 125 136; 150 136 137; 151 137 138;
MEMBER PROPERTY CANADIAN
134 PRIS AX 66.96 IX 1675.266 IY 2286.92 IZ 748.51
133 PRIS AX 54.36 IX 902.515 IY 1259.95 IZ 401.33
125 126 PRIS AX 37.27 IX 509.992 IY 1003.85 IZ 184.9
124 127 PRIS AX 38.273 IX 583.606 IY 1393.28 IZ 197.98
123 128 PRIS AX 38.364 IX 639.518 IY 1811.65 IZ 205.49
122 129 PRIS AX 37.964 IX 667.994 IY 2111.49 IZ 207.97
140 TO 143 PRIS AX 0.021382 IX 3.6e-005 IY 3.6e-005 IZ 3.6e-005
144 145 PRIS AX 0.5 IX 1e-005 IY 12.25 IZ 0.167
149 150 151 PRIS AX 8.91 IX 28.599 IY 120.46 IZ 6.7
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 140 TO 145
MATERIAL MATERIAL3 MEMB 122 TO 124 127 TO 129 150 TO 151
SUPPORTS
133 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
142 TO 145 START FX FY FZ MX MY MZ
142 TO 145 END FX FY FZ MX MY MZ
*111 TO 114 START MZ
LOAD 1 SELF
SELFWEIGHT Y -1
LOAD 2 PRESTRESS
TEMPERATURE LOAD
140 141 TEMP -100
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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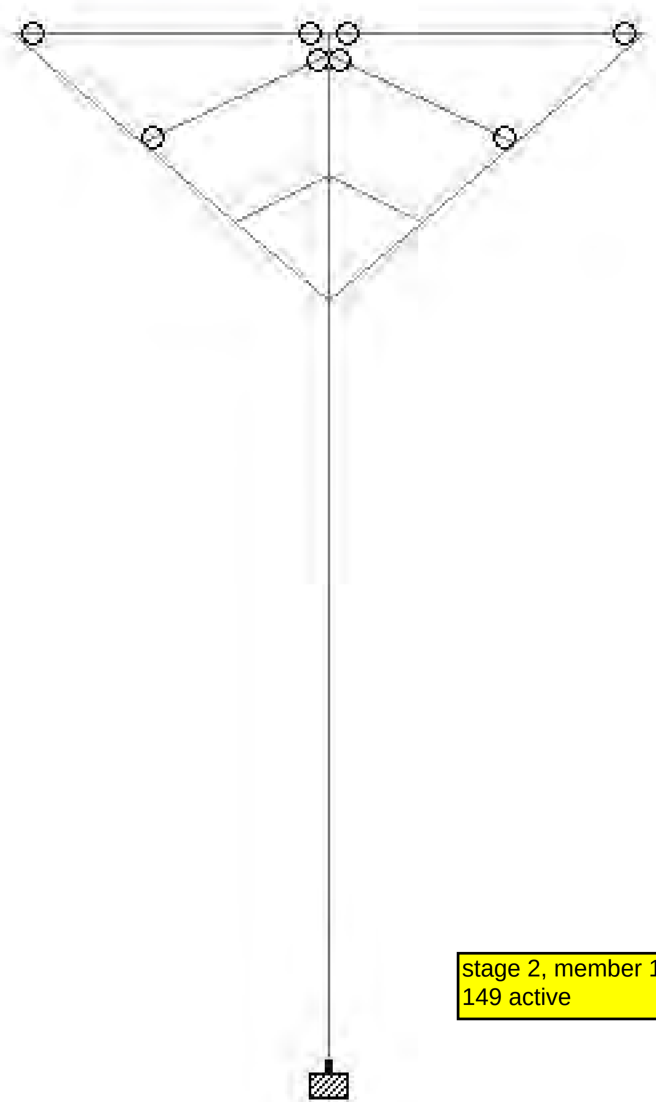

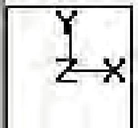

stage 2, member 124 to 127 133 134 140 141 and 149 active

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ENGINEER DATE 02-Nov-11
END JOB INFORMATION
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PAGE LENGTH 15000
UNIT METER MTON
JOINT COORDINATES
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124 252.817 102.968 0; 125 264.25 93.35 0; 126 275.683 102.968 0;
127 287.116 112.586 0; 128 298.549 122.204 0; 129 303.061 126 0;
132 264.25 30 0; 133 264.25 0 0; 136 264.25 108.725 0;
137 264.25 123.5 0; 138 264.25 126 0;
MEMBER INCIDENCES
122 121 122; 123 122 123; 124 123 124; 125 124 125; 126 125 126;
127 126 127; 128 127 128; 129 128 129; 133 125 132; 134 132 133;
140 124 136; 141 136 126; 142 123 137; 143 137 127; 144 121 138;
145 138 129; 149 125 136; 150 136 137; 151 137 138;
MEMBER PROPERTY CANADIAN
134 PRIS AX 66.96 IX 1675.266 IY 2286.92 IZ 748.51
133 PRIS AX 54.36 IX 902.515 IY 1259.95 IZ 401.33
125 126 PRIS AX 37.27 IX 509.992 IY 1003.85 IZ 184.9
124 127 PRIS AX 38.273 IX 583.606 IY 1393.28 IZ 197.98
123 128 PRIS AX 38.364 IX 639.518 IY 1811.65 IZ 205.49
122 129 PRIS AX 37.964 IX 667.994 IY 2111.49 IZ 207.97
140 TO 143 PRIS AX 0.021382 IX 3.6e-005 IY 3.6e-005 IZ 3.6e-005
144 145 PRIS AX 0.5 IX 1e-005 IY 12.25 IZ 0.167
149 150 151 PRIS AX 8.91 IX 28.599 IY 120.46 IZ 6.7
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 140 TO 145
MATERIAL MATERIAL3 MEMB 122 123 125 126 128 129 133 134 149 151
SUPPORTS
133 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
142 TO 145 START FX FY FZ MX MY MZ
142 TO 145 END FX FY FZ MX MY MZ
*111 TO 114 START MZ
LOAD 1 SELF
SELFWEIGHT Y -1
LOAD 2 PRESTRESS
TEMPERATURE LOAD
140 141 TEMP -100
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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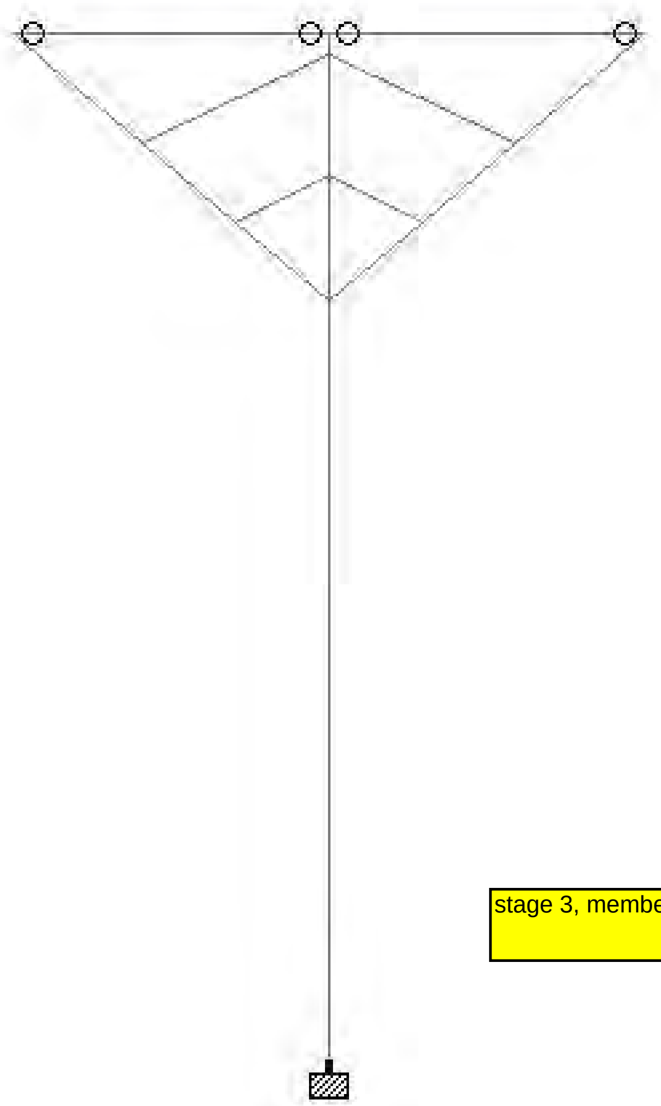

stage 3, member 123 to 128 133 134 140 to 143 149 150 active

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START JOB INFORMATION
ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
JOINT COORDINATES
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124 252.817 102.968 0; 125 264.25 93.35 0; 126 275.683 102.968 0;
127 287.116 112.586 0; 128 298.549 122.204 0; 129 303.061 126 0;
132 264.25 30 0; 133 264.25 0 0; 136 264.25 108.725 0;
137 264.25 123.5 0; 138 264.25 126 0;
MEMBER INCIDENCES
122 121 122; 123 122 123; 124 123 124; 125 124 125; 126 125 126;
127 126 127; 128 127 128; 129 128 129; 133 125 132; 134 132 133;
140 124 136; 141 136 126; 142 123 137; 143 137 127; 144 121 138;
145 138 129; 149 125 136; 150 136 137; 151 137 138;
MEMBER PROPERTY CANADIAN
134 PRIS AX 66.96 IX 1675.266 IY 2286.92 IZ 748.51
133 PRIS AX 54.36 IX 902.515 IY 1259.95 IZ 401.33
125 126 PRIS AX 37.27 IX 509.992 IY 1003.85 IZ 184.9
124 127 PRIS AX 38.273 IX 583.606 IY 1393.28 IZ 197.98
123 128 PRIS AX 38.364 IX 639.518 IY 1811.65 IZ 205.49
122 129 PRIS AX 37.964 IX 667.994 IY 2111.49 IZ 207.97
140 TO 143 PRIS AX 0.021382 IX 3.6e-005 IY 3.6e-005 IZ 3.6e-005
144 145 PRIS AX 0.5 IX 1e-005 IY 12.25 IZ 0.167
149 150 151 PRIS AX 8.91 IX 28.599 IY 120.46 IZ 6.7
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POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 140 TO 145
MATERIAL MATERIAL3 MEMB 122 124 TO 127 129 133 134 149 TO 150
SUPPORTS
133 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
144 145 START FX FY FZ MX MY MZ
144 145 END FX FY FZ MX MY MZ
*111 TO 114 START MZ
LOAD 1 SELF
SELFWEIGHT Y -1
LOAD 2 PRESTRESS
TEMPERATURE LOAD
142 143 TEMP -100
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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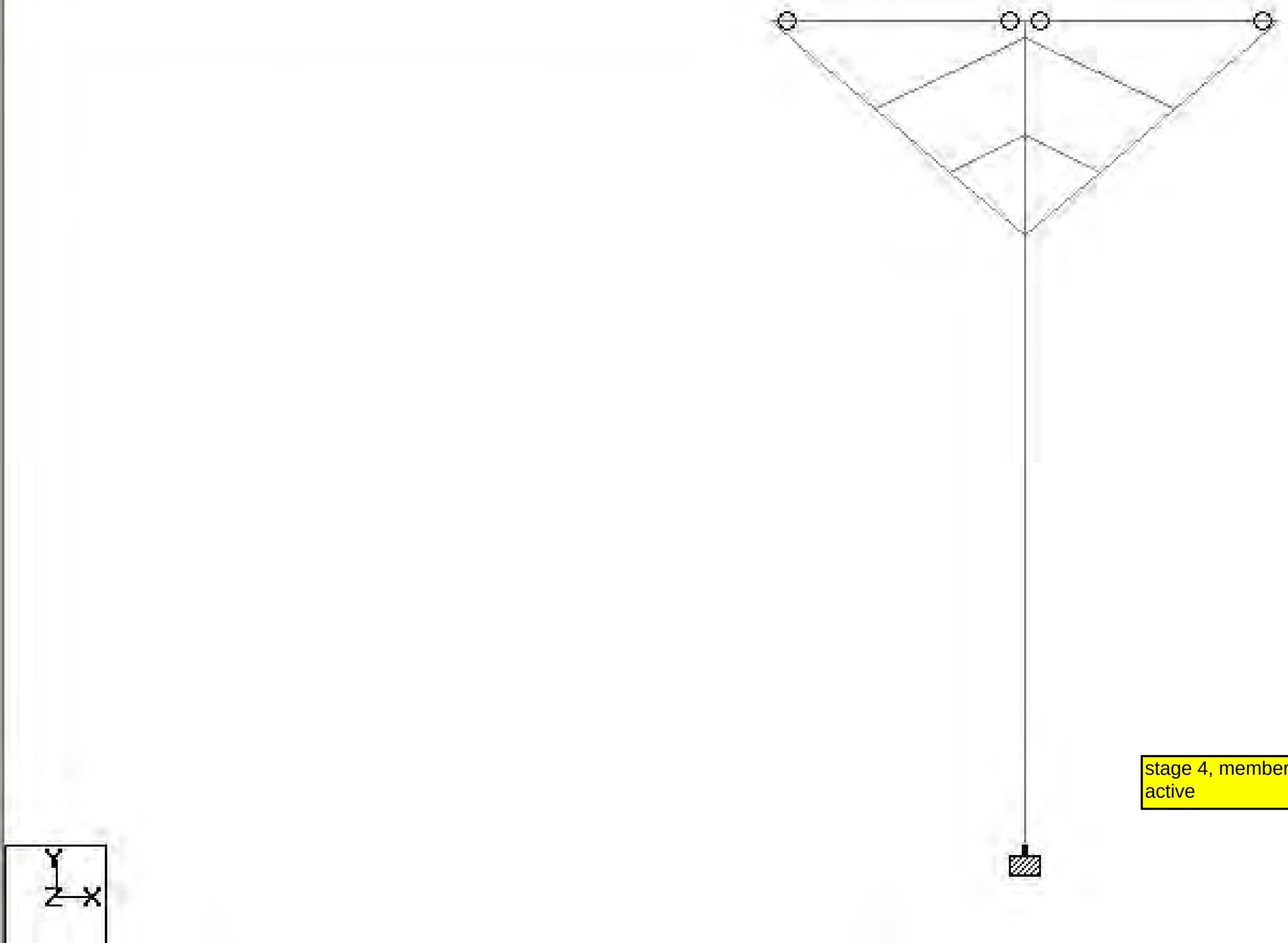

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POISSON 0.17
DENSITY 2.5
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MEMBER RELEASE
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TEMPERATURE LOAD
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PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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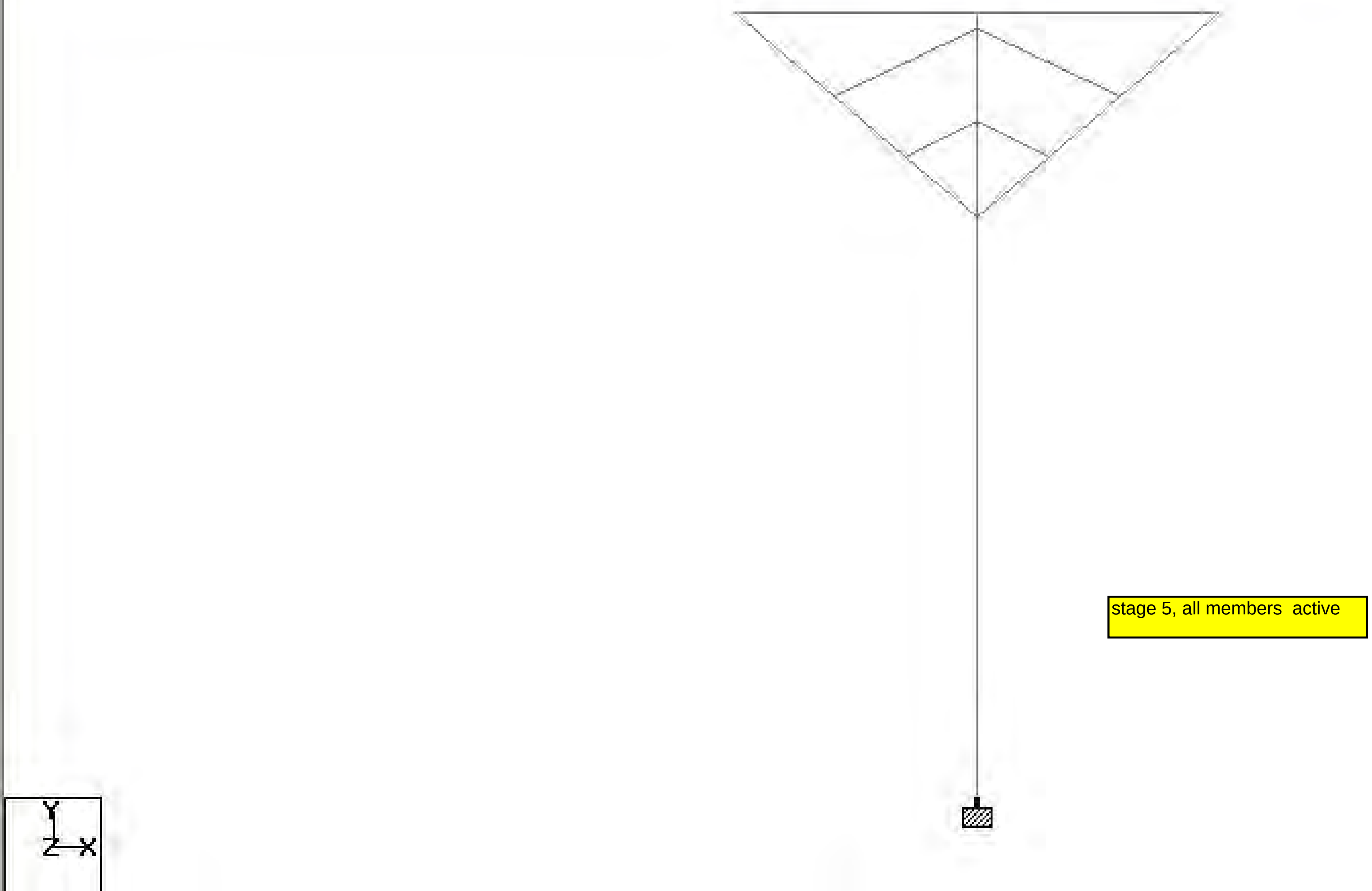
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140 TO 143 PRIS AX 0.021382 IX 3.6e-005 IY 3.6e-005 IZ 3.6e-005
144 145 PRIS AX 0.5 IX 1e-005 IY 12.25 IZ 0.167
149 150 151 PRIS AX 8.91 IX 28.599 IY 120.46 IZ 6.7
DEFINE MATERIAL START
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POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 7.85
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 140 TO 145
MATERIAL MATERIAL3 MEMB 122 TO 129 133 134 149 TO 151
SUPPORTS
133 FIXED
LOAD 1 SELF
SELFWEIGHT Y -1
LOAD 2 prestress UPPER LAYER
TEMPERATURE LOAD
142 143 TEMP -100
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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Appendix – 5

Design of Superstructure

CLIENT:

GOVERNMENT OF KARNATAKA

PROJECT TITLE:

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48

TITLE OF CALCULATION:

PRELIM DESIGN OF SUPERSTRUCTURE (65+80+80+65M)

Note No:	KG/SHIRDI GHAT/DN-201		
Revision No:	R0	No. of Sheets	1+
Date:	Oct-15		

Prepared By:	RP
Checked By:	CDS
Approved By:	AB

Date	Rev No.	Revision	By

CONSULTANT:

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PLOT NO 473, INDUSTRIAL STATE, UDYOG VIHAR PHASE V, GURGAON 122016

Tel: +91 124 4569731, +91 124 4569710; Web : www.geoconsult.co.in

FOUR LANING OF SHIRDI GHAT BYPASS FROM KM 238.00 TO 261.45 OF NH48
PRELIM DESIGN OF SUPERSTRUCTURE (65+80+80+80+65M)

CONTENTS

1 INTRODUCTION

These calculations pertain to design of superstructure for from Pier P2 to P5 of Bridge 2. The superstucture consists of 5 span continuous precast PSC box girder with span arrangement of 65+80x3+65m supported on Piers P2 to P5. Superstructure is monolithic with Y arms of P3 & P4 and simply supported at P2 & P5. Longitudinally guided POT-PTFE Bearings are proposed at P2 & P5 in addition to metallic guided bearings. Refer drawings no. SAGA/FS/GEN-1001 for general arrangement.

It is proposed to construct the superstructre by cantilever construction technique. The construction sequence assumed in design is explained below.

A. Construct 7m long Pier Head at two forks of Pier P3 & P4

B. Errect Laucning Girder.

C. Errect one/two precast segments on either side of pier head
Stress cantilver cables
Repeat the above steps 12 times till all 12 segments on either side of P3/P4 fork are complete.

D. Errect end closure pour of 26 m near P2 & P5 and stress the top and bottom continuity cables.
Construct closure pour of 1.0 m over P3 & P4. Stress continuity cables.

E. Construct wearing coat and crash barrier.

2 Codes

All the elements of bridge shall be designed as per provisions of IRC codes. Following codes shall be used.

IRC - 5	Standard Specifications and code of practice for road bridges, Section I - General Features
IRC - 6	Standard Specifications and code of practice for road bridges, Section II - Load & Stresses
IRC - 112	Code of practice for concrete Road Bridges
IRC:SP:65-2005	Guideline for design & construction of Segmental Bridges
IRC - 83 Part III	Standard Specifications and code of practice for road bridges, Section IX - Bearings
	Part III POT, POT-CUM-PTFE, PIN & METALLIC GUIDE Bearings

Other codes (BIS, BS etc.) and specilist literature will also be refered as and when required.

3 Material

Concrete grade for Box Girder			M60	mpa
$E_{concrete}$			3.70E+04	mpa
Reiforcement			Fe500	confirming to IS: 1786
Cable Type	19 K15	duct dia	120	mm
strand dia			15.2	mm
Nominal Area			140	sqmm
Nominal Mass			1.10	kg/m
Pu			260.6	kN
UTS			4951	kN
Jacking F			3788	kN
E_{cable}			1.95E+08	kN/sqm

4 Computation of Section Properties

4.1 CANTILEVER

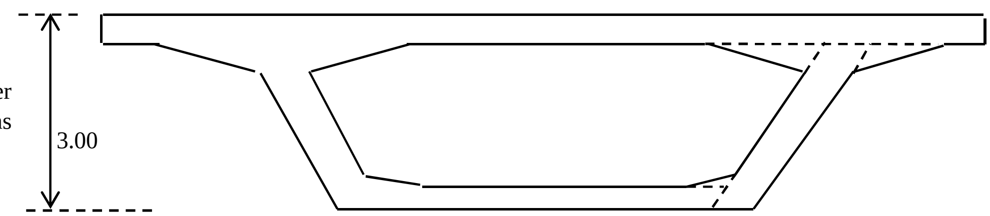
Central span	80	m
max depth	3	m
min depth at mid span	3	m
Length of cantilever	40	m
Length of Pier head	7	m

Length of outer to outer face of plate piers	3.5	m
Length of segments	3m*12	m
No of segments	12	
Length of cast in situ stitch (one side)	1.0	m

	60m Cantilever				
S no.	dist	depth	web thick	soffit th	ANGLE
1	1	3.000	300	275	0.000
2	4	3.000	300	275	0.000
3	7	3.000	300	275	0.000
4	10	3.000	300	275	0.000
5	13	3.000	300	275	0.000
6	16	3.000	300	275	0.000
7	19	3.000	300	275	0.000
8	22	3.000	300	275	0.000
9	25	3.000	300	275	0.000
10	28	3.000	300	356	0.000
11	31	3.000	300	438	0.000
12	34	3.000	300	519	0.000
13	37	3.000	300	600	0.000
14	40.50	3.000	300	600	0.000

4.2 SECTION PROPERTIES OF BOX GIRDER FOR 60M CANTILEVER

X Section of box girder with detailed dimensions are given in Appendix C.



4.2.1 Pier Head

top flange	5.85	tf at mid	0.275	Cant ftp side	1.425	web to web spacing		2.700	0.00
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.425	Wb height		2.725	
Soffit Thick.	0.600	Web th	0.300	Haunch 1	0.940	0.20	soffit wdth	3	
Cant tip thick	0.275			Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	$A_x y$	$A_x y^2$	I_o	I_y
Top slab 1	5.850	0.275	1	1.609	0.138	0.221	0.030	0.010	4.588
Top slab 2	2.400	0.000	1	0.000	0.275	0.000	0.000	0.000	0.000
Haunch(inner)	0.979	0.200	2	0.196	0.342	0.067	0.023	0.000	0.160
Haunch(outer)	0.901	0.200	2	0.180	0.342	0.062	0.021	0.000	0.593
Web	0.306	2.725	2	1.665	1.638	2.727	4.465	1.030	3.048
Soffit slab	2.505	0.600	1	1.503	2.700	4.057	10.955	0.045	0.786
Bott. Haunch	0.571	0.150	2	0.086	2.350	0.201	0.473	0.000	0.089
Total				5.238		7.335	15.967	1.087	9.262

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	1.588	eq. th.	0.634
Yt	1.400	m	Ix	6.7827	m^4	Zt	4.8439	m^3	
Yb	1.600		Iy	9.2624	m^4	Zb	4.2399	m^3	
Calculation of C		width at top	3.785	width bot	2.817	height	2.513		

Area a 8.295 ds/t 32.659 C= 8.427

u= 16.465 2A/u 0.636

4.2.2 3.500 m away from Pier centre

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.600	Web th	0.300	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	$A \times y^2$	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.609	0.138	0.221	0.030	0.010	4.588
Top slab 2	2.4000	0.0000	1	0.000	0.275	0.000	0.000	0.000	0.000
Haunch(inner)	0.979	0.2000	2	0.196	0.342	0.067	0.023	0.000	0.160
Haunch(outer)	0.901	0.2000	2	0.180	0.342	0.062	0.021	0.000	0.593
Web	0.3055	2.7250	2	1.665	1.638	2.727	4.465	1.030	3.048
Soffit slab	2.505	0.6000	1	1.503	2.700	4.057	10.955	0.045	0.786
Bott. Haunch	0.571	0.1500	2	0.086	2.350	0.201	0.473	0.000	0.089
Total				5.238		7.335	15.967	1.087	9.262

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	1.588	eq. th.	0.634
Yt	1.400	m	Ix	6.7827	m^4	Zt	4.8439	m^3	
Yb	1.600		Iy	9.2624	m^4	Zb	4.2399	m^3	
Calculation of C		width at top	3.785	width bot	2.817	height	2.513		
		Area a	8.295	ds/t	32.659	C=	8.427		
		u=	16.465	2A/u	0.636				

4.2.3 6.500 m away from Pier centre

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.519	Web th	0.3	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	$A \times y^2$	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.6088	0.1375	0.2212	0.0304	0.0101	4.588
Top slab 2	2.4000	0.0000	1	0.0000	0.2750	0.0000	0.0000	0.0000	0.000
Haunch(inner)	0.979	0.2000	2	0.1957	0.3417	0.0669	0.0228	0.0004	0.1598
Haunch(outer)	0.901	0.2000	2	0.1803	0.3417	0.0616	0.0210	0.0004	0.5926
Web	0.306	2.7250	2	1.6651	1.6375	2.7265	4.4647	1.0303	3.0475
Soffit slab	2.489	0.5188	1	1.2911	2.7406	3.5385	9.6976	0.0290	0.6665
Bott. Haunch	0.571	0.1500	2	0.0857	2.4313	0.2083	0.5064	0.0001	0.0889
Total				5.0266		6.8230	14.7430	1.0704	9.1433

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	1.377	eq. th.	0.553
Yt	1.357	m	Ix	6.5521	m^4	Zt	4.8271	m^3	
Yb	1.643		Iy	9.1433	m^4	Zb	3.9888	m^3	
Calculation of C		width at top	3.785	width bot	2.801	height	2.554		
		Area a	8.410	ds/t	33.560	C=	8.430		
		u=	16.465	2A/u	0.611				

4.2.4 9.500 m away from Pier face

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.438	Web th	0.3	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	A x y^2	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.6088	0.1375	0.2212	0.0304	0.0101	4.588
Top slab 2	2.4000	0.0000	1	0.0000	0.2750	0.0000	0.0000	0.0000	0.000
Haunch(inner)	0.979	0.2000	2	0.1957	0.3417	0.0669	0.0228	0.0004	0.1598
Haunch(outer)	0.901	0.2000	2	0.1803	0.3417	0.0616	0.0210	0.0004	0.5926
Web	0.306	2.7250	2	1.6651	1.6375	2.7265	4.4647	1.0303	3.0475
Soffit slab	2.473	0.4375	1	1.0820	2.7813	3.0094	8.3700	0.0173	0.5516
Bott. Haunch	0.571	0.1500	2	0.0857	2.5125	0.2152	0.5408	0.0001	0.0889
Total				4.8175		6.3009	13.4498	1.0587	9.0284

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	1.168	eq. th.	0.472
Yt	1.308	m	Ix	6.2675	m^4	Zt	4.7920	m^3	
Yb	1.692		Iy	9.0284	m^4	Zb	3.7040	m^3	
Calculation of C		width at top	3.785	width bot	2.785	height	2.594		
		Area a	8.522	ds/t	34.667	C=	8.380		
		u=	16.465	2A/u	0.585				

4.2.5 12.500 m away from Pier face

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.356	Web th	0.3	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	A x y^2	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.6088	0.1375	0.2212	0.0304	0.0101	4.588
Top slab 2	2.4000	0.0000	1	0.0000	0.2750	0.0000	0.0000	0.0000	0.000
Haunch(inner)	0.979	0.2000	2	0.1957	0.3417	0.0669	0.0228	0.0004	0.1598
Haunch(outer)	0.901	0.2000	2	0.1803	0.3417	0.0616	0.0210	0.0004	0.5926
Web	0.306	2.7250	2	1.6651	1.6375	2.7265	4.4647	1.0303	3.0475
Soffit slab	2.458	0.3563	1	0.8755	2.8219	2.4706	6.9718	0.0093	0.4407
Bott. Haunch	0.571	0.1500	2	0.0857	2.5938	0.2222	0.5763	0.0001	0.0889
Total				4.6110		5.7690	12.0871	1.0507	8.9175

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	0.961	eq. th.	0.391
Yt	1.251	m	Ix	5.9199	m^4	Zt	4.7316	m^3	
Yb	1.749		Iy	8.9175	m^4	Zb	3.3850	m^3	
Calculation of C		width at top	3.785	width bot	2.770	height	2.635		
		Area a	8.636	ds/t	36.128	C=	8.257		
		u=	16.465	2A/u	0.560				

4.2.6 15.500 m away from Pier face

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.275	Web th	0.3	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	A x y^2	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.6088	0.1375	0.2212	0.0304	0.0101	4.588
Top slab 2	2.4000	0.0000	1	0.0000	0.2750	0.0000	0.0000	0.0000	0.000
Haunch(inner)	0.979	0.2000	2	0.1957	0.3417	0.0669	0.0228	0.0004	0.1598
Haunch(outer)	0.901	0.2000	2	0.1803	0.3417	0.0616	0.0210	0.0004	0.5926
Web	0.306	2.7250	2	1.6651	1.6375	2.7265	4.4647	1.0303	3.0475
Soffit slab	2.442	0.2750	1	0.6715	2.8625	1.9223	5.5025	0.0042	0.3337
Bott. Haunch	0.571	0.1500	2	0.0857	2.6750	0.2292	0.6130	0.0001	0.0889

Total				4.4070		5.2276	10.6545	1.0457	8.8105
	Area of top flange		1.985	Eq. Th	0.339	Bott flange	0.757	eq. th.	0.310
Yt	1.186	m	Ix	5.4991	m^4	Zt	4.6359	m^3	
Yb	1.814		Iy	8.8105	m^4	Zb	3.0318	m^3	
Calculation of C		width at top	3.785	width bot	2.754	height	2.675		
		Area a	8.746	ds/t	38.200	C=	8.010		
		u=	16.465	2A/u	0.535				

4.2.7 18.500 m away from Pier face

top flange	5.85	tf at mid	0.275	Cant ftp side	1.43	web to web spacing		2.700	
Overall Depth	3.000	Web slope	0.190	Cant (M) side	1.43	Wb height		2.725	
Soffit Thick.	0.275	Web th	0.3	Haunch 1	0.940	0.20	soffit wdth	3	
				Haunch 2	0.940	0.20	Haunch 3	0.600	0.15

Component	Width	Height	Numbers	A	y	A x y	A x y^2	I_o	I_y
Top slab 1	5.8500	0.2750	1	1.6088	0.1375	0.2212	0.0304	0.0101	4.588
Top slab 2	2.4000	0.0000	1	0.0000	0.2750	0.0000	0.0000	0.0000	0.000
Haunch(inner)	0.979	0.2000	2	0.1957	0.3417	0.0669	0.0228	0.0004	0.1598
Haunch(outer)	0.901	0.2000	2	0.1803	0.3417	0.0616	0.0210	0.0004	0.5926
Web	0.306	2.7250	2	1.6651	1.6375	2.7265	4.4647	1.0303	3.0475
Soffit slab	2.442	0.2750	1	0.6715	2.8625	1.9223	5.5025	0.0042	0.3337
Bott. Haunch	0.571	0.1500	2	0.0857	2.6750	0.2292	0.6130	0.0001	0.0889
Total				4.4070		5.2276	10.6545	1.0457	8.8105

	Area of top flange		1.985	Eq. Th	0.339	Bott flange	0.757	eq. th.	0.310
Yt	1.186	m	Ix	5.4991	m^4	Zt	4.6359	m^3	
Yb	1.814		Iy	8.8105	m^4	Zb	3.0318	m^3	
Calculation of C		width at top	3.785	width bot	2.754	height	2.675		
		Area a	8.746	ds/t	38.200	C=	8.010		
		u=	16.465	2A/u	0.535				

5 TABULATION OF BENDING MOMENTS & SHEAR FORCE

LOADING DATA

Dead load	Computed by STAADPRO based on cross sectional area of box girder								
SIDL	Wearing coat	5.4	x	2	kN/sqm		=	10.80	kN/m
	Crash Barrier	1	x	7.5	kN/m		=	7.50	kN/m
LIVE LOAD	70R Wheeled at interval of 30m or 2 Lane of Class A @ interval of 20 meters								
TEMPERATURE GRADIENT	As per clause 215.3 of IRC 6 2014								
CREEP REDISTRIBUTION	Notional thickness (2Ac/μ)			h_0 =				554	mm
(CL 7.7.2.2 OF IRC 112)	Average humidity							70%	
	average age of concrete at the time of introducing continuity							90	days
	CREEP FACTOR ϕ	Refer table 6.9 of IRC 112						1.51	
	Reduction coefficient α_1	Refer Eq 7.5 of IRC 113				1-exp(-ϕ)=		0.78	
WIND LOAD	As per clause 209 of IRC 6 2014								
DIFFERENTIAL SETTLEMENT	Differential Support settlement has been assumed as 10 mm, however considered 5 mm due to effect of creep.								

5.1 SUMMARY OF BENDING MOMENTS

The structure is modelled as space frame and anylysed for appropriate loads at appropriate stages. The results at different sections are tabulated below.

S No.	Dead Load							SIDL	LIVE LOAD +ve	LIVE LOAD ve	Diff Set	Prestress Sec Effects			PREST CREEP
	CON_{STG} 1	CON_{STG} 2	CON_{STG} 3	CON_{STG} 4	INST	INST-ASB	DL_{CREEP}	WC+Crash				Stg 2A	Stg 2B	Stg 2C	
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	-1546	1	-3124	-1579	-1230	-566	61	-1042	75	0	-913	20	1983
3	50	0	-1318	1	-3044	-1777	-1384	-551	68	-1015	84	0	-1024	23	2224
4	198	0	-1089	1	-2865	-1975	-1539	-518	75	-954	93	0	-1135	25	2464
5	446	0	-861	2	-2586	-2173	-1693	-467	83	-897	102	0	-1246	27	2704
6	793	0	-633	2	-2209	-2371	-1847	-399	90	-814	111	0	-1356	30	2945
7	1239	0	-404	2	-1732	-2569	-2002	-312	97	-694	121	0	-1467	32	3185
8	1785	0	-176	2	-1157	-2767	-2156	-207	105	-556	130	0	-1578	35	3426
9	2429	0	52	2	-482	-2966	-2310	-85	112	-438	139	0	-1688	37	3666
10	3173	0	281	2	292	-3164	-2465	56	203	-325	148	0	-1799	40	3906

11	4017	0	509	2	1167	-3362	-2619	215	375	-233	157	0	-1910	42	4147
12	4965	0	738	2	2145	-3560	-2774	392	569	-160	166	0	-2021	44	4387
13	6021	0	966	3	3231	-3758	-2928	586	800	-109	175	0	-2131	47	4628
14	7190	0	1194	3	4431	-3956	-3082	799	1096	-84	184	0	-2242	49	4868
15	7385	0	1211	2	4401	-4196	-3269	793	1142	-99	171	-462	-2152	49	4234
16	7818	103	83	-2	5339	-2664	-2075	957	1541	-37	8	-1741	-116	31	3102
17	7190	95	81	-2	4703	-2661	-2073	846	1369	-35	8	-1736	-112	29	3100
18	6021	78	75	-2	3517	-2655	-2069	636	1046	-30	7	-1727	-105	26	3097
19	4965	61	70	-2	2445	-2650	-2064	444	758	-50	7	-1719	-98	22	3094
20	4017	45	65	-1	1481	-2644	-2060	270	507	-133	6	-1710	-90	19	3090
21	3173	28	60	-1	621	-2639	-2056	114	289	-235	6	-1701	-83	15	3087
22	2429	11	54	-1	-139	-2633	-2051	-24	144	-345	5	-1692	-76	12	3084
23	1785	-6	49	-1	-800	-2627	-2047	-144	51	-450	5	-1684	-68	8	3081
24	1239	-23	44	0	-1362	-2622	-2043	-246	45	-554	4	-1675	-61	5	3078
25	793	-39	38	0	-1824	-2616	-2038	-330	41	-665	4	-1666	-54	1	3074
26	446	-56	33	0	-2187	-2611	-2034	-396	36	-743	4	-1657	-46	-3	3071
27	198	-73	28	1	-2451	-2605	-2030	-444	32	-805	4	-1649	-39	-6	3068
28	50	-90	23	1	-2616	-2600	-2025	-474	27	-845	4	-1640	-32	-10	3065
29	0	-107	17	1	-2682	-2594	-2021	-486	23	-861	4	-1631	-24	-13	3062
30	0	-107	15	1	-2682	-2592	-2020	-486	21	-862	4	-1628	-22	-14	3061
31	50	-90	10	2	-2616	-2587	-2016	-474	24	-854	4	-1619	-15	-18	3057
32	198	-73	5	2	-2450	-2582	-2012	-444	29	-818	5	-1611	-7	-21	3054
33	446	-56	0	2	-2186	-2577	-2008	-396	33	-752	5	-1602	0	-25	3051
34	793	-39	-6	2	-1822	-2572	-2004	-330	37	-659	5	-1593	7	-28	3048
35	1239	-23	-11	3	-1359	-2567	-2000	-245	42	-550	6	-1584	15	-32	3045
36	1785	-6	-16	3	-796	-2562	-1996	-143	51	-453	6	-1576	22	-35	3042
37	2429	11	-22	3	-135	-2557	-1992	-23	141	-343	7	-1567	29	-39	3038
38	3173	28	-27	4	625	-2552	-1988	115	289	-241	8	-1558	36	-43	3035
39	4017	45	-32	4	1486	-2547	-1985	271	501	-137	8	-1549	44	-46	3032
40	4965	61	-37	4	2451	-2542	-1981	445	750	-67	9	-1541	51	-50	3029
41	6021	78	-43	4	3524	-2537	-1977	637	1040	-28	10	-1532	58	-53	3026

42	7190	95	-48	5	4710	-2532	-1973	847	1364	-33	10	-1523	66	-57	3022
43	7385	97	-6	10	5454	-2033	-1584	976	1552	-40	12	-960	15	-101	3719
44	7818	0	0	101	5259	-2660	-2073	944	1474	-243	221	0	0	-1647	3278
45	7190	0	0	93	4623	-2660	-2072	832	1309	-232	213	0	0	-1645	3274
46	6021	0	0	76	3437	-2660	-2072	622	1004	-212	195	0	0	-1640	3266
47	4965	0	0	59	2364	-2660	-2072	430	737	-192	178	0	0	-1635	3258
48	4017	0	0	43	1400	-2659	-2072	256	513	-253	160	0	0	-1630	3250
49	3173	0	0	26	540	-2659	-2072	100	342	-336	143	0	0	-1625	3241
50	2429	0	0	9	-220	-2659	-2072	-38	215	-431	125	0	0	-1621	3233
51	1785	0	0	-8	-881	-2659	-2071	-158	158	-538	108	0	0	-1616	3225
52	1239	0	0	-24	-1443	-2659	-2071	-260	136	-638	90	0	0	-1611	3217
53	793	0	0	-41	-1906	-2658	-2071	-344	113	-724	73	0	0	-1606	3209
54	446	0	0	-58	-2270	-2658	-2071	-410	91	-792	55	0	0	-1601	3200
55	198	0	0	-74	-2534	-2658	-2071	-458	68	-845	38	0	0	-1596	3192
56	50	0	0	-91	-2699	-2658	-2071	-488	46	-878	20	0	0	-1592	3184
57	0	0	0	-108	-2765	-2658	-2070	-500	26	-890	3	0	0	-1587	3176
58	0	0	0	-108	-2765	-2658	-2070	-500	20	-891	3	0	0	-1585	3173
59	50	0	0	-91	-2699	-2658	-2071	-488	38	-875	21	0	0	-1580	3165
60	198	0	0	-74	-2534	-2658	-2071	-458	58	-837	38	0	0	-1575	3157
61	446	0	0	-57	-2269	-2659	-2071	-410	78	-770	56	0	0	-1571	3148
62	793	0	0	-40	-1906	-2659	-2072	-344	99	-680	73	0	0	-1566	3140
63	1239	0	0	-23	-1443	-2659	-2072	-260	119	-604	91	0	0	-1561	3132
64	1785	0	0	-6	-881	-2660	-2072	-158	139	-512	108	0	0	-1556	3124
65	2429	0	0	10	-220	-2660	-2072	-38	227	-420	126	0	0	-1551	3115
66	3173	0	0	27	540	-2660	-2073	100	359	-325	143	0	0	-1546	3107
67	4017	0	0	44	1401	-2661	-2073	256	534	-243	160	0	0	-1542	3099
68	4965	0	0	61	2365	-2661	-2073	430	763	-211	178	0	0	-1537	3091
69	6021	0	0	78	3438	-2661	-2073	622	1036	-234	195	0	0	-1532	3083
70	7190	0	0	95	4624	-2662	-2074	832	1346	-257	213	0	0	-1527	3074
71	7385	0	-41	93	4572	-2865	-2232	822	1327	-220	203	-462	49	-1395	2572
72	7818	103	-50	5	5347	-2531	-1972	959	1543	-32	10	-1741	68	-53	3009

73	7190	95	-47	5	4710	-2533	-1974	847	1370	-30	10	-1736	65	-52	3011
74	6021	78	-42	5	3524	-2538	-1977	637	1045	-26	9	-1727	58	-48	3015
75	4965	61	-37	4	2451	-2543	-1981	445	755	-55	9	-1719	50	-45	3019
76	4017	45	-31	4	1486	-2548	-1985	271	503	-134	8	-1710	43	-42	3023
77	3173	28	-26	4	626	-2553	-1989	115	285	-240	7	-1701	36	-39	3027
78	2429	11	-21	3	-135	-2558	-1993	-23	141	-344	7	-1692	29	-35	3031
79	1785	-6	-16	3	-796	-2563	-1997	-143	53	-454	6	-1684	22	-32	3035
80	1239	-23	-11	3	-1359	-2568	-2000	-245	43	-558	5	-1675	14	-29	3039
81	793	-39	-6	2	-1822	-2572	-2004	-330	38	-664	5	-1666	7	-26	3043
82	446	-56	0	2	-2186	-2577	-2008	-396	34	-742	5	-1657	0	-22	3047
83	198	-73	5	2	-2450	-2582	-2012	-444	29	-803	5	-1649	-7	-19	3051
84	50	-90	10	2	-2616	-2587	-2016	-474	25	-845	4	-1640	-15	-16	3055
85	0	-107	15	1	-2682	-2592	-2019	-486	21	-862	4	-1631	-22	-12	3059
86	0	-107	17	1	-2682	-2594	-2021	-486	23	-864	4	-1628	-24	-11	3060
87	50	-90	22	1	-2617	-2599	-2025	-474	27	-855	4	-1619	-31	-8	3064
88	198	-73	27	1	-2452	-2605	-2029	-444	31	-819	4	-1611	-39	-5	3068
89	446	-56	32	0	-2188	-2610	-2034	-396	36	-753	4	-1602	-46	-1	3072
90	793	-39	38	0	-1824	-2616	-2038	-330	40	-659	4	-1593	-53	2	3076
91	1239	-23	43	0	-1362	-2621	-2042	-246	44	-553	4	-1584	-60	5	3080
92	1785	-6	48	-1	-800	-2627	-2046	-144	50	-452	5	-1576	-67	8	3084
93	2429	11	53	-1	-140	-2632	-2051	-24	144	-346	5	-1567	-75	12	3088
94	3173	28	58	-1	620	-2638	-2055	114	287	-237	6	-1558	-82	15	3092
95	4017	45	63	-2	1481	-2643	-2059	270	471	-137	6	-1549	-89	18	3096
96	4965	61	69	-2	2445	-2648	-2063	444	724	-69	7	-1541	-96	21	3100
97	6021	78	74	-2	3517	-2654	-2068	636	1018	-32	7	-1532	-103	25	3104
98	7190	95	79	-2	4702	-2659	-2072	846	1346	-36	8	-1523	-111	28	3108
99	7385	97	103	-1	5442	-2142	-1669	974	1498	-25	11	-960	-127	30	3946
100	7818	0	1272	2	5066	-4026	-3137	911	1225	-71	188	0	-2265	101	5070
101	7190	0	1159	2	4423	-3928	-3060	798	1050	-69	184	0	-2211	99	4948
102	6021	0	932	2	3223	-3731	-2907	585	807	-80	175	0	-2102	94	4704
103	4965	0	705	1	2137	-3534	-2754	390	575	-131	165	0	-1993	89	4460

104	4017	0	479	1	1160	-3338	-2600	214	376	-214	156	0	-1883	84	4215
105	3173	0	252	1	286	-3141	-2447	55	205	-311	147	0	-1774	79	3971
106	2429	0	26	1	-488	-2944	-2294	-86	94	-427	138	0	-1665	74	3726
107	1785	0	-201	1	-1163	-2747	-2140	-208	88	-558	129	0	-1556	69	3482
108	1239	0	-428	1	-1738	-2551	-1987	-313	82	-685	120	0	-1447	65	3238
109	793	0	-654	1	-2214	-2354	-1834	-400	76	-806	111	0	-1337	60	2993
110	446	0	-881	1	-2591	-2157	-1681	-468	70	-901	102	0	-1228	55	2749
111	198	0	-1108	1	-2869	-1961	-1527	-519	63	-983	93	0	-1119	50	2505
112	50	0	-1334	1	-3048	-1764	-1374	-551	57	-1034	84	0	-1010	45	2260
113	0	0	-1561	1	-3127	-1567	-1221	-566	51	-1060	75	0	-901	40	2016

5.2 SUMMARY OF SHEAR FORCE

S No.	Dead Load							SIDL	LIVE LOAD +ve	LIVE LOAD ve	Diff Set	Prestress Sec Effects			PREST CREEP
	CON_{STG} 1	CON_{STG} 2	CON_{STG} 3	CON_{STG} 4	INST	INST-ASBLT	DL_{CREEP}	WC+Crash				Stg 2	Stg 3	Stg 4	
1	0	0	201	0	263	62	48	48	104	-2	3	0	37	-1	-80
2	0	0	-76	0	-10	66	51	-2	36	-36	3	0	37	-1	-80
3	-33	0	-76	0	-43	66	51	-8	31	-44	3	0	37	-1	-80
4	-66	0	-76	0	-76	66	51	-14	25	-48	3	0	37	-1	-80
5	-99	0	-76	0	-109	66	51	-20	22	-56	3	0	37	-1	-80
6	-132	0	-76	0	-142	66	51	-26	16	-61	3	0	37	-1	-80
7	-165	0	-76	0	-175	66	51	-32	14	-70	3	0	37	-1	-80
8	-198	0	-76	0	-208	66	51	-38	11	-74	3	0	37	-1	-80
9	-231	0	-76	0	-242	66	51	-44	8	-81	3	0	37	-1	-80
10	-264	0	-76	0	-275	66	51	-50	5	-90	3	0	37	-1	-80
11	-298	0	-76	0	-308	66	51	-56	4	-101	3	0	37	-1	-80
12	-334	0	-76	0	-344	66	51	-62	2	-108	3	0	37	-1	-80
13	-371	0	-76	0	-381	66	51	-68	2	-122	3	0	37	-1	-80
14	-409	0	-76	0	-419	66	51	-74	1	-129	3	0	37	-1	-80
15	26	-24	277	1	-234	-513	-400	-41	242	-344	41	178	-506	5	73
16	429	6	2	0	434	-2	-1	76	140	-1	0	-3	-2	1	1

17	409	6	2	0	414	-2	-1	73	135	-1	0	-3	-2	1	1
18	371	6	2	0	376	-2	-1	67	128	-1	0	-3	-2	1	1
19	334	6	2	0	339	-2	-1	61	120	-1	0	-3	-2	1	1
20	298	6	2	0	304	-2	-1	55	110	-1	0	-3	-2	1	1
21	264	6	2	0	270	-2	-1	49	102	-3	0	-3	-2	1	1
22	231	6	2	0	237	-2	-1	43	92	-5	0	-3	-2	1	1
23	198	6	2	0	204	-2	-1	37	84	-7	0	-3	-2	1	1
24	165	6	2	0	171	-2	-1	31	74	-10	0	-3	-2	1	1
25	132	6	2	0	138	-2	-1	25	66	-14	0	-3	-2	1	1
26	99	6	2	0	105	-2	-1	19	59	-19	0	-3	-2	1	1
27	66	6	2	0	72	-2	-1	13	53	-23	0	-3	-2	1	1
28	33	6	2	0	38	-2	-1	7	47	-28	0	-3	-2	1	1
29	0	6	2	0	5	-2	-1	1	42	-34	0	-3	-2	1	1
30	0	-6	2	0	-6	-2	-1	-1	39	-35	0	-3	-2	1	1
31	-33	-6	2	0	-39	-2	-1	-7	34	-42	0	-3	-2	1	1
32	-66	-6	2	0	-72	-2	-1	-13	28	-47	0	-3	-2	1	1
33	-99	-6	2	0	-105	-2	-1	-19	23	-56	0	-3	-2	1	1
34	-132	-6	2	0	-138	-2	-1	-25	18	-61	0	-3	-2	1	1
35	-165	-6	2	0	-171	-2	-1	-31	15	-72	0	-3	-2	1	1
36	-198	-6	2	0	-204	-2	-1	-37	10	-78	0	-3	-2	1	1
37	-231	-6	2	0	-237	-2	-1	-43	7	-89	0	-3	-2	1	1
38	-264	-6	2	0	-270	-2	-1	-49	4	-95	0	-3	-2	1	1
39	-298	-6	2	0	-304	-2	-1	-55	2	-107	0	-3	-2	1	1
40	-334	-6	2	0	-339	-2	-1	-61	2	-114	0	-3	-2	1	1
41	-371	-6	2	0	-376	-2	-1	-67	2	-125	0	-3	-2	1	1
42	-409	-6	2	0	-415	-2	-1	-73	2	-132	0	-3	-2	1	1
43	26	24	9	-20	247	207	162	42	348	-279	48	-124	-8	352	238
44	429	0	0	6	434	0	0	76	140	-7	6	0	0	-2	3
45	409	0	0	6	415	0	0	73	135	-7	6	0	0	-2	3
46	371	0	0	6	376	0	0	67	126	-7	6	0	0	-2	3
47	334	0	0	6	339	0	0	61	118	-7	6	0	0	-2	3

48	298	0	0	6	304	0	0	55	108	-7	6	0	0	-2	3
49	264	0	0	6	270	0	0	49	100	-7	6	0	0	-2	3
50	231	0	0	6	237	0	0	43	90	-9	6	0	0	-2	3
51	198	0	0	6	204	0	0	37	83	-12	6	0	0	-2	3
52	165	0	0	6	171	0	0	31	72	-14	6	0	0	-2	3
53	132	0	0	6	138	0	0	25	67	-19	6	0	0	-2	3
54	99	0	0	6	105	0	0	19	60	-22	6	0	0	-2	3
55	66	0	0	6	72	0	0	13	54	-29	6	0	0	-2	3
56	33	0	0	6	39	0	0	7	49	-32	6	0	0	-2	3
57	0	0	0	6	6	0	0	1	43	-39	6	0	0	-2	3
58	0	0	0	-6	-6	0	0	-1	41	-40	6	0	0	-2	3
59	-33	0	0	-6	-39	0	0	-7	36	-47	6	0	0	-2	3
60	-66	0	0	-6	-72	0	0	-13	30	-52	6	0	0	-2	3
61	-99	0	0	-6	-105	0	0	-19	27	-60	6	0	0	-2	3
62	-132	0	0	-6	-138	0	0	-25	22	-66	6	0	0	-2	3
63	-165	0	0	-6	-171	0	0	-31	18	-74	6	0	0	-2	3
64	-198	0	0	-6	-204	0	0	-37	14	-81	6	0	0	-2	3
65	-231	0	0	-6	-237	0	0	-43	11	-90	6	0	0	-2	3
66	-264	0	0	-6	-270	0	0	-49	8	-98	6	0	0	-2	3
67	-298	0	0	-6	-304	0	0	-55	8	-106	6	0	0	-2	3
68	-334	0	0	-6	-339	0	0	-61	8	-116	6	0	0	-2	3
69	-371	0	0	-6	-376	0	0	-67	8	-124	6	0	0	-2	3
70	-409	0	0	-6	-415	0	0	-73	8	-133	6	0	0	-2	3
71	26	-24	-9	21	-194	-208	-162	-34	290	-346	48	178	8	-325	-284
72	429	6	-2	0	434	2	1	76	140	-1	0	-3	2	-1	-1
73	409	6	-2	0	415	2	1	73	137	-1	0	-3	2	-1	-1
74	371	6	-2	0	376	2	1	67	128	-1	0	-3	2	-1	-1
75	334	6	-2	0	339	2	1	61	120	-1	0	-3	2	-1	-1
76	298	6	-2	0	304	2	1	55	110	-1	0	-3	2	-1	-1
77	264	6	-2	0	270	2	1	49	102	-2	0	-3	2	-1	-1
78	231	6	-2	0	237	2	1	43	92	-5	0	-3	2	-1	-1

79	198	6	-2	0	204	2	1	37	84	-7	0	-3	2	-1	-1
80	165	6	-2	0	171	2	1	31	74	-11	0	-3	2	-1	-1
81	132	6	-2	0	138	2	1	25	66	-14	0	-3	2	-1	-1
82	99	6	-2	0	105	2	1	19	59	-18	0	-3	2	-1	-1
83	66	6	-2	0	72	2	1	13	53	-24	0	-3	2	-1	-1
84	33	6	-2	0	39	2	1	7	48	-27	0	-3	2	-1	-1
85	0	6	-2	0	6	2	1	1	42	-34	0	-3	2	-1	-1
86	0	-6	-2	0	-5	2	1	-1	40	-35	0	-3	2	-1	-1
87	-33	-6	-2	0	-38	2	1	-7	33	-42	0	-3	2	-1	-1
88	-66	-6	-2	0	-72	2	1	-13	27	-49	0	-3	2	-1	-1
89	-99	-6	-2	0	-105	2	1	-19	24	-56	0	-3	2	-1	-1
90	-132	-6	-2	0	-138	2	1	-25	17	-61	0	-3	2	-1	-1
91	-165	-6	-2	0	-171	2	1	-31	14	-71	0	-3	2	-1	-1
92	-198	-6	-2	0	-204	2	1	-37	9	-78	0	-3	2	-1	-1
93	-231	-6	-2	0	-237	2	1	-43	7	-88	0	-3	2	-1	-1
94	-264	-6	-2	0	-270	2	1	-49	5	-95	0	-3	2	-1	-1
95	-298	-6	-2	0	-304	2	1	-55	2	-106	0	-3	2	-1	-1
96	-334	-6	-2	0	-339	2	1	-61	2	-114	0	-3	2	-1	-1
97	-371	-6	-2	0	-376	2	1	-67	2	-125	0	-3	2	-1	-1
98	-409	-6	-2	0	-414	2	1	-73	2	-132	0	-3	2	-1	-1
99	26	24	-268	0	288	507	395	49	343	-236	41	-124	499	-16	-92
100	429	0	76	0	439	-66	-51	77	141	-1	3	0	-36	2	81
101	409	0	76	0	419	-66	-51	74	136	-1	3	0	-36	2	81
102	371	0	76	0	381	-66	-51	68	123	-1	3	0	-36	2	81
103	334	0	76	0	344	-66	-51	62	97	-2	3	0	-36	2	81
104	298	0	76	0	308	-66	-51	56	92	-2	3	0	-36	2	81
105	264	0	76	0	274	-66	-51	50	88	-4	3	0	-36	2	81
106	231	0	76	0	241	-66	-51	44	82	-5	3	0	-36	2	81
107	198	0	76	0	208	-66	-51	38	77	-8	3	0	-36	2	81
108	165	0	76	0	175	-66	-51	32	73	-10	3	0	-36	2	81
109	132	0	76	0	142	-66	-51	26	67	-14	3	0	-36	2	81

110	99	0	76	0	109	-66	-51	20	63	-17	3	0	-36	2	81
111	66	0	76	0	76	-66	-51	14	55	-22	3	0	-36	2	81
112	33	0	76	0	43	-66	-51	8	51	-26	3	0	-36	2	81
113	0	0	76	0	10	-66	-51	2	43	-32	3	0	-36	2	81

5.3 COMPUTATION OF ULS MOMENT AND SHEAR

ULS LOAD FACTORS

S No.	Dead Load							SIDL	LIVE LOAD +ve	LIVE LOAD ve	Diff Set	Prestress Sec Effects			PREST CREEP
	CON_{STG} 1	CON_{STG} 2	CON_{STG} 3	CON_{STG} 4	INST	INST-ASBLT	DL_{CREEP}	WC+Crash				Stg 2	Stg 3	Stg 4	
ULS 1	1.35	1.35	1.35	1.35				1.55	1.632 *			1.00	1.00	1.00	1.0
ULS 2	1.35	1.35	1.35	1.35			1.35	1.55	1.632			1.00	1.00	1.00	1.0
ULS 3	1.35	1.35	1.35	1.35				1.55		1.632		1.00	1.00	1.00	1.0
ULS 4	1.35	1.35	1.35	1.35			1.35	1.55		1.632		1.00	1.00	1.00	1.0

* Load factors for live load include impact factor of 1.088 also (i.e. 1.5*1.088=1.632)

ULS SHEAR

Section	ULS 1	ULS 2	ULS 3	ULS 4
1	471	535	297	362
2	-92	-22	-209	-139
3	-153	-83	-275	-205
4	-217	-148	-336	-267
5	-276	-207	-404	-334
6	-339	-270	-465	-396
7	-397	-328	-534	-464
8	-456	-386	-595	-525
9	-515	-445	-660	-590
10	-572	-503	-728	-659
11	-630	-561	-802	-732
12	-689	-620	-870	-801
13	-749	-680	-951	-882
14	-812	-742	-1024	-955
15	458	-82	-498	-1038

ULS BM

Section	ULS 1	ULS 2	ULS 3	ULS 4
1	0	0	0	0
2	-1773	-3434	-3573	-5234
3	-1231	-3100	-2998	-4867
4	-527	-2604	-2207	-4284
5	339	-1947	-1261	-3546
6	1366	-1128	-109	-2603
7	2556	-147	1264	-1439
8	3907	996	2828	-82
9	5420	2301	4522	1403
10	7231	3903	6370	3042
11	9337	5801	8345	4809
12	11648	7903	10459	6715
13	14193	10240	12711	8758
14	17025	12864	15099	10938
15	16369	11956	14344	9930

16	932	930	701	699
17	892	890	670	668
18	820	818	608	606
19	748	746	549	547
20	674	673	492	490
21	606	604	435	433
22	535	533	378	376
23	468	467	321	319
24	398	396	261	259
25	332	330	200	199
26	266	264	139	137
27	203	201	79	77
28	139	137	17	15
29	76	74	-48	-50
30	53	52	-68	-69
31	-9	-11	-133	-134
32	-71	-73	-195	-197
33	-135	-137	-263	-264
34	-196	-198	-326	-327
35	-255	-257	-397	-398
36	-318	-320	-460	-462
37	-376	-377	-532	-534
38	-435	-437	-597	-599
39	-492	-494	-671	-672
40	-551	-553	-739	-741
41	-610	-612	-817	-818
42	-671	-673	-890	-892
43	1144	1362	120	338
44	933	933	694	694
45	895	895	663	663
46	819	819	602	602

16	16078	13277	13504	10702
17	14767	11968	12476	9677
18	12316	9523	10559	7766
19	10101	7315	8783	5996
20	8123	5342	7078	4297
21	6366	3591	5512	2737
22	4892	2123	4093	1324
23	3664	901	2846	82
24	2740	-18	1763	-995
25	1980	-772	828	-1924
26	1382	-1364	110	-2636
27	945	-1795	-419	-3159
28	671	-2063	-752	-3486
29	558	-2170	-883	-3612
30	557	-2170	-885	-3612
31	672	-2049	-761	-3482
32	952	-1764	-430	-3146
33	1394	-1317	113	-2598
34	1997	-708	861	-1844
35	2762	62	1797	-904
36	3697	1002	2874	180
37	4925	2236	4135	1445
38	6410	3725	5545	2861
39	8163	5484	7121	4442
40	10144	7471	8811	6137
41	12365	9697	10622	7953
42	14824	12161	12544	9881
43	16825	14687	14227	12090
44	16190	13392	13389	10591
45	14887	12089	12372	9574
46	12459	9662	10475	7677

47	747	747	543	542
48	673	673	485	485
49	605	605	430	430
50	535	535	374	374
51	469	468	314	314
52	398	398	256	256
53	335	335	194	194
54	270	270	136	135
55	207	207	71	71
56	144	144	12	12
57	81	81	-54	-54
58	58	59	-73	-73
59	-2	-2	-139	-139
60	-67	-67	-201	-201
61	-126	-126	-268	-268
62	-188	-188	-332	-331
63	-248	-248	-398	-398
64	-309	-309	-464	-464
65	-367	-367	-532	-532
66	-427	-427	-600	-599
67	-482	-482	-668	-668
68	-539	-539	-740	-740
69	-598	-598	-813	-813
70	-659	-659	-889	-889
71	15	-204	-1023	-1242
72	928	929	697	698
73	892	893	665	667
74	816	817	604	606
75	743	745	545	547
76	670	672	488	490
77	602	604	431	433

47	10274	7477	8758	5961
48	8333	5536	7084	4287
49	6648	3851	5541	2744
50	5197	2400	4142	1346
51	4022	1226	2885	89
52	3065	269	1802	-994
53	2270	-526	903	-1893
54	1636	-1160	195	-2600
55	1165	-1631	-325	-3121
56	855	-1940	-652	-3448
57	711	-2084	-784	-3579
58	701	-2095	-787	-3582
59	835	-1961	-656	-3451
60	1134	-1662	-327	-3123
61	1595	-1201	211	-2585
62	2219	-578	949	-1848
63	3004	207	1824	-973
64	3951	1153	2888	91
65	5169	2371	4113	1315
66	6622	3824	5506	2708
67	8309	5510	7039	4241
68	10250	7451	8660	5862
69	12439	9640	10366	7567
70	14868	12069	12253	9453
71	14245	11232	11719	8706
72	15922	13260	13351	10690
73	14615	11951	12330	9666
74	12173	9504	10425	7756
75	9969	7294	8648	5973
76	8002	5322	6962	4282
77	6257	3572	5401	2716

78	531	533	374	376
79	464	466	315	317
80	394	395	256	258
81	328	330	197	199
82	263	264	136	138
83	199	201	73	75
84	136	138	13	15
85	72	74	-51	-50
86	51	53	-72	-70
87	-13	-12	-137	-135
88	-77	-75	-201	-199
89	-137	-135	-267	-265
90	-202	-200	-330	-328
91	-261	-259	-400	-398
92	-323	-321	-464	-462
93	-381	-379	-535	-534
94	-438	-436	-601	-599
95	-497	-495	-674	-672
96	-555	-553	-744	-742
97	-614	-612	-820	-818
98	-675	-674	-894	-892
99	608	1141	-336	197
100	1077	1008	845	776
101	1037	968	814	745
102	955	886	752	683
103	853	784	692	623
104	788	719	634	565
105	727	658	577	508
106	663	594	520	451
107	601	532	462	393
108	541	472	405	336

78	4797	2107	4005	1315
79	3589	894	2763	67
80	2672	-29	1691	-1009
81	1924	-782	779	-1927
82	1338	-1372	73	-2638
83	915	-1801	-443	-3159
84	652	-2069	-766	-3487
85	554	-2172	-888	-3614
86	562	-2166	-886	-3614
87	692	-2042	-748	-3482
88	984	-1755	-404	-3144
89	1438	-1307	151	-2594
90	2054	-697	913	-1838
91	2832	75	1856	-900
92	3774	1011	2954	192
93	5022	2253	4222	1454
94	6510	3736	5656	2881
95	8229	5449	7238	4458
96	10230	7444	8936	6150
97	12471	9680	10757	7966
98	14949	12152	12692	9895
99	17082	14830	14596	12343
100	18591	14356	16476	12242
101	17058	12927	15233	11102
102	14308	10384	12860	8936
103	11756	8039	10604	6887
104	9432	5922	8468	4958
105	7321	4018	6479	3175
106	5473	2376	4622	1525
107	3956	1067	2902	12
108	2602	-81	1350	-1333

109	477	408	345	276
110	415	346	285	216
111	350	281	223	155
112	288	219	163	94
113	222	153	99	30

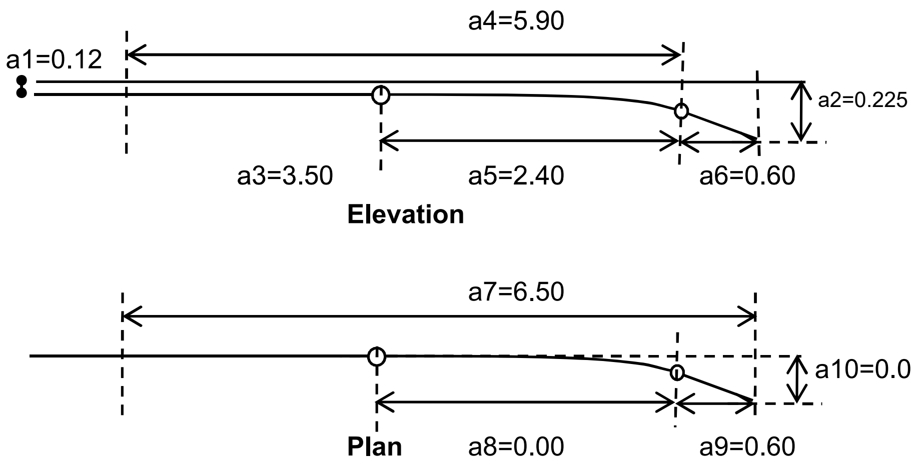
109	1409	-1067	-30	-2505
110	378	-1891	-1205	-3474
111	-491	-2553	-2199	-4261
112	-1199	-3054	-2981	-4836
113	-1745	-3393	-3558	-5206

6 PRESTRESSING EFFECTS

6.1 ASSESSMENT OF FRICTION AND SLIP LOSSES

Type of cable	19K15		Dist of cable CG from soffit/deck	0.138
Area of one cable	0.00266	sqm	Dist of Cantilever Cbl at Anchorage	0.225
UTS	4959	kN	Dist of Continuity Cbl at Dead End	0.25
E	1.95E+08	kN/sqm	Dist of Soffit Cbl at Live End	0.525
μ	0.17		Dist of top cont. Cbl at Live End	0.6
k	0.002	per m	Cable anch abv soffit/deck	0.25
Jacking force (0.765 UTS)	3794	kN		
Slip	6	mm		
Half area of Slip F. diag	1556.10	kN		

6.1.1 CANTILEVER CABLES



CABLE NO. 1

Dist of cable CG from top of box at pier centre	a1	0.138
Dist of cable CG from top of box at anchorage	a2	0.225
Dist of start of vert curve from pier centre	a3	3.5
Dist of end of vert curve from pier centre	a4	5.9
Length of vert curve	a5	2.4
Length of straight part at end	a6	0.6
Half length of cable	a7	6.5
Dist of start of hor curve from pier centre	a4	5.9
Length of hor curve	a8	0
Horizontal deviation	a10	0.00
Length of straight part of hor curve at end	a9	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)		0.058
$Kv=Y_v/L^2$		0.010
Total Change in angle due to vert curve		0.048 Radians= 2.77deg
Kh=		0.000
Total Change in angle due to hor curve		0.000 Radians= 0.00deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0.00	0.00	0.000	0.000	6.502	0.048	0.979	3714	204.3	3298
2	2.00	0.00	2.000	0.000	4.502	0.048	0.983	3729	122.4	3283
3	3.50	0.00	3.500	0.000	3.002	0.048	0.986	3740	80.4	3272
4	6.50	0.09	6.502	0.048	0.000	0.000	1.000	3794		3219

Av force	3751	kN
Elongation	49.6	mm
Slip will travel upto	pier centre	
c	-1351.8	kN
Force at Null Point	3506	kN

CABLE NO. 2

Dist of cable CG from top of box at pier centre	0.138		
Dist of cable CG from top of box at anchorage	0.225		
Dist of start of vert curve from pier centre	6.5		
Dist of end of vert curve from pier centre	8.9		
Length of vert curve	2.4		
Length of straight part at end	0.6		
Half length of cable	9.5		
Dist of start of hor curve from pier centre	5.9		
Length of hor curve	3		
Horizontal deviation	0.25		
Length of straight part of hor curve at end	0.6		
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058		
$Kv=Y_v/L^2$	0.010		
Total Change in angle due to vert curve	0.048	Radians=	2.77deg
Kh=	0.028		
Total Change in angle due to hor curve	0.165	Radians=	9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	9.514	0.174	0.953	3614	558.2	3404
2	2.0	0.00	2.000	0.000	7.514	0.174	0.956	3628	434.9	3390
3	3.50	0.00	3.500	0.000	6.014	0.174	0.959	3639	361.1	3379
4	6.50	0.00	6.500	0.033	3.014	0.140	0.971	3682	168.4	3336
5	9.50	0.09	9.514	0.174	0.000	0.000	1.000	3794		3224

Av force	3691	kN
Elongation	70.2	mm
Slip will travel between		
c	-997.9	kN
Force at Null Point	3509	kN

CABLE NO. 3

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	9.5
Dist of end of vert curve from pier centre	11.9

Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	12.5
Dist of start of hor curve from pier centre	5.9
Length of hor curve	6
Horizontal deviation	0.50
Length of straight part of hor curve at end	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058
$Kv=Y_v/L^2$	0.010
Total Change in angle due to vert curve	0.048 Radians= 2.77deg
Kh=	0.014
Total Change in angle due to hor curve	0.165 Radians= 9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	12.528	0.181	0.946	3588	960.9	3493
2	2	0.00	2.000	0.000	10.528	0.181	0.949	3602	795.2	3478
3	3.50	0.00	3.500	0.000	9.028	0.181	0.952	3613	689.3	3467
4	6.50	0.00	6.500	0.017	6.028	0.164	0.961	3645	448.0	3435
5	9.50	0.00	9.506	0.100	3.022	0.081	0.980	3719	112.8	3361
6	12.50	0.09	12.528	0.181	0.000	0.000	1.000	3794		3287

Av force	3691	kN
Elongation	91.6	mm
Slip will travel between		
c	-595.2	kN
Force at Null Point	3540	kN

CABLE NO. 4

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	12.5
Dist of end of vert curve from pier centre	14.9
Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	15.5
Dist of start of hor curve from pier centre	7.9
Length of hor curve	7
Horizontal deviation	0.00
Length of straight part of hor curve at end	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058
$Kv=Y_v/L^2$	0.010
Total Change in angle due to vert curve	0.048 Radians= 2.77deg
Kh=	0.000
Total Change in angle due to hor curve	0.000 Radians= 0.00deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	15.502	0.048	0.962	3648	932.4	3567

2	2	0.00	2.000	0.000	13.502	0.048	0.965	3662	720.4	3553
3	3.50	0.00	3.500	0.000	12.002	0.048	0.968	3673	580.1	3542
4	6.50	0.00	6.500	0.000	9.002	0.048	0.974	3695	347.9	3520
5	9.50	0.00	9.500	0.000	6.002	0.048	0.980	3718	181.1	3497
6	12.50	0.00	12.500	0.000	3.002	0.048	0.986	3740	80.4	3475
7	15.50	0.09	15.502	0.048	0.000	0.000	1.000	3794		3421

Av force 3726 kN
Elongation 113.9 mm
Slip will travel between
c -623.7 kN
Force at Null Point 3608 kN

CABLE NO. 5

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	15.5
Dist of end of vert curve from pier centre	17.9
Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	18.5
Dist of start of hor curve from pier centre	14.9
Length of hor curve	3
Horizontal deviation	0.25
Length of straight part of hor curve at end	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058
$Kv=Y_v/L^2$	0.010
Total Change in angle due to vert curve	0.048 Radians= 2.77deg
Kh=	0.028
Total Change in angle due to hor curve	0.165 Radians= 9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	18.514	0.174	0.936	3549	1460.8	3539
2	2	0.00	2.000	0.000	16.514	0.174	0.939	3564	1211.7	3525
3	3.50	0.00	3.500	0.000	15.014	0.174	0.942	3574	1042.9	3514
4	6.50	0.00	6.500	0.000	12.014	0.174	0.948	3596	752.2	3493
5	9.50	0.00	9.500	0.000	9.014	0.174	0.954	3617	524.7	3471
6	12.50	0.00	12.500	0.000	6.014	0.174	0.959	3639	361.1	3449
7	15.50	0.00	15.500	0.033	3.014	0.140	0.971	3682	168.4	3407
8	18.50	0.09	18.514	0.174	0.000	0.000	1.000	3794		3295

Av force 3657 kN
Elongation 133.0 mm

Slip will travel between	3.5000	to	2.000				
Slope of force	7.113		a	3.56	c		-344.4
distance	2.710	m	b	117.463	Force at Null Point		3544

CABLE NO. 6

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225

Dist of start of vert curve from pier centre	18.5		
Dist of end of vert curve from pier centre	20.9		
Length of vert curve	2.4		
Length of straight part at end	0.6		
Half length of cable	21.5		
Dist of start of hor curve from pier centre	14.9		
Length of hor curve	6		
Horizontal deviation	0.50		
Length of straight part of hor curve at end	0.6		
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058		
$Kv=Y_v/L^2$	0.010		
Total Change in angle due to vert curve	0.048	Radians=	2.77deg
Kh=	0.014		
Total Change in angle due to hor curve	0.165	Radians=	9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	21.528	0.181	0.929	3524	2049.9	3524
2	2	0.00	2.000	0.000	19.528	0.181	0.933	3538	1760.0	3538
3	3.50	0.00	3.500	0.000	18.028	0.181	0.935	3548	1560.4	3548
4	6.50	0.00	6.500	0.000	15.028	0.181	0.941	3570	1207.5	3528
5	9.50	0.00	9.500	0.000	12.028	0.181	0.947	3591	916.9	3506
6	12.50	0.00	12.500	0.000	9.028	0.181	0.952	3613	689.3	3484
7	15.50	0.00	15.500	0.017	6.028	0.164	0.961	3645	448.0	3452
8	18.50	0.00	18.506	0.100	3.022	0.081	0.980	3719	112.8	3378
9	21.50	0.09	21.528	0.181	0.000	0.000	1.000	3794		3304
						Av force		3655	kN	
						Elongation		154.2	mm	

Slip will travel between	6.5000	to	3.500				
Slope of force	7.118		a	3.56	c		-348.6
distance	2.966	m	b	106.970	Force at Null Point		3549

CABLE NO. 6 (Not used)

Dist of cable CG from top of box at pier centre	0.138		
Dist of cable CG from top of box at anchorage	0.225		
Dist of start of vert curve from pier centre	18.5		
Dist of end of vert curve from pier centre	20.9		
Length of vert curve	2.4		
Length of straight part at end	0.6		
Half length of cable	21.5		
Dist of start of hor curve from pier centre	7.9		
Length of hor curve	13		
Horizontal deviation	0.50		
Length of straight part of hor curve at end	0.6		
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058		
$Kv=Y_v/L^2$	0.010		
Total Change in angle due to vert curve	0.048	Radians=	2.77deg

Kh=	0.003	
Total Change in angle due to hor curve	0.077	Radians= 4.40deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	24.524	0.176	0.924	3506	2816.6	3506
2	2	0.00	2.000	0.000	22.524	0.176	0.928	3520	2486.0	3520
3	3.50	0.00	3.500	0.000	21.024	0.176	0.931	3530	2255.8	3530
4	6.50	0.00	6.500	0.000	18.024	0.176	0.936	3552	1840.9	3552
5	9.50	0.00	9.500	0.009	15.024	0.166	0.943	3579	1392.7	3579
6	12.50	0.00	12.501	0.027	12.023	0.148	0.952	3611	954.2	3590
7	15.50	0.00	15.503	0.045	9.021	0.131	0.961	3644	610.0	3558
8	18.50	0.00	18.507	0.063	6.017	0.113	0.969	3677	361.8	3525
9	21.50	0.00	21.515	0.126	3.009	0.050	0.986	3739	82.3	3463
10	24.50	0.09	24.524	0.176	0.000	0.000	1.000	3794		3408
						Av force		3664	kN	
						Elongation		175.7	mm	

Slip will travel between	9.5000	to	6.500			
Slope of force	9.043	a	4.52	c		-163.4
distance	1.158 m	b	135.865	Force at Null Point		3601

CABLE NO. 7

Dist of cable CG from top of box at pier centre	0.138	
Dist of cable CG from top of box at anchorage	0.225	
Dist of start of vert curve from pier centre	21.5	
Dist of end of vert curve from pier centre	23.9	
Length of vert curve	2.4	
Length of straight part at end	0.6	
Half length of cable	24.5	
Dist of start of hor curve from pier centre	14.9	
Length of hor curve	9	
Horizontal deviation	0.75	
Length of straight part of hor curve at end	0.6	
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058	
$Kv=Y_v/L^2$	0.010	
Total Change in angle due to vert curve	0.048	Radians= 2.77deg
Kh=	0.009	
Total Change in angle due to hor curve	0.165	Radians= 9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	27.599	0.267	0.904	3431	3671.3	3431
2	2	0.00	2.000	0.000	25.599	0.267	0.908	3444	3305.6	3444
3	3.50	0.00	3.500	0.000	24.099	0.267	0.911	3455	3048.4	3455
4	6.50	0.00	6.500	0.000	21.099	0.267	0.916	3475	2578.6	3475
5	9.50	0.00	9.500	0.000	18.099	0.267	0.922	3496	2168.7	3496
6	12.50	0.00	12.500	0.000	15.099	0.267	0.927	3517	1819.4	3499
7	15.50	0.00	15.500	0.011	12.099	0.256	0.935	3545	1440.6	3471

8	18.50	0.00	18.503	0.067	9.096	0.200	0.949	3600	856.2	3416
9	21.50	0.00	21.516	0.122	6.082	0.145	0.964	3656	432.6	3360
10	24.50	0.00	24.551	0.203	3.048	0.064	0.983	3730	97.6	3287
11	27.50	0.09	27.599	0.267	0.000	0.000	1.000	3794		3223

Av force 3618 kN

Elongation 194.9 mm

Slip will travel between	15.5000	to	12.500			
Slope of force	9.286		a	4.64	c	-115.5
distance	0.988 m		b	112.349	Force at Null Point	3508

CABLE NO. 8

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	24.5
Dist of end of vert curve from pier centre	26.9
Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	27.5
Dist of start of hor curve from pier centre	14.9
Length of hor curve	12
Horizontal deviation	1.00
Length of straight part of hor curve at end	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058
$Kv=Y_v/L^2$	0.010
Total Change in angle due to vert curve	0.048 Radians= 2.77deg
Kh=	0.007
Total Change in angle due to hor curve	0.165 Radians= 9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	30.609	0.263	0.899	3412	4426.5	3412
2	2	0.00	2.000	0.000	28.609	0.263	0.903	3426	4021.6	3426
3	3.50	0.00	3.500	0.000	27.109	0.263	0.906	3436	3734.8	3436
4	6.50	0.00	6.500	0.000	24.109	0.263	0.911	3457	3205.2	3457
5	9.50	0.00	9.500	0.000	21.109	0.263	0.917	3478	2734.9	3474
6	12.50	0.00	12.500	0.000	18.109	0.263	0.922	3499	2324.5	3453
7	15.50	0.00	15.500	0.008	15.109	0.255	0.929	3525	1891.9	3427
8	18.50	0.00	18.502	0.050	12.107	0.213	0.941	3571	1260.5	3380
9	21.50	0.00	21.509	0.091	9.099	0.172	0.954	3618	762.6	3333
10	24.50	0.00	24.528	0.133	6.080	0.131	0.966	3666	402.4	3286
11	27.50	0.00	27.564	0.205	3.044	0.058	0.984	3734	91.1	3218
12	30.50	0.09	30.609	0.263	0.000	0.000	1.000	3794		3158

Av force 3615 kN

Elongation 215.8 mm

Slip will travel between	18.5000	to	15.500			
Slope of force	15.460		a	7.73	c	-295.6
distance	1.488 m		b	187.176	Force at Null Point	3476

CABLE NO. 9

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	27.5
Dist of end of vert curve from pier centre	29.9
Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	30.5
Dist of start of hor curve from pier centre	14.9
Length of hor curve	15
Horizontal deviation	1.25
Length of straight part of hor curve at end	0.6
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058
$Kv=Y_v/L^2$	0.010
Total Change in angle due to vert curve	0.048 Radians= 2.77deg
Kh=	0.006
Total Change in angle due to hor curve	0.165 Radians= 9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	33.620	0.262	0.894	3392	5240.7	3392
2	2	0.00	2.000	0.000	31.620	0.262	0.898	3406	4797.2	3406
3	3.50	0.00	3.500	0.000	30.120	0.262	0.901	3416	4481.3	3416
4	6.50	0.00	6.500	0.000	27.120	0.262	0.906	3437	3892.9	3437
5	9.50	0.00	9.500	0.000	24.120	0.262	0.911	3457	3363.0	3457
6	12.50	0.00	12.500	0.000	21.120	0.262	0.917	3478	2892.4	3478
7	15.50	0.00	15.500	0.007	18.120	0.255	0.923	3503	2403.8	3503
8	18.50	0.00	18.501	0.040	15.119	0.222	0.934	3544	1720.7	3483
9	21.50	0.00	21.506	0.073	12.114	0.189	0.945	3586	1154.8	3442
10	24.50	0.00	24.518	0.106	9.102	0.156	0.956	3628	709.3	3400
11	27.50	0.00	27.541	0.139	6.079	0.123	0.967	3670	387.2	3358
12	30.50	0.00	30.578	0.208	3.042	0.054	0.985	3736	87.8	3292
13	33.50	0.09	33.620	0.262	0.000	0.000	1.000	3794		3234

Av force 3610 kN
Elongation 236.4 mm

Slip will travel between	18.5000	to	21.500				
Slope of force	13.831		a	6.92	c		-401.3
distance	2.196	m	b	167.545	Force at Null Point		3514

CABLE NO. 9 (Not used)

Dist of cable CG from top of box at pier centre	0.138
Dist of cable CG from top of box at anchorage	0.225
Dist of start of vert curve from pier centre	27.5
Dist of end of vert curve from pier centre	29.9
Length of vert curve	2.4
Length of straight part at end	0.6
Half length of cable	30.5
Dist of start of hor curve from pier centre	14.9
Length of hor curve	15

Horizontal deviation	1.25		
Length of straight part of hor curve at end	0.6		
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058		
$Kv=Y_v/L^2$	0.010		
Total Change in angle due to vert curve	0.048	Radians=	2.77deg
Kh=	0.006		
Total Change in angle due to hor curve	0.165	Radians=	9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	36.691	0.329	0.879	3333	6487.3	3333
2	2	0.00	2.000	0.000	34.691	0.329	0.882	3347	6010.5	3347
3	3.50	0.00	3.500	0.000	33.191	0.329	0.885	3357	5669.2	3357
4	6.50	0.00	6.500	0.000	30.191	0.329	0.890	3377	5029.1	3377
5	9.50	0.00	9.500	0.000	27.191	0.329	0.895	3397	4446.0	3397
6	12.50	0.00	12.500	0.000	24.191	0.329	0.901	3418	3920.8	3418
7	15.50	0.00	15.500	0.007	21.191	0.323	0.907	3442	3365.6	3442
8	18.50	0.00	18.501	0.040	18.190	0.289	0.918	3482	2570.4	3482
9	21.50	0.00	21.506	0.073	15.185	0.256	0.929	3523	1889.0	3523
10	24.50	0.00	24.518	0.106	12.172	0.223	0.940	3565	1324.5	3528
11	27.50	0.00	27.541	0.139	9.149	0.190	0.951	3606	880.0	3487
12	30.50	0.00	30.578	0.208	6.112	0.122	0.968	3671	387.8	3422
13	33.50	0.00	33.632	0.276	3.058	0.054	0.985	3736	87.8	3357
14	36.50	0.09	36.691	0.329	0.000	0.000	1.000	3794		3299
						Av force		3582	kN	
						Elongation		255.8	mm	

Slip will travel between	21.5000	to	24.500				
Slope of force	13.700		a	6.85	c		-231.6
distance	1.318	m	b	166.767	Force at Null Point		3547

CABLE NO. 10

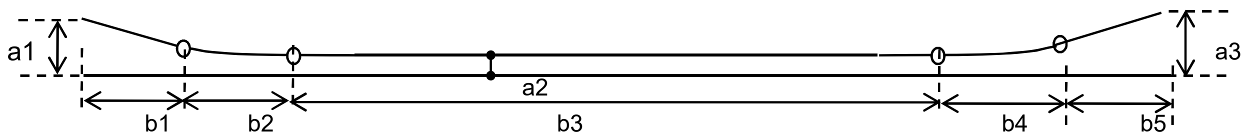
Dist of cable CG from top of box at pier centre	0.138		
Dist of cable CG from top of box at anchorage	0.225		
Dist of start of vert curve from pier centre	30.5		
Dist of end of vert curve from pier centre	32.9		
Length of vert curve	2.4		
Length of straight part at end	0.6		
Half length of cable	33.5		
Dist of start of hor curve from pier centre	14.9		
Length of hor curve	18		
Horizontal deviation	1.50		
Length of straight part of hor curve at end	0.6		
Yv = (0.225-0.138)/(1+2*0.6/2.4)	0.058		
$Kv=Y_v/L^2$	0.010		
Total Change in angle due to vert curve	0.048	Radians=	2.77deg
Kh=	0.005		
Total Change in angle due to hor curve	0.165	Radians=	9.46deg

Section	Dist from Pier Centre	y	len from pier centre	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip
1	0	0.00	0.000	0.000	39.698	0.327	0.874	3315	7401.9	3315
2	2	0.00	2.000	0.000	37.698	0.327	0.877	3328	6887.8	3328
3	3.50	0.00	3.500	0.000	36.198	0.327	0.880	3338	6518.4	3338
4	6.50	0.00	6.500	0.000	33.198	0.327	0.885	3358	5821.4	3358
5	9.50	0.00	9.500	0.000	30.198	0.327	0.890	3378	5180.9	3378
6	12.50	0.00	12.500	0.000	27.198	0.327	0.896	3398	4597.5	3398
7	15.50	0.00	15.500	0.006	24.198	0.322	0.902	3422	3988.9	3422
8	18.50	0.00	18.501	0.033	21.197	0.294	0.912	3459	3151.7	3459
9	21.50	0.00	21.504	0.061	18.193	0.266	0.922	3496	2417.6	3496
10	24.50	0.00	24.513	0.089	15.185	0.238	0.932	3534	1789.1	3534
11	27.50	0.00	27.529	0.116	12.169	0.211	0.942	3572	1269.0	3528
12	30.50	0.00	30.554	0.143	9.143	0.184	0.952	3610	859.7	3490
13	33.50	0.00	33.592	0.210	6.106	0.118	0.968	3673	378.8	3426
14	36.50	0.00	36.644	0.275	3.054	0.052	0.985	3737	85.8	3362
15	39.50	0.09	39.698	0.327	0.000	0.000	1.000	3794		3306

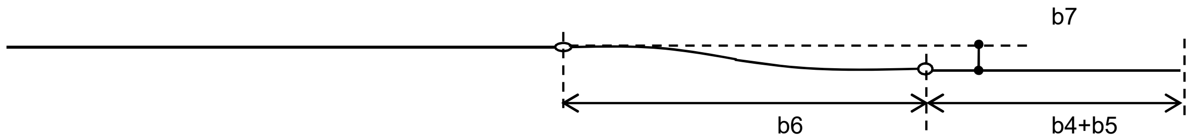
Av force	3576	kN	
Elongation	276.1	mm	

Slip will travel between	27.5000	to	24.500			
Slope of force	12.610		a	6.31	c	-287.1
distance	1.746	m	b	153.455	Force at Null Point	3550

6.1.2 BOTTOM CONTINUITY CABLE
NEAR P2 & P5 (END SPAN) (One End Stressing)



ELEVATION



PLAN

CABLE NO. 1

Dist of cable CG from soffit at Dead anchorage	a1	0.25		Start of curve 2	33.75
Dist of cable CG from soffit after end of curve	a2	0.138		Stat of Hor curve	33.75
Dist of cable CG from soffit at Live anchorage	a3	0.525		End of Hor curve	33.75
Length of straight part at dead end	b1	1		Start of curve 1	1.00
Length of vert curve near dead end	b2	1.5		Ed of curve 1	2.50
Length of central straight part in elevation	b3	31.3		Delta H	0.00
Length of vert curve near live end	b4	2.4		soffit thick.	0.275
Length of straight part at live end	b5	0.6		total length	36.75
Length of hor curve	b6	0.0			
Horizontal deviation	b7	0.0			
Yv1 = (0.25-0.138)/(1+2/1.5)		0.048			
$Kv1=Y_v/L^2$		0.021			
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258			
$Kv2=Y_v/L^2$		0.045			
Change in angle due to vert curve 1		0.064	Radians=	3.66deg	
Change in angle due to vert curve 2		0.212	Radians=	12.13deg	
Kh= 0 0		0.000			
Change in angle due to one hor curve		0.000	Radians=	0.00deg	

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0.00	0.130	0.000	0.000	36.750	0.276	0.887	3363	6239.0	3363	3367	0.500
2	1.00	0.048	1.000	0.000	35.750	0.276	0.888	3370	5994.9	3370	3394	1.750
3	2.50	0.00	2.500	0.064	34.250	0.212	0.901	3417	4348.1	3400	3474	10.625
4	18.75	0.00	18.750	0.064	18.000	0.212	0.931	3530	1399.0	3287	3541	20.250
5	21.75	0.00	21.750	0.064	15.000	0.212	0.936	3551	1048.5	3266	3562	23.250
6	24.75	0.00	24.750	0.064	12.000	0.212	0.942	3573	760.0	3245	3583	26.250
7	27.75	0.00	27.750	0.064	9.000	0.212	0.947	3594	534.2	3223	3605	29.250
8	30.75	0.00	30.750	0.064	6.000	0.212	0.953	3616	372.0	3202	3627	32.250
9	33.75	0.000	33.750	0.064	3.000	0.212	0.959	3638	274.0	3180	3713	34.950
10	36.15	0.258	36.150	0.276	0.600	0.000	0.999	3789	1.4	3028	3791	36.450
11	36.75	0.387	36.750	0.276	0.000	0.000	1.000	3794		3024		

Av force 3635 kN

Elongation 260.0 mm

Slip will travel between 2.5 to 18.8

Slope of force 6.947 a 3.47 c -157.1 kN

distance	1.215	m	b	125.040	Force at Null Point	3409	kN	

CABLE NO. 2

Dist of cable CG from soffit at Dead anchorage	a1	0.25	Start of curve 2	30.75
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	30.75
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	30.75
Length of straight part at dead end	b1	1	Start of curve 1	1.00
Length of vert curve near dead end	b2	1.5	Ed of curve 1	2.50
Length of central straight part in elevation	b3	28.25	Delta H	0.00
Length of vert curve near live end	b4	2.4	soffit thick.	0.275
Length of straight part at live end	b5	0.6	total length	33.75
Length of hor curve	b6	0.00		
Horizontal deviation	b7	0.00		
Yv1 = (0.25-0.138)/(1+2/1.5)		0.048		
$Kv1=Y_v/L^2$		0.021		
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258		
$Kv2=Y_v/L^2$		0.045		
Change in angle due to vert curve 1		0.064	Radians=	3.66deg
Change in angle due to vert curve 2		0.212	Radians=	12.13deg
Kh= 0 0		0.000		
Change in angle due to one hor curve		0.000	Radians=	0.00deg

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0	0.130	0.000	0.000	33.750	0.276	0.892	3384	5410.2	3384	3387	0.500
2	1	0.048	1.000	0.000	32.750	0.276	0.894	3390	5184.9	3390	3414	1.750
3	2.5	0.00	2.500	0.064	31.250	0.212	0.906	3438	3670.2	3438	3463	6.125
4	9.75	0.00	9.750	0.064	24.000	0.212	0.919	3488	2283.1	3488	3498	11.250
5	12.75	0.00	12.750	0.064	21.000	0.212	0.925	3509	1810.8	3509	3520	14.250
6	15.75	0.00	15.750	0.064	18.000	0.212	0.931	3530	1399.0	3513	3541	17.250
7	18.75	0.00	18.750	0.064	15.000	0.212	0.936	3551	1048.5	3492	3562	20.250
8	21.75	0.00	21.750	0.064	12.000	0.212	0.942	3573	760.0	3471	3583	23.250
9	24.75	0.00	24.750	0.064	9.000	0.212	0.947	3594	534.2	3449	3605	26.250
10	27.75	0.00	27.750	0.064	6.000	0.212	0.953	3616	372.0	3427	3627	29.250
11	30.75	0.000	30.750	0.064	3.000	0.212	0.959	3638	274.0	3406	3713	31.950
12	33.15	0.258	33.150	0.276	0.600	0.000	0.999	3789	1.4	3254	3791	33.450
13	33.75	0.387	33.750	0.276	0.000	0.000	1.000	3794		3250		
						Av force		3624	kN			
						Elongation		238.3	mm			

Slip will travel between	12.8	to	15.8				
Slope of force	7.039		a	3.52	c	-157.1	kN
distance	1.200	m	b	126.703	Force at Null Point	3522	kN

CABLE NO. 3

Dist of cable CG from soffit at Dead anchorage	a1	0.25	Start of curve 2	39.75
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	39.75
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	39.75
Length of straight part at dead end	b1	1	Start of curve 1	1.00
Length of vert curve near dead end	b2	1.5	Ed of curve 1	2.50
Length of central straight part in elevation	b3	37.3	Delta H	0.00
Length of vert curve near live end	b4	2.4	soffit thick.	0.275

Length of straight part at live end	b5	0.6	total length 42.75
Length of hor curve	b6	0.0	
Horizontal deviation	b7	0.0	
Yv1 = (0.25-0.138)/(1+2/1.5)		0.048	
$Kv1=Y_v/L^2$		0.021	
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258	
$Kv2=Y_v/L^2$		0.045	
Change in angle due to vert curve 1		0.064	Radians= 3.66deg
Change in angle due to vert curve 2		0.212	Radians= 12.13deg
Kh= 0 0		0.000	
Change in angle due to one hor curve		0.000	Radians= 0.00deg

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0.00	0.130	0.000	0.000	42.750	0.276	0.876	3323	8061.2	3323	3327	0.500
2	1.00	0.048	1.000	0.000	41.750	0.276	0.878	3330	7780.1	3330	3353	1.750
3	2.50	0.00	2.500	0.064	40.250	0.212	0.890	3376	5873.9	3376	3453	13.625
4	24.75	0.00	24.750	0.064	18.000	0.212	0.931	3530	1399.0	3513	3541	26.250
5	27.75	0.00	27.750	0.064	15.000	0.212	0.936	3551	1048.5	3492	3562	29.250
6	30.75	0.00	30.750	0.064	12.000	0.212	0.942	3573	760.0	3471	3583	32.250
7	33.75	0.00	33.750	0.064	9.000	0.212	0.947	3594	534.2	3449	3605	35.250
8	36.75	0.00	36.750	0.064	6.000	0.212	0.953	3616	372.0	3427	3627	38.250
9	39.75	0.000	39.750	0.064	3.000	0.212	0.959	3638	274.0	3406	3713	40.950
10	42.15	0.258	42.150	0.276	0.600	0.000	0.999	3789	1.4	3254	3791	42.450
11	42.75	0.387	42.750	0.276	0.000	0.000	1.000	3794		3250		

Av force 3631 kN

Elongation 301.7 mm

Slip will travel between	2.5	to	24.8				
Slope of force	6.905	a	3.45	c	-157.1	kN
distance	1.222	m	b	124.297	Force at Null Point	3522	kN

CABLE NO. 4

Dist of cable CG from soffit at Dead anchorage	a1	0.25	Start of curve 2	45.75
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	45.75
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	45.75
Length of straight part at dead end	b1	1	Start of curve 1	1.00
Length of vert curve near dead end	b2	1.5	Ed of curve 1	2.50
Length of central straight part in elevation	b3	43.25	Delta H	0.00
Length of vert curve near live end	b4	2.4	soffit thick.	0.275
Length of straight part at live end	b5	0.6	total length	48.75
Length of hor curve	b6	0.00		
Horizontal deviation	b7	0.00		
Yv1 = (0.25-0.138)/(1+2/1.5)		0.048		
$Kv1=Y_v/L^2$		0.021		
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258		
$Kv2=Y_v/L^2$		0.045		
Change in angle due to vert curve 1		0.064	Radians= 3.66deg	
Change in angle due to vert curve 2		0.212	Radians= 12.13deg	
Kh= 0 0		0.000		
Change in angle due to one hor curve		0.000	Radians= 0.00deg	

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0	0.130	0.000	0.000	48.750	0.276	0.866	3284	10091.7	3284	3287	0.500
2	1	0.048	1.000	0.000	47.750	0.276	0.867	3290	9774.5	3290	3313	1.750
3	2.5	0.00	2.500	0.064	46.250	0.212	0.879	3336	7615.5	3336	3412	13.625
4	24.75	0.00	24.750	0.064	24.000	0.212	0.919	3488	2283.1	3488	3498	26.250
5	27.75	0.00	27.750	0.064	21.000	0.212	0.925	3509	1810.8	3509	3520	29.250
6	30.75	0.00	30.750	0.064	18.000	0.212	0.931	3530	1399.0	3513	3541	32.250
7	33.75	0.00	33.750	0.064	15.000	0.212	0.936	3551	1048.5	3492	3562	35.250
8	36.75	0.00	36.750	0.064	12.000	0.212	0.942	3573	760.0	3471	3583	38.250
9	39.75	0.00	39.750	0.064	9.000	0.212	0.947	3594	534.2	3449	3605	41.250
10	42.75	0.00	42.750	0.064	6.000	0.212	0.953	3616	372.0	3427	3627	44.250
11	45.75	0.000	45.750	0.064	3.000	0.212	0.959	3638	274.0	3406	3713	46.950
12	48.15	0.258	48.150	0.276	0.600	0.000	0.999	3789	1.4	3254	3791	48.450
13	48.75	0.39	48.750	0.276	0.000	0.000	1.000	3794		3250		

Av force 3611 kN

Elongation 341.8 mm

Slip will travel between	27.8	to	30.8					
Slope of force	7.039		a	3.52	c	-157.1	kN
distance	1.200	m	b	126.703	Force at Null Point	3522	kN

MID OF 80M SPAN

CABLE NO. 1

Dist of cable CG from soffit at Dead anchorage	a1	0.525	Start of curve 2	21.5
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	21.5
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	21.5
Length of straight part at dead end	b1	0.6	Start of curve 1	0.6
Length of vert curve near dead end	b2	2.40	Ed of curve 1	3
Length of central straight part in elevation	b3	18.50	Delta H	0
Length of vert curve near live end	b4	2.4	soffit thick.	0.275
Length of straight part at live end	b5	0.6	Half length	24.5
Length of hor curve	b6			
Horizontal deviation	b7			

Yv1 = (0.525-0.138)/(1+2*0.6/2.4)	0.258	
$Kv1=Y_v/L^2$	0.045	
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)	0.258	
$Kv2=Y_v/L^2$	0.045	
Change in angle due to vert curve 1	0.212	Radians= 12.13deg
Change in angle due to vert curve 2	0.212	Radians= 12.13deg
Kh= 0 0	0.000	
Change in angle due to one hor curve	0.000	Radians= 0.00deg

Section	Dist from Anchorage	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av force at Sec n & n+1	av length
1	0.00	0.387	0.000	0.000	0.000	0.000	1.000	3794	2367.6	3279	3791	0.300
2	0.60	0.258	0.600	0.000	0.600	0.000	0.999	3789	2366.3	3284	3713	1.800
3	3.00	0.00	3.000	0.212	3.000	0.212	0.959	3638	2093.6	3436	3627	4.500
4	6.00	0.00	6.000	0.212	6.000	0.212	0.953	3616	1995.7	3457	3605	7.500
5	9.00	0.00	9.000	0.212	9.000	0.212	0.947	3594	1833.4	3479	3583	10.500

6	12.00	0.00	12.000	0.212	12.000	0.212	0.942	3573	1607.7	3500	3562	13.500
7	15.00	0.00	15.000	0.212	15.000	0.212	0.936	3551	1319.1	3522	3541	16.500
8	18.00	0.00	18.000	0.212	18.000	0.212	0.931	3530	968.6	3530	3520	19.500
9	21.00	0.00	21.000	0.212	21.000	0.212	0.925	3509	556.8	3509	3498	22.500
10	24.00	0.00	24.000	0.212	24.000	0.212	0.919	3488	84.5	3488	3486	24.250
11	24.50	0.00	24.500	0.212	24.500	0.212	0.919	3484		3484		

Av force 3535 kN

Elongation 169.4 mm

Slip will travel between	18.0	to	15.0					
Slope of force	7.124		a	3.56	c		-237.0	kN
distance	2.074	m	b	106.86	Force at Null Point		3537	kN

CABLE NO. 2

Dist of cable CG from soffit at Dead anchorage	a1	0.525	Start of curve 2	18.5
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	18.5
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	18.5
Length of straight part at dead end	b1	0.6	Start of curve 1	0.6
Length of vert curve near dead end	b2	2.4	Ed of curve 1	3
Length of central straight part in elevation	b3	15.5	Delta H	0
Length of vert curve near live end	b4	2.4	soffit thick.	0.275
Length of straight part at live end	b5	0.6	total length	21.5
Length of hor curve	b6			
Horizontal deviation	b7			

Yv1 = (0.525-0.138)/(1+2*0.6/2.4)	0.258	
$Kv1=Y_v/L^2$	0.045	
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)	0.258	
$Kv2=Y_v/L^2$	0.045	
Change in angle due to vert curve 1	0.212	Radians= 12.13deg
Change in angle due to vert curve 2	0.212	Radians= 12.13deg
Kh= 0 0	0.000	
Change in angle due to one hor curve	0.000	Radians= 0.00deg

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0.00	0.387	0.000	0.000	0.000	0.000	1.000	3794	1885.3	3425	3791	0.300
2	0.60	0.258	0.600	0.000	0.600	0.000	0.999	3789	1884.0	3429	3713	1.800
3	3.00	0.00	3.000	0.212	3.000	0.212	0.959	3638	1611.3	3581	3627	4.500
4	6.00	0.00	6.000	0.212	6.000	0.212	0.953	3616	1513.3	3603	3605	7.500
5	9.00	0.00	9.000	0.212	9.000	0.212	0.947	3594	1351.1	3594	3583	10.500
6	12.00	0.00	12.000	0.212	12.000	0.212	0.942	3573	1125.4	3573	3562	13.500
7	15.00	0.00	15.000	0.212	15.000	0.212	0.936	3551	836.8	3551	3541	16.500
8	18.00	0.00	18.000	0.212	18.000	0.212	0.931	3530	486.3	3530	3520	19.500
9	21.00	0.00	21.000	0.212	21.000	0.212	0.925	3509	74.5	3509	3507	21.250
10	21.50	0.00	21.500	0.212	21.500	0.212	0.924	3505	0.0	3505		

Av force 3550 kN

Elongation 149.5 mm

Slip will travel between	6.0	to	3.0					
Slope of force	7.253		a	3.63	c		-42.8	kN
distance	0.913	m	b	43.520	Force at Null Point		3609	kN

CABLE NO. 3

Dist of cable CG from soffit at Dead anchorage	a1	0.525		Start of curve 2	15.5
Dist of cable CG from soffit after end of curve	a2	0.138		Stat of Hor curve	15.5
Dist of cable CG from soffit at Live anchorage	a3	0.525		End of Hor curve	15.5
Length of straight part at dead end	b1	0.6		Start of curve 1	0.6
Length of vert curve near dead end	b2	2.40		Ed of curve 1	3
Length of central straight part in elevation	b3	12.50		Delta H	0
Length of vert curve near live end	b4	2.4		soffit thick.	0.275
Length of straight part at live end	b5	0.6		Half length	18.5
Length of hor curve	b6				
Horizontal deviation	b7				
Yv1 = (0.525-0.138)/(1+2*0.6/2.4)		0.258			
$Kv1=Y_v/L^2$		0.045			
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258			
$Kv2=Y_v/L^2$		0.045			
Change in angle due to vert curve 1		0.212	Radians=	12.13deg	
Change in angle due to vert curve 2		0.212	Radians=	12.13deg	
Kh= 0 0		0.000			
Change in angle due to one hor curve		0.000	Radians=	0.00deg	

Section	Dist from Anchorage	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av force at Sec n & n+1	av length
1	0.00	0.387	0.000	0.000	0.000	0.000	1.000	3794	1463.4	3249	3791	0.300
2	0.60	0.258	0.600	0.000	0.600	0.000	0.999	3789	1462.0	3254	3713	1.800
3	3.00	0.00	3.000	0.212	3.000	0.212	0.959	3638	1189.3	3406	3627	4.500
4	6.00	0.00	6.000	0.212	6.000	0.212	0.953	3616	1091.4	3427	3605	7.500
5	9.00	0.00	9.000	0.212	9.000	0.212	0.947	3594	929.2	3449	3583	10.500
6	12.00	0.00	12.000	0.212	12.000	0.212	0.942	3573	703.4	3470	3562	13.500
7	15.00	0.00	15.000	0.212	15.000	0.212	0.936	3551	414.9	3492	3541	16.500
8	18.00	0.00	18.000	0.212	18.000	0.212	0.931	3530	64.4	3513	3528	18.250
11	18.50	0.00	18.500	0.212	18.500	0.212	0.930	3527		3517		

Av force 3565 kN

Elongation 129.6 mm

c -5.0 kN

Force at Null Point 3522 kN

CABLE NO. 4

Dist of cable CG from soffit at Dead anchorage	a1	0.525	Start of curve 2	12.5
Dist of cable CG from soffit after end of curve	a2	0.138	Stat of Hor curve	12.5
Dist of cable CG from soffit at Live anchorage	a3	0.525	End of Hor curve	12.5
Length of straight part at dead end	b1	0.6	Start of curve 1	0.6
Length of vert curve near dead end	b2	2.4	Ed of curve 1	3
Length of central straight part in elevation	b3	9.5	Delta H	0
Length of vert curve near live end	b4	2.4	soffit thick.	0.275
Length of straight part at live end	b5	0.6	total length	15.5
Length of hor curve	b6			
Horizontal deviation	b7			
Yv1 = (0.525-0.138)/(1+2*0.6/2.4)		0.258		
$Kv1=Y_v/L^2$		0.045		
Yv2 = (0.525-0.138)/(1+2*0.6/2.4)		0.258		
$Kv2=Y_v/L^2$		0.045		

Change in angle due to vert curve 1		0.212	Radians= 12.13deg
Change in angle due to vert curve 2		0.212	Radians= 12.13deg
Kh=	0 0	0.000	
Change in angle due to one hor curve		0.000	Radians= 0.00deg

Section	Dist from EJ	y	Dist along curve	θ	Dist from Jacking End	θ from jack end	exp(-μθ-kx)	F in Cable bfr slip	Area (1/2) of F diag	F in Cable aft slip	av f	av l
1	0.00	0.387	0.000	0.000	0.000	0.000	1.000	3794	1102.6	3243	3791	0.300
2	0.60	0.258	0.600	0.000	0.600	0.000	0.999	3789	1101.2	3248	3713	1.800
3	3.00	0.00	3.000	0.212	3.000	0.212	0.959	3638	828.6	3399	3627	4.500
4	6.00	0.00	6.000	0.212	6.000	0.212	0.953	3616	730.6	3421	3605	7.500
5	9.00	0.00	9.000	0.212	9.000	0.212	0.947	3594	568.4	3443	3583	10.500
6	12.00	0.00	12.000	0.212	12.000	0.212	0.942	3573	342.7	3464	3562	13.500
7	15.00	0.00	15.000	0.212	15.000	0.212	0.936	3551	54.1	3486	3550	15.250
10	15.50	0.00	15.500	0.212	15.500	0.212	0.935	3548		3489		

Av force	3581	kN
Elongation	109.4	mm

c	-29.3	kN
Force at Null Point	3519	kN

6.2 Summary of Cable forces after Slip for cantilever

Sec No.	Cable No.													Total	Yt	Ycable	Mom
	1	2	3	4	5	6	7	8	9	10	11	12	13				
No_Cbls	2	2	2	2	2	0	2	2	2	2	0	2	0				
1																	
2												3306.3		6613	1.186	0.961	6356
3											3299.5	3362.5		6725	1.186	1.048	7049
4										3234.1	3356.9	3426.5		13321	1.186	1.005	13384
5									3157.7	3291.9	3422.3	3489.5		19878	1.186	1.019	20260
6								3222.8	3217.6	3357.5	3486.8	3527.9		26652	1.186	1.026	27357
7							3408	3286.9	3285.8	3399.9	3528.5	3533.9		33829	1.186	1.031	34871
8						3303.6	3462.7	3360.2	3333.3	3441.9	3523.3	3496.3		34189	1.186	1.048	35837
9					3295	3378.3	3524.6	3416.1	3380.2	3483.5	3482.5	3459		41117	1.186	1.034	42503
10				3421.4	3406.7	3452.4	3557.6	3471.2	3426.6	3503.1	3442.1	3422.1		48418	1.186	1.036	50150
11			3286.6	3474.9	3449.4	3484.4	3590.3	3499.1	3452.7	3478.2	3417.6	3398.4		55259	1.251	1.102	60911
12		3224	3361	3497	3471	3506	3579	3496	3474	3457	3397	3378		61877	1.308	1.160	71792
13	3219	3336	3435	3520	3493	3528	3552	3475	3457	3437	3377	3358		68562	1.357	1.211	83006
14	3272	3379	3467	3542	3514	3548	3530	3455	3436	3416	3357	3338		68699	1.400	1.262	86717
15	3283	3390	3478	3553	3525	3538	3520	3444	3426	3406	3347	3328		68706	1.400	1.262	86725
15'	3298	3404	3493	3567	3539	3524	3506	3431	3412	3392	3333	3315		68714	1.400	1.262	86736
16	3283	3390	3478	3553	3525	3538	3520	3444	3426	3406	3347	3328		68706	1.400	1.262	86725
17	3272	3379	3467	3542	3514	3548	3530	3455	3436	3416	3357	3338		68699	1.400	1.262	86717
18	3219	3336	3435	3520	3493	3528	3552	3475	3457	3437	3377	3358		61877	1.357	1.219	75451
19		3224	3361	3497	3471	3506	3579	3496	3474	3457	3397	3378		55259	1.308	1.170	64649
20			3287	3475	3449	3484	3590	3499	3453	3478	3418	3398		48418	1.251	1.113	53896
21				3421	3407	3452	3558	3471	3427	3503	3442	3422		41117	1.186	1.048	43099
22					3295	3378	3525	3416	3380	3483	3482	3459		34189	1.186	1.048	35837
23						3304	3463	3360	3333	3442	3523	3496		33829	1.186	1.048	35460
24							3408	3287	3286	3400	3528	3534		26652	1.186	1.048	27937
25								3223	3218	3358	3487	3528		19878	1.186	1.048	20836
26									3158	3292	3422	3490		13321	1.186	1.048	13963
27										3234	3357	3426		6725	1.186	1.048	7049
28											3299	3362		6613	1.186	1.048	6931
29												3306		0	1.186	1.048	0
30																	

Av Cable Force		
sec	No_Cbls	Av F
2	2	3306
3	2	3362
4	4	3330
5	6	3313
6	8	3331
7	10	3383
8	10	3419
9	12	3426
10	14	3458
11	16	3454
12	18	3438
13	20	3428
14	20	3435
15	20	3435
16	20	3435
17	20	3435
18	20	3435
19	18	3438
20	16	3454
21	14	3458
22	12	3426
23	10	3419
24	10	3383
25	8	3331
26	6	3313
27	4	3330
28	2	3362
29	2	3306
Av along length		3395

6.4 Summary of Cable forces after Slip for Bottom Continuity Cable

Summary of Cable forces after Slip (Near P2) for stress check

Sec No.	Cable No.				Cable ord for cbl				Total1 (incl anch)	Total2 (Excl anch)	Yb	cbl cg (incl anch)	cbl cg (excl anch)	Ycbl1 (incl anch)	Ycbl2 (excl anch)	Mom1 (incl anch)	Mom2 (excl anch)	Av F nr P2	2 cables (C2) at top					
	1	2	3	4	1	2	3	4											Yt	Ecc (t)	Total2 (Excl anch)	Mom2 (excl anch)		
No_Cbls	1	1	2	3																				
1	3363	3384	3323	3284	0.268	0.268	0.268	0.268	23245	23245	-1.81	0.268	0.268	-1.55	-1.55	-35931	-35931	3321	1.186	0.918	6767.3	6213.8	7	114
2	3245	3449	3513	3488	0.138	0.138	0.138	0.138	24184	24184	-1.81	0.138	0.138	-1.68	-1.68	-40528	-40528	3455	1.186	1.048	6898.2	7230.7	7	113
3	3223	3427	3492	3509	0.138	0.138	0.138	0.138	24162	24162	-1.81	0.138	0.138	-1.68	-1.68	-40490	-40490	3452	1.186	1.048	6854.9	7185.4	7	112
4	3202	3406	3471	3513	0.138	0.138	0.138	0.138	24088	24088	-1.81	0.138	0.138	-1.68	-1.68	-40367	-40367	3441	1.186	1.048	6811.4	7139.7	7	111
5	3180	3250	3449	3492	0.138	0.525	0.138	0.138	23804	20554	-1.81	0.193	0.138	-1.62	-1.68	-38574	-34444	3401	1.186	0.661	6499.3	4297.4	7	110
6	3024		3427	3471	0.525		0.138	0.138	20291	17267	-1.81	0.203	0.138	-1.61	-1.68	-32694	-28935	3382	1.186				6	109
7			3406	3449			0.138	0.138	17159	17159	-1.81	0.138	0.138	-1.68	-1.68	-28754	-28754	3432	1.186				5	108
8			3250	3427			0.525	0.138	16782	10282	-1.81	0.293	0.138	-1.52	-1.68	-25525	-17231	3356	1.186				5	107
9				3406				0.138	10217	10217	-1.81	0.138	0.138	-1.68	-1.68	-17122	-17122	3406	1.186				3	106
10				3250				0.525	9749	9749	-1.81	0.525	0.525	-1.29	-1.29	-12564	-12564	3250	1.186				3	105
														Average				3389						

Summary of Cable forces after Slip for Secondary Effect

Near P2

Member No.	Force	ES	EM	EE
1	30482	-0.998	-1.034	-1.070
2	31071	-1.070	-1.070	-1.070
3	30980	-1.070	-1.070	-1.070
4	30757	-1.070	-1.092	-1.113
5	20422	-1.676	-1.644	-1.611
6	17213	-1.676	-1.676	-1.676
7	16970	-1.676	-1.598	-1.521
8	10250	-1.676	-1.676	-1.676
9	9983	-1.676	-1.482	-1.289

Near P5

Member No.	Force	ES	EM	EE
113	30482	-1.070	-1.034	-0.998
112	31071	-1.070	-1.070	-1.070
111	30980	-1.070	-1.070	-1.070
110	30757	-1.113	-1.092	-1.070
109	20422	-1.611	-1.644	-1.676
108	17213	-1.676	-1.676	-1.676
107	16970	-1.521	-1.598	-1.676
106	10250	-1.676	-1.676	-1.676
105	9983	-1.289	-1.482	-1.676

Summary of Cable forces after Slip (At Mid span of 80m span) 5

Sec No.	Cable No.				Ordinates for Cable Nos.				Total1 (incl anch)	Total2 (Excl anch)	Yb	cbl cg (incl anch)	cbl cg (excl anch)	Ycbl1 (incl anch)	Ycbl2 (excl anch)	Mom1 (incl anch)	Mom2 (excl anch)	Av Force	4 cables (C4) at top				
	1	2	3	4	1	2	3	4											Yt	Ecc (t)	Total2 (Excl anch)	Mom2 (excl anch)	
No_Cbls	3	2	1	1																			
21	3279				0.525				9838	9838	-1.81	0.525		-1.289		-12680	-12680	3279					
22	3436	3425			0.138	0.525			17156	10307	-1.81	0.293	0.138	-1.521	-1.676	-26094	-17272	3431					
23	3457	3581	3249		0.138	0.138	0.525		20783	17533	-1.81	0.203	0.138	-1.611	-1.676	-33487	-29382	3464					
24	3479	3603	3406	3243	0.138	0.138	0.138	0.525	24291	21047	-1.81	0.193	0.138	-1.621	-1.676	-39363	-35271	3470	1.186	0.661	16217	10723	7
25	3500	3594	3427	3399	0.138	0.138	0.138	0.138	24516	24516	-1.81	0.138	0.138	-1.676	-1.676	-41084	-41084	3502	1.186	1.048	16997	17817	7

26	3522	3573	3449	3421	0.138	0.138	0.138	0.138	24581	24581	-1.81	0.138	0.138	-1.676	-1.676	-41192	-41192	3512	1.186	1.048	17106	17931	7
27	3530	3551	3470	3443	0.138	0.138	0.138	0.138	24606	24606	-1.81	0.138	0.138	-1.676	-1.676	-41235	-41235	3515	1.186	1.048	17214	18044	7
28	3509	3530	3492	3464	0.138	0.138	0.138	0.138	24543	24543	-1.81	0.138	0.138	-1.676	-1.676	-41129	-41129	3506	1.186	1.048	17322	18157	7
29	3488	3509	3513	3486	0.138	0.138	0.138	0.138	24481	24481	-1.81	0.138	0.138	-1.676	-1.676	-41024	-41024	3497	1.186	1.048	17429	18269	7
30	3488	3509	3513	3486	0.138	0.138	0.138	0.138	24481	24481	-1.81	0.138	0.138	-1.676	-1.676	-41024	-41024	3497	1.186	1.048	17429	18269	7
31	3509	3530	3492	3464	0.138	0.138	0.138	0.138	24543	24543	-1.81	0.138	0.138	-1.676	-1.676	-41129	-41129	3506	1.186	1.048	17322	18157	7
32	3530	3551	3470	3443	0.138	0.138	0.138	0.138	24606	24606	-1.81	0.138	0.138	-1.676	-1.676	-41235	-41235	3515	1.186	1.048	17214	18044	7
33	3522	3573	3449	3421	0.138	0.138	0.138	0.138	24581	24581	-1.81	0.138	0.138	-1.676	-1.676	-41192	-41192	3512	1.186	1.048	17106	17931	7
34	3500	3594	3427	3399	0.138	0.138	0.138	0.138	24516	24516	-1.81	0.138	0.138	-1.676	-1.676	-41084	-41084	3502	1.186	1.048	16997	17817	7
35	3479	3603	3406	3243	0.138	0.138	0.138	0.525	24291	21047	-1.81	0.193	0.138	-1.621	-1.676	-39363	-35271	3470	1.186	0.661	16217	10723	
36	3457	3581	3249		0.138	0.138	0.525		20783	17533	-1.81	0.203	0.138	-1.611	-1.676	-33487	-29382	3464					
37	3436	3425			0.138	0.525			17156	10307	-1.81	0.293	0.138	-1.521	-1.676	-26094	-17272	3431					
38	3279				0.525				9838	9838	-1.81	0.525		-1.289		-12680	-12680	3279					
																		3464					

Summary of Cable forces after Slip for Secondary Effect

Member No.			Force	ES	EM	EE
21	49	77	10072	-1.289	-1.482	-1.676
22	50	78	17345	-1.521	-1.598	-1.676
23	51	79	20915	-1.611	-1.644	-1.676
24	52	80	40621	-0.791	-0.738	-0.685
25	53	81	41546	-0.685	-0.685	-0.685
26	54	82	41700	-0.685	-0.685	-0.685
27	55	83	41789	-0.685	-0.685	-0.685
28	56	84	41834	-0.685	-0.685	-0.685
29	57	85	41909	-0.685	-0.685	-0.685
30	58	86	41940	-0.685	-0.685	-0.685
31	59	87	41896	-0.685	-0.685	-0.685
32	60	88	41808	-0.685	-0.685	-0.685
33	61	89	41655	-0.685	-0.685	-0.685
34	62	90	39779	-0.685	-0.012	0.661
35	63	91	20915	-1.676	-1.644	-1.611
36	64	92	17345	-1.676	-1.598	-1.521
37	65	93	10072	-1.676	-1.482	-1.289

6.6 COMPUTATION OF LONG TERM LOSSES

Computation of shrinkage strain (Refer cl. 6.4.2.6 of IRC 112)

Auogenous Shrinkage strain

t	28	35	42	49	56	63	70	77	84	91	98	105	154
ε_{ca}	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05	9.50E-05
β_{as} (t)	0.65	0.69	0.73	0.75	0.78	0.80	0.81	0.83	0.84	0.85	0.86	0.87	0.92
$\varepsilon_{ca(t)}$	6.20E-05	6.59E-05	6.90E-05	7.16E-05	7.37E-05	7.56E-05	7.72E-05	7.86E-05	7.98E-05	8.09E-05	8.19E-05	8.28E-05	8.71E-05

Drying shrinkage strain

Relative humidity 70 % Concrete Grade 60 $\varepsilon_{cd.0} \times 10^6$ 275 for 70% humidity

h_0	554	554	554	554	554	554	554	554	554	554	554	554	554
ts=	28	28	28	28	28	28	28	28	28	28	28	28	28
β_{ds} (t,ts)	0.000	0.013	0.026	0.039	0.051	0.063	0.075	0.086	0.097	0.108	0.118	0.129	0.195
k_h	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700	0.700
$\varepsilon_{cd(t)}$	0.00E+00	2.55E-06	5.03E-06	7.44E-06	9.80E-06	1.21E-05	1.43E-05	1.65E-05	1.86E-05	2.07E-05	2.28E-05	2.47E-05	3.74E-05
Resid. strain	2.25E-04	2.19E-04	2.13E-04	2.08E-04	2.04E-04	2.00E-04	1.96E-04	1.92E-04	1.89E-04	1.86E-04	1.83E-04	1.80E-04	1.63E-04

(0.7*0.000275-0.000003)+(0.000095-0.000066)

Computation of Creep strain (Refer cl. 6.4.2.7 of IRC 112)

Stress in co	10	10	10	10	10	10	10	10	10	10	10	10	10
Ec	37000	37000	37000	37000	37000	37000	37000	37000	37000	37000	37000	37000	37000
Elastic strain	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04	2.70E-04
f_{cm} (f_{ck}+10)	70	70	70	70	70	70	70	70	70	70	70	70	70
α_1	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720	0.720
α_2	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910	0.910
α_3	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791	0.791
ϕ_{RH}	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150	1.150

$\beta(f_{cm})$	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245	2.245
t_0	28	28	28	28	28	28	28	28	28	28	28	28	28
t	28	35	42	49	56	63	70	77	84	91	98	105	154
$\beta(t_0)$	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488	0.488
ϕ_0	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260	1.260
β_H	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63	1064.63
$\beta(t, t_0)$	0.00	0.221	0.272	0.306	0.333	0.356	0.375	0.392	0.407	0.421	0.434	0.445	0.510
Creep Strain	3.41E-04	2.65E-04	2.48E-04	2.36E-04	2.27E-04	2.20E-04	2.13E-04	2.07E-04	2.02E-04	1.97E-04	1.93E-04	1.89E-04	1.67E-04

Initial residual shrinkage strain for pier head	2.25E-04	Initial residual shrinkage strain for last segment	2.25E-04
final residual shrinkage strain for pier head (before continuity)	1.63E-04	final residual shrinkage strain for last segment(before continuity)	2.25E-04
Loss in strain	6.24E-05	Loss in strain	0.00E+00
Loss of average shrinkage strain during cantilever constrction	3.12E-05		
Residual shrinkage strain after continuity	1.94E-04		

Similarly creep strian considered for losses before continuity	8.68E-05
And creep strain considered after continuity	2.54E-04

6.6.1 LOSSES IN CANTILEVER CABLES OVER P3, P4

Loss due to Elastic Shortening

Average force in cable after friction and slip (Refer Section 6.2)		3395	kN	339.5	T
Cocrete stress at cable cg after stressing cables 1 & 2		-3	t/sqm	(Refer 8.2.2 (1))	
Cocrete stress at cable cg after stressing all cantilever cables		1465	t/sqm	(Refer 8.2.2 (1))	
Increase in stress	1465--3	1468	t/sqm		
Increase in strain	1468/(3700000)=	0.00040			
Loss in force for one cable	0.0004*195000000*0.00266/10=	20.75	t		
Loss in force for the cables stresses at the end		0.000	t		
Average loss	(20.748+0)/2	10.37	t		
%age loss	10.37/339.5*100=	3.05	%		

Loss due to Shrinkage

Loss in shrinkage strain during cantilever construction				3.10E-05			
Loss in force			0.000031*195000000*0.00266/10=	1.61	t		
%age loss			1.61/339.5*100=	0.47	%		
Loss in shrinkage strain after cantilever construction						1.94E-04	
Loss in force			0.000194*195000000*0.00266/10=			10.06	t
%age loss			10.06/339.5*100=			2.96	%
Loss due to Creep							
Loss in creep strain per 10 mpa during cantilever construction				8.70E-05			
Average stress at the cg of cables			(-3+1465)/200	7.31	mpa		
Loss in force			0.000087*7.31*195000000*0.00266/10=	3.30	t		
%age loss			3.3/339.5*100=	0.97	%		
Loss in creep strain per 10 mpa after cantilever construction						2.54E-04	
Average stress at the cg of cables						5.85	mpa
Loss in force			0.000254*5.848*195000000*0.00266/10=			7.70	t
%age loss			7.7/339.5*100=			2.27	%

Loss due to Relaxation of steel

Initial Cable force after elastic shortening loss			339.5-10.37	329.13	t		
As ratio of UTS			329.13/(4951.4/10)	0.665	times UTS		
1000 hour relaxation loss (Refer Table 6.2 of IRC 112)			(1.25+(2.5-1.25)*(0.665-0.6)/(0.7-0.6))	2.063	%		
Assuming average age at continuity	120	days i.e.	2880 Hours				
Relaxation loss			2.063*(2880/1000)^0.143	2.400	%	Eq A2.38 of IRC 112	
Balance relaxation loss (after continuity)			2.063*3-2.4			3.79	%
Total loss in cables before continuity			3.05+0.47+0.97+2.40=	6.90	%		
Total loss in cables after continuity			2.96+2.27+3.79=			9.02	%
Total Long term loss including before and after continuity			6.90+9.02=	15.92	%		

6.6.2 LOSSES IN CONTINUITY CABLES

Loss due to Elastic Shortening

Average force in cable after friction and slip		3464	kN	346.4	T
Cocrete stress at cable cg after stressing 1st cable		0	t/sqm		
Cocrete stress at cable cg after stressing all cables		782	t/sqm		
Increase in stress	782-0	782	t/sqm		
Increase in strain	782/(3700000)=	0.0002			
Loss in force for one cable	0.000211*195000000*0.00266/10=	10.94	t		
Loss in force for the cables stresses at the end		0.000	t		
Average loss	(10.94457+0)/2	5.47	t		
%age loss	5.47/346.4*100=	1.58	%		

Loss due to Shrinkage

Loss in shrinkage strain after cantilever construction		2.30E-04	
Loss in force	0.00023*195000000*0.00266/10=	11.93	t
%age loss	11.93/346.4*100=	3.44	%

Loss due to Creep

Loss in creep strain per 10 mpa after cantilever construction		2.50E-04	
Average stress at the cg of cables		7.82	mpa
Loss in force	0.00025*7.82*195000000*0.00266/10=	10.14	t
%age loss	10.141/346.4*100=	2.93	%

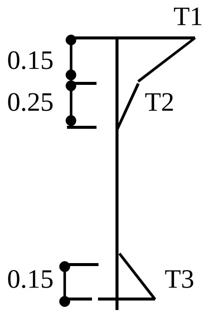
Loss due to Relaxation of steel

Initial Cable force after elastic shortening loss	346.4-5.47	340.93	t
As ratio of UTS	340.93/(4951.4/10)	0.689	times UTS
1000 hour relaxation loss	(1.25+(2.5-1.25)*(0.689-0.6)/(0.7-0.6))	2.363	%
Total relaxation loss	3*2.363	7.089	%
Total loss in cables after continuity	1.58+3.44+2.93+7.09=	15.04	%
Conclusion			
Average force after friction and slip for cantilever cables		340	t
Losses before continuity		6.90	%
Losses after continuity		9.02	%

Average force after friction and slip for bottom continuity cables	346	t
Long term Losses	15.04	%
Average force after friction and slip for top continuity cables	346	t
Long term Losses	15.04	%

7 Temperature Gradient Effects

7.1 Positive temperature difference

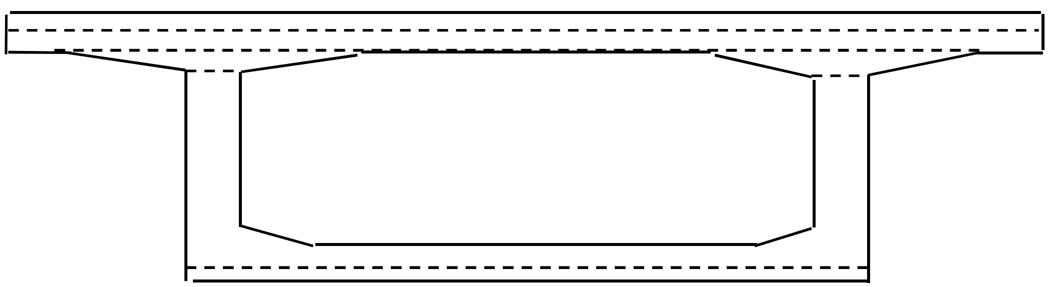


T1= 17.8 σ_t 7.903 mpa

T2= 4.0 σ_b 0.932 mpa

T3= 2.1

α= 0.000012 Ec= 3.70E+07 kN/m^2



	Width	Ht	T_top	T_bottm
Element 1	5.85	0.15	17.8	4.0
Element 2	5.85	0.125	4.0	2
Element 3	2.491	0.125	2	0
Element 4	3.00	0.15	0	2.1

Computation of Axial Force and Moment at Support Section under fully restrained condition

Element 1	F1	1.56E+03	Ecc	1.111	M	1.73E+03	
	F2	2.69E+03	Ecc	1.136	M	3.05E+03	
Element 2	F1	6.49E+02	Ecc	0.974	M	6.32E+02	
	F2	3.25E+02	Ecc	0.995	M	3.23E+02	
Element 3	F1	1.38E+02	Ecc	0.870	M	1.20E+02	
Element 4	F1	2.10E+02	Ecc	-1.764	M	-3.7E+02	
		5569	kN			5492	kNm

The P & M under fixed condition are computed for all the members. The equal and opposite amount of force and moment is applied on the structure (in STAAD PRO) to obtain the secondary effect due to continuity. The final moment including secondary effect is presented in appendix B.

Computation of Top & Bottom Stresses due to +ve Temperature Gradient

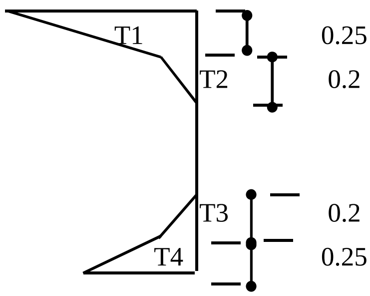
S No.	top				Bottom			
	Prim Stres	Release P	Release M	Total	Prim Stres	Release P	Release M	Total
1	7.90	-1.26	-1.18	5.45	0.93	-1.26	1.81	1.48
2	7.90	-1.26	-0.43	6.21	0.93	-1.26	0.65	0.32
3	7.90	-1.26	-0.34	6.30	0.93	-1.26	0.51	0.18
4	7.90	-1.26	-0.24	6.40	0.93	-1.26	0.37	0.04
5	7.90	-1.26	-0.15	6.49	0.93	-1.26	0.23	-0.10
6	7.90	-1.26	-0.06	6.58	0.93	-1.26	0.09	-0.24
7	7.90	-1.26	0.03	6.67	0.93	-1.26	-0.05	-0.38
8	7.90	-1.26	0.12	6.76	0.93	-1.26	-0.19	-0.52
9	7.90	-1.26	0.22	6.85	0.93	-1.26	-0.33	-0.66
10	7.90	-1.26	0.31	6.95	0.93	-1.26	-0.47	-0.80
11	7.90	-1.21	0.39	7.09	0.93	-1.21	-0.55	-0.82
12	7.90	-1.16	0.47	7.22	0.93	-1.16	-0.61	-0.84
13	7.90	-1.11	0.56	7.35	0.93	-1.11	-0.68	-0.85
14	7.90	-1.06	0.65	7.49	0.93	-1.06	-0.74	-0.87
15	7.90	-1.20	0.32	7.03	0.93	-1.20	-0.37	-0.63
16	7.90	-1.30	-0.02	6.58	0.93	-1.30	0.02	-0.35
17	7.90	-1.30	-0.02	6.58	0.93	-1.30	0.02	-0.35
18	7.90	-1.36	-0.02	6.52	0.93	-1.36	0.03	-0.40
19	7.90	-1.42	-0.02	6.46	0.93	-1.42	0.03	-0.45
20	7.90	-1.48	-0.03	6.40	0.93	-1.48	0.03	-0.51
21	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.58
22	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
23	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
24	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
25	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.57
26	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.57
27	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.57
28	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
29	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
30	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
31	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.05	-0.56

32	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
33	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
34	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
35	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
36	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.06	-0.55
37	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.06	-0.55
38	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.06	-0.55
39	7.90	-1.48	-0.04	6.38	0.93	-1.48	0.06	-0.49
40	7.90	-1.42	-0.04	6.44	0.93	-1.42	0.06	-0.43
41	7.90	-1.36	-0.04	6.50	0.93	-1.36	0.05	-0.37
42	7.90	-1.30	-0.04	6.56	0.93	-1.30	0.05	-0.32
43	7.90	-1.22	0.18	6.86	0.93	-1.22	-0.20	-0.49
44	7.90	-1.12	0.05	6.83	0.93	-1.12	-0.06	-0.24
45	7.90	-1.12	0.05	6.83	0.93	-1.12	-0.05	-0.24
46	7.90	-1.17	0.04	6.78	0.93	-1.17	-0.05	-0.29
47	7.90	-1.22	0.04	6.73	0.93	-1.22	-0.05	-0.34
48	7.90	-1.27	0.04	6.67	0.93	-1.27	-0.05	-0.40
49	7.90	-1.33	0.04	6.61	0.93	-1.33	-0.06	-0.46
50	7.90	-1.33	0.03	6.61	0.93	-1.33	-0.05	-0.45
51	7.90	-1.33	0.03	6.60	0.93	-1.33	-0.05	-0.45
52	7.90	-1.33	0.03	6.60	0.93	-1.33	-0.04	-0.44
53	7.90	-1.33	0.03	6.60	0.93	-1.33	-0.04	-0.44
54	7.90	-1.33	0.02	6.59	0.93	-1.33	-0.03	-0.43
55	7.90	-1.33	0.02	6.59	0.93	-1.33	-0.03	-0.43
56	7.90	-1.33	0.02	6.59	0.93	-1.33	-0.02	-0.42
57	7.90	-1.33	0.01	6.58	0.93	-1.33	-0.02	-0.42
58	7.90	-1.33	0.01	6.58	0.93	-1.33	-0.02	-0.42
59	7.90	-1.33	0.01	6.58	0.93	-1.33	-0.01	-0.41
60	7.90	-1.33	0.01	6.58	0.93	-1.33	-0.01	-0.41
61	7.90	-1.33	0.00	6.57	0.93	-1.33	-0.01	-0.40
62	7.90	-1.33	0.00	6.57	0.93	-1.33	0.00	-0.40
63	7.90	-1.33	0.00	6.57	0.93	-1.33	0.00	-0.40
64	7.90	-1.33	-0.01	6.57	0.93	-1.33	0.01	-0.39
65	7.90	-1.33	-0.01	6.56	0.93	-1.33	0.01	-0.39
66	7.90	-1.33	-0.01	6.56	0.93	-1.33	0.02	-0.38
67	7.90	-1.27	-0.01	6.62	0.93	-1.27	0.02	-0.32
68	7.90	-1.22	-0.02	6.67	0.93	-1.22	0.02	-0.26
69	7.90	-1.17	-0.02	6.72	0.93	-1.17	0.02	-0.21
70	7.90	-1.12	-0.02	6.76	0.93	-1.12	0.03	-0.16

71	7.90	-1.22	-0.28	6.40	0.93	-1.22	0.32	0.04
72	7.90	-1.30	-0.05	6.55	0.93	-1.30	0.06	-0.31
73	7.90	-1.30	-0.05	6.55	0.93	-1.30	0.06	-0.31
74	7.90	-1.36	-0.05	6.50	0.93	-1.36	0.06	-0.37
75	7.90	-1.42	-0.05	6.44	0.93	-1.42	0.06	-0.42
76	7.90	-1.48	-0.05	6.38	0.93	-1.48	0.06	-0.48
77	7.90	-1.55	-0.05	6.31	0.93	-1.55	0.07	-0.54
78	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.07	-0.55
79	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.07	-0.55
80	7.90	-1.55	-0.04	6.31	0.93	-1.55	0.06	-0.55
81	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.55
82	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
83	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
84	7.90	-1.55	-0.04	6.32	0.93	-1.55	0.06	-0.56
85	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
86	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
87	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.56
88	7.90	-1.55	-0.03	6.32	0.93	-1.55	0.05	-0.57
89	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.05	-0.57
90	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
91	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
92	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.57
93	7.90	-1.55	-0.03	6.33	0.93	-1.55	0.04	-0.58
94	7.90	-1.55	-0.02	6.33	0.93	-1.55	0.04	-0.58
95	7.90	-1.48	-0.02	6.40	0.93	-1.48	0.03	-0.52
96	7.90	-1.42	-0.02	6.47	0.93	-1.42	0.03	-0.46
97	7.90	-1.36	-0.02	6.53	0.93	-1.36	0.02	-0.40
98	7.90	-1.30	-0.02	6.58	0.93	-1.30	0.02	-0.35
99	7.90	-1.20	0.27	6.97	0.93	-1.20	-0.30	-0.57
100	7.90	-1.06	0.73	7.57	0.93	-1.06	-0.83	-0.96
101	7.90	-1.06	0.68	7.52	0.93	-1.06	-0.78	-0.91
102	7.90	-1.11	0.59	7.39	0.93	-1.11	-0.72	-0.89
103	7.90	-1.16	0.51	7.25	0.93	-1.16	-0.66	-0.88
104	7.90	-1.21	0.42	7.12	0.93	-1.21	-0.59	-0.86
105	7.90	-1.26	0.34	6.98	0.93	-1.26	-0.52	-0.85
106	7.90	-1.26	0.24	6.88	0.93	-1.26	-0.37	-0.70
107	7.90	-1.26	0.15	6.79	0.93	-1.26	-0.23	-0.56
108	7.90	-1.26	0.06	6.70	0.93	-1.26	-0.09	-0.42
109	7.90	-1.26	-0.04	6.60	0.93	-1.26	0.06	-0.27

110	7.90	-1.26	-0.13	6.51	0.93	-1.26	0.20	-0.13
111	7.90	-1.26	-0.22	6.41	0.93	-1.26	0.34	0.01
112	7.90	-1.26	-0.32	6.32	0.93	-1.26	0.49	0.16
113	7.90	-1.26	-0.41	6.23	0.93	-1.26	0.63	0.30

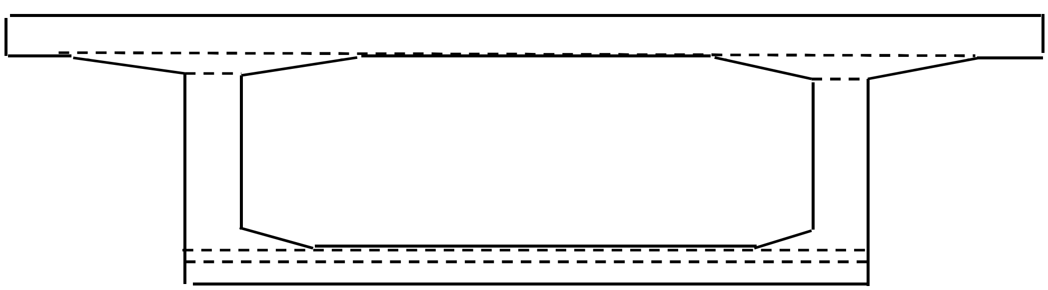
7.2 Negative temperature difference



T1= 10.6
T2= 0.7
T3= 0.8
T4= 6.6

σ_t -4.706
σ_b -2.930

α= 0.000012 Ec= 3.7E+07 kN/m^2



Section where soffit is more than 450 thick.

	Width	Ht	T_top	T_bottm
Element 1	5.85	0.250	10.6	0.7
Element 2	5.85	0.025	0.7	0.6125
Element 3	2.49	0.175	0.6125	0
Element 4	0.61	0.175	0.00	0.70
Element 5	3.00	0.025	0.70	0.80
Element 6	3.00	0.25	0.80	6.60

Computation of Axial Force and Moment at Support Section under fully restrained condition

Element 1	F1	4.55E+02	Ecc	1.061	M	4.82E+02
	F2	3.21E+03	Ecc	1.103	M	3.54E+03
Element 2	F1	4.26E+01	Ecc	0.924	M	3.9E+01
Element 3	F1	5.93E+01	Ecc	0.853	M	5.1E+01
Element 4	F1	1.66E+01	Ecc	-1.480	M	-2.5E+01

Element 5	F1	2.50E+01	Ecc	-1.551	M	-3.9E+01
Element 6	F1	2.66E+02	Ecc	-1.689	M	-4.5E+02
	F2	9.66E+02	Ecc	-1.730	M	-1.7E+03
		5044				1933

Computation of Final stresses due to Negative Temperature Gradient

S No.	top				Bottom			
	Prim Stres	Release P	Release M	Total	Prim Stres	Release P	Release M	Total
1	-4.71	1.14	0.42	-3.14	-2.93	1.14	-0.64	-2.42
2	-4.71	1.14	0.11	-3.45	-2.93	1.14	-0.17	-1.95
3	-4.71	1.14	0.07	-3.49	-2.93	1.14	-0.11	-1.90
4	-4.71	1.14	0.04	-3.53	-2.93	1.14	-0.05	-1.84
5	-4.71	1.14	0.00	-3.56	-2.93	1.14	0.00	-1.78
6	-4.71	1.14	-0.04	-3.60	-2.93	1.14	0.06	-1.73
7	-4.71	1.14	-0.08	-3.64	-2.93	1.14	0.12	-1.67
8	-4.71	1.14	-0.11	-3.67	-2.93	1.14	0.17	-1.61
9	-4.71	1.14	-0.15	-3.71	-2.93	1.14	0.23	-1.56
10	-4.71	1.14	-0.19	-3.75	-2.93	1.14	0.29	-1.50
11	-4.71	1.09	-0.22	-3.83	-2.93	1.09	0.31	-1.53
12	-4.71	1.05	-0.25	-3.91	-2.93	1.05	0.33	-1.56
13	-4.71	1.00	-0.29	-3.99	-2.93	1.00	0.35	-1.58
14	-4.71	0.96	-0.32	-4.06	-2.93	0.96	0.37	-1.60
15	-4.71	0.85	-0.04	-3.89	-2.93	0.85	0.04	-2.04
16	-4.71	0.76	0.03	-3.92	-2.93	0.76	-0.04	-2.21
17	-4.71	0.76	0.03	-3.92	-2.93	0.76	-0.04	-2.21
18	-4.71	0.79	0.03	-3.88	-2.93	0.79	-0.04	-2.18
19	-4.71	0.82	0.03	-3.85	-2.93	0.82	-0.04	-2.15
20	-4.71	0.86	0.03	-3.81	-2.93	0.86	-0.05	-2.12
21	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
22	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
23	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
24	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
25	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
26	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
27	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
28	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
29	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
30	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08

31	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
32	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
33	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
34	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
35	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
36	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
37	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
38	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
39	-4.71	0.86	0.03	-3.81	-2.93	0.86	-0.05	-2.12
40	-4.71	0.82	0.03	-3.85	-2.93	0.82	-0.04	-2.15
41	-4.71	0.79	0.03	-3.88	-2.93	0.79	-0.04	-2.18
42	-4.71	0.76	0.03	-3.92	-2.93	0.76	-0.04	-2.21
43	-4.71	0.83	-0.16	-4.04	-2.93	0.83	0.19	-1.91
44	-4.71	0.92	-0.04	-3.82	-2.93	0.92	0.04	-1.96
45	-4.71	0.92	-0.04	-3.82	-2.93	0.92	0.04	-1.97
46	-4.71	0.96	-0.04	-3.78	-2.93	0.96	0.04	-1.93
47	-4.71	1.00	-0.03	-3.74	-2.93	1.00	0.04	-1.89
48	-4.71	1.05	-0.03	-3.69	-2.93	1.05	0.04	-1.84
49	-4.71	1.10	-0.03	-3.64	-2.93	1.10	0.05	-1.79
50	-4.71	1.10	-0.03	-3.64	-2.93	1.10	0.04	-1.79
51	-4.71	1.10	-0.02	-3.64	-2.93	1.10	0.04	-1.80
52	-4.71	1.10	-0.02	-3.63	-2.93	1.10	0.03	-1.80
53	-4.71	1.10	-0.02	-3.63	-2.93	1.10	0.03	-1.81
54	-4.71	1.10	-0.02	-3.63	-2.93	1.10	0.03	-1.81
55	-4.71	1.10	-0.01	-3.63	-2.93	1.10	0.02	-1.81
56	-4.71	1.10	-0.01	-3.62	-2.93	1.10	0.02	-1.82
57	-4.71	1.10	-0.01	-3.62	-2.93	1.10	0.01	-1.82
58	-4.71	1.10	-0.01	-3.62	-2.93	1.10	0.01	-1.82
59	-4.71	1.10	-0.01	-3.62	-2.93	1.10	0.01	-1.83
60	-4.71	1.10	0.00	-3.61	-2.93	1.10	0.01	-1.83
61	-4.71	1.10	0.00	-3.61	-2.93	1.10	0.00	-1.83
62	-4.71	1.10	0.00	-3.61	-2.93	1.10	0.00	-1.84
63	-4.71	1.10	0.00	-3.61	-2.93	1.10	-0.01	-1.84
64	-4.71	1.10	0.01	-3.61	-2.93	1.10	-0.01	-1.84
65	-4.71	1.10	0.01	-3.60	-2.93	1.10	-0.01	-1.85
66	-4.71	1.10	0.01	-3.60	-2.93	1.10	-0.02	-1.85
67	-4.71	1.05	0.01	-3.65	-2.93	1.05	-0.02	-1.90
68	-4.71	1.00	0.02	-3.69	-2.93	1.00	-0.02	-1.95
69	-4.71	0.96	0.02	-3.73	-2.93	0.96	-0.02	-1.99

70	-4.71	0.92	0.02	-3.76	-2.93	0.92	-0.02	-2.03
71	-4.71	0.83	0.25	-3.62	-2.93	0.83	-0.29	-2.39
72	-4.71	0.76	0.04	-3.91	-2.93	0.76	-0.04	-2.22
73	-4.71	0.76	0.04	-3.91	-2.93	0.76	-0.04	-2.22
74	-4.71	0.79	0.04	-3.88	-2.93	0.79	-0.05	-2.19
75	-4.71	0.82	0.04	-3.84	-2.93	0.82	-0.05	-2.15
76	-4.71	0.86	0.04	-3.81	-2.93	0.86	-0.05	-2.12
77	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
78	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
79	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
80	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
81	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
82	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.09
83	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.06	-2.08
84	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
85	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
86	-4.71	0.90	0.04	-3.77	-2.93	0.90	-0.05	-2.08
87	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
88	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
89	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
90	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
91	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
92	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
93	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
94	-4.71	0.90	0.03	-3.77	-2.93	0.90	-0.05	-2.08
95	-4.71	0.86	0.03	-3.81	-2.93	0.86	-0.04	-2.11
96	-4.71	0.82	0.03	-3.85	-2.93	0.82	-0.04	-2.15
97	-4.71	0.79	0.03	-3.89	-2.93	0.79	-0.04	-2.18
98	-4.71	0.76	0.03	-3.92	-2.93	0.76	-0.03	-2.21
99	-4.71	0.85	-0.22	-4.07	-2.93	0.85	0.25	-1.83
100	-4.71	0.96	-0.37	-4.11	-2.93	0.96	0.42	-1.54
101	-4.71	0.96	-0.35	-4.09	-2.93	0.96	0.40	-1.57
102	-4.71	1.00	-0.32	-4.02	-2.93	1.00	0.38	-1.55
103	-4.71	1.05	-0.28	-3.94	-2.93	1.05	0.36	-1.52
104	-4.71	1.09	-0.25	-3.86	-2.93	1.09	0.34	-1.49
105	-4.71	1.14	-0.21	-3.77	-2.93	1.14	0.32	-1.46
106	-4.71	1.14	-0.17	-3.74	-2.93	1.14	0.27	-1.52
107	-4.71	1.14	-0.13	-3.70	-2.93	1.14	0.21	-1.58
108	-4.71	1.14	-0.10	-3.66	-2.93	1.14	0.15	-1.64

109	-4.71	1.14	-0.06	-3.62	-2.93	1.14	0.09	-1.70
110	-4.71	1.14	-0.02	-3.58	-2.93	1.14	0.03	-1.76
111	-4.71	1.14	0.02	-3.54	-2.93	1.14	-0.03	-1.82
112	-4.71	1.14	0.06	-3.50	-2.93	1.14	-0.09	-1.88
113	-4.71	1.14	0.10	-3.46	-2.93	1.14	-0.15	-1.93

Section where soffit ismore than 275 mm

section 11

soffit th= 0.356	Width	Ht	T_top	T_bottm
Element 1	5.85	0.25	10.60	0.70
Element 2	5.85	0.03	0.70	0.61
Element 3	2.49	0.18	0.61	0.00
Element 4	0.61	0.09	0.00	0.38
Element 5	3.00	0.11	0.38	0.80
Element 6	3.00	0.25	0.80	6.60

Computation of Axial Force and Moment

Element 1	F1	4.55E+02	Ecc	1.126	M	5.12E+02
	F2	3.21E+03	Ecc	1.168	M	3.75E+03
Element 2	F1	4.26E+01	Ecc	0.989	M	4.2E+01
Element 3	F1	5.93E+01	Ecc	0.889	M	5.3E+01
Element 4	F1	4.78E+00	Ecc	-1.361	M	-6.5E+00
Element 5	F1	8.31E+01	Ecc	-1.446	M	-1.2E+02
Element 6	F1	2.66E+02	Ecc	-1.624	M	-4.3E+02
	F2	9.66E+02	Ecc	-1.666	M	-1.6E+03
		5091				2193

section 12

soffit th= 0.438	Width	Ht	T_top	T_bottm
Element 1	5.85	0.25	10.60	0.70
Element 2	5.85	0.03	0.70	0.61
Element 3	2.49	0.18	0.61	0.00
Element 4	0.61	0.013	0.00	0.05
Element 5	3.00	0.188	0.05	0.80
Element 6	3.00	0.250	0.80	6.60

Computation of Axial Force and Moment

Element 1	F1	4.55E+02	Ecc	1.183	M	5.38E+02
	F2	3.21E+03	Ecc	1.225	M	3.94E+03
Element 2	F1	4.26E+01	Ecc	1.045	M	4.5E+01
Element 3	F1	5.93E+01	Ecc	0.945	M	5.6E+01
Element 4	F1	8.49E-02	Ecc	-1.250	M	-1.1E-01
Element 5	F1	1.06E+02	Ecc	-1.348	M	-1.4E+02

Element 6	F1	2.66E+02	Ecc	-1.567	M	-4.2E+02
	F2	9.66E+02	Ecc	-1.609	M	-1.6E+03
		5109				2460

section 13

soffit th= 0.519

	Width	Ht	T_top	T_bottm
Element 1	5.85	0.25	10.60	0.70
Element 2	5.85	0.03	0.70	0.61
Element 3	2.49	0.18	0.61	0.00
Element 4	0.61	0.000	0.00	0.00
Element 5	3.00	0.200	0.00	0.80
Element 6	3.00	0.250	0.80	6.60

Computation of Axial Force and Moment

Element 1	F1	4.55E+02	Ecc	1.232	M	5.60E+02
	F2	3.21E+03	Ecc	1.274	M	4.10E+03
Element 2	F1	4.26E+01	Ecc	1.095	M	4.7E+01
Element 3	F1	5.93E+01	Ecc	0.995	M	5.9E+01
Element 4	F1	0.00E+00	Ecc	-1.193	M	0.0E+00
Element 5	F1	1.07E+02	Ecc	-1.293	M	-1.4E+02
Element 6	F1	2.66E+02	Ecc	-1.518	M	-4.0E+02
	F2	9.66E+02	Ecc	-1.559	M	-1.5E+03
		5109				2713

section 14

soffit th= 0.600

	Width	Ht	T_top	T_bottm
Element 1	5.85	0.25	10.60	0.70
Element 2	5.85	0.03	0.70	0.61
Element 3	2.49	0.18	0.61	0.00
Element 4	0.61	0.000	0.00	0.00
Element 5	3.00	0.200	0.00	0.80
Element 6	3.00	0.250	0.80	6.60

Computation of Axial Force and Moment

Element 1	F1	4.55E+02	Ecc	1.275	M	5.80E+02
	F2	3.21E+03	Ecc	1.317	M	4.23E+03
Element 2	F1	4.26E+01	Ecc	1.138	M	4.8E+01
Element 3	F1	5.93E+01	Ecc	1.038	M	6.2E+01
Element 4	F1	0.00E+00	Ecc	-1.150	M	0.0E+00
Element 5	F1	1.07E+02	Ecc	-1.250	M	-1.3E+02
Element 6	F1	2.66E+02	Ecc	-1.475	M	-3.9E+02
	F2	9.66E+02	Ecc	-1.516	M	-1.5E+03
		5109				2932

8 STRESS CHECK

8.1 STRESS CHECK DURING SERVICE

8.1.1 SECTION PROPERTIES & PREST. FORCES

Sec No.	sec properties									Wind effect			
	A	Iz	ZT	ZB	Ecc Top	Ecc Bot	I_Y	Z_{YTop}	Z_{YBott}	M_{YWIND}	M_{ZWIND}	σ_t	σ_b
1	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	0	0		
2	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	309	-215	56	-18
3	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	389	-207	84	-2
4	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	478	-192	117	18
5	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	575	-169	155	42
6	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	682	-139	197	70
7	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	798	-101	243	103
8	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	923	-56	294	139
9	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	1057	-4	350	179
10	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	1200	56	411	223
11	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	1352	123	470	264
12	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	1514	198	532	305
13	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	1684	280	610	353
14	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	1864	369	680	397
15	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	1856	353	674	392
16	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	956	390	390	251
17	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	891	344	360	229
18	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	768	258	305	194
19	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	654	180	249	157
20	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	550	109	203	125
21	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	454	45	160	92
22	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	368	-11	120	59
23	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	290	-60	83	29
24	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	222	-102	52	4
25	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	163	-136	25	-17
26	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	113	-163	2	-35

27	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	72	-183	-16	-48
28	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	40	-195	-29	-57
29	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	17	-200	-37	-63
30	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	11	-199	-39	-64
31	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	1	-194	-42	-64
32	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-1	-182	-40	-60
33	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	6	-162	-33	-52
34	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	23	-135	-21	-41
35	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	49	-100	-5	-25
36	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	83	-58	15	-5
37	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	127	-9	40	19
38	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	180	48	70	46
39	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	242	112	103	74
40	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	313	184	140	102
41	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	393	263	183	132
42	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	483	349	228	162
43	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	534	388	253	180
44	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	714	311	296	192
45	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	649	269	266	171
46	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	525	188	211	136
47	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	410	115	157	99
48	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	304	50	110	66
49	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	208	-8	67	33
50	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	120	-59	27	1
51	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	42	-102	-8	-27
52	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-28	-138	-39	-50
53	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-88	-167	-65	-70
54	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-139	-188	-87	-86
55	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-181	-202	-104	-98
56	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-214	-209	-116	-105
57	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-238	-208	-124	-109
58	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-244	-206	-125	-109

59	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-256	-195	-127	-108
60	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-259	-177	-124	-102
61	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-252	-151	-116	-93
62	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-237	-119	-104	-79
63	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-212	-78	-87	-62
64	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-179	-31	-66	-41
65	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-136	24	-40	-15
66	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-84	87	-9	14
67	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	-23	157	26	42
68	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	47	234	64	71
69	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	126	318	107	101
70	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	214	410	154	132
71	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	266	398	168	138
72	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	400	394	211	159
73	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	355	348	187	141
74	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	272	262	143	111
75	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	198	183	102	82
76	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	133	112	67	55
77	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	77	48	36	29
78	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	31	-9	8	2
79	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-7	-58	-15	-20
80	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-36	-100	-33	-39
81	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-55	-134	-47	-54
82	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-65	-162	-57	-64
83	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-67	-181	-61	-71
84	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-59	-194	-61	-74
85	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-42	-199	-57	-73
86	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-34	-199	-54	-71
87	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	-5	-194	-44	-65
88	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	33	-181	-28	-54
89	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	80	-162	-8	-40
90	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	136	-135	16	-21

91	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	202	-100	45	1
92	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	276	-59	79	28
93	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	360	-10	117	58
94	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	452	47	160	93
95	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	554	111	205	126
96	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	665	182	253	160
97	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	785	261	312	197
98	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	914	347	368	234
99	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	1029	392	414	263
100	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	1957	339	704	405
101	5.238	6.783	4.844	4.240	1.262	1.462	9.028	3.09	6.02	1864	294	664	379
102	5.027	6.552	4.827	3.989	1.219	1.505	8.917	3.05	5.94	1684	208	596	335
103	4.818	6.268	4.792	3.704	1.170	1.554	9.028	3.09	6.02	1514	130	518	287
104	4.611	5.920	4.732	3.385	1.113	1.611	8.917	3.05	5.94	1352	59	456	245
105	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	1200	-4	398	203
106	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	1057	-60	338	160
107	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	923	-109	283	121
108	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	798	-150	233	86
109	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	682	-184	187	55
110	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	575	-211	146	28
111	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	478	-230	109	6
112	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	389	-241	77	-13
113	4.407	5.499	4.636	3.032	1.048	1.676	8.811	3.01	5.87	309	-246	50	-28

Sample Calculation of stress check Sec 14 A= 5.24 Zt= 4.84 Zb= 4.24

Load	Axial F	Moment	P/A	M/Zt	M/Zb	P/A+M/zt	P/A+M/zb	Cum top	Cum bot
Stg 1 DL (Cantilever comlete)	0.000	7190	0.000	-1484	1696	-1484	1696	**-1484**	**1696**
Prestress (Cantilever Cable)	6870	-8672	1311	1790	-2045	3102	-734	1617	962
Losses bfr cont. as 6.9%	-474	598	-91	-124	141	-214	51	**1403**	**1013**
Stg 2 DL (Cont @ P9D & P14 st'd)		0.00	0	0	0	0.00	0.00	1403	1013
Prestress (stg 2)			0	0	0	0.00	0.00	1403	1013

Sec Effect Prestress stg 2		0	0	0	0	0	0	**1403**	**1013**
DL Stage 3		1194	0	-247	282	-247	282	1157	1294
Prestress (stg 3)			0	0	0	0	0	1157	1294
Sec Effect Prestress stg 3		-2242	0	463	-529	463	-529	**1620**	**766**
DL Stage 4		3	0	-1	1	-1	1	1619	766
Prestress (stg 4)	0.000	0	0	0	0	0	0	1619	766
Sec Effect Prestress stg 4		49	0	-10	12	-10	12	**1609**	**778**
SIDL		799	0	-165	188	-165	188	**1444**	**966**
Losses after cont	-620	546	-118	-113	129	**-231**	**10**	1213	977

Stresses at all the sections are calculated and tabulated below in same sequesnce as shown above.

IMPACT AND WARPING considered for live load 1.088*1.05 = 1.142

8.1.2 COMPUTATION OF STRESSES (STAGE BY STAGE)

Sec No.	**STAGE 1 (Including 6% losses on Prestress)**							**STAGE 2 DL**		**Prest Stage 2A**			Stg 2A sec effect	
	Dead Load		P- Dir	Prest- M		Stage 1 (Total)		DL Closure Pour		P- Dir	Prest- M			
	Top	Bottom	T/B	Top	Bottom	Top	Bottom	Top	Bottom	T/B	Top	Bottom	T	B
1														
2	0	0	150	137	(210)	267	(55)	0	0				0	0
3	(11)	16	153	152	(233)	273	(58)	0	0				0	0
4	(43)	65	302	289	(441)	507	(64)	0	0				0	0
5	(96)	147	451	437	(668)	731	(55)	0	0				0	0
6	(171)	262	605	590	(902)	941	(15)	0	0				0	0
7	(267)	409	768	752	(1150)	1148	53	0	0				0	0
8	(385)	589	776	773	(1182)	1057	210	0	0				0	0
9	(524)	801	933	917	(1402)	1198	365	0	0				0	0
10	(684)	1047	1099	1082	(1654)	1346	529	0	0				0	0
11	(849)	1187	1198	1287	(1799)	1465	627	0	0				0	0
12	(1036)	1340	1284	1498	(1938)	1555	732	0	0				0	0
13	(1247)	1509	1364	1720	(2081)	1623	842	0	0				0	0
14	(1484)	1696	1311	1790	(2045)	1403	1013	0	0				0	0
15	(1525)	1742	1312	1790	(2045)	1363	1059	(0)	0				60	(144)
16	(1614)	1844	1312	1790	(2045)	1274	1161	(21)	24				282	(488)
17	(1484)	1696	1311	1790	(2045)	1403	1013	(20)	22				281	(487)

18	(1247)	1509	1231	1563	(1892)	1354	894	(16)	20				277	(514)
19	(1036)	1340	1147	1349	(1745)	1288	783	(13)	17				275	(548)
20	(849)	1187	1050	1139	(1592)	1189	682	(9)	13				274	(593)
21	(684)	1047	933	930	(1422)	1050	592	(6)	9	223	(274)	418	275	(653)
22	(524)	801	776	773	(1182)	918	423	(2)	4	234	(373)	570	273	(650)
23	(385)	589	768	765	(1170)	1042	214	1	(2)	398	(634)	969	271	(647)
24	(267)	409	605	603	(921)	857	114	5	(7)	846	(530)	810	270	(644)
25	(171)	262	451	449	(687)	667	42	8	(13)	942	(502)	767	268	(641)
26	(96)	147	302	301	(461)	466	(0)	12	(19)	946	(502)	767	266	(638)
27	(43)	65	153	152	(233)	241	(9)	16	(24)	949	(500)	765	264	(635)
28	(11)	16	150	150	(229)	268	(57)	19	(30)	950	(496)	758	262	(633)
29						0	0	23	(35)	951	(491)	751	260	(630)
30	0	0	150	137	(210)	267	(55)	23	(35)	951	(491)	751	259	(629)
31	(11)	16	153	152	(233)	273	(58)	19	(30)	950	(496)	758	258	(626)
32	(43)	65	302	289	(441)	507	(64)	16	(24)	949	(500)	765	256	(623)
33	(96)	147	451	437	(668)	731	(55)	12	(19)	946	(502)	767	254	(620)
34	(171)	262	605	590	(902)	941	(15)	8	(13)	942	(502)	767	252	(617)
35	(267)	409	768	752	(1150)	1148	53	5	(7)	846	(530)	810	250	(614)
36	(385)	589	776	773	(1182)	1057	210	1	(2)	398	(634)	969	248	(611)
37	(524)	801	933	917	(1402)	1198	365	(2)	4	234	(373)	570	246	(609)
38	(684)	1047	1099	1082	(1654)	1346	529	(6)	9	223	(274)	418	244	(606)
39	(849)	1187	1198	1287	(1799)	1465	627	(9)	13				240	(545)
40	(1036)	1340	1284	1498	(1938)	1555	732	(13)	17				238	(500)
41	(1247)	1509	1364	1720	(2081)	1623	842	(16)	20				237	(464)
42	(1484)	1696	1311	1790	(2045)	1403	1013	(20)	22				237	(436)
43	(1525)	1742	1312	1790	(2045)	1363	1059	(20)	23				162	(262)
44	(1614)	1844	1312	1790	(2045)	1274	1161	0	0				0	0
45	(1484)	1696	1311	1790	(2045)	1403	1013	0	0				0	0
46	(1247)	1509	1231	1563	(1892)	1354	894	0	0				0	0
47	(1036)	1340	1147	1349	(1745)	1288	783	0	0				0	0
48	(849)	1187	1050	1139	(1592)	1189	682	0	0				0	0
49	(684)	1047	933	930	(1422)	1050	592	0	0				0	0

50	(524)	801	776	773	(1182)	918	423	0	0				0	0
51	(385)	589	768	765	(1170)	1042	214	0	0				0	0
52	(267)	409	605	603	(921)	857	114	0	0				0	0
53	(171)	262	451	449	(687)	667	42	0	0				0	0
54	(96)	147	302	301	(461)	466	(0)	0	0				0	0
55	(43)	65	153	152	(233)	241	(9)	0	0				0	0
56	(11)	16	150	150	(229)	268	(57)	0	0				0	0
57						0	0	0	0				0	0
58			150	137	(210)	267	(55)	0	0				0	0
59	(11)	16	153	152	(233)	273	(58)	0	0				0	0
60	(43)	65	302	289	(441)	507	(64)	0	0				0	0
61	(96)	147	451	437	(668)	731	(55)	0	0				0	0
62	(171)	262	605	590	(902)	941	(15)	0	0				0	0
63	(267)	409	768	752	(1150)	1148	53	0	0				0	0
64	(385)	589	776	773	(1182)	1057	210	0	0				0	0
65	(524)	801	933	917	(1402)	1198	365	0	0				0	0
66	(684)	1047	1099	1082	(1654)	1346	529	0	0				0	0
67	(849)	1187	1198	1287	(1799)	1465	627	0	0				0	0
68	(1036)	1340	1284	1498	(1938)	1555	732	0	0				0	0
69	(1247)	1509	1364	1720	(2081)	1623	842	0	0				0	0
70	(1484)	1696	1311	1790	(2045)	1403	1013	0	0				0	0
71	(1525)	1742	1312	1790	(2045)	1363	1059	(0)	0				60	(144)
72	(1614)	1844	1312	1790	(2045)	1274	1161	(21)	24				282	(488)
73	(1484)	1696	1311	1790	(2045)	1403	1013	(20)	22				281	(487)
74	(1247)	1509	1231	1563	(1892)	1354	894	(16)	20				277	(514)
75	(1036)	1340	1147	1349	(1745)	1288	783	(13)	17				275	(548)
76	(849)	1187	1050	1139	(1592)	1189	682	(9)	13				274	(593)
77	(684)	1047	933	930	(1422)	1050	592	(6)	9	223	(274)	418	275	(653)
78	(524)	801	776	773	(1182)	918	423	(2)	4	234	(373)	570	273	(650)
79	(385)	589	768	765	(1170)	1042	214	1	(2)	398	(634)	969	271	(647)
80	(267)	409	605	603	(921)	857	114	5	(7)	846	(530)	810	270	(644)
81	(171)	262	451	449	(687)	667	42	8	(13)	942	(502)	767	268	(641)

82	(96)	147	302	301	(461)	466	(0)	12	(19)	946	(502)	767	266	(638)
83	(43)	65	153	152	(233)	241	(9)	16	(24)	949	(500)	765	264	(635)
84	(11)	16	150	150	(229)	268	(57)	19	(30)	950	(496)	758	262	(633)
85	0	0				0	0	23	(35)	951	(491)	751	260	(630)
86	0	0	150	137	(210)	267	(55)	23	(35)	951	(491)	751	259	(629)
87	(11)	16	153	152	(233)	273	(58)	19	(30)	950	(496)	758	258	(626)
88	(43)	65	302	289	(441)	507	(64)	16	(24)	949	(500)	765	256	(623)
89	(96)	147	451	437	(668)	731	(55)	12	(19)	946	(502)	767	254	(620)
90	(171)	262	605	590	(902)	941	(15)	8	(13)	942	(502)	767	252	(617)
91	(267)	409	768	752	(1150)	1148	53	5	(7)	846	(530)	810	250	(614)
92	(385)	589	776	773	(1182)	1057	210	1	(2)	398	(634)	969	248	(611)
93	(524)	801	933	917	(1402)	1198	365	(2)	4	234	(373)	570	246	(609)
94	(684)	1047	1099	1082	(1654)	1346	529	(6)	9	223	(274)	418	244	(606)
95	(849)	1187	1198	1287	(1799)	1465	627	(9)	13				240	(545)
96	(1036)	1340	1284	1498	(1938)	1555	732	(13)	17				238	(500)
97	(1247)	1509	1364	1720	(2081)	1623	842	(16)	20				237	(464)
98	(1484)	1696	1311	1790	(2045)	1403	1013	(20)	22				237	(436)
99	(1525)	1742	1312	1790	(2045)	1363	1059	(20)	23				162	(262)
100	(1614)	1844	1312	1790	(2045)	1274	1161	0	0				0	0
101	(1484)	1696	1311	1790	(2045)	1403	1013	0	0				0	0
102	(1247)	1509	1231	1563	(1892)	1354	894	0	0				0	0
103	(1036)	1340	1147	1349	(1745)	1288	783	0	0				0	0
104	(849)	1187	1050	1139	(1592)	1189	682	0	0				0	0
105	(684)	1047	933	930	(1422)	1050	592	0	0				0	0
106	(524)	801	776	773	(1182)	918	423	0	0				0	0
107	(385)	589	768	765	(1170)	1042	214	0	0				0	0
108	(267)	409	605	603	(921)	857	114	0	0				0	0
109	(171)	262	451	449	(687)	667	42	0	0				0	0
110	(96)	147	302	301	(461)	466	(0)	0	0				0	0
111	(43)	65	153	152	(233)	241	(9)	0	0				0	0
112	(11)	16	150	150	(229)	268	(57)	0	0				0	0
113	0	0				0	0	0	0				0	0

Sec No.	End of Stg 2A		STAGE 2B DL		STAGE 2B PRESTRESS			Stg 2B Sec Effect				STAGE 2C DL	
			DL Closure Pour		P- Dir	Prest- M		Prest- M		TOTAL		DL Closure Pour	
	Top	Bottom	Top	Bottom	T/B	T	B	T	B	T	B	Top	Bottom
1													
2	267	(55)	334	(510)	705	(718)	1098	197	(301)	785	937	(0)	0
3	273	(58)	284	(435)	704	(718)	1098	221	(338)	763	972	(0)	0
4	507	(64)	235	(359)	701	(717)	1096	245	(374)	972	999	(0)	0
5	731	(55)	186	(284)	614	(650)	994	269	(411)	1149	858	(0)	0
6	941	(15)	136	(209)	392	(624)	954	293	(447)	1138	675	(0)	1
7	1148	53	87	(133)	389	(620)	948	316	(484)	1320	773	(0)	1
8	1057	210	38	(58)	233	(372)	568	340	(520)	1297	434	(0)	1
9	1198	365	(11)	17	232	(369)	565	364	(557)	1413	622	(0)	1
10	1346	529	(61)	93	221	(271)	414	388	(593)	1623	664	(0)	1
11	1465	627	(108)	150				404	(564)	1761	213	(0)	1
12	1555	732	(154)	199				422	(546)	1822	385	(1)	1
13	1623	842	(200)	242				441	(534)	1865	550	(1)	1
14	1403	1013	(247)	282				463	(529)	1620	766	(1)	1
15	1423	914	(250)	286				452	(500)	1625	700	(0)	0
16	1535	697	(17)	20				32	(19)	1549	698	1	(1)
17	1665	548	(17)	19				31	(19)	1679	549	0	(1)
18	1615	401	(16)	19				30	(18)	1630	401	0	(1)
19	1550	252	(15)	19				29	(18)	1564	253	0	(0)
20	1453	102	(14)	19				28	(18)	1468	104	0	(0)
21	1269	590	(13)	20				27	(18)	1283	591	0	(0)
22	1050	580	(12)	18				26	(16)	1064	583	0	(0)
23	1079	933	(11)	16				24	(13)	1092	936	0	(0)
24	1447	1118	(9)	14				23	(11)	1460	1121	0	(0)
25	1384	1097	(8)	13				21	(8)	1396	1101	0	(0)
26	1188	1056	(7)	11				19	(6)	1200	1061	(0)	0
27	969	1045	(6)	9				18	(3)	981	1051	(0)	0
28	1004	989	(5)	7				16	(1)	1015	995	(0)	0

29	743	1037	(4)	6				15	1	754	1044	(0)	0
30	1010	982	(3)	5				14	2	1021	989	(0)	0
31	1004	994	(2)	3				13	5	1015	1002	(0)	1
32	1228	1003	(1)	2				11	7	1238	1011	(0)	1
33	1441	1020	0	(0)				9	9	1450	1029	(0)	1
34	1642	1064	1	(2)				8	12	1651	1074	(1)	1
35	1719	1086	2	(4)				6	14	1727	1097	(1)	1
36	1070	964	4	(5)				5	17	1079	975	(1)	1
37	1303	563	5	(7)				3	19	1311	575	(1)	1
38	1534	574	6	(9)				2	21	1541	587	(1)	1
39	1696	95	7	(9)				(0)	22	1702	107	(1)	1
40	1779	248	8	(10)				(2)	22	1785	261	(1)	1
41	1844	397	9	(11)				(4)	23	1849	409	(1)	1
42	1621	599	10	(11)				(6)	23	1625	611	(1)	1
43	1506	819	1	(1)				1	7	1507	826	(2)	2
44	1274	1161	0	0				0	0	1274	1161	(21)	24
45	1403	1013	0	0				0	0	1403	1013	(19)	22
46	1354	894	0	0				0	0	1354	894	(16)	19
47	1288	783	0	0				0	0	1288	783	(12)	16
48	1189	682	0	0				0	0	1189	682	(9)	13
49	1050	592	0	0				0	0	1050	592	(6)	9
50	918	423	0	0				0	0	918	423	(2)	3
51	1042	214	0	0				0	0	1042	214	2	(2)
52	857	114	0	0				0	0	857	114	5	(8)
53	667	42	0	0				0	0	667	42	9	(13)
54	466	(0)	0	0				0	0	466	(0)	12	(19)
55	241	(9)	0	0				0	0	241	(9)	16	(25)
56	268	(57)	0	0				0	0	268	(57)	20	(30)
57	0	0	0	0				0	0	0	0	23	(36)
58	267	(55)	0	0				0	0	267	(55)	23	(36)
59	273	(58)	0	0				0	0	273	(58)	20	(30)
60	507	(64)	0	0				0	0	507	(64)	16	(24)

61	731	(55)	0	0				0	0	731	(55)	12	(19)
62	941	(15)	0	0				0	0	941	(15)	9	(13)
63	1148	53	0	0				0	0	1148	53	5	(8)
64	1057	210	0	0				0	0	1057	210	1	(2)
65	1198	365	0	0				0	0	1198	365	(2)	3
66	1346	529	0	0				0	0	1346	529	(6)	9
67	1465	627	0	0				0	0	1465	627	(9)	13
68	1555	732	0	0				0	0	1555	732	(13)	17
69	1623	842	0	0				0	0	1623	842	(16)	20
70	1403	1013	0	0				0	0	1403	1013	(20)	22
71	1423	914	8	(10)				(6)	15	1425	920	(19)	22
72	1535	697	10	(12)				(6)	24	1539	710	(1)	1
73	1665	548	10	(11)				(6)	23	1669	560	(1)	1
74	1615	401	9	(10)				(4)	23	1620	413	(1)	1
75	1550	252	8	(10)				(2)	22	1555	264	(1)	1
76	1453	102	7	(9)				(0)	22	1460	115	(1)	1
77	1269	590	6	(9)				2	21	1276	602	(1)	1
78	1050	580	5	(7)				3	19	1058	592	(1)	1
79	1079	933	3	(5)				5	16	1087	944	(1)	1
80	1447	1118	2	(4)				6	14	1456	1128	(1)	1
81	1384	1097	1	(2)				8	12	1392	1107	(1)	1
82	1188	1056	0	(0)				9	9	1197	1065	(0)	1
83	969	1045	(1)	2				11	7	979	1054	(0)	1
84	1004	989	(2)	3				12	5	1014	997	(0)	1
85	743	1037	(3)	5				14	2	754	1044	(0)	0
86	1010	982	(4)	6				15	1	1021	989	(0)	0
87	1004	994	(5)	7				16	(1)	1016	1000	(0)	0
88	1228	1003	(6)	9				18	(3)	1239	1008	(0)	0
89	1441	1020	(7)	11				19	(6)	1453	1024	(0)	0
90	1642	1064	(8)	12				21	(8)	1654	1068	0	(0)
91	1719	1086	(9)	14				22	(11)	1732	1090	0	(0)
92	1070	964	(10)	16				24	(13)	1084	967	0	(0)

93	1303	563	(11)	18				25	(15)	1317	566	0	(0)
94	1534	574	(13)	19				27	(18)	1548	576	0	(0)
95	1696	95	(13)	19				28	(17)	1710	96	0	(0)
96	1779	248	(14)	19				29	(17)	1794	249	0	(1)
97	1844	397	(15)	18				30	(18)	1858	398	0	(1)
98	1621	599	(16)	19				31	(18)	1635	599	1	(1)
99	1506	819	(21)	24				34	(22)	1518	821	0	(0)
100	1274	1161	(263)	300				468	(534)	1479	926	(0)	0
101	1403	1013	(239)	273				456	(522)	1621	764	(0)	0
102	1354	894	(193)	234				435	(527)	1596	601	(0)	0
103	1288	783	(147)	190				416	(538)	1556	436	(0)	0
104	1189	682	(101)	141				398	(556)	1486	267	(0)	0
105	1050	592	(54)	83	221	(271)	414	383	(585)	1328	725	(0)	0
106	918	423	(6)	8	232	(369)	565	359	(549)	1134	679	(0)	0
107	1042	214	43	(66)	233	(372)	568	336	(513)	1282	437	(0)	0
108	857	114	92	(141)	389	(620)	948	312	(477)	1030	834	(0)	0
109	667	42	141	(216)	392	(624)	954	289	(441)	865	731	(0)	0
110	466	(0)	190	(291)	614	(650)	994	265	(405)	884	912	(0)	0
111	241	(9)	239	(365)	701	(717)	1096	241	(369)	706	1054	(0)	0
112	268	(57)	288	(440)	704	(718)	1098	218	(333)	759	972	(0)	0
113	0	0	337	(515)	705	(718)	1098	194	(297)	518	992	(0)	0

Sec No.	STAGE 2C PRESTRESS			Stg 2C Sec Effect		End of Stg 2C		SIDL		Stress after Laying SIDL		Stress_cant Cbls if applied on compl'd struc.	
	P- Dir	Prest- M		Prest- M				WC+CRASH B					
	T/B	T	B	T	B	Top	Bottom	T	B	T	B	T	B
1													
2				(4)	7	780	944	122	(187)	902	757	(258)	774
3				(5)	7	758	980	119	(182)	877	798	(307)	855
4				(5)	8	966	1008	112	(171)	1078	837	(87)	897
5				(6)	9	1142	868	101	(154)	1243	714	144	920
6				(6)	10	1131	685	86	(131)	1217	554	385	941

7				(7)	11	1313	784	67	(103)	1380	682	644	957
8				(7)	11	1289	446	45	(68)	1334	377	606	1035
9				(8)	12	1405	635	18	(28)	1423	607	842	1072
10				(9)	13	1614	678	(12)	19	1602	697	1106	1087
11				(9)	12	1752	226	(45)	63	1706	290	1368	961
12				(9)	12	1812	398	(82)	106	1731	504	1615	857
13				(10)	12	1855	562	(121)	147	1733	709	1861	762
14				(10)	12	1609	778	(165)	188	1444	966	1820	731
15				(10)	11	1615	712	(164)	187	1451	899	1912	459
16				(6)	7	1544	705	(198)	226	1346	930	2125	47
17				(6)	7	1674	555	(175)	199	1499	755	2124	46
18				(5)	7	1625	408	(132)	159	1493	567	1808	171
19				(5)	6	1560	259	(93)	120	1467	379	1498	301
20				(4)	6	1464	109	(57)	80	1407	189	1173	450
21				(3)	5	1280	596	(25)	38	1256	634	822	631
22				(2)	4	1062	586	5	(8)	1067	578	509	712
23				(2)	3	1091	938	31	(48)	1122	891	494	715
24				(1)	2	1460	1123	53	(81)	1513	1042	169	799
25				(0)	0	1396	1102	71	(109)	1467	993	(137)	878
26				1	(1)	1201	1061	85	(131)	1286	930	(433)	955
27				1	(2)	982	1049	96	(146)	1078	903	(731)	1032
28				2	(3)	1017	992	102	(156)	1120	836	(735)	1032
29				3	(4)	757	1040	105	(160)	862	880	(1034)	1110
30				3	(5)	1024	985	105	(160)	1128	825	(747)	1050
31				4	(6)	1018	997	102	(156)	1121	841	(728)	1028
32				5	(7)	1242	1005	96	(146)	1338	859	(441)	968
33				6	(8)	1455	1021	85	(130)	1541	891	(143)	889
34				6	(9)	1657	1065	71	(109)	1728	957	164	808
35				7	(10)	1734	1087	53	(81)	1787	1006	490	721
36				8	(12)	1086	965	31	(47)	1117	918	519	696
37				9	(13)	1319	564	5	(8)	1324	556	822	632
38				9	(14)	1549	574	(25)	38	1525	612	1153	544

39				10	(13)	1711	95	(57)	80	1654	175	1483	372
40				10	(13)	1795	249	(93)	120	1702	369	1799	227
41				11	(13)	1859	397	(132)	160	1727	557	2115	94
42				12	(13)	1636	599	(175)	200	1461	798	2142	27
43				18	(27)	1524	801	(201)	230	1322	1031	2025	297
44				329	(399)	1582	785	(195)	223	1387	1008	2199	215
45				329	(399)	1713	636	(172)	196	1541	832	2199	214
46				328	(423)	1666	491	(129)	156	1538	647	1889	346
47				329	(453)	1605	346	(90)	116	1515	462	1585	483
48				332	(494)	1512	200	(54)	76	1458	276	1267	641
49	223	(274)	418	338	(549)	1331	693	(22)	33	1310	725	922	833
50	234	(373)	570	337	(548)	1114	682	8	(13)	1122	670	611	912
51	398	(634)	969	336	(546)	1143	1033	34	(52)	1177	981	596	913
52	846	(530)	810	335	(544)	1512	1217	56	(86)	1569	1131	273	996
53	942	(502)	767	333	(543)	1450	1195	74	(114)	1524	1081	(32)	1073
54	946	(502)	767	332	(541)	1255	1153	88	(135)	1343	1018	(327)	1148
55	949	(500)	765	331	(540)	1037	1141	99	(151)	1136	990	(624)	1223
56	950	(496)	758	330	(538)	1073	1083	105	(161)	1178	922	(627)	1221
57	951	(491)	751	329	(536)	813	1130	108	(165)	921	965	(924)	1297
58	951	(491)	751	329	(536)	1080	1075	108	(165)	1188	910	(636)	1236
59	950	(496)	758	328	(534)	1075	1085	105	(161)	1180	924	(617)	1213
60	949	(500)	765	327	(533)	1299	1093	99	(151)	1398	942	(328)	1150
61	946	(502)	767	326	(531)	1513	1108	88	(135)	1601	973	(30)	1070
62	942	(502)	767	325	(529)	1715	1151	74	(114)	1789	1038	279	986
63	846	(530)	810	324	(528)	1792	1172	56	(86)	1848	1087	606	898
64	398	(634)	969	323	(526)	1145	1049	34	(52)	1179	997	637	872
65	234	(373)	570	322	(525)	1379	647	8	(13)	1387	634	941	805
66	223	(274)	418	321	(523)	1610	657	(22)	33	1588	690	1273	715
67				313	(468)	1769	172	(54)	76	1715	248	1599	532
68				309	(427)	1851	321	(90)	116	1761	437	1910	378
69				306	(395)	1913	466	(129)	156	1784	622	2222	236
70				304	(371)	1688	664	(172)	196	1516	860	2246	161

71				285	(332)	1691	609	(170)	194	1521	803	2322	(41)
72				10	(13)	1548	698	(198)	226	1350	924	2146	23
73				10	(13)	1678	549	(175)	200	1503	749	2145	24
74				9	(13)	1629	401	(132)	160	1497	561	1827	149
75				9	(13)	1563	253	(93)	120	1470	373	1516	279
76				8	(13)	1467	103	(57)	80	1410	183	1190	428
77				8	(13)	1283	590	(25)	38	1258	628	837	609
78				7	(12)	1064	581	5	(8)	1069	573	523	693
79				6	(11)	1092	934	31	(47)	1123	886	505	699
80				6	(10)	1461	1119	53	(81)	1514	1038	179	786
81				5	(9)	1397	1099	71	(109)	1468	990	(129)	867
82				4	(8)	1201	1058	85	(130)	1286	928	(427)	947
83				3	(7)	982	1048	96	(146)	1078	901	(726)	1027
84				3	(6)	1017	991	102	(156)	1119	835	(732)	1029
85				2	(5)	756	1040	105	(160)	860	879	(1033)	1109
86				2	(4)	1022	985	105	(160)	1127	825	(746)	1050
87				1	(3)	1017	997	102	(156)	1119	841	(729)	1032
88				0	(2)	1240	1006	96	(146)	1335	860	(444)	974
89				(0)	(1)	1452	1023	85	(131)	1538	893	(148)	897
90				(1)	(0)	1653	1068	71	(109)	1725	959	158	819
91				(2)	1	1730	1091	53	(81)	1783	1010	482	735
92				(2)	2	1082	969	31	(48)	1113	921	510	713
93				(3)	3	1314	569	5	(8)	1320	561	810	651
94				(4)	4	1544	580	(25)	38	1520	617	1139	566
95				(4)	5	1706	101	(57)	80	1649	180	1469	394
96				(5)	5	1789	254	(93)	120	1696	374	1783	249
97				(6)	6	1853	403	(132)	159	1722	562	2097	117
98				(6)	6	1629	605	(175)	199	1455	804	2123	50
99				(7)	7	1512	828	(201)	230	1311	1057	1977	384
100				(21)	24	1458	951	(188)	215	1270	1165	1764	795
101				(20)	23	1600	788	(165)	188	1435	976	1796	758
102				(19)	24	1576	625	(121)	147	1455	772	1548	847

103				(19)	24	1538	460	(81)	105	1456	566	1307	940
104				(18)	25	1468	292	(45)	63	1423	355	1050	1049
105				(17)	26	1311	752	(12)	18	1299	770	768	1185
106				(16)	25	1118	704	18	(28)	1136	675	522	1165
107				(15)	23	1267	460	45	(69)	1312	391	573	1066
108				(14)	21	1016	855	67	(103)	1083	752	315	1048
109				(13)	20	851	751	86	(132)	938	619	75	1025
110				(12)	18	872	931	101	(154)	973	776	(154)	1000
111				(11)	16	695	1070	112	(171)	807	899	(386)	976
112				(10)	15	749	987	119	(182)	868	806	(324)	874
113				(9)	13	509	1005	122	(187)	631	818	(556)	850

Sec No.	Stress_Cont. cbl if applied on comp'd struc		Stress_due to balance loss on cont structure		Final stress due to prestress including losses		Final stress due to addl 10% prestress (cl 7.9.5)		Final stress due to lower 10% prestress (cl 7.9.5)	
	T	B	T	B	T	B	T	B	T	B
1										
2	177	1513	(3)	(297)	464	1152	46	115	(46)	(115)
3	200	1472	(2)	(299)	504	1093	50	109	(50)	(109)
4	223	1424	(26)	(295)	789	997	79	100	(79)	(100)
5	(17)	1198	(10)	(263)	1104	726	110	73	(110)	(73)
6	49	913	(42)	(222)	1207	389	121	39	(121)	(39)
7	75	858	(69)	(215)	1529	267	153	27	(153)	(27)
8	189	300	(83)	(138)	1660	(252)	166	(25)	(166)	25
9	213	242	(108)	(133)	1960	(350)	196	(35)	(196)	35
10	372	(569)	(156)	(12)	2354	(513)	235	(51)	(235)	51
11	387	(541)	(182)	(5)	2699	(1158)	270	(116)	(270)	116
12	405	(524)	(206)	1	2988	(1186)	299	(119)	(299)	119
13	424	(513)	(232)	8	3284	(1231)	328	(123)	(328)	123
14	444	(507)	**(231)**	**10**	3323	(1241)	332	(124)	(332)	124
15	492	(620)	(246)	52	3357	(1315)	336	(131)	(336)	131
16	308	(496)	(238)	70	3172	(1163)	317	(116)	(317)	116
17	306	(495)	(238)	70	3170	(1162)	317	(116)	(317)	116

18	302	(522)	(209)	63	2888	(1123)	289	(112)	(289)	112
19	299	(556)	(180)	57	2615	(1101)	262	(110)	(262)	110
20	298	(602)	(151)	50	2336	(1097)	234	(110)	(234)	110
21	247	(7)	(111)	(56)	2001	(569)	200	(57)	(200)	57
22	121	605	(64)	(155)	1643	(419)	164	(42)	(164)	42
23	43	931	(51)	(205)	1540	103	154	10	(154)	(10)
24	502	1172	(91)	(248)	1724	437	172	44	(172)	(44)
25	592	1081	(77)	(242)	1553	582	155	58	(155)	(58)
26	590	1091	(50)	(250)	1284	660	128	66	(128)	(66)
27	588	1098	(23)	(258)	1014	735	101	73	(101)	(73)
28	586	1103	(22)	(259)	1013	733	101	73	(101)	(73)
29	584	1109	6	(267)	743	802	74	80	(74)	(80)
30	583	1112	(20)	(262)	1004	749	100	75	(100)	(75)
31	580	1115	(22)	(260)	1012	740	101	74	(101)	(74)
32	577	1116	(47)	(255)	1264	697	126	70	(126)	(70)
33	573	1114	(73)	(248)	1528	630	153	63	(153)	(63)
34	468	946	(85)	(215)	1816	582	182	58	(182)	(58)
35	(16)	1021	(42)	(219)	2057	444	206	44	(206)	(44)
36	29	746	(51)	(175)	1522	179	152	18	(152)	(18)
37	123	182	(93)	(84)	1876	(352)	188	(35)	(188)	35
38	258	(598)	(143)	41	2243	(471)	224	(47)	(224)	47
39	252	(537)	(172)	47	2563	(1091)	256	(109)	(256)	109
40	249	(491)	(200)	53	2829	(1091)	283	(109)	(283)	109
41	247	(455)	(228)	60	3100	(1112)	310	(111)	(310)	111
42	246	(426)	(230)	62	3115	(1098)	311	(110)	(311)	110
43	182	(276)	(210)	15	3073	(1000)	307	(100)	(307)	100
44	329	(390)	(248)	39	3183	(1094)	318	(109)	(318)	109
45	328	(390)	(248)	39	3183	(1093)	318	(109)	(318)	109
46	329	(413)	(220)	31	2903	(1052)	290	(105)	(290)	105
47	330	(444)	(193)	23	2633	(1029)	263	(103)	(263)	103
48	333	(484)	(164)	15	2357	(1021)	236	(102)	(236)	102
49	286	116	(126)	(93)	2024	(489)	202	(49)	(202)	49

50	162	725	(79)	(191)	1667	(342)	167	(34)	(167)	34
51	85	1049	(67)	(240)	1566	179	157	18	(157)	(18)
52	547	1287	(107)	(283)	1751	511	175	51	(175)	(51)
53	638	1193	(93)	(276)	1581	654	158	65	(158)	(65)
54	638	1200	(67)	(284)	1314	730	131	73	(131)	(73)
55	638	1204	(40)	(291)	1045	803	105	80	(105)	(80)
56	638	1207	(39)	(292)	1045	800	104	80	(104)	(80)
57	637	1210	(12)	(299)	777	866	78	87	(78)	(87)
58	637	1212	(38)	(294)	1038	812	104	81	(104)	(81)
59	636	1212	(40)	(292)	1047	802	105	80	(105)	(80)
60	635	1210	(66)	(286)	1301	756	130	76	(130)	(76)
61	633	1205	(93)	(278)	1565	687	157	69	(157)	(69)
62	530	1035	(105)	(245)	1855	638	185	64	(185)	(64)
63	47	1107	(62)	(247)	2098	497	210	50	(210)	(50)
64	94	829	(72)	(203)	1564	231	156	23	(156)	(23)
65	190	262	(113)	(112)	1919	(302)	192	(30)	(192)	30
66	327	(520)	(164)	14	2287	(423)	229	(42)	(229)	42
67	320	(465)	(192)	22	2607	(1047)	261	(105)	(261)	105
68	315	(425)	(220)	30	2872	(1051)	287	(105)	(287)	105
69	312	(394)	(247)	38	3142	(1075)	314	(107)	(314)	107
70	311	(370)	(249)	41	3157	(1064)	316	(106)	(316)	106
71	347	(465)	(262)	74	3179	(1122)	318	(112)	(318)	112
72	290	(477)	(237)	70	3151	(1141)	315	(114)	(315)	114
73	289	(477)	(237)	70	3151	(1141)	315	(114)	(315)	114
74	286	(504)	(208)	62	2869	(1102)	287	(110)	(287)	110
75	285	(539)	(180)	56	2598	(1081)	260	(108)	(260)	108
76	285	(584)	(150)	49	2321	(1077)	232	(108)	(232)	108
77	234	10	(111)	(56)	1986	(549)	199	(55)	(199)	55
78	110	620	(64)	(156)	1630	(402)	163	(40)	(163)	40
79	33	945	(51)	(205)	1528	118	153	12	(153)	(12)
80	494	1183	(90)	(249)	1714	450	171	45	(171)	(45)
81	585	1090	(76)	(242)	1545	592	154	59	(154)	(59)

82	585	1098	(49)	(250)	1277	667	128	67	(128)	(67)
83	584	1102	(22)	(258)	1009	740	101	74	(101)	(74)
84	583	1105	(22)	(259)	1010	736	101	74	(101)	(74)
85	582	1110	6	(267)	742	802	74	80	(74)	(80)
86	582	1112	(20)	(262)	1003	748	100	75	(100)	(75)
87	581	1112	(22)	(260)	1012	737	101	74	(101)	(74)
88	579	1111	(47)	(255)	1266	691	127	69	(127)	(69)
89	577	1107	(73)	(247)	1532	622	153	62	(153)	(62)
90	473	937	(85)	(215)	1821	572	182	57	(182)	(57)
91	(10)	1010	(42)	(218)	2064	431	206	43	(206)	(43)
92	37	733	(51)	(175)	1531	164	153	16	(153)	(16)
93	132	166	(93)	(84)	1887	(370)	189	(37)	(189)	37
94	268	(615)	(143)	42	2254	(492)	225	(49)	(225)	49
95	264	(555)	(172)	48	2577	(1111)	258	(111)	(258)	111
96	262	(509)	(200)	54	2843	(1112)	284	(111)	(284)	111
97	261	(473)	(228)	61	3116	(1133)	312	(113)	(312)	113
98	262	(445)	(231)	62	3132	(1120)	313	(112)	(313)	112
99	191	(278)	(207)	7	3084	(1004)	308	(100)	(308)	100
100	441	(504)	(225)	4	3323	(1240)	332	(124)	(332)	124
101	430	(491)	(227)	6	3311	(1226)	331	(123)	(331)	123
102	410	(497)	(201)	(2)	3009	(1166)	301	(117)	(301)	117
103	392	(507)	(177)	(9)	2717	(1121)	272	(112)	(272)	112
104	375	(524)	(151)	(16)	2418	(1090)	242	(109)	(242)	109
105	308	98	(116)	(122)	2063	(534)	206	(53)	(206)	53
106	200	282	(77)	(147)	1677	(282)	168	(28)	(168)	28
107	144	752	(73)	(209)	1641	(300)	164	(30)	(164)	30
108	62	892	(38)	(229)	1237	336	124	34	(124)	(34)
109	26	1133	(11)	(263)	933	426	93	43	(93)	(43)
110	209	1445	(18)	(308)	803	755	80	76	(80)	(76)
111	215	1448	2	(306)	522	1059	52	106	(52)	(106)
112	193	1488	0	(303)	493	1103	49	110	(49)	(110)
113	171	1487	24	(300)	197	1219	20	122	(20)	(122)

Sec No.	STRESSES DUE TO OTHER LOADS													
	LL HOGG		LL SAGG		+VE Temp Grad.		-VE Temp Grad.		Diff Settlement		DL Creep		Prest Creep	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
1														
2	(15)	23	257	(393)	621	32	(345)	(195)	(16)	25	265	(406)	(428)	654
3	(17)	26	250	(382)	630	18	(349)	(190)	(18)	28	299	(457)	(480)	733
4	(19)	28	235	(359)	640	4	(353)	(184)	(20)	31	332	(508)	(532)	813
5	(20)	31	221	(338)	649	-10	(356)	(178)	(22)	34	365	(558)	(583)	892
6	(22)	34	201	(307)	658	-24	(360)	(173)	(24)	37	398	(609)	(635)	971
7	(24)	37	171	(262)	667	-38	(364)	(167)	(26)	40	432	(660)	(687)	1051
8	(26)	39	137	(210)	676	-52	(367)	(161)	(28)	43	465	(711)	(739)	1130
9	(28)	42	108	(165)	685	-66	(371)	(156)	(30)	46	498	(762)	(791)	1209
10	(50)	76	80	(122)	695	-80	(375)	(150)	(32)	49	532	(813)	(843)	1288
11	(91)	127	56	(79)	709	-82	(383)	(153)	(33)	46	554	(774)	(876)	1225
12	(136)	175	38	(49)	722	-84	(391)	(156)	(35)	45	579	(749)	(916)	1184
13	(189)	229	26	(31)	735	-85	(399)	(158)	(36)	44	607	(734)	(959)	1160
14	(258)	295	20	(23)	749	-87	(406)	(160)	(38)	43	636	(727)	(1005)	1148
15	(269)	308	23	(27)	703	-63	(389)	(204)	(35)	40	675	(771)	(934)	938
16	(363)	415	9	(10)	658	-35	(392)	(221)	(2)	2	428	(489)	(761)	611
17	(323)	369	8	(9)	658	-35	(392)	(221)	(2)	2	428	(489)	(761)	610
18	(248)	300	7	(9)	652	-40	(388)	(218)	(1)	2	429	(519)	(768)	650
19	(181)	234	12	(16)	646	-45	(385)	(215)	(1)	2	431	(557)	(777)	704
20	(122)	171	32	(45)	640	-51	(381)	(212)	(1)	2	435	(609)	(791)	775
21	(71)	109	58	(88)	633	-58	(377)	(208)	(1)	2	443	(678)	(810)	874
22	(36)	54	85	(130)	633	-57	(377)	(208)	(1)	2	443	(677)	(809)	873
23	(13)	19	111	(170)	633	-57	(377)	(208)	(1)	2	442	(675)	(808)	872
24	(11)	17	136	(209)	633	-57	(377)	(208)	(1)	1	441	(674)	(808)	871
25	(10)	15	164	(251)	632	-57	(377)	(208)	(1)	1	440	(672)	(807)	870
26	(9)	14	183	(280)	632	-57	(377)	(208)	(1)	1	439	(671)	(806)	869
27	(8)	12	198	(303)	632	-57	(377)	(208)	(1)	1	438	(669)	(806)	868
28	(7)	10	208	(318)	632	-56	(377)	(208)	(1)	1	437	(668)	(805)	867

29	(6)	9	212	(324)	632	-56	(377)	(208)	(1)	1	436	(667)	(804)	866
30	(5)	8	212	(325)	632	-56	(377)	(208)	(1)	1	436	(666)	(804)	866
31	(6)	9	210	(322)	632	-56	(377)	(208)	(1)	1	435	(665)	(803)	865
32	(7)	11	202	(308)	632	-56	(377)	(208)	(1)	2	434	(664)	(803)	864
33	(8)	12	185	(283)	632	-56	(377)	(208)	(1)	2	433	(662)	(802)	863
34	(9)	14	162	(248)	632	-56	(377)	(208)	(1)	2	432	(661)	(801)	861
35	(10)	16	136	(207)	632	-56	(377)	(208)	(1)	2	431	(660)	(801)	860
36	(13)	19	112	(171)	631	-55	(377)	(208)	(1)	2	431	(658)	(800)	859
37	(35)	53	85	(129)	631	-55	(377)	(208)	(2)	2	430	(657)	(799)	858
38	(71)	109	59	(91)	631	-55	(377)	(208)	(2)	3	429	(656)	(799)	857
39	(121)	169	33	(46)	638	-49	(381)	(212)	(2)	2	419	(586)	(778)	758
40	(179)	231	16	(21)	644	-43	(385)	(215)	(2)	2	413	(535)	(764)	686
41	(246)	298	7	(8)	650	-37	(388)	(218)	(2)	2	410	(496)	(753)	632
42	(322)	368	8	(9)	656	-32	(392)	(221)	(2)	2	407	(465)	(745)	592
43	(366)	418	9	(11)	686	-49	(404)	(191)	(3)	3	327	(374)	(839)	806
44	(348)	397	57	(65)	683	-24	(382)	(196)	(46)	52	428	(489)	(704)	746
45	(309)	353	55	(63)	683	-24	(382)	(197)	(44)	50	428	(489)	(703)	745
46	(238)	288	50	(61)	678	-29	(378)	(193)	(40)	49	429	(520)	(705)	791
47	(176)	227	46	(59)	673	-34	(374)	(189)	(37)	48	432	(559)	(709)	850
48	(124)	173	61	(85)	667	-40	(369)	(184)	(34)	47	438	(612)	(717)	929
49	(84)	129	83	(127)	661	-46	(364)	(179)	(31)	47	447	(683)	(731)	1037
50	(53)	81	106	(162)	661	-45	(364)	(179)	(27)	41	447	(683)	(729)	1034
51	(39)	60	133	(203)	660	-45	(364)	(180)	(23)	36	447	(683)	(728)	1032
52	(33)	51	157	(240)	660	-44	(363)	(180)	(19)	30	447	(683)	(726)	1029
53	(28)	43	178	(273)	660	-44	(363)	(181)	(16)	24	447	(683)	(724)	1026
54	(22)	34	195	(298)	659	-43	(363)	(181)	(12)	18	447	(683)	(722)	1024
55	(17)	26	208	(318)	659	-43	(363)	(181)	(8)	12	447	(683)	(721)	1021
56	(11)	17	216	(331)	659	-42	(362)	(182)	(4)	7	447	(683)	(719)	1018
57	(6)	10	219	(335)	658	-42	(362)	(182)	(1)	1	447	(683)	(717)	1015
58	(5)	8	220	(336)	658	-42	(362)	(182)	(1)	1	447	(683)	(716)	1015
59	(9)	14	216	(330)	658	-41	(362)	(183)	(4)	7	447	(683)	(715)	1012
60	(14)	22	206	(315)	658	-41	(361)	(183)	(8)	13	447	(683)	(713)	1009

61	(19)	30	190	(290)	657	-40	(361)	(183)	(12)	18	447	(683)	(711)	1006
62	(24)	37	167	(256)	657	-40	(361)	(184)	(16)	24	447	(683)	(709)	1004
63	(29)	45	149	(228)	657	-40	(361)	(184)	(20)	30	447	(683)	(708)	1001
64	(34)	52	126	(193)	657	-39	(361)	(184)	(23)	36	447	(683)	(706)	998
65	(56)	85	104	(158)	656	-39	(360)	(185)	(27)	41	447	(684)	(704)	996
66	(88)	135	80	(122)	656	-38	(360)	(185)	(31)	47	447	(684)	(702)	993
67	(129)	180	59	(82)	662	-32	(365)	(190)	(34)	47	438	(612)	(686)	885
68	(182)	235	50	(65)	667	-26	(369)	(195)	(37)	48	433	(560)	(674)	805
69	(245)	297	55	(67)	672	-21	(373)	(199)	(40)	49	430	(520)	(667)	745
70	(317)	363	61	(69)	676	-16	(376)	(203)	(44)	50	428	(489)	(662)	698
71	(313)	358	52	(59)	640	4	(362)	(239)	(42)	48	461	(526)	(601)	537
72	(364)	416	8	(9)	655	-31	(391)	(222)	(2)	2	407	(465)	(742)	589
73	(323)	369	7	(8)	655	-31	(391)	(222)	(2)	2	407	(465)	(742)	590
74	(247)	299	6	(7)	650	-37	(388)	(219)	(2)	2	410	(496)	(750)	630
75	(180)	233	13	(17)	644	-42	(384)	(215)	(2)	2	413	(535)	(761)	684
76	(121)	170	32	(45)	638	-48	(381)	(212)	(2)	2	420	(586)	(776)	756
77	(70)	107	59	(90)	631	-54	(377)	(209)	(2)	2	429	(656)	(796)	855
78	(35)	53	85	(130)	631	-55	(377)	(209)	(1)	2	430	(657)	(797)	857
79	(13)	20	112	(171)	631	-55	(377)	(209)	(1)	2	431	(659)	(798)	858
80	(11)	16	137	(210)	631	-55	(377)	(209)	(1)	2	431	(660)	(799)	859
81	(9)	14	164	(250)	632	-55	(377)	(209)	(1)	2	432	(661)	(800)	861
82	(8)	13	183	(279)	632	-56	(377)	(209)	(1)	2	433	(662)	(801)	862
83	(7)	11	198	(303)	632	-56	(377)	(208)	(1)	2	434	(664)	(801)	863
84	(6)	9	208	(318)	632	-56	(377)	(208)	(1)	1	435	(665)	(802)	864
85	(5)	8	213	(325)	632	-56	(377)	(208)	(1)	1	436	(666)	(803)	866
86	(6)	9	213	(326)	632	-56	(377)	(208)	(1)	1	436	(667)	(803)	866
87	(7)	10	211	(322)	632	-56	(377)	(208)	(1)	1	437	(668)	(804)	868
88	(8)	12	202	(309)	632	-57	(377)	(208)	(1)	1	438	(669)	(805)	869
89	(9)	13	186	(284)	633	-57	(377)	(208)	(1)	1	439	(671)	(806)	870
90	(10)	15	162	(248)	633	-57	(377)	(208)	(1)	1	440	(672)	(807)	871
91	(11)	17	136	(209)	633	-57	(377)	(208)	(1)	1	441	(674)	(808)	873
92	(12)	19	111	(170)	633	-57	(377)	(208)	(1)	2	441	(675)	(809)	874

93	(36)	54	85	(130)	633	-58	(377)	(208)	(1)	2	442	(676)	(809)	875
94	(71)	108	58	(89)	633	-58	(377)	(208)	(1)	2	443	(678)	(810)	877
95	(114)	159	33	(46)	640	-52	(381)	(211)	(1)	2	435	(608)	(791)	778
96	(173)	223	16	(21)	647	-46	(385)	(215)	(1)	2	431	(557)	(778)	706
97	(241)	292	8	(9)	653	-40	(389)	(218)	(2)	2	428	(518)	(769)	653
98	(318)	363	9	(10)	658	-35	(392)	(221)	(2)	2	428	(489)	(762)	613
99	(353)	404	6	(7)	697	-57	(407)	(183)	(2)	3	345	(394)	(875)	871
100	(289)	330	17	(19)	757	-96	(411)	(154)	(39)	44	648	(740)	(1047)	1196
101	(248)	283	16	(19)	752	-91	(409)	(157)	(38)	43	632	(722)	(1022)	1167
102	(191)	231	19	(23)	739	-89	(402)	(155)	(36)	44	602	(729)	(974)	1179
103	(137)	177	31	(40)	725	-88	(394)	(152)	(35)	45	575	(743)	(931)	1204
104	(91)	127	52	(72)	712	-86	(386)	(149)	(33)	46	550	(768)	(891)	1245
105	(51)	77	77	(117)	698	-85	(377)	(146)	(32)	49	528	(807)	(857)	1310
106	(23)	36	105	(161)	688	-70	(374)	(152)	(30)	46	495	(757)	(804)	1229
107	(22)	33	138	(210)	679	-56	(370)	(158)	(28)	43	462	(706)	(751)	1149
108	(20)	31	169	(258)	670	-42	(366)	(164)	(26)	40	429	(655)	(698)	1068
109	(19)	29	199	(304)	660	-27	(362)	(170)	(24)	37	396	(605)	(646)	987
110	(17)	26	222	(339)	651	-13	(358)	(176)	(22)	34	363	(554)	(593)	907
111	(16)	24	242	(370)	641	1	(354)	(182)	(20)	31	329	(504)	(540)	826
112	(14)	22	255	(390)	632	16	(350)	(188)	(18)	28	296	(453)	(488)	746
113	(13)	19	261	(399)	623	30	(346)	(193)	(16)	25	263	(403)	(435)	665

FINAL STRESS IN DIFFERENT COMBINATIONS

	Dif Sttlmnt	LL $_{HOG}$	LL $_{SAG}$	$_{+VE}$ TG	$_{-VE}$ TG	DL_{creep}	PRS_{creep}	WIND	Bal Losses	ΔP (+10%)	ΔP (-10%)
COMB 1	-1	1		0		1	1		1		
COMB 2	1	0.75			1	1	1		1		
COMB 3	-1		1	0		1	1		1		
COMB 4	-1		0.75		1	1	1		1	0	1
COMB 5	1	1				1	1	0.6	1		
COMB 6	1	0.75	0		1	1	1		1		
COMB 7	1	0.75	0		1	1	1		1	0	0

	STRESSES IN DIFF COMBINATIONS		

Sec No.	COMB 1		COMB 2		COMB 3		COMB 4		COMB 5		COMB 6		COMB 7	
	T	B	T	B	T	B	T	B	T	B	T	B	T	B
1														
2	738	706	364	555	1010	291	554	78	739	745	364	555	364	555
3	695	774	314	633	962	366	500	163	710	828	314	633	314	633
4	854	845	466	715	1108	457	617	263	884	917	466	715	466	715
5	1016	782	621	663	1258	412	736	246	1065	874	621	663	621	663
6	940	691	538	583	1163	350	632	215	1010	806	538	583	538	583
7	1058	853	648	757	1253	555	693	427	1152	994	648	757	648	757
8	979	654	562	569	1142	405	574	322	1100	823	562	569	562	569
9	1025	917	601	843	1161	710	566	631	1175	1116	601	843	601	843
10	1117	1187	691	1116	1247	989	617	920	1300	1419	691	1116	691	1116
11	1145	816	718	724	1291	611	624	593	1360	1067	718	724	718	724
12	1087	1071	660	962	1260	847	561	822	1336	1344	660	962	660	962
13	996	1329	572	1201	1211	1069	478	1042	1290	1629	572	1201	572	1201
14	624	1650	206	1503	902	1332	158	1301	956	1975	206	1503	206	1503
15	711	1385	319	1185	1004	1051	273	985	1045	1701	319	1185	319	1185
16	413	1535	109	1214	785	1110	74	1008	644	1689	109	1214	109	1214
17	607	1313	293	1004	938	935	228	833	820	1455	293	1004	293	1004
18	699	1059	370	770	954	751	275	647	880	1179	370	770	370	770
19	762	813	419	543	954	564	305	463	909	911	419	543	419	543
20	780	575	427	324	935	359	312	268	899	653	427	324	427	324
21	708	881	346	649	837	684	245	554	802	940	346	649	346	649
22	602	673	231	454	723	488	160	354	671	711	231	454	231	454
23	692	901	316	691	816	712	257	536	740	922	316	691	316	691
24	1045	1006	668	797	1192	781	608	581	1074	1012	668	797	668	797
25	1014	963	638	753	1188	697	615	493	1027	955	638	753	638	753
26	861	890	484	681	1053	597	501	392	860	872	484	681	484	681
27	681	854	304	645	887	539	359	333	670	828	304	645	304	645
28	724	785	347	577	939	457	408	254	705	753	347	577	347	577
29	494	819	117	612	712	486	207	279	470	784	117	612	117	612
30	736	769	358	562	953	436	423	234	710	734	358	562	358	562

31	725	788	348	580	942	457	411	255	698	752	348	580	348	580
32	916	813	538	605	1125	494	571	293	890	780	538	605	538	605
33	1091	854	714	646	1285	559	709	358	1070	826	714	646	714	646
34	1265	954	888	746	1437	692	838	488	1250	933	888	746	888	746
35	1367	1002	990	794	1512	779	896	578	1361	991	990	794	990	794
36	685	961	308	752	809	771	252	587	691	962	308	752	308	752
37	829	724	457	507	948	541	362	400	850	740	457	507	457	507
38	943	961	580	730	1073	761	457	623	982	994	580	730	580	730
39	1004	561	650	312	1158	345	512	254	1062	610	650	312	650	312
40	975	802	631	534	1170	550	498	450	1055	868	631	534	631	534
41	912	1049	581	761	1165	743	465	638	1018	1133	581	761	581	761
42	574	1352	258	1044	903	975	198	866	706	1454	258	1044	258	1044
43	237	1894	(80)	1605	613	1465	(101)	1377	384	2008	(80)	1605	(80)	1605
44	562	1649	175	1458	967	1187	252	1116	648	1869	175	1458	175	1458
45	753	1430	361	1246	1117	1015	403	943	825	1633	361	1246	361	1246
46	845	1188	446	1021	1133	839	452	767	891	1367	446	1021	446	1021
47	907	955	503	806	1129	669	480	598	927	1111	503	806	503	806
48	924	734	518	602	1109	476	489	415	923	868	518	602	518	602
49	846	1069	441	952	1013	813	426	715	825	1182	441	952	441	952
50	734	869	329	752	893	626	336	521	696	952	329	752	329	752
51	814	1113	414	990	985	851	432	704	762	1168	414	990	414	990
52	1169	1215	775	1082	1359	923	782	752	1106	1244	775	1082	775	1082
53	1141	1167	754	1024	1348	852	782	674	1071	1173	754	1024	754	1024
54	990	1090	609	937	1208	757	665	578	915	1075	609	937	**609**	937
55	813	1049	439	887	1038	705	519	523	735	1016	439	887	439	887
56	859	976	491	804	1087	628	566	449	781	926	491	804	491	804
57	632	1007	270	825	857	662	363	477	556	944	270	825	270	825
58	875	954	513	772	1099	611	579	431	798	891	513	772	513	772
59	867	969	499	797	1092	625	572	445	782	918	499	797	499	797
60	1060	991	685	828	1280	654	737	474	969	955	685	828	685	828
61	1237	1030	857	876	1446	710	881	531	1143	1011	857	876	857	876
62	1413	1127	1027	982	1605	834	1017	650	1319	1127	1027	982	1027	982

63	1516	1172	1124	1036	1694	899	1087	722	1425	1194	1124	1036	1124	1036
64	838	1125	439	999	998	880	450	721	752	1172	439	999	439	999
65	988	878	587	755	1147	635	569	520	910	952	587	755	587	755
66	1112	1101	712	976	1280	843	671	731	1044	1204	712	976	712	976
67	1180	675	780	535	1368	413	728	348	1128	796	780	535	780	535
68	1155	900	757	742	1387	599	718	526	1119	1039	757	742	757	742
69	1095	1133	703	957	1396	769	695	694	1079	1291	703	957	703	957
70	760	1423	375	1229	1138	991	431	911	765	1603	375	1229	375	1229
71	848	1197	481	964	1213	780	520	668	865	1375	481	964	481	964
72	417	1531	112	1210	788	1107	80	1002	539	1632	112	1210	112	1210
73	611	1309	296	1000	941	932	233	827	719	1399	296	1000	296	1000
74	703	1055	373	766	956	748	280	641	785	1126	373	766	373	766
75	765	808	422	539	958	559	311	455	823	862	422	539	422	539
76	784	569	430	319	937	354	317	261	821	607	430	319	430	319
77	711	876	349	645	841	678	250	546	730	898	349	645	349	645
78	605	668	234	450	724	485	163	349	607	674	234	450	234	450
79	694	898	318	689	818	708	261	530	682	890	318	689	318	689
80	1046	1003	670	794	1194	777	612	576	1024	983	670	794	670	794
81	1016	960	639	751	1189	696	617	490	985	931	639	751	639	751
82	862	888	485	679	1053	596	503	390	826	852	485	679	485	679
83	682	852	305	644	887	538	360	332	643	812	305	644	305	644
84	725	783	347	576	939	456	409	253	686	742	347	576	347	576
85	494	819	117	611	712	486	208	278	458	778	117	611	117	611
86	735	770	357	562	953	436	423	234	700	730	357	562	357	562
87	724	789	347	581	941	457	410	255	696	753	347	581	347	581
88	914	815	537	606	1124	494	569	294	895	785	537	606	537	606
89	1089	857	713	648	1284	560	707	360	1083	836	713	648	713	648
90	1263	958	887	748	1435	694	835	491	1271	947	887	748	887	748
91	1364	1006	988	796	1511	781	893	582	1389	1009	988	796	988	796
92	683	963	306	754	806	774	248	592	728	983	306	754	306	754
93	825	728	454	510	946	544	359	405	893	767	454	510	454	510
94	940	964	578	733	1069	767	452	630	1034	1023	578	733	578	733

95	1008	555	653	307	1155	350	508	261	1129	634	653	307	653	307
96	978	798	633	532	1167	554	493	456	1127	898	633	532	633	532
97	913	1047	582	760	1162	746	460	644	1097	1169	582	760	582	760
98	574	1351	258	1044	900	979	193	873	791	1495	258	1044	258	1044
99	222	1943	(101)	1664	582	1532	(136)	1451	466	2106	(101)	1664	(101)	1664
100	395	1911	(22)	1763	701	1562	(47)	1536	740	2243	(22)	1763	(22)	1763
101	609	1667	186	1526	873	1365	128	1336	932	1981	186	1526	186	1526
102	727	1408	300	1283	937	1154	229	1122	1012	1697	300	1283	300	1283
103	821	1150	392	1043	989	933	316	903	1062	1412	392	1043	392	1043
104	872	897	443	809	1015	698	374	676	1080	1137	443	809	443	809
105	836	1180	408	1111	963	985	360	922	1011	1399	408	1111	408	1111
106	757	991	329	921	885	794	317	711	900	1178	329	921	329	921
107	955	615	535	534	1115	371	547	296	1069	773	535	534	535	534
108	782	927	369	835	971	638	439	505	869	1058	369	835	369	835
109	682	731	277	627	899	399	395	262	746	837	277	627	277	627
110	730	814	332	699	969	448	475	282	773	898	332	699	332	699
111	603	909	212	783	860	515	393	320	628	974	212	783	212	783
112	681	789	298	652	950	378	487	177	691	836	298	652	298	652
113	488	775	112	626	762	356	330	141	485	807	112	626	112	626

Combination	MIN		MAX	
	TOP	BOT	TOP	BOT
1	222	555	1516	1943
2	-101	307	1124	1763
3	582	291	1694	1562
4	-136	78	1087	1536
5	384	607	1425	2243
6	-101	307	1124	1763
7	-101	307	1124	1763

Permissible tensile stress in cast in situ part	-350	t/sqm
Permissible tensile stress at joints between two precast segments	0	t/sqm
Permissible compressive stress	2880	t/sqm

It may be observed that the stresses are within permissible limits.

8.2 CHECK FOR STRESSES DURING CANTILEVER CONSTRUCTION

8.2.1 CANTILEVER OVER P3/P4

Average Force in cable after friction and slip 340 t Stresses are in **T/SQM**

1 PIER FACE

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
0	15		0	0	0	5.24	4.84	4.24	-3.04	3.47	0.0	0.0	-3	3	-3	3
1	0		2	679	857	5.24	4.84	4.24	0.00	0.00	306.6	-72.5	307	-73	304	-69
2	110		2	679	857	5.24	4.84	4.24	-22.78	26.03	306.6	-72.5	284	-46	587	-116
3	212		2	679	857	5.24	4.84	4.24	-43.72	49.94	306.6	-72.5	263	-23	850	-138
4	304		2	679	857	5.24	4.84	4.24	-62.75	71.69	306.6	-72.5	244	-1	1094	-139
5	397		0	0	0	5.24	4.84	4.24	-81.88	93.55	0.0	0.0	-82	94	1012	-45
6	496		2	679	857	5.24	4.84	4.24	-102.35	116.93	306.6	-72.5	204	44	1216	-1
7	595		2	679	857	5.24	4.84	4.24	-122.83	140.32	306.6	-72.5	184	68	1400	67
8	694		2	679	857	5.24	4.84	4.24	-143.30	163.71	306.6	-72.5	163	91	1563	158
9	793		2	679	857	5.24	4.84	4.24	-163.77	187.09	306.6	-72.5	143	115	1706	273
10	892		0	0	0	5.24	4.84	4.24	-184.24	210.48	0.0	0.0	-184	210	1522	483
11	992		2	679	857	5.24	4.84	4.24	-204.71	233.87	306.6	-72.5	102	161	1624	644
12	1091		2	679	857	5.24	4.84	4.24	-225.18	257.25	306.6	-72.5	81	185	1705	829
Losses		0		-469	-591	5.24	4.84	4.24			-211.6	50.0	-212	50	1494	879

2 END OF PIER HEAD

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
1	0		2	679	822	5.03	4.83	3.99	0.00	0.00	305.4	-71.0	305	-71	305	-71
2	55		2	679	822	5.03	4.83	3.99	-11.39	13.78	305.4	-71.0	294	-57	599	-128
3	159		2	679	822	5.03	4.83	3.99	-32.88	39.79	305.4	-71.0	272	-31	872	-159
4	253		2	679	822	5.03	4.83	3.99	-52.46	63.49	305.4	-71.0	253	-8	1125	-167
5	347		0	0	0	5.03	4.83	3.99	-71.90	87.01	0.0	0.0	-72	87	1053	-80
6	446		2	679	822	5.03	4.83	3.99	-92.44	111.87	305.4	-71.0	213	41	1266	-39
7	545		2	679	822	5.03	4.83	3.99	-112.98	136.72	305.4	-71.0	192	66	1458	27
8	645		2	679	822	5.03	4.83	3.99	-133.52	161.58	305.4	-71.0	172	91	1630	117
9	744		2	679	822	5.03	4.83	3.99	-154.07	186.44	305.4	-71.0	151	115	1781	233
10	843		0	0	0	5.03	4.83	3.99	-174.61	211.30	0.0	0.0	-175	211	1607	444
11	942		2	679	822	5.03	4.83	3.99	-195.15	236.16	305.4	-71.0	110	165	1717	609
12	1041		2	679	822	5.03	4.83	3.99	-215.69	261.02	305.4	-71.0	90	190	1807	799
Losses				-469	-567	5.03	4.83	3.99			-210.7	49.0	-211	49	1596	848

3 END OF SEGMENT 1

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
2	55		2	679	788	4.818	4.792	3.704	-11.47	14.84	305.3	-71.7	294	-57	294	-57
3	159		2	679	788	4.818	4.792	3.704	-33.12	42.85	305.3	-71.7	272	-29	566	-86
4	253		2	679	788	4.818	4.792	3.704	-52.85	68.37	305.3	-71.7	252	-3	819	-89
5	347		0	0	0	4.818	4.792	3.704	-72.42	93.70	0.0	0.0	-72	94	746	5
6	446		2	679	788	4.818	4.792	3.704	-93.12	120.47	305.3	-71.7	212	49	958	53
7	545		2	679	788	4.818	4.792	3.704	-113.81	147.24	305.3	-71.7	192	75	1150	129
8	645		2	679	788	4.818	4.792	3.704	-134.50	174.01	305.3	-71.7	171	102	1321	231
9	744		2	679	788	4.818	4.792	3.704	-155.19	200.78	305.3	-71.7	150	129	1471	360
10	843		0	0	0	4.818	4.792	3.704	-175.89	227.55	0.0	0.0	-176	228	1295	588
11	942		2	679	788	4.818	4.792	3.704	-196.58	254.32	305.3	-71.7	109	183	1404	770
12	1041		2	679	788	4.818	4.792	3.704	-217.27	281.09	305.3	-71.7	88	209	1492	979
Losses				-422	-489	4.818	4.792	3.704			-189.6	44.6	-190	45	1302	1024

4 END OF SEGMENT 2

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
3	53		2	679	748	4.6	4.7	3.4	-11.13	15.55	305.4	-73.8	294	-58	294	-58
4	152		2	679	748	4.6	4.7	3.4	-32.08	44.84	305.4	-73.8	273	-29	568	-87
5	248		0	0	0	4.6	4.7	3.4	-52.39	73.23	0.0	0.0	-52	73	515	-14
6	347		2	679	748	4.6	4.7	3.4	-73.35	102.53	305.4	-73.8	232	29	747	15
7	446		2	679	748	4.6	4.7	3.4	-115.26	161.11	305.4	-73.8	190	87	938	102
8	545		2	679	748	4.6	4.7	3.4	-115.26	161.11	305.4	-73.8	190	87	1107	218
9	645		2	679	748	4.6	4.7	3.4	-136.22	190.41	305.4	-73.8	169	117	1276	335
10	744		0	0	0	4.6	4.7	3.4	-157.17	219.70	0.0	0.0	-157	220	1119	555
11	843		2	679	748	4.6	4.7	3.4	-178.13	248.99	305.4	-73.8	127	175	1246	730
12	942		2	679	748	4.6	4.7	3.4	-199.09	278.28	305.4	-73.8	106	204	1352	934
Losses		0		-375	-413	4.6	4.7	3.4	0.00	0.00	-168.6	40.8	-169	41	1184	975

5 END OF SEGMENT 3

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
4	50		2	679	703	4.407	4.636	3.032	-10.86	16.61	305.8	-77.9	295	-61	295	-61
5	149		0	0	0	4.407	4.636	3.032	-32.08	49.06	0.0	0.0	-32	49	263	-12
6	248		2	679	703	4.407	4.636	3.032	-53.47	81.76	305.8	-77.9	252	4	515	-8

7	347		2	679	703	4.407	4.636	3.032	-74.86	114.47	305.8	-77.9	231	37	746	28
8	446		2	679	703	4.407	4.636	3.032	-96.25	147.18	305.8	-77.9	210	69	956	97
9	545		2	679	703	4.407	4.636	3.032	-117.64	179.88	305.8	-77.9	188	102	1144	199
10	645		0	0	0	4.407	4.636	3.032	-139.03	212.59	0.0	0.0	-139	213	1005	412
11	744		2	679	703	4.407	4.636	3.032	-160.42	245.29	305.8	-77.9	145	167	1150	579
12	843		2	679	703	4.407	4.636	3.032	-181.81	278.00	305.8	-77.9	124	200	1274	780
Losses				-328	-340	4.407	4.636	3.032	0.00	0.00	-147.7	37.6	-148	38	1126	817

6 **END OF SEGMENT 4**

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
5	50		0	0	0	4.407	4.636	3.032	-10.69	16.35	0.0	0.0	-11	16	-11	16
6	149		2	679	702	4.407	4.636	3.032	-32.08	49.06	305.5	-77.4	273	-28	263	-12
7	248		2	679	702	4.407	4.636	3.032	-53.47	81.76	305.5	-77.4	252	4	515	-8
8	347		2	679	702	4.407	4.636	3.032	-74.86	114.47	305.5	-77.4	231	37	745	29
9	446		2	679	702	4.407	4.636	3.032	-96.25	147.18	305.5	-77.4	209	70	955	99
10	545		0	0	0	4.407	4.636	3.032	-117.64	179.88	0.0	0.0	-118	180	837	279
11	645		2	679	702	4.407	4.636	3.032	-139.03	212.59	305.5	-77.4	166	135	1003	414
12	744		2	679	702	4.407	4.636	3.032	-160.42	245.29	305.5	-77.4	145	168	1148	582
Losses				-281	-291	4.407	4.636	3.032	0.00	0.00	-126.5	32.1	-126	32	1022	614

7 **END OF SEGMENT 5**

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
6	50		2	679	702	4.4	4.6	3.0	-10.69	16.35	305.5	-77.4	295	-61	295	-61
7	149		2	679	702	4.4	4.6	3.0	-32.08	49.06	305.5	-77.4	273	-28	568	-89
8	248		2	679	702	4.4	4.6	3.0	-53.47	81.76	305.5	-77.4	252	4	820	-85
9	347		2	679	702	4.4	4.6	3.0	-74.86	114.47	305.5	-77.4	231	37	1051	-48
10	446		0	0	0	4.4	4.6	3.0	-96.25	147.18	0.0	0.0	-96	147	955	99
11	545		2	679	702	4.4	4.6	3.0	-117.64	179.88	305.5	-77.4	188	102	1142	202
12	645		2	679	702	4.4	4.6	3.0	-139.03	212.59	305.5	-77.4	166	135	1309	337
Losses				-281	-291	4.4	4.6	3.0	0.00	0.00	-126.5	32.1	-126	32	1182	369

8 **END OF SEGMENT 6**

Seg	SECTION		No of	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	

Cast	BM_S/WT	BM_CCE	Cables						TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
7	50		2	679	702	4.4	4.6	3.0	-10.69	16.35	305.5	-77.4	295	-61	295	-61
8	149		2	679	702	4.4	4.6	3.0	-32.08	49.06	305.5	-77.4	273	-28	568	-89
9	248		2	679	702	4.4	4.6	3.0	-53.47	81.76	305.5	-77.4	252	4	820	-85
10	347		0	0	0	4.4	4.6	3.0	-74.86	114.47	0.0	0.0	-75	114	745	29
11	446		2	679	702	4.4	4.6	3.0	-96.25	147.18	305.5	-77.4	209	70	955	99
12	545		2	679	702	4.4	4.6	3.0	-117.64	179.88	305.5	-77.4	188	102	1142	202
Losses				-234	-242	4.4	4.6	3.0	0.00	0.00	-105.4	26.7	-105	27	1037	228

9 END OF SEGMENT 7

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
8	50		2	679	702	4.4	4.6	3.0	-10.69	16.35	305.5	-77.4	295	-61	295	-61
9	149		2	679	702	4.4	4.6	3.0	-32.08	49.06	305.5	-77.4	273	-28	568	-89
10	248		0	0	0	4.4	4.6	3.0	-53.47	81.76	0.0	0.0	-53	82	515	-8
11	347		2	679	702	4.4	4.6	3.0	-74.86	114.47	305.5	-77.4	231	37	745	29
12	446		2	679	702	4.4	4.6	3.0	-96.25	147.18	305.5	-77.4	209	70	955	99
Losses				-187	-194	4.4	4.6	3.0	0.00	0.00	-84.3	21.4	-84	21	870	120

10 END OF SEGMENT 8

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
9	50	0	2	679	702	4.407	4.636	3.032	-10.69	16.35	305.5	-77.4	295	-61	295	-61
10	149	0	0	0	0	4.407	4.636	3.032	-32.08	49.06	0.0	0.0	-32	49	263	-12
11	248	0	2	679	702	4.407	4.636	3.032	-53.47	81.76	305.5	-77.4	252	4	515	-8
12	347	0	2	679	702	4.407	4.636	3.032	-74.86	114.47	305.5	-77.4	231	37	745	29
Losses		0		-141	-145	4.407	4.636	3.032	0.00	0.00	-63.2	16.0	-63	16	682	45

11 END OF SEGMENT 9

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
10	50		0	0	0	4.407	4.636	3.032	-10.69	16.35	0.0	0.0	-11	16	-11	16
11	149		2	679	702	4.407	4.636	3.032	-32.08	49.06	305.5	-77.4	273	-28	263	-12
12	248		2	679	702	4.407	4.636	3.032	-53.47	81.76	305.5	-77.4	252	4	515	-8
Losses				-94	-97	4.407	4.636	3.032	0.00	0.00	-42.2	10.7	-42	11	473	3

12 END OF SEGMENT 10

Seg	SECTION		No of	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	

Cast	BM_S/WT	BM_CCE	Cables	PR_P	PR_M	A	ZT	ZB	TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
11	50	0	2	679	702	4.407	4.636	3.032	-10.69	16.35	305.5	-77.4	295	-61	295	-61
12	149	0	2	679	702	4.407	4.636	3.032	-32.08	49.06	305.5	-77.4	273	-28	568	-89
Losses		0		-94	-97	4.407	4.636	3.032	0.00	0.00	-42.2	10.7	-42	11	526	-79

13 END OF SEGMENT 11

Seg Cast	SECTION		No of Cables	PR_P	PR_M	A	ZT	ZB	STRESS DL		STRESS PREST		TOTAL		TOTAL CUM	
	BM_S/WT	BM_CCE							TOP	BOTT	TOP	BOT	TOP	BOT	TOP	BOT
12	50	0	2	679	702	4.407	4.636	3.032	-10.69	16.35	305.5	-77.4	295	-61	295	-61
Losses		0		-47	-48	4.407	4.636	3.032	0.00	0.00	-21.1	5.3	-21	5	-21	5

9 CHECK AT ULS FOR SHEAR AND TORSION

Refer Section 10 of IRC 112 2011

f_{ck} 60 duct dia 0.120

Shear is checked at section 16-22 and reinforcement calculated at section 16 is provided till section 17 and so on.

Tabulation of Shear Force

Refer Section 5.2 for Shear at various sections

Section No.		16	17	18	19	20	21	22
SHEAR		932	892	820	748	674	606	535
LL Shear (ULS)		252	243	231	216	198	184	165
TORSION due to LL	252*1.155	291	280	266	250	229	212	191
Relief due to comp in soffit		0	0	0	0	0	0	0
Total		932	892	820	748	674	606	535

Computation of Vertical component of Soffit slab

section No.	16	17	18	19	20	21	22
DL Stress	2498	2347	2198	2079	1994	1949	1696
SDL stress	226	199	159	120	80	38	-8
LL Stress	415	369	300	234	171	109	54
Prestress ⟷	-1604	-1602	-1597	-1619	-1670	-1215	-1070
Total	1535	1313	1059	813	575	881	673
ULS stress	2741	2429	2066	1724	1402	1639	1289
soffit thick	600	519	438	356	275	275	275
Inclination	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Upward component of soffit due to inclination	0	0	0	0	0	0	0

Computation of Shear stress τ_t and Shear Force in webs due to Torsion

A_k (sqm)	8.30	8.41	8.52	8.64	8.75	8.75	8.75
t_{ef} (mm)	300	300	300	300	300	300	300
Area of outer web (sqm)	0.83	0.83	0.83	0.83	0.83	0.83	0.83
Stress due to torsion (mpa)	0.585	0.555	0.521	0.482	0.437	0.404	0.363
Max shear F in web due to torsion	49	46	43	40	36	34	30
Design V_{ED}	1029	984	907	828	747	673	596

932+0+2*49

CHECK AT ULS FOR MAXIMUM SHEAR

SECTION		16	17	18	19	20	21	22
V_{ED}(kN)=		10293	9845	9066	8278	7472	6733	5959
I=		6.78	6.78	6.55	6.27	5.92	5.50	5.50
S=		2.82	2.82	2.70	2.57	2.42	2.26	2.26
b_w		600	600	600	600	600	600	600
bwc (Eq 10.14)	b_w-0.5Σϕ	600	600	600	600	600	600	600
fctd (refer Table 6.5 for fctk)	f_{ctk}/γ_m	1.67	1.67	1.67	1.67	1.67	1.67	1.67
k1=		1	1	1	1	1	1	1
f_{cd}	$\alpha_{cc}.f_{ck}/\gamma_m$	26.80	26.80	26.80	26.80	26.80	26.80	26.80
N_{sd}		68706	68699	61877	55259	48418	41117	34189

Ac		5.24	5.24	5.03	4.82	4.61	4.41	4.41
$\sigma_{cp,}$ limited to 0.2 fctd	$N_{sd}/A_c <= 0.2\ f_{ctd}$	5.36	5.36	5.36	5.36	5.36	5.36	5.36
$V_{RD.c}$ Eq 10.4	I. b_{wc}/S SQRT($fctd^2+k_1.f_{ctd}.\sigma_{cp}$)	4945	4945	4979	5003	5013	5000	5000
$V_{RD.c}$ Eq 10.5	0.5 b_w d ν f_{cd}	11134	11134	11134	11134	11134	11134	11134
		>	>	>	>	>	>	
		10293	9845	9066	8278	7472	6733	5959
d		2862	2862	2862	2862	2862	2862	2862
ν (Eq 10.6)	0.6*(1-fck/310)	0.48	0.48	0.48	0.48	0.48	0.48	0.48
K (Eq 10.2)	1+SQRT(200/d)	1.264	1.264	1.264	1.264	1.264	1.264	1.264
ρ_1	As/(bw.d) <= 0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ν_{min} (Eq 10.3)	$0.031\ K^{3/2}\ fck^{0.5}$	0.341	0.341	0.341	0.341	0.341	0.341	0.341
$V_{RD.c}$	$(0.12K(80.\rho_1.f_{ck})^{0.33}+0.15\ \sigma_{cp})$*bw.d	2556	2556	2556	2556	2556	2556	2556
$V_{RD.c}$ (Eq 10.1)	$(\nu_{min}+0.15\ \sigma_{cp})$*bw.d	1967	1967	1967	1967	1967	1967	1967
Asw		804	804	804	804	804	452	452
s		125	175	175	200	225	150	150
fywd	f_{yk}/γ_m	348	348	348	348	348	348	348
θ	Angle assumed	25	25	25	25	25	25	25
z =0.9 d		2576	2576	2576	2576	2576	2576	2576
$V_{RD.s}$ (Eq 10.7)	$A_{sw}\ z\ f_{ywd}$ Cot (θ) /s	12358	8827	8827	7724	6866	5790	5790
$V_{RD.max}$ (Eq 10.8)	$\alpha_{cw}\ b_w\ z\ \nu_1\ f_{cd}/(\cot(\theta)+\tan(\theta))$	11898	11898	11898	11898	11898	11898	11898
ν_1		0.6	0.6	0.6	0.6	0.6	0.6	0.6
σ_{cp}	N_{sd}/A_c	13.12	13.11	12.31	11.47	10.50	9.33	7.76
σ_{cp}/f_{cd}		0.490	0.490	0.460	0.430	0.390	0.350	0.290
α_{cw} (Equation 10.9)		1.250	1.250	1.250	1.250	1.250	1.250	1.250
min reinf ratio eq. 10.20	0.072 SQRT(fck)/fyk	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Min reinf	min reinf ratio * bw	669	669	669	669	669	669	669
6 Legged Tor		12	12	12	12	12	12	12
No of bars in 1m length		0.99	0.99	0.99	0.99	0.99	0.99	0.99
Spacing required		1014	1014	1014	1014	1014	1014	1014

Check for combined shear and torison

α_{cw}		1.49	1.49	1.46	1.43	1.39	1.35	1.29
$T_{RD.max}$ (Eq 10.48)		36819	36818	36075	35301	34406	33326	31876
$T_{ED}/T_{RD.max}+V_{ED}/V_{RD\ max}$ (Eq 10.47)		0.94	0.90	0.84	0.77	0.69	0.63	0.56
		<1	<1	<1	<1	<1	<1	<2

10 CHECK AT ULS FOR FLEXURE

(Refer clause 8.2 and A2.9 of IRC 112)

ULS Flexure is checked at section 54, 57, 60, 63, 66, 69,72 and 74.

area of one cable 0.00266

	Section	16	19	22	25	29	32	35	
	f_{pu}	1860	1860	1860	1860	1860	1860	1860	
	f_{pd}	1407	1407	1407	1407	1407	1407	1407	
	initial pretstrain	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	0.0055	
	No of Cables	20	16	12	8	7	7	5	
	Web Thickness	0.600	0.600	0.600	0.600	0.600	0.600	0.600	
	Aps	0.0532	0.0426	0.0319	0.0213	0.0186	0.0186	0.0133	
	fck	60	60	60	60	60	60	60	
	b	3000	3000	3000	3000	5850	5850	5850	
	d	2862	2862	2862	2862	2862	2862	2862	
	x (assumed)	*2640*	*2760*	*2130*	*1000*	*210*	*210*	*150*	
	soffit/deck thickness	600	356	275	275	275	275	275	
	strain in steel	0.008	0.007	0.018	0.071	0.448	0.448	0.638	
	stress in steel	1407	1359	1407	1407	1407	1407	1407	
	Ten force (fpd.Aps)	*74859*	*57853*	*44916*	*29944*	*26201*	*26201*	*18715*	
soffit	Comp F (λ.x.η.f_{cd})	50099	29298	22500	22500	23638	23638	16884	
Web	Comp F (λ.x.η.f_{cd})	24760	30324	23401	8597	2701	2701	1930	
Total		*74859*	*59622*	*45901*	*31098*	*26339*	*26339*	*18814*	
	CG of comp F	649	649	502	210	84	84	60	
	Mu=TF.(d-cg)	165,643	128,027	106,012	79,409	72,786	72,786	52,439	
	Mu acting	160,781	101,014	48,924	19,800	36,119	31,459	9,037	
	Status	OK	OK	OK	OK	OK	OK	OK	
	%Age Margin	3.02%	26.74%	116.7%	301%	102%	131%	480%	

11 Design of end block

Design of Local Zone behind Anchorage :

As per clause 13.5.1.2 of IRC:112 – Recommendation of the Anchorage System Supplier shall be followed in case of Internal Anchorages for Anchorage Dimension, Minimum Spacing, Minimum Concrete Grade and Reinforcement for Bursting. There is no need for any additional calculation by the Designer.

The anchorages of M/S Dynamic Prestress is proposed to be used.

11.1 Calculation of stress behind Anchorage as per Annex J of EC2-2 :

Since IRC:112 do not give any guideline on method of checking of concrete bearing stresses behind anchorage, reference may be made to Euro Code EC2 - Annex J for checking of concrete stresses.

The reinforcement required to prevent bursting and spalling in anchorage zones is determined in relation to a rectangular prism of concrete, known as the primary regularisation prism, located behind each anchorage. The cross section of the prism associated with each anchorage is known as the associate rectangle. The associate rectangle has the same centre and the same axes of symmetry as the anchorage plate (which should have two axes of symmetry) and should satisfy:

$$\frac{P_{max}}{c \cdot c'} \leq 0{,}6 \cdot f_{ck}(t) \qquad (J.101)$$

Where :

Pmax = Maximum Force applied to the tendon.

C & C' are the dimensions of the associated rectangle

The prism dimension for various Tendons are as given in the Table below :

The dimensions are based on rectangular prism associated with each anchorage having the same centre.

Cable No	Prism Dim 2Y0	
	Vertical	Lateral
1	400	400
2	400	400
3	400	400
4	400	400

C x C' = 400x400 = 160000 mm2 for Cables 1 & 2

fck (t) = 60 Mpa (cube) = 48 Mpa (cylinder)

Pmax = Max. Force applied to the Tendon

= 3794 kN

$\sigma 1$ = Pmax / CxC' = 3794x1000/160000= 23.71 mpa

Permissible compressive stress behind anchorage = 0.6 x fck,cyl

0.6 x 48 = 28.8 Mpa > 23.71 Mpa ,

11.2 Calculation of Bursting Reinforcement as per Annex J of EC2-2 :

Since IRC:112 do not give any guideline on method of checking of bursting reinforcement, reference may be made to Euro code.

(103) Reinforcement to prevent bursting and spalling of the concrete, in each regularisation prism (as defined in rule (102) above) should not be less than:

$$A_s = 0{,}15 \frac{P_{max}}{f_{yd}} \gamma_{p,unfav} \text{ with } \gamma_{p,unfav} \geq 1{,}20 \qquad (J.102)$$

Pmax = 3794 fyk = 500 fyd= 0.87*500= 435 mpa

$g_{p,unfav}$ = 1.2 As = 0.15 x 3794*1000*1.2/435 1569.9 mm^2

Strictly, a check of crack width would be necessary. To avoid such checks, stress in reinforcement can be restricted to 250 Mpa

As, revised = 1569.93*435/250 2731.68 mm^2

Spiral Reinf. provided as per Catalogue of M/S Dynamic Prestress for 12K15

= 2x16φ – 8 legs = 3216mm^2 Hence OK

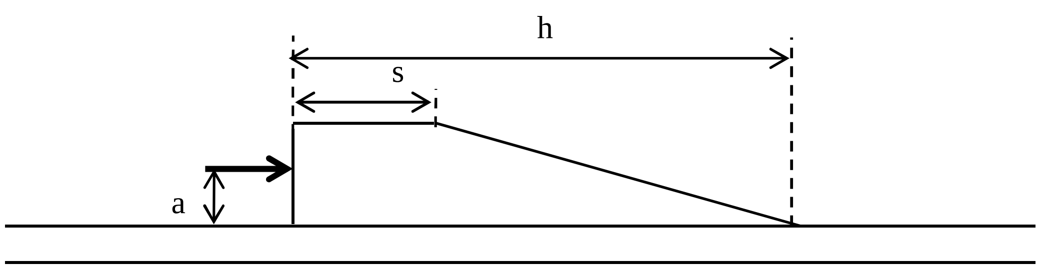
11.3 Calculation of Spalling Reinforcement (As per Annex J of EC2-2)

Clause 13.5.2 describes the need for spalling reinforcement. However the quantum of reinforcement required is not specified in the code for post tensioned beams. In absence of specific provision in IRC:112, reference may be made to Euro Code EC2-2. As per Annex J of EC2-2, Area of such reinforcement shall not be less than 0.03 x Pmax / fyd x γp,unfav in each direction. This reinforcement needs to be distributed in each direction over the length of the rectangular prism. To avoid crack width calculations, fyd may be considered as 250 Mpa.

As, reqd = 0.03 x 3794*1000*1.2 / 250 546.336 mm^2

Provide 4 Tor 12 or equivalent in each direction

11.4 DESIGN OF INTERMEDIATE BLISTER BLOCK



Design as a bracket (Refer Chapter 24 (Page 378-379) of V K Raina BooK)

a			250	mm
s			850	mm
h			1700	mm
d '			1644	mm
b			600	mm
d	=	0.8 x d'	1315.2	mm
Vu			3794	KN
Hu	=	0.2 x Vu	758.8	KN
f sy			500	Mpa
f'_c	=	0.8 x f_{ck}	48	Mpa
μ			1.4	

Checks

(1)	S / d ' > = 0.5	850/1644=	0.52	>	0.50	OK	
(2)	Vu / b d	3794*1e3/(600*1315.2)=	4.81	<	7.20	OK	0.15 f'_c
(3)	A_{vf}= V_u /(0.85 x fsy x μ)	3794*1e3/(0.85*500*1.4)/100=			63.76	cm^2	
(4)	At = Hu / (0.85 x fsy)	758.8*1e3/(0.85*500)/100=			17.85	cm^2	
(5)	A f = [Vu a + Hu (h - d')] / (0.85x fsy x d)						
	(3794*1e3*250+758.8*1e3*(1700-1644))/(0.85*500*1315.2)/100=				17.73	cm^2	
(6)	As (Max of following)						
	(i) A f + A t	17.73+17.85=			35.58	cm^2	
	(ii) 2/3 Av f + A t	2/3*63.76+17.85=			60.36	cm^2	
	(iii) (0.04 f'c/ fsy)* b d'	0.04*48/500*600*1644			37.88	cm^2	
	As				60.36	cm^2	
	Provide 5	Nos	32	mm bars	40.21	cm^2	
(7)	Ah (Max of following)						
	(i) 0.5 A f	0.5*17.73			8.87	cm^2	
	(ii) 0.333 Av f	0.333*63.76			21.25	cm^2	
	Ah				21.25	cm^2	

Longitudinal Reinforcement in soffit slab

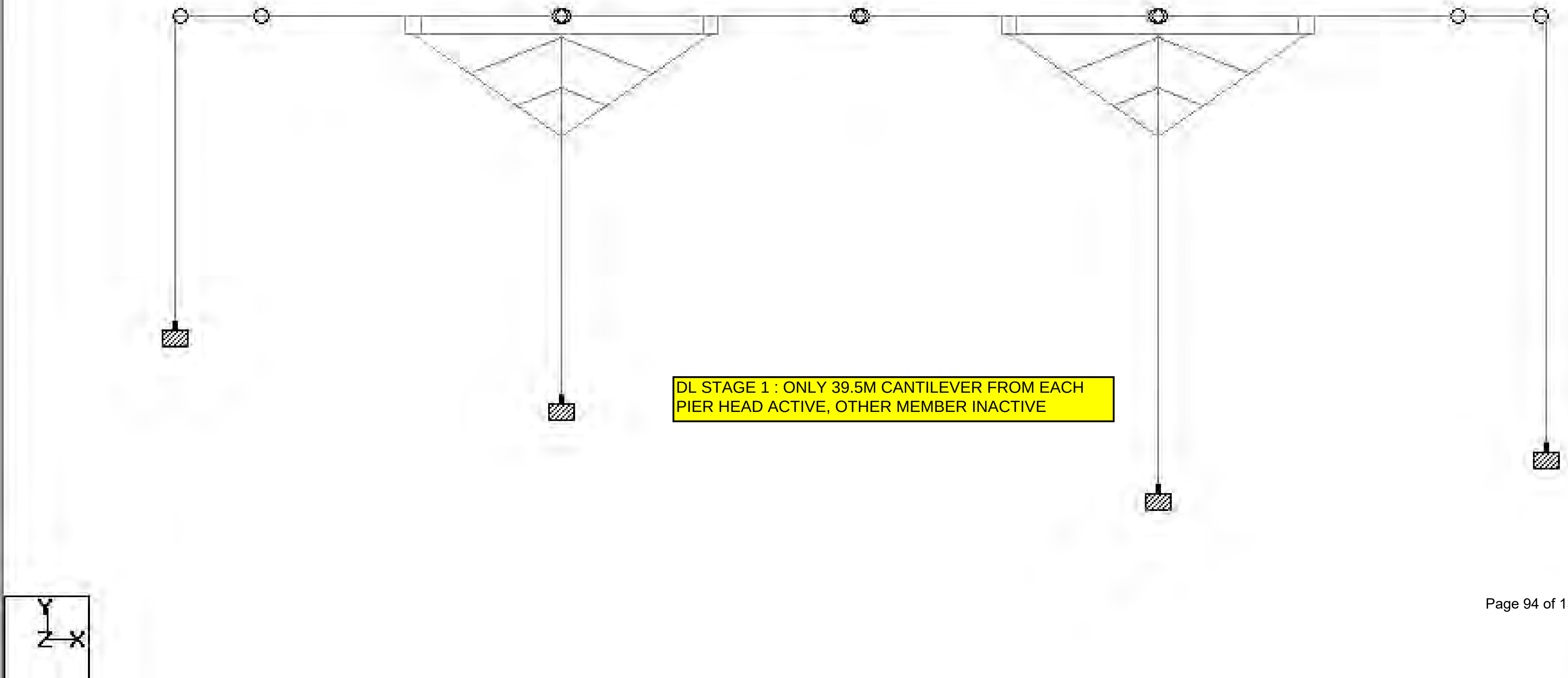
Due to tension behind anchorage		3794*1e3/2/250/100		75.88	cm^2
Provide 6	Nos	32	mm bars	48.25	cm^2

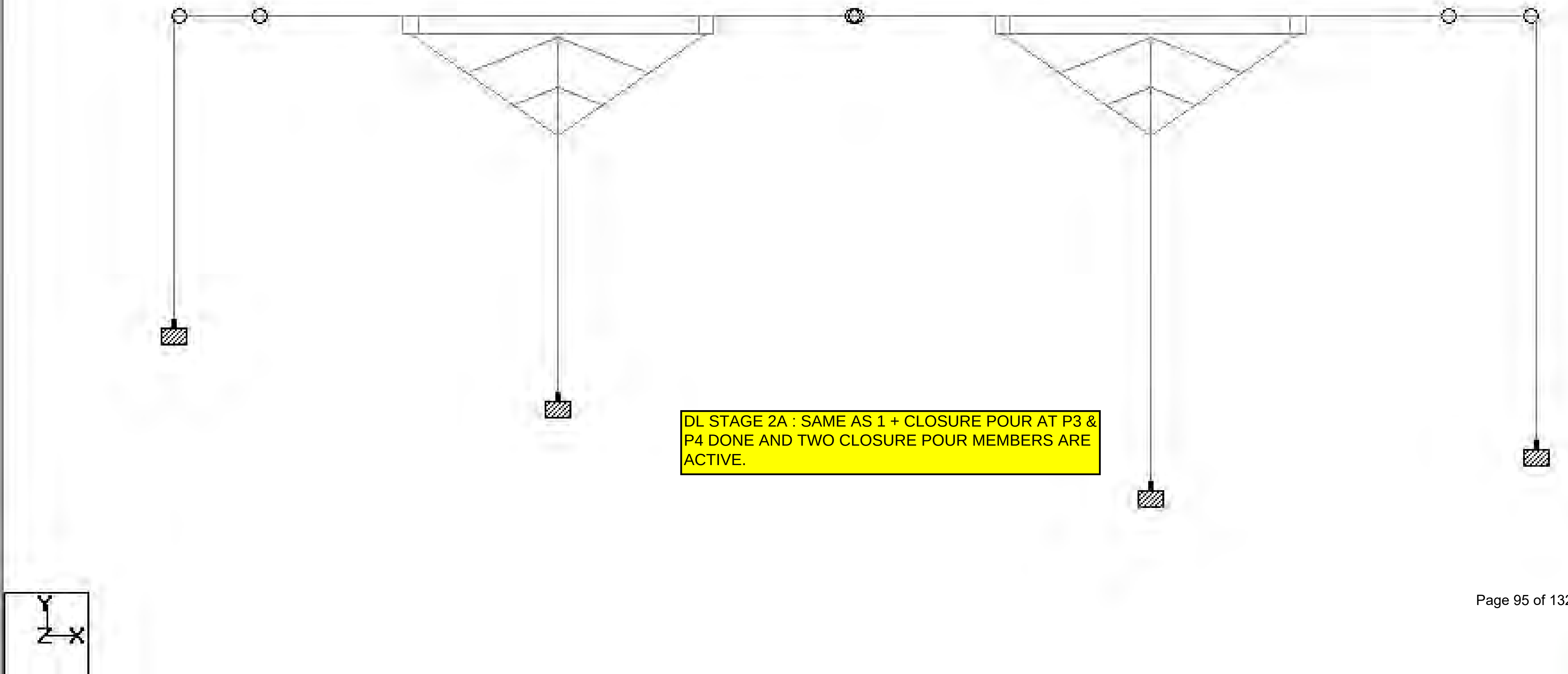
Reinf. To Resist Radial Force

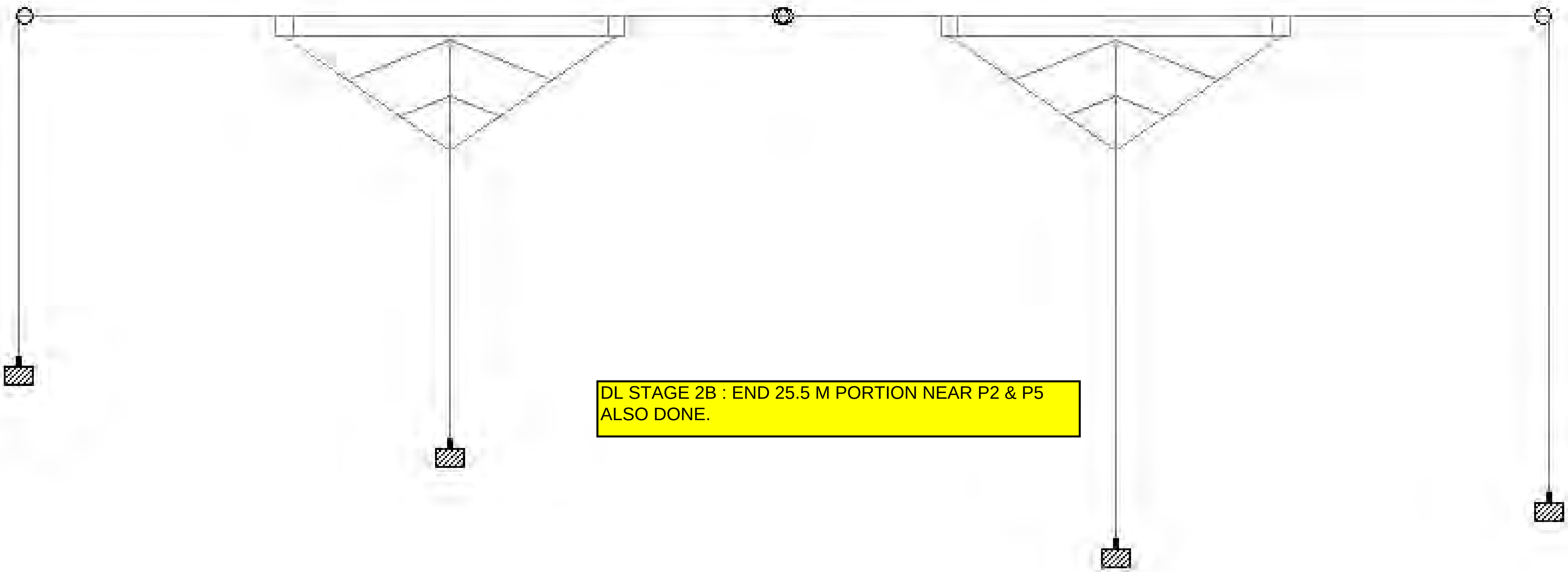
Angle of emergence		0.212	Radians
Radial Force	3794*Sin(0.212)	798	kN
Ast Required	798*1e3/250/100	31.92	cm^2
Distributed over curved length of tendon i.e.		1.50	m

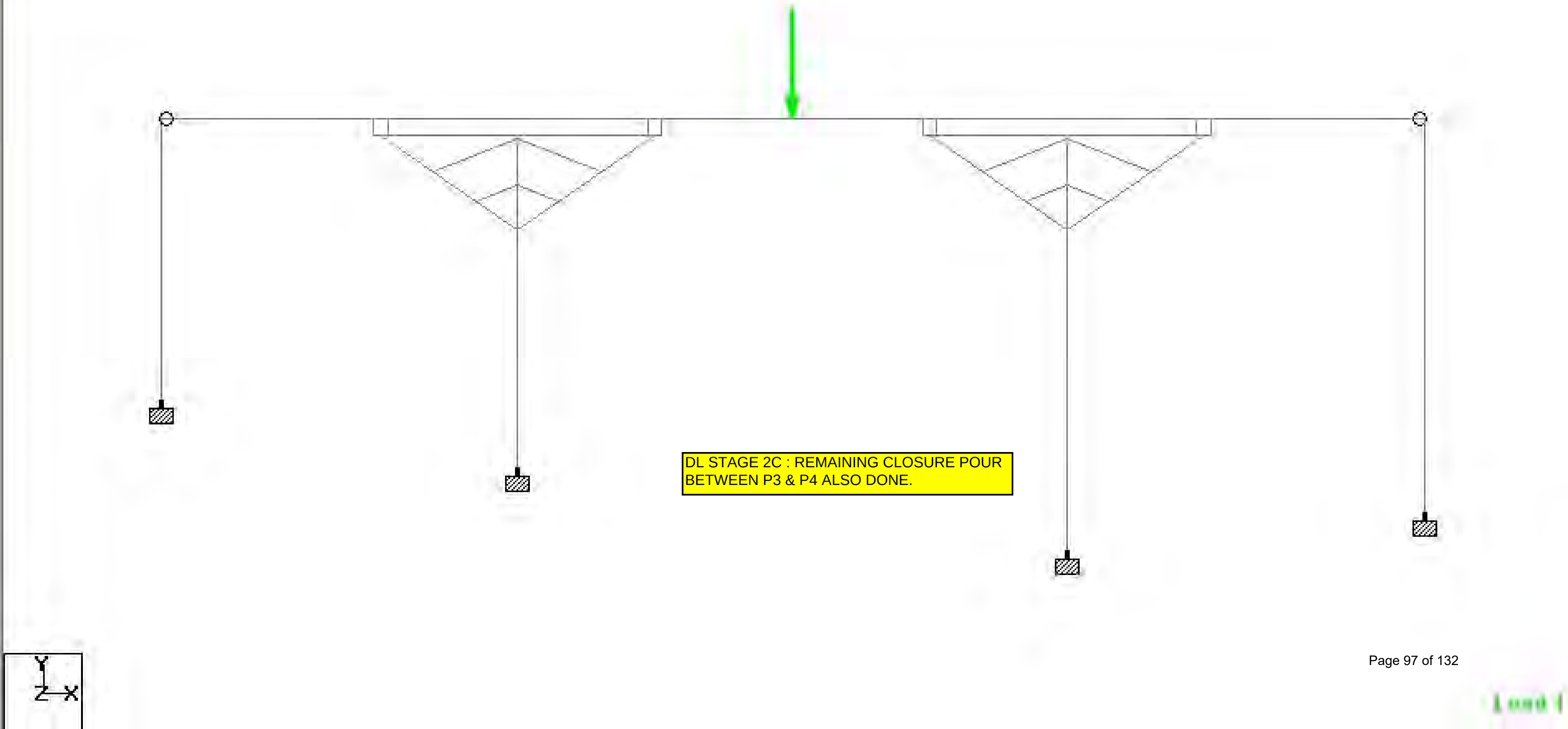
APPENDIX A

STAAD INPUT FILES


DL STAGE 1 : ONLY 39.5M CANTILEVER FROM EACH
PIER HEAD ACTIVE, OTHER MEMBER INACTIVE
Y
Z
X


DL STAGE 2A : SAME AS 1 + CLOSURE POUR AT P3 & P4 DONE AND TWO CLOSURE POUR MEMBERS ARE ACTIVE.
Y
Z
X


DL STAGE 2B : END 25.5 M PORTION NEAR P2 & P5
ALSO DONE.



DL STAGE 2C : REMAINING CLOSURE POUR
BETWEEN P3 & P4 ALSO DONE.
Y
Z
X

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STAAD SPACE DL STAGE 1
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ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
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11 19 39 47 67 75 95 103 PRIS AX 4.714 IX 8.319 IY 8.973 IZ 6.094
12 18 40 46 68 74 96 102 PRIS AX 4.922 IX 8.405 IY 9.086 IZ 6.41
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POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
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POISSON 0.17
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ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
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DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 2 TO 28 30 TO 56 58 TO 84 86 TO 112 114 TO 149
SUPPORTS
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PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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ENGINEER DATE 02-Nov-11
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100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
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END DEFINE MATERIAL
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MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 1 29 57 85 113 TO 149
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PRINT MEMBER FORCES
FINISH
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STAAD SPACE DL STAGE 2b
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ENGINEER DATE 02-Nov-11
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13 17 41 45 69 73 97 101 PRIS AX 5.132 IX 8.429 IY 9.203 IZ 6.667
14 TO 16 42 TO 44 70 TO 72 98 TO 99 -
100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
123 TO 130 PRIS AX 3 IX 1 IY 2.25 IZ 0.25
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POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
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E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 114 TO 149
SUPPORTS
115 142 TO 144 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
1 57 START FX FZ MX MY MZ
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LOAD 1 SELF
MEMBER LOAD
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PERFORM ANALYSIS
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POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
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END DEFINE MATERIAL
CONSTANTS
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SUPPORTS
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LOAD 1 SELF
MEMBER LOAD
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PERFORM ANALYSIS
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ENGINEER DATE 02-Nov-11
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PERFORM ANALYSIS
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FINISH
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ENGINEER DATE 02-Nov-11
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80 80 81; 81 81 82; 82 82 83; 83 83 84; 84 84 85; 85 85 86; 86 86 87;
87 87 88; 88 88 89; 89 89 90; 90 90 91; 91 91 92; 92 92 93; 93 93 94;
94 94 95; 95 95 96; 96 96 97; 97 97 98; 98 98 99; 99 99 100;
100 100 101; 101 101 102; 102 102 103; 103 103 104; 104 104 105;
105 105 106; 106 106 107; 107 107 108; 108 108 109; 109 109 110;
110 110 111; 111 111 112; 112 112 113; 113 113 114; 114 116 117;
115 117 118; 116 119 120; 117 120 121; 118 122 123; 119 123 124;
120 125 126; 121 126 127; 122 1 115; 123 15 116; 124 16 118; 125 43 119;
126 44 121; 127 71 122; 128 72 124; 129 99 125; 130 100 127;
131 114 142; 132 117 128; 133 128 129; 134 129 130; 135 130 131;
136 131 132; 137 132 133; 138 133 134; 139 134 120; 140 123 135;
141 135 136; 142 136 137; 143 137 138; 144 138 139; 145 139 140;
146 140 141; 147 141 126; 148 131 143; 149 138 144; 150 131 145;
151 145 146; 152 146 147; 153 138 148; 154 148 149; 155 149 150;
156 130 145; 157 145 132; 158 129 146; 159 146 133; 160 118 147;
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161 147 119; 162 137 148; 163 148 139; 164 136 149; 165 149 140;
166 124 150; 167 150 125;
MEMBER PROPERTY CANADIAN
1 TO 9 21 TO 37 49 TO 65 77 TO 93 105 TO 112 -
113 PRIS AX 4.407 IX 8.01 IY 8.811 IZ 5.499
10 20 38 48 66 76 94 104 PRIS AX 4.509 IX 8.134 IY 8.864 IZ 5.71
11 19 39 47 67 75 95 103 PRIS AX 4.714 IX 8.319 IY 8.973 IZ 6.094
12 18 40 46 68 74 96 102 PRIS AX 4.922 IX 8.405 IY 9.086 IZ 6.41
13 17 41 45 69 73 97 101 PRIS AX 5.132 IX 8.429 IY 9.203 IZ 6.667
14 TO 16 42 TO 44 70 TO 72 98 TO 99 -
100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
123 TO 130 PRIS AX 3 IX 1 IY 2.25 IZ 0.25
122 131 PRIS AX 32 IX 496.125 IY 282.667 IZ 410.667
148 149 PRIS AX 44 IX 1244.46 IY 654.667 IZ 1134.67
132 TO 147 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
150 TO 155 PRIS AX 1.5 IX 0.011 IY 36.75 IZ 0.5
156 TO 159 162 TO 165 PRIS AX 0.027 IX 6e-005 IY 6e-005 IZ 6e-005
160 161 166 167 PRIS AX 0.5 IX 0.00042 IY 12.25 IZ 0.167
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 2 TO 28 30 TO 56 58 TO 84 86 TO 112 114 TO 149
SUPPORTS
115 142 TO 144 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
122 131 START FY MZ
LOAD 1 CANTILEVER CABLES ONE GO
MEMBER PRESTRESS LOAD
*TOP CABLES
2 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
3 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
4 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
5 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
6 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
7 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
8 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
9 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
10 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
11 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
12 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
13 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
14 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
15 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
16 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
17 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
18 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
19 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
20 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
21 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
22 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
23 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
24 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
25 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
26 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
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27 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
28 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
30 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
31 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
32 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
33 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
34 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
35 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
36 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
37 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
38 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
39 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
40 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
41 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
42 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
43 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
44 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
45 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
46 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
47 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
48 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
49 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
50 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
51 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
52 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
53 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
54 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
55 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
56 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
58 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
59 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
60 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
61 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
62 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
63 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
64 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
65 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
66 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
67 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
68 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
69 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
70 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
71 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
72 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
73 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
74 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
75 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
76 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
77 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
78 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
79 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
80 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
81 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
82 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
83 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
84 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
86 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
87 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
88 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
89 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
90 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
91 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
92 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
93 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
94 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
95 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
96 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
97 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
98 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
99 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
100 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
101 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
102 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160

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103 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
104 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
105 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
106 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
107 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
108 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
109 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
110 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
111 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
112 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
LOAD 2 CONTINUITY CABLES ONE GO
MEMBER PRESTRESS LOAD
*span 1
1 FORCE 30482 ES -0.998 EM -1.034 EE -1.070
2 FORCE 31071 ES -1.070 EM -1.070 EE -1.070
3 FORCE 30980 ES -1.070 EM -1.070 EE -1.070
4 FORCE 30757 ES -1.070 EM -1.092 EE -1.113
5 FORCE 20422 ES -1.676 EM -1.644 EE -1.611
6 FORCE 17213 ES -1.676 EM -1.676 EE -1.676
7 FORCE 16970 ES -1.676 EM -1.598 EE -1.521
8 FORCE 10250 ES -1.676 EM -1.676 EE -1.676
9 FORCE 9983 ES -1.676 EM -1.482 EE -1.289
*span 5
113 FORCE 30482 ES -1.070 EM -1.034 EE -0.998
112 FORCE 31071 ES -1.070 EM -1.070 EE -1.070
111 FORCE 30980 ES -1.070 EM -1.070 EE -1.070
110 FORCE 30757 ES -1.113 EM -1.092 EE -1.070
109 FORCE 20422 ES -1.611 EM -1.644 EE -1.676
108 FORCE 17213 ES -1.676 EM -1.676 EE -1.676
107 FORCE 16970 ES -1.521 EM -1.598 EE -1.676
106 FORCE 10250 ES -1.676 EM -1.676 EE -1.676
105 FORCE 9983 ES -1.289 EM -1.482 EE -1.676
*span 2
21 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
22 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
23 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
24 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
25 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
26 FORCE 38278 ES -0.685 EM -0.685 EE -0.685
27 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
28 FORCE 38369 ES -0.685 EM -0.685 EE -0.685
29 FORCE 38423 ES -0.685 EM -0.685 EE -0.685
30 FORCE 38455 ES -0.685 EM -0.685 EE -0.685
31 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
32 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
33 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
34 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
35 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
36 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
37 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
*span 3
49 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
50 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
51 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
52 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
53 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
54 FORCE 38278 ES -0.685 EM -0.685 EE -0.685
55 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
56 FORCE 38369 ES -0.685 EM -0.685 EE -0.685
57 FORCE 38423 ES -0.685 EM -0.685 EE -0.685
58 FORCE 38455 ES -0.685 EM -0.685 EE -0.685
59 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
60 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
61 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
62 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
63 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
64 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
65 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
*span 4
77 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
78 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
79 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
80 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
```

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81 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
82 FORCE 38278 ES -0.685 EM -0.685 EE -0.685
83 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
84 FORCE 38369 ES -0.685 EM -0.685 EE -0.685
85 FORCE 38423 ES -0.685 EM -0.685 EE -0.685
86 FORCE 38455 ES -0.685 EM -0.685 EE -0.685
87 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
88 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
89 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
90 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
91 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
92 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
93 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
LOAD 3 CANTILEVER CABLES ONE GO
MEMBER POSTRESS LOAD
*TOP CABLES
2 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
3 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
4 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
5 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
6 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
7 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
8 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
9 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
10 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
11 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
12 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
13 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
14 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
15 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
16 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
17 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
18 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
19 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
20 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
21 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
22 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
23 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
24 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
25 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
26 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
27 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
28 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
30 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
31 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
32 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
33 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
34 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
35 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
36 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
37 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
38 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
39 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
40 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
41 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
42 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
43 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
44 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
45 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
46 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
47 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
48 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
49 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
50 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
51 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
52 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
53 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
54 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
55 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
56 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
58 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
59 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
60 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
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61 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
62 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
63 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
64 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
65 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
66 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
67 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
68 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
69 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
70 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
71 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
72 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
73 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
74 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
75 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
76 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
77 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
78 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
79 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
80 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
81 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
82 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
83 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
84 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
86 FORCE 6612.5 ES 0.961 EM 1.005 EE 1.048
87 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
88 FORCE 13321.1 ES 1.005 EM 1.026 EE 1.048
89 FORCE 19878.2 ES 1.019 EM 1.034 EE 1.048
90 FORCE 26651.7 ES 1.026 EM 1.037 EE 1.048
91 FORCE 33829.1 ES 1.031 EM 1.040 EE 1.048
92 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
93 FORCE 41116.8 ES 1.034 EM 1.041 EE 1.048
94 FORCE 48417.6 ES 1.036 EM 1.074 EE 1.113
95 FORCE 55259.4 ES 1.102 EM 1.136 EE 1.170
96 FORCE 61876.7 ES 1.160 EM 1.190 EE 1.219
97 FORCE 68562.1 ES 1.211 EM 1.236 EE 1.262
98 FORCE 68699.2 ES 1.262 EM 1.262 EE 1.262
99 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
100 FORCE 68705.6 ES 1.262 EM 1.262 EE 1.262
101 FORCE 68699.2 ES 1.262 EM 1.236 EE 1.211
102 FORCE 61876.7 ES 1.219 EM 1.190 EE 1.160
103 FORCE 55259.4 ES 1.170 EM 1.136 EE 1.102
104 FORCE 48417.6 ES 1.113 EM 1.074 EE 1.036
105 FORCE 41116.8 ES 1.048 EM 1.041 EE 1.034
106 FORCE 34188.8 ES 1.048 EM 1.048 EE 1.048
107 FORCE 33829.1 ES 1.048 EM 1.040 EE 1.031
108 FORCE 26651.7 ES 1.048 EM 1.037 EE 1.026
109 FORCE 19878.2 ES 1.048 EM 1.034 EE 1.019
110 FORCE 13321.1 ES 1.048 EM 1.026 EE 1.005
111 FORCE 6725.0 ES 1.048 EM 1.048 EE 1.048
112 FORCE 6612.5 ES 1.048 EM 1.005 EE 0.961
LOAD 4 CONTINUITY CABLES ONE GO
MEMBER POSTRESS LOAD
*span 1
1 FORCE 30482 ES -0.998 EM -1.034 EE -1.070
2 FORCE 31071 ES -1.070 EM -1.070 EE -1.070
3 FORCE 30980 ES -1.070 EM -1.070 EE -1.070
4 FORCE 30757 ES -1.070 EM -1.092 EE -1.113
5 FORCE 20422 ES -1.676 EM -1.644 EE -1.611
6 FORCE 17213 ES -1.676 EM -1.676 EE -1.676
7 FORCE 16970 ES -1.676 EM -1.598 EE -1.521
8 FORCE 10250 ES -1.676 EM -1.676 EE -1.676
9 FORCE 9983 ES -1.676 EM -1.482 EE -1.289
*span 5
113 FORCE 30482 ES -1.070 EM -1.034 EE -0.998
112 FORCE 31071 ES -1.070 EM -1.070 EE -1.070
111 FORCE 30980 ES -1.070 EM -1.070 EE -1.070
110 FORCE 30757 ES -1.113 EM -1.092 EE -1.070
109 FORCE 20422 ES -1.611 EM -1.644 EE -1.676
108 FORCE 17213 ES -1.676 EM -1.676 EE -1.676
107 FORCE 16970 ES -1.521 EM -1.598 EE -1.676
106 FORCE 10250 ES -1.676 EM -1.676 EE -1.676
105 FORCE 9983 ES -1.289 EM -1.482 EE -1.676
```

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*span 2
21 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
22 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
23 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
24 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
25 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
26 FORCE 38278 ES -0.685 EM -0.685 EE -0.685
27 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
28 FORCE 38369 ES -0.685 EM -0.685 EE -0.685
29 FORCE 38423 ES -0.685 EM -0.685 EE -0.685
30 FORCE 38455 ES -0.685 EM -0.685 EE -0.685
31 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
32 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
33 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
34 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
35 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
36 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
37 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
*span 3
49 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
50 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
51 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
52 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
53 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
54 FORCE 38278 ES -0.685 EM -0.685 EE -0.685
55 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
56 FORCE 38369 ES -0.685 EM -0.685 EE -0.685
57 FORCE 38423 ES -0.685 EM -0.685 EE -0.685
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59 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
60 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
61 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
62 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
63 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
64 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
65 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
*span 4
77 FORCE 10072 ES -1.289 EM -1.482 EE -1.676
78 FORCE 17345 ES -1.521 EM -1.598 EE -1.676
79 FORCE 20915 ES -1.611 EM -1.644 EE -1.676
80 FORCE 37377 ES -0.791 EM -0.738 EE -0.685
81 FORCE 38146 ES -0.685 EM -0.685 EE -0.685
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83 FORCE 38346 ES -0.685 EM -0.685 EE -0.685
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86 FORCE 38455 ES -0.685 EM -0.685 EE -0.685
87 FORCE 38432 ES -0.685 EM -0.685 EE -0.685
88 FORCE 38365 ES -0.685 EM -0.685 EE -0.685
89 FORCE 38233 ES -0.685 EM -0.685 EE -0.685
90 FORCE 36380 ES -0.685 EM -0.012 EE 0.661
91 FORCE 20915 ES -1.676 EM -1.644 EE -1.611
92 FORCE 17345 ES -1.676 EM -1.598 EE -1.521
93 FORCE 10072 ES -1.676 EM -1.482 EE -1.289
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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STAAD SPACE TEMP GRADIENT LOAD
START JOB INFORMATION
ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
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113 PRIS AX 4.407 IX 8.01 IY 8.811 IZ 5.499
10 20 38 48 66 76 94 104 PRIS AX 4.509 IX 8.134 IY 8.864 IZ 5.71
11 19 39 47 67 75 95 103 PRIS AX 4.714 IX 8.319 IY 8.973 IZ 6.094
12 18 40 46 68 74 96 102 PRIS AX 4.922 IX 8.405 IY 9.086 IZ 6.41
13 17 41 45 69 73 97 101 PRIS AX 5.132 IX 8.429 IY 9.203 IZ 6.667
14 TO 16 42 TO 44 70 TO 72 98 TO 99 -
100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
123 TO 130 PRIS AX 3 IX 1 IY 2.25 IZ 0.25
122 131 PRIS AX 32 IX 496.125 IY 282.667 IZ 410.667
148 149 PRIS AX 44 IX 1244.46 IY 654.667 IZ 1134.67
132 TO 147 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
150 TO 155 PRIS AX 1.5 IX 0.011 IY 36.75 IZ 0.5
156 TO 159 162 TO 165 PRIS AX 0.027 IX 6e-005 IY 6e-005 IZ 6e-005
160 161 166 167 PRIS AX 0.5 IX 0.00042 IY 12.25 IZ 0.167
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 2 TO 28 30 TO 56 58 TO 84 86 TO 112 114 TO 149
SUPPORTS
115 142 TO 144 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
1 START FX FZ MX MY MZ
113 END FX FZ MX MY MZ
*111 TO 114 START MZ
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FIXED END FORCE
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74 5109 0 0 0 0 -2713 -5109 0 0 0 0 2460
75 5109 0 0 0 0 -2460 -5091 0 0 0 0 2193
76 5091 0 0 0 0 -2193 -5044 0 0 0 0 1933
77 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
78 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
79 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
80 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
81 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
82 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
83 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
84 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
85 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
86 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
87 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
88 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
89 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
90 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
91 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
92 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
93 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
94 5044 0 0 0 0 -1933 -5091 0 0 0 0 2193
95 5091 0 0 0 0 -2193 -5109 0 0 0 0 2460
96 5109 0 0 0 0 -2460 -5109 0 0 0 0 2713
97 5109 0 0 0 0 -2713 -5109 0 0 0 0 2932
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99 5109 0 0 0 0 -2932 -5109 0 0 0 0 2932
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101 5109 0 0 0 0 -2932 -5109 0 0 0 0 2713
102 5109 0 0 0 0 -2713 -5109 0 0 0 0 2460
103 5109 0 0 0 0 -2460 -5091 0 0 0 0 2193
104 5091 0 0 0 0 -2193 -5044 0 0 0 0 1933
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106 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
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111 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
112 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
113 5044 0 0 0 0 -1933 -5044 0 0 0 0 1933
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
```

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STAAD SPACE DIFF SETTLEMENT
START JOB INFORMATION
ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
JOINT COORDINATES
1 0 0 0; 2 24.75 0 0; 3 27.75 0 0; 4 30.75 0 0; 5 33.75 0 0;
6 36.75 0 0; 7 39.75 0 0; 8 42.75 0 0; 9 45.75 0 0; 10 48.75 0 0;
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16 66.25 0 0; 17 67.75 0 0; 18 70.75 0 0; 19 73.75 0 0; 20 76.75 0 0;
21 79.75 0 0; 22 82.75 0 0; 23 85.75 0 0; 24 88.75 0 0; 25 91.75 0 0;
26 94.75 0 0; 27 97.75 0 0; 28 100.75 0 0; 29 103.75 0 0; 30 104.75 0 0;
31 107.75 0 0; 32 110.75 0 0; 33 113.75 0 0; 34 116.75 0 0;
35 119.75 0 0; 36 122.75 0 0; 37 125.75 0 0; 38 128.75 0 0;
39 131.75 0 0; 40 134.75 0 0; 41 137.75 0 0; 42 140.75 0 0;
43 142.25 0 0; 44 146.25 0 0; 45 147.75 0 0; 46 150.75 0 0;
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55 177.75 0 0; 56 180.75 0 0; 57 183.75 0 0; 58 184.75 0 0;
59 187.75 0 0; 60 190.75 0 0; 61 193.75 0 0; 62 196.75 0 0;
63 199.75 0 0; 64 202.75 0 0; 65 205.75 0 0; 66 208.75 0 0;
67 211.75 0 0; 68 214.75 0 0; 69 217.75 0 0; 70 220.75 0 0;
71 222.25 0 0; 72 226.25 0 0; 73 227.75 0 0; 74 230.75 0 0;
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79 245.75 0 0; 80 248.75 0 0; 81 251.75 0 0; 82 254.75 0 0;
83 257.75 0 0; 84 260.75 0 0; 85 263.75 0 0; 86 264.75 0 0;
87 267.75 0 0; 88 270.75 0 0; 89 273.75 0 0; 90 276.75 0 0;
91 279.75 0 0; 92 282.75 0 0; 93 285.75 0 0; 94 288.75 0 0;
95 291.75 0 0; 96 294.75 0 0; 97 297.75 0 0; 98 300.75 0 0;
99 302.25 0 0; 100 306.25 0 0; 101 307.75 0 0; 102 310.75 0 0;
103 313.75 0 0; 104 316.75 0 0; 105 319.75 0 0; 106 322.75 0 0;
107 325.75 0 0; 108 328.75 0 0; 109 331.75 0 0; 110 334.75 0 0;
111 337.75 0 0; 112 340.75 0 0; 113 343.75 0 0; 114 368.5 0 0;
115 0 -82 0; 116 62.25 -5 0; 117 64.25 -5 0; 118 66.25 -5 0;
119 142.25 -5 0; 120 144.25 -5 0; 121 146.25 -5 0; 122 222.25 -5 0;
123 224.25 -5 0; 124 226.25 -5 0; 125 302.25 -5 0; 126 304.25 -5 0;
127 306.25 -5 0; 128 67.098 -6.945 0; 129 79.606 -15.488 0;
130 92.107 -24.026 0; 131 104.25 -32.319 0; 132 116.393 -24.026 0;
133 128.894 -15.488 0; 134 141.402 -6.945 0; 135 227.098 -6.945 0;
136 239.606 -15.488 0; 137 252.107 -24.026 0; 138 264.25 -32.319 0;
139 276.393 -24.026 0; 140 288.894 -15.488 0; 141 301.402 -6.945 0;
142 368.5 -115 0; 143 104.25 -102 0; 144 264.25 -126 0;
145 104.25 -19.214 0; 146 104.25 -5.695 0; 147 104.25 -5 0;
148 264.25 -19.214 0; 149 264.25 -5.695 0; 150 264.25 -5 0;
MEMBER INCIDENCES
1 1 2; 2 2 3; 3 3 4; 4 4 5; 5 5 6; 6 6 7; 7 7 8; 8 8 9; 9 9 10;
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17 17 18; 18 18 19; 19 19 20; 20 20 21; 21 21 22; 22 22 23; 23 23 24;
24 24 25; 25 25 26; 26 26 27; 27 27 28; 28 28 29; 29 29 30; 30 30 31;
31 31 32; 32 32 33; 33 33 34; 34 34 35; 35 35 36; 36 36 37; 37 37 38;
38 38 39; 39 39 40; 40 40 41; 41 41 42; 42 42 43; 43 43 44; 44 44 45;
45 45 46; 46 46 47; 47 47 48; 48 48 49; 49 49 50; 50 50 51; 51 51 52;
52 52 53; 53 53 54; 54 54 55; 55 55 56; 56 56 57; 57 57 58; 58 58 59;
59 59 60; 60 60 61; 61 61 62; 62 62 63; 63 63 64; 64 64 65; 65 65 66;
66 66 67; 67 67 68; 68 68 69; 69 69 70; 70 70 71; 71 71 72; 72 72 73;
73 73 74; 74 74 75; 75 75 76; 76 76 77; 77 77 78; 78 78 79; 79 79 80;
80 80 81; 81 81 82; 82 82 83; 83 83 84; 84 84 85; 85 85 86; 86 86 87;
87 87 88; 88 88 89; 89 89 90; 90 90 91; 91 91 92; 92 92 93; 93 93 94;
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110 110 111; 111 111 112; 112 112 113; 113 113 114; 114 116 117;
115 117 118; 116 119 120; 117 120 121; 118 122 123; 119 123 124;
120 125 126; 121 126 127; 122 1 115; 123 15 116; 124 16 118; 125 43 119;
126 44 121; 127 71 122; 128 72 124; 129 99 125; 130 100 127;
131 114 142; 132 117 128; 133 128 129; 134 129 130; 135 130 131;
136 131 132; 137 132 133; 138 133 134; 139 134 120; 140 123 135;
141 135 136; 142 136 137; 143 137 138; 144 138 139; 145 139 140;
146 140 141; 147 141 126; 148 131 143; 149 138 144; 150 131 145;
151 145 146; 152 146 147; 153 138 148; 154 148 149; 155 149 150;
156 130 145; 157 145 132; 158 129 146; 159 146 133; 160 118 147;
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161 147 119; 162 137 148; 163 148 139; 164 136 149; 165 149 140;
166 124 150; 167 150 125;
MEMBER PROPERTY CANADIAN
1 TO 9 21 TO 37 49 TO 65 77 TO 93 105 TO 112 -
113 PRIS AX 4.407 IX 8.01 IY 8.811 IZ 5.499
10 20 38 48 66 76 94 104 PRIS AX 4.509 IX 8.134 IY 8.864 IZ 5.71
11 19 39 47 67 75 95 103 PRIS AX 4.714 IX 8.319 IY 8.973 IZ 6.094
12 18 40 46 68 74 96 102 PRIS AX 4.922 IX 8.405 IY 9.086 IZ 6.41
13 17 41 45 69 73 97 101 PRIS AX 5.132 IX 8.429 IY 9.203 IZ 6.667
14 TO 16 42 TO 44 70 TO 72 98 TO 99 -
100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
123 TO 130 PRIS AX 3 IX 1 IY 2.25 IZ 0.25
122 131 PRIS AX 32 IX 496.125 IY 282.667 IZ 410.667
148 149 PRIS AX 44 IX 1244.46 IY 654.667 IZ 1134.67
132 TO 147 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
150 TO 155 PRIS AX 1.5 IX 0.011 IY 36.75 IZ 0.5
156 TO 159 162 TO 165 PRIS AX 0.027 IX 6e-005 IY 6e-005 IZ 6e-005
160 161 166 167 PRIS AX 0.5 IX 0.00042 IY 12.25 IZ 0.167
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 114 TO 149
SUPPORTS
115 142 TO 144 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
1 START FX FZ MX MY MZ
113 END FX FZ MX MY MZ
LOAD 1 SUPPORT 2 AND 4 SETTLES
SUPPORT DISPLACEMENT LOAD
115 144 FY -0.0125
LOAD 2 SUPPORT 1 AND 2 SETTLES
SUPPORT DISPLACEMENT LOAD
143 144 FY -0.0125
LOAD 3 SUPPORT 1 AND 3 SETTLES
SUPPORT DISPLACEMENT LOAD
142 144 FY -0.0125
LOAD 4 SUPPORT 1 3 AND 5 SETTLES
SUPPORT DISPLACEMENT LOAD
115 143 144 FY -0.0125
PERFORM ANALYSIS
PRINT MEMBER FORCES
FINISH
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STAAD SPACE LIVE LOAD
START JOB INFORMATION
ENGINEER DATE 02-Nov-11
END JOB INFORMATION
INPUT WIDTH 72
PAGE LENGTH 15000
UNIT METER MTON
JOINT COORDINATES
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51 165.75 0 0; 52 168.75 0 0; 53 171.75 0 0; 54 174.75 0 0;
55 177.75 0 0; 56 180.75 0 0; 57 183.75 0 0; 58 184.75 0 0;
59 187.75 0 0; 60 190.75 0 0; 61 193.75 0 0; 62 196.75 0 0;
63 199.75 0 0; 64 202.75 0 0; 65 205.75 0 0; 66 208.75 0 0;
67 211.75 0 0; 68 214.75 0 0; 69 217.75 0 0; 70 220.75 0 0;
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87 267.75 0 0; 88 270.75 0 0; 89 273.75 0 0; 90 276.75 0 0;
91 279.75 0 0; 92 282.75 0 0; 93 285.75 0 0; 94 288.75 0 0;
95 291.75 0 0; 96 294.75 0 0; 97 297.75 0 0; 98 300.75 0 0;
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107 325.75 0 0; 108 328.75 0 0; 109 331.75 0 0; 110 334.75 0 0;
111 337.75 0 0; 112 340.75 0 0; 113 343.75 0 0; 114 368.5 0 0;
115 0 -82 0; 116 62.25 -5 0; 117 64.25 -5 0; 118 66.25 -5 0;
119 142.25 -5 0; 120 144.25 -5 0; 121 146.25 -5 0; 122 222.25 -5 0;
123 224.25 -5 0; 124 226.25 -5 0; 125 302.25 -5 0; 126 304.25 -5 0;
127 306.25 -5 0; 128 67.098 -6.945 0; 129 79.606 -15.488 0;
130 92.107 -24.026 0; 131 104.25 -32.319 0; 132 116.393 -24.026 0;
133 128.894 -15.488 0; 134 141.402 -6.945 0; 135 227.098 -6.945 0;
136 239.606 -15.488 0; 137 252.107 -24.026 0; 138 264.25 -32.319 0;
139 276.393 -24.026 0; 140 288.894 -15.488 0; 141 301.402 -6.945 0;
142 368.5 -115 0; 143 104.25 -102 0; 144 264.25 -126 0;
145 104.25 -19.214 0; 146 104.25 -5.695 0; 147 104.25 -5 0;
148 264.25 -19.214 0; 149 264.25 -5.695 0; 150 264.25 -5 0;
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38 38 39; 39 39 40; 40 40 41; 41 41 42; 42 42 43; 43 43 44; 44 44 45;
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66 66 67; 67 67 68; 68 68 69; 69 69 70; 70 70 71; 71 71 72; 72 72 73;
73 73 74; 74 74 75; 75 75 76; 76 76 77; 77 77 78; 78 78 79; 79 79 80;
80 80 81; 81 81 82; 82 82 83; 83 83 84; 84 84 85; 85 85 86; 86 86 87;
87 87 88; 88 88 89; 89 89 90; 90 90 91; 91 91 92; 92 92 93; 93 93 94;
94 94 95; 95 95 96; 96 96 97; 97 97 98; 98 98 99; 99 99 100;
100 100 101; 101 101 102; 102 102 103; 103 103 104; 104 104 105;
105 105 106; 106 106 107; 107 107 108; 108 108 109; 109 109 110;
110 110 111; 111 111 112; 112 112 113; 113 113 114; 114 116 117;
115 117 118; 116 119 120; 117 120 121; 118 122 123; 119 123 124;
120 125 126; 121 126 127; 122 1 115; 123 15 116; 124 16 118; 125 43 119;
126 44 121; 127 71 122; 128 72 124; 129 99 125; 130 100 127;
131 114 142; 132 117 128; 133 128 129; 134 129 130; 135 130 131;
136 131 132; 137 132 133; 138 133 134; 139 134 120; 140 123 135;
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166 124 150; 167 150 125;
MEMBER PROPERTY CANADIAN
1 TO 9 21 TO 37 49 TO 65 77 TO 93 105 TO 112 -
113 PRIS AX 4.407 IX 8.01 IY 8.811 IZ 5.499
10 20 38 48 66 76 94 104 PRIS AX 4.509 IX 8.134 IY 8.864 IZ 5.71
11 19 39 47 67 75 95 103 PRIS AX 4.714 IX 8.319 IY 8.973 IZ 6.094
12 18 40 46 68 74 96 102 PRIS AX 4.922 IX 8.405 IY 9.086 IZ 6.41
13 17 41 45 69 73 97 101 PRIS AX 5.132 IX 8.429 IY 9.203 IZ 6.667
14 TO 16 42 TO 44 70 TO 72 98 TO 99 -
100 PRIS AX 5.238 IX 8.427 IY 9.262 IZ 6.783
114 TO 121 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
123 TO 130 PRIS AX 3 IX 1 IY 2.25 IZ 0.25
122 131 PRIS AX 32 IX 496.125 IY 282.667 IZ 410.667
148 149 PRIS AX 44 IX 1244.46 IY 654.667 IZ 1134.67
132 TO 147 PRIS AX 18 IX 205.031 IY 76.5 IZ 411
150 TO 155 PRIS AX 1.5 IX 0.011 IY 36.75 IZ 0.5
156 TO 159 162 TO 165 PRIS AX 0.027 IX 6e-005 IY 6e-005 IZ 6e-005
160 161 166 167 PRIS AX 0.5 IX 0.00042 IY 12.25 IZ 0.167
DEFINE MATERIAL START
ISOTROPIC MATERIAL1
E 3.6e+006
POISSON 0.17
DENSITY 2.5
ALPHA 1.2e-005
ISOTROPIC MATERIAL2
E 2e+007
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
ISOTROPIC MATERIAL3
E 3.6e+006
POISSON 0.17
DENSITY 0
ALPHA 1.2e-005
END DEFINE MATERIAL
CONSTANTS
MATERIAL MATERIAL1 ALL
MATERIAL MATERIAL2 MEMB 150 TO 167
MATERIAL MATERIAL3 MEMB 114 TO 149
SUPPORTS
115 142 TO 144 FIXED
*2 131 FIXED BUT FX MY MZ
MEMBER RELEASE
1 START FX FZ MX MY MZ
113 END FX FZ MX MY MZ
DEFINE MOVING LOAD
TYPE 1 LOAD 17 17 17 17 12 12 8
DIST 1.37 3.05 1.37 2.13 1.52 3.96
TYPE 2 LOAD 2.7 2.7 11.4 11.4 6.8 6.8 6.8 6.8
DIST 1.1 3.2 1.2 4.3 3 3 3
LOAD GENERATION 160
TYPE 1 -10 0 0 XINC 2.0
TYPE 1 34.92 0 0 XINC 2.0
LOAD GENERATION 170
TYPE 1 -10 0 0 XINC 2.2
LOAD GENERATION 135
TYPE 1 -10 0 0 XINC 2
TYPE 1 34.92 0 0 XINC 2
TYPE 1 79.84 0 0 XINC 2
LOAD GENERATION 115
TYPE 1 -10 0 0 XINC 2.
TYPE 1 34.92 0 0 XINC 2.
TYPE 1 79.84 0 0 XINC 2.
TYPE 1 124.76 0 0 XINC 2.
PERFORM ANALYSIS
PRINT FORCE ENVELOPE NSEC 1
FINISH
```

APPENDIX B
STAAD OUTPUT (PROCESSED)

TABLE B.1 **STAAD OUTPUT AT I END (UNIT T, TM) FOR DEAD LOAD OF BOX**

(Shear, torsion and bending at I end of all the members are reproduced from STAAD Output)

	DEAD LOAD STAGE 1				DEAD LOAD STAGE 2A				DEAD LOAD STAGE 2B				DEAD LOAD STAGE 2C				DEAD LOAD INSTANTANIOUS			
S NO.	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending
1	0	0	0	0	0	0	0	0	0	201	0	0	0	0	0	0	0	263	0	0
2	0	0	0	0	0	0	0	0	0	-76	0	-1546	0	0	0	1	0	-10	0	-3124
3	0	-33	0	50	0	0	0	0	0	-76	0	-1318	0	0	0	1	0	-43	0	-3044
4	0	-66	0	198	0	0	0	0	0	-76	0	-1089	0	0	0	1	0	-76	0	-2865
5	0	-99	0	446	0	0	0	0	0	-76	0	-861	0	0	0	2	0	-109	0	-2586
6	0	-132	0	793	0	0	0	0	0	-76	0	-633	0	0	0	2	0	-142	0	-2209
7	0	-165	0	1239	0	0	0	0	0	-76	0	-404	0	0	0	2	0	-175	0	-1732
8	0	-198	0	1785	0	0	0	0	0	-76	0	-176	0	0	0	2	0	-208	0	-1157
9	0	-231	0	2429	0	0	0	0	0	-76	0	52	0	0	0	2	0	-242	0	-482
10	0	-264	0	3173	0	0	0	0	0	-76	0	281	0	0	0	2	0	-275	0	292
11	0	-298	0	4017	0	0	0	0	0	-76	0	509	0	0	0	2	0	-308	0	1167
12	0	-334	0	4965	0	0	0	0	0	-76	0	738	0	0	0	2	0	-344	0	2145
13	0	-371	0	6021	0	0	0	0	0	-76	0	966	0	0	0	3	0	-381	0	3231
14	0	-409	0	7190	0	0	0	0	0	-76	0	1194	0	0	0	3	0	-419	0	4431
15	-130	26	0	7385	0	-24	0	0	-29	277	0	1211	0	1	0	2	-246	-234	0	4401
16	0	429	0	7818	1	6	0	103	-35	2	0	83	-1	0	0	-2	-321	434	0	5339
17	0	409	0	7190	1	6	0	95	-35	2	0	81	-1	0	0	-2	-321	414	0	4703
18	0	371	0	6021	1	6	0	78	-35	2	0	75	-1	0	0	-2	-321	376	0	3517
19	0	334	0	4965	1	6	0	61	-35	2	0	70	-1	0	0	-2	-321	339	0	2445
20	0	298	0	4017	1	6	0	45	-35	2	0	65	-1	0	0	-1	-321	304	0	1481
21	0	264	0	3173	1	6	0	28	-35	2	0	60	-1	0	0	-1	-321	270	0	621
22	0	231	0	2429	1	6	0	11	-35	2	0	54	-1	0	0	-1	-321	237	0	-139
23	0	198	0	1785	1	6	0	-6	-35	2	0	49	-1	0	0	-1	-321	204	0	-800
24	0	165	0	1239	1	6	0	-23	-35	2	0	44	-1	0	0	0	-321	171	0	-1362
25	0	132	0	793	1	6	0	-39	-35	2	0	38	-1	0	0	0	-321	138	0	-1824
26	0	99	0	446	1	6	0	-56	-35	2	0	33	-1	0	0	0	-321	105	0	-2187
27	0	66	0	198	1	6	0	-73	-35	2	0	28	-1	0	0	1	-321	72	0	-2451
28	0	33	0	50	1	6	0	-90	-35	2	0	23	-1	0	0	1	-321	38	0	-2616
29	0	0	0	0	1	6	0	-107	-35	2	0	17	-1	0	0	1	-321	5	0	-2682
30	0	0	0	0	1	-6	0	-107	-35	2	0	15	-1	0	0	1	-321	-6	0	-2682
31	0	-33	0	50	1	-6	0	-90	-35	2	0	10	-1	0	0	2	-321	-39	0	-2616
32	0	-66	0	198	1	-6	0	-73	-35	2	0	5	-1	0	0	2	-321	-72	0	-2450
33	0	-99	0	446	1	-6	0	-56	-35	2	0	0	-1	0	0	2	-321	-105	0	-2186
34	0	-132	0	793	1	-6	0	-39	-35	2	0	-6	-1	0	0	2	-321	-138	0	-1822
35	0	-165	0	1239	1	-6	0	-23	-35	2	0	-11	-1	0	0	3	-321	-171	0	-1359
36	0	-198	0	1785	1	-6	0	-6	-35	2	0	-16	-1	0	0	3	-321	-204	0	-796
37	0	-231	0	2429	1	-6	0	11	-35	2	0	-22	-1	0	0	3	-321	-237	0	-135

TABLE B.1 **STAAD OUTPUT AT I END (UNIT T, TM) FOR DEAD LOAD OF BOX**

(Shear, torsion and bending at I end of all the members are reproduced from STAAD Output)

	DEAD LOAD STAGE 1				DEAD LOAD STAGE 2A				DEAD LOAD STAGE 2B				DEAD LOAD STAGE 2C				DEAD LOAD INSTANTANIOUS			
S NO.	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending
38	0	-264	0	3173	1	-6	0	28	-35	2	0	-27	-1	0	0	4	-321	-270	0	625
39	0	-298	0	4017	1	-6	0	45	-35	2	0	-32	-1	0	0	4	-321	-304	0	1486
40	0	-334	0	4965	1	-6	0	61	-35	2	0	-37	-1	0	0	4	-321	-339	0	2451
41	0	-371	0	6021	1	-6	0	78	-35	2	0	-43	-1	0	0	4	-321	-376	0	3524
42	0	-409	0	7190	1	-6	0	95	-35	2	0	-48	-1	0	0	5	-321	-415	0	4710
43	-130	26	0	7385	0	24	0	97	-17	9	0	-6	1	-20	0	10	-244	247	0	5454
44	0	429	0	7818	0	0	0	0	0	0	0	0	4	6	0	101	6	434	0	5259
45	0	409	0	7190	0	0	0	0	0	0	0	0	4	6	0	93	6	415	0	4623
46	0	371	0	6021	0	0	0	0	0	0	0	0	4	6	0	76	6	376	0	3437
47	0	334	0	4965	0	0	0	0	0	0	0	0	4	6	0	59	6	339	0	2364
48	0	298	0	4017	0	0	0	0	0	0	0	0	4	6	0	43	6	304	0	1400
49	0	264	0	3173	0	0	0	0	0	0	0	0	4	6	0	26	6	270	0	540
50	0	231	0	2429	0	0	0	0	0	0	0	0	4	6	0	9	6	237	0	-220
51	0	198	0	1785	0	0	0	0	0	0	0	0	4	6	0	-8	6	204	0	-881
52	0	165	0	1239	0	0	0	0	0	0	0	0	4	6	0	-24	6	171	0	-1443
53	0	132	0	793	0	0	0	0	0	0	0	0	4	6	0	-41	6	138	0	-1906
54	0	99	0	446	0	0	0	0	0	0	0	0	4	6	0	-58	6	105	0	-2270
55	0	66	0	198	0	0	0	0	0	0	0	0	4	6	0	-74	6	72	0	-2534
56	0	33	0	50	0	0	0	0	0	0	0	0	4	6	0	-91	6	39	0	-2699
57	0	0	0	0	0	0	0	0	0	0	0	0	4	6	0	-108	6	6	0	-2765
58	0	0	0	0	0	0	0	0	0	0	0	0	4	-6	0	-108	6	-6	0	-2765
59	0	-33	0	50	0	0	0	0	0	0	0	0	4	-6	0	-91	6	-39	0	-2699
60	0	-66	0	198	0	0	0	0	0	0	0	0	4	-6	0	-74	6	-72	0	-2534
61	0	-99	0	446	0	0	0	0	0	0	0	0	4	-6	0	-57	6	-105	0	-2269
62	0	-132	0	793	0	0	0	0	0	0	0	0	4	-6	0	-40	6	-138	0	-1906
63	0	-165	0	1239	0	0	0	0	0	0	0	0	4	-6	0	-23	6	-171	0	-1443
64	0	-198	0	1785	0	0	0	0	0	0	0	0	4	-6	0	-6	6	-204	0	-881
65	0	-231	0	2429	0	0	0	0	0	0	0	0	4	-6	0	10	6	-237	0	-220
66	0	-264	0	3173	0	0	0	0	0	0	0	0	4	-6	0	27	6	-270	0	540
67	0	-298	0	4017	0	0	0	0	0	0	0	0	4	-6	0	44	6	-304	0	1401
68	0	-334	0	4965	0	0	0	0	0	0	0	0	4	-6	0	61	6	-339	0	2365
69	0	-371	0	6021	0	0	0	0	0	0	0	0	4	-6	0	78	6	-376	0	3438
70	0	-409	0	7190	0	0	0	0	0	0	0	0	4	-6	0	95	6	-415	0	4624
71	-130	26	0	7385	0	-24	0	0	-17	-9	0	-41	1	21	0	93	-244	-194	0	4572
72	0	429	0	7818	1	6	0	103	-34	-2	0	-50	-1	0	0	5	-321	434	0	5347
73	0	409	0	7190	1	6	0	95	-34	-2	0	-47	-1	0	0	5	-321	415	0	4710
74	0	371	0	6021	1	6	0	78	-34	-2	0	-42	-1	0	0	5	-321	376	0	3524

TABLE B.1 **STAAD OUTPUT AT I END (UNIT T, TM) FOR DEAD LOAD OF BOX**

(Shear, torsion and bending at I end of all the members are reproduced from STAAD Output)

	DEAD LOAD STAGE 1				DEAD LOAD STAGE 2A				DEAD LOAD STAGE 2B				DEAD LOAD STAGE 2C				DEAD LOAD INSTANTANIOUS			
S NO.	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending
75	0	334	0	4965	1	6	0	61	-34	-2	0	-37	-1	0	0	4	-321	339	0	2451
76	0	298	0	4017	1	6	0	45	-34	-2	0	-31	-1	0	0	4	-321	304	0	1486
77	0	264	0	3173	1	6	0	28	-34	-2	0	-26	-1	0	0	4	-321	270	0	626
78	0	231	0	2429	1	6	0	11	-34	-2	0	-21	-1	0	0	3	-321	237	0	-135
79	0	198	0	1785	1	6	0	-6	-34	-2	0	-16	-1	0	0	3	-321	204	0	-796
80	0	165	0	1239	1	6	0	-23	-34	-2	0	-11	-1	0	0	3	-321	171	0	-1359
81	0	132	0	793	1	6	0	-39	-34	-2	0	-6	-1	0	0	2	-321	138	0	-1822
82	0	99	0	446	1	6	0	-56	-34	-2	0	0	-1	0	0	2	-321	105	0	-2186
83	0	66	0	198	1	6	0	-73	-34	-2	0	5	-1	0	0	2	-321	72	0	-2450
84	0	33	0	50	1	6	0	-90	-34	-2	0	10	-1	0	0	2	-321	39	0	-2616
85	0	0	0	0	1	6	0	-107	-34	-2	0	15	-1	0	0	1	-321	6	0	-2682
86	0	0	0	0	1	-6	0	-107	-34	-2	0	17	-1	0	0	1	-321	-5	0	-2682
87	0	-33	0	50	1	-6	0	-90	-34	-2	0	22	-1	0	0	1	-321	-38	0	-2617
88	0	-66	0	198	1	-6	0	-73	-34	-2	0	27	-1	0	0	1	-321	-72	0	-2452
89	0	-99	0	446	1	-6	0	-56	-34	-2	0	32	-1	0	0	0	-321	-105	0	-2188
90	0	-132	0	793	1	-6	0	-39	-34	-2	0	38	-1	0	0	0	-321	-138	0	-1824
91	0	-165	0	1239	1	-6	0	-23	-34	-2	0	43	-1	0	0	0	-321	-171	0	-1362
92	0	-198	0	1785	1	-6	0	-6	-34	-2	0	48	-1	0	0	-1	-321	-204	0	-800
93	0	-231	0	2429	1	-6	0	11	-34	-2	0	53	-1	0	0	-1	-321	-237	0	-140
94	0	-264	0	3173	1	-6	0	28	-34	-2	0	58	-1	0	0	-1	-321	-270	0	620
95	0	-298	0	4017	1	-6	0	45	-34	-2	0	63	-1	0	0	-2	-321	-304	0	1481
96	0	-334	0	4965	1	-6	0	61	-34	-2	0	69	-1	0	0	-2	-321	-339	0	2445
97	0	-371	0	6021	1	-6	0	78	-34	-2	0	74	-1	0	0	-2	-321	-376	0	3517
98	0	-409	0	7190	1	-6	0	95	-34	-2	0	79	-1	0	0	-2	-321	-414	0	4702
99	-130	26	0	7385	0	24	0	97	-28	-268	0	103	0	0	0	-1	-245	288	0	5442
100	0	429	0	7818	0	0	0	0	0	76	0	1272	0	0	0	2	0	439	0	5066
101	0	409	0	7190	0	0	0	0	0	76	0	1159	0	0	0	2	0	419	0	4423
102	0	371	0	6021	0	0	0	0	0	76	0	932	0	0	0	2	0	381	0	3223
103	0	334	0	4965	0	0	0	0	0	76	0	705	0	0	0	1	0	344	0	2137
104	0	298	0	4017	0	0	0	0	0	76	0	479	0	0	0	1	0	308	0	1160
105	0	264	0	3173	0	0	0	0	0	76	0	252	0	0	0	1	0	274	0	286
106	0	231	0	2429	0	0	0	0	0	76	0	26	0	0	0	1	0	241	0	-488
107	0	198	0	1785	0	0	0	0	0	76	0	-201	0	0	0	1	0	208	0	-1163
108	0	165	0	1239	0	0	0	0	0	76	0	-428	0	0	0	1	0	175	0	-1738
109	0	132	0	793	0	0	0	0	0	76	0	-654	0	0	0	1	0	142	0	-2214
110	0	99	0	446	0	0	0	0	0	76	0	-881	0	0	0	1	0	109	0	-2591
111	0	66	0	198	0	0	0	0	0	76	0	-1108	0	0	0	1	0	76	0	-2869

TABLE B.1 **STAAD OUTPUT AT I END (UNIT T, TM) FOR DEAD LOAD OF BOX**

(Shear, torsion and bending at I end of all the members are reproduced from STAAD Output)

	DEAD LOAD STAGE 1				DEAD LOAD STAGE 2A				DEAD LOAD STAGE 2B				DEAD LOAD STAGE 2C				DEAD LOAD INSTANTANIOUS			
S NO.	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending
112	0	33	0	50	0	0	0	0	0	76	0	-1334	0	0	0	1	0	43	0	-3048
113	0	0	0	0	0	0	0	0	0	76	0	-1561	0	0	0	1	0	10	0	-3127
114	130	-455	0	-216	0	24	0	-1	29	-353	0	-47	0	-1	0	-1	246	-205	0	-555
115	-690	454	0	687	-1	30	0	57	-40	-274	0	-529	-2	-1	0	-1	-624	719	0	1702
116	-690	-454	0	-220	-1	-30	0	-2	-43	-7	0	38	-4	20	0	4	-626	-680	0	266
117	130	455	0	693	0	-24	0	-50	17	-9	0	-61	4	26	0	45	250	240	0	-84
118	130	-455	0	-216	0	24	0	-1	17	9	0	-42	4	-26	0	-7	250	-240	0	-563
119	-690	454	0	687	-1	30	0	57	-42	7	0	50	-4	-21	0	-37	-626	680	0	1625
120	-690	-454	0	-220	-1	-30	0	-2	-40	266	0	20	-2	1	0	1	-624	-721	0	263
121	130	455	0	693	0	-24	0	-50	28	344	0	642	0	0	0	0	245	203	0	-149
122	0	0	0	0	0	0	0	0	201	0	0	0	0	0	0	0	263	0	0	0
123	455	130	0	433	-24	0	0	0	353	29	0	98	1	0	0	1	205	246	0	673
124	455	-130	0	-433	30	-2	0	-6	-275	6	0	21	-1	0	0	1	720	75	0	103
125	455	130	0	433	30	2	0	6	7	-18	0	-45	-20	-2	0	-5	681	-77	0	-107
126	455	-130	0	-433	-24	0	0	0	-9	-17	0	-42	26	-4	0	-11	240	-250	0	-688
127	455	130	0	433	-24	0	0	0	-9	17	0	41	26	4	0	11	240	250	0	688
128	455	-130	0	-433	30	-2	0	-6	7	18	0	44	-21	2	0	5	681	77	0	107
129	455	130	0	433	30	2	0	6	-267	-6	0	-21	-1	-1	0	-1	722	-75	0	-103
130	455	-130	0	-433	-24	0	0	0	344	-28	0	-95	0	0	0	-1	203	-245	0	-672
131	0	0	0	0	0	0	0	0	202	0	0	0	0	0	0	0	263	0	0	0
132	1189	-288	0	6	4	-4	0	-107	101	-26	0	1187	2	2	0	1	1240	-272	0	-1847
133	1189	-288	0	999	4	-4	0	-93	101	-26	0	1275	2	2	0	-4	1240	-272	0	-908
134	1215	-250	0	5359	4	-4	0	-29	100	-28	0	1663	2	2	0	-27	1258	-245	0	3216
135	1227	-232	0	9149	4	-4	0	31	99	-29	0	2080	2	2	0	-54	1267	-231	0	6918
136	1227	232	0	12565	4	4	0	88	52	-41	0	-1985	9	1	0	110	1270	224	0	10113
137	1215	250	0	9149	4	4	0	31	51	-40	0	-1377	9	1	0	100	1261	237	0	6815
138	1189	288	0	5359	4	4	0	-29	48	-36	0	-776	9	1	0	91	1242	265	0	3221
139	1189	288	0	999	4	4	0	-93	48	-36	0	-236	9	1	0	82	1242	265	0	-795
140	1189	-288	0	6	4	-4	0	-107	48	35	0	-111	9	-1	0	82	1242	-265	0	-1709
141	1189	-288	0	999	4	-4	0	-93	48	35	0	-232	9	-1	0	84	1242	-265	0	-794
142	1215	-250	0	5359	4	-4	0	-29	50	39	0	-763	9	-1	0	93	1261	-238	0	3225
143	1227	-232	0	9149	4	-4	0	31	51	41	0	-1355	9	-1	0	103	1270	-224	0	6821
144	1227	232	0	12565	4	4	0	88	98	29	0	2473	2	-2	0	-83	1267	231	0	10314
145	1215	250	0	9149	4	4	0	31	99	28	0	2050	2	-2	0	-56	1258	245	0	6911
146	1189	288	0	5359	4	4	0	-29	100	26	0	1632	2	-2	0	-29	1239	272	0	3208
147	1189	288	0	999	4	4	0	-93	100	26	0	1243	2	-2	0	-5	1239	272	0	-915
148	1819	0	0	0	11	0	0	0	76	0	0	4506	6	-4	0	-191	1846	-6	0	209

TABLE B.1 **STAAD OUTPUT AT I END (UNIT T, TM) FOR DEAD LOAD OF BOX**

(Shear, torsion and bending at I end of all the members are reproduced from STAAD Output)

	DEAD LOAD STAGE 1				DEAD LOAD STAGE 2A				DEAD LOAD STAGE 2B				DEAD LOAD STAGE 2C				DEAD LOAD INSTANTANIOUS			
S NO.	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending	Axial	Shear	Torsion	Bending
149	1819	0	0	0	11	0	0	0	76	0	0	-4444	6	4	0	198	1846	6	0	-193
150	52	0	0	0	0	0	0	0	1	1	0	-18	0	0	0	1	39	0	0	-1
151	36	0	0	0	0	0	0	0	1	-3	0	-26	0	0	0	1	27	0	0	-1
152	2	0	0	0	0	0	0	0	0	-9	0	9	0	0	0	0	2	0	0	0
153	52	0	0	0	0	0	0	0	1	-1	0	18	0	0	0	-1	39	0	0	1
154	36	0	0	0	0	0	0	0	1	3	0	25	0	0	0	-1	27	0	0	0
155	2	0	0	0	0	0	0	0	0	9	0	-9	0	0	0	0	2	0	0	0
156	-22	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-16	0	0	0
157	-22	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	-16	0	0	0
158	-45	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	-33	0	0	0
159	-45	0	0	0	0	0	0	0	-5	0	0	0	0	0	0	0	-34	0	0	0
160	-820	-1	0	-4	-2	0	0	0	-34	0	0	11	-2	0	0	0	-549	-1	0	-11
161	-820	1	0	42	-2	0	0	0	-25	0	0	9	-2	0	0	0	-549	1	0	36
162	-22	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	-16	0	0	0
163	-22	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	-16	0	0	0
164	-45	0	0	0	0	0	0	0	-5	0	0	0	0	0	0	0	-33	0	0	0
165	-45	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	-33	0	0	0
166	-820	-1	0	-4	-2	0	0	0	-25	0	0	-8	-2	0	0	1	-549	-1	0	-11
167	-820	1	0	42	-2	0	0	0	-34	0	0	-7	-2	0	0	0	-549	1	0	36

TABLE B.3

	ONE GO PREST FORCE			AS BUILT PREST FORCE			AS BUILT PREST FORCE INCL SEC EFFECTS			DIFF BETWEEN ONE GO & AS BUILT			CREEP EFFECT			CANT_CBL EFFECT IF APPLIED ON COMP'D STRUCT			CONT_CBL EFFECT IF APPLIED ON COMP'D STRUCT		
	Sum of Load case 1, 2			Sum of Load case 3 & 4									Red factor =		0.779						
	Unit T & TM															Unit kN & kNM					
MEMBER	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z
1	3048	-76	3042	3048	-9	3042	3048	27	3042	0	-103	0	0	-80	0	0	-1022	0	30482	265	30421
2	3768	-47	4341	3768	20	2689	3768	56	1796	0	-103	2546	0	-80	1983	6610	-826	18933	31071	354	24481
3	3770	-67	4463	3771	0	2610	3771	36	1608	0	-103	2854	0	-80	2224	6725	-1022	21305	30980	354	23322
4	4407	-95	4005	4407	-28	1952	4407	8	842	0	-103	3163	0	-80	2464	13320	-840	18031	30754	-107	22021
5	4029	-3	3650	4029	63	1397	4029	100	179	0	-103	3471	0	-80	2704	19877	-816	14228	20417	783	22275
6	4386	-47	2604	4386	20	150	4386	56	-1176	0	-103	3780	0	-80	2945	26651	-826	10204	17213	354	15835
7	5077	43	2010	5078	110	-644	5078	146	-2078	0	-103	4088	0	-80	3185	33828	-807	5736	16947	1242	14365
8	4444	-67	989	4444	0	-1865	4444	36	-3408	0	-103	4397	0	-80	3426	34188	-1022	7849	10249	354	2040
9	5101	82	476	5102	149	-2578	5101	185	-4230	0	-103	4706	0	-80	3666	41116	-830	4229	9898	1649	530
10	4840	54	-1761	4840	121	-5016	4840	157	-6776	0	-103	5014	0	-80	3906	48402	189	-351	-3	354	-17264
11	5524	58	-2635	5525	125	-6090	5524	161	-7957	0	-103	5323	0	-80	4147	55246	231	-8021	-3	354	-18326
12	6186	59	-3523	6186	126	-7178	6186	162	-9154	0	-103	5631	0	-80	4387	61865	236	-15837	-3	354	-19389
13	6855	45	-4447	6855	112	-8303	6855	148	-10387	0	-103	5940	0	-80	4628	68552	98	-24024	-3	354	-20451
14	6870	-67	-4614	6870	0	-8670	6870	36	-10862	0	-103	6248	0	-80	4868	68700	-1022	-24628	-3	354	-21513
15	6320	-230	-5801	6871	0	-8671	6725	-323	-11235	-405	93	5434	-315	73	4234	64625	803	-32864	-1423	-3098	-25150
16	5695	-3	-6515	6871	0	-8671	6508	-4	-10496	-814	1	3981	-634	1	3102	60494	12	-46973	-3546	-40	-18178
17	5693	-124	-6510	6869	-121	-8670	6507	-126	-10489	-814	1	3979	-634	1	3100	60477	-1202	-46982	-3546	-40	-18118
18	5011	-120	-5375	6187	-118	-7543	5824	-122	-9349	-814	1	3975	-634	1	3097	53652	-1164	-35747	-3546	-40	-17999
19	4349	-128	-4289	5525	-125	-6465	5162	-129	-8259	-814	1	3971	-634	1	3094	47034	-1241	-25008	-3546	-40	-17879
20	3664	-130	-3204	4840	-128	-5389	4478	-132	-7170	-814	1	3967	-634	1	3090	40189	-1263	-14278	-3546	-40	-17759
21	3935	-151	-817	5111	-148	-3011	4748	-153	-4780	-814	1	3963	-634	1	3087	32903	-180	-3515	6443	-1332	-4657
22	3975	-91	1257	5151	-88	-945	4789	-93	-2701	-814	1	3958	-634	1	3084	25976	12	3711	13778	-924	8862
23	4298	-66	2035	5474	-64	-176	5112	-68	-1920	-814	1	3954	-634	1	3081	25615	-157	4053	17367	-507	16294
24	5225	110	2382	6400	113	163	6038	108	-1568	-814	1	3950	-634	1	3078	18438	-184	11540	33810	1281	12284
25	4627	-21	2757	5802	-18	530	5440	-22	-1189	-814	1	3946	-634	1	3074	11664	-167	18603	34602	-40	8969
26	3984	-23	3462	5160	-20	1226	4798	-24	-480	-814	1	3942	-634	1	3071	5107	-188	25440	34734	-40	9179
27	3331	-3	4166	4507	0	1922	4145	-4	228	-814	1	3938	-634	1	3068	-1488	12	32318	34802	-40	9345
28	3322	-22	4188	4498	-19	1935	4136	-23	254	-814	1	3934	-634	1	3065	-1603	-176	32400	34825	-40	9480
29	2667	-3	4893	3842	0	2632	3480	-4	963	-814	1	3930	-634	1	3062	-8213	12	39295	34879	-40	9637
30	3331	17	4263	4506	20	1999	4144	15	334	-814	1	3929	-634	1	3061	-1603	208	32929	34911	-40	9699
31	3340	-3	4200	4516	0	1928	4154	-4	276	-814	1	3924	-634	1	3057	-1488	12	32201	34888	-40	9803
32	3993	15	3570	5168	18	1289	4807	14	-350	-814	1	3920	-634	1	3054	5107	194	25826	34821	-40	9876
33	4635	18	2883	5811	21	593	5449	16	-1033	-814	1	3916	-634	1	3051	11664	217	18923	34689	-40	9905
34	4741	1649	2055	5916	1652	-242	5554	1648	-1857	-814	1	3912	-634	1	3048	18438	207	11799	28969	16283	8756
35	4298	63	2324	5474	65	18	5112	61	-1584	-814	1	3908	-634	1	3045	25615	226	4231	17367	399	19009
36	3975	88	1639	5151	91	-676	4789	87	-2265	-814	1	3904	-634	1	3042	25976	12	3243	13778	868	13145
37	3935	147	-240	5110	150	-2563	4748	146	-4140	-814	1	3900	-634	1	3038	32903	204	-3477	6443	1266	1075
38	3664	118	-2684	4840	121	-5016	4478	117	-6580	-814	1	3896	-634	1	3035	40189	1222	-11157	-3546	-40	-15686
39	4349	122	-3749	5525	125	-6090	5162	121	-7641	-814	1	3892	-634	1	3032	47034	1264	-21928	-3546	-40	-15566
40	5011	123	-4829	6186	126	-7178	5824	122	-8717	-814	1	3888	-634	1	3029	53652	1270	-32844	-3546	-40	-15447
41	5679	109	-5946	6855	112	-8303	6493	108	-9829	-814	1	3884	-634	1	3026	60340	1132	-44131	-3546	-40	-15327
42	5694	-3	-6304	6870	0	-8670	6508	-4	-10184	-814	1	3879	-634	1	3022	60488	12	-47835	-3546	-40	-15208
43	6214	525	-4943	6871	0	-8671	6689	220	-9716	-475	305	4774	-370	238	3719	63808	3034	-39066	-1672	2213	-10360
44	6632	2	-6110	6871	0	-8671	6813	-2	-10318	-181	4	4208	-141	3	3278	66681	31	-44838	-359	-12	-16260
45	6630	-119	-6112	6869	-121	-8670	6811	-123	-10315	-181	4	4203	-141	3	3274	66664	-1183	-44876	-359	-12	-16242

TABLE B.3

	ONE GO PREST FORCE			AS BUILT PREST FORCE			AS BUILT PREST FORCE INCL SEC EFFECTS			DIFF BETWEEN ONE GO & AS BUILT			CREEP EFFECT			CANT_CBL EFFECT IF APPLIED ON COMP'D STRUCT			CONT_CBL EFFECT IF APPLIED ON COMP'D STRUCT		
	Sum of Load case 1, 2			Sum of Load case 3 & 4									Red factor =		0.779						
	Unit T & TM															Unit kN & kNM					
MEMBER	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z
46	5948	-116	-4990	6187	-118	-7543	6129	-119	-9183	-181	4	4192	-141	3	3266	59839	-1145	-33698	-359	-12	-16207
47	5286	-123	-3919	5525	-125	-6465	5467	-127	-8100	-181	4	4182	-141	3	3258	53221	-1222	-23016	-359	-12	-16172
48	4602	-126	-2848	4840	-128	-5389	4783	-129	-7019	-181	4	4171	-141	3	3250	46376	-1244	-12344	-359	-12	-16136
49	4872	-147	-476	5111	-148	-3011	5053	-150	-4636	-181	4	4161	-141	3	3241	39090	-161	-1638	9630	-1304	-3118
50	4913	-87	1585	5151	-88	-945	5094	-90	-2565	-181	4	4150	-141	3	3233	32163	31	5530	16965	-896	10316
51	5236	-62	2348	5474	-64	-176	5417	-65	-1792	-181	4	4140	-141	3	3225	31802	-138	5814	20554	-479	17664
52	6162	114	2681	6400	113	163	6343	111	-1448	-181	4	4129	-141	3	3217	24625	-165	13244	36997	1309	13571
53	5564	-16	3042	5802	-18	530	5745	-20	-1076	-181	4	4118	-141	3	3209	17851	-148	20250	37789	-12	10171
54	4922	-18	3733	5160	-20	1226	5103	-22	-375	-181	4	4108	-141	3	3200	11294	-169	27029	37921	-12	10297
55	4269	2	4423	4507	0	1922	4450	-2	325	-181	4	4097	-141	3	3192	4699	31	33849	37989	-12	10379
56	4260	-17	4430	4498	-19	1935	4441	-20	344	-181	4	4087	-141	3	3184	4584	-157	33875	38012	-12	10430
57	3604	2	5121	3842	0	2632	3785	-2	1045	-181	4	4076	-141	3	3176	-2026	31	40712	38066	-12	10502
58	4268	22	4486	4506	20	1999	4449	18	414	-181	4	4073	-141	3	3173	4584	227	34327	38098	-12	10536
59	4277	2	4410	4516	0	1928	4458	-2	348	-181	4	4062	-141	3	3165	4699	31	33541	38075	-12	10556
60	4930	20	3765	5168	18	1289	5111	17	-286	-181	4	4052	-141	3	3157	11294	213	27109	38008	-12	10545
61	5573	22	3064	5811	21	593	5754	19	-977	-181	4	4041	-141	3	3148	17851	236	20148	37876	-12	10490
62	5678	1654	2222	5916	1652	-242	5859	1650	-1808	-181	4	4031	-141	3	3140	24625	226	12967	32156	16311	9256
63	5236	67	2477	5474	65	18	5417	64	-1543	-181	4	4020	-141	3	3132	31802	245	5341	20554	427	19425
64	4913	93	1777	5151	91	-676	5094	89	-2232	-181	4	4009	-141	3	3124	32163	31	4296	16965	896	13477
65	4872	152	-116	5110	150	-2563	5053	148	-4115	-181	4	3999	-141	3	3115	39090	223	-2481	9630	1294	1323
66	4602	123	-2574	4840	121	-5016	4783	119	-6563	-181	4	3988	-141	3	3107	46376	1241	-10219	-359	-12	-15523
67	5286	127	-3653	5525	125	-6090	5467	124	-7631	-181	4	3978	-141	3	3099	53221	1283	-21047	-359	-12	-15487
68	5948	128	-4747	6186	126	-7178	6129	124	-8714	-181	4	3967	-141	3	3091	59839	1289	-32021	-359	-12	-15452
69	6617	114	-5878	6855	112	-8303	6798	110	-9835	-181	4	3957	-141	3	3083	66527	1151	-43365	-359	-12	-15416
70	6632	2	-6251	6870	0	-8670	6812	-2	-10197	-181	4	3946	-141	3	3074	66675	31	-47127	-359	-12	-15381
71	6216	-504	-7177	6871	0	-8671	6688	-139	-10479	-471	-364	3302	-367	-284	2572	63841	-3556	-53417	-1677	-1480	-18356
72	5694	-3	-6533	6871	0	-8671	6504	-2	-10396	-810	-2	3863	-631	-1	3009	60520	-15	-47994	-3577	-18	-17340
73	5693	-125	-6528	6869	-121	-8670	6503	-123	-10393	-810	-2	3865	-631	-1	3011	60503	-1229	-47964	-3577	-18	-17313
74	5010	-121	-5391	6187	-118	-7543	5820	-119	-9261	-810	-2	3870	-631	-1	3015	53678	-1191	-36649	-3577	-18	-17258
75	4348	-129	-4303	5525	-125	-6465	5158	-127	-8179	-810	-2	3875	-631	-1	3019	47060	-1267	-25830	-3577	-18	-17203
76	3664	-131	-3217	4840	-128	-5389	4474	-129	-7098	-810	-2	3881	-631	-1	3023	40215	-1290	-15021	-3577	-18	-17148
77	3934	-152	-829	5111	-148	-3011	4744	-150	-4715	-810	-2	3886	-631	-1	3027	32929	-207	-4178	6412	-1311	-4111
78	3975	-92	1247	5151	-88	-945	4785	-90	-2644	-810	-2	3891	-631	-1	3031	26002	-15	3127	13747	-903	9343
79	4298	-67	2026	5474	-64	-176	5108	-65	-1870	-810	-2	3896	-631	-1	3035	25641	-184	3549	17336	-485	16710
80	5224	109	2375	6400	113	163	6035	111	-1526	-810	-2	3901	-631	-1	3039	18464	-210	11115	33779	1302	12636
81	4626	-21	2751	5802	-18	530	5436	-19	-1155	-810	-2	3906	-631	-1	3043	11690	-194	18258	34571	-18	9256
82	3984	-23	3458	5160	-20	1226	4794	-22	-454	-810	-2	3911	-631	-1	3047	5133	-215	25175	34703	-18	9401
83	3331	-3	4163	4507	0	1922	4141	-2	247	-810	-2	3916	-631	-1	3051	-1462	-15	32132	34771	-18	9502
84	3322	-22	4187	4498	-19	1935	4132	-20	265	-810	-2	3921	-631	-1	3055	-1577	-202	32294	34794	-18	9573
85	2666	-3	4893	3842	0	2632	3476	-2	967	-810	-2	3927	-631	-1	3059	-8187	-15	39269	34848	-18	9664
86	3330	16	4263	4506	20	1999	4141	18	335	-810	-2	3928	-631	-1	3060	-1577	181	32929	34880	-18	9705
87	3340	-3	4202	4516	0	1928	4150	-2	269	-810	-2	3933	-631	-1	3064	-1462	-15	32281	34857	-18	9744
88	3992	15	3574	5168	18	1289	4803	17	-365	-810	-2	3938	-631	-1	3068	5133	167	25985	34790	-18	9752
89	4635	17	2888	5811	21	593	5445	19	-1056	-810	-2	3944	-631	-1	3072	11690	191	19162	34658	-18	9717
90	4740	1648	2062	5916	1652	-242	5550	1650	-1887	-810	-2	3949	-631	-1	3076	18464	181	12117	28938	16304	8502

TABLE B.3

	ONE GO PREST FORCE Sum of Load case 1, 2			AS BUILT PREST FORCE Sum of Load case 3 & 4			AS BUILT PREST FORCE INCL SEC EFFECTS			DIFF BETWEEN ONE GO & AS BUILT			CREEP EFFECT Red factor = 0.779			CANT_CBL EFFECT IF APPLIED ON COMP'D STRUCT			CONT_CBL EFFECT IF APPLIED ON COMP'D STRUCT		
	Unit T & TM															Unit kN & kNM					
MEMBER	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z	FORCE-X	FORCE-Y	MOM Z
91	4298	62	2332	5474	65	18	5108	64	-1622	-810	-2	3954	-631	-1	3080	25641	199	4629	17336	421	18690
92	3975	87	1648	5151	91	-676	4785	89	-2311	-810	-2	3959	-631	-1	3084	26002	-15	3721	13747	889	12762
93	3934	146	-229	5110	150	-2563	4744	148	-4193	-810	-2	3964	-631	-1	3088	32929	177	-2919	6412	1288	627
94	3664	118	-2672	4840	121	-5016	4474	119	-6641	-810	-2	3969	-631	-1	3092	40215	1196	-10520	-3577	-18	-16199
95	4348	122	-3736	5525	125	-6090	5158	124	-7710	-810	-2	3974	-631	-1	3096	47060	1238	-21211	-3577	-18	-16144
96	5010	123	-4814	6186	126	-7178	5820	124	-8793	-810	-2	3979	-631	-1	3100	53678	1243	-32048	-3577	-18	-16089
97	5679	109	-5929	6855	112	-8303	6489	110	-9913	-810	-2	3984	-631	-1	3104	60366	1105	-43255	-3577	-18	-16035
98	5694	-3	-6286	6870	0	-8670	6504	-2	-10276	-810	-2	3990	-631	-1	3108	60514	-15	-46880	-3577	-18	-15980
99	6316	241	-4661	6871	0	-8671	6720	359	-9727	-404	-118	5065	-315	-92	3946	64627	-1081	-36021	-1462	3490	-10593
100	6870	70	-4327	6871	0	-8671	6870	-35	-10835	0	105	6508	0	81	5070	68707	1041	-21918	-3	-343	-21351
101	6869	-52	-4431	6869	-121	-8670	6869	-156	-10782	0	105	6351	0	81	4948	68690	-173	-23471	-3	-343	-20837
102	6186	-48	-3513	6187	-118	-7543	6186	-152	-9551	0	105	6038	0	81	4704	61865	-135	-15322	-3	-343	-19808
103	5524	-55	-2645	5525	-125	-6465	5524	-160	-8369	0	105	5724	0	81	4460	55246	-212	-7671	-3	-343	-18779
104	4840	-58	-1778	4840	-128	-5389	4840	-162	-7188	0	105	5410	0	81	4215	48402	-234	-28	-3	-343	-17750
105	5101	-78	380	5102	-147	-3022	5101	-182	-4717	0	105	5097	0	81	3971	41116	849	7648	9898	-1624	-3853
106	4444	70	1327	4444	0	-1865	4444	-35	-3456	0	105	4783	0	81	3726	34188	1041	11786	10249	-343	1487
107	5077	-34	2019	5078	-103	-964	5078	-138	-2451	0	105	4469	0	81	3482	33828	872	9041	16947	-1208	11149
108	4386	50	2866	4386	-20	92	4386	-54	-1290	0	105	4156	0	81	3238	26651	845	13440	17213	-343	15215
109	4029	6	3771	4029	-63	1207	4029	-98	-71	0	105	3842	0	81	2993	19877	862	17416	20417	-799	20295
110	4407	92	4382	4407	22	2027	4407	-13	854	0	105	3529	0	81	2749	13320	841	21166	30754	77	22657
111	3770	70	4756	3771	0	2610	3771	-35	1541	0	105	3215	0	81	2505	6725	1041	24956	30980	-343	22602
112	3768	51	4568	3768	-19	2632	3768	-54	1667	0	105	2901	0	81	2260	6610	853	21952	31071	-343	23728
113	3048	79	4989	3048	9	3262	3048	-26	2401	0	105	2588	0	81	2016	0	1041	25759	30482	-254	24127
114	550	163	-1464	0	0	0	145	359	-409	405	-196	-1056	315	-153	-822	4082	-1824	-10650	1420	3453	-3995
115	207	227	1926	0	0	0	100	318	1152	107	-92	774	83	-72	603	1024	-790	8090	1045	3056	11173
116	308	-528	1222	0	0	0	128	-224	440	180	-304	782	140	-237	609	1845	-3022	7658	1234	-2255	4562
117	419	-523	-2207	0	0	0	124	-221	-786	295	-302	-1421	230	-235	-1107	2873	-3003	-14009	1313	-2225	-8065
118	416	505	-1156	0	0	0	125	138	-343	291	368	-813	226	287	-634	2840	3587	-7965	1318	1468	-3597
119	305	501	2227	0	0	0	123	138	720	182	363	1507	142	282	1174	1865	3541	14750	1184	1465	7522
120	210	-244	1469	0	0	0	99	-361	517	111	117	952	87	91	742	1057	1065	9621	1040	-3505	5071
121	554	-171	-1814	0	0	0	150	-394	-1208	404	223	-605	315	174	-472	4080	2122	-6376	1459	-3833	-11761
122	-67	0	0	0	0	0	36	0	0	-103	0	0	-80	0	0	-1022	0	0	354	0	0
123	-163	550	1287	0	0	0	-359	145	318	196	405	969	153	315	755	1824	4082	9760	-3453	1420	3105
124	227	625	1632	0	0	0	319	217	552	-92	409	1080	-72	319	841	-791	4131	10899	3059	2123	5422
125	528	-519	-1358	0	0	0	224	-181	-462	304	-338	-896	237	-263	-698	3022	-3314	-8795	2253	-1874	-4788
126	-523	-419	-932	0	0	0	-221	-124	-277	-302	-295	-655	-235	-230	-510	-3003	-2873	-6364	-2225	-1313	-2951
127	-505	416	923	0	0	0	-138	125	284	-368	291	639	-287	226	498	-3587	2840	6235	-1468	1318	2993
128	500	522	1370	0	0	0	138	183	474	363	339	896	283	264	698	3541	3321	8803	1461	1900	4902
129	244	-622	-1620	0	0	0	361	-216	-547	-117	-406	-1073	-91	-316	-836	-1066	-4107	-10845	3508	-2115	-5359
130	-171	-554	-1298	0	0	0	-394	-150	-329	223	-404	-969	174	-315	-755	2122	-4080	-9778	-3833	-1459	-3203
131	-70	0	0	0	0	0	35	0	0	-105	0	0	-81	0	0	-1041	0	0	343	0	0

Prepared for:

सड़क परिवहन और राजमार्ग मंत्रालय
MINISTRY OF ROAD TRANSPORT & HIGHWAYS

Karnataka
Public Works, Ports & Inland Water Transport Department

Project:

Consultancy Services for "Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.000 to 261.450 on NH-48 in the State of Karnataka"

Subject:

KD-6 - Draft Detailed Project Report for Final Approved Alignment for Bypass

Volume-II : Design Report

Part IV: Geological Design and Geotechnical Report

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Disclaimer

Revision History

Rev.	Date	Long Description

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INTRODUCTION

This report is prepared under Contract Agreement clause 2.8; "Key Date No: KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR)" after incorporation of Client's observations on earlier submitted "KD5: Kucha Draft Detailed Project Report (KDDPR)"vide letter no. NH/PIU-Tunnel/NH-48/KD-3/2015-16/383-386 dated 14.12.2015.

The present submission (10 Hard Bound Sets and 5 Soft Copies of each) is as detailed below:

(i) Volume-I Main Report:

- *Executive summary*
- *Project Description*
- *Socio Economic Profile*
- *Materials Surveys and Investigation*
- *Traffic Surveys and Analysis*
- *Design Standards and Specifications*
- *Alignment Proposals*
- *Summary of EIA/IEE and Action Plan*
- *Summary of Resettlement Plan*
- *Preliminary Cost Estimates*
- *Preliminary Economic Analysis*
- *Preliminary Financial Analysis*
- *Suggested Methods of procurement and packaging*
- *Conclusions and Recommendations*
- *Acknowledgement*
- *Compliance of the Observations*

The basic data obtained from the field studies and investigations and input data used for the detailed engineering design (if any) shall be submitted in a separate volume as an Appendix to Main Report.

(ii) Volume – II : Design Report

Part- I Traffic Study, Analysis and Forecast :

- *Description of Existing Road in Ghat Section*
- *Road and Bridge Inventory*
- *Traffic Surveys, analysis and forecast*
- *Proposed Pavement Design*

Part-II Design of Tunnels :

- *Proposed Tunnel Design, Standards*
- *Technical Note on Tunnel Section and System*

- *Structural Analysis- Primary Lining*
- *Structural analysis of Inner lining and Design*

Part-III Design of Bridges and Cross-Drainage Structures :

- *Proposed Bridges and Structures Design Basis and*
- *Bridges Dimensioning*

Part-IV Geological Design and Geotechnical Report:

- *Geological Survey and Analysis*
- *Geotechnical Investigations Report*

(iii) Volume-III Materials Report :

(iv) Volume - IV(a) Environmental Assessment Report including Environmental Management Plan (EMP) &

(v) Volume - IV(b) Resettlement Action Plan (RAP) :

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(xii) Volume - XI Project Clearances :

VOLUME - II: DESIGN REPORT

PART- IV: GEOLOGICAL DESIGN AND GEOTECHNICAL REPORT

A. General

This Volume - II: Design Report- Part IV: Geological Design and Geotechnical Report, a part of KD 6: Draft Detailed Project Report for Final Approved Alignment for Bypass (DDPR) is submitted in accordance with the Contract Agreement and as per requirement specified in Terms of Reference (ToR) for preparation of Design Report -Part IV: Geological Design and Geotechnical Report of “Feasibility-Cum-Geo Technical Study for the bypass to Shiradi Ghat from Km 238.00 to 261.45 on NH-48 in the State of Karnataka”.

1 INTRODUCTION

With the letter of acceptance LoA Ref.:NH/PIU-Tunnel/NH-48/Tender/2015-16/33-36, dated 10th July 2015, GEOCONSULT has been appointed for “Consultancy Service of feasibility-cum-geotechnical study for bypass to Shiradi Ghat from km 238.00 to 261.45 on NH-48 in the state of Karnataka”.

This report deals with the geological survey conducted till date, preliminary assessment of rock mass condition based on geological reconnaissance survey, study of available literature, maps and geotechnical/ geological model for design of the primary support measures for the tunnels in the proposed alignment for the bypass road from Maranhally to Gundya on NH-48 in Shiradi Ghat Section. It also deals with the plan for further geotechnical investigation shall be carried out. Forest clearance has been obtained so far for carrying out topographical survey, detailed engineering geological mapping and geophysical survey. However permissions are awaited for conducting geotechnical drilling, sampling, in-situ and laboratory testing from forest department.

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3 GEOLOGICAL SURVEY AND ANALYSIS

3.1 Desk study of Existing Geological Literature and Maps

Geological study has been undertaken for the Shiradi Ghat bypass project as per requirements given in scope of work. Maps and literature and other relevant material have been collected for this purpose. Geological map of Karnataka, geological map (quadrangle map 48 P) and more detailed geological map of project area (48P9), geological report, district resource maps of Hassan, Dakshin Kannda have been gathered from GSI. Other literature (articles, papers etc) have also been referred to or have been collected from other sources. Information is also collected from other sources e.g. Department of Mines and Geology (Bangalore) for getting information on geological and related topics as mentioned in scope of work.

Besides geological mapping and geotechnical investigation will be conducted as mentioned in inception report. The information obtained currently from various sources mentioned above are presented in the following sections.

3.1.1 General Geology

Karnataka lies within Peninsular India (Southern part of Indian Sub Continent) which is part of the Indian Shield. The shield portions are remnant of the original earth crust formed during the early stage of earth's geological history (Precambrian). They are large areas of tectonically stable, relatively flat regions of continental crust that have not been subsequently submerged (under the ocean) after their formation.

The geology of Karnataka lies widespread in the major eras, namely the Archean, Proterozoic, Mesozoic and the Cenozoic (Fig. 1). It consists of rock formations ranging in age from as early as 3400 m.y. to recent 5 m.y. The geology of Karnataka is largely confined to the two oldest eras; the Archean and the Proterozoic. The period from Cambrian to recent are represented by minor sediments of recent age (Tertiary and Quaternary) exposed along the coastal margin to the West covering about 5000 sq km and parts of North Karnataka covered by Deccan trap, representing large and voluminous outburst of volcanic activity at the dawn of the Cenozoic era (65-67 m.y.) covering about 28,000 sq km.

The state has exposed oldest rocks in Gorur area, Hassan district, Karnataka date back to about 3300 million years. The Precambrian craton of Karnataka is made up of western and eastern segments. The Precambrians of Karnataka have been divided into older Sargur supracrustals (about 3300 to 3000 million year old) and younger Dharwar supracrustals (about 3000 to 2600 million year old. The Dharwar supracrustals Supergroup has been further divided into older Bababudan Group (ca.3000 to 2700 million years) and younger Chitradurga Group (ca.2700 to 2500 million years).

The Karnataka craton has been extensively intruded by granites and granitoids of ranging in age from 2600 to 2500 million years. The eastern Karnataka abounds in these granites and granitoids. The northern part of Karnataka is made up of Kaladgi and Badami and Bhima Group of sediments, approximately of Proterozoic age. Further north the terrain is covered by extensive volcanic flows known as Deccan traps of Cretaceous -Tertiary age.

The lithology of Karnataka consists of a wide variety of rocks ranging in age from Palaeoarchaean to Holocene. About 75% area of the state, mainly its south and central segments have Precambrian crystalline rocks consisting of basement gneisses, migmatites, supracrustals of Sargurtype, greenstone belts of both Dharwar and Kolar type (in western and eastern blocks respectively) and intrusive granitoids; besides that, there are charnockite and granulite confining to the southernmost segments. In the north, the sedimentary sequence of Kaladgi, Badami and Bhima Groups are part of Purana sediments. They are partly concealed by continental flood basalts of Deccan Trap that occupy about 16% of the total area of the State. Neogene and Quaternary sediments spreading mainly along the coastal plains and major riverbanks constitute less than 2% of areal extent of the state.

Geological aspects for Karnataka are presented in geological maps (Fig. 1) and Table 1. The general geology for Karnataka is briefly described as follow:

3.1.2 Basement Gneiss

The Basement Gneiss (Gorur Gneiss) is the remnant of the original sialic crust is currently seen in Mysore-Hassan, Gundlupet, Holenarsipur and Bangalore (Beckinsale et al. 1980, Nutman et al 1992). These protoliths are about 3400 m.y. and formed the basement for supracrustals like the Sargur type.

3.1.3 Peninsular Gneissic Complex (PGC)

It was earlier referred to as Fundamental Gneiss or Basement Gneiss. It is considered to be extensively remobilized gneiss subjected to polyphase migmatisation and ductile deformation and is found at different levels within the chronostratigraphy of the region.

It can be divided into PGC-I and PGC-II depending upon the period of emplacement. The PGC-I (Peninsular Gneissic Complex I) emplacement took place at around 3000 m.y. Bulk of Peninsular Gneiss-I belongs to tonalite-trondhjemite-granodiorite (TTG) suite, and forms the basement for the Dharwar Super group of rocks. Based on the field characters, three major variants have been recognised in this Supersuite. They are a) Tonalite-trondhjemite gneiss b) Banded migmatitic gneiss with weakly developed gneissic banding and migmatitic structures and c) Older granitoids.

The PGC-II (Peninsular Gneissic Complex II) is around 2500-2600 m.y. is mostly confined to the east of Closepet Granite. It encompasses different intrusive granitoids with a complex sialic magmatic history (Naqvi 2005).This is recognized by a wide variety of gneisses and granitoids identified and mapped in this segment. Presence of remnants of PG-I dating 3000-2900 m.y. is also reported within the Peninsular Gneiss-II in this sector. Some granitoids of 2600-2500 m.y north of Kolar in the eastern block were earlier referred as Closepet Granite are now designated as granitoids of PG-II event and labeled accordingly (Jayananda et al. 2000).

Peninsular Gneiss thus, seems to have been evolved over a period of time involving at least two major tectono- thermal episodes, that is reworking of ancient crust of 3000-2900 m.y. age with the accretion of the juvenile crust around 2600-2500 m.y; still younger events up to 2350m.y., occurrences are said to have been sporadically recorded further east in the Andhra Pradesh sector. The sialic crust has undergone major transformation during the entire period of cratonisation involving a billion year history, before attaining its present complex character.

Besides the above rock types others that are encountered in the western and eastern blocks are as follows:

1) Ancient Supracrustal, 2) Auriferous Schist Belt, 3) Larger Schist Belt, 4) Younger Granites, 5) Granulites, 6) Younger Intrusive-Dyke Swarms, 7) Great Eparchaen Intervals, 8) Deccan Traps, and 9) Laterite. Brief descriptions of the above groups are explained bellow:

3.1.4 Ancient Supracrustal

Supracrustals are rocks which were deposited on the existing basement rocks of the crust. The Sargur group of rocks occurs as independent enclaves within the peninsular gneisses confined mainly to the southern fringes of the lower grade terrain of Dharwar craton and occur within the transition zone between northern lower and southern higher grade terrain. The supracrustal rocks of the Sargur group are composed of diversified igneous and sedimentary lithologies. They include ultramafic-mafic volcanic rocks, pelites, quartzites, impure carbonates, iron formations and ultramafic-mafic intrusive bodies (Swaminath and Ramakrishan, 1981).

3.1.5 Auriferous Schist Belts (Kolar type)

These are a series of basic igneous rocks of basaltic composition together associated with intrusive. They are mainly igneous in character with a subordinate sedimentary intercalation. The most characteristic feature of these rocks is their auriferous nature. They are well developed in the eastern part of the Karnataka state. A typical representative of these eastern belts is the Kolar schist belt. The name, ‘Auriferous schist belt’ are the belts, which are largely volcanic and gold bearing

3.1.6 Larger schist belts (Dharwar type)

These are the prominent schistose rocks of Karnataka named ‘Dharwar schist belt’ with a super group status. They belong to the late Archean and their age group dates back to 2900-2600 m.y. The two main divisions in this super group are recognized. The older group is mainly igneous in character. Overlying this is a more extensive group of schistose, largely sedimentary in nature, composed of conglomerates, quartzites, limestone, greywacke and associated manganiferous and ferruginous cherts which are named as ‘Chitradurga group’. The ‘Rani Bennur group’ is the youngest series of sediments, mostly greywacke in composition and intercalated with cherty iron formation. These are classified as topmost formation within the Chitradurga group.

3.1.7 Younger (Closepet) granite

Most prominent of the younger granite is the linear belt of Clospet granite having a length of nearly 500 kilometers. The trend of this granite is roughly North- South and parallel to the structural grains of the host rock. The geochronological data suggest that the two major events experienced in the emplacement of Closepet granite at 2400-2600 m.y and 2000 m.y (Ikramuddin, and Stueber, 1976 and Jayaram et al., 1983). Chitradurga and Banawara groups belong to the same age.

3.1.8 Granulites

Southern part of the Dharwar craton is granulite terrain with extensive development of charnokite and pyroxene granulite. Geochronological data indicates an age of 2500-2700 m.y. (Ramiengar et al., 1978). These are believed to be originated because of high-grade metamorphism and metasomatic alternation of the older gneisses.

3.1.9 Younger intrusive dykes swarms

Towards the end of Archean there were numerous intrusions of dyke formation with both NS and EW trending dykes traversing rocks of earlier ages. These are ultramafic of doleritic composition and may belong to different ages. The majority of the dykes are younger than 2400 m.y. Besides ultramafic dolerite, a number of alkaline dyke intrusives have been seen especially from southern parts of Karnataka, (Bangalore and Mysore) which are younger and in all probability unrelated to the dolerite dykes but may be connected with younger granitic activity.

3.1.10 Great Eparchaean interval

There is a long period of stability of more than 1000 m.y duration exceeds the Archaean, during which the earlier rocks were exposed to the action of winds and water. This period is called as Eparchaean unconformity.

3.1.11 Deccan traps

The next major event is the burst of volcanic activity took place at the end of the cretaceous period. This is represented by a thick succession of basaltic lava flows. The total thickness of these is nearly 2km and extending over an area of about 5,00,000 km2 (covering portions of Maharashtra, Madhya Pradesh, Gujarat, and Karnataka). The burst of volcanic activity took place within a short span was sudden and continuous with hardly any interval between the flows. This entire activity took place within short span of few million years. Northern Karnataka particularly the districts of Belgaum, Bidar, Bijapur and Gulburga are covered by these Deccan traps. The western margin close to the coast was affected by large- scale dyke intrusion. The dyke assigned an age around 65 m.y, connects them with the Deccan volcanic activity.

3.1.12 Laterite

Over the Deccan trap capping of laterite is found which probably started forming at the cessation of Deccan volcanic activity in early tertiary and are continuing to form even today. The narrow coastal belt between the coast line and the precipitous edge of the western ghat in a plain of marine denudation and is covered by the extensive capping of detrital and residual laterite.

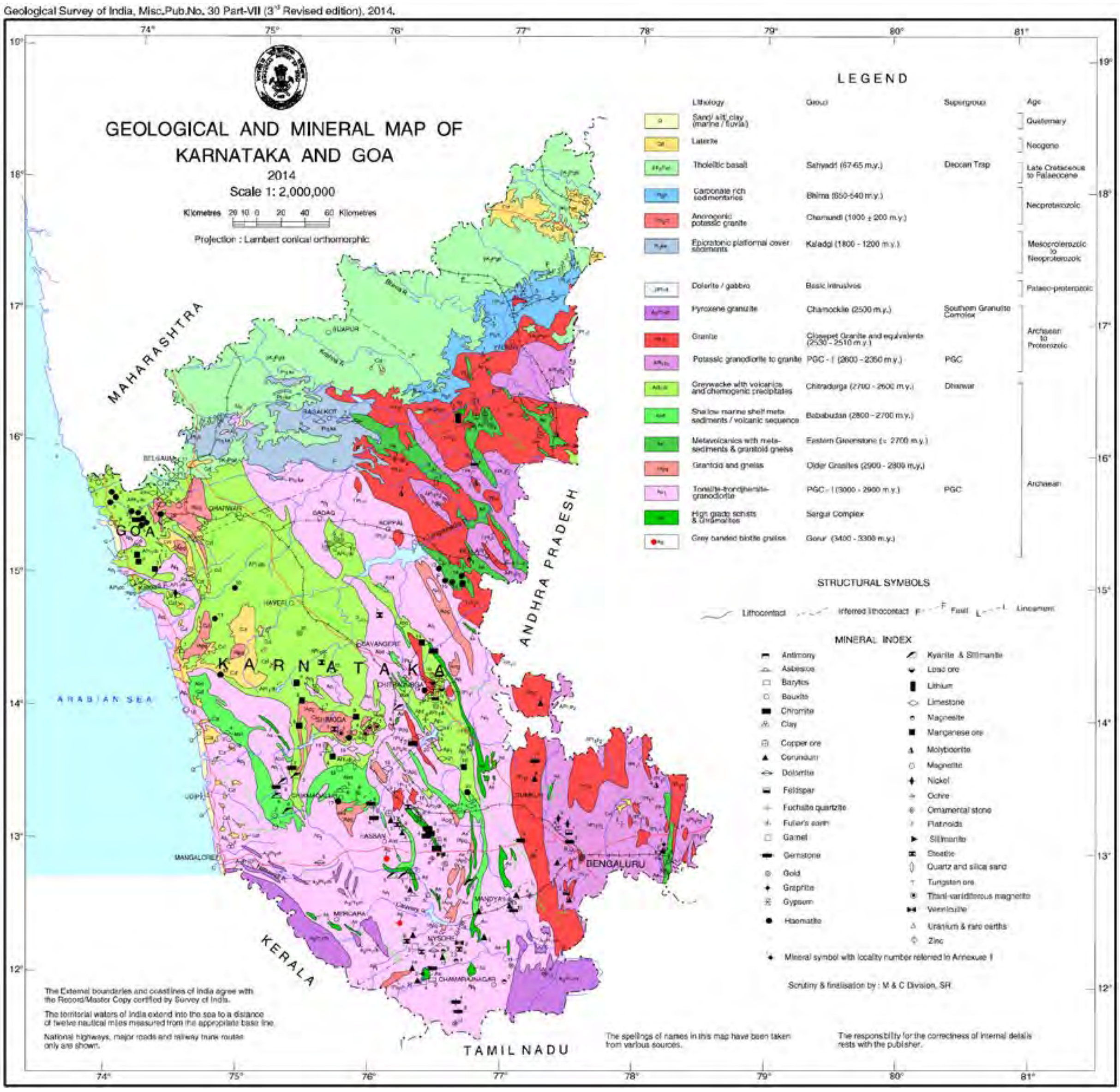


Figure 1 : Geological Map of Karnataka and Goa

Table 1: Generalised Stratigraphy of Karnataka Western Block

(After GSI 2013)

Eon/Era/Epoch	*Suite / Assemblage Supergroup*	*Group/Formation and other lower ranks*	*Lithology*
Quaternary(<2m.y.)		Coastal and fluvial	Undifferentiated fluvial sediments coastal sediments: transported red soil/alluvium
Neogene			Laterite
Mio-Pliocene		Warkalli Beds	Sandstone, clay, marl and limestone
Upper CretaceousTo Palaeocene(67-65 m.y)	Deccan Trap	Sahyadri Group	Continental flood basalt of tholeiitic chemistry with inter-trappean beds of chert and marl
Neoproterozoic (650-540 m.y.)		Bhima Group	Predominantly Mg poor carbonate sequence with shale; sandstone and conglomerate at the base
Mesoproterozoic to Neoproterozoic (1000±200 m.y.)		Chamundi Granite	Anorogenic K-rich porphyritic granite to homophanous granite
Mesoproterozoic (1800-1200 m.y.)		Kaladgi Group	Two mega cycles of repeated sequence of argillite followed by chemogenic precipitates
			predominantly of limestone and dolomite; quartzites and conglomerates forming the base
Palaeoproterozoic		Intrusives	Dolerite/gabbro, pegmatite and quartz veins
Neoarchaean (2500 m.y.)	Southern Granulite Complex	Charnockite Suite	Pyroxene granulite
Neoarchaean (2530-2510 m.y.)	Younger Granitoids	Closepet Granite	Granites, monzogranite/ adamellite to granodiorite
		Chitradurg Group (2700-2600 m.y.) — Ranebennur Subgroup	Greywacke/BIF/ Polymict conglomerates/ volcanics (Mardihalli, Bellara, Medur)
Neoarchaean (2800-2600 m.y.)	Dharwar Supergroup	Vanivilas Subgroup	Polymict conglomerate, cross beddedquartzites, pelites, stromatolitic carbonates, biogenic cherts, BIF & manganese formations (Ingaldhal volcanics-thoeliitic basalt-rhyolite suite (Tekkalvatti, Jagalur)
		Bababudan Group (2800-2700 m.y.)	BIF & carbonaceous phyllites, basalt-dacite suite (locally pillowed) with minor ultramafics/alterations of amygdular basalts/cross bedded quartzites, pelites/ minor BIF/ basal quartz pebble conglomerate
Neoarchaean to Mesoarchaean (2800-2900 m.y.)		Older Granites	Granitoids and gneiss
Mesoarchaean (3000-2900 m.y.)	Peninsular Gneissic Complex	PeninsularGneissic Complex-I	Tonalite-trondhjemite-granodiorite
Mesoarchaean (3200-3100 m.y.)	Ancient Supracrustals	Sargur Complex	Mafic-ultramafic intrusive complex (Holenarsipur-

			Nuggihalli)/serpentinized komatiites, komatiitic and thoeliitic amphibolites, cherts, BIF/garnet biotite schists (with kyanite, sillimanite and staurolite)/local marbles and calc silicates/fuchsite quartzites with chromite and baryte layers
Palaeoarchaean] (3400-3300 m.y.)	Basement Gneiss	Gorur Gneiss	Trondjhemite, granodiorite, grey coloured banded biotite orthogneiss

Eon/Era/Epoch	*Suite / Assemblage Supergroup*	*Group/Formation and other lower ranks*	*Lithology*
Neoarchaean (2530-2510 m.y.)	Closepet Granite		Granites, monzogranite/ adamellite to granodiorite
Neoarchaean to Palaeoproterozoic (2600-2350 m.y.)	Peninsular Gneissic Complex	Peninsular Gneissic Complex-II	Potassic granodioritic to granitic material
Neoarchaean (H"2700 m.y.)		Greenstone belts,viz. Kolar Sandur Raichur Hutti Mangalur Hungund-Kushtagi-Hagari	Metamorphosed grits/arenites, pelites/ BIF Bimodal mafic-felsic volcanics, pyroclasts, agglomerates, BIF, local komatiites (main unit in all belts).Quartzites (locally cross bedded), manganese marble, stromatolitic carbonate, calc-silicate, cordierite bearing pelites, amphibolite, BIF (Sakarasanahalli, Lepakshi)

3.2 Geological Reconnaissance Survey

Reconnaissance field studies were conducted at the project location to assess the ground conditions (geology, terrain, geotechnical), for purpose of carrying out geotechnical investigation, geological studies and survey.

The site visits were carried out between the period from 8th July to 10th, 15July and 23rd September, 15. The route taken for this visit was along the existing rail route in the project area. The rail route crosses the approved alignment at several locations. Due to presence of limited access roads in the vicinity and due to rain, this route was most approachable. It also provided better view of project area and also better exposures of rock outcrops as a result of slope cuttings and tunnels which were made to facilitate the rail route (South Western Railway).

Geological data have been collected along the rail route using geological compass and broadly different structures of alignment (Tunnel Portal Locations, Bridges, Cut & fill sections, location) of alignment have been identified with the help of hand held GPS. The idea was to see different conditions that are encountered along the rail route which consisted of several tunnels and bridges (across streams or gorges) as similar conditions would be expected along the proposed alignment for the project.

The rock encountered along the rail route consisted mostly of granite gneiss (from the Peninsular Gneissic Complex group). These often included banded gneisses (consisting of alternating layers leucocratic and mesocratic layers). The rocks were intruded by veins or layers of pegmatite. The rock is some locations showed folding caused as a result of undergoing deformation in several phases (2-3). These were noticeable as seen by changes in the orientation of the foliation. The rock mass encountered along the rail route varied from massive to ones with close to moderately spaced joints. Weathering condition also varied in the rock cuttings from fresh/slightly weathered to highly weathered. There were sections where very deep weathering was seen. There were several lineaments which were cutting across the rocky terrain along some of which streams or streamlets were flowing. These may be expected to intersect the tunnel alignment. Some of these may be potential fault zones or weakness zones (“hot spots”).

The existing rail route has been chosen along a route which was close to the previously existing slopes and tunnels usually have shallow to moderate overburden. In such locations some amount of weathering would be expected. The proposed tunnel alignment would be mostly passing much deeper and would thus be expected to be better in terms of weathering state and rock mass condition except for locations of fault zones, shear zones which could possible occur along the existing lineaments.

The structural data collected during geological reconnaissance traverse is given in the Table 2 below:

Table 2: Structural data of all discontinuities collected during geological reconnaissance traverse

Discontinuity Data collected during geological reconnaissance traverse									
WAY POINT Reference	Rock Type	Foliation/ Bedding/ Contact plane		Joint Set 1		Joint Set 2		Joint Set 3	
		Direction	Dip	Direction	Dip	Direction	Dip	Direction	Dip
WP 790	Granite Gneiss	50	45	0	80	240	65	295	70
		120	55						
WP 793	Granite Gneiss			350	70	175	60	25	60
WP 794	Pegmatite Band	150	50						
WP 795	Contact Pegmatite and Gneiss	170	35						
WP 796	Gneiss	95	50	180	60	30	45		
WP 797	Gneiss intruded by thick pegmatite bands					260	45	25	65
WP 800	Contact Gneiss and Pegmatite	205	70						
WP 801	End of Pegmatite band	185	60						
WP 803	Gneiss			185	75	40	80		
WP 804		330	40						
WP 805		275	75	5	85	140	85	260	30
WP 806		85	45						
WP 808		90	25						
WP 809	Highly deformed and folded pegmatite vein								
WP 813	Schistose Gneiss/ schist , Moderately to Highly weathered	310	55						

Discontinuity Data collected during geological reconnaissance traverse									
WAY POINT Reference	Rock Type	Foliation/ Bedding/ Contact plane		Joint Set 1		Joint Set 2		Joint Set 3	
		Direc-tion	Dip	Direc-tion	Dip	Direc-tion	Dip	Direc-tion	Dip
WP 814	Banded Gneiss, strong to very strong, Slightly weathered to unweathered, (Railway Tunnel T 5, mostly unlined, dripping from crown)	350	45						
WP 816	Banded Gneiss, strong to very Strong								
WP 817	Gneiss, strong	70	45	170	75	100	40		
WP 827		80	35	55	75	50	35		
WP 828	Strong to very strong, unweath-ered rock			105	30	50	75	310	70
WP 831	folded & sheared gneiss								
WP 834	Gneiss (GSI 60-65)	240	35	255	75				
WP 835	Gneiss (GSI 70-75)	255	50	350	75				
WP 838	Gneiss, strong to Very strong, unweathered			310	60	20	75	175	35
WP 850	Gneiss, Strong (GSI 60-65)								

3.3 Study of Satellite Imagery

Cartosat 1 Satellite Image obtained from National Remote Sensing Centre, Hyderabad (NRSC) with an accuracy of 5m has been used to generate Digital Terrain Model (DTM). Geomorphology of the area and identifications of lineaments have been studied using this DTM and Google earth and marked on the preliminary geological model prepared based on the above mentioned studies.

The alignment is being refined. Topographic survey has been started and high resolution satellite image from NRSC shall be obtained with a sub-meter accuracy to generate contours of 1-m interval and used for further refinement and detailed alignment design.

3.4 Geological and Mineral Aspects

Data related to mineralogical and geological aspects have been obtained from GSI geological report of Karnataka (2014) and Geological and Mineralogical Map of Karnataka (Fig 1.), district resource maps of Hassan and Dakshin Kannada (Fig 2. and Fig 3).

Karnataka is plentiful in reserves of minerals and ores. The Kolar gold fields are main source of gold for India. Others include chromite, Manganese, Iron ores, copper, lead, nickel, Uranium, zinc and rare earths for metals and minerals include asbestos, feldspars, graphite, gypsum, dolomite, kyanite & sillimanite etc.

3.5 Seismicity and Earthquakes

The seismic zone map of India (Fig 4) shows the susceptibility of various regions to earthquake based on intensity. Karnataka falls within the category II (least active) to III (moderate) category. The seismic vulnerability of different regions of Karnataka are shown in Fig 5. The earthquake hazard map along with locations of faults and thrusts are shown in Fig 6.

As per data from National Institute for Disaster Management (NIDM) site about 22.13% of the total geographical area of Karnataka is under Moderate earthquake damage risk zone & remaining area of the state is under low damage risk zone. The state has witnessed occurrences of over 500 earthquake tremors in the last three decades with most of them having low magnitude. The weak zones are around the northern Karnataka bordering Maharashtra and could cause heavy damages in future. The areas of southern part of Karnataka are also not free from frequent tremors. The Karnataka state is categorized as moderate to low seismic risk zone. The following Districts are falling in Zone III (Moderate Damage Risk Zone (MSK VII);

Bidar, Gulbarga, Bijapur, Bagalkot, Belgaum, Dharwad, Uttar kannada, Shimoga, Udupi, Dakshina Kannada, Kodagu. All other Districts are falling under Zone II (Low Damage Risk zone MSK VI). The chart shows the occurrence of earthquake activities in Karnataka are presented in Fig 7.

The project area falls within the zone II (least active) in the Dakshin Kannada section.

3.6 Landslides

The following details have been mentioned about occurrences of landslides in the Shiradi Ghat portion (along NH-48) from report on Karnataka (NIDM site).

- About 20 occurrences of landslides have been recorded.
- Majority of landslides were found to be debris slides
- The slides are shallow with < 2m depth
- The general slope varies between 25° to 35°
- The slopes are moderately vegetated
- The overburden thickness varies from 1-5m and consists of soil and weathered rock
- The cut slope angle is 70° to 80° with height varying from 2-15m
- The cut slopes have failed due to heavy rain in the Ghat section during monsoon.
- Geologically the area comprises of gneisses and granulites

One rock slide with wedge failure is observed in this section.

Figure 2 : District Resource Map Hassan (GSI)

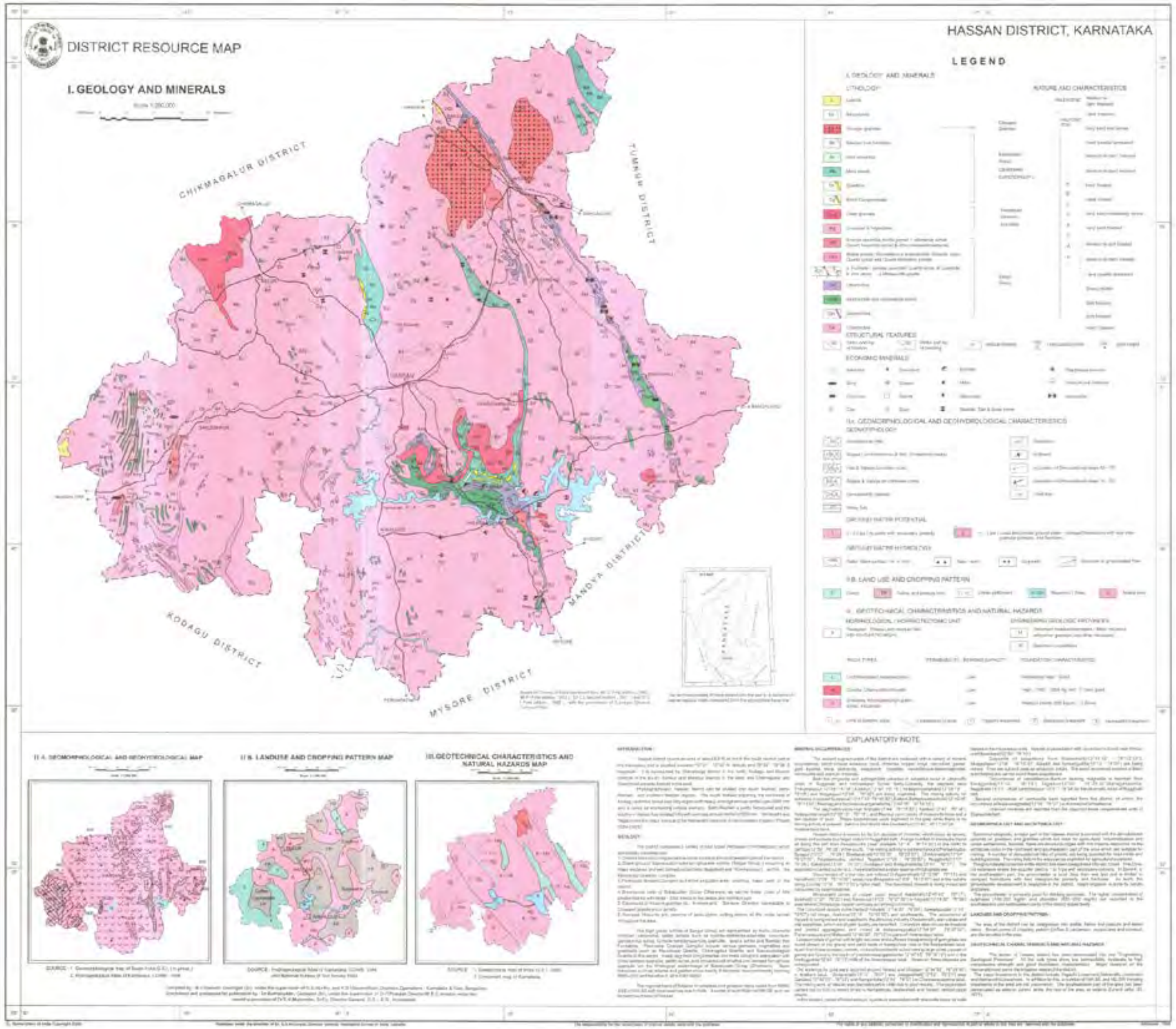


Figure 3 : District Resource Map Dakshiin Kanada (GSI)

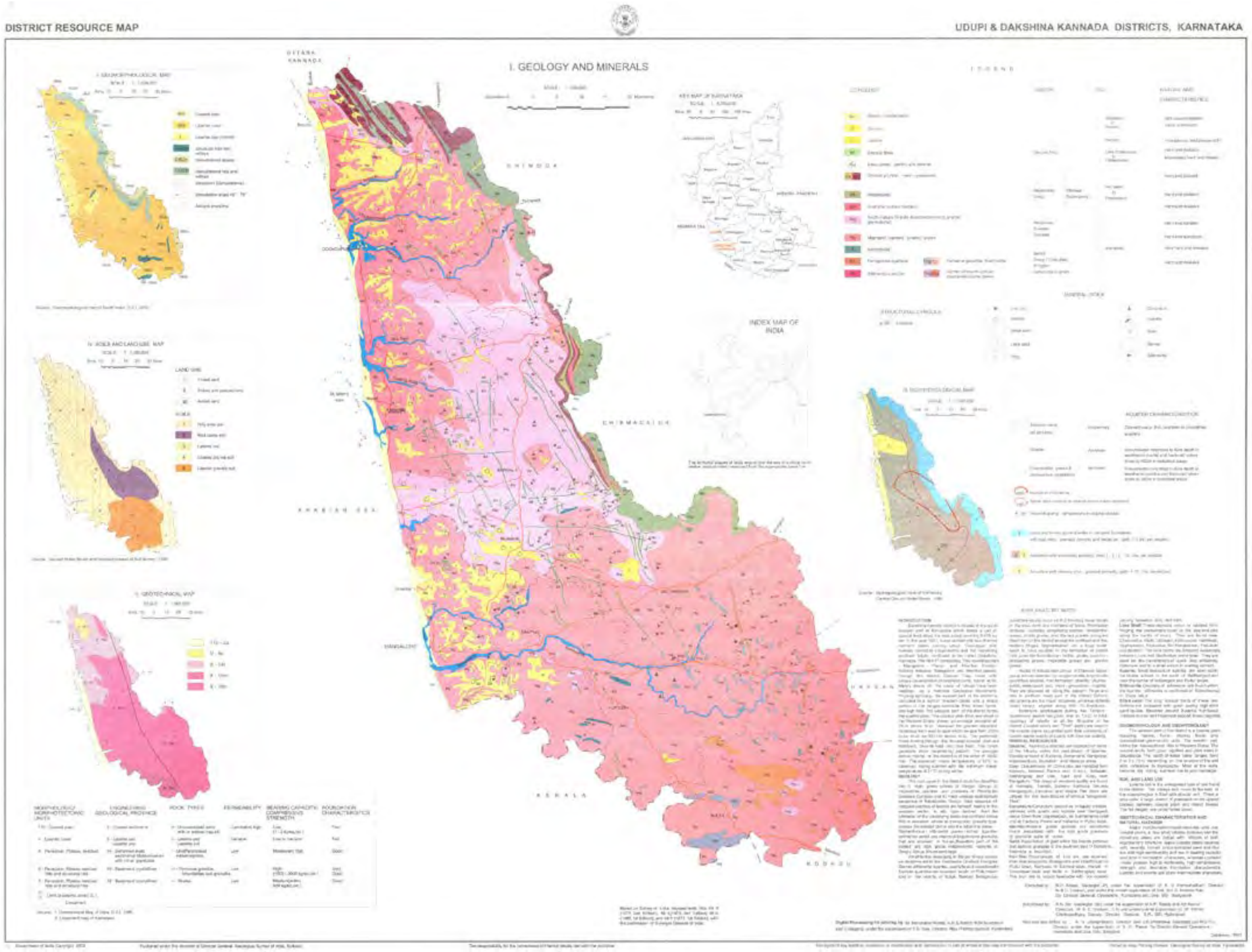


Figure 4 : Seismic Zone map of India (2014, mapsofindia)

Figure 5 : Seismic Zone Map of Karnataka (NIDM Portal)

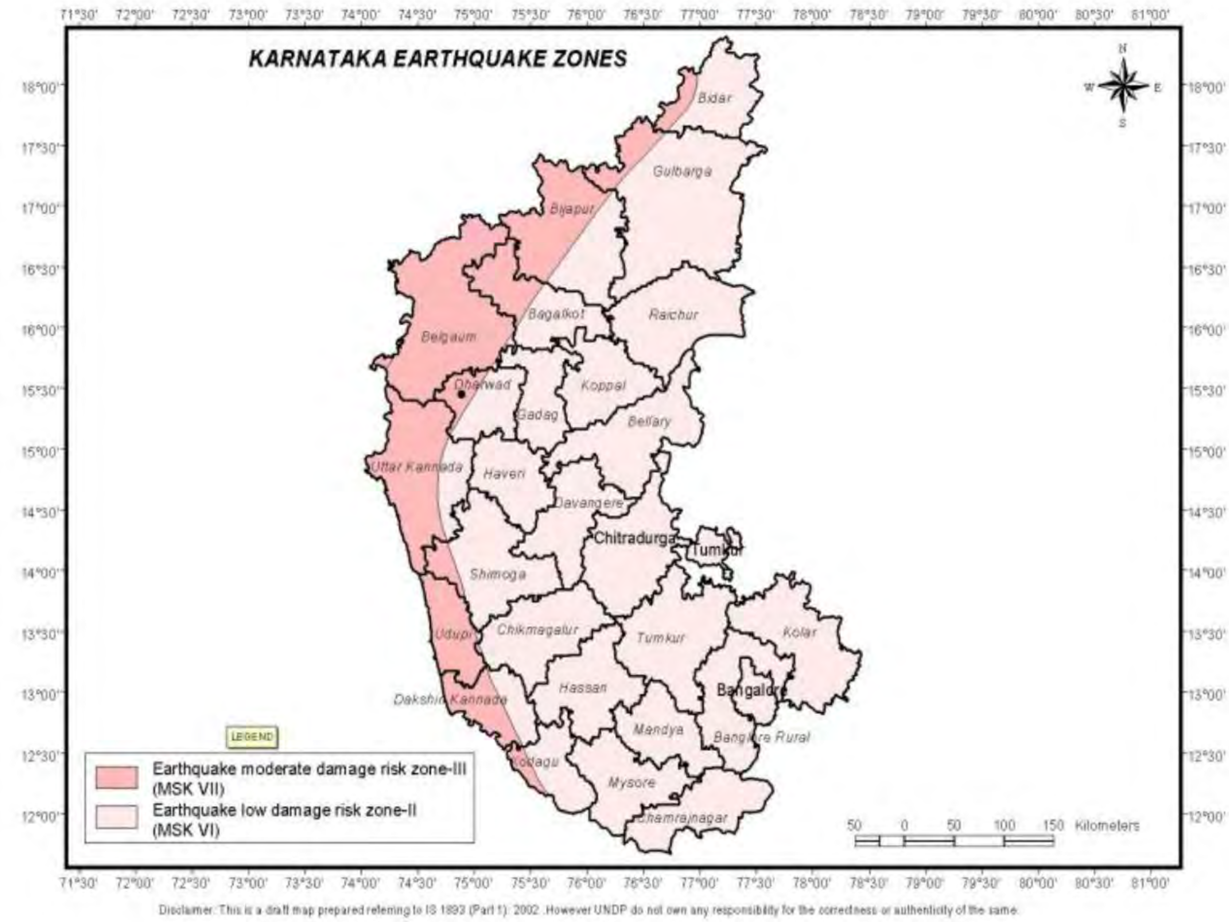
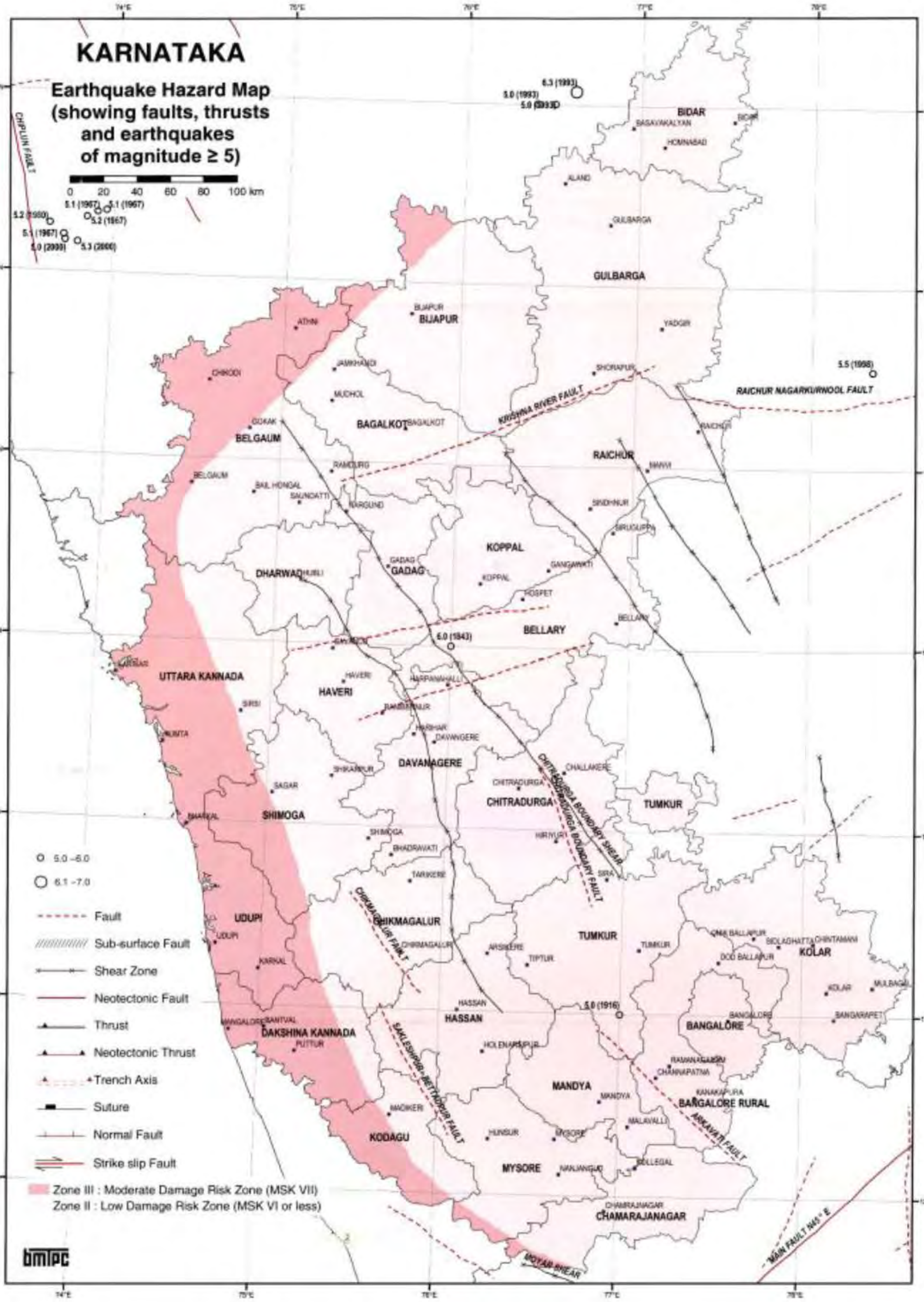
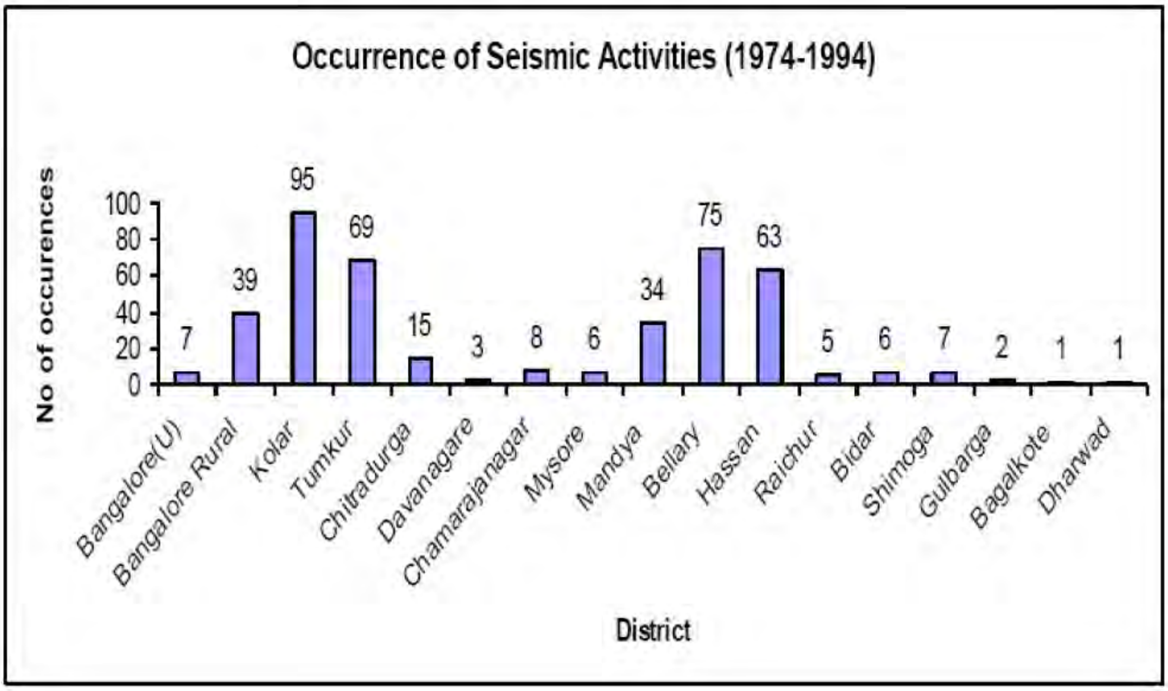


Figure 6 : Earthquake Hazard Map of Karnataka (NIDM Portal)



BMTPC : Vulnerability Atlas - 2nd Edition; Peer Group, MoH&UPA; Map is Based on digitised data of SOI, GOI; Seismic Zones of ... Map IS:1893 - 2002; Seismotectonic Atlas of India, GSI, GOI

Figure 7 : Earthquake Occurrences in Karnataka (NIDM Portal)



The analysis and interpretation of all the geological data have been discussed in the following sections.

4 GEOLOGICAL UNITS

Regionally the area comprises of the rocks of Sargur Group, Peninsular Gneiss-I of PGC, Charnokite suit of Archean age traversed by basic intrusive rocks of palaeoproterozoic age. The area is a hilly terrain covered by thick forest.

The following geological units which are relevant for Bypass Alignment of Option-A, characterized based on the geological reconnaissance traverse & collection of geological data, identifications of geomorphologic features (lineament, faults etc.) and study of geological map (1:50,000 scale) of Geological survey of India.

4.1 Laterite/ Residual Soil

Residual soil occurs in the hill slope. It is medium to fine grained yellowish to reddish in colour. It forms due to prolonged insitu weathering of bed rock.

4.2 Sargur Group

The Sargur group comprises of Silimanite Schist (±, Garnet) and amphibolites which occurs as a lensoidal bodies within PGC. Schist (± Silimanite, Garnet) occurs near Km 12000 and amphibolite occurs near Yedakumari Railway stations (Approx. km 11,000).

4.3 Peninsular Gneissic Complex (PGC)

Majority of the area occupies with PGC and represented by granite gneiss and migmatite at places. Granite gneiss is coarse grained, jointed and frequently cut across by thick pegmatite bands.

4.4 Strength Parameters

Since no laboratory tests have been carried out so far, the following tables represent the characteristic values of different rock types based on different published literature [2], [3], [4], and [5].

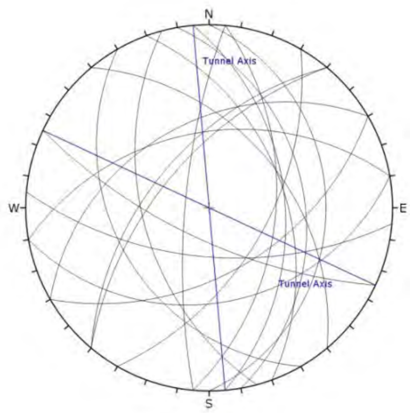
Table 3: Bulk Density, UCS and Tensile strength of different Geological Units

Rock Type	**Bulk Density**	**Uniaxial compression Test**	**Tensile strength**
Unit	**[g/cm3]**	**[MPa]**	**[MPa]**
Laterite/ Residual soil/ Completely weathered rock	1.7-1.9	0.1-0.5*	
Granite Gneiss/ banded Gneiss	2.7-2.8	70-175	7 -10
Pegmatite	2.7	45-125	
Amphibolite	2.7	70-150	
Schist (± Silimanite, Garnet)	2.6	35-70	

4.5 Discontinuities

The discontinuity data collected during geological reconnaissance survey

Foliation



Joints

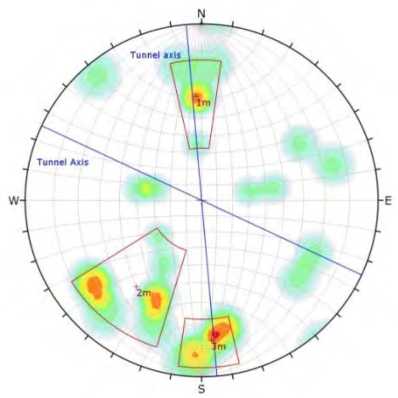


Figure 8 & Figure 9: Discontinuity pattern of Shiradi Ghat tunnel alignments, Left: foliation orientations plotted as great circles, Right: orientation of Joints given as a pole plot

The main discontinuity set in metamorphic rock is foliation. Analysing the foliation data using Dips V6 software there is a big scatter exists. No preferential trend of foliation observed which indicate the rock mass is quite folded and deformed. The spacing of the foliations depends on the rock types, thickly to very thickly (60-200 cm) in Amphibolite, thinly to medium (6-60 cm) in granite gneiss and very thinly to thinly (2-20 cm) in schist.

Apart from foliation three prominent sets of discontinuity exists within the rock mass. Refer above figure, discontinuity Set 1 & 3striking E-W and dipping towards south and north respectively; discontinuity set 2 striking NW-SE and dipping towards NE. Spacing of the discontinuities is within the range between 60 cm to > 2m and discontinuity surfaces are mainly planar to undulating and slightly rough.

During reconnaissance traverse and study of satellite imagery shears and lineaments are picked up and shown in geological plan and section (Annexure-1).

4.6 Hydro-geological Condition

The completely weathered rock/ residual soil may attain high porosity but may have low permeability. This type of formation generally form perched aquifer and when encountered during excavation sudden inflow of water can be expected.

On the contrary, the bed rock is generally impervious and nonporous but foliations, joints and shear/ fault s which are present in the rock mass are generally pervious and show considerable permeability. The interconnecting discontinuities may constitute an aquifer and during excavation within the jointed rock mass inflow of water can be expected.

During traversing along existing railway tunnel, dripping and flowing conditions in some of the tunnels have been noted. The proximities of nalla sections to the tunnel alignment are expected to be areas of increased ground water movement. Near vertical lineaments and interconnected discontinuities could transmit ground water to greater depths as well as extended stretches of the tunnel alignment. The occurrence and amount of inflows are also depending on monsoonal climate. During monsoon the more inflows of water is expected. The drainage pattern is dendritic to sub-dendritic and sub-parallel.

Office of the Director, Ground water Directorate, Bangalore, Government of Karnataka has provided depth to ground water table of an observation well located in Gundya village of puttur Taluk, Dakshina Kannada District. The last 10 years data reflects a shallow water table with a maximum fluctuation between 1.38m to 8.97m. below ground level. The data has been provided as Annexure-2.

5 ROCK MASS CLASSIFICATIONS

5.1 Rock Mass Types (RMT)

For Geotechnical design soil/ rocks pertaining to Shiradi Ghat bypass alignment project rock mass types has be characterized based on the following basic parameters

- Expected rock types,
- State of weathering
- Discontinuity spacing/ block sizes
- Primary stress condition and
- Ground water conductivity

Table 4: Rock Mass Types (RMT) for Shiradi Ghat Bypass Alignment

Rock Types	Rock Mass Types	Weathering Grade		Discontinuity Mean edge length of blocks				Stress Conditions (Rock Mass Strength/ Vertical stress)			Ground water conductivity		
		Low	High	>60 cm	10-60 cm	2-10 cm	<2 cm	Low	Medium	High	Low Inflow	Medium Inflow	High Inflow
Granite Gneiss/ banded Gneiss	RMT 1	■		■					■		■		
	RMT 2		■		■			■				■	
Schist (± Silimanite, Garnet)	RMT 3	■			■				■		■		
	RMT 4		■			■	■	■				■	
Faulted/ sheared rock	RMT 5		■				■	■					■
Amphibolites	RMT6	■		■					■		■		
Pegmatite	RMT 7	■			■				■		■		
Laterite/ Completely weather rock/ residual soil	RMT 8		■				■	■			■		

5.1.1 Granite Gneiss/ Banded Gneiss (RMT-1 & RMT-2)

Granite Gneiss is the dominant rock mass types in this area. It constitutes over 80-90 % of the area. It is crystalline, medium to coarse grained metamorphic rock. It is leucocratic to mesocratic consists of quartz, plagioclase feldspar and minor amounts of mafics.

The Granite Gneiss is generally jointed and fractures having atleast 4sets of discontinuities. Being the oldest rock, it is having a long history of structural evolution and undergone poly-phase deformation. The discontinuities are summarized and briefly characterized in the **Table 5** below:

Table 5: Discontinuity Properties

Type	Orientation	Morphology						Persistence (m)					Spacing (cm)						Fillings		
	(dip direction & dip angle)	S	U	P	r	s	sl	<1	1-3	3-10	10-30	>30	<2	2-6	6-20	20-60	60-200	>200	Clay	Iron oxide	Other/ cemented
F_o	050-150/ 50-55; 240-330/45-55			X	X						X	X		X						X	X
J1	040-050/ 55-75		X		X					X					X	X				X	
J2	175-185/ 60-75		X			X			X	X						X				X	X
J3	310-350/ 75-85		X		X				X	X						X	X			X	X

RMT-1, Unweathered to slightly weathered Granite Gneiss appears quite competent and massive despite of above described discontinuities (GSI-65-75). RMT-2. Moderately to highly weathered Granite Gneiss appears blocky with reduced frictional properties along discontinuities (45-55).

The following strength and deformational properties have been derived using Roclab program and considered in preliminary design.

Table 6: Geotechnical properties of Granite Gneiss/ Banded Gneiss

ROCK Type: Granite Gneiss/ Banded Gneiss	**UCS* [MPa]**	**GSI**	**v***	**Φ [°]**	**E [GPa]**
RMT-1; Unweathered to slightly weathered	125	65	0.15	43	41
RMT-2. Moderately to highly weathered	70	45	0.15	37	8

Figure 10 : Granite Gneiss, Unweathered to slightly weathered

Figure 11 : Granite Gneiss, moderately to highly weathered

5.1.2 Schist (RMT 3 and RMT-4)

Schist (with or without garnet, silimanite) occurs as a lensoidal body within garnet gneiss. Mineral association is dominated by micaceous mineral followed by quartz. Other minerals constitutes the rock are feldspar, silimanite, garnet and trace minerals.

It is a highly anisotropic rock, medium to fine grained with orientation of flaky (micaceous) minerals in a preferential direction. It exhibits different strength properties in different direction, highest being perpendicular to the schistosity and lowest parallel to schistosity.

RMT 3- Fresh to slightly weathered schist (GSI 45-55) is expected to have higher strength and deformational properties as compared to RMT 4- moderately to highly weathered schist (GSI 30-35). The following consideration is made using loclab program for preliminary design.

Table 7: Geotechnical properties of Schist

ROCK Type: Schist (± silimanite, garnet)	UCS* [MPa]	GSI	v*	Φ [°]	E [GPa]
RMT-3; Unweathered to slightly weathered	70	45	0.2	29	10
RMT-4. Moderately to highly weathered	35	30	0.2-0.25	25	1.9

Figure 12 : Schist outcropping near km 12500

5.1.3 Faulted/Sheared Rock (RMT-5)

During reconnaissance traversing shears within granite gneiss have been observed represented by crushed rock mass associated with folding (GSI 15-25). Several lineaments are also identified analyzing the google earth and cartosat-1 imagery and shown in the geological plan and section (Annexure-1).

The rock mass associated with shear zone is generally week having low UCS. Presence of ground water during tunneling is also expected in these zones which further reduce its shear strength properties.

Table 8: Geotechnical properties of Faulted/ sheared Rock

ROCK Type: Faulted/ sheared Rock	UCS* [MPa]	GSI	v*	Φ [°]	E [GPa]
RMT-5; Faulted/ sheared rock	5	20	0.3	22	0.8

5.1.4 Amphiboloite (RMT-6)

Amphibolite is a dark green massive/ schistose rock. The main minerals constitutes amphibolites are hornblende and plagioclase feldspar with subordinate amount of biotite and quartz. It occurs as a thin lensoidal bodies within granite gneiss (PGC) outcropping near km 11000 (Yedakumari station).

The rock mass is generally unweathered to slightly weathered, jointed with blocky structure having atleast three discontinuity sets (GSI 60-65). The discontinuities are summarized and characterized in the **Table 9** below:

Table 9: Discontinuity Properties

Type	Orientation	Morphology						Persistence (m)					Spacing (cm)						Fillings		
	(dip direction & dip angle)	S	U	P	r	s	sl	<1	1-3	3-10	10-30	>30	<2	2-6	6-20	20-60	60-200	>200	Clay	Iron oxide	Other/ cemented
J1	50/75		X			X				X						X					X
J2	105/30		X			X			X	X						X					X
J3	310/70		X		X				X	X						X	X			X	

The following strength and deformational properties have been derived using Roclab program and considered in preliminary design.

Table 10: Geotechnical properties of Amphibolite

ROCK Type: Amphibolite	UCS* [MPa]	GSI	v*	Φ [°]	E [GPa]
RMT-6; Unweathered to slightly weathered	80	60	0.2	41	18

Figure 13 : View of Amphibolite

5.1.5 Pegmatite (RMT-7)

Pegmatite is a holocrystalline very coarse grained intrusive igneous rock having interlocking texture. The rock comprises of mainly quartz, feldspar and subordinate amount of mica. It occurs as a dyke, cutting across the granite gneiss. During traversing bands of pegmatite within granite gneiss have been noted in several places. The individual band width ranges from tens of centimes to tens of meters. The rock is generally unweathered to slightly weathered.

The following are the characteristic strength and deformational properties which have been derived considered in preliminary design.

Table 11: Geotechnical properties of Pegmatite

ROCK Type: Pegmatite	UCS* [MPa]	GSI	v*	Φ [°]	E [GPa]
RMT-7; Unweathered to slightly weathered	60	70	0.2	46	18

Figure 14 : Pegmatite Band cutting across Granite Gneiss

5.1.6 Laterite/ Completely weather rock/ Residual soil (RMT-8)

Laterite soil is rich in aluminum and iron, formed in wet and hot tropical areas. It is formed by the prolonged and rigorous weathering of the parent rock. Laterisation or tropical weathering is a long drawn-out process of chemical and mechanical weathering which results in a diversity in the nature, grade, thickness and mineralogy of the ensuing soils. It occurs in the hill slope and forms as a capping zone over parent rock.

The following is the characteristic strength parameter estimated in preliminary design from various literatures.

Table 12: Geotechnical properties of Laterite

ROCK Type: Laterite	**UCS* [KPa]**	**GSI**	**v***	**Φ [°]**	**C [KPa]**	**E [MPa]**
RMT-8; Laterite/ Completely weather rock/ Residual soil	500	15-20	0.4	12-15	10-15	4.5

Figure 15 : View of Laterite/ Residual soil

Index

UCS…… Uniaxial/ Unconfined Compressive strength,

GSI……. Geological Strength Index

v……….. Poisson ration,

φ………. Angle of internal friction,

E……….. Deformation Modulus

C……….. Cohesion

*……….. Estimate

5.2 Rock Mass Behaviour Types (BT)

The combination of rock mass types and their properties with a given set of geological and geotechnical condition leads to a specific range of rock mass behavior types. The behaviour types (BT) refer to the expected interaction of rock mass and the (assumed unsupported) tunnel structure during a main tunnel drive. They include a number of possible failure modes and mechanisms, which may apply to one or several rock mass types. The following **Table 13**represents the basic rock mass behavior types based on Austrian guide lines for characterizing rock mass for NATM design [6].

Table 13: Basic Rock Mass behaviour types

Basic categories of Behaviour Types (BT)		**Description of potential failure modes/mechanisms during excavation of the unsupported ground**
1	Stable	Stable ground with the potential of small local gravity induced falling or sliding of blocks
2	Potential of discontinuity controlled block fall	Voluminous discontinuity controlled, gravity induced falling and sliding of blocks, occasional local shear failure on discontinuities
3	Shallow failure	Shallow stress induced failure in combination with discontinuity and gravity controlled failure
4	Voluminous stress induced failure	Stress induced failure involving large ground volumes and large deformation
5	Rock burst	Sudden and violent failure of the rock mass, caused by highly stressed brittle rocks and the rapid release of accumulated strain energy
6	Buckling	Buckling of rocks with a narrowly spaced discontinuity set, frequently associated with shear failure
7	Crown failure	Voluminous over breaks in the crown with progressive shear failure
8	Raveling ground	Flow of dry or moist, intensely fractured, poorly interlocked rocks or soil with low cohesion
9	Flowing ground	Flow of intensely fractured, poorly interlocked rocks or soil with high water content
10	Swelling ground	Time dependent volume increase of the ground caused by physical-chemical reaction of rock and water in combination with stress relief, leading to inward movement of the tunnel perimeter
11	Ground with frequently changing deformation characteristics	Combination of several behaviours with strong local variations of stresses and deformations over longer sections due to heterogeneous ground (i.e. in heterogeneous fault zones; block-in-matrix rock, tectonic melanges)

The specific behaviour types expected in Shiradi Ghat bypass alignment tunnels in line with the above behaviour types are listed in the **Table 14** below:

Table 14: Rock Mass Behaviour Types for Shiradi Ghat Bypass alignment tunnels

Behaviour Types (BT)	**Description of rock mass types and potential failure models/ mechanisms during tunnel excavation**	**Rock Mass Type (RMT)**
BT1……..	Stable rock mass with small local gravity induced falling or sliding of blocks. Water inflow has little or no influence on rock mass behavior.	RMT-1, RMT-6, RMT-7
BT2……..	Deep reaching discontinuity controlled, gravity induced falling or sliding of blocks. Ground water has significant influence on rock mass behavior if discontinuities (infillings) are susceptible to water (e.g. clayey material)/ oc-	RMT-2, RMT-3

Behaviour Types (BT)	Description of rock mass types and potential failure models/ mechanisms during tunnel excavation	Rock Mass Type (RMT)
	casional shear failure on discontinuities.	
BT3……..	Rock mass of low to medium strength. The stresses at the tunnel perimeter exceed the rock mass strength. Stress induced failure of the rock mass at the tunnel perimeter in terms of brittle failure of the rock or shear failure along discontinuities, resulting in a failure zone of limited depth. Shearing sliding and failure along principal schistoity, gneisosity and joint planes. Increased hydraulic conductivity distinctly reduces shear strength of discontinuities. Frequent shear failure expected.	RMT-2, RMT-4
BT4……..	Intensely fractured and sheared rock mass with low friction properties results in quasi-isotropic rock mass behavior. Deep seated stress induced shear failures with large and long lasting deformation expected.	RMT-5
BT 7……..	Voluminous over breaks at crown and progressive shear failure induced by low confining pressure. Excessive over breaks can propagate up to the surface. Low stress level in combination with low horizontal stresses.	RMT-5, RMT-8
BT9…….	Flowing of ground due to high permeability and lack of cohesion or interlocking within the rock mass/ soil in combination with ground water. With increased water inflow or water pressure expected to show flowing behavior. High and sudden water ingression is possible.	RMT-5, RMT-8

Schematic exemplary sketches and descriptions of anticipated rock mass types with their expected behavior types have been developed given in the tables below:

Table 15: BEHAVIOUR TYPE-1 -STABLE

Ground Types	RMT-1, RMT-6, RMT-7
Block size	Widely to moderately widely spaced discontinuity, inclined to steeply inclined
Discontinuity Condition	Fresh to slightly weathered, slightly rough
Ground water Condition	Predominantly dry condition with local dripping along major discontinuity
Stress condition	Various, stresses are below rock mass strength
Rock Mass Behaviour	Stable rock mass with local small gravity induced block fall
Recommended Support	SC-I

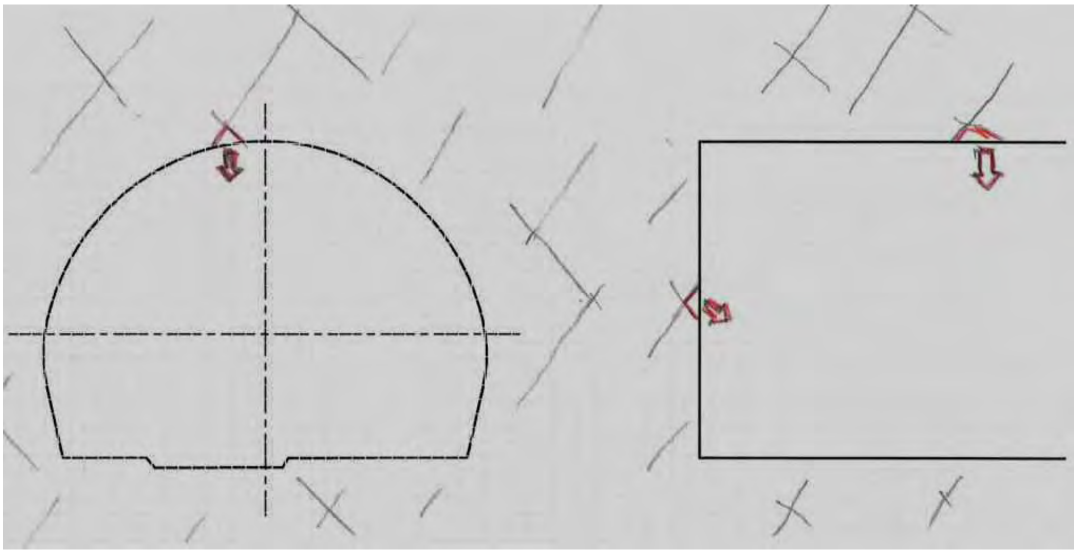


Table 16: BEHAVIOUR TYPE-2 –DISCONTINUTY CONTROL BLOCK FALL

Ground Types	RMT-2, RMT-3
Block size	Blocky with moderately to closely spaced discontinuity, Atleast 3 sets of discontinuity present, foliated.
Discontinuity Condition	Moderately weathered with slightly rough to planar surface
Ground water Condition	Predominantly dry condition with local dripping along major discontinuity
Stress condition	Low to medium, stresses locally exceeding shear strength along discontinuity
Rock Mass Behaviour	Deep Gravity controlled falling and sliding of blocks, occasionally shear failure along discontinuity
Recommended Support	SC-II

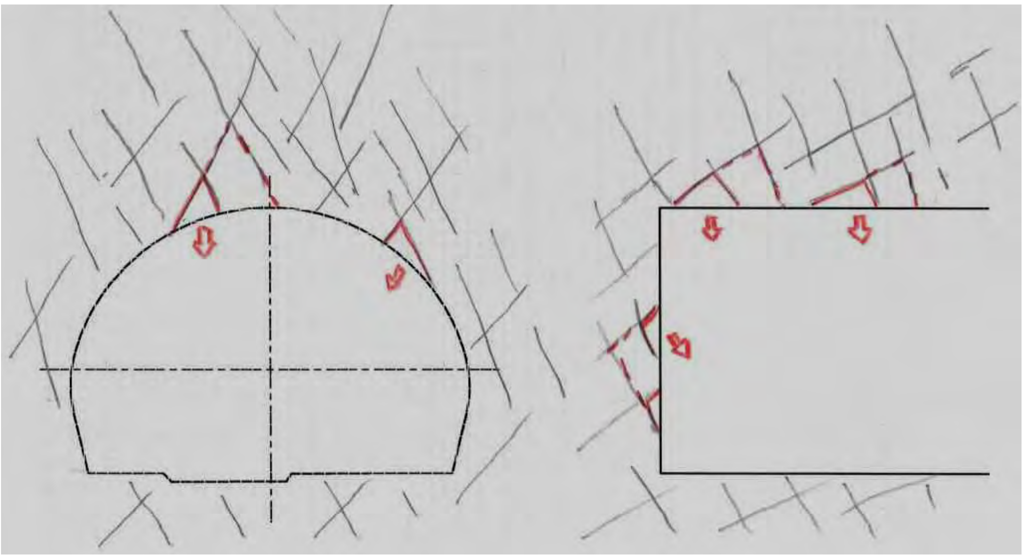


Table 17: BEHAVIOUR TYPE-3 –SHALLOW FAILURE

Ground Types	RMT-2, RMT-4
Block size	Very blocky, seamy, closely to very spaced discontinuity sets, closely foliated
Discontinuity Condition	Highly weathered, slightly rough to plan dis-continuity surface
Ground water Condition	Low water pressure, local dripping to seeping along major discontinuity
Stress condition	Medium, frequently stresses at tunnel perime-ter exceeds rock mass strength
Rock Mass Behaviour	Frequent shear failure along discontinuities combined with gravity controlled falling and sliding of blocks
Recommended Support	SC-III

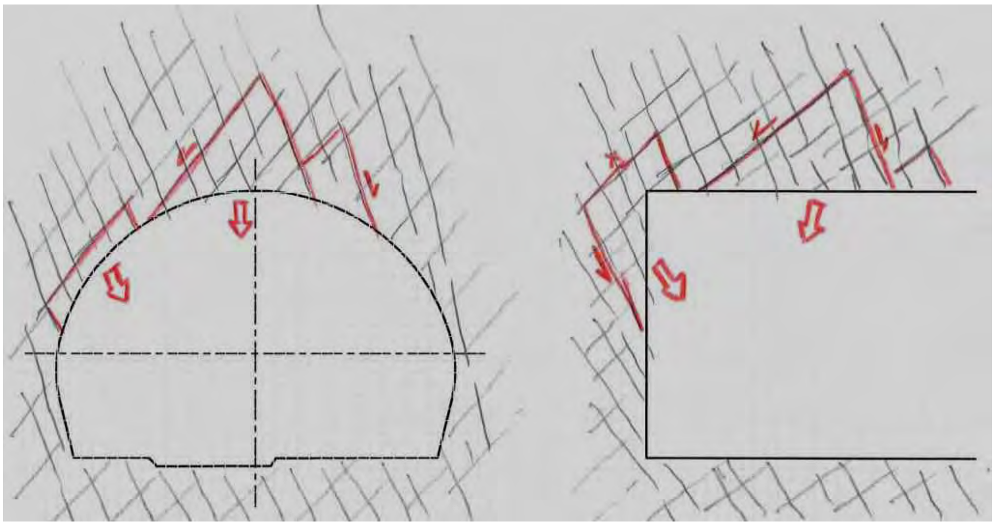


Table 18: BEHAVIOUR TYPE-4 –DEEP SEATED SHEAR FAILURE

Ground Types	RMT-5
Block size	Fracture zone, shear zone, very thinly foliated sheared rock mass
Discontinuity Condition	Moderately weathered rough to planar surface, unfavorably oriented
Ground water Condition	Possibility of high water inflow along the highly permeable fracture zone.
Stress condition	Stresses exceeds rock mass strength
Rock Mass Behaviour	Deep stress induced shear failure
Recommended Support	SC-V

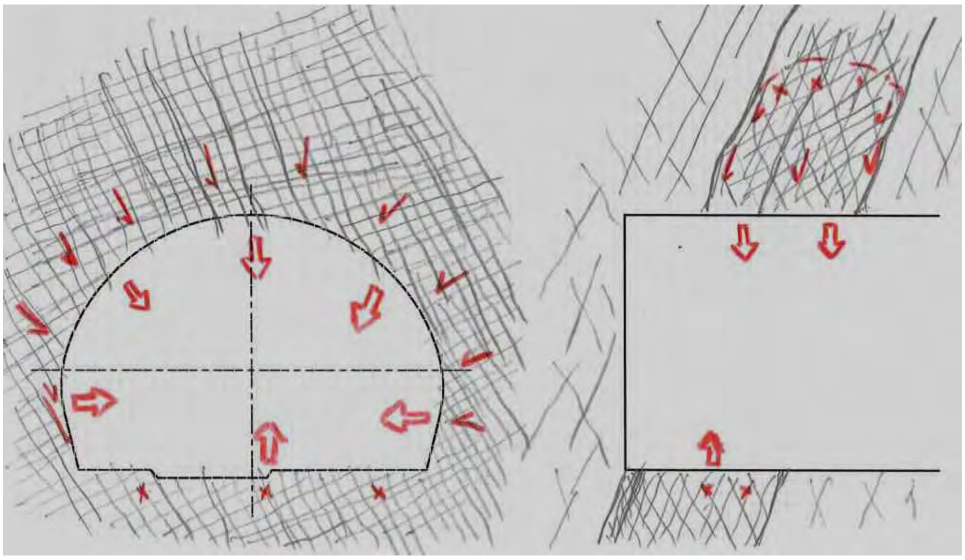


Table 19: BEHAVIOUR TYPE-7 –CROWN FAILURE

Ground Types	RMT-5, RMT-8
Block size	Not applicable/ relevant
Discontinuity Condition	Not applicable/ relevant
Ground water Condition	Mainly dry
Stress condition	Low stress in combination with low horizontal stress
Rock Mass Behaviour	Progressive shear failure
Recommended Support	SC-IV

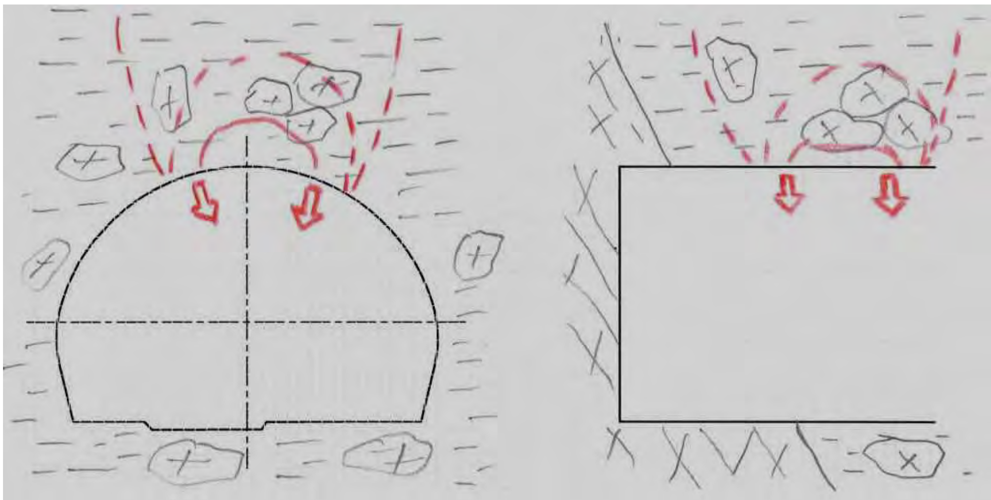
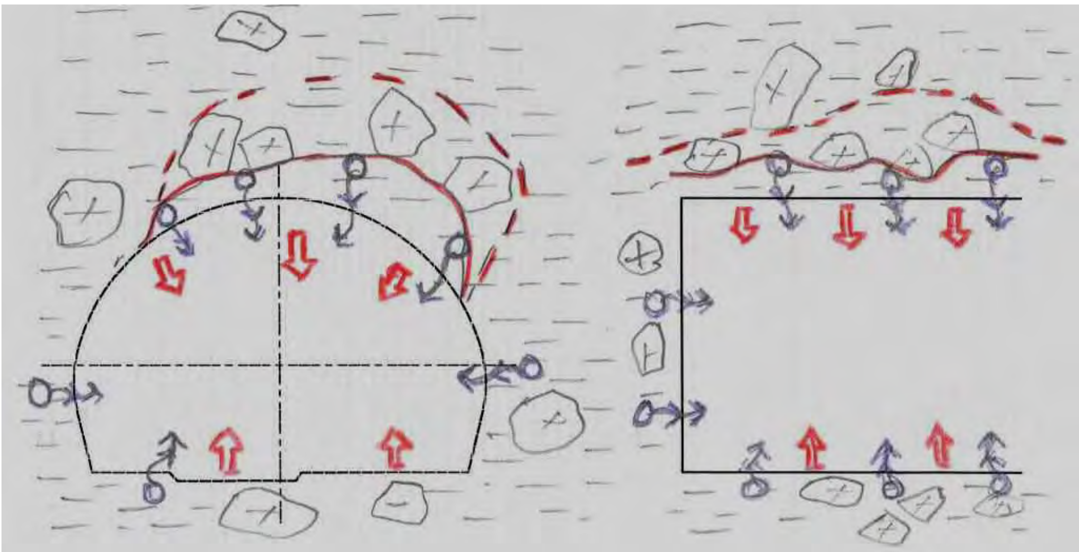


Table 20: BEHAVIOUR TYPE-9 –FLOWING GROUND

BEHAVIOUR TYPE-9 –FLOWING GROUND	
Ground Types	RMT-5, RMT-8
Block size	Not applicable/ relevant
Discontinuity Condition	Not applicable/ relevant
Ground water Condition	Water inflow due to local perched water table condition and or high permeable sheared rock / soil mass
Stress condition	Low stress
Rock Mass Behaviour	Flowing of soil/ weathered & sheared rock mass due to lack of cohesion in combination with ground water
Recommended Support	SC-V



6 GEOTECHNICAL INVESTIGATION

Recently the forest permission to enter into the reserve forest for carrying out Topographical Survey, Detailed Geological Mapping, Geophysical Survey has been obtained from the concerned ranges forest offices. Accordingly topographical surveys have been started. The plan of the geotechnical investigation has been outlined below.

6.1 Geotechnical Investigation Plan

Geotechnical Investigation plan has been firmed up based on the guidelines given in Terms of reference of contract agreement, study of available literature, geological map (48P9 in 1:50,000 scale) of Geological survey of India, study of Google and Carosat-1 imagery for generation of contour maps with ± 5m accuracy & identifications of lineaments and geological reconnaissance traverse along the existing Bangalore- Mangalore railway line close to the approved alignment and inspection of rock condition exposed on railway tunnel.

Based on the above study a basic geological plan and section has been prepared to plan further geotechnical investigation for detailed design and preparation of DPR for Shiradi Ghat Bypass Project focusing on the potential points of interest (“Hot spots”). The integrated geotechnical investigation plan has been shown on the attached drawing (**Annexure-III**). The integrated geotechnical investigation shall be carried out in three stages as given below:

6.1.1 Detailed Engineering Geological Mapping

During and after carrying out of the detailed topographical survey detailed engineering geological mapping shall be carried out to verify the basic geological model. All attempts shall be made to map all the exposure along the alignment, picking up different litho units, lineaments (fault/ shear etc.) through outcrops and geomorphology, structural condition of rock mass, document all visible/ exposed discontinuities, their orientation, properties and surface condition to classify and distribute the expected rock mass condition during tunneling.

6.1.2 Geophysical Survey (Seismic Refraction survey & 2D Electrical Resistivity Tomography)

The aim of geophysical survey is to provide information about the ground in geological, geotechnical, and environmental respect; geophysical methods are widely used in environmental and geotechnical work since long back. However since last few decades the advances made in Geophysical instrumentation, software development has greatly improved the accuracy and preciseness in data acquisition, processing and knowledge of interpretation techniques. Due to this, the geophysical technique has gained in importance and there is an increase in its demand in identification of various geotechnical and geohazard problems.

In comparison to drilling, which is basically one dimensioned (line information), geophysical investigation give at least information in a plane or even in three dimension (spatial information). Based on the results of geophysical investigation and Geological mapping the number of exploratory drilling with depth can be planned in areas of potential subsurface problems/ areas of geological interest or significance (“Hot Spots”).

6.1.2.1 Objective of Geophysical survey (SRS & 2D ERT)

- Mapping of subsurface Stratigraphy with variation in velocity and resistivity both lateral ly and vertically.
- To delineate overburden Material (slope debris & rock slumps),Weathered , Fractured, jointed and fresh bedrock mass
- To assess the Velocity & Resistivity of the overburden, weathered jointed and fresh bedrock ("bottom velocity") along the profile.
- To establish rock mass parameters through published and accepted correlations.
- To determine local low velocity zones inside the fresh bedrock if any.
- Ground water Conditions such as water table and saturated zone within the rock mass.

Geophysical Investigations shall be carried out to aid in geological interpretation/inferences. Present investigation methods include Seismic Refraction Survey and 2D ERT survey for delineating the sub surface geology with rock characteristics at the tunnel and Bridge site; especially the strata interface between "loose" material and competent rock is crucial for portal/tunnel alignment and establishing of bridge foundation depth. In this respect geophysical investigations add to the information gained through outcrops and can be correlated with borehole data for further detailing.

6.1.2.2 Seismic Refraction survey (SRS):

Seismic Refraction Survey shall be undertaken using a 24 channel seismograph at bridge and via duct locations to have a continuous profile of engineering rock level.

SRS survey shall be carried out by using digital signal enhancement technique with variable profile lengths with geophone spacing of 5m to 10.0m covering spread length of 115m to 230m. Profile shall be planned in such a way that five numbers of shots can be taken, considering 1 in the centre, 1 in each extremity, and 1 far offset in each side. Seismic waves shall be generated by using hammer blow on metallic plate and the energy travels through the earth material and is recorded by an array of sensors (Geophones) spread along the profile line. Recorded seismic data shall be processed through industry standard processing software.

An example of output result is shown in Figure 16 below. High velocity zone indicate good rock.

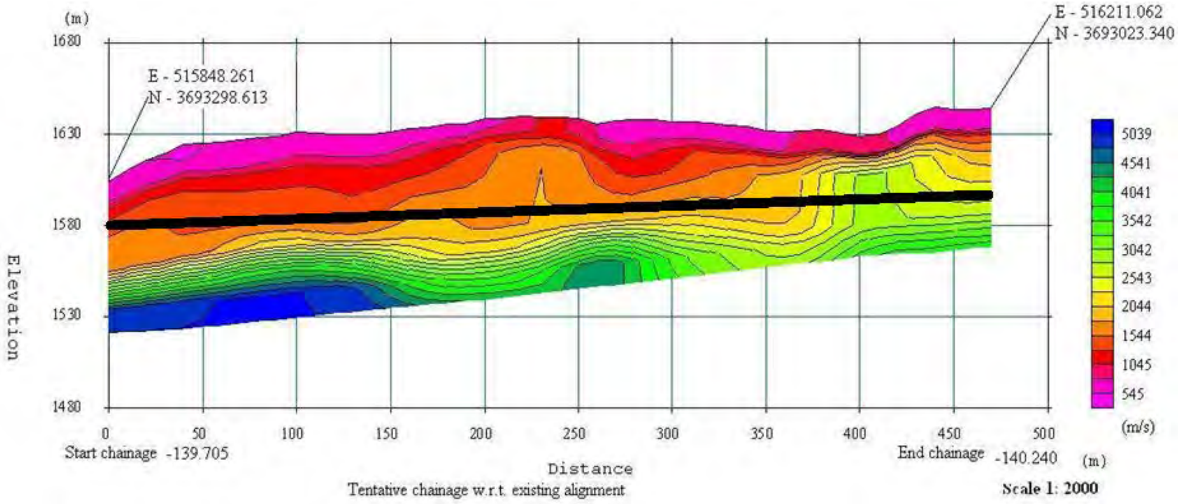


Figure 16 – Result of a seismic refraction survey (example)

6.1.2.3 2D Electrical Resistivity Tomography (ERT):

2D ERT survey with multi-electrode Resistivity imaging system shall be undertaken at selected locations of tunnel site along the proposed alignment. ERT shall be covering 300m on each portal site to interpret the continuity of subsurface below the portal for portal slope stability assessment as well. ERT profile shall be carried out from 50m below. At T-1,T-3,T-5 & T-6 tunnel ERT profile shall be carried out at the drainage/ low overburden cover area as shown in the attached drawing.

2-D Resistivity survey is one of the most practical methods for obtaining very accurate results in rather short time. Typical 1-D resistivity sounding usually involve about 10 to 20 readings, while 2-D imaging surveys involve about few 100 to 1000 measurements. In most of the geological situations, 2-D electrical imaging survey give useful results that are complementary to the information obtained by drilling and other method.

For carrying out 2-D electrical imaging/tomography surveys, multi-electrode resistivity system shall be used for automatic data collection with 21 to 81 electrodes spaced at 3m to 10m intervals as per site condition. Gradient array and Dipole-Dipole array shall be used for data acquisition. In 2D ERT survey large number of electrodes is connected to a multi-core cable. A microcomputer together with an electronic switching unit is used to automatically select the relevant four electrodes for each measurement. The acquired field data shall be processed by using RES2DINV software with all elevation and terrain correction. An example of output result of the ERT is shown in Figure 17 below.

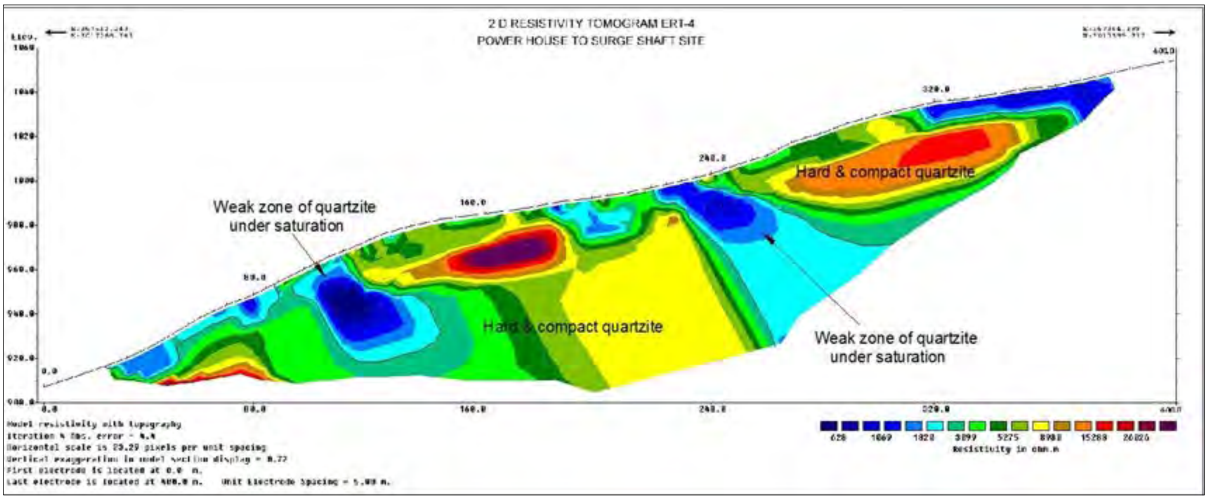


Figure 17 – Result of ERT survey (example)

6.1.2.4 Advantages of Geophysical methods

- Rapid assessment of reliable sub surface information in continuous manner
- Optimization of drilling to location to maximize special information.
- Geotechnical model for project planning & cost estimation
- Less time for acquiring large volume of data
- Methods are non destructive in nature and hence environmental friendly
- Accessibility to remote region

All the geophysical data shall be finally co-related with the geological mapping and core logging data to provide an overall integrated geological model. The scope of the geophysical work is given as (**Annexure-IV)**.

6.1.3 Geotechnical drilling, In-situ and Laboratory testing

Based on the above described investigation method a representative geological model can be prepared which would be further refined by additionally drilling bore holes at the previously identified “hot spots”. The number and locations of bore holes are so chosen to verify and augment the geological model prepared. Any significant deviation from the geological model so conceived shall be explored further by additional bore holes, if required. Areas of interest are in particular tunnel portals, bridge abutment and selected bridge pier locations.

The drilling activity shall include drilling in all kind of soil and sampling by taking UDS and SPT alternatively at every 1m interval or change in strata. Permeability test in soil shall be carried out by constant head/ falling head method. Drilling in rock shall involve coring of Nx size core, carrying out single or double packer permeability test and in-situ pressure meter test in rock at locations of interest to represent overall geological condition of the project site and deriving design parameter.

All soil and rock core samples shall be logged by an experienced engineering geologist and logging data shall be integrated to the geological mapping data to represent the overall geological model. Soil and rock core samples shall be further selected sufficiently for carrying out laboratory tests for their physical-mechanical properties. The scope of the geotechnical drilling and testing work is given in (**Annexure-V)**.

7 CONCLUSION

- This version of geotechnical report and geological model has been prepared based on the limited geological data collected during the initial site visits and desk study which including the cartosat-1 satellite imagery.
- An investigation program consisting geological mapping, geophysical surveys and core drilling with geotechnical testing has been planned to carry out during the DPR stage. This shall improve the geological model and provide a better assessment of geotechnical parameters for design.
- The geological model (distribution and disposition of rock mass types) shall be revised based on the finding of the investigation program.
- This report is intended to work as baseline report for project geological/ geotechnical data and shall be regularly updated as and when new information is collected during the project life cycle.

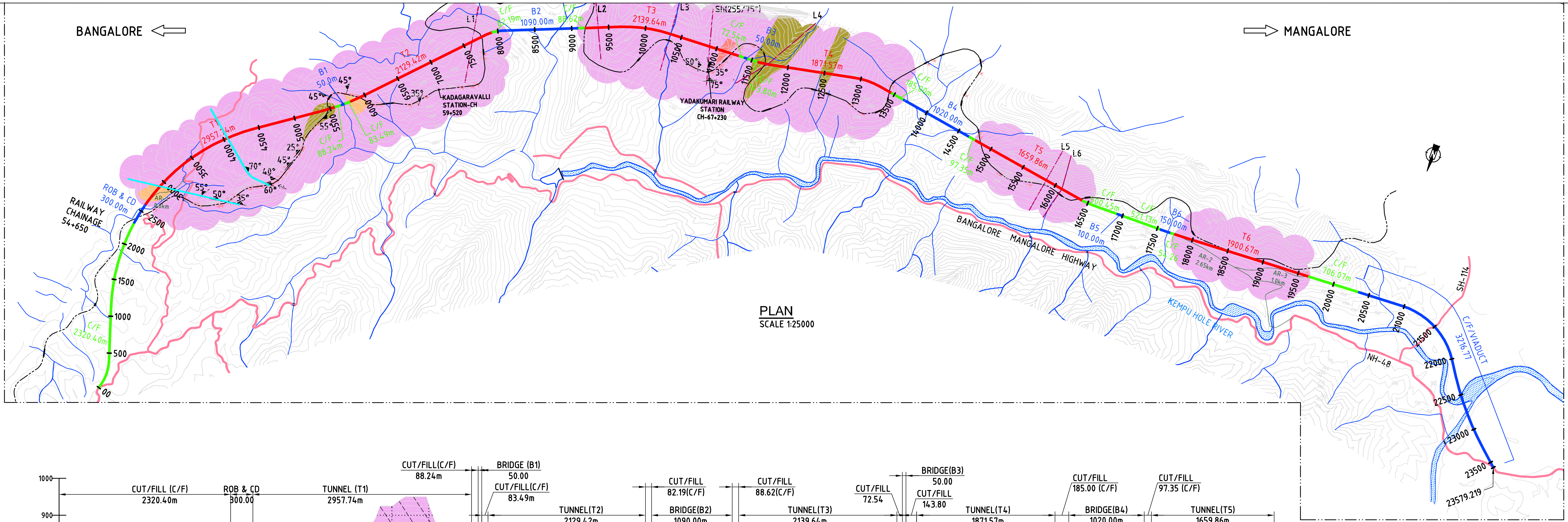
-------- End of main document --------

8 TABLE OF ANNEXURES

Annexure - 1

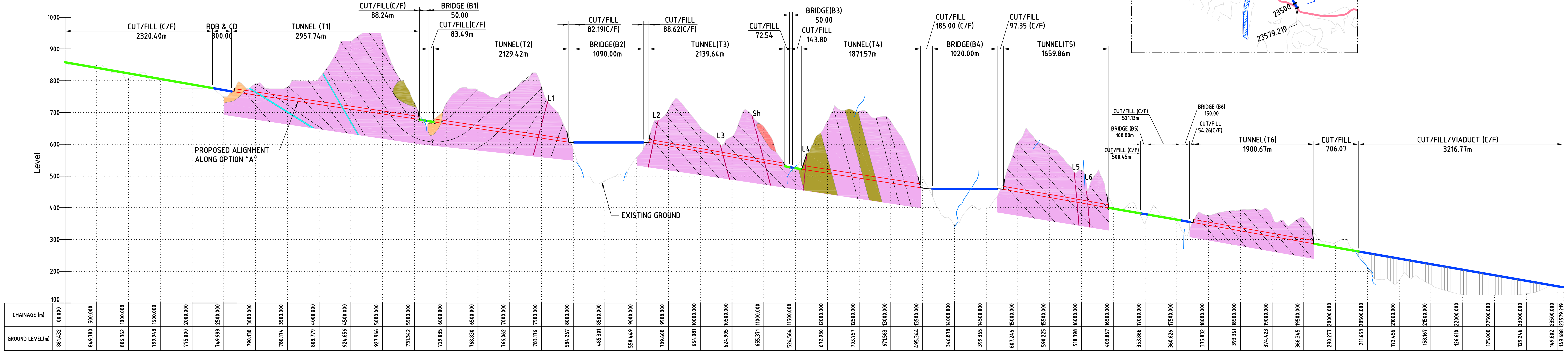
Alignment Option “A” - Preliminary Geological Model Plan and Profile

Original Drawing Size 1200x600mm



INDEX:

- LATERITE/ RESIDUAL SOIL
- GRANITE GNEISS/ BANDED GNEISS
- PEGMATITE
- SCHIST/ SCHISTOSE GNEISS
- SHEAR/ LINEAMENT
- AMPHIBOLITE
- BEDDING
- 70° FOLIATION
- SYNCLINE



LONGITUDINAL SECTION

SCALE HOR. 1:25000, VERT. 1:5000

NOTES:-

1. ALL DIMENSIONS ARE SHOWN IN mm AND LEVELS ARE SHOWN IN METERS UNLESS OTHERWISE SPECIFIED.
2. NO DIMENSIONS TO BE MEASURED FROM DRAWING. WRITTEN DIMENSIONS TO BE FOLLOWED.
3. ALIGNMENT DESIGN AND STRUCTURES, RAIL INTERFERENCES SHOWN IN THE DRAWING ARE BASED ON PRELIMINARY DATA ONLY AND MAY CHANGE AFTER GETTING DETAILED SURVEY DONE.
4. PRELIMINARY GEOLOGICAL MODEL PREPARED BASED ON LIMITED DATA COLLECTED DURING RECONNAISSANCE TRANSVERSE AND DESK STUDY. THIS MODEL IS SUBJECT TO CHANGE AFTER DETAILED GEOLOGICAL MAPPING, GEOTECHNICAL INVESTIGATION AND GEOPHYSICAL SURVEY.

SCALE 1 : 5000 (VERTICAL)
100m 0 100m 500m

SCALE 1 : 25000 (HORIZONTAL)
1000m 0 1000m 2000m 2500m

PRELIMINARY

REFERENCE DRAWINGS:

LEGEND:

- EXISTING ROAD
- RIVER
- NALA
- RAILWAY LINE
- CUT/FILL (C/F)
- BRIDGES (B)
- TUNNELS (T)
- ACCESS ROAD

REVISION

REV.	DATE	PARTICULARS	Drawn	Checked	Approved
-	-	-	-	-	-

QUALITY ASSURANCE

The responsibility of control, check and verification of accuracy, correctness, completeness, integration and full compliance of contract provisions in respect of design analysis and drawings rests with the design consultants and the contractor.

Date (FIRST ISSUE)	OCT 2015	OCT 2015	OCT 2015	OCT 2015	OCT 2015
Name	MKu	RMe	SGa	ATk	AKg
	Drawn	Drafting Chk	Designed	Design Chk	Approved
Originators					

DESIGN CONSULTANTS :
GEOCONSULT India Pvt. Ltd.
Plot No. 473, Industrial Estate,
Udyog Vihar, Phase V
Gurgaon-122016, (India)

PROJECT TITLE
CONSULTANCY SERVICES FOR FEASIBILITY-CUM-GEO TECHNICAL STUDY FOR BYPASS TO SHIRADI GHAT FROM Km 238.00 TO 261.45 ON NH-48 IN THE STATE OF KARNATAKA- JOB NUMBER NH-48-KNT-2015-16-780

CLIENT
GOVERNMENT OF KARNATAKA

DRAWING TITLE
ALIGNMENT OPTION "A"-PRELIMINARY GEOLOGICAL MODEL PLAN AND PROFILE

DRAWING NUMBER: SHGA-FS-LAY-1402 | REV: 3

SCALE: AS SHOWN | MONTH (Current Issue): OCT 2015

Annexure - 2

Geological and Hydrological Information pertains to Shirdi Ghat Bypass project area by Office of the Director, Ground water Directorate, Bangalore

GOVERNMENT OF KARNATAKA

NO: Cd¤/vÁAwæPÀ /FGS/14 /2015-16

Office of the Director
Groundwater Directorate
No. 49, Khanija Bhavana, Race Course Road,
Bangalore, Dated: 06.11.2015
E-Mail: director.gw.hp2@gmail.com
Ph. No: 080-22384134/35/36

To,
M/s Geoconsult India Pvt. Ltd.,
Plot No. 473, Industrial estate,
Udyog vihar, phase V,
Gurgaon-122016, India.

Dear Sir,

Sub: Geological and Hydrological information pertains to Shirdi Ghat Bypass project area,

Ref :
1. Your letter dated: 12.08.2015.
2. No. DKD/DMG/2015-16/3399 Dated: 23.09.2015.
3. ¸ÀASÉå: CAd¤/ »¨sÀÆ«/ fCAfPÀ/ 2015-16/ 341 ¢£ÁAPÀ: 03.09.2015.

*****

Adverting to the above, the Geological and Hydrological information pertains to Shirdi Ghat Bypass project area, as submitted by the Deputy Director, DMG, Mangalore and the Senior Geologist Groundwater Department, Mangalore, is given as below.

1. The area under study between Gundya and Maranhally is in the boundary scarp of westernghat. It encompasses Peninsular gneiss and granulites of 2.5 billion year old. It is cut across by Quartz and Dolerite veins seen in few sections in the road. The bed rock is overlain by thick lateritic cover ranging from 1m to 10 m.,

Technically controlled Kempu Hole runs on the southern flank of the National Highway with a steep slope. The ghat extends towards Northern end with height ranging from 2 m to 15m.,

Structurally, the rocks consist of multiple sets of inclined and horizontal joint sets. On interpreting the Google earth imagery, majority of lineaments and fault trend towards NE and SE inferring intracratonic tectonic activity.

Historical data indicates landslides are common in this zone during monsoon. Certain active spots of potential slides were noticed during inspection, wherein lateritic top soil and rock mass were in the verge of flow. Rainwater outlets are seen flowing on the northern flank of the road should be taken to decrease the pore pressure in the clayey soil.

2. The Groundwater static water levels of an Observation Well located in Gundya village of puttur Taluk, Dakshina Kannada District is given below.

SWL at Gundya Puttur Taluk, D.K. District During the year 2005 to 2014													
Sl No.	**Year**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1	**2005**	7.23	7.34	8.01	8.32	8.51	5.34	4.68	5.18	4.26	5.34	5.53	6.97
2	**2006**	7.18	7.27	7.53	8.05	6.18	1.50	2.20	**1.38**	4.68	6.26	6.84	7.05
3	**2007**	7.18	7.43	7.48	7.88	8.65	5.08	3.23	4.28	4.07	4.23	6.92	7.04
4	**2008**	7.23	7.32	7.14	6.38	6.51	5.26	3.33	3.68	5.43	5.93	6.28	6.68
5	**2009**	6.83	6.93	8.03	**8.97**	8.18	7.18	2.26	2.10	2.98	3.74	4.19	4.34
6	**2010**	7.13	7.38	7.59	7.83	7.91	6.05	1.55	3.18	5.05	4.70	6.30	6.98
7	**2011**	7.10	7.18	7.26	7.32	7.48	6.38	1.48	1.68	1.80	2.02	2.18	2.48

8	**2012**	5.88	7.38	7.93	8.36	8.48	6.83	1.6	1.52	1.58	2.48	2.70	6.10
9	**2013**	6.20	7.98	8.12	8.32	8.40	5.43	1.50	3.58	4.08	4.13	7.05	7.38
10	**2014**	7.20	7.53	7.58	7.64	7.58	5.18	NR	1.48	1.66	2.33	6.68	7.08

3. The Rain fall data of a nearest Raingauge station to the purposed project, for the period 2005 to 2014 is given below: Rain Gauge station: Shiradi, Puttur Taluk.

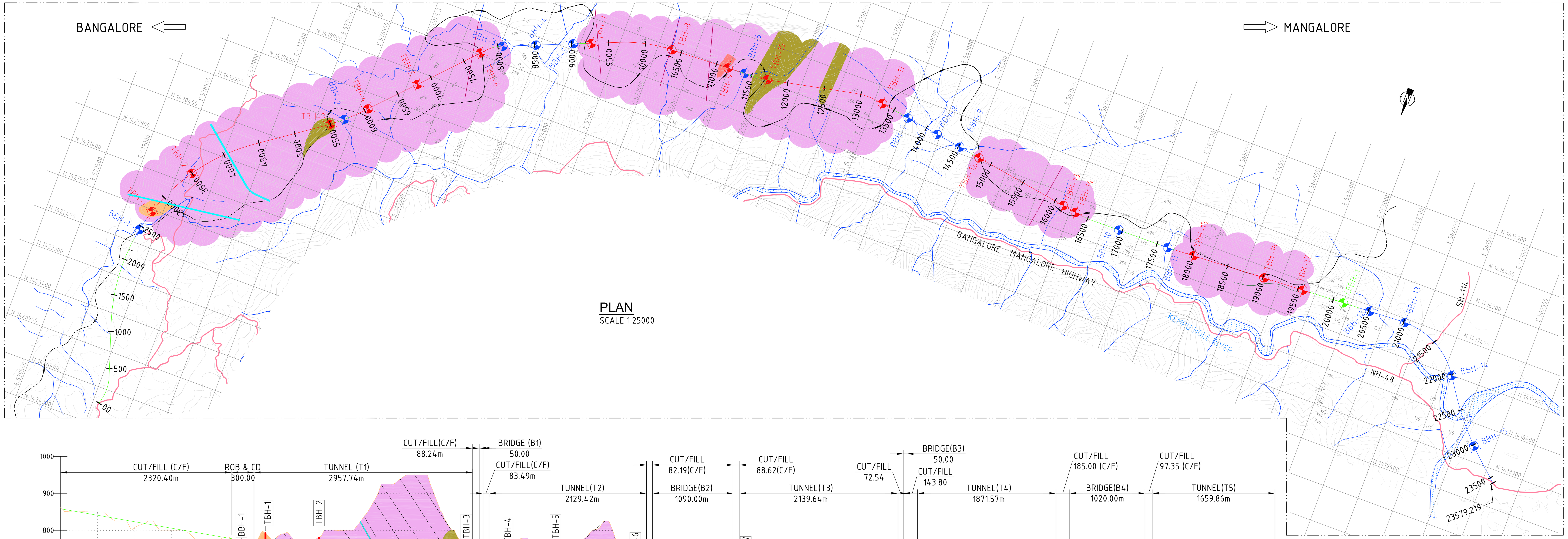
Sl. No.	**Year**	**Rainfall in mm.,**	**No. of Rainy days**
1	**2005**	5247.0	135
2	**2006**	5689.8	151
3	**2007**	5286.0	122
4	**2008**	8144.8	133
5	**2009**	5472.2	149
6	**2010**	6791.2	166
7	**2011**	6329.2	146
8	**2012**	3653.8	109
9	**2013**	4845.4	130
10	**2014**	4023.4	119

4. The proposed project area lies in the watershed bearing code 5A3B2. The average rainfall data for the last 10 years is 5548 mm. The minimum Static Water Level of a nearest Observation well at Gundya, for the last 10 years, is 1.38 m and the maximum static water level is 8.97m. As per the Estimation of Groundwater Resources of the state as on 2011, the puttur taluk is categorised as '**safe**' (Groundwater utilization is less than 70% of annual recharge)

Your's faithfully,
Sd/-
Director

Annexure - 3

Geotechnical Investigation Plan



PLAN
SCALE 1:25000

LONGITUDINAL SECTION
SCALE HOR. 1:25000, VERT. 1:5000

Original Drawing Size 1200x600mm

BORE HOLE NR.	TENTATIVE DEPTH (m)	POINT CO-ORDINATES (UTM)	
		EASTING	NORTHING
TBH-1	45.92	578642.357	1421925.561
TBH-2	55.03	578314.269	1421254.125
TBH-3	66.20	576789.787	1419979.913
TBH-4	95.66	576384.881	1419611.037
TBH-5	120.72	575871.357	1419064.897
TBH-6	104.52	575220.893	1418373.120
TBH-7	72.34	573858.245	1417727.856
TBH-8	47.13	572806.265	1417433.815
TBH-9	73.76	572008.012	1417399.576
TBH-10	71.33	571458.209	1417365.713
TBH-11	113.44	569884.282	1417126.036
TBH-12	56.50	568404.189	1417363.333
TBH-13	75.10	567111.995	1417570.504
TBH-14	114.18	566923.275	1417600.761
TBH-15	46.05	565225.164	1417597.829
TBH-16	79.64	564226.465	1417546.851
TBH-17	78.90	563677.116	1417520.092

BORE HOLE NR.	TENTATIVE DEPTH (m)	POINT CO-ORDINATES (UTM)	
		EASTING	NORTHING
BBH-1	25.0	578717.204	1422215.421
BBH-2	25.0	576634.709	1419854.167
BBH-3	25.0	574967.055	1418180.499
BBH-4	25.0	574552.616	1418011.315
BBH-5	25.0	574089.702	1417822.342
BBH-6	25.0	571805.908	1417339.561
BBH-7	25.0	569490.319	1417189.198
BBH-8	25.0	569045.993	1417260.435
BBH-9	25.0	568700.406	1417315.841
BBH-10	25.0	566292.382	1417621.671
BBH-11	25.0	565590.179	1417614.188
BBH-12	25.0	562728.241	1417473.873
BBH-13	25.0	562228.800	1417450.500
BBH-14	25.0	561385.014	1417905.970
BBH-15	25.0	560773.027	1418694.246
CFBH-1	36.43	563102.197	1417492.088

INDEX:

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- GRANITE GNEISS/ BANDED GNEISS
- PEGMATITE
- SCHIST/ SCHISTOSE GNEISS
- SHEAR/ LINEAMENT
- AMPHIBOLITE
- BEDDING
- 70° FOLIATION
- SYNCLINE
- SRS — SEISMIC REFRACTION SURVEY
- ERI — ELECTRICAL RESISTIVITY TOMOGRAPHY (2D)
- BBH-x — BORE HOLES (FOR BRIDGES)
- TBH-x — BORE HOLES (FOR TUNNELS)
- CFBH-x — BORE HOLES (FOR CUT & FILL)

NOTES:-

1. ALL DIMENSIONS ARE SHOWN IN mm AND LEVELS ARE SHOWN IN METERS UNLESS OTHERWISE SPECIFIED.
2. NO DIMENSIONS TO BE MEASURED FROM DRAWING. ONLY WRITTEN DIMENSIONS TO BE FOLLOWED.
3. THIS DRAWING IS MEANT TO SHOW GEOLOGICAL INFORMATION, BORE HOLE LOCATIONS ONLY. FOR OTHER INFORMATION RELATED DRAWINGS SHALL BE REFERRED TO.
4. FOR CUT AND FILL LOCATIONS HAND AUGER DRILLING SHALL BE CARRIED OUT AT EVERY 500m.
5. FOR TUNNEL LOCATIONS BORE HOLES SHALL BE TERMINATED 15m BELOW INVERT AND FOR BRIDGE LOCATION BORE HOLE SHALL BE TERMINATED AT 15m OR ENCOUNTER OF HARD (FRESH) ROCK, WHICEVER IS EARLIER.

PRELIMINARY

SCALE 1 : 25000 (HORIZONTAL)
1000m 0 1000m 2000m 2500m

SCALE 1 : 5000 (VERTICAL)
100m 0 100m 500m

REFERENCE DRAWINGS:
SHGA-FS-LAY-1000

LEGEND:
- EXISTING ROAD
- RIVER
- NALA
- RAILWAY LINE
- CUT/FILL (C/F)
- BRIDGES (B)
- TUNNELS (T)

REVISION

REV.	DATE	PARTICULARS	Drawn	Checked	Approved
A	NOV 2015	FIRST DRAFT (PRELIMINARY)	PRa	RMe	AKg

QUALITY ASSURANCE

The responsibility of control, check and verification of accuracy, correctness, completeness, integration and full compliance of contract provisions in respect of design analysis and drawings rests with the design consultants and the contractor.

Date (FIRST ISSUE)	NOV 2015	NOV 2015	NOV 2015	NOV 2015	NOV 2015
Name	PRa	RMe	SGa	FKr	FKr
	Drawn	Drafting Chk	Designed	Design Chk	Approved

Originators

DESIGN CONSULTANTS :
GEOCONSULT India Pvt. Ltd.
Plot No. 473, Industrial Estate,
Udyog Vihar, Phase V
Gurgaon-122016, (India)

PROJECT TITLE
CONSULTANCY SERVICES FOR FEASIBILITY-CUM-GEO TECHNICAL STUDY FOR BYPASS TO SHIRADI GHAT FROM Km 238.00 TO 261.45 ON NH-48 IN THE STATE OF KARNATAKA- JOB NUMBER NH-48-KNT-2015-16-780

CLIENT
GOVERNMENT OF KARNATAKA

DRAWING TITLE
ALIGNMENT OPTION "A"
PROPOSED GEOTECHNICAL INVESTIGATION SCHEME

DRAWING NUMBER: SHGA-FS-GEO-1403
REV: A
SCALE: AS SHOWN
MONTH (Current Issue): NOV 2015

Annexure - 4

Scope of the Geophysical work

Planning of Geophysical Investigation for Bridges and Tunnels between Km 238 and Km 261

Structures	Chainage		Length (m)	No. of ERT	No. of SRS	Unit spacing	No.of Electrod	Length of each profile (m)	Total length to be covered (m)
	From	To							
Tunnels									
T-1	2620	5578	2958	2	0	5	60	300	600
T-2	5799	7930	2131	3	0	5	60	300	900
T-3	9190	11330	2140	3	0	5	60	300	900
T-4	11596	13468	1872	2	0	5	60	300	600
T-5	14770	16430	1660	3	0	5	60	300	900
T-6	17756	19656	1900	3	0	5	60	300	900
								Total ERT	**4800**
Bridges/ Viaduct									
Br-1	5666	5717	51	0	1	5	23	115	115
Br-2	8010	9105	1095	0	10	5	23	115	1150
BR-3	11400	11455	55	0	1	5	23	115	115
Br-4	13650	14675	1025	0	9	5	23	115	1035
BR-5	16930	17030	100	0	1	5	23	115	115
BR-6	17550	17705	155	0	2	5	23	115	230
Viaduct	20350	23567	3217	0	28	5	23	115	3220
								Total SRS	**5980**

Note:-

1. ERT indicates 2D Electrical Resistivity Tomography
2. SRS indicates Seismic Refraction Survey
3. For tunnel sites, ERT shall be covered 300m on each portal site, profile shall be carried out from 50m below.At T-1,T-3,T-5 & T-6 tunnel ERT profile shall be carried out at the drainge/ low overburden cover area.
   the portal on each site to interpret the continuity of subsurface below the portal for portal slope stability assesment

Annexure - 5

Scope of the geotechnical drilling and testing work

ANNEXURE - I

PROJECT: BY PASS TO SHIRADI GHAT FROM Km 23.00 TO 261.45 ON NH-48 IN STATE OF KARNATAKA

Serial No	Item Description	Unit	Qty
	TUNNEL LOCATION		
1	Mobilisation charges of drilling equipment and manpower (min 3 working sets of rigs + required equipment and accessories)	LS	
2	Mobilisation of additional set of rig + equipment and accessories	No	
3	De- Mobilisation charges of Drilling Equipment and Manpower	LS	
4	Drilling of Nx size bore holes (75 mm diameter) in all types of Soil, rock (weathered and fresh rock) and collection of soil and rock core samples from boreholes at tunnel sites (Conducting SPT if CR≤ 20%). Frequency of SPT and UDS as per scope		
4a	Up to 50m Depth	m	
4b	Beyond 50m Up to 100m	m	
4c	Beyond 100m Up to 150m	m	
4d	Beyond 150m Up to 200m	m	
4e	Upto 50m depth in soil / weathered rock (CR<20%)	m	
5	In-Situ Permeability Tests in Borehole at Tunnel Locations		
5a	Using Single Packer	each	
5b	Using Double Packer	each	
5c	Constant / falling head (in soil)	each	
5d	Pressure meter test	each	
6	Erection of drilling equipment from one bore hole site to another bore hole site and construction of working platform for drilling machine including making of approaches.(After Site Visit we may revise)	Each	
7	Laboratory Testing of Rock Samples	Each	
7a	(i) Uniaxial compressive strength and hardness	Each	
	(ii) Natural and dry density and specific gravity	Each	
	(iii) Water absorption and porosity and moisture content	Each	
	(iv) Slake Durability	Each	
	(v) Swelling Index	Each	
	(vi) Point Load Index	Each	
7b	(i) Triaxial Test	Each	
	(ii) Deformability of rock materials (young's modulus, modulus of deformability, stress strain curve, failure energy) IS 9221, IS9143 for Rock samples [extra above 7b(i) for measurement]	Each	
	(iii) Poisson's ratio of Rock [extra above 7b(i) for measurement]	Each	
7c	Petro graphic Description of Rock (grain size, mineral content, texture) for Rock Samples (including thin section study and report)	Each	
7d	Tensile strength of rock materials (indirect tensile strength, "Brazilian test") IS-10082 for Rock Samples.	Each	
7e	Hardness and abrasiveness of rock (together with CAI index abrasivity test) for Rock samples	Each	
7f	Soil samples : Grain Size Analysis, Hydrometer Analysis, Atterberg Limits, Trixial Shear Tests (UU), Natural Moisture Content, Specific Gravity and Bulk Unit Weight, Consolidation Tests, Unconfined Compression Test, Free swell Index, Shrinkage Limit, Swell Pressure Test,etc. as per standard norms. (individual break up)	Each	
	(i) GSA		
	(ii) HA		
	(iii) Atterberg Limits		
	(iv) UU		

Serial No	Item Description	Unit	Qty
	(v) NMC		
	(vi) Spg. & Bulk Den		
	(vii) Consolidation Test		
	(viii) UCS		
	(ix) Free Swell Index		
	(x) Shrinkage Limit		
	(xi) Swell Pressure Test		
7g	Direct shear test	each	
7h	Chemical Tests (soil)	each	
7i	Chemical Tests (ground water) incuding in tunnels	each	
	BRIDGE LOCATION		
8	Erection of drilling equipment from one bore hole site to another bore hole site and construction of working platform for drilling machine including making of approaches. (In Land)	Each	
9	Rotary core drilling 'NX' size barrel filled with diamond bit in all kind of soil including hard strata (N>100) rock formation upto maximum depth of 25 meter including collection of samples determination of core recovery and RQD and preserving the work core samples in boxes.	m	
10	Conducting required laboratory test on selected soil/rock samples.		
10a	Soil samples : Grain Size Analysis, Hydrometer Analysis, Atterberg Limits, Trixial Shear Tests (UU), Natural Moisture Content, Specific Gravity and Bulk Unit Weight, Consolidation Tests, Unconfined Compression Test, Free swell Index, Shrinkage Limit, Swell Pressure Test,etc. as per standard norms. (individual break up)	Each	
	(i) GSA		
	(ii) HA		
	(iii) Atterberg Limits		
	(iv) UU		
	(v) NMC		
	(vi) Spg. & Bulk Den		
	(vii) Consolidation Test		
	(viii) UCS		
	(ix) Free Swell Index		
	(x) Shrinkage Limit		
	(xi) Swell Pressure Test		
10b	Rock samples : Density, Sp. Gravity, Porosity, Water Absorption, Crushing Strength, Point Load Index, Triaxial strength etc.	Each	
	(i) Uniaxial compressive strength	Each	
	(ii) Natural and dry density and specific gravity	Each	
	(iii) Water absorption and porosity and moisture content	Each	
	(iv) Point Load Index	Each	
	(v) Triaxial Strength		
10c	Direct shear test	each	
10d	Chemical Tests (soil) Incl pH, Cl, SO4, CO3	each	
10e	Chemical Tests (ground water) incuding in tunnels for pH, Cl, SO4, CO3	each	
	ROAD LOCATION		
11	Hand Auger Boring at 1 km interval along Realignment / widening portions of approaches upto 2 m depth or refusal strata whichever is earlier, collection of undisturbed samples at specified intervals including all laboratory tests on collected samples as per Technical Specification. (Tests to be specified)	Each	
	(i) Seive analysis		

Serial No	Item Description	Unit	Qty
	(ii) NMC		
	(iii) Atterberg Limits		
	(iv) Sp.G. & Bulk Density		
	(v) Density relation / characteristics		
	(vi) Free Swell Index		
	(vii) CBR Lab		
	(viii) Field Density		
12	Determination of sub grade CBR (soaked) every one km of the Project Highway (Road length of 6.9 km) by conducting field DCPT.	Each	
13	Excavation of pit and collection of samples, determination of characteristics of the existing soil in every one km interval for Roads of the Project Highway (Road length of 6.9 km) (Tests to be specified)	Each	
	(i) Seive analysis		
	(ii) NMC		
	(iii) Atterberg Limits		
	(iv) Sp.G. & Bulk Density		
	(v) Density relation / characteristics		
	(vi) Free Swell Index		
	(vii) CBR Lab		
	(viii) Field Density		
	(ix) DCP (Field)		
	MATERIAL TESTING		
14	Borrow Soils and Granular Material	Each	
	(i) Grain Size Analysis		
	(ii) Atterberg Limits		
	(iii) Compaction Test		
	(iv) 4-Day Soaked CBR		
	(v) 10% Fine (BS 812 Part III)		
15	Aggregate Testing (From Quarry)	Each	
	(i) Grading		
	(ii) Combined FI & EI		
	(iii) Aggregate Impact Value		
	(iv) Specific Gravity and Absorption Soundness		
	(v) Stripping Value of Coarse Aggregate		
	(vi) Soundness of Coarse Aggregate		
16	Lab Test on Natural Sand	Each	
	(i) Gradation and Fineness modulus		
	(ii) Deleterious Constituents (sulphate, chlorides and organic)		
17	Preparation and submission of Report giving all the Field and Laboratory Test Results, Graphs, Charts, tables etc. along with Recommendations on Foundation system, bearing capacity, pile capacity etc. in 3 (three) copies with a soft copy in CD.	LS	