

THE PROJECT FOR
THE OPERATION AND MAINTENANCE
OF
THE SINDHULI ROAD PHASE 2

PLANNING AND DESIGN MANUAL
FOR
RC CONTINUOUS SLAB BRIDGE (RCSB)

DECEMBER 2022

JICA EXPERT TEAM

CONTENTS

CHAPTER 1. INTRODUCTION	1-1
CHAPTER 2. ADVANTAGE OF THE RC CONTINUOUS SLAB BRIDGE (RCSB)	2-1
2.1 Characteristics of the RCSB	2-1
2.2 Applicability of RCSB	2-1
2.3 Standardization of RCSB	2-1
CHAPTER 3. SITE CONDITION SURVEY FOR BRIDGE LOCATION.....	3-1
3.1 Preliminary Survey for suitable bridge location	3-1
3.2 Survey of existing information/material	3-1
3.3 Survey planning	3-2
3.4 Types of survey	3-2
3.4.1 Analysis of Satellite Photograph System	3-4
3.4.2 Site Condition Surveys.....	3-5
3.5 Particular survey for bridge locations	3-6
3.5.1 Survey of alluvial fan in Hilly Terrain.....	3-6
3.5.2 Surveys of Soft Ground.....	3-6
3.5.3 Test Pit Survey in the Alluvial Plain.....	3-7
3.5.4 Survey of River Characteristics and Water Utilization.....	3-8
3.5.5 Topographical Survey for Hydrological and Hydraulic Study.....	3-8
3.5.6 Evaluation of Geotechnical Parameters for Foundation Design	3-9
3.5.7 Survey of Construction Condition.....	3-9
CHAPTER 4. PLANNING OF RCSB	4-1
4.1 Underground water condition at alluvial plain.....	4-1
4.2 Bearing Ground Condition.....	4-2
4.3 River condition for RCSB.....	4-4
4.3.1 Considerations for incidental large debris-flow	4-4
4.3.2 River flow with debris and boulders	4-7
4.3.3 Floating obstacles (driftwood).....	4-8
4.4 Determination of RCSB outer walls and bridge length	4-9
4.4.1 Positioning the Outer Walls and Bridge Length	4-9
4.4.2 Bridge length by Lacey's Regime Theory	4-11
4.4.3 Bridge length at waterway in hilly terrain.....	4-12
4.5 Determination of RCSB height	4-12
4.5.1 Peak Flood Discharge.....	4-12
4.5.2 Vertical clearance height under slab girder	4-13
4.5.3 Scouring Dept.....	4-14

4.6	Determination of the RCSB dimension	4-15
CHAPTER 5. STRUCTURAL DESIGN OF RCSB		5-17
5.1	Design conditions.....	5-17
5.2	Actual load value to the structural analysis model.....	5-19
5.2.1	Dead load calculation on deck slab surface.....	5-19
5.2.2	Footpath loading.....	5-20
5.2.3	Live load calculation on carriageway	5-20
5.2.4	Coefficient of foundation bed reaction.....	5-27
5.3	Design calculation procedure.....	5-30
5.3.1	Determination of general dimension of RCSB.....	5-30
5.3.2	Assumption of the dimension of RCSB members.....	5-31
5.3.3	Conducting frame analysis	5-31
5.3.4	Conducting sectional analysis	5-31
CHAPTER 6. SUPPLEMENTAL INFORMATION		6-1
6.1	Counterplan for deep-embedded bottom slab	6-1
6.2	Discharge diagram	6-2
ANNEXURE.....		1

Abbreviations

ARMP	Annual Road Maintenance Plan
BES	Brief Environmental Study
cis	Cast-in-situ
C/P	Counter Part
DCID	Development Cooperation Implementation Division
DCP	Dynamic Cone Penetration
DDC	District Development Committee
DDG	Deputy Director General
DFL	Design Flood Level
DOHM	Department of Hydrology and Meteorology
DOR	Department of Roads
DOTM	Department of Transport Management
DR	District Road
DWRI	Department of Water Resources and Irrigation
EIA	Environmental Impact Assessment
EIS	Emergency Information System
EMP	Environmental Management Plan
EPA	Environment Protection Act
EPR	Environment Protection Rules
FR	Feeder Road
GESU	Geo-Environmental & Social Unit
GOJ	Government of Japan
GON	Government of Nepal
HFL	Highest design Flood Level or Highest known Flood Level
HkFL	Highest known Flood Level
IEE	Initial Environmental Examination
IRC	Indian Roads Congress
IS	Indian Standard
JICA	Japan International Cooperation Agency
LWL	Low Water Level in dry season
MOPIT	Ministry of Physical Infrastructure and Transport
MOEWRI	Ministry of Energy, Water Resources & Irrigation
NBS	Nepal Bridge Standard
OFL	Ordinary Flood Level in rainy season
PC	Prestressed Concrete
PMU	Project Management Unit
PPA	Public Procurement Act
RC	Reinforced Concrete
RCSB	RC continuous slab bridge
ROW	Right of Way
SPT	Standard Penetration Test
SR0M2	The Project for the Operation and Maintenance of the Sindhuli Road Phase 2
WECS	Water and Energy Commission Secretariat

CHAPTER 1. INTRODUCTION

Sindhuli Road (B. P. Highway) has many multi-cell-shaped-causeways which have been designed and constructed as waterway crossing structures on the widely flat alluvial fans in the Lower Himalayan and the Siwalik Hills. By allowing occasional overflow on its slab and easy repairability for damage on RC members by debris or sediment flow, they become economical structures and can be used for bridges of small to medium length with lower height.

Based on the proven causeway on the Sindhuli Road, a RC continuous slab bridge (hereinafter called as RCSB) has been adopted for structural type of the Mamti Bridge on SROM 2 Project (The Project for the Operation and Maintenance of the Sindhuli Road Phase 2).

Because of these accomplishments, JICA Expert Team was asked to establish the planning and design manual for RCSB. This manual complies with the Nepal Bridge Standards as well as the Indian, Japanese and other relevant standards.

In this manual, general planning, design procedures and conditions for RCSB are regulated, and three standard bridge types of length are summarized.



Source: JICA Expert Team

Figure 1-1 Photo of RCSB on Sindhuli Road and its feeder line

CHAPTER 2. ADVANTAGE OF THE RC CONTINUOUS SLAB BRIDGE (RCSB)

2.1 CHARACTERISTICS OF THE RCSB

- a) The concept of RCSB is similar to the multi-cell box culvert, only the difference which top slab (superstructure) and wall/bottom slab (substructure) are structurally separated. This is why occasional attack by large debris or boulder to superstructure would not harm the whole structural system.
- b) Due to the separation of superstructure and substructure by movable support on the walls, there is no burden on substructure due to temperature changes.
- c) The continuous deck slab superstructure can eliminate the need of reinforcing bars connecting to the substructure. This idea avoids dense reinforcement and complicated formwork, ensuring better quality, constructability and repairability.
- d) Raft foundation is not required any increase against scour depth by any factor as in case of open foundation as stipulated in IRC SP-13.
- e) It is possible to carry out construction by all staging support without using heavy machinery such as large cranes, and then higher safety during construction works is expected.

2.2 APPLICABILITY OF RCSB

(1) RCSB is suitable for the location where:

- a) The river channel/stream is relatively flat, and the sedimentary layer of the riverbed is thick, and scouring is likely to occur,
- b) The river has a deep groundwater level during dry season and can be excavated without any dewatering or slope protection work,
- c) Geological condition of the foundation is relatively soft at shallow layer, open foundation at deep level can be established, or pile foundation can be considered, and
- d) Land use condition around the bridge location restricts the road elevation to keep lower as much as possible not to harm the social impact.

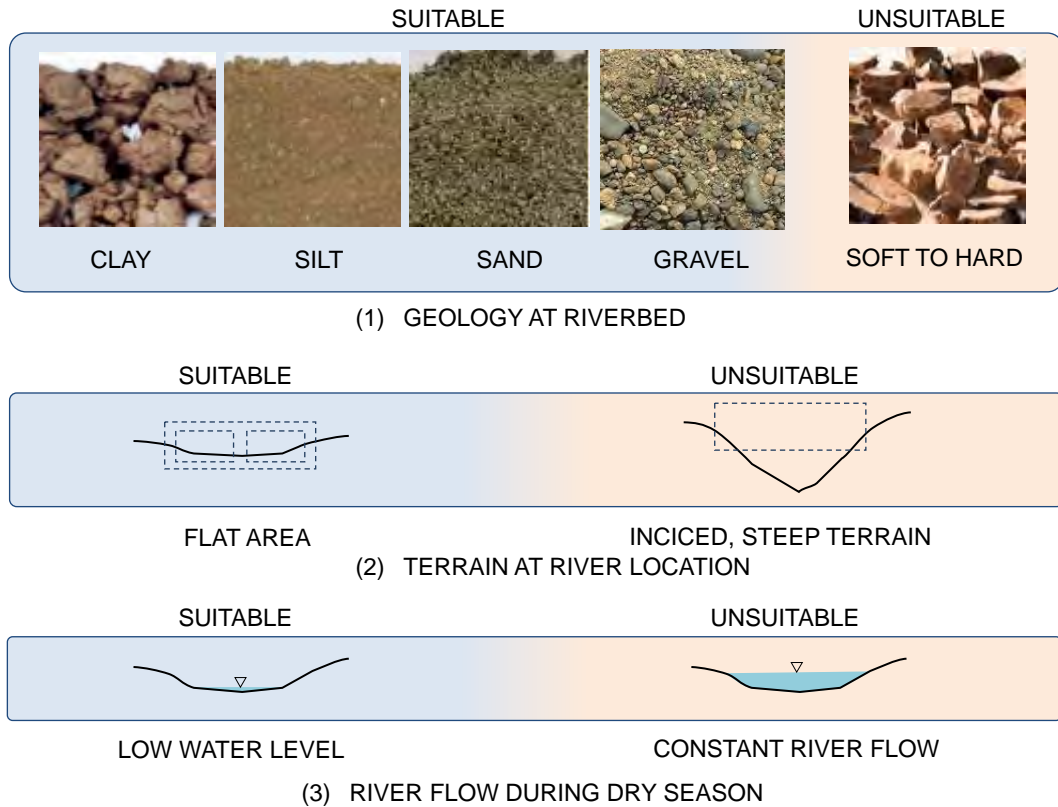
(2) RCSB is NOT recommendable for the location where:

- a) Incised river, steep terrain, natural rocky bottom for waterway,
- b) River with much amount of driftwood and/or debris flows including large sized boulders, and/or
- c) River with constant flow and/or shallow water depth in dry season.

2.3 STANDARDIZATION OF RCSB

Based on the economic comparison, RCSB might be most economic bridge when the total height of structure is relatively low (less than 10m or around).

In this manual, overall design procedures and methods are described for RCSB. Especially for the bridge length of 20m, 30, and 40m, the length which might be frequently planned and adopted, general drawings and reinforcement bar arrangement are prepared.



Source: JICA Expert Team

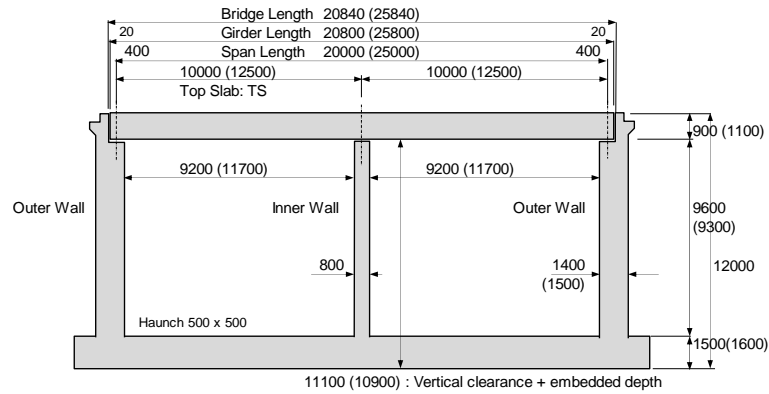
Figure 2-1 Suitable location for RCSB

Table 2.1 Alternative List of Typical Bridge with Design Conditions

Type SN	Span length	Span arrangement	Total height	Inner height	Sub-grade reaction for design	Remarks
1	20 m	10m + 10m	10m	9.6m	SPT N=10	
2	30 m	3 @ 10 m	10m	9.6m	SPT N=10	
3	40 m	12m + 16m +12m	12m	9.3m	SPT N=10	

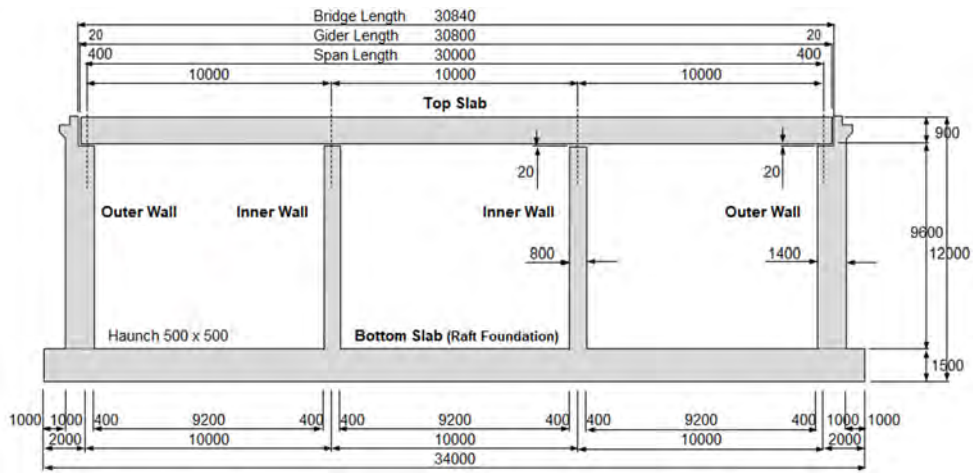
Source: JICA Expert Team

The elevation view of the RCSB is shown in Figure-2-2 for one case of two-cell type and Figure 2-3 and 2-4 for two cases of the three-cell type.



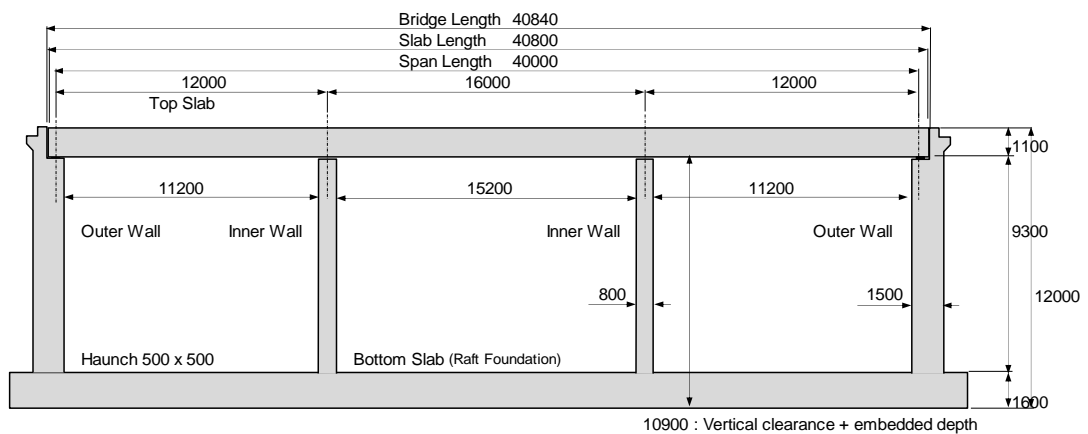
Source: JICA Expert Team

Figure 2-2 Cross Section of Standard RCSB two-cell Type



Source: JICA Expert Team

Figure 2-3 Cross Section of Standard RCSB three-cell Type



Source: JICA Expert Team

Figure 2-4 Cross Section of Standard RCSB three-cell Type (Mamti Bridge)

CHAPTER 3. SITE CONDITION SURVEY FOR BRIDGE LOCATION

3.1 PRELIMINARY SURVEY FOR SUITABLE BRIDGE LOCATION

When choosing the location of a bridge along the highway-class road, engineers often need to reach a compromise between the simplest river intersection and the shortest road alignment. In that case, the choice of location is an economical decision. The most economical and potentially longest-lived bridge site is:

- It is located straight on the river.
- Beyond the disturbing effects of larger tributaries.
- There are well-defined banks.
- There is a reasonably straight approach road.
- Allow square intersections as much as possible.
- The bearing layer of the foundation is good condition.
- The ground water depth is deep in the dry season, making it suitable for open excavation with dewatering.

On this site, the maximum slope of the approach road will not only be suitable for the type of vehicle that may travel on the road, but also provide a vertical curve and viewing distance on the bridge.

A Bridge located at right angle (90 degree) to the direction of river flow will provide the shortest economical superstructure. The standard drawing is also prepared based on such planning of the bridge.

When crossing an alluvial fan, the bridge should be located as near to the throat of the fan as possible where the tributary stream has sufficient gradient to be self-scouring. If this is not practicable and the crossing has to be located across the body of the fan, there will be a requirement for extensive training works to confine the flood flow and for the regular removal of sediment from under the bridge. Bridge crossings over alluvial rivers nearly always require river training works to stabilize the channel flow within the bridge waterway opening.

3.2 SURVEY OF EXISTING INFORMATION/MATERIAL

In designing substructures, it is necessary to recognize the geotechnical structures at the site, determine approximate sub-structural dimensions and foundation arrangements, perform necessary ground surveys, and obtain design information. Preliminary surveys should be performed to identify geotechnical structures and the contents of the principal surveys.

Surveys of existing information are conducted to comprehend the outline of the geo-graphical and geotechnical features at the site through existing geotechnical investigation data, geographical maps, aerial photographs, current and past satellite photo-graphs (Google Earth). Accordingly, historical surveys should be performed at the first stage of the preliminary surveys in order to understand the approximate geotechnical structures and so that the results can be used in other surveys.

1) Data and Information Collection

Correction of the topographical map and metrological rainfall data, etc.

2) Surveys of Existing Ground Information

Existing geological maps and geographical should be collected for the survey of the geographical and geotechnical structures. Furthermore, it is often possible to define the outline of the geotechnical layers by collecting borehole data and in-formation on wells near to the investigation site.

3) Surveys of Other Information

In addition to the above, the following information is needed for the bridge planning.

- a) Cadastral maps (check for right of way, forest area, private land etc.), land condition maps, land use maps, land classification maps, old maps, etc.
- b) Wide area information including aerial photographs, remote sensing data, GPS, etc.
- c) Information on disasters such as river floods, floating debris, slope failures, land-slides.
- d) Laws, regulations, and guidelines on environmental protection including noise and vibration.
- e) Information on active faults

4) Collection of Construction Records

Collation of information on bridge type, scale, subsidence and slope, and construction records of existing bridge structures near the candidate survey site can provide an overview of the geotechnical layer at the bridge location.

3.3 SURVEY PLANNING

In order to understand the approximate properties of the proposed bridge site, and to obtain necessary for preliminary design and principal survey plan, the following data collection and surveys shall be performed.

Survey of Existing Information

- a) Site Reconnaissance
- b) Test pits survey (alluvial plain in Terai)

Site reconnaissance is used to evaluate subsurface geology from the properties of rocks and soils observed at the surface. In other words, geological plans are prepared by combining sectional geological maps made from rock outcrops and other properties along rivers and roads in the survey area. Furthermore, the existence of landslides, and other geographical and geological features adverse to the construction should be examined in the geographical observation.

When choosing the location of a small bridge, engineers often need to reach a compromise between the simplest river intersection and the shortest road alignment. In that case, the choice of location is an economical decision. The cheapest bridge sites and potentially the longest-lived sites are:

3.4 TYPES OF SURVEY

In order to understand the approximate properties of the proposed bridge site, and to obtain necessary for preliminary design and principal survey plan, the following data collections and surveys shall be performed. The following surveys shall be performed for the design and construction of the Raft Foundation for the bridge:

- a) Surveys of river characteristics (discharge)
- b) Topographical survey (sub-contract survey)
- c) Geotechnical survey (sub-contract survey)
- d) Surveys of construction conditions

Table 3-1 shows the principal objectives and contents of various survey of 1) to 4).

Table 3.1 Survey Points

Survey Method	Principal Objectives	Survey Items	Remarks
1. Survey of River Characteristic			
Survey of River Characteristics	Understanding rivers/channel/stream, degree of change	<ul style="list-style-type: none"> a. Current river/channel bed and bed gradient, conditions b. Current channel velocity, flow rate, water quality, maximum wave height in flood, difference between high and low water levels, increase in water levels by rainfall, change in water flow by scour, backwater effects behind pier/wall c. Observation of floating debris, boulders in debris-flow and their past records d. Conditions of management of rivers and ponds and future plans e. Change in water flow by scour f. Aggradation of the riverbed g. Backwater effects behind existing bridge pier 	
	Flood-flow condition in rainy season/flood	<ul style="list-style-type: none"> a. Positioning of the flood water b. Past record of the waterway c. Occurrence of flowing and drifting substance d. Water utilization for irrigation channel, agriculture 	Determination of the bridge end positioning
Ground water level by Test pits survey	Test pits survey for bridge location at open excavation in alluvial plain in Terai area	<ul style="list-style-type: none"> a. Test pits by manual b. Test pits by auger-hole 	For selection of the proposed bridge site considering construction ability to avoid sand boiling for open excavation
2. Topographical Survey			
Survey of Waterway	Assume channelization bed line and gradient	<ul style="list-style-type: none"> a. Waterway profile b. Waterway cross section c. Road center cross section 	
3. Geotechnical Investigations			
<ul style="list-style-type: none"> 1. Boring 2. Sampling 3. Sounding 4. Ground water survey 	<ul style="list-style-type: none"> i) Overview of ground, structures, and properties of soil layers (preparation of layers geological maps and bore logs) ii) Rotary boring iii) Core tube sampling iv) Measurement of ground water table in situ v) Measurement of pore-water pressure 	<ul style="list-style-type: none"> a. Survey of geography and geology b. Type of soil by coring c. SPT (Standard Penetration Test) N-value for all types of soil and/or soft soils d. DCP (Dynamic Cone Penetration) test for gravel, boulder (convert to SPT N-value) e. Underground water level f. Record for past damages 	<p>Flat Plain area</p> <p>Soft soil must be done by Standard Penetration Test (SPT) method not done by DCP test.</p>
Survey of ground water	<p>Study of construction methods and working procedure</p> <p>In case of open excavation with dewatering by pump,</p>	<ul style="list-style-type: none"> a. Underground water level If available b. Water quality test c. Pore-water pressures 	

		d. Flow direction and velocity	
Soil Test	In situ and/or laboratory	a. Sieve grading test	Particle size analysis
4. Survey of Construction Conditions			
Survey of Existing Information	General reference material for design and construction of sub-structures	<ul style="list-style-type: none"> a. Design documents and construction records from typical construction examples b. Records of experiences from persons concerned and opinions of experts c. Past evidence of flooding, geological structures, and land use situation from aerial photographs 	Study of construction methods, machines, equipment and working procedures
Survey of Surrounding Environment	<ul style="list-style-type: none"> i) Study of the effects of construction works on environment ii) Study of construction methods, machines, and working methods iii) Study of measures for protecting surrounding environment 	<ul style="list-style-type: none"> a. Present houses, construction works on vibration levels, ground environment movement, water level b. Generation of noise, vibration change in well water, and traffic change likely to occur during construction due to construction methods machines and operation methods adopted c. Existence of historical d. monuments and sites of cultural heritage e. Existence of special environments including forests, riverheads 	
Survey of Construction Environment	<ul style="list-style-type: none"> i) Understanding various restrictions and conditions on construction works ii) Study of interactions between adjacent structures and the substructures concerned iii) Study of construction methods, location of operation facilities, machines, and procedures iv) Study of protection measures at the construction site and safety measures of construction operations v) Weather forecast for construction period 	<ul style="list-style-type: none"> a. Working area; working space: width, alignment, traffic volume, and traffic restrictions on access roads b. Locations, amounts, and procedures for disposal of excavated soil and stabilities c. Location and availability of electricity, water supply, sewerage, etc. d. Location, type, and scale of adjustment structures, buried structures, cables, etc. e. Records of rainfall, temperature and humidity, wind direction, freezing and melting, etc. 	“Industrial safety and hygiene law, Ordinance on industrial safety and Hygiene and related regulations should be fully understood.

Source: JICA Expert Team, referred to Specifications for Highway Bridges IV Substructure, Japan Road Association

3.4.1 Analysis of Satellite Photograph System

Useful information is available from the satellite photography system (Google Earth), which has coordinates and altitude, such as current waterway conditions and bed gradients, flood routes, traces of flood routes, revetments, land use conditions such as houses, cultivated land, access routes, and quarrying site.

In addition, by checking past records on the system, engineer can obtain information on evidence and traces of waterways (channel course and width of channel, water retention status, boulders, driftwood, etc.). At this time, it is important to consider the time when the satellite photo was taken in the rainy season or the dry season.

It is necessary to conduct a field survey to verify the information obtained from existing survey data and satellite photos and to observe and estimate the mechanism of channel change or shift.

3.4.2 Site Condition Surveys

Once the engineer has identified a likely site for the bridge, the engineer needs to obtain field information on the local terrain and river conditions in addition to the soil information (by geotechnical survey) and hydraulic data. The key points of field information relate to:

- Observation of both site condition in rainy/flood season and dry season
 - Water levels and location of waterway in flood
 - Gradation of riverbed and catchment area of the river
 - Vertical clearance requirements
- 1) Water levels and location of waterway in flood

Information is needed on the highest known flood level (HkFL), the ordinary flood level (OFL) in rainy season and the low water level (LWL) in dry season at the proposed site.

The ordinary flood level (OFL) is the level to which the river normally rises during the wettest part of the year.

The low water level (LWL) is the level prevailing in the river during dry season. If there is little or no flow in dry season, the period during which the riverbed remains dry should be noted. The LWL affects the dewatering method and its scale by open excavation or planning cofferdam for excavation in dry season.

Especially, the HkFL with positioning of the waterway while flooding should be determined by local observation wherever possible, supplemented by inquiries in the locality including DOR site engineers.

The LWL affects the dewatering method and its scale by open excavation or planning cofferdam plan for excavation in dry season. The silt marks that high floods generally leave on tree trunks and housings can remain visible for several years. However, it is imperative to ask people who have lived in the area for a long time, especially about their recollections of particularly high floods and concern information.

2) Catchment area

River basin ranges can be used to determine areas included in plans and sections and to estimate peak flood discharges for bridge design (design flood discharge). If topographic maps (1/25,000 scale maps taken by the research department), aerial photographs are collected and/or Google Earth is used, mark catchment limits and specify the total area. Based on this catchment area, it is also possible to estimate the required bridge length by assuming the design flood discharge.

3) Vertical and horizontal clearance requirements

The waterways below the superstructure must be designed to pass through design floods and floating and/or rolling debris carried over them. The height of the bridge superstructure should consider the removal of suspended matter during floods. Drainage channels and other alluvial channels may require regular dredging. When rivers are full, river maintenance equipment is unlikely to move, but this is the time when trees and other floating debris can be carried by floods. Experience from other structures on the similar river and local surveys will help record driftwood, boulders, sediments and identify the required clearance between the design flood level and the underside of the superstructure.

3.5 PARTICULAR SURVEY FOR BRIDGE LOCATIONS

For surveys in specific cases under the following conditions, special attention shall be given to existing data, geography, geology, and environment:

- 1) Alluvial fan in hilly terrain
- 2) Alluvial plain in Terai plain with soft ground and shallow ground water table
- 3) Test pits survey in the alluvial plain

For design stage survey, it is necessary to perform surveys of the construction conditions. At the construction stage, supplementary surveys of the construction should be implemented, as needed, only after fully understanding the results of the surveys obtained at the design stage. Furthermore, during construction, various surveys need to be performed for the purposes of construction management. Basically, geotechnical investigations should be performed at each bridge foundation location. For the raft foundation of large size bridge, a couple of surveys should be conducted diagonally at both ends. In cases of complex or simple geographical variations, however, the number of survey points can be increased or decreased, respectively.

The ground to which the RCSB can be applied is plain terrain on flat ground and alluvial fan in hilly terrain. So, it does not mention incised river, rocky ground with steep geographic features in mountainous area, which cannot be applied.

3.5.1 Survey of alluvial fan in Hilly Terrain

When the design and construction of substructures are undertaken in hilly terrain, it is important to evaluate the ground conditions (mainly sedimented gravel, sand, and boulder) and study the construction methods. As the geotechnical conditions and construction conditions in hilly terrain will differ from those for plain field, specific evaluation methods should be employed to take the ground features into account.

1) Survey of Existing Materials

When debris flows, rolling/floating boulders, landslides, and slope failures are likely to occur, existing information focusing on the results of geological surveys should be collected as needed. Furthermore, with reference to past disasters that occurred nearby, substructure types, construction methods, and subsidiary construction methods shall be examined.

2) Survey of Geography and Geology

The designer must carefully examine the locations and number of investigation sites, as mountainous areas often have steep geographic features, and the structure of the geotechnical layers is generally complex. Accurate information on the geography and geotechnical structures should be obtained by increasing the number of surveys and boreholes.

In general, as alluvial fan in hilly area are deposit sedimentation ground, the survey items and their evaluation procedures will differ from those for ground.

3) Survey of Construction Conditions

A study of the construction conditions is of primary importance in the design of sub-structures in alluvial fan in hilly terrain. For example, the construction methods, the selection of appropriate machinery, temporary works designs, and the design of access roads are important items. Surveys of the surrounding environment as well as construction sites are also necessary.

3.5.2 Surveys of Soft Ground

It is generally difficult to evaluate the geotechnical conditions of soft ground, and such an evaluation

would have a significant effect on surrounding structures and ground, as well as the design of the structures concerned. Therefore, careful surveys of soft ground should be performed in consideration of the following points.

1) Survey of Existing Materials

An overview of the ground conditions should be first obtained from available information in geotechnical bore logs or geological profiles. In cases of soft ground, more detailed studies are necessary. Therefore, it is important to carefully collect and examine existing geological data when making a ground survey plan. At the same time, a study of previous construction including structural scales, evaluations of geotechnical parameters and types of auxiliary construction methods introduced will provide valuable information for planning the design and construction.

2) Geotechnical Investigations

When designing and constructing structures on the soft ground, detailed investigations of consolidation settlement, negative skin friction, lateral ground movement and the stability of retaining and cofferdam walls are needed. As a result of these studies, it is important to evaluate the appropriate geotechnical parameters.

Surcharges on fills, eccentric earth pressures during construction, ground creep, and the lowering of groundwater levels may cause specific changes of the ground properties. In such cases, it is necessary to increase the number of test sites and investigations in order to comprehend conditions such as the variation, thickness, and structure of soil layers, and to ensure the adequacy of geotechnical parameters evaluated from the tests.

3) Surveys of Surrounding Environment

At sites on soft ground, a significant number of additional works including enlargement of foundation works for main structures, temporary works such as cofferdams, and soft ground improvement works may be required. In addition, environmental effects such as propagation of ground vibration, large ground displacement, contamination of underground water and other problems are likely to arise. Accordingly, surveys on adjacent facilities and buried structures need to be performed.

As ground conditions differ from one site to another, adequate geotechnical investigations should be selected in accordance with the type and scale of the foundations, and the design stages. It is possible to perform effective geotechnical investigations by re-viewing survey items and accuracy, and by distinguishing between the preliminary and principal surveys.

3.5.3 Test Pit Survey in the Alluvial Plain

Test pits and auger-holes in the proposed bridge site for confirmation of the under-ground water table and soil type in each layer (Bridge Branch/DOR).

If the site is an alluvial plain (Terai Plain) and open excavation is assumed in the foundation work, it is desirable to confirm the possibility of sand boiling and/or spring water by test pits when selecting the bridge position (candidate site). Since the foundation work will be in the dry season, the test pit survey must be conducted in the dry season as well.

The test pit, which requires the bottom to be at least 1m square, is a cheap and easy underground exploration method. The pits are usually dug by hand, but most of the material can be removed using a mechanical excavator before the sides and bottom are squared and cleaned for inspection. This survey method provides excellent data on underground conditions within the depth of excavation of the pits, allowing clear images of soil stratification, the presence of lenses or pockets of weak materials, ground water table and its condition. The maximum practical depth at which a pit can be excavated is approximately 3 m. Below a depth of about 1.5 m from ground level, the sides of the pit need to be supported or excavated at a safe cutting slope angle.

3.5.4 Survey of River Characteristics and Water Utilization

Surveys of river characteristics and water utilization shall be performed in terms of Future River, water utilization and transportation plans, etc.

Bridge and girder fall are often caused by damage to the bridge substructures during flooding. Surveys of river characteristics and water utilization are performed to avoid bridge damage due to river flows, and to minimize the effects of substructures on water utilization and shipping.

Therefore, when planning a bridge over a river, sufficient coordination with the river control organizations should be established. Further, related laws, especially Ordinance on Structures on River Management Facilities," should be conformed to, because it specifies regulations on the locations of abutments and piers, their configurations, embedment depths of foundations from the planned riverbed, span lengths, clearances, and other factors. Regulations on embedment depths of foundations, however, indicate minimum requirements from the viewpoint of river management. It should be noted that these regulations do not guarantee the long-term stability of foundations against scour.

The stability of bridge foundations against the effects of scour is one of the most important aspects to be considered in the maintenance and management of bridges. The amount of scour during flooding will be affected by water depth, flow velocity, riverbed gradient, riverbed materials, configurations and intervals of bridge piers, angles between river flow and the bridge axis, etc. Appropriate surveys must be performed to estimate the amount of scour.

Surveys of river characteristics consist of reviews of water level, flow, velocity, current and past waterway center lines, movement of the riverbed (degradation and aggradation), flood history, high tides, and surges. Further, for a river improvement plan, the planned high water level and dredge elevation should be identified, and the locations and embedment depths of substructures should be determined. Moreover, the elevations of riverbeds at bends and rapid streams will drop temporarily during flooding and recover to the original following the drop in water level. Therefore, the results of surveys performed during normal conditions will sometimes underestimate the amount of lowering of the riverbed.

Additional surveys on backwater actions behind piers, flowing timbers, drift ice, debris flow, dynamic water pressures, currents, wave heights, sand accumulation, changes in flow due to tidal differences, etc. should be performed.

Furthermore, surveys on water use situations such as irrigation and hydraulic power generation, fishing rights and shipping should be conducted, and co-ordination with related organizations and groups need to be fully secured.

3.5.5 Topographical Survey for Hydrological and Hydraulic Study

Topographic survey shall be done for hydrological analysis for bridge waterway and hydraulic study for bridge design. The detailed activities of topographic survey are presented as follows.

- 1) Benchmark setting and report of BM location
- 2) Raw data (coordinate table: X, Y, Z) from the topographic survey
- 3) Check/validation sheet for accuracy of the topographic survey
- 4) Digital Elevation Models (DEMs) having one (1) meter grid spacing
- 5) Contour lines with an interval of one (1) meter
- 6) Topographic maps prepared at a scale of 1:500
- 7) Longitudinal profile and cross sections of planned road prepared at a scale of 1:500
- 8) Water course profile and cross sections of river/stream at 200 m or more at U/S side and 100 m

at D/S side prepared at a scale of 1:500

3.5.6 Evaluation of Geotechnical Parameters for Foundation Design

Geotechnical parameters for design shall be established by evaluation of the results of geotechnical investigations. The principal survey to identify ground conditions, construction conditions, and geotechnical parameters for the detailed design of foundations shall generally consist of the following:

- 1) Boring by rotary drilling
- 2) Sampling
- 3) Sounding: SPT N-value test
- 4) Underground water survey

In order to obtain the information necessary to design and construct economical and safe substructures, these ground surveys should be performed at each abutment, pier location, or raft foundation (of the Bridge). For a large raft foundation, it is preferable to carry out at two points on the diagonal. In cases of complex or simple geographical variations, the number of survey points may be increased or decreased, respectively.

3.5.7 Survey of Construction Condition

The following surveys of construction conditions shall be performed:

- 1) Survey of existing information
- 2) Survey of surrounding environment
- 3) Survey of construction environment

At the design stage, attention is not usually paid to surveys of construction conditions. However, the safety and reliability of the construction should be carefully investigated at the design stage because such considerations are important.

At the construction planning stage, selection of the construction methods, scales, construction seasons and periods and schedules are necessary.

- 1) Surveys of existing information

Examples of substructures close to the new bridge site are useful when examining overall procedures for the design and construction. Accordingly, the collection of design documents, construction records and related information of actual examples is desirable. Reviewing the experiences of persons involved in previous similar projects is also recommended.

- 2) Surveys of surrounding environment

During the construction of substructures, land subsidence, soil excavation in ground-water, oil dust, noise and vibrations affect the surrounding environment. Therefore, it is necessary to investigate the quality of well, the location of buildings, houses, cultivated land, etc., the impact of excavation, and the traffic conditions around the candidate bridge site in advance. It is also necessary to evaluate the extent of the impact of construction on the surrounding environment. The location of the bridge should be carefully considered, especially in environments with wells and irrigation canals, including handling during construction. In addition, cultural and historic buildings, heritage, and riverbanks should be carefully considered.

- 3) Survey of construction environment

When choosing the type, scale, and method of construction of the foundation, it is necessary to investigate all the types and arrangements of construction facilities and machines, materials, work procedures, geography of the construction site, and work-space and area. Therefore, it is necessary to conduct field surveys and various information surveys to understand these factors.

The presence of adjacent or underground structures near the new construction site also has a significant impact on the construction of certain types of foundations, so location, type, embedding depth, etc. must be investigated. Especially for adjacent structures, it is necessary to collate their design documents with construction records. In some cases, the interaction between the new substructure and adjacent structures may need to be investigated by performing geotechnical survey to determine the embedding depth of the foundation.

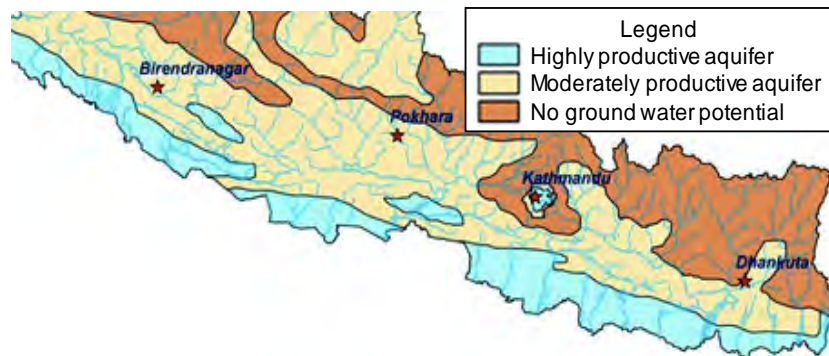
CHAPTER 4. PLANNING OF RCSB

4.1 UNDERGROUND WATER CONDITION AT ALLUVIAL PLAIN

A bridge is planned in an alluvial plain, for selection of the proposed bridge site, it is required to confirm the underground water table and condition in dry season for construction of foundation by open excavation method to avoid sand boiling and spring water.

The soft soil in the Terai Plain is alluvial deposits of fine to medium textured as sand, clay, silt, gravels, and coarse fragments. High groundwater potential zone are spread in Terai Plain as shown in Figure 4-1, underground water level survey is considered indispensable when selecting the bridge position.

As shown in figure 4-2, the bridge construction at these locations were canceled while the excavation because the excavated area of the raft foundation was filled with water. Water level stays in the dry season and sand boiling at the high underground water table at the sandy soil bed.



Source: Groundwater Resources of Nepal SpringerLin

Figure 4-1 Preliminary Ground Water Potential Map

As the preliminary bridge site selection, it is necessary to confirm the water level of the candidate site for the bridge in the dry season with test pits or hand auger-holes boring survey on the premise that the foundation work will be conducted by open excavation with dewatering pump method in the dry season. If the groundwater table by test pit survey is high, it shall be changed the bridge position, excavate by temporary coffer-dam work, or consider other type of bridge with pile foundation or pile bent.

There was a case where the construction of a box-type causeway has required site and design changed by sand boiling. In the construction of the slab bridge in the Terai Plain (refer to photos below), the bridge construction at this location was canceled while the open excavation because the excavated area of the raft foundation was filled with spring water due to sand boiling at the high ground water table with sandy soil bed.

Very loose and uniform grain sized fine sand with rapidly changing ground water table tends to suffer large subsidence under load, and in this case, it is assumed that the SPT N-value and safe bearing capacity of bearing strata were lower than the minimum requirement. Sand boiling occur when water under pressure wells up through a bed of sand.

As same as the above paragraph 1), if the soil condition and groundwater table cannot be confirmed by geological survey or excavation work by other project near the site or the expert knowledge, it is necessary to confirm them by test pits by shovel or borehole investigation at the site.



Trouble case due to high groundwater:

A box type causeway was planned on the moist sandy soil ground in the Terai Plain (alluvial plain).

The open excavation work was conducted during the rainy season, but a large amount of spring water was generated. Subsequent sand boiling of groundwater continued, and construction was suspended.

The position of the bridge was moved to the upstream side, the length and depth of the bridge were minimized, and the riverbed prevention measures were combined to complete the work.

Source: JICA Expert Team

Figure 4-2 Troubles due to high ground water level

4.2 BEARING GROUND CONDITION

To apply the slab bridge, the following points must be satisfied. In addition, it is desirable to confirm the design conditions by geotechnical survey.

- 1) Sub-grade below the raft foundation shall be equal or more than SPT N-value 10.
- 2) It is required to confirm no sand boiling in the ground water at plain area.

In the design of bridge foundations, the bearing capacity of the foundation base needs to be proved by geological survey. In the design of the Raft Foundation, the SPT N-value and soil material type is confirmed by drilling borehole survey.

- 1) Sub-grade below the slab bridge shall be equal or more than SPT N-value 10

Raft foundations of the slab bridge are found to be quite suitable for small bridges where the founding strata is soft and has Safe Bearing Capacity up to 100 kN/m² stated in Clause 13.5.13, IRC: SP13-2014.

Tables 4-1 and 4-2 show the relationship between safe bearing capacity and SPT N-value according to the type of soil. In addition, Table 4-3 summarizes the design constants on alluvial fan in hilly terrain and plain areas that are the targets of the slab bridge construction.

However, if the geological condition cannot be confirmed by geological survey or excavation work by other project near the site or the expert knowledge, it is necessary to confirm the safe bearing capacity by borehole investigation or plate loading test at the site.

- 2) It is required to confirm the ground water table in the alluvial plain to avoid sand boiling

In the construction of the slab bridge at the alluvial fan of the hilly terrain on the Sindhuli Road, the ground water table is deep and riverbed gradient is relatively steep, the riverbed material is sedimented dense gravel and coarse sand with high permeability, so there was less influence of spring water while excavation of the raft foundation.

Table 4-1 Safe Bearing Capacity

Type of soil/rock		Safe Bearing Capacity kN/m ²
Rocks	Residual deposits of broken bed rock	880
	Soft rock	440
Cohesionless soils	Gravel, sand and gravel	440
	Coarse sand	440
	Medium sand, loose gravel	245
	Fine sand and silt	150
Cohesive soils	Hard or stiff clay	440
	Moist clay and sand-clay mixture	100
	Soft clay	100
	Very soft clay	50

Source: IS:1904

Table 4-2 Type of Bearing Stratum and Safe Bearing Capacity

Type of bearing stratum		Safe bearing capacity kN/m ²	Reference value	
			Uniaxial compressive strength kN/m ²	SPT N-value
Relative density				
Gravel	Very dense	600	-	-
	Not dense	300	-	-
Cohesionless soils	Dense	300	-	30 ~ 50
	Midium dense	200	-	20 ~ 30
Cohesive soils	Very hard	200	200 ~ 400	15 ~ 30
	Hard	100	100 ~ 200	10 ~ 15

Source: Japan Road Association

Table 4-3 Design N-value for Spring Support of Foundation Base below Raft Foundation

Location of River	Type of Soil		N-value for Spring Support of Foundation Design	
			Assumed SBC kN/m ²	SPT N-value for design
Alluvial fan	Gravel, granular soil (Deposit sedimentation)	Cohesionless soil	440	30
Terai Plain	Fine sand and silt	Cohesionless soil	150~200	15~20
	Soft clay	Cohesive soil	100	10 Min. requirement

Source: IS: 1904 and Japan road association

4.3 RIVER CONDITION FOR RCSB

4.3.1 Considerations for incidental large debris-flow

Since the slab bridge has a short span and a limited horizontal opening width, the principle is that there are no occurrence debris-flows that will be obstacles after construction.

The nature of debris-flow is governed by the gradient of riverbed based on the flow movement material of gravel or mud as mentioned in Table 4-4.

Debris flow occurs when water-laden masses of unconsolidated soil and fragmented rock move down mountainsides in response to gravitational attraction, funnel into stream channels, entrain objects in their paths, and form thick, muddy deposits on valley floors.

“The Study for the Design Criteria on the Transit Roads over Devastated Rivers, 1982, Technical Center for Sediment Control and Landslide, Japan” recommended a design policy for the bridges to be constructed at rivers with debris-flow. It classified debris-flows and its characteristics as shown in Table 4-4 and Table 4-5.

Table 4-4 Riverbed Gradient and Types of Debris-flow

Riverbed Gradient	Type of Flood
1/3 (35%) 20°	Debris-flow Occurrence section
1/4 (25%) 15°	Debris-flow Passing section
1/5 (17%) 10°	Debris-flow Stopping, Sediment-flow Passing section
1/20 (5%) 3°	Debris/Sediment-flow Stopping section
1/60 (2%) 1°	Sediment-flow Stopping section
	Flood-flow section

Source: *The Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center*

Table 4-5 Deposit Characteristics of Debris Flow in Alluvial Fan/Plain

Flow Type	Characteristics of Flow
Debris-flow	<ul style="list-style-type: none"> The flow is divided into large boulders at the tip of debris-flow and a subsequent part of sediment-flow A maximum boulder dia. of 1.5 m or more exists There is as welling in the center part of debris-flow There are traces flowing down from the upstream and high straightness Deposit relatively thick There are 2 types of movement material as gravel or mud Mainly observed in Himalayan hilly terrain
Sediment-flow	<ul style="list-style-type: none"> Traces of stratified structure carried by the flow can be seen There is boulder with a maximum particle diameter of 0.5 to 1.0 m around, while there are many fine-grained substances Existence of sprayed deposits widely
Mud-flow	<ul style="list-style-type: none"> Existing of layer upon layer deposit Studding of boulder dia. 0.5-1.0m Existing of fine materials Existing of sprayed deposits widely Mainly observed in Siwalik hilly terrain
Flood-flow	<ul style="list-style-type: none"> Relatively uniform grain size and flat deposition surface Flowing and bedding structures are seen The maximum gravel diameter is about 0.1 to 0.2 m Widely dispersed and deposited, relatively thin Mainly observed in Terai Plain

Source: The Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

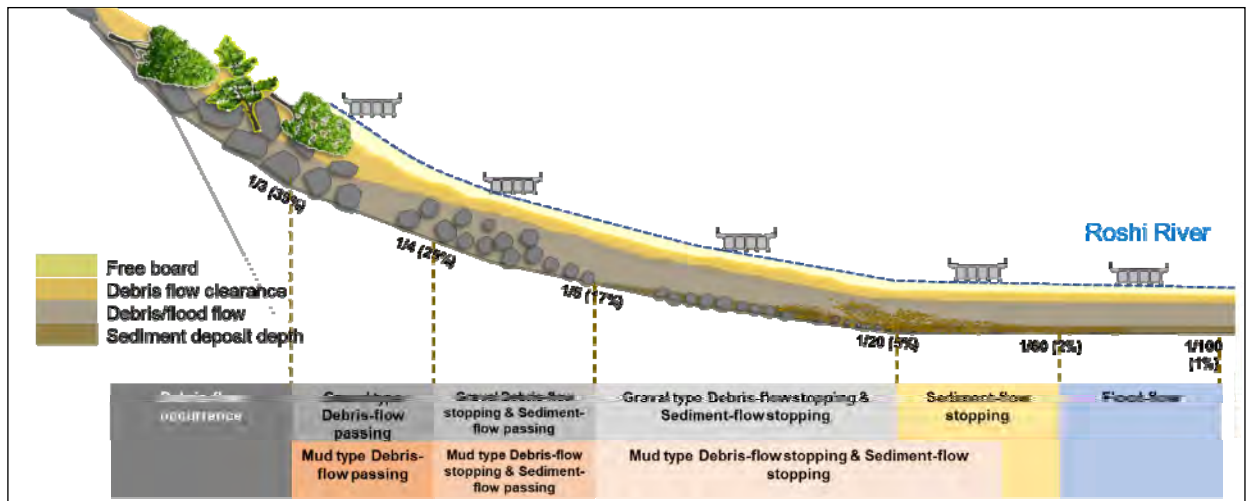
The nature of debris flow is governed by the gradient of riverbed based on the flow movement material of gravel or mud as mentioned in Table 4-6 below, same way riverbed grading, and nature of debris-flow is presented in Figure 4-3.

Table 4-4 River Gradient and Nature of Debris-flow based on Material Type

Gravel Type Debris-flow		Mud Type Debris-flow		General flow material
Bed gradient	Nature of Debris Flow	Bed gradient	Nature of Debris Flow	
steeper than 35% (>1/3)	Debris-flow occurrence section			Boulder larger than 1.5m
35~25% (1/3~1/4)	Gravel type Debris-flow passing section	35~25% (1/3~1/4)	Mud type Debris-flow passing section	
25~17% (1/4~1/5)	Gravel type Debris-flow stopping and Sediment-flow passing section	25~17% (1/4~1/5)	Mud type Debris-flow stopping and Sediment-flow passing section	Boulder size 0.5~1m
17~5% (1/5~1/20)	Gravel type Debris-flow stopping and Sediment-flow passing section	17~3% (1/5~1/30)	Mud type Debris-flow stopping and Sediment-flow passing section	Scattering boulder size Max. 0.5~1m, mostly granular material
5~2% (1/20~1/60)	Sediment-flow stopping section	3~2% (1/30~1/60)	Sediment-flow stopping section	
2~1% (1/60~1/100)	Flood-flow section			Max. granular size 0.1~0.2m

Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

The tributary or river that crossing the bridge is flowing mainly gravel material and located where the normal gravel type debris-flow stopping, and sediment-flow section overlap.



Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

Figure 4-3 Riverbed Gradient and Nature of Debris-flow

The possibility of constructing bridge piers or inner wall of the slab bridge at locations of debris-flow is required as shown in Table 4-7.

Table 4-5 Bridge Pier/Wall Construction Possibility in River

Type of debris	Flowing point	Possibility of constructing pier in river
Gravel type Debris-flow	Flowing section	Not recommendable
	Stopping section	Not recommendable
Mud type Debris-flow	Flowing section	Not recommendable
	Stopping section	Practicable
Sediment-flow	Sediment flow section	Practicable
Flood-flow	Flood flow section	

Source: The Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

Based on above consideration at normal debris-flow section, the following detailed and modified bridge inner walls for the slab bridge construction possibility proposed in Table 4-8.

Table 4-6 Bridge Construction Possibility in Debris-flow

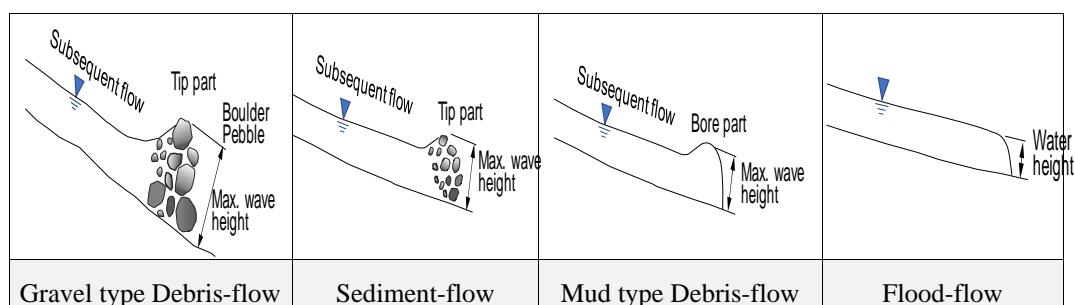
Type of flow	Crossing section	Typical riverbed gradient	Typical normal boulder size	Possibility of constructing inner wall of slab bridge
Gravel type Debris-flow	Occurrence section	>35% (>1/3)	Boulder larger than 1.5m (Max. 10m)	Not recommendable
	Passing section	35~25% (1/3~1/4)		Not recommendable
	Stopping section	25~17% (1/4~1/5)	Boulder size 0.5~1m	Not recommendable
Mud type Debris-flow	Passing section	35~25% (1/3~1/4)	Less boulder	Practicable
	Stopping section	25~17% (1/4~1/5)		Practicable
Normal Debris-flow	Stopping section	17~5% (1/5~1/20)	Scattering boulder size Max. 0.5~1m, mostly granular material	<u>Practicable: according to some conditions</u>
Sediment-flow	Sediment flow	5~2% (1/20~1/60)		Practicable
Flood-flow	Flood flow	2%~ (1/60~)	Max. granular size 0.1~0.2m	Practicable

Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

4.3.2 River flow with debris and boulders

In river with debris-flow, if the boulder size is medium and the river stream tends to stabilize riverbed and bank year by year, it may be possible to adopt the bridge.

The debris-flow is divided into a gravel type debris-flow and a mud type debris-flow, and the state of each flow is schematically represented as shown in Figure 4-4. Gravel type debris-flow is occurred in mountain or hilly stream with rich sand, gravel, and rock, on the other hands, mud type debris-flow occurred in stream mainly much contain silt, clay, and fine particles. In the gravel type debris flow, boulders are concentrated at the tip of flow, but there is no boulder concentration at the tip of mud type debris-flow. In addition, although the subsequent flow is in the state of flood flow, there are some disaster cases where some amount of gravel and debris is flowing out.



Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

Figure 4-4 Pattern Diagram of Flow Type and Maximum Wave Height

If the debris-flow is in a stopping section, it would be liked to consider that it is possible to install a bridge pier (inner walls for the slab bridge) in the river or channel so as to meet the following conditions, it might be possible to adopt a slab bridge.

If the debris flow is in a stopping section, it is considered that the piers (walls) of the slab bridge can be installed in the waterways to satisfy the following conditions.

- 1) It has been confirmed that the river channel is stable year by year, and the size and amount of

boulders tend to decrease.

- 2) The maximum size of boulder deposited in recent years is equal or less than about 0.5 m in diameter. (Based on the diameter of the 10th largest boulder in the surrounding area)
- 3) If the height of the bridge girder is increased by a long span without inner walls, the social impacts such as on the surrounding area will increase (such as in connection with houses, access road and approach roads).

On the Sindhuli Road, many box-shaped causeways with a structure similar to the RCSB had been constructed in alluvial fan. As shown in the photos below, some of the box type causeways constructed in the river with debris-flow carrying boulders have gabion-wired boxes or jacketing concrete to protect inner walls.



Installed protective measures (gabion blocks) on the upstream side of the inner walls in river where dia. 1m boulder flows are observed.

Same case as the left side photo. To protect walls by gabion walls for dia. 1m boulder.

A case where the base of the intermediate wall is protected by reinforced/plain concrete against the sediment flow.

Source: JICA Expert Team

Figure 4-5 Troubles due to debris flow

4.3.3 Floating obstacles (driftwood)

To avoid applying the slab bridge to rivers where driftwood (especially rooted driftwood) flows down.

Since the slab bridge has a short span length of 10~16 m, in principle there is no driftwood that blocks the limited openings and if unavoidable, long span bridge should be considered instead of the slab bridge.

The presence, scale and type of driftwood shall be confirmed by traces of damage caused by driftwood in the past and interview survey to local residents.

It has been reported that driftwood generated during a sediment-related disaster blocks the span of the bridge and raises the riverbed and/or water level, which increasing damage. There are two types of driftwood, log-shaped and rooted ones. In the former, the driftwood flows down when it is submerged in the water, whereas in the latter, it floats on the water surface and flows down, causing a collision with the bridge super-structure. Since it is easy to do so, there is a high probability that obstruction will occur, so special attention is required.

It is desirable to consider the use of reinforced concrete girder bridges with a span of 25 m or more in order to secure the horizontal opening on the safe side where there is a risk that the flood flow will be obstructed by driftwood while maintaining a margin height as a bridge.

Driftwood includes log-shaped driftwood and rooted driftwood, whereas the former flows down

when the driftwood is submerged in the water, whereas the latter floats down on the water surface and flows down, which makes collisions with bridge superstructure easier. Therefore, special attention is required because there is a high probability of blockage for the short span length of the horizontal opening of the box type bridge.



A case where log-shaped driftwood was confirmed on the upstream side of the box type causeway in the alluvial fan in hilly terrain.

The opening of the submersible slab bridge was blocked by rooted driftwood during mud-flood (photo: outside Nepal)

Source: JICA Expert Team

Figure 4-6 Troubles due to floating obstacles

4.4 DETERMINATION OF RCSB OUTER WALLS AND BRIDGE LENGTH

4.4.1 Positioning the Outer Walls and Bridge Length

The engineers should choose trial positions of the abutments (outer walls) and which location of them must be determined from the flow path during floods in the past rainy season and while flooding.

Bridge length is determined by the location of the abutments (outer walls in case of RCSB). The location of the outer walls is dependent on bridge opening requirements, and the method used to terminate the approach embankment and transition to the structure. The abutments are determined in such a manner as to produce optimum bridge economy within the constraints of horizontal clearance requirements, stream flow requirements and aesthetics.

The engineer should choose trial positions for the abutments (so-called outer walls) of RCSB, bearing in mind the guidelines in the introduction to this chapter and Figure 4-7. A configuration of outer walls (abutments) and inner walls (piers) should be selected, and the length of waterway measured, i.e., the distance between the outer walls, measured perpendicular to the flow, minus the sum of the inner walls' widths.

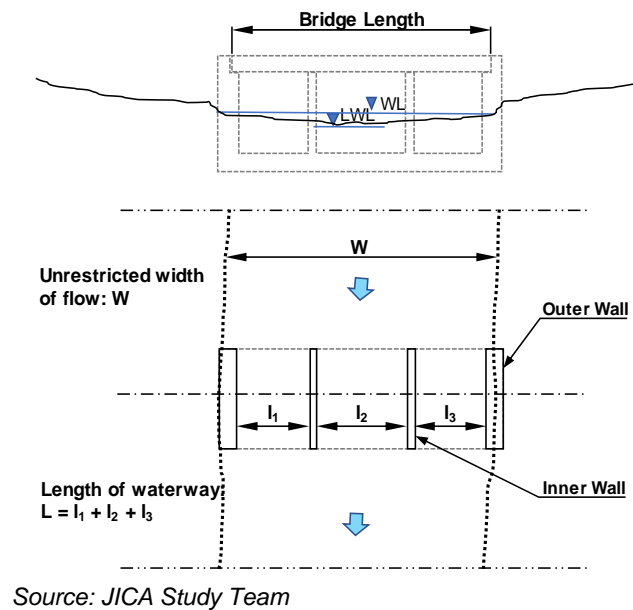


Figure 4-7 Linear Waterway

It is necessary to make a judgment based on on-site surveys, hearings from site engineers and residents around the site, and damage historical records regarding the position and the width and course of the flood flow path during rainy season.

Experience from other structures on the same river, together with inquiries locally, will help to determine the required clearance between the design flood level and the underside of the superstructure.

It is required to select the configuration of the abutments and the length of the total span of the bridge and measure the length of the channel. In other words, it is the distance between the abutments measured perpendicular to the flow minus the sum of the inner walls' width.

The hydraulic data required for the design process mentions relate to design flood level, flow volume and velocity as below.

- peak (maximum) flood level, flow volume and velocity,
- bed characteristics - particle size, vegetation,
- channel shape and flood plain width,
- sedimentation and meander characteristics, and
- clearance of floating debris.

Using these measurements and the flow and velocity estimates or calculations outlines in 4.4.2, engineers can determine if the width of the Lacey's regime waterway is a bridge length that almost satisfies the total span length. Alternatively, it can be confirmed that the bridge length is secured as a supercritical flow flowing through a river channel with a steep riverbed gradient outline in 4.4.3. If these prove unacceptable, a different configuration of abutments location and total length of bridge span should be tried.



To assume flood plain width while the flood

To assume flood plain width

To assume flood plain width

Source: JICA Expert Team

Figure 4-8 Flood plain width

4.4.2 Bridge length by Lacey’s Regime Theory

The linear waterway of the bridge W should be equal to Lacey’s regime waterway given by the equation of $W=4.8Q_P^{1/2}$ as stated in IRC:5-1998.

It is desirable to determine the linear waterway* (hydraulic opening width) of the river at bridge section to pass to the downstream side safely. The width is generally determined considering the following points. (Source: H10: Hydrology Manual for Roads and Bridges, WECS, GON 2018)

- The contributing watershed area,
- The magnitude and frequency of the design flood,
- The roadway alignment and profile, and
- Physical and environmental constraints.

The hydraulic design process for sizing the bridge waterway opening shall include the evaluation of water surface elevations in the main channel for existing conditions and for proposed conditions. A comparison of the elevations between these two conditions shall be made to identify the effects of the bridge on the waterway. These results shall clearly identify and mitigate any backwater effects caused by the project.

As per Clause 104.3 of IRC:5-1998, linear waterway (bridge opening width) should be nearly equal or wider than Lacey’s regime waterway given by the following equation:

$$W = CQ_P^{1/2} \quad \text{--- Lacey’s Regime Formula} \quad \text{Clause 104.3, IRC:5-1998}$$

Where,

W = Regime width (m) equal to effective linear waterway* under regime condition

C = a constant usually taken as 4.8 for regime channels but it may vary from 4.5 to 6.3 according to local conditions.

Q_P = Peak flood discharge of normal flood flow (m^3/s)

*: linear waterway, i.e., distance between abutments minus width of piers, measured perpendicular to the flow (m)

If the assumed designed opening width of the bridge is much smaller than the result of the Lacey’s regime waterway width, then it should be considered relocation of the bridge or increase the length of the bridge by adopting other type of bridge to ensure the opening of the linear waterway. However, if the site is in a hilly terrain, in the 4.4.3 determine if the initially assumed bridge length is appropriate or not.

4.4.3 Bridge length at waterway in hilly terrain

The slab bridge located in a hilly terrain with steep bed slope, for supercritical flow (Froude's number >1) minimum waterway under the bridge will be determined by the linear waterway at HFL.

In a hilly or mountainous terrain where the river flows in gorges with steep bed slope, the flow is usually in supercritical state when depth (y) is small and velocity of flow (V) is very high, in supercritical flow, Froude's number of flow, defined as $Fr = V/(gy)^{1/2}$, is more than one (1.0). Lacey's regime waterway in such situations is very high compared to liner waterway at HFL. Thus, the minimum waterway under the bridge will be determined by the liner waterway at HFL and not by Lacey's regime waterway. In fact, Lacey's regime condition is not valid in such a terrain at all (Source: Mazumdar S. K., Determination of Waterway under a bridge in Himalayan Region – Case Studies, Article).

$$Fr = V/(g y)^{1/2} \quad \text{--- Froude's Number of Flow}$$

Where,

Fr	=	Froude's number of flow (-)
V	=	Velocity of flow (m/s)
g	=	Acceleration due to gravity 9.81 (m/s ²)
y	=	Flow water depth (m)

Judgement,

$Fr > 1.0$	Supercritical flow: No restriction of Lacey's regime waterway
$Fr = 1.0$	Critical flow: No restriction of Lacey's regime waterway
$Fr < 1.0$	Sub-critical flow: The waterway restricted Lacey's regime waterway

For supercritical flow ($Fr >1$) minimum waterway under the bridge will be determined by the linear waterway at HFL corresponding to design flood discharge.

4.5 DETERMINATION OF RCSB HEIGHT

4.5.1 Peak Flood Discharge

The peak flood discharge (Q_p) at 100-years return period in the river is required for estimate of the adequate linear waterway of the bridge by hydrological analysis.

All permanent bridges shall be designed for a discharge of 100-years return period. For the calculation of design discharge empirical formulas especially developed for other catchments shall not be used (stipulated in 3.2 Design Discharge of Nepal Bridges Standards - 2067 (2010), DOR). Therefore, the peak flood discharge, de-signed HFL and velocity, which is the basic condition for determining the scale and size of the waterway crossing structure, is based on the observation data of a Rainfall Station near the target point of the bridge construction. The peak flood discharges in the tributaries are estimated using Rational method. For this, at first, time of concentration of flow in rivers and then basin rainfall intensities are determined by hydrologist with hydrological analysis.

The hydrologist is required to analyze a design flood level (DFL), a design flood discharge i.e., flow volume, and a design velocity, on which to base calculations of waterway geometry, foundation, scour protection depth and vertical clearance. For the procedure of the design flood discharge analysis, refer to ANNEX B Design report for Mamti Bridge.

4.5.2 Vertical clearance height under slab girder

Assumed vertical clearance height above the design riverbed of the bridge considering two cases of debris-flow

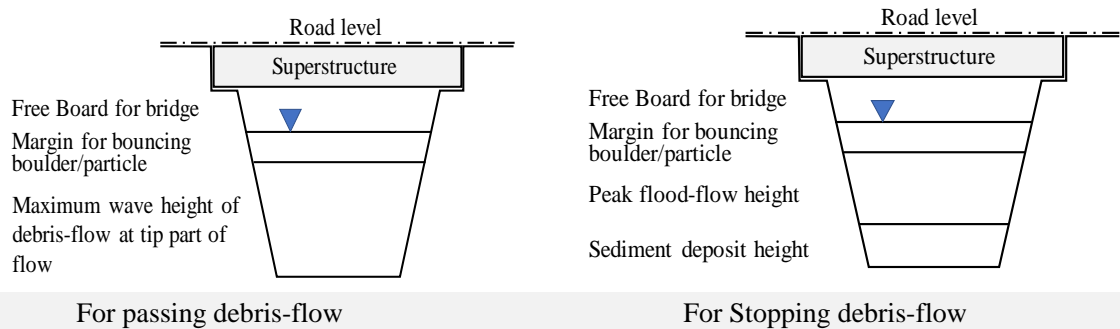
The vertical clearance height of the bridge shall be equal to or greater than the sum of the respective heights shown below and in the Table 4-11 in the two cases of the Case-1 against stopping of debris-flow and passing of sediment-flow and Case-2 against the deposition of debris-flow shown in Figure 4-6.

When confirming the appropriateness of vertical clearance in each standard drawing of the slab bridge, refer to the assumed vertical clearance height shown in Table 4-9.

Table 4-7 Flow Type and Reference Vertical Clearance Height to be Secured for the Bridge

Flow type	State of flow at river crossing point	Vertical clearance to be secured considering		Assumed vertical clearance height for debris-flow
		Case-1 Passing debris flow/sediment flow	Case-2 Deposition of debris flow/sediment flow	
Gravel type debris flow	Passing	Deposit sedimentation (not consider)	Deposit sediment height (5-6m)	Around 8~10m N.A. for the slab bridge
		Maximum wave height of debris flow (5-10m) (based on analysis)	Height of peak flood flow (based on analysis)	
		Margin for debris flow (1-3m)	Margin for flood (0.6-0.8m)	
		Freeboard for bridge (1-2m) by NBS 2067	Freeboard for bridge (1-2m) by NBS 2067	
	Stopping	Deposit sedimentation (not consider)	Deposit sediment height (5-6m)	Around 8~10m N.A. for the slab bridge
		Maximum wave height of debris flow (5-10m) (based on analysis)	Height of peak flood flow (based on analysis)	
		Margin for debris flow (1-3m)	Margin for flood flow (0.6-0.8m)	
		Freeboard for bridge (1-2m)	Freeboard for bridge (1-2m)	
Normal debris flow	Passing/ stopping	Deposit sedimentation (not consider)	Deposit sediment height (3-5m)	Around 4~6m
		Maximum wave height of debris flow (3-5m) (based on analysis)	Height of peak flood flow (based on analysis)	
		Margin for debris flow (1-3m)	Margin for flood (0.6-0.8m)	
		Freeboard for bridge (1-2m)	Freeboard for bridge (1-2m)	
Sediment flow	Passing and stopping	Deposit sedimentation (not consider)	Deposit sediment height (Max 1.5m, Ave. 0.5m)	Around 4~5m
		Height of peak sediment flow (based on analysis)	Height of peak flood flow (based on analysis)	
		Margin for sediment flow (0.6-0.8m)	Margin for flood flow (0.6-0.8m)	
		Freeboard for bridge (1-2m)	Freeboard for bridge (1-2m)	
Flood flow	-	Deposit sediment height (Max 1m, Ave. 0.3m)		Around 3~5m
		Height of peak flood flow (based on analysis)		
		Margin for flood flow (0.6-0.8m)		
		Margin for freeboard (1-2m)		

Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center



Source: JICA Study Team based on the Study for the design criteria on the transit roads over devastated rivers, 1982, Technical Center

Figure 4-9 Vertical Clearance to be Secured

The structurally preferable inner opening height (height between top slab soffit and top of bottom slab) of the slab bridge is around 9.0 to 9.5 m at the maximum (Total slab bridge height will be 12 m), and when calculated backwards, the vertical opening height above the upstream side riverbed is expected to be about 5.0m and 3.5m for scour depth between D/S side of bed and top of the raft foundation.

4.5.3 Scouring Dept

Assumed scouring depth below the downstream side bed of the bridge considering Lacey’s Regime Equation and other equations.

It is required to confirm the sieve grading of the riverbed to analyze the scour depth.

To design the depth of the raft foundation, the following scour depth equation can be considered. It is also recommended to check the appropriate method of scour depth equations with Bridge Branch/DOR and consider it according to the terrain and type of bed material.

Three kind of the scour depth equations are recommended to design for the depth of raft foundation as below equations.

- a) Equation-1 Lacey’s Regime Equation (1930) stipulated in Clause 110.1.3., IRC:5-1998, IRC:78-2014
- b) Equation-2 Scour Depth Calculation by Farraday and Charlton Equation
- c) Equation-3 Scour Depth Calculation by Blench Equation (1969)

For purely alluvial streams which are contracted beyond Lacey’s regime waterway width (W) at the bridge site, the value of Lacey’s scour depth may be computed by using the below formula. *Lacey’s Regime Condition for Scour in Boulder Strata: Mean scour depth*

$$R_s = 1.34 (q^2/f)^{1/3} \quad \text{for Lacey’s Regime Condition in Boulder Strata} \quad \text{--- IRC:78-2014}$$

Where,

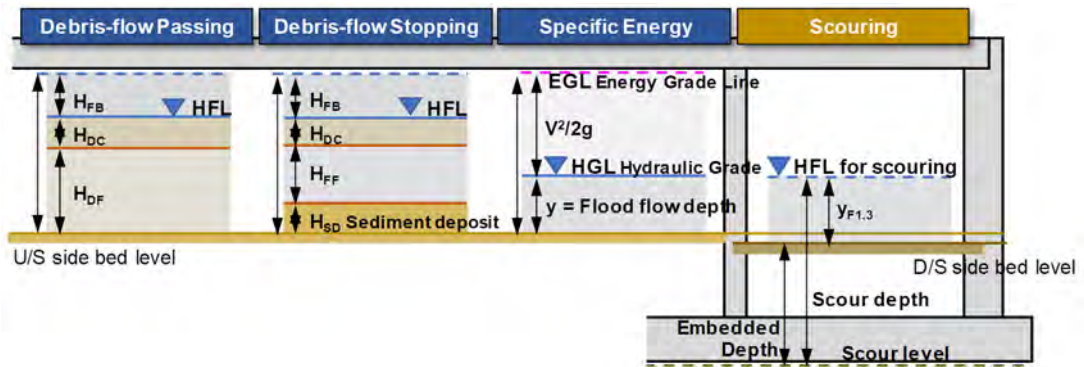
- Q_P = Peak flood discharge at 100 years retune period (m^3/s)
- $Q_{F1.3}$ = 30% increased design discharge at 100 years retune period for foundation (m^3/s) by Clause 703.1.1, IRC: 78-2014
- R_s = Mean scour depth by Lacey’s regime condition = $1.35(q^2/f)^{1/3}$
- q = Discharge intensity = (Design discharge $Q_{F1.3}$ / width of river L) ($m^3/s/m$)
- f = Silt factor = $1.76\sqrt{m}$
- m = Size of bed materials in mm, 50% materials are smaller (mm) D_{50}

Calculation for these equations will be required the data of sieve grading by field and laboratory testing for estimation of size of bed material in mm smaller than 50% and 90% of passing sieve.

4.6 DETERMINATION OF THE RCSB DIMENSION

Based on the results of the above study, if the RCSB is judged to be suitable for the proposed site, topographical and geological conditions.

A definition sketch showing various aspects of vertical clearance with embedded depth by scouring based on the hydraulics requirement for clearance and raft foundation are presented in Figure 4-6 below.



Source: JICA Expert Team

Figure 4-10 Definition Sketch of Vertical Clearance of the bridge

However, the required height of the inner clearance height varies greatly depending on the river and various conditions. The maximum height is about 12m, and the standard range is estimated to be between 10m and 12m in height. In preparing the standard design drawings, it is necessary to determine the structural height uniformly, and assuming Table 4-10, the structural height is set to 12m for bridge lengths of 20m, 30m and 40m, its span 10m for 20m and 30m, and 12m+16m+12m.

Table 4-8 Total Structure Height for Typical Drawing for RCSCB

Vertical Clearance		Opening Height (Assumed)	
		Alluvial fan	Alluvial plain
Bridge length (Typical drawing)		20m, 30m, 40m	
Span length		2@10m, 3@10m, 12m+16m+12m	
Bed grading		3%~7%	1%~2%
1	Vertical clearance above design bed level at U/S side (A)	4.0~5.0 m	4.0~4.5 m
2	Difference in elevation of the riverbed between the U/S and D/S side (B)	0.5 ~ 0.8 m	0.1 ~ 0.2 m
3	Embedded depth below design bed level at D/S side up to the bottom of foundation (C)	4.0~5.0 m	4.0~4.5 m
4	Raft foundation (bottom slab) thickness minus (D)	1.4 ~ 1.6	1.3 ~ 1.5
	Inner height total (=inner wall height) A+B+C-D	9.1~9.4	Around
Top slab thickness		0.9, 1.1m	0.9, 1.1m
Total structure height for typical drawings (around)		11.5m	11.0m
Total structure height for typical drawings		<u>12.0</u>	

Source: JICA Expert Team

CHAPTER 5. STRUCTURAL DESIGN OF RCSB

5.1 DESIGN CONDITIONS

Design criteria for designing RCSB is described in the table below.

Table 5.1 Design Criteria of RCSB

No.	Items	Description	Remarks
1.	Design Standards		
1-1	Principals	Nepal Bridge Standards-2067, Department of Roads	2010 AD
1-2		Nepal Road Standard 2070, Department of Roads	2013 AD
1-3		Standard specifications for road and bridge works, 2073, Department of Roads	2016 AD
1-4	Supplementals	IRC: 5-1998 Standard Specifications and Code of Practice for Road Bridges Section I General Features of Design, India	
1-5		IRC: 6-2017 Standard Specifications and Code of Practice for Road Bridges Section II Loads and Stresses, India	
1-6		IRC: 21-2000 Standard Specifications and Code of Practice for Road Bridges Section III Cement Concrete (Plain and Reinforced), India	
1-7		IRC: 78-2014 Standard Specifications and Code of Practice for Road Bridges Section VII Foundation and Substructure, India	
1-8		IRC: 89-1997 Guidelines for Design and Construction of River Training and Control Works for Road Bridges, India	
1-9		IRC: SP13-2004 Guidelines for the Design of Small Bridges and Culverts, India	
1-10		IS 456:2000 Plain and Reinforced Concrete - Code of Practice, India	
1-11		IS 1786:2008 High Strength Deformed Steel Bars and Wires for Concrete Reinforcement - Specification, India	
1-12	References	Hydrological Manual for Infrastructures, H10; Hydrology Manual for Roads and Bridges June 2018, WECS (Water and Energy Commission Secretariat)	
1-13		The Study for the design criteria on the transit road over devastated river, 1982, Technical Center for Sediment Control and Landslide, Japan	
2.	General Condition		
2-1	Design Life	50 years	1-1 p.2
2-2	Basis of Design	Working Stress Method	1-6
2-3	Bridge Classification	Culvert	1-1 p.4
3.	Road Condition		
3-1	Road Classification	Equivalent to Feeder Road (Important bridge I=1.0)	1-2
3-2	Horizontal Alignment	Liner ($R=\infty$)	
3-3	Longitudinal Gradient	Level	
3-4	Crossfall	2.00%	
3-5	Width	11.00m (1.75+7.50 (dual lane) +1.75)	
3-6	Pavement	Asphalt concrete, t=50mm	

3-7	Typical Cross Section																																																									
4.	Loadings																																																									
4-1	Dead Load	Concrete (cement-reinforced) Steel (rolled or cast) Concrete (asphalt) Stone masonry (lime mortar) Earth (compacted) Water	25.0 kN/m ³ 78.0 kN/m ³ 22.0 kN/m ³ 24.0 kN/m ³ 20.0 kN/m ³ 10.0 kN/m ³	1-5 p.8-9																																																						
4-2	Live Load	<ul style="list-style-type: none"> - One Lane of IRC Class 70R Loading of Wheeled and Tracked (uniform strength load) - Two Lanes of IRC Class A Loading, and - One Lane of IRC Class A Loading, whichever governs Special vehicle Loadings are not considered.		1-1 p.3 1-5 p.10																																																						
4-3	Braking Effect	20% of live load		1-5																																																						
4-4	Live Load Surcharge	Equivalent height of earth leveling L=1.2m $W_{L2}=K_0 \times W_{L1}=0.5 \times 1.2 \times 19.0=11.4 \text{ kN/m}^2$		1-5, 1-7																																																						
4-5	Footpath Load	50kN/m ² (500kg/m ²)		1-5 p.24																																																						
4-6	Seismic Load	kh=0.18		1-5 p.63																																																						
4-7	Temperature	Not considered (temperature load are not required to design due to isolated superstructure of top slab)																																																								
4-8	Wind Load	Not considered																																																								
4-9	Load Combination	<table border="1"> <thead> <tr> <th>Load</th> <th>2</th> <th>3</th> <th>5</th> <th>10</th> <th>13</th> <th>14</th> <th>18</th> <th>20</th> </tr> <tr> <th>Combination</th> <th>Dead Load</th> <th>Live Load</th> <th>Vehicle Impact</th> <th>Braking Effort</th> <th>Earth Pressure</th> <th>Temperature</th> <th>Seismic</th> <th>Permissible</th> </tr> <tr> <th>LC-</th> <th>G</th> <th>Q</th> <th>Q_{im}</th> <th>F_b</th> <th>F_{ep}</th> <th>F_{tc}</th> <th>F_{eq}</th> <th></th> </tr> </thead> <tbody> <tr> <td>I</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td></td> <td></td> <td>10</td> </tr> <tr> <td>IIA</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td>1</td> <td></td> <td>11</td> </tr> <tr> <td>VI</td> <td>1</td> <td>0.2</td> <td>Q x 1</td> <td>0.2</td> <td>1</td> <td></td> <td>1</td> <td>15</td> </tr> </tbody> </table>		Load	2	3	5	10	13	14	18	20	Combination	Dead Load	Live Load	Vehicle Impact	Braking Effort	Earth Pressure	Temperature	Seismic	Permissible	LC-	G	Q	Q _{im}	F _b	F _{ep}	F _{tc}	F _{eq}		I	1	1	1	1	1			10	IIA	1	1	1	1	1	1		11	VI	1	0.2	Q x 1	0.2	1		1	15	1-5 p.7
Load	2	3	5	10	13	14	18	20																																																		
Combination	Dead Load	Live Load	Vehicle Impact	Braking Effort	Earth Pressure	Temperature	Seismic	Permissible																																																		
LC-	G	Q	Q _{im}	F _b	F _{ep}	F _{tc}	F _{eq}																																																			
I	1	1	1	1	1			10																																																		
IIA	1	1	1	1	1	1		11																																																		
VI	1	0.2	Q x 1	0.2	1		1	15																																																		
4-10	Impact	10% for 70R Tracked Vehicle 25% for 70R Wheeled Vehicle and Class A (span 12m) 20% for 70R Wheeled Vehicle and Class A (span 16m)		1-5 p.30																																																						
4-11	Earth Pressure	Ordinary condition KA=0.30 (Coulomb's formula) Seismic condition Ca=0.51 (dynamic active earth pressure)		1-5 p.47																																																						
5.	Materials																																																									
5-1	Concrete	Main body of RCSB Precast footpath slabs, Parapet post and base, road kerb	M30 $f_{ck}=30\text{N/mm}^2$	1-10																																																						

		Approach slab Retaining wall Lean concrete	M35 M30 M20 M15	$f_{ck}=35\text{N/mm}^2$ $f_{ck}=30\text{N/mm}^2$ $f_{ck}=20\text{N/mm}^2$ $f_{ck}=15\text{N/mm}^2$	
*Specified characteristic compressive strengths are value of 150mm cube specimen at 28 days					
5-2	Reinforcing Bar	Fe500 (Min. 0.2 percent proof stress 500N/mm ²)			1-11
5-3	Backfilling material	Riverbed sand and gravel		$\gamma_t=19.0\text{kN/m}^3$ $\gamma_{\text{sat}}=10.0\text{kN/m}^3$ $\phi=32$ degree	

Source: JICA Expert Team

5.2 ACTUAL LOAD VALUE TO THE STRUCTURAL ANALYSIS MODEL

5.2.1 Dead load calculation on deck slab surface

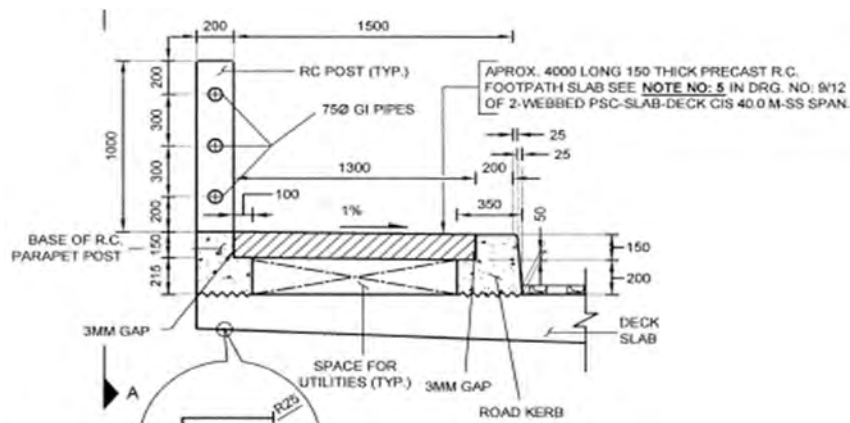
(1) Self weight of RCSB

	Depth (m)	Width (m)	Unit weight	Subtotal
Top slab	1.100 x	1.000 x	25.0 kN/m ³ =	27.5 kN/m
Wall	Dw x	1.000 x	25.0 kN/m ³ =	25.0 Dw kN/m
Bottom	Db x	1.000 x	25.0 kN/m ³ =	25.0 Db kN/m

(2) Carriageway area

	Thickness (m)	Unit weight	Subtotal
Asphalt concrete	0.075 x	22.0 kN/m ³ =	1.65 kN/m ²
Overlay by AC	0.050 x	22.0 kN/m ³ =	1.10 kN/m ²
Total unit weight (kN/m ²)			2.75 kN/m ²
Unit weight in 1m width			2.75 kN/m

(3) Footpath area without footpath loading



Source: JICA Expert Team

Figure 5-1 Detailed cross section of deck slab

	Thickness (m)	Width (m)	Unit weight	Subtotal
Parapet post			150 kg/m =	1.50 kN/m

Parapet post base	0.300 x	0.365 x	25.0 kN/m ³ =	2.74 kN/m
Precast footpath slab	0.150 x	1.100 x	25.0 kN/m ³ =	4.13 kN/m
Road kerb	0.325 x	0.365 x	25.0 kN/m ³ =	2.97 kN/m
Utility			100 kg/m =	1.00 kN/m
Total unit weight (kN/m)				12.34 kN/m
Unit weight in 1m width			12.34 / 1.750 =	7.05 kN/m

(4) Footpath area with footpath loading

			Unit weight	Subtotal
Parapet post base	0.100 x	0.365 x	25.0 kN/m ³ =	0.91 kN/m
Precast footpath slab	0.150 x	1.100 x	25.0 kN/m ³ =	4.13 kN/m
Road kerb	0.325 x	0.365 x	25.0 kN/m ³ =	2.97 kN/m
Utility			100 kg/m =	1.00 kN/m
Total unit weight (kN/m)				9.01 kN/m
Unit weight in 1m width			9.01 / 1.500 =	6.00 kN/m

5.2.2 Footpath loading

Footpath loading is calculated by the formula on IRC:6-2017.

$$P = P_1 - (40L - 300)/9$$

Here, P_1 Basic footpath loading $P_1 = 500 \text{ kg/m}^2$

L Span $L = 16, 12, 10 \text{ m}$

Table 5.2 Footpath loading by spans

Span (m)	Footpath loading (kg/m ²)	Footpath loading (kN/m ²)
16	462	4.52
12	480	4.70
10	489	4.79

Source: JICA Expert Team

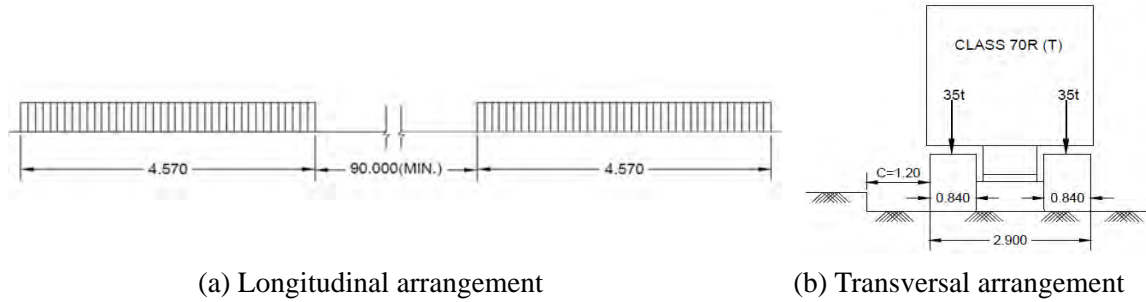
5.2.3 Live load calculation on carriageway

Live loads are considered these loadings of IRC:6-2017.

- Class 70R Tracked Vehicle
- Class 70R Wheeled Vehicle
- Class A Train of Vehicle

1) Class 70R Tracked Vehicle

One set of uniformed distribution load will be loaded to the center of the span (point of moment max) as per IRC:6-2017 Section 204.1.1.



Source: IRC:6-2017

Figure 5-2 Class 70R Tracked Vehicle

Span length	$l_0 =$	10, 12, 16	m
Concentrated load	$P =$	350	kN (35t)
Thickness of top slab		1.100	m
Thickness of asphalt		0.050	m
Width of deck slab	$b =$	11.000	m
Breadth of tyre	$b_w =$	0.840	m
Breadth of load on slab	$b_l =$	0.940	m = 0.840+2x0.050
Effective width	$b_{ef} = \alpha \cdot a(1-a/l_0)+b_l$	(IRC:21-2000 305.16.2)	
	$\alpha =$	(below table) (IRC:21-2000 305.16.2)	

Table 5.9 Calculation of constant α on IRC:21-2000

l_0	b/l_0	α for continuous slab	
	0.1	0.40	
	0.2	0.80	
	0.3	1.16	
	0.4	1.44	
	0.5	1.68	
	0.6	1.84	
16	0.688	-	1.946
	0.7	1.96	
	0.8	2.08	
	0.9	2.16	
12	0.916	-	2.174
	1.0	2.24	
10	1.1	2.28	2.280
	1.2	2.36	
	1.3	2.40	

Source: JICA Expert Team

Distance of the center of gravity

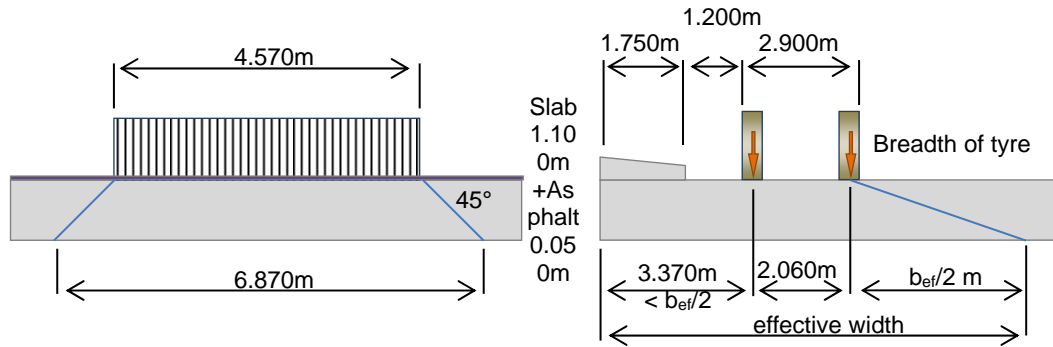
$$a = 5.0, 6.0, 8.0 \text{ m} = l_0/2$$

Then the effective width is; $b_{ef} = \alpha \cdot a(1-a/l_0)+b_l$

$$= 6.640 \text{ m} (l_0=10.0\text{m})$$

$$= 7.462 \text{ m} (l_0=12.0\text{m})$$

$$= 8.724 \text{ m} (l_0=16.0\text{m})$$



Source: JICA Expert Team

Figure 5-3 Effective width to transverse direction of Class 70R Tracked Vehicle

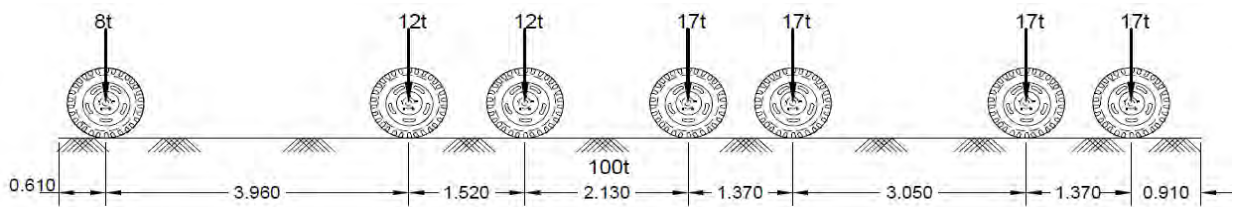
Effective widths to transverse direction are;

- 8.750 m ($l_0=10.0\text{m}$)
- 9.161 m ($l_0=12.0\text{m}$)
- 9.792 m ($l_0=16.0\text{m}$)

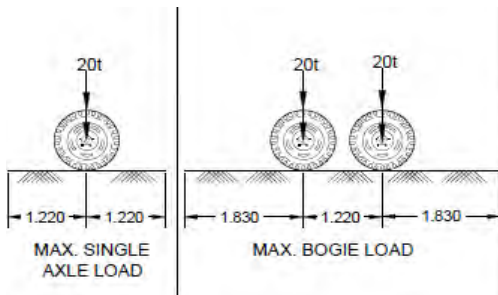
Unit weight loads by Class 70R Tracked Vehicle are;

$$\begin{aligned}
 700 \text{ kN} / (6.870 \times 8.750) &= 11.64 \text{ kN/m}^2 \quad (l_0=10.0\text{m}) \\
 700 \text{ kN} / (6.870 \times 9.161) &= 11.12 \text{ kN/m}^2 \quad (l_0=12.0\text{m}) \\
 700 \text{ kN} / (6.870 \times 9.792) &= 10.41 \text{ kN/m}^2 \quad (l_0=16.0\text{m})
 \end{aligned}$$

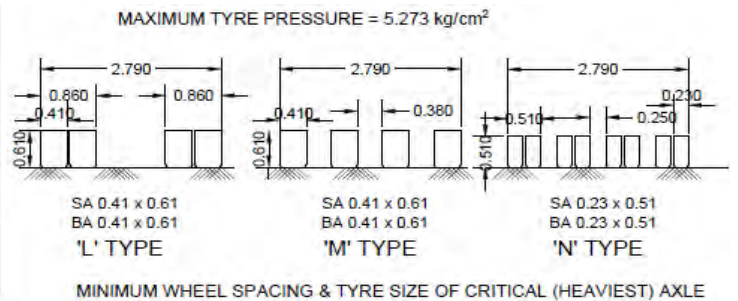
2) Class 70R Wheeled Vehicle



(a) Longitudinal arrangement



(b) Longitudinal wheel arrangement



(c) Transverse wheel arrangement

Source: IRC:6-2017

Figure 5-3 Class 70R Wheeled Vehicle

Span length	$l_0 = 10, 12, 16$ m
Concentrated load	$P = 85, 60, 40$ kN (17/2t, 12/2t, 8/2t)
Thickness of top slab	1.100 m
Thickness of asphalt	0.050 m
Width of deck slab	$b = 11.000$ m
Breadth of tire	$b_w = 0.860$ m (considering L type wheel)
Breadth of load on slab	$b_l = 0.960$ m = $0.860 + 2 \times 0.050$
Effective width	$b_{ef} = \alpha \cdot a(1-a/l_0) + b_l$ (IRC:21-2000 305.16.2)
	$\alpha =$ (below table) (IRC:21-2000 305.16.2)

Table 5.4 Calculation of constant α on IRC:21-2000

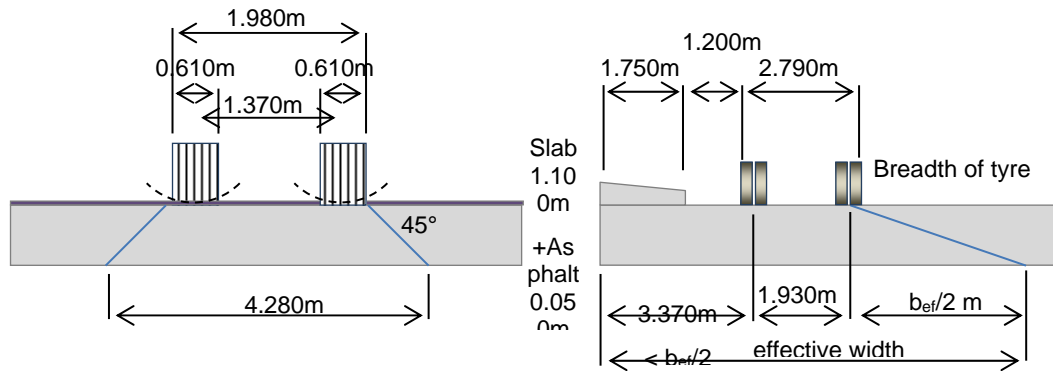
l_0	b/l_0	α for continuous slab	
	0.1	0.40	
	0.2	0.80	
	0.3	1.16	
	0.4	1.44	
	0.5	1.68	
	0.6	1.84	
16	0.688	-	1.946
	0.7	1.96	
	0.8	2.08	
	0.9	2.16	
12	0.916	-	2.174
	1.0	2.24	
10	1.1	2.28	2.280
	1.2	2.36	
	1.3	2.40	

Source: JICA Expert Team

Distance of the center of gravity

$$a = 5.0, 6.0, 8.0 \text{ m} = l_0/2$$

Then the effective width is; $b_{ef} = \alpha \cdot a(1-a/l_0) + b_l = 6.660$ m ($l_0=10.0$ m)
 $= 7.482$ m ($l_0=12.0$ m)
 $= 8.744$ m ($l_0=16.0$ m)



Source: JICA Expert Team

Figure 5-4 Effective width to transverse direction of Class 70R Wheeled Vehicle

Effective widths to transverse direction are; 8.630 m ($l_0=10.0\text{m}$)

9.041 m ($l_0=12.0\text{m}$)

9.672 m ($l_0=16.0\text{m}$)

Unit weight loads by Class 70R Wheeled Vehicle ($P=170\text{kN}$) are;

$$85 \times 4 \text{ kN} / (4.280 \times 8.630) \quad = 9.48 \text{ kN/m}^2$$

($l_0=10.0\text{m}$)

$$85 \times 4 \text{ kN} / (4.280 \times 9.041) \quad = 8.79 \text{ kN/m}^2$$

($l_0=12.0\text{m}$)

$$85 \times 4 \text{ kN} / (4.280 \times 9.672) \quad = 8.21 \text{ kN/m}^2$$

($l_0=16.0\text{m}$)

Unit weight loads by Class 70R Wheeled Vehicle ($P=120\text{kN}$) are;

$$60 \times 4 \text{ kN} / (4.280 \times 8.630) \quad = 6.50 \text{ kN/m}^2$$

($l_0=10.0\text{m}$)

$$60 \times 4 \text{ kN} / (4.280 \times 9.041) \quad = 6.20 \text{ kN/m}^2$$

($l_0=12.0\text{m}$)

$$60 \times 4 \text{ kN} / (4.280 \times 9.672) \quad = 5.81 \text{ kN/m}^2$$

($l_0=16.0\text{m}$)

Unit weight loads by Class 70R Wheeled Vehicle ($P=80\text{kN}$) are;

$$40 \times 4 \text{ kN} / (4.280 \times 8.630) \quad = 4.33 \text{ kN/m}^2$$

($l_0=10.0\text{m}$)

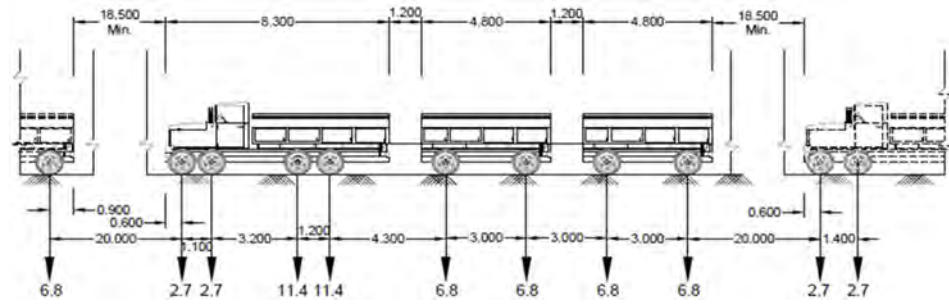
$$40 \times 4 \text{ kN} / (4.280 \times 9.041) \quad = 4.13 \text{ kN/m}^2$$

($l_0=12.0\text{m}$)

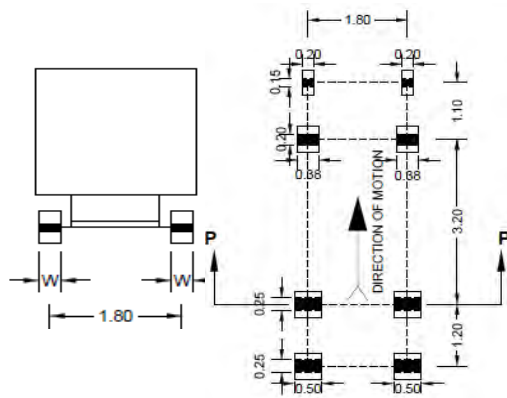
$$40 \times 4 \text{ kN} / (4.280 \times 9.672) \quad = 3.87 \text{ kN/m}^2$$

($l_0=16.0\text{m}$)

3) Class A Train of Vehicles



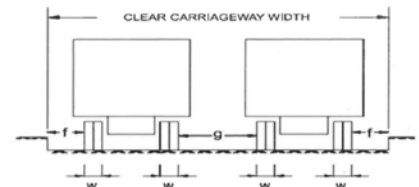
(a) Longitudinal arrangement



(b) Section

(c) Plan of Train of Vehicle

Axle load (tonne)	Ground contact area	
	B (mm)	W (mm)
11.4	250	500
6.8	200	380
2.7	150	200



Clear carriageway width	g	f
5.3 m(*) to 6.1 m(**)	Varying between 0.4 m to 1.2 m	150 mm for all carriageway width
Above 6.1 m	1.2 m	

(d) Sectional Arrangements

Source: IRC:6-2017

Figure 5-5 Class A Train of Vehicle

- Span length $l_0 = 10, 12, 16$ m
- Concentrated load $P = 114, 68, 27$ kN (11.4, 6.8, 2.7t)
- Thickness of top slab 1.100 m
- Thickness of asphalt 0.050 m
- Width of deck slab $b = 11.000$ m

Table 5.5 Breadth of Tyre and Load on Slab

Axle load	P (kN)	114	68	27
Breadth of tyre	b_{w1} (m)	0.500	0.380	0.200
Contact length of tyre	b_{w2} (m)	0.250	0.200	0.150
Breadth of load on slab	b_l (m)	0.600	0.480	0.300

Source: JICA Expert Team

- Effective width $b_{ef} = \alpha \cdot a(1-a/l_0) + b_l$ (IRC:21-2000 305.16.2)
- $\alpha =$ (below table) (IRC:21-2000 305.16.2)

Table 5.6 Calculation of constant α on IRC:21-2000

l_0	b/l_0	α for continuous slab	
	0.1	0.40	
	0.2	0.80	
	0.3	1.16	
	0.4	1.44	
	0.5	1.68	
	0.6	1.84	
16	0.688	-	1.946
	0.7	1.96	
	0.8	2.08	
	0.9	2.16	
12	0.916	-	2.174
	1.0	2.24	
10	1.1	2.28	2.280
	1.2	2.36	
	1.3	2.40	

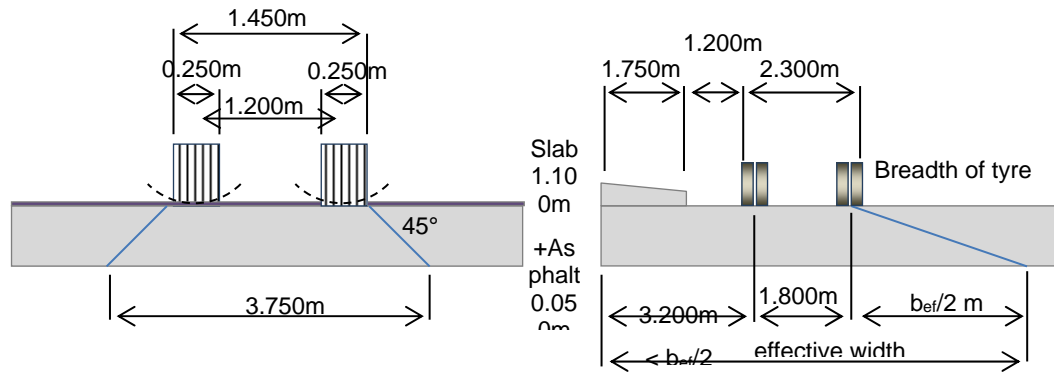
Source: JICA Expert Team

Distance of the center of gravity $a = 5.0, 6.0, 8.0m = l_0/2$

Table 5.7 Unit weight loads by Class A Train of Vehicles

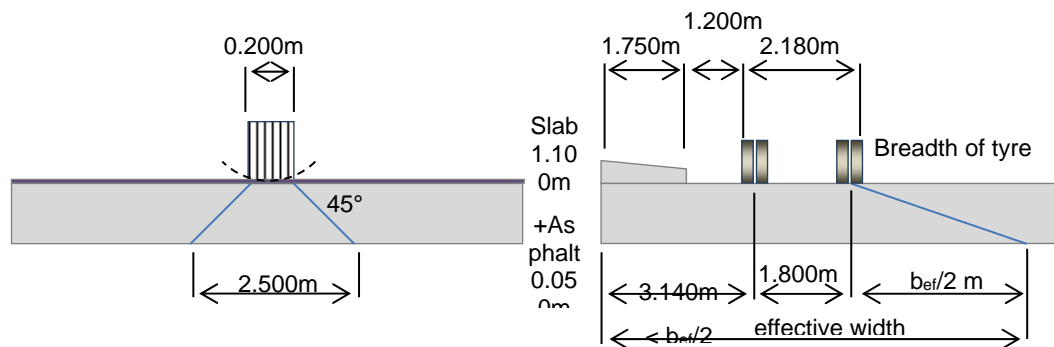
Span l_0 (m)	Effective width (m)			Unit weight loads by Class A Train of Vehicles		
	114	68	27	114	68	27
16	9.192	9.072	16	6.61	3.00	1.71
12	8.561	8.441	12	7.10	3.22	1.84
10	8.15	8.030	10	7.46	3.39	1.94

Source: JICA Expert Team



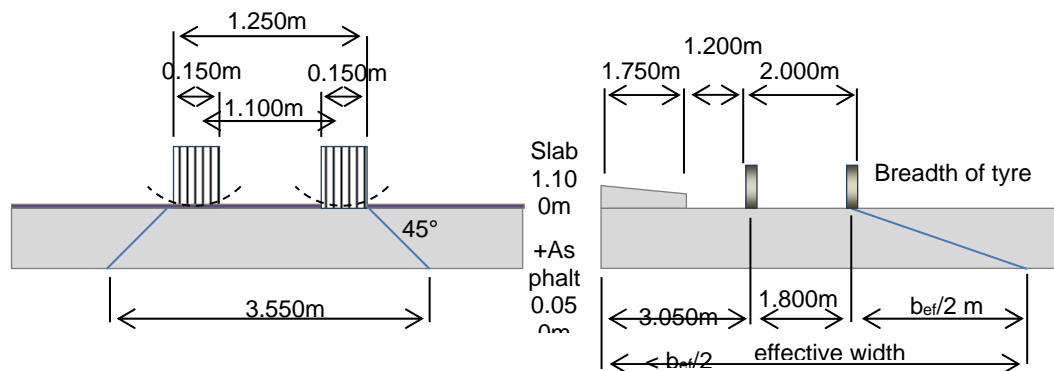
Source: JICA Expert Team

Figure 5-6 Effective width to transverse direction of Class A Train of Vehicle (P=11.4t)



Source: JICA Expert Team

Figure 5-7 Effective width to transverse direction of Class A Train of Vehicle (P=6.8t)



Source: JICA Expert Team

Figure 5-8 Effective width to transverse direction of Class A Train of Vehicle (P=2.7t)

5.2.4 Coefficient of foundation bed reaction

Reactions from earth are considered as spring support. The vertical coefficient of bed reaction is assumed by the formula based on Japanese Highway Bridge Standards shown in Table. In this Manual, Case II is adopted.

Table 5.8 Coefficient of foundation bed reaction

Soil case	Description	Vertical coefficient K_v
Case I	Percentage of <u>sandy soil</u> is greater than cohesive soil	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-1/2}$
Case II	Equal percentage of sandy soil and cohesive soil	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-3/4}$
Case III	Percentage of <u>cohesive soil</u> is greater than sandy soil	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-1}$

Source: JICA Expert Team

$$K_{v0} = \frac{1}{0.3} \times \alpha \times E_0$$

Here, K_v : Coefficient of foundation bed reaction (kN/m²)

α : Correction factor, $\alpha=1$, when using N value in normal condition

E_0 : Modulus of Elasticity of soil (kN/m²)

$$E_0 = 2,800N = 2,800 \times 10 = 28,000 \text{ (kN/m}^2\text{)}$$

N: SPT-N value (times), in this Manual N-10 is adopted.

B_v : Converted width of foundation, $\sqrt{(B \times L)}$ when $B > L$, $\sqrt{(B \times B)}$ when $B \leq L$

B: Bottom slab length (longitudinal, m)

L: Bottom slab width (transverse, m)

Table 5.9 Calculation result of the reaction

RCSB type	B (m)	L (m)	B_v (m)	K_{v0} (kN/m ²)	K_v (kN/m)
20m	23.4	11.0	16.04	93,333	4,720
30m	34.0	11.0	19.34	93,333	4,102
40m	44.2	11.0	22.05	93,333	3,718

Source: JICA Expert Team

5.2.5 Earth pressure

Lateral earth pressure is considered to the outer walls. Backfill earth is supposed to be non-cohesive material like sand and/or gravel.

At ordinary conditions (without seismic case), Coulomb's formula is adopted for the active pressure.

$$K_a = \frac{\cos^2(\phi - \alpha)}{\cos^2 \alpha \cos(\delta + \alpha)} \times \left[\frac{1}{1 + \left\{ \frac{\sin(\phi + \delta) \sin(\phi - \beta)}{\cos(\alpha - \beta) \cos(\delta + \alpha)} \right\}^{1/2}} \right]^2$$

Where,

ϕ : Angle of internal friction of soil (30 degrees)

α : Angle which earth face of the wall makes with the vertical (0 degree)

β : Slope of earth fill (0 degree)

δ : Angle of friction between the earth and earth fill should be equal to $2/3$ of ϕ subject to a maximum of 22.5 degrees (20 degrees)

$$K_A = \frac{\cos^2(30)}{\cos^2(0)\cos(20)} \left[\frac{1}{1 + \left\{ \frac{\sin(50)\sin(30)}{\cos(0)\cos(20)} \right\}^{1/2}} \right] = 0.297 \dots = 0.30$$

At seismic condition, dynamic active earth pressure on IRC:6-2017 is described as

$$C_a = \frac{(1 \pm A_v) \cos^2(\phi - \lambda - \alpha)}{\cos \lambda \cos^2 \alpha \cos(\delta + \alpha + \lambda)} \times \left[\frac{1}{1 + \left\{ \frac{\sin(\phi + \delta) \sin(\phi - \beta - \lambda)}{\cos(\alpha - \beta) \cos(\delta + \alpha + \lambda)} \right\}^{1/2}} \right]^2$$

Where,

A_v : Vertical seismic coefficient (here $1/2$ of A_h is considered $A_v=0.09$)

ϕ : Angle of internal friction of soil (30 degrees)

λ : $\tan^{-1}(A_h/(A_h/(1 \pm A_v)))$ (=0.164, 0.195)

α : Angle which earth face of the wall makes with the vertical (0 degree)

β : Slope of earth fill (0 degree)

δ : Angle of friction between the earth and earth fill should be equal to $2/3$ of ϕ subject to a maximum of 22.5 degrees (20 degrees)

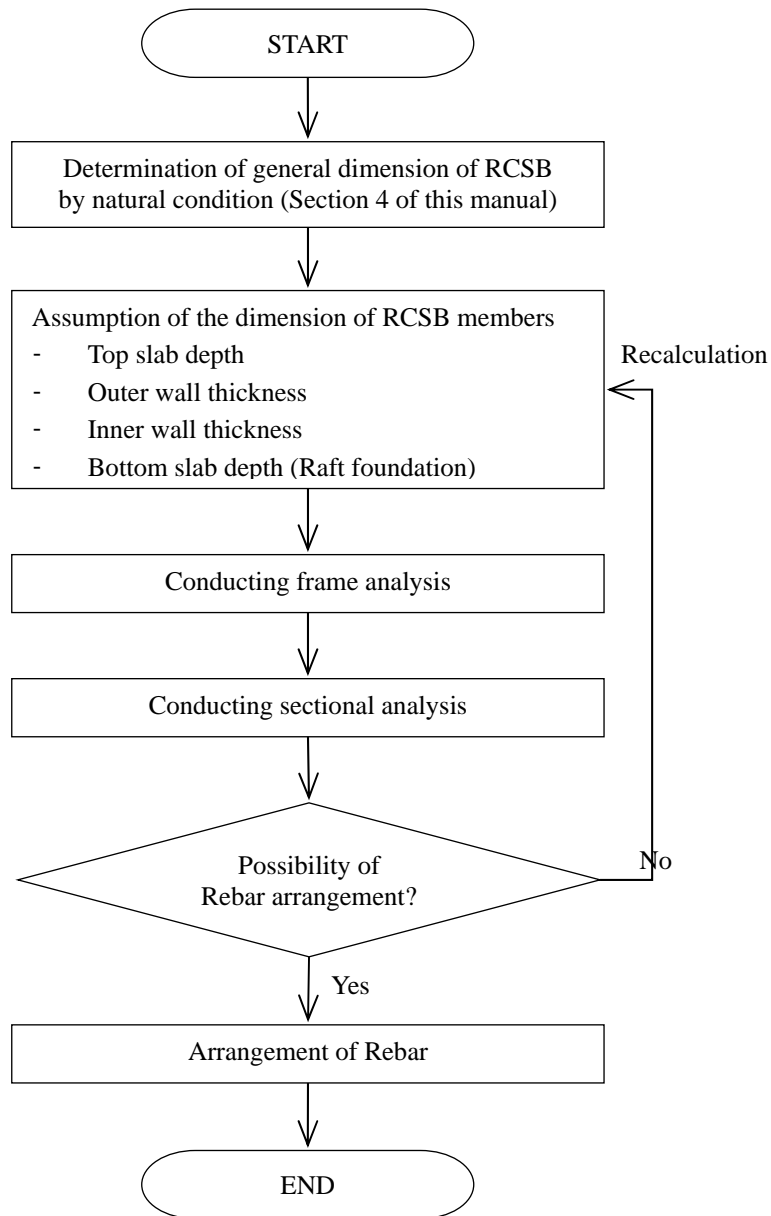
A_h : 0.18 (Zone V of India)

$$C_a = \frac{(1 \pm 0.09)\cos^2(30 - [9.38,11.19])}{\cos([9.38,11.19])\cos^2(0)\cos(20 + [9.38,11.19])} \times \left[\frac{1}{1 + \left\{ \frac{\sin(50)\sin(30 - [9.38,11.19])}{\cos(0)\cos(20 + [9.38,11.19])} \right\}^{1/2}} \right] = [0.51, 0.40]$$

$C_a=0.51$ is adopted for active earth pressure.

5.3 DESIGN CALCULATION PROCEDURE

Design calculation of RCSB is carried out by both frame analysis software and sectional analysis software.



Source: JICA Expert Team

Figure 5-9 Flowchart of the RCSB design calculation

5.3.1 Determination of general dimension of RCSB

General dimension of RCSB (bridge length, spans, height, etc.) are determined by the bridge plan mentioned in Section 4 of this Manual.

Bridge width shall be planned and determined by the road condition. In this manual, 11.0m of width including 7.5m of carriageway and 1.75m of footpath on both side is considered.

5.3.2 Assumption of the dimension of RCSB members

Because conducting the frame analysis needs the assumption of the section properties, such as stiffness and dead load per unit length, sectional dimension of the RCSB members shall be required.

The designer needs to recalculate the series of the design analysis with changing the sectional dimension if the sectional stresses exceed the material strength.

5.3.3 Conducting frame analysis

1) Input of nodes and elements

For the first step of the frame analysis, the coordinates of the member and principal points on the axis line, which is called “node” in general, will be inputted. The member will be expressed as the connection of two nodes, which is called “element” in general.

Frame analysis of RCSB is carried out by 2-dimensional model, because the profile shape of the RCSB has the same dimension like extruded mold.

2) Input member (sectional) data

The property of the section assumed previously, e.g. dimension of the section, material, tension/compression strength, unit weight, Young’s modulus, Poisson’s ratio, shear modulus of elasticity, linear coefficient of expansion, etc., will be assigned to all the elements.

By this operation, dead load of the element will automatically be inputted in some software.

3) Input boundary condition (bearing)

For the calculation of raft foundation like RCSB, the boundary condition between foundation and bearing layer is assumed by the spring. Coefficient of foundation bed reaction is calculated by the formula mentioned in the section 5.2.4.

4) Input loadings

Dead load, live load, earth pressure and seismic loads are inputted to the program.

Live loads of Class 70R Tracked Vehicle, Class 70R Wheeled Vehicle, and Class A Train of Vehicle in IRC:6-2017 are arranged to be loaded to the unfavorably position of the structure.

5) Arrangement of the individual loadings to combination loadings

In the previous step, loadings are recognized individually to the program. Operation of the combination of individual loadings are needed.

6) Conduct analysis

Although there might be a small difference in each analysis program, basic input items are mentioned above. Design engineer can conduct frame analysis.

5.3.4 Conducting sectional analysis

From the result of the frame analysis, design engineer can conduct sectional analysis by using the result of sectional forces obtained by the frame analysis (maximum/minimum bending moment and shear force).

- Reinforcement bar can be arranged properly (application of cover, pitch, maximum reinforcement bar ratio and related condition) inside the section against tension and shear stress
- Compression stress will not exceed the strength of concrete

If the compression stress of concrete, tensile stress or shear stress of reinforcement bar exceeds the material strength, recalculation of frame analysis shall be needed after the review of the sectional dimension or, in some cases, material strength.

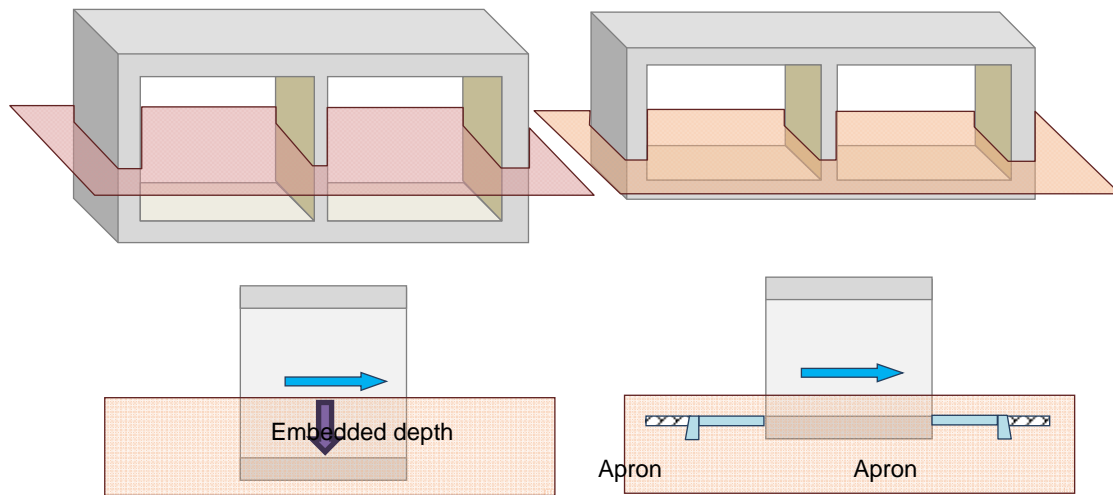
CHAPTER 6. SUPPLEMENTAL INFORMATION

6.1 COUNTERPLAN FOR DEEP-EMBEDDED BOTTOM SLAB

By using this design manual, the bottom slab of RCSB will be embedded relatively deep level to prevent from the damage by scouring. On the other hand, one of the necessary design conditions for planning the bottom slab is ground water level. If the ground water level is shallower than planning depth of the bottom slab, construction works need large capacity of drain pump, and sometimes it makes difficult to execute the excavation work as well as main body work.

To avoid such extra work, it is better to plan the shallower bottom slab (around 50cm) with apron at bottom slab level. This measure can prevent the shallow bottom slab from the damage of scouring. The design of apron and river training work shall carefully be planned and designed by experienced and skilled engineer.

As mentioned in Section 3 of this manual, it is better to conduct test pit survey to monitor the ground water level especially during dry season.

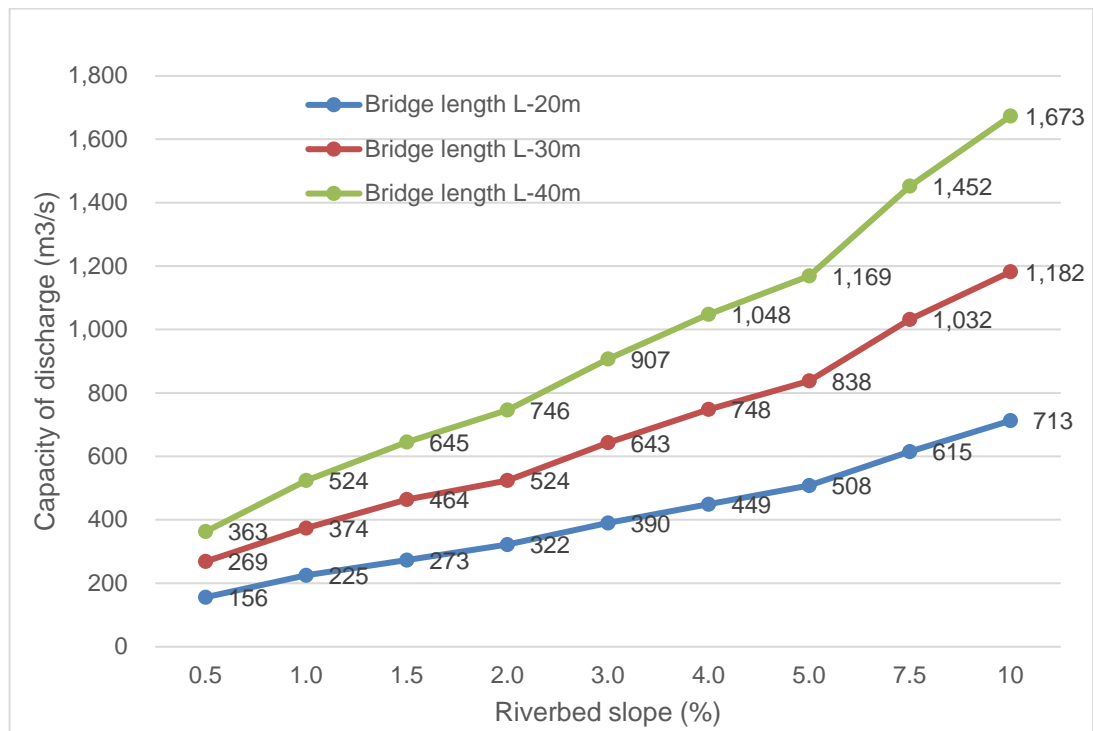


Source: JICA Expert Team

Figure 6-1 Design planning of bottom slab

6.2 DISCHARGE DIAGRAM

Figure 6.2 shows the discharge diagram of the RCSB in this Manual.

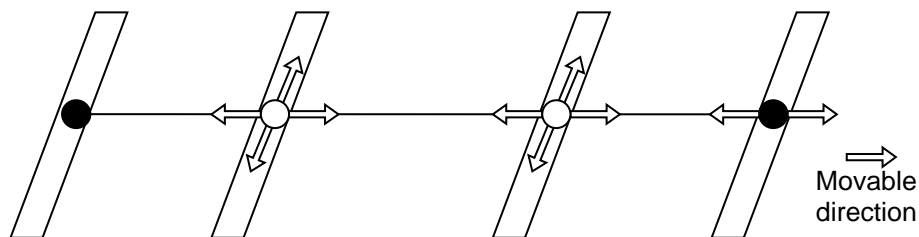


Source: JICA Expert Team

Figure 6-2 Discharge diagram of RCSB

6.3 BEARING CONDITION AND ANCHOR BAR DESIGN

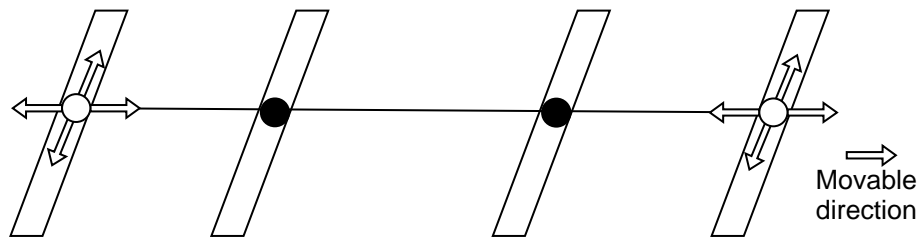
Bearing condition of top slab (superstructure) of Mamti Bridge was fix at one abutment and move at another abutment for longitudinal direction. Movement of transversal direction will be fixed at two abutments with anchor bars. Vertical load would be supported by elastomeric bearing.



Source: JICA Expert Team

Figure 6-3 Bearing condition of Mamti bridge

In this manual (standard drawing attached), bearing condition was changed to fix at intermediate wall and move at abutments to ensure the horizontal strength of anchor bar.



Source: JICA Expert Team

Figure 6-4 Bearing condition of RCSB

Horizontal Bearing capacity of anchor bar is not uniformly determined. Here “Handbook for Bearing Design of Road Bridges” in Japan is applied.

Shear capacity of anchor bar is described as

$$\tau_a = \frac{\sigma_{sa}}{\sqrt{3}} = 115(N/mm^2)$$

Here,

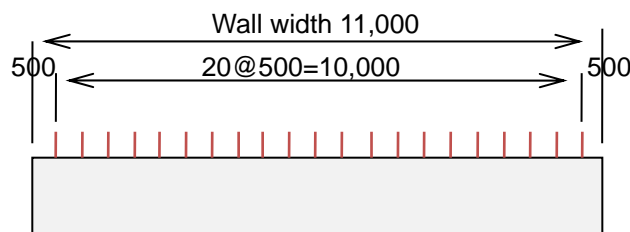
τ_a : Shear capacity of anchor bar (reinforcing bar)

σ_{sa} : Allowable stress of reinforcing bar (200N/mm² for SD345 or F500)

Numbers of anchor bar are required to .

RCSB type	Top slab weight (kN)	Horizontal seismic force (kN, k=0.18)	Shear capacity of an anchor bar (kN, D25)	Required nos of anchor bar
20m	5,390	970	58.3	16.6
30m	8,085	1,455		25.0
40m	11,858	2,134		36.6

21 nos of anchor bar (20@500=10,000) on an intermediate wall will be sufficient for the horizontal force.



Source: JICA Expert Team

Figure 6-5 Anchor bar arrangement of RCSB

If the shear capacity of anchor bar would be deemed as emergency case, ultimate strength of the reinforcing bar might be used for the shear capacity ($\tau_a=500N/mm^2$).

ANNEXURE

ANNEX A :Standard drawings

ANNEX B: Design report for Mamti Bridge

STANDARD DRAWINGS FOR RC CONTINUOUS SLAB BRIDGE (RCSB)

20m, 30m and 40m Cast-in-situ Concrete Bridge

Prepared by JICA Expert Team

December 2022

GENERAL NOTES FOR RC CONTINUOUS SLAB BRIDGE

1. PREFACE

- This standard drawing was prepared by JICA Expert Team and submitted to DOR based on the Minutes of Meeting of 3rd Joint Coordination Committee (JCC) held in 24 December 2019 under the technical cooperation project "The Project for Operation and Maintenance of the Sindhuli Road Phase 2" (SROM2).
- The standard drawing was created based on the design of RC Continuous Slab Bridge of Mamti Bridge (L=40m), which was implemented as the pilot project under the SROM2 and prepared with the difference bridge length of 20m, 30m and 40m.
- Since RC Continuous Slab Bridge (RCSB) has a structural feature suitable for river bridges located in alluvial fans of Terai Plain where river erosion is large. The Team expects that it will be actively utilized and spread to rivers throughout Nepal.

2. INSTRUCTIONS

- The concept of RCSB is similar to the multi-cell box culvert, only the difference which top slab (superstructure) and wall/bottom slab (substructure) are structurally separated. This is why occasional attack by large debris or boulder to superstructure would not harm the whole structural system.
- RCSB is designed as the road structure of directly loading on the top slab.
- The width and height of RCSB in this Standard Drawings is one of the variations of dimension. If other dimension is selected for the bridge site condition, design plan and structural calculation shall be conducted.

3. DESIGN CONDITIONS

A. DIMENSIONS

- Unless indicated otherwise, all dimensions, distances and sizes (members and reinforcing steel) are in millimeters.
- Indicated dimensions shall govern over scaled dimensions. Scaled dimensions shall not be used for construction purposes.

B. SPECIFICATIONS

- Nepal Bridge Standards-2067, Department of Roads
- Nepal Road Standard 2070, Department of Roads
- Standard specifications for road and bridge works, 2073, Department of Roads
- Other relevant Indian Standards

C. LOADINGS

- Dead load

Concrete	25.0 kN/m ³
Steel	78.0 kN/m ³
Earth (compacted)	20.0 kN/m ³
- Live load
 - One Lane of IRC Class 70R Loading of
Wheeled and Tracked (uniform strength load)
 - Two Lanes of IRC Class A Loading
 - One Lane of IRC Class A Loading (whichever governs)
 - Special vehicle Loadings are not considered.
- Braking effect (20% of live load)
- Footpath loading 50 kN/m²
- Live load surcharge
Equivalent height of earth leveling L=1.2 m

- Seismic load
Kh=0.15

vii. Load combination

Load Combination	2	3	5	10	13	18	Permissible Stresses
	Dead load	Live load	Vehicle impact	Braking effect	Earth pressure	Seismic	
LC-I	G	Q	Q _{im}	F _b	F _{ep}	F _{eq}	%
I	1	1	1	1	1		100%
VI	1	0.2	0.2	0.2	1	1	150%

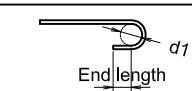
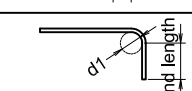
2. MATERIALS

- Concrete grade: M-30 as IRC:21-2000
- Reinforcing bar: Fe500 as IRC:21-2000

3. REINFORCEMENT

- All reinforcing steel bars shall be High Yield Strength Deformed type and Thermo Mechanically Treated, having specified minimum 0.2 percent proof stress of 500 MPa.
- Minimum lap-length of reinforcement bars shall be 65d where d is dia. of the smaller diameter bar to be lapped (unless otherwise specified)
- No more than 50 percent of reinforcement crossing a section shall be lapped at that location.
- All laps in reinforcement shall be properly staggered and minimum distance between the laps shall be 1.33 times the lap length.
- Bending of reinforcement bars shall be as per IS 2502.
- Legend for reinforcement bar-marking
First two digits refer to "bar diameter" in mm.
Next two digits refer to "bar-shape" mark.
e.g. Bar designated as : 2005 means 20mm dia bar of shape '05'.

vii. Hooks and bends

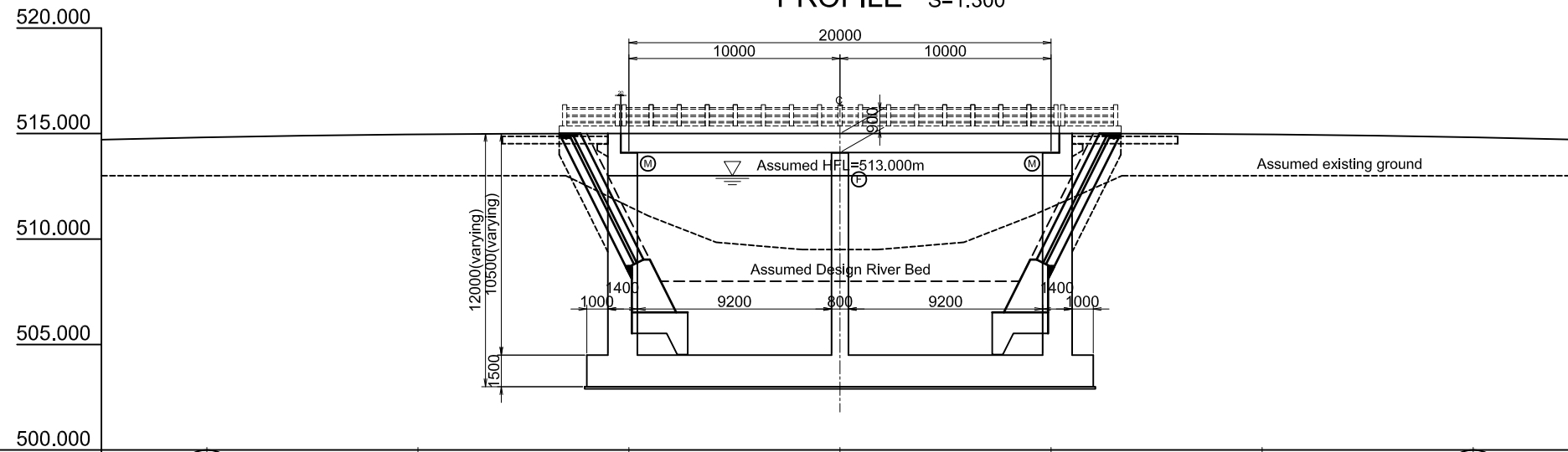
Bending angle of Bar	Figure	Bending diameter d1	End length
Bar end ≥135°		6d	5d
Bar end with Hooks		6d	10d

Note: d is a diameter of reinforcing bar

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2	REMARKS:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;"></td> <td style="width: 15%;">DESIGNED BY</td> <td style="width: 15%;">APPROVED BY</td> <td style="width: 20%;">NAME OF BRIDGE</td> <td style="width: 35%;">GENERAL NOTES FOR</td> </tr> <tr> <td style="border: none;"></td> <td>T. Hayakawa</td> <td></td> <td>STANDARD DRAWING</td> <td>RC CONTINUOUS SLAB BRIDGE</td> </tr> <tr> <td style="border: none;">NAME :</td> <td></td> <td></td> <td>SCALE</td> <td>DRAWING NO</td> </tr> <tr> <td style="border: none;">SIGNATURE :</td> <td></td> <td></td> <td>1:200</td> <td>G-1</td> </tr> <tr> <td style="border: none;">DATE :</td> <td>September 2022</td> <td></td> <td></td> <td></td> </tr> </table>		DESIGNED BY	APPROVED BY	NAME OF BRIDGE	GENERAL NOTES FOR		T. Hayakawa		STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE	NAME :			SCALE	DRAWING NO	SIGNATURE :			1:200	G-1	DATE :	September 2022			
	DESIGNED BY	APPROVED BY	NAME OF BRIDGE	GENERAL NOTES FOR																								
	T. Hayakawa		STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE																								
NAME :			SCALE	DRAWING NO																								
SIGNATURE :			1:200	G-1																								
DATE :	September 2022																											

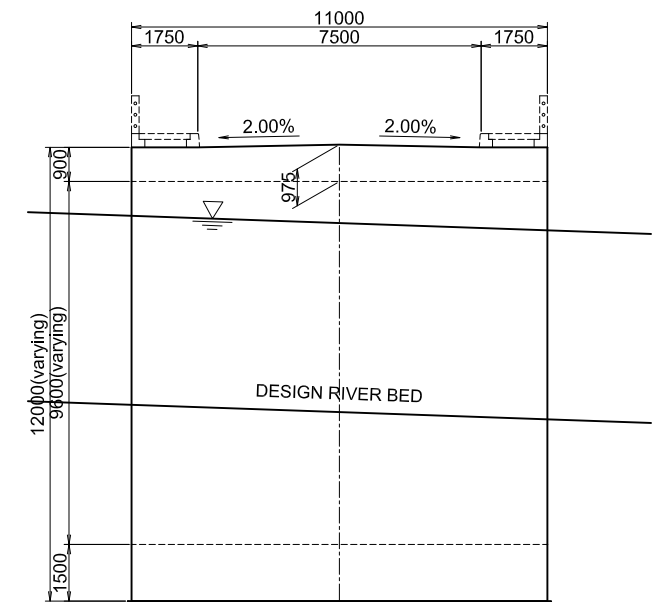
CONCEPTUAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=20M

PROFILE S=1:300

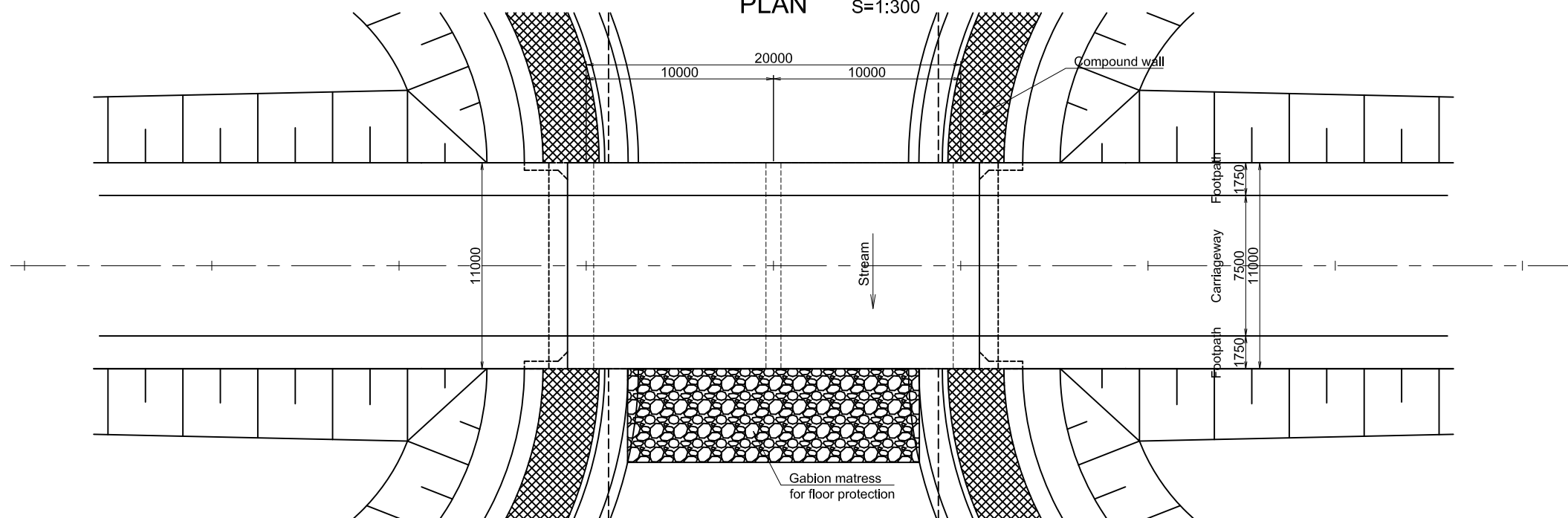


Grade	LEVEL					
Proposed Height	515.000	515.000	515.000	515.000	515.000	515.000
Existing Height	515.000	515.000	511.000	508.000	511.000	515.000
Station	STA.10+0.000	10.000	A1 20.000	P1 30.000	A2 40.000	60.000
Curve Element	R=∞					
Super Elevation	-4.000%					

CROSS SECTION S=1:200



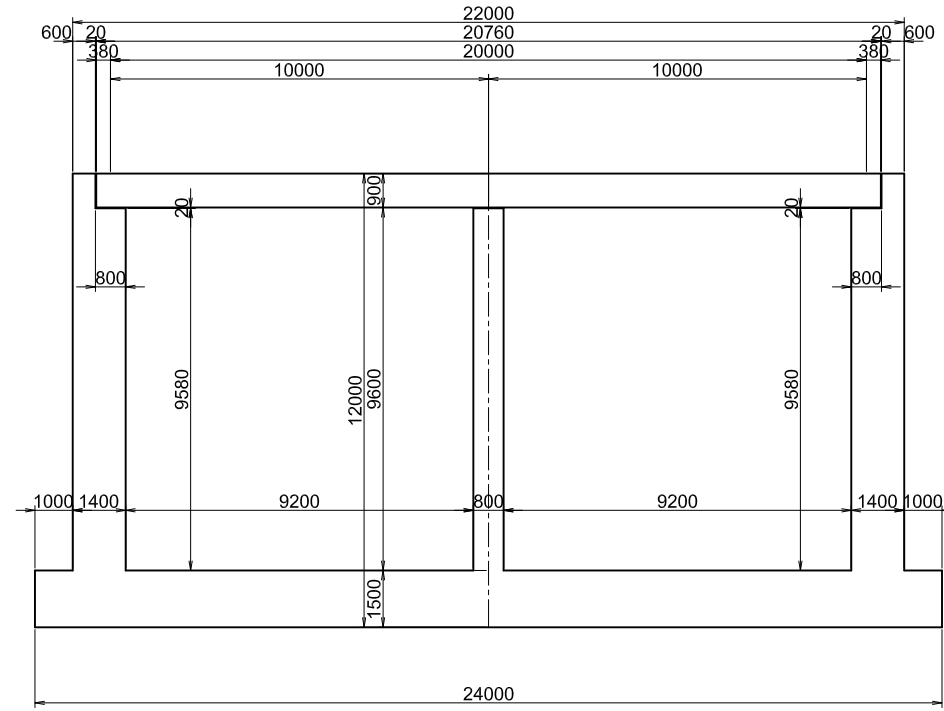
PLAN S=1:300



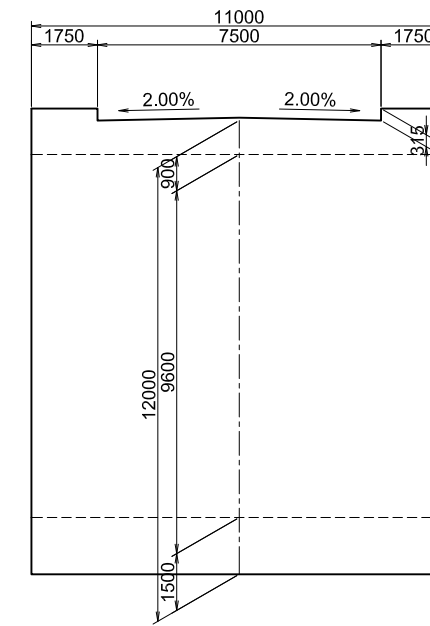
Note: Proposed height, existing ground height, high flood level (HFL) and design river bed are assumed values in this drawing.
The designer shall adjust the structural proportions to actual design conditions of the construction site.

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:			NAME OF BRIDGE		CONCEPTUAL VIEW OF	
	JICA EXPERT TEAM				STANDARD DRAWING		RC CONTINUOUS SLAB BRIDGE L=20M	
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2				DESIGNED BY	APPROVED BY	SCALE	DRAWING NO
					T. Hayakawa		1:300	A-1
				SIGNATURE :	DATE :	December 2022		

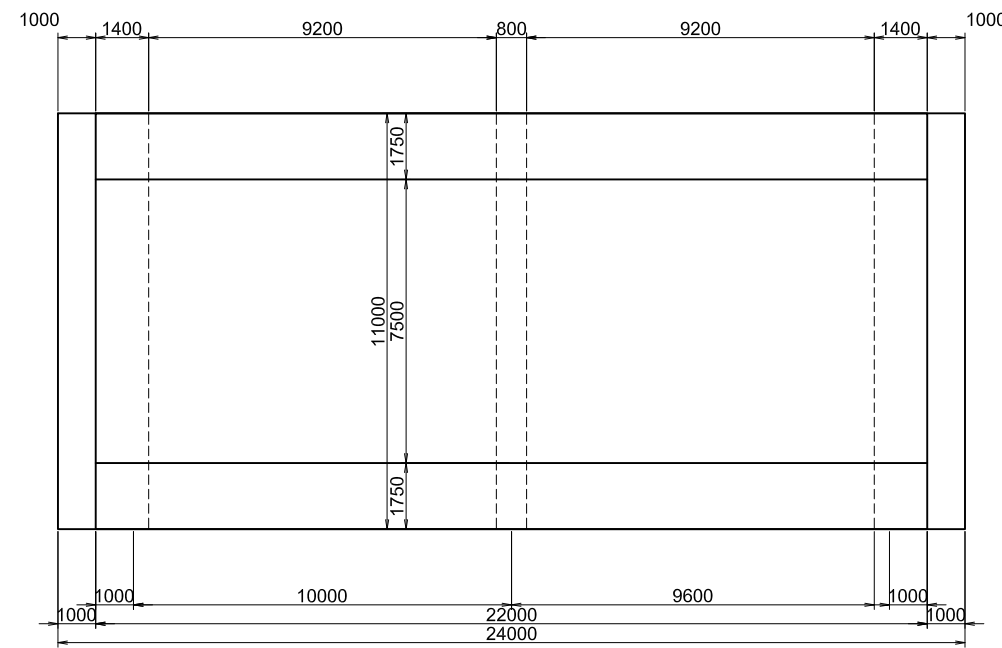
GENERAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=20M



PROFILE



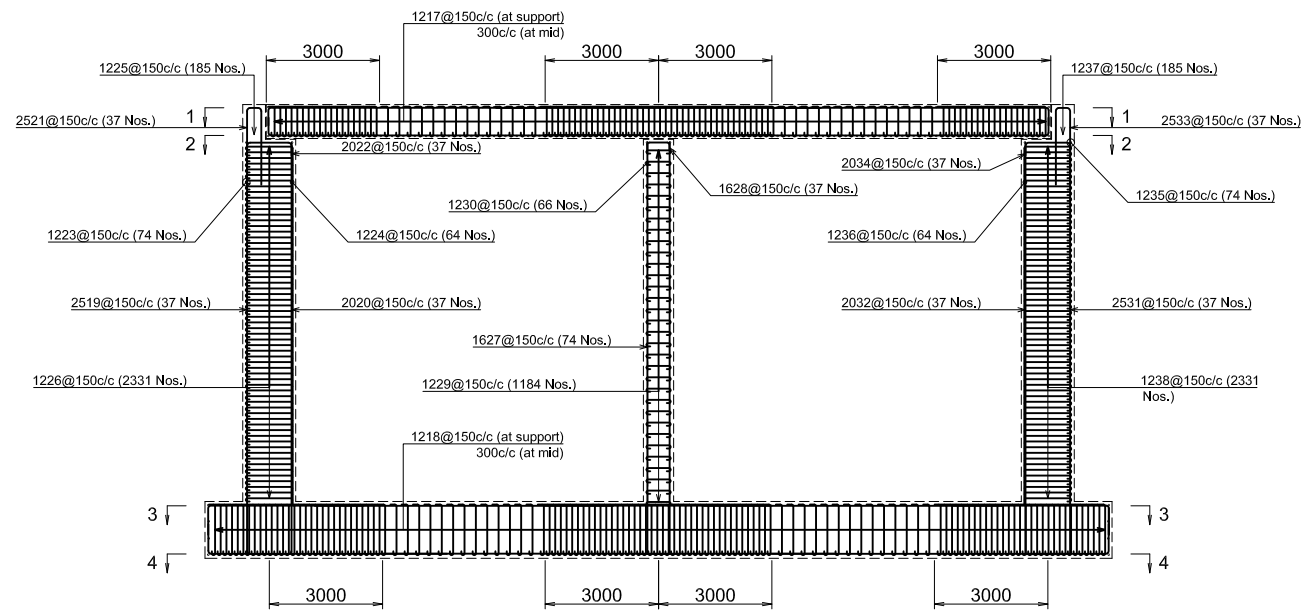
FRONT VIEW



PLAN

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:			
	JICA EXPERT TEAM				NAME OF BRIDGE STANDARD DRAWING
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2				GENERAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=20M
					SCALE 1:200
			DESIGNED BY T. Hayakawa	APPROVED BY	DRAWING NO A-2
			SIGNATURE :		
			DATE : December 2022		

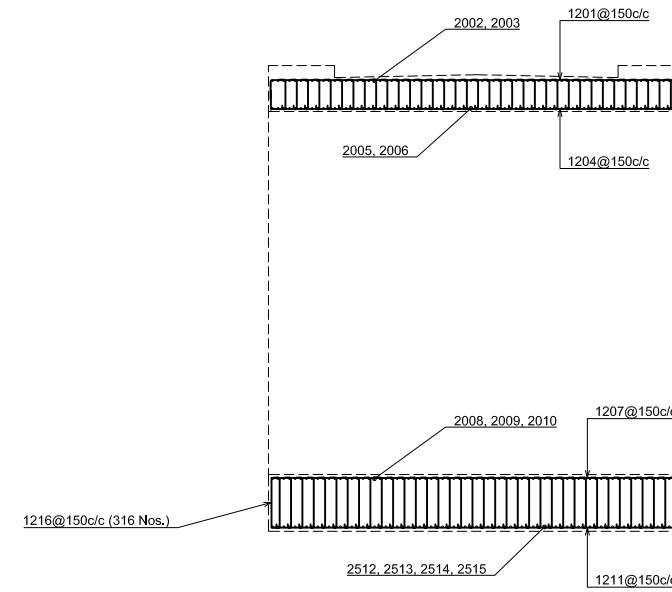
REINFORCEMENT PLAN OF RC CONTINUOUS SLAB BRIDGE L=20M



PROFILE

1 - 1

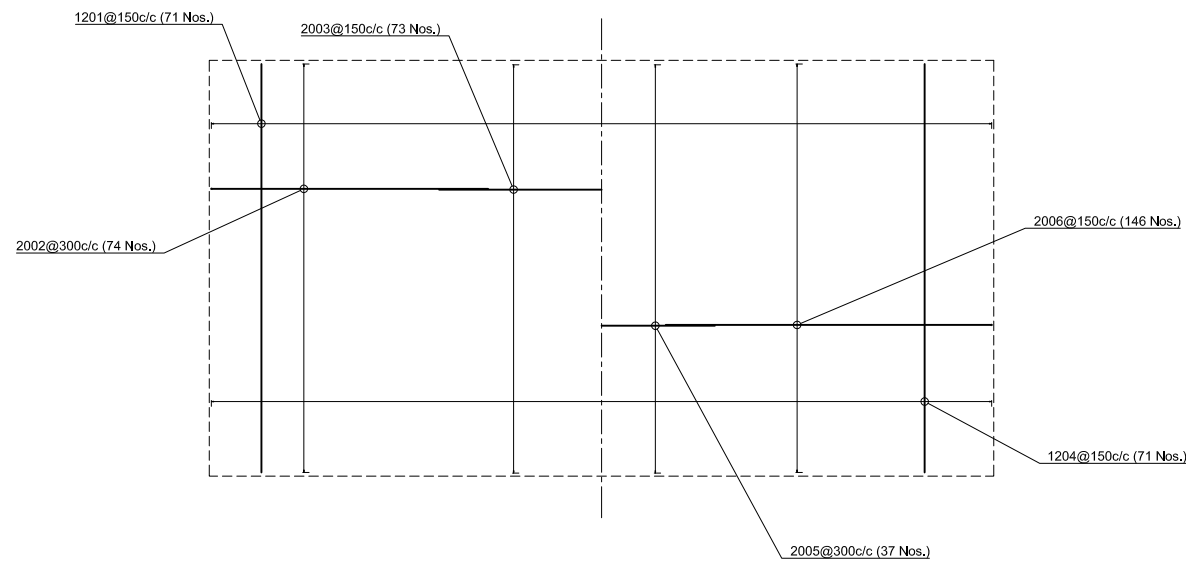
2 - 2



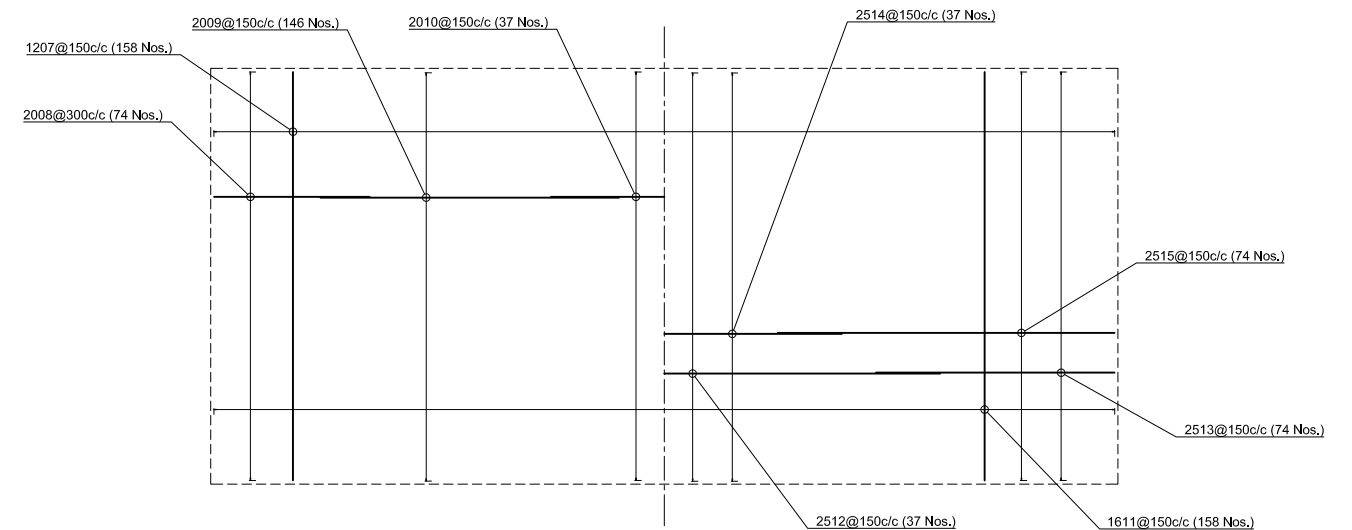
SECTION

3 - 3

4 - 4



TOP SLAB



BOTTOM SLAB

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:	DESIGNED BY		APPROVED BY		NAME OF BRIDGE		REINFORCEMENT PLAN OF	
	JICA EXPERT TEAM		T. Hayakawa		STANDARD DRAWING		RC CONTINUOUS SLAB BRIDGE L=20M		DRAWING NO	
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2		SCALE		1:200		A-3			
	CHAKUPAT LALITPUR, KATHMANDU		DATE :		December 2022					

BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=20M

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
1	1201		12	11840	71	840.6	746.5
2	2002		20	7760	74	574.2	1418.3
3	2003		20	8600	73	627.8	1550.7
4	1204		12	11840	71	840.6	746.5
5	2005		20	6000	37	222.0	548.3
6	2006		20	9060	71	643.3	1589.0
7	1207		12	10850	158	1714.3	1522.3
8	2008		20	4855	74	359.3	887.5
9	2009		20	7900	146	1153.4	2848.9
10	2010		20	6000	74	444.0	1096.7
11	1211		12	10850	158	1714.3	1522.3
12	2512		25	12000	37	444.0	1709.4
13	2513		25	7062	74	522.6	2012.0
14	2514		25	12000	37	444.0	1709.4
15	2515		25	9662	74	715.0	2752.8
16	1216		12	1598	316	505.0	448.4
17	1217		12	1082	3745	4052.1	3598.3
18	1218		12	1632	4644	7579.0	6730.2
19	2519		25	11931	37	441.4	1699.4
20	2020		20	11886	37	439.8	1086.3
21	2521		25	4367	37	161.6	622.2
22	2022		20	1779	37	65.8	162.5

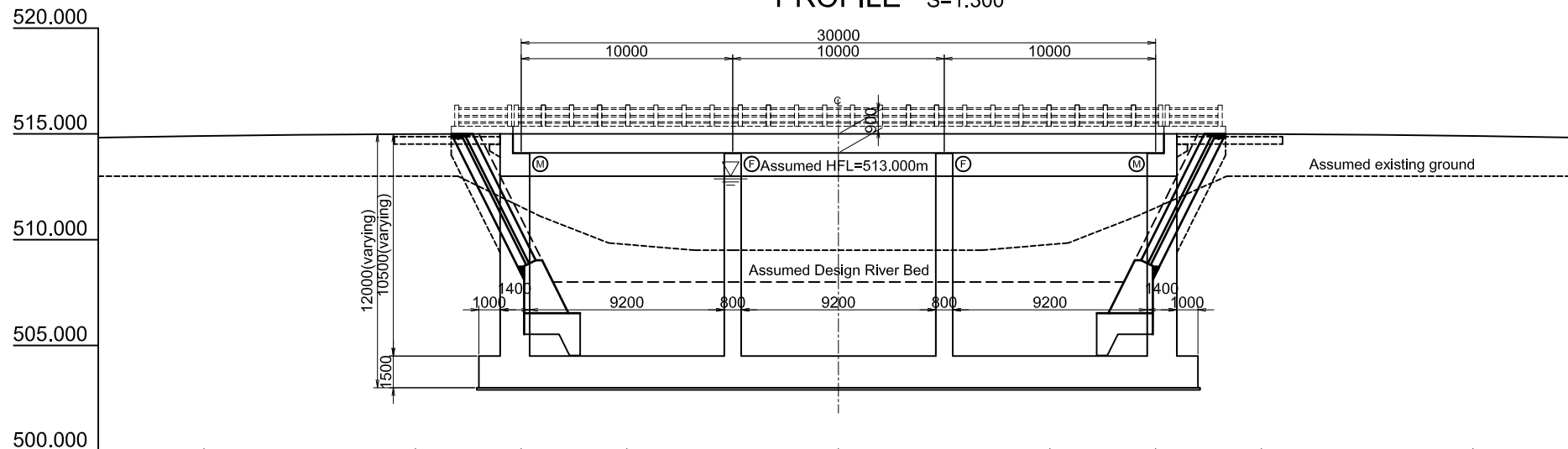
S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
23	1223		12	10850	74	802.9	713.0
24	1224		12	10850	64	694.4	616.6
25	1225		12	738	185	136.5	121.2
26	1226		12	1532	2331	3571.1	3171.1
27	1627		16	11670	74	863.6	1364.5
28	1628		16	970	37	35.9	56.7
29	1229		12	938	1184	1110.0	986.2
30	1230		12	10850	66	716.1	635.9
31	2531		25	11931	37	441.4	1699.4
32	2032		20	11886	37	439.8	1086.3
33	2533		25	4367	37	161.6	622.2
34	2034		20	1779	37	65.8	162.5
35	1235		12	10850	74	802.9	713.0
36	1236		12	10850	64	694.4	616.6
37	1237		12	738	185	136.5	121.2
38	1238		12	1532	2331	3571.1	3171.1

Total Weight 52,865.4 (kg)

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2	REMARKS:							
				DESIGNED BY	APPROVED BY	NAME OF BRIDGE		BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=20M	
			NAME :	T. Hayakawa		STANDARD DRAWING			
			SIGNATURE :			SCALE NTS		DRAWING NO	
			DATE :	December 2022			A-4		

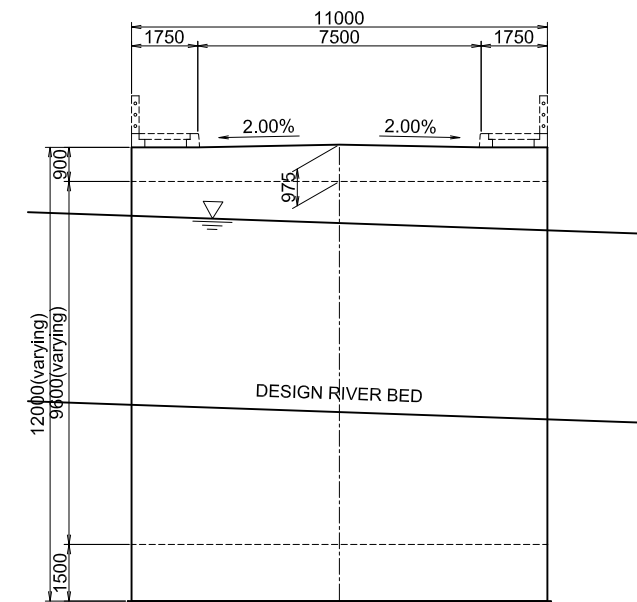
CONCEPTUAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=30M

PROFILE S=1:300

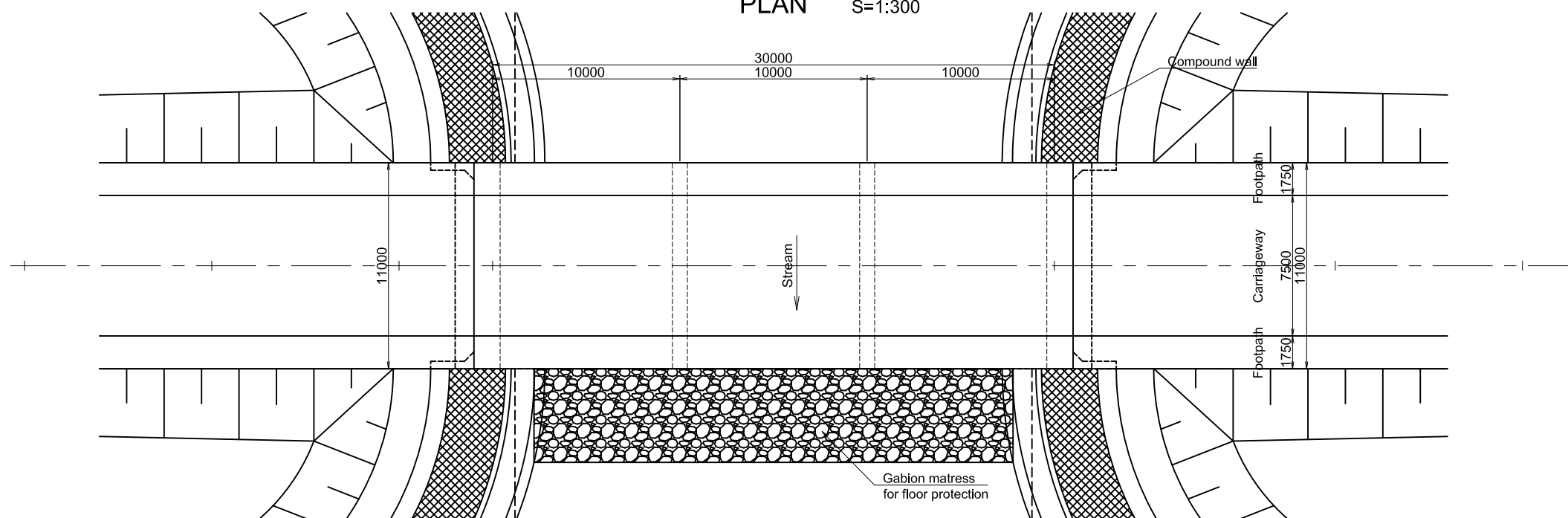


Grade	515.000	LEVEL										515.000
Proposed Height	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000
Existing Height	515.000	515.000	511.000	508.000	508.000	508.000	508.000	508.000	508.000	511.000	515.000	515.000
Station	STA.10+0.000	10.000	A1 15.000	20.000	P1 25.000	30.000	P2 35.000	40.000	A2 45.000	50.000	60.000	
Curve Element		R=∞										
Super Elevation		-4.000%										

CROSS SECTION S=1:200



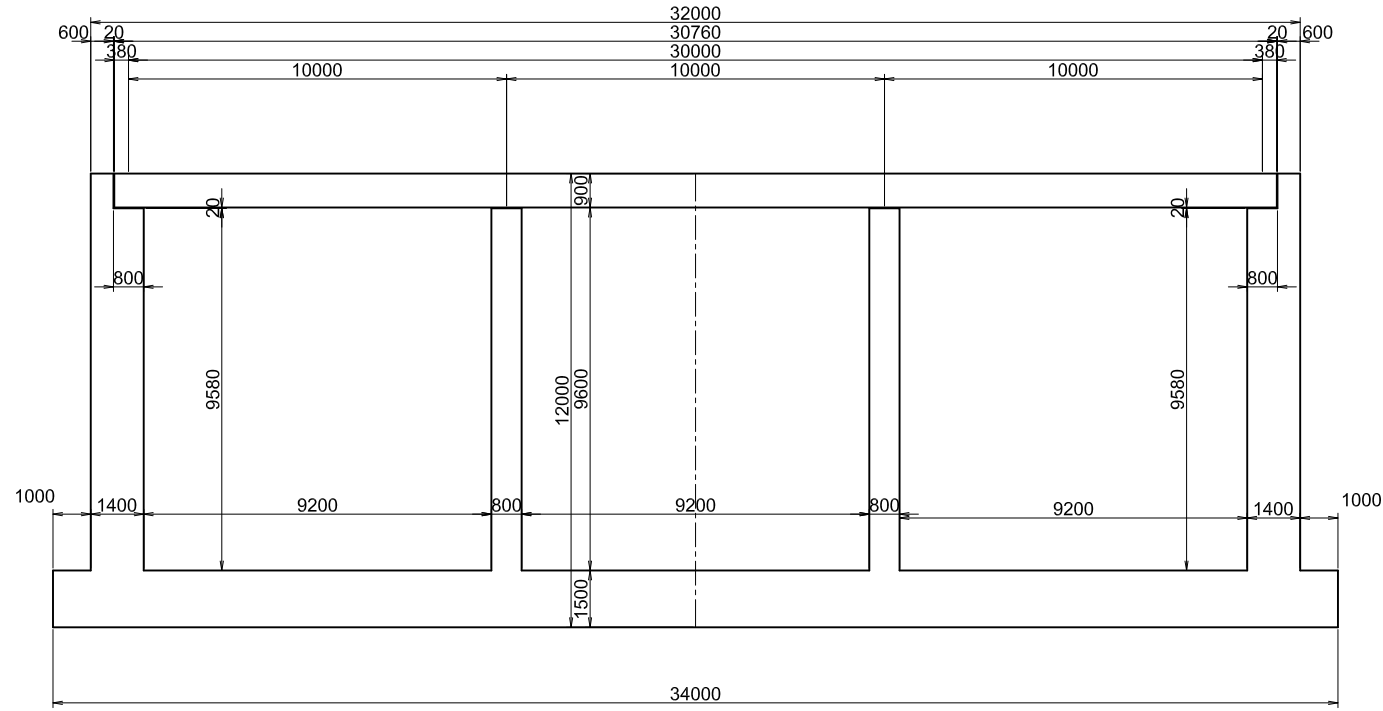
PLAN S=1:300



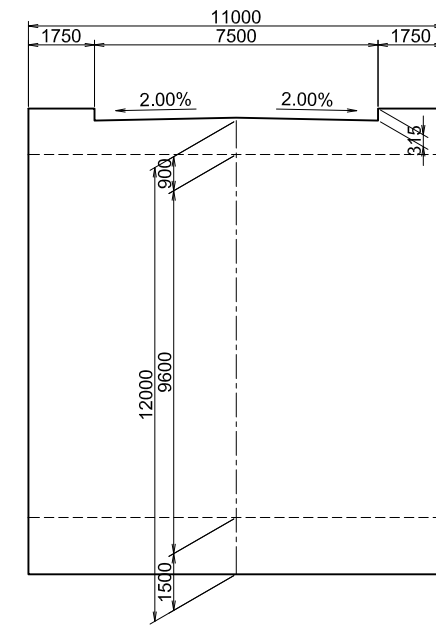
Note: Proposed height, existing ground height, high flood level (HFL) and design river bed are assumed values in this drawing. The designer shall adjust the structural proportions to actual design conditions of the construction site.

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:	DESIGNED BY		APPROVED BY	NAME OF BRIDGE	CONCEPTUAL VIEW OF		
	JICA EXPERT TEAM		T. Hayakawa				STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE L=30M	
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2		SIGNATURE :	[Signature]			SCALE	DRAWING NO	
			DATE :	December 2022			1:300	B-1	

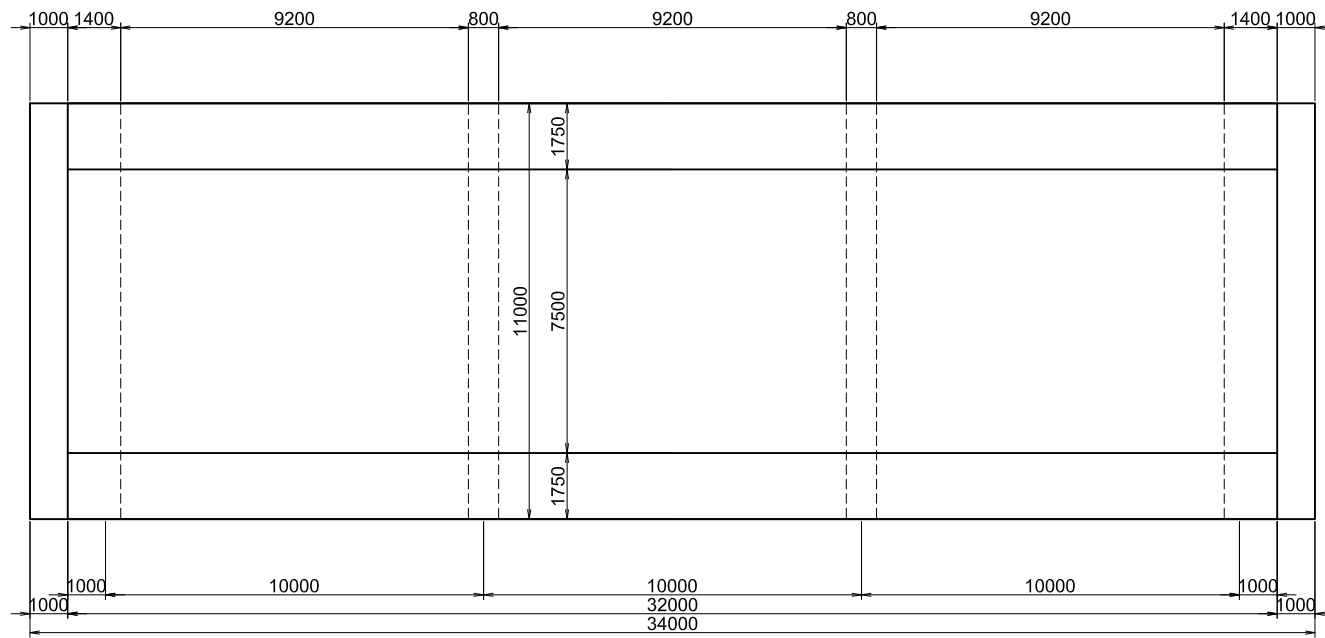
GENERAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=30M



PROFILE



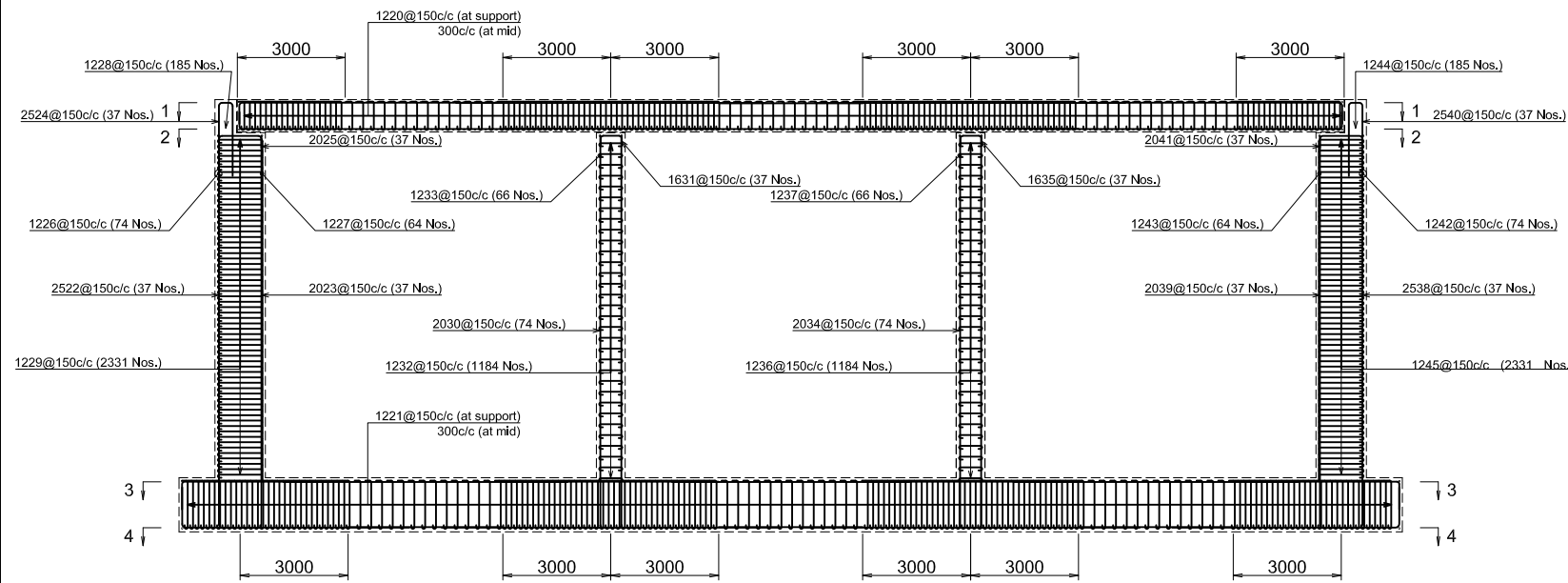
FRONT VIEW



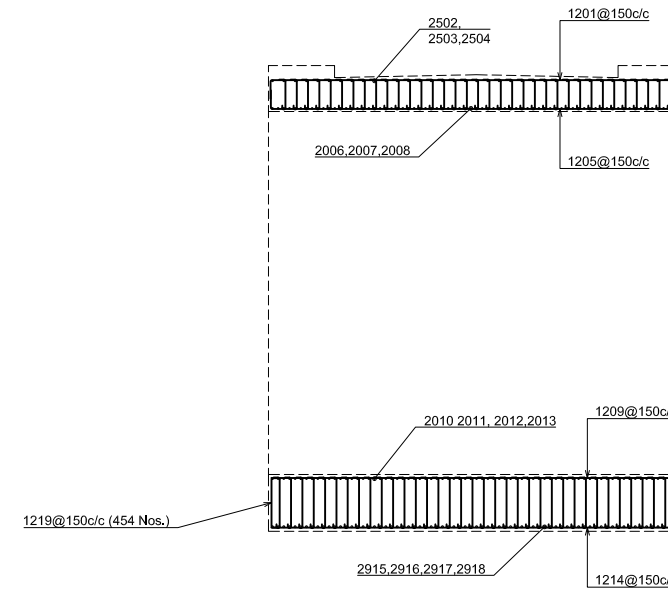
PLAN

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:				
	JICA EXPERT TEAM				NAME OF BRIDGE	GENERAL VIEW OF
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2				STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE L=30M
					SCALE	DRAWING NO
			1:200	B-2		
			DESIGNED BY	APPROVED BY		
			NAME :	T. Hayakawa		
			SIGNATURE :			
			DATE :	December 2022		

REINFORCEMENT PLAN OF RC CONTINUOUS SLAB BRIDGE L=30M



PROFILE



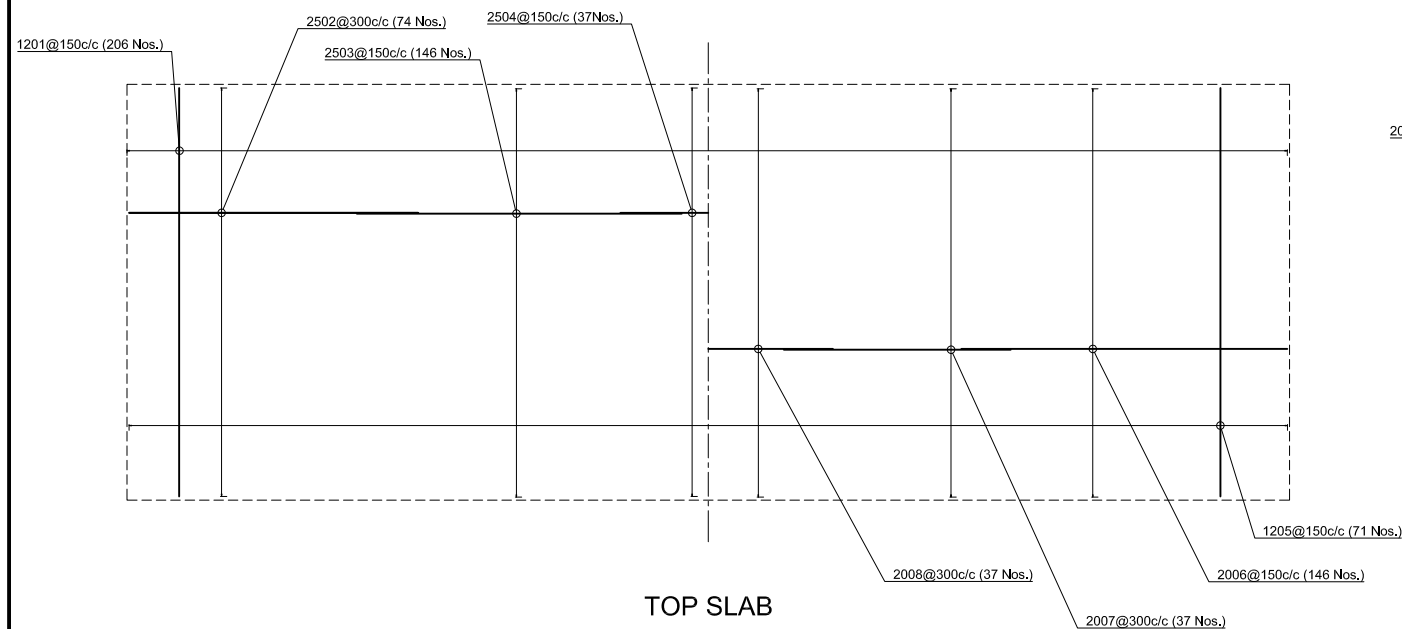
SECTION

1 - 1

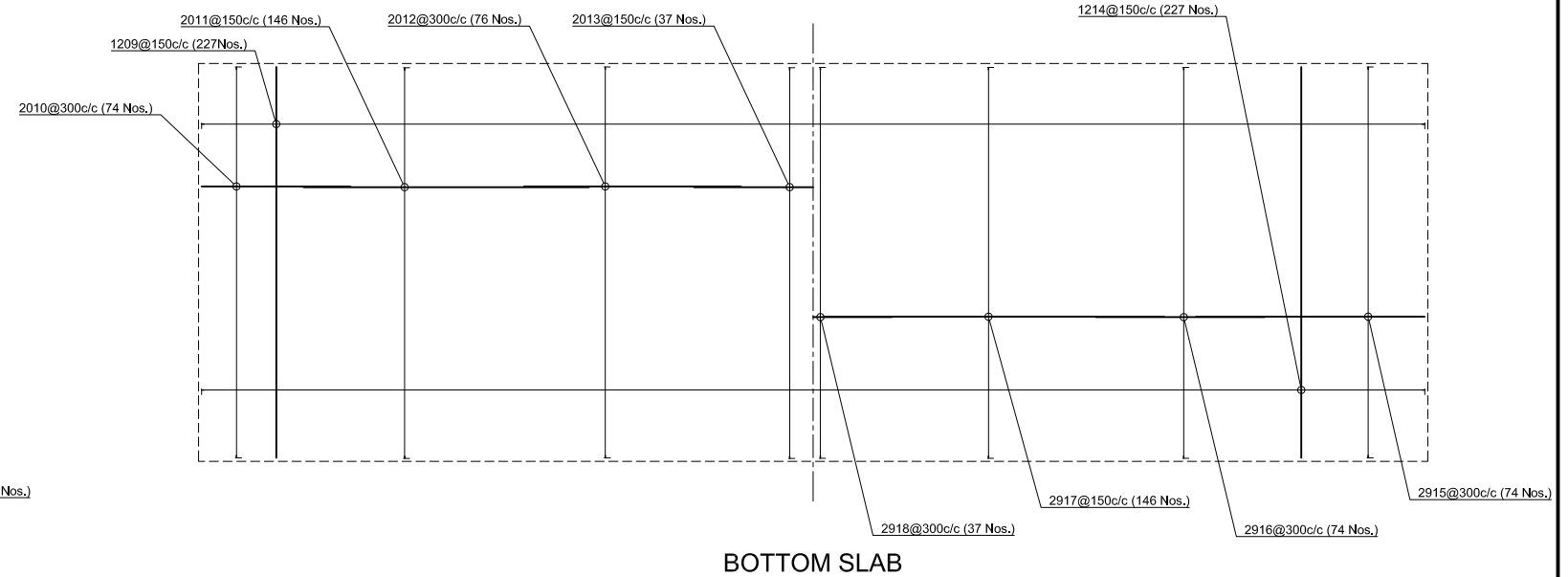
2 - 2

3 - 3

4 - 4



TOP SLAB



BOTTOM SLAB

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU		Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2	REMARKS:	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;"></td> <td style="width: 15%;">DESIGNED BY</td> <td style="width: 15%;">APPROVED BY</td> <td style="width: 20%;">NAME OF BRIDGE</td> <td style="width: 35%;">REINFORCEMENT PLAN OF</td> </tr> <tr> <td>NAME :</td> <td>T. Hayakawa</td> <td></td> <td>STANDARD DRAWING</td> <td>RC CONTINUOUS SLAB BRIDGE L=30M</td> </tr> <tr> <td>SIGNATURE :</td> <td></td> <td></td> <td>SCALE</td> <td>DRAWING NO</td> </tr> <tr> <td>DATE :</td> <td>December 2022</td> <td></td> <td>1:200</td> <td>B-3</td> </tr> </table>			DESIGNED BY	APPROVED BY	NAME OF BRIDGE	REINFORCEMENT PLAN OF	NAME :	T. Hayakawa		STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE L=30M	SIGNATURE :			SCALE	DRAWING NO	DATE :	December 2022		1:200	B-3
	DESIGNED BY	APPROVED BY	NAME OF BRIDGE	REINFORCEMENT PLAN OF																					
NAME :	T. Hayakawa		STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE L=30M																					
SIGNATURE :			SCALE	DRAWING NO																					
DATE :	December 2022		1:200	B-3																					

BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=30M

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
1	1201		12	11840	206	2439.0	2165.8
2	2502		25	7760	74	574.2	2210.7
3	2503		25	8600	146	1255.6	4834.1
4	2504		25	4700	37	173.9	669.5
5	1205		12	11840	206	2439.0	2165.8
6	2006		20	9060	146	1322.8	3267.3
7	2007		20	6000	74	444.0	1096.7
8	2008		20	6600	146	963.6	2380.1
9	1209		12	10850	227	2463.0	2187.1
10	2010		20	4855	74	359.3	887.5
11	2011		20	7900	146	1153.4	2848.9
12	2012		20	6000	76	456.0	1126.3
13	2013		20	6600	73	481.8	1190.0
14	1214		12	10850	227	2463.0	2187.1
15	2915		29	7385	146	1078.2	5207.7
16	2916		29	4670	74	345.6	1669.2
17	2917		29	9400	146	1372.4	6628.7
18	2918		29	4370	37	161.7	781.0
19	1219		12	1598	316	505.0	448.4
20	1220		12	1082	3745	4052.1	3598.3
21	1221		12	1632	4644	7579.0	6730.2
22	2522		25	11931	37	441.4	1699.4

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
23	2023		20	11886	37	439.8	1086.3
24	2524		25	4367	37	161.6	622.2
25	2025		20	1779	37	65.8	162.5
26	1226		12	10850	74	802.9	713.0
27	1227		12	10850	64	694.4	616.6
28	1228		12	738	185	136.5	121.2
29	1229		12	1532	2331	3571.1	3171.1
30	2030		20	11931	74	882.8	2180.5
31	2031		20	1064	37	39.4	97.3
32	1232		12	938	1184	1110.0	986.2
33	1233		12	10850	66	716.1	635.9
34	2034		20	11931	74	882.8	2180.5
35	2035		20	1064	37	39.4	97.3
36	1236		12	938	1184	1110.0	986.2
37	1237		12	10850	66	716.1	635.9
38	2538		25	11931	37	441.4	1699.4
39	2039		20	11886	37	439.8	1086.3
40	2540		25	4367	37	161.6	622.2
41	2041		20	1779	37	65.8	162.5
42	1242		12	10850	74	802.9	713.0
43	1243		12	10850	64	694.4	616.6
44	1244		12	738	185	136.5	121.2

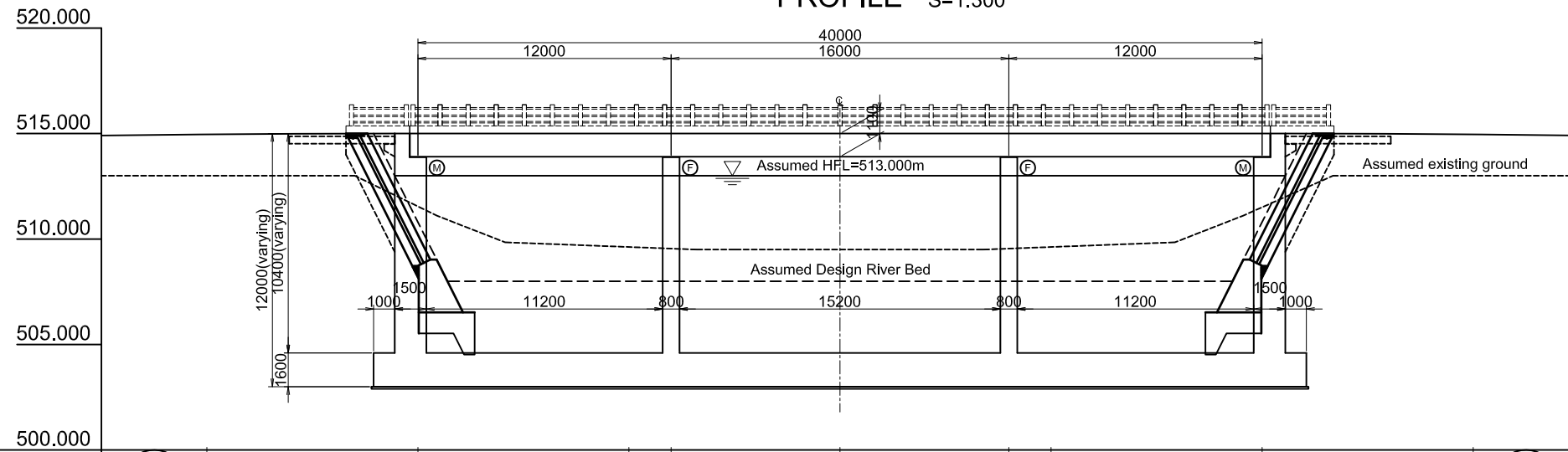
S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
45	1245		12	1532	2331	3571.1	3171.1

Total Weight 82,623.6 (kg)

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2	REMARKS:	NAME OF BRIDGE STANDARD DRAWING BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=30M			
			DESIGNED BY	APPROVED BY	SCALE	DRAWING NO
			NAME :	T. Hayakawa	NTS	B-4
			SIGNATURE :		DATE :	December 2022

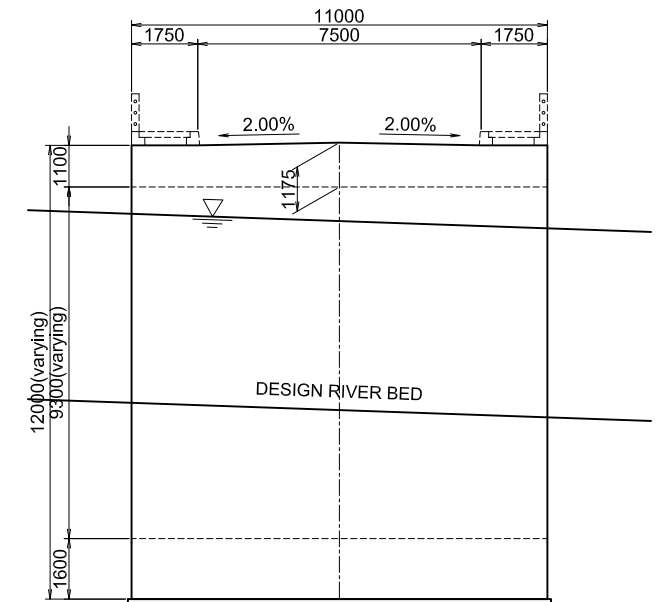
CONCEPTUAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=40M

PROFILE S=1:300

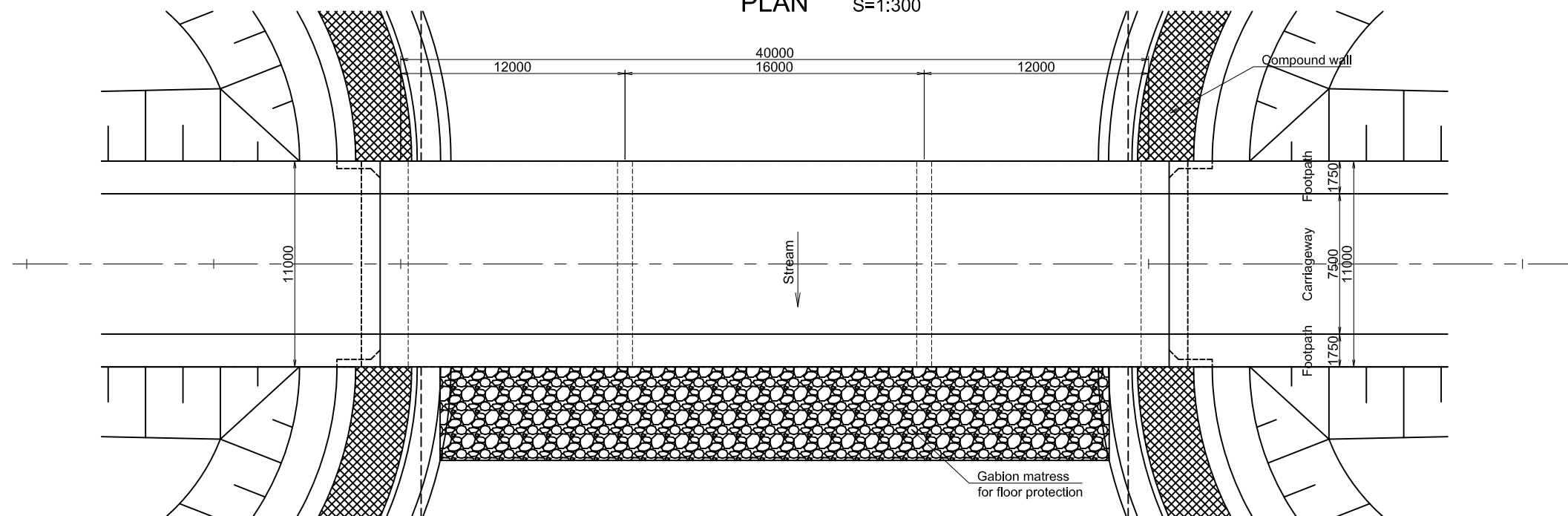


Grade	515.000	LEVEL										515.000
Proposed Height	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000	515.000
Existing Height	515.000	510.800	508.000	508.000	508.000	508.000	508.000	508.000	508.000	510.800	515.000	515.000
Station	STA.10+0.000	A1 10.000	20.000	P1 22.000	30.000	P2 38.000	40.000	50.000	A2 50.000	60.000		
Curve Element		R=∞										
Super Elevation		-4.000%										

CROSS SECTION S=1:200



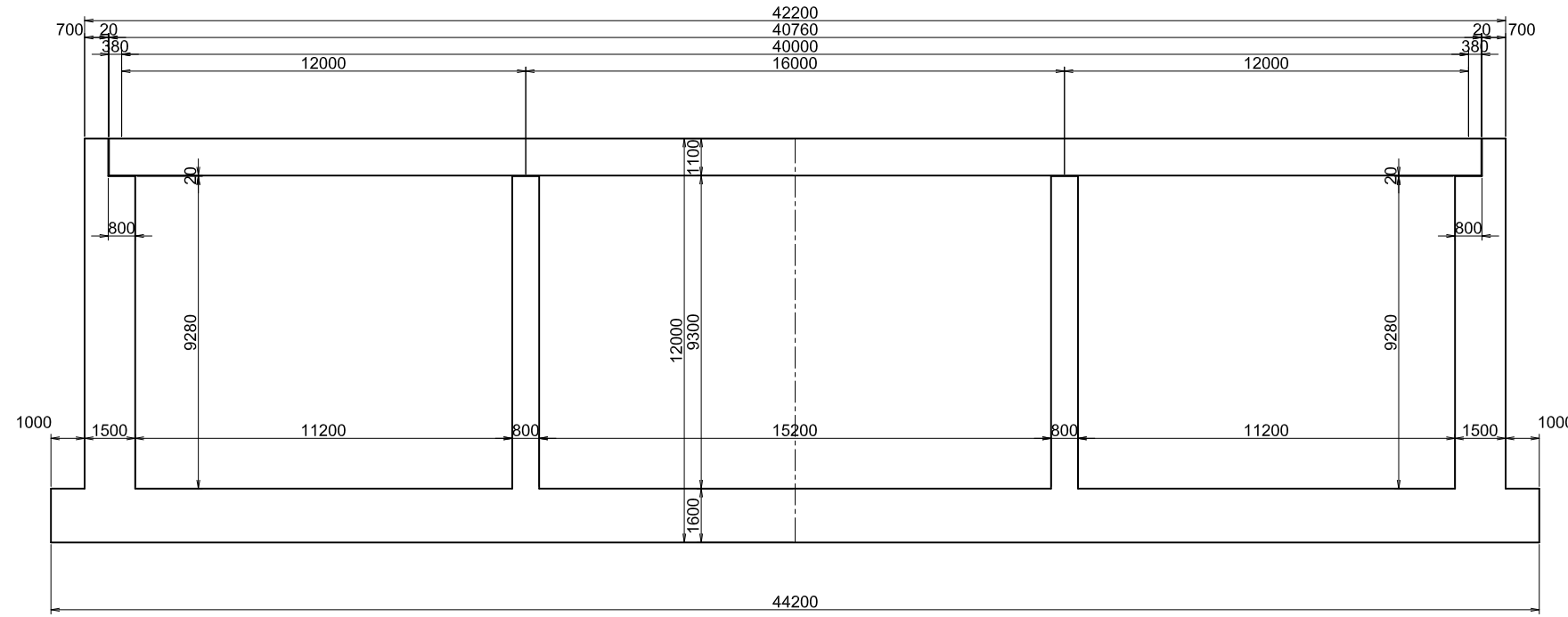
PLAN S=1:300



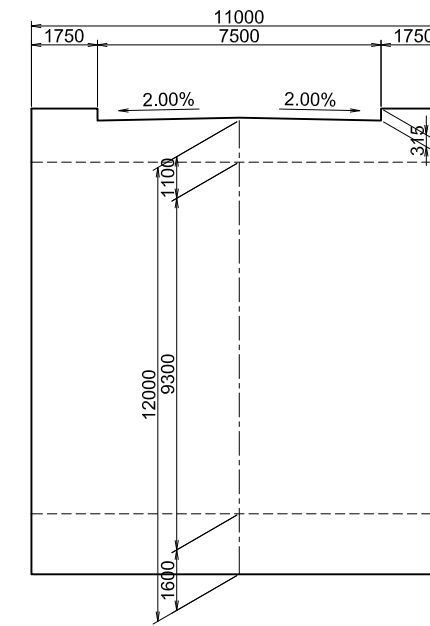
Note: Proposed height, existing ground height, high flood level (HFL) and design river bed are assumed values in this drawing.
The designer shall adjust the structural proportions to actual design conditions of the construction site.

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:	DESIGNED BY		APPROVED BY		NAME OF BRIDGE		CONCEPTUAL VIEW OF		
	JICA EXPERT TEAM		T. Hayakawa				STANDARD DRAWING		RC CONTINUOUS SLAB BRIDGE L=40M		
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2		SIGNATURE:				SCALE 1:300		DRAWING NO		
			DATE: December 2022						C-1		

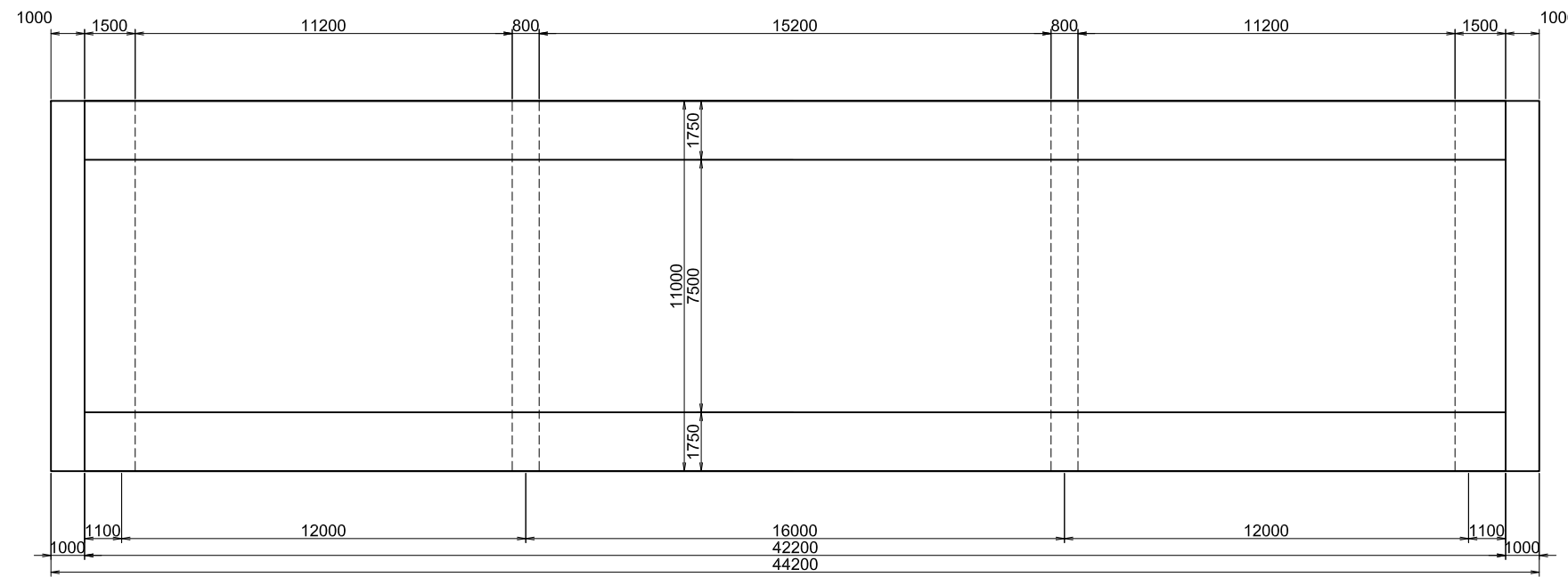
GENERAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=40M



PROFILE



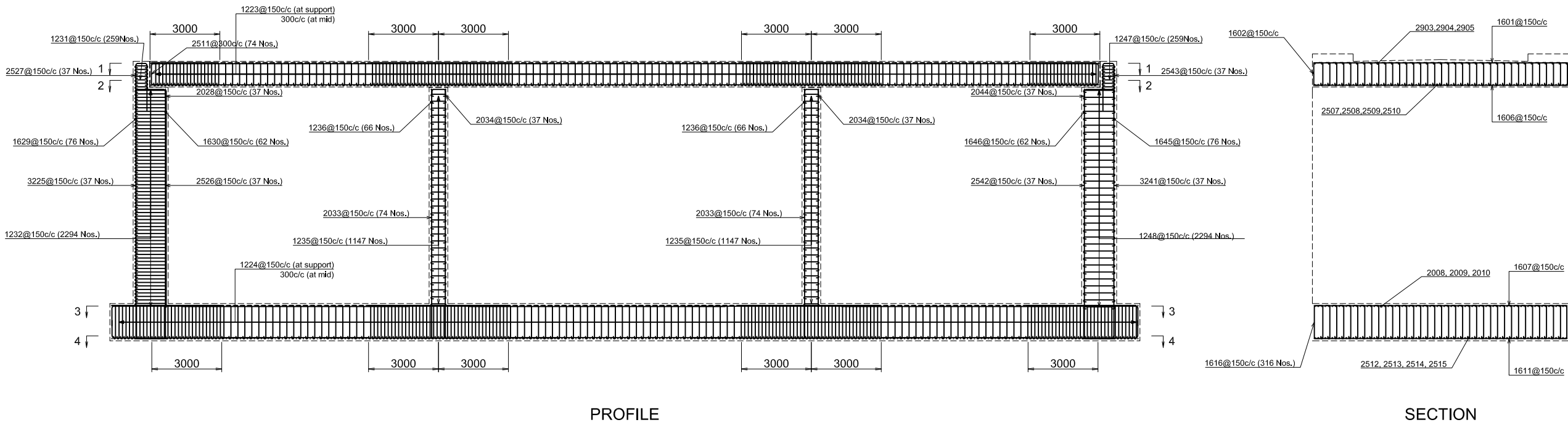
FRONT VIEW



PLAN

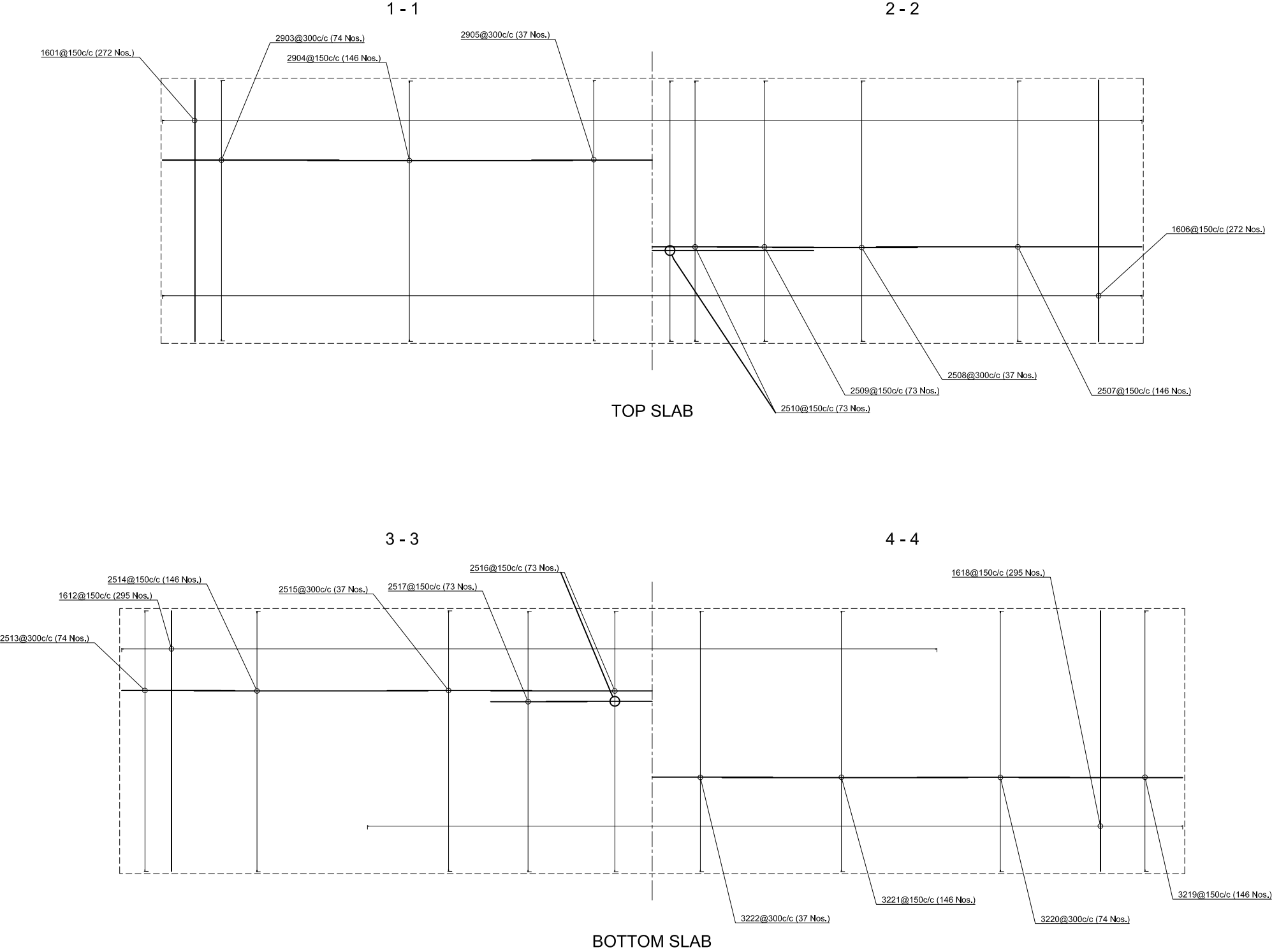
GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:				
	JICA EXPERT TEAM				NAME OF BRIDGE STANDARD DRAWING	
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2				GENERAL VIEW OF RC CONTINUOUS SLAB BRIDGE L=40M	
			DESIGNED BY	APPROVED BY	SCALE	DRAWING NO
			NAME :	T. Hayakawa	1:200	C-2
			SIGNATURE :			
			DATE :	December 2022		

REINFORCEMENT PLAN OF RC CONTINUOUS SLAB BRIDGE L=40M (1)



GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:			NAME OF BRIDGE		GENERAL VIEW OF		
	JICA EXPERT TEAM				STANDARD DRAWING		RC CONTINUOUS SLAB BRIDGE L=40M		
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2		DESIGNED BY	APPROVED BY	SCALE	DRAWING NO			
			T. Hayakawa			1:200	C-3		
			NAME :		T. Hayakawa				
			SIGNATURE :						
			DATE :		December 2022				

REINFORCEMENT PLAN OF RC CONTINUOUS SLAB BRIDGE L=40M (2)



GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:						
	JICA EXPERT TEAM							
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2							
				DESIGNED BY	APPROVED BY	NAME OF BRIDGE	GENERAL VIEW OF	
			NAME :	T. Hayakawa		STANDARD DRAWING	RC CONTINUOUS SLAB BRIDGE L=40M	
			SIGNATURE :			SCALE	DRAWING NO	
			DATE :	December 2022		1:200	C-4	

BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=40M

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
1	1601	10900	16	10900	272	2964.8	4684.4
2	1602	978 $\left\{ \begin{array}{l} 224 \\ 224 \end{array} \right.$	16	1344	544	731.1	1155.1
3	2903	9318	29	9318	74	689.5	3330.3
4	2904	9700	29	9400	146	1426.4	6889.5
5	2905	10000	29	10000	37	370.0	1787.1
6	1606	10900	16	10900	272	2964.8	4684.4
7	2507	11018	25	11018	146	1608.6	6193.1
8	2508	6000	25	6000	74	444.0	1709.4
9	2509	4000	25	4000	73	292.0	1124.2
10	2510	11100	25	11100	73	810.3	3119.7
11	2511	936 $\left\{ \begin{array}{l} 350 \\ 350 \end{array} \right.$	25	1511	74	111.8	430.4
12	1612	10850	16	10850	295	3200.8	5057.3
13	2513	885 $\left\{ \begin{array}{l} 4708 \end{array} \right.$	25	5500	74	407.0	1567.0
14	2514	9718	25	9718	146	1418.8	5462.4
15	2515	6000	25	6000	74	444.0	1709.4
16	2516	11000	25	11000	73	803.0	3091.6
17	2517	4000	25	4000	73	292.0	1124.2
18	1618	10850	16	10850	295	3200.8	5057.3
19	3219	789 $\left\{ \begin{array}{l} 6811 \end{array} \right.$	32	7500	146	1489.2	9396.9
20	3220	6318	32	6318	74	467.5	2949.9
21	3221	10200	32	10200	146	1489.2	9396.9
22	3222	10000	32	10000	37	370.0	2334.7

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
23	1223	168 $\left\{ \begin{array}{l} 108 \\ 108 \end{array} \right.$	12	1282	6790	8704.8	7729.9
24	1224	168 $\left\{ \begin{array}{l} 108 \\ 1450 \end{array} \right.$	12	1732	7630	13215.2	11735.1
25	3225	10730 $\left\{ \begin{array}{l} 1350 \end{array} \right.$	32	12000	37	444.0	2801.6
26	2526	10730 $\left\{ \begin{array}{l} 1333 \end{array} \right.$	25	12000	37	444.0	1709.4
27	2527	2045 $\left\{ \begin{array}{l} 498 \\ 2045 \end{array} \right.$	25	4463	37	165.1	635.6
28	2028	350 $\left\{ \begin{array}{l} 1285 \\ 350 \end{array} \right.$	20	1869	37	69.2	170.9
29	1629	10850	16	10850	76	824.6	1302.9
30	1630	10850	16	10850	62	672.7	1062.9
31	1231	550 $\left\{ \begin{array}{l} 96 \\ 108 \end{array} \right.$	12	838	259	217.0	192.7
32	1232	1346 $\left\{ \begin{array}{l} 96 \\ 108 \end{array} \right.$	12	1628	2294	3734.6	3316.3
33	2033	10712 $\left\{ \begin{array}{l} 1078 \end{array} \right.$	20	11730	74	868.0	2144.0
34	2034	280 $\left\{ \begin{array}{l} 604 \\ 280 \end{array} \right.$	20	1064	37	39.4	97.3
35	1235	650 $\left\{ \begin{array}{l} 96 \\ 108 \end{array} \right.$	12	938	1147	1075.9	955.4
36	1236	10850	12	10850	62	672.7	597.4
37	2037	10712 $\left\{ \begin{array}{l} 1078 \end{array} \right.$	20	11730	74	868.0	2144.0
38	2038	280 $\left\{ \begin{array}{l} 604 \\ 280 \end{array} \right.$	20	1064	37	39.4	97.3
39	1239	650 $\left\{ \begin{array}{l} 96 \\ 108 \end{array} \right.$	12	938	1147	1075.9	955.4
40	1240	10850	12	10850	62	672.7	597.4
41	3241	10730 $\left\{ \begin{array}{l} 1350 \end{array} \right.$	32	12000	37	444.0	2801.6
42	2542	10730 $\left\{ \begin{array}{l} 1333 \end{array} \right.$	25	12000	37	444.0	1709.4
43	2543	2045 $\left\{ \begin{array}{l} 498 \\ 2045 \end{array} \right.$	25	4463	37	165.1	635.6
44	2044	350 $\left\{ \begin{array}{l} 1285 \\ 350 \end{array} \right.$	20	1869	37	69.2	170.9

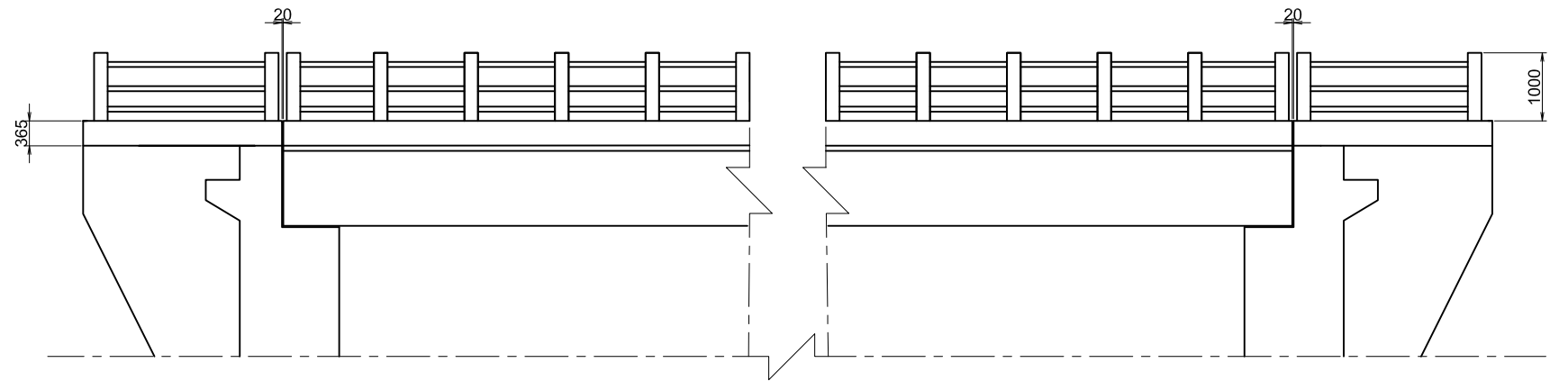
S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
45	1645	10850	16	10850	76	824.6	1302.9
46	1646	10850	16	10850	62	672.7	1062.9
47	1247	550 $\left\{ \begin{array}{l} 108 \\ 108 \end{array} \right.$	12	838	259	217.0	192.7
48	1248	1346 $\left\{ \begin{array}{l} 108 \\ 108 \end{array} \right.$	12	1628	2294	3734.6	3316.3

Total Weight 129,205,6 (kg)

GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2	REMARKS:	NAME OF BRIDGE STANDARD DRAWING BAR BENDING SCHEDULE OF RC CONTINUOUS SLAB BRIDGE L=40M			
			DESIGNED BY	APPROVED BY	SCALE	DRAWING NO
			NAME :	T. Hayakawa	NTS	C-5
			SIGNATURE :		DATE :	December 2022

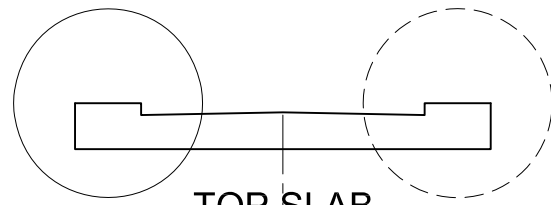
ACCESSORIES (1)

PROFILE OF FOOTPATH AND RAILINGS S=1:100



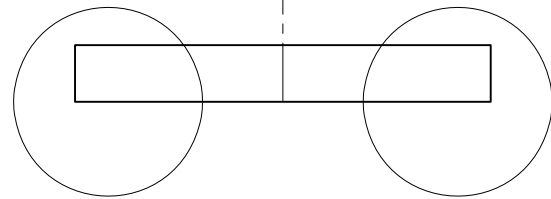
CROSS SECTION

FOOTPATH



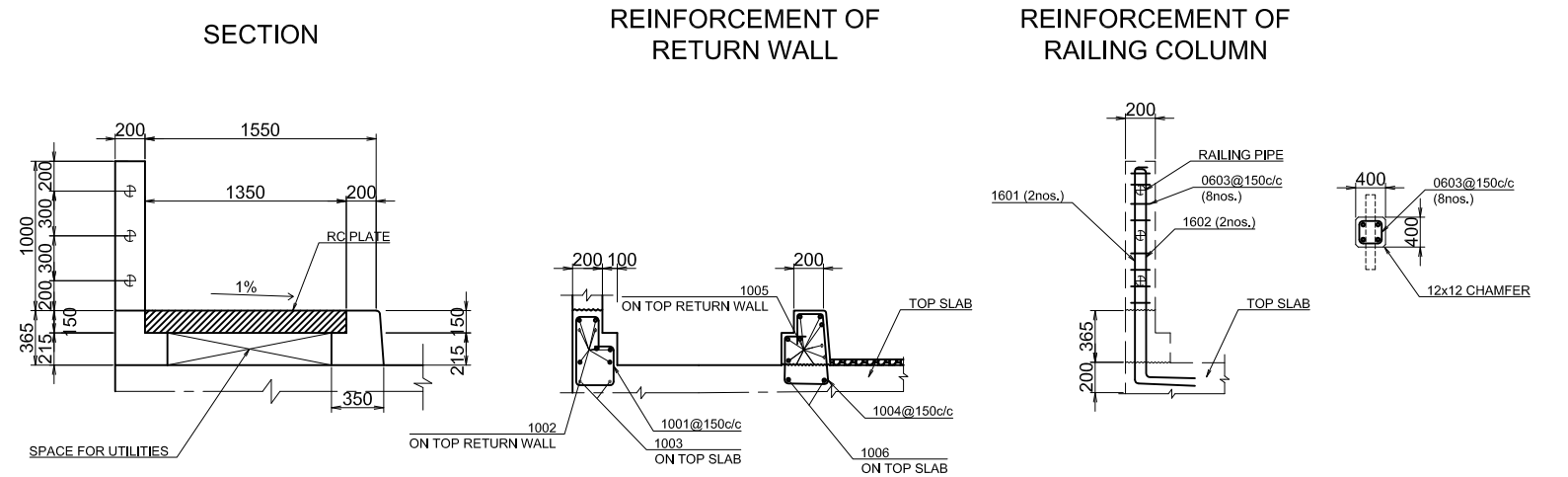
TOP SLAB

BOTTOM SLAB

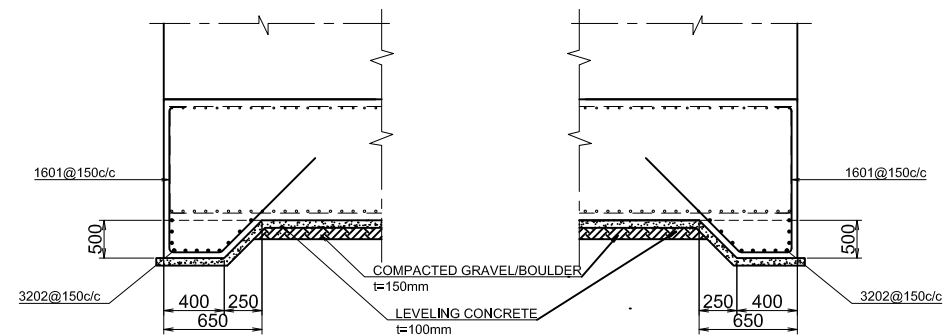


RAFT FOUNDATION

DETAIL OF FOOTPATH AND RAILINGS S=1:50



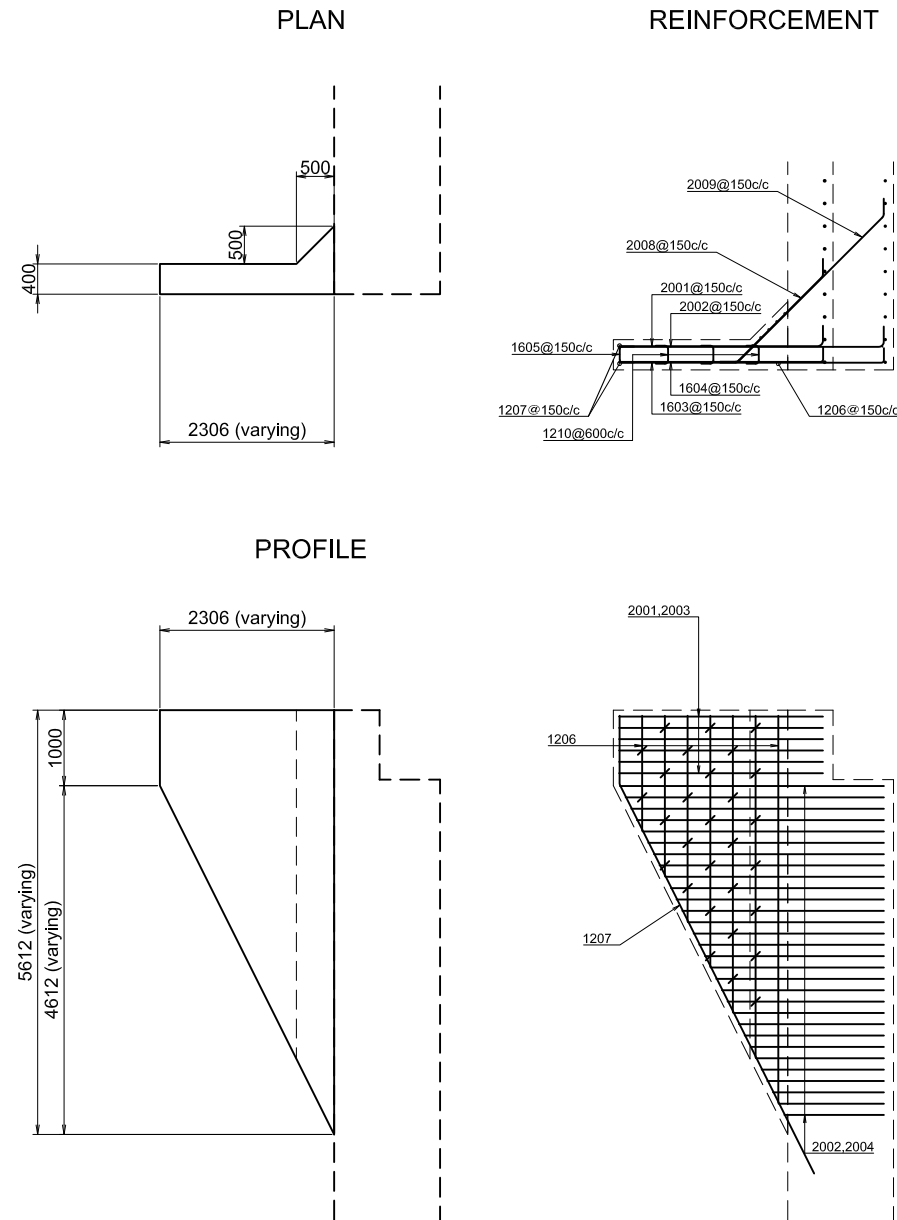
DETAIL OF RAFT FOUNDATION S=1:100



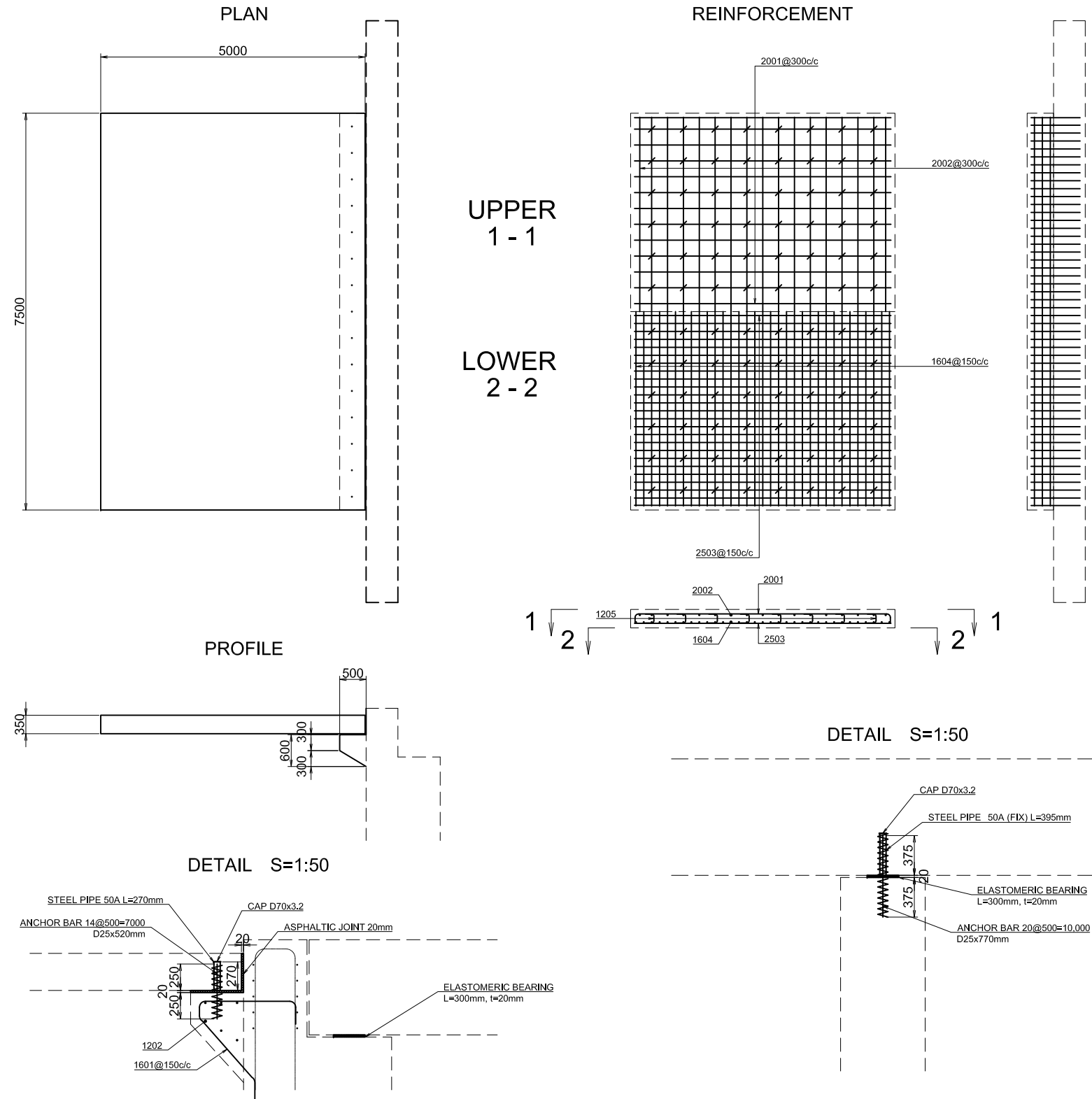
<p>GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU</p>	<p>Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2</p>	<p>REMARKS:</p>			NAME OF BRIDGE		ACCESSORIES (1)	
					STANDARD DRAWING			
			DESIGNED BY	APPROVED BY	SCALE	DRAWING NO		
			NAME :	T. Hayakawa	1:100	M-1		
SIGNATURE :		DATE :	December 2022					

ACCESSORIES (2)

RETURN WING WALL (REFERENCE)



APPROACH SLAB AND CRADLE (REFERENCE)



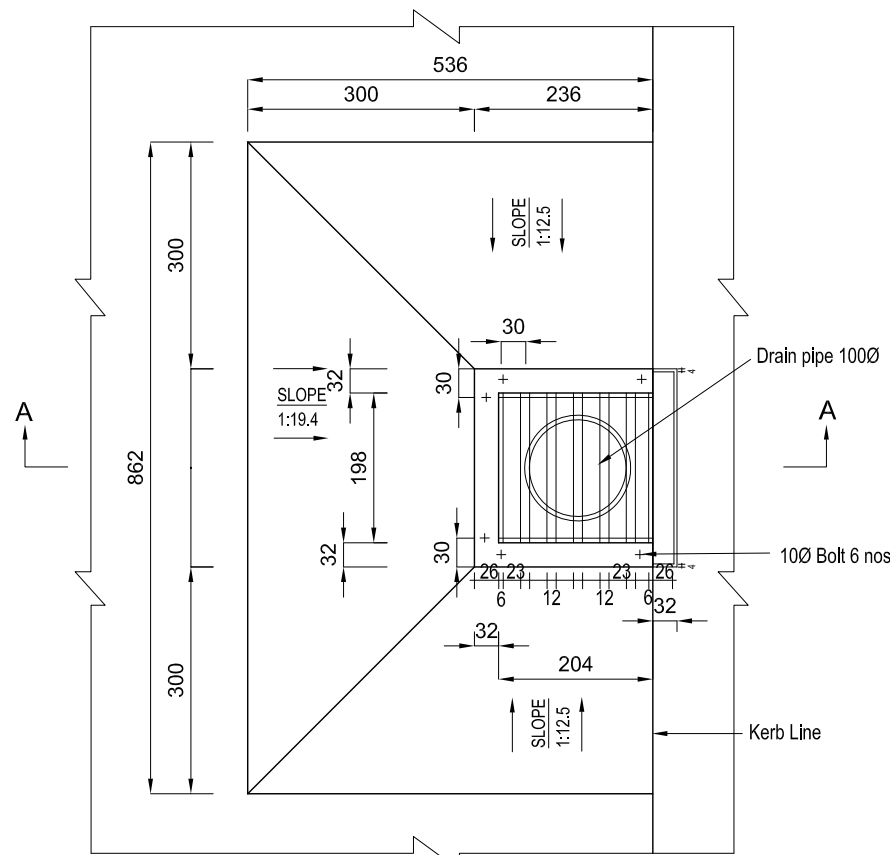
GOVERNMENT OF NEPAL
MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT
DEPARTMENT OF ROADS
CHAKUPAT LALITPUR, KATHMANDU

Support by
JICA EXPERT TEAM
THE PROJECT FOR THE OPERATION
AND MAINTENANCE OF THE
SINDHULI ROAD, PHASE 2

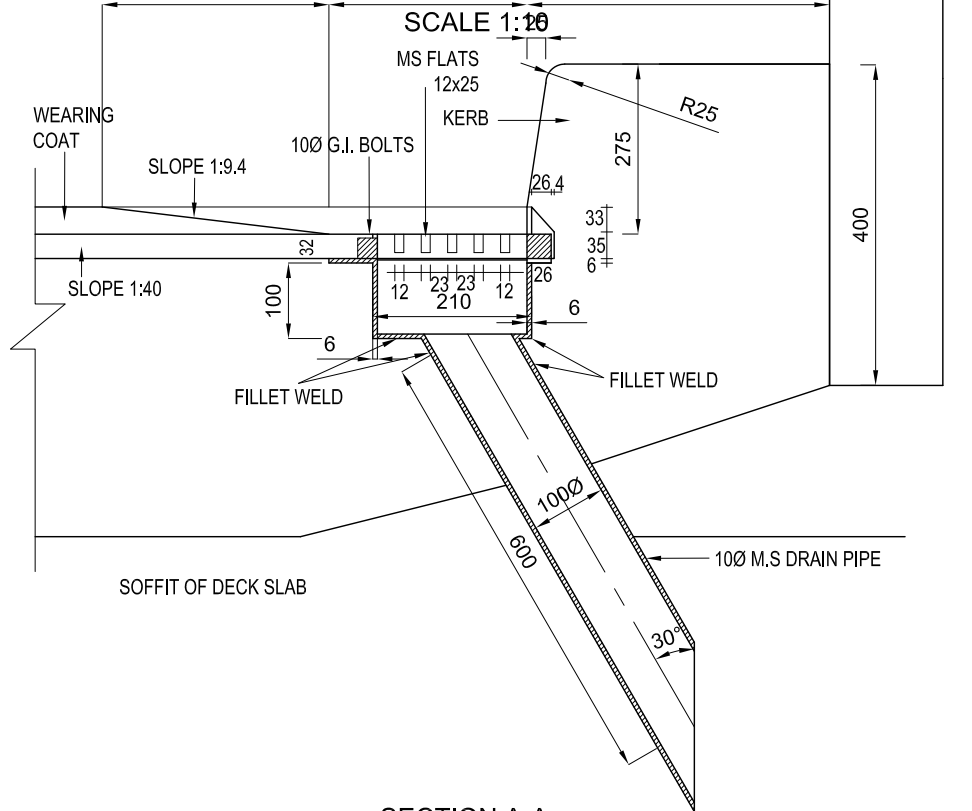
REMARKS:

DESIGNED BY	APPROVED BY	NAME OF BRIDGE STANDARD DRAWING	ACCESSORIES (2)	
NAME :	T. Hayakawa		SCALE	DRAWING NO
SIGNATURE :		1:100	M-2	
DATE :	December 2022			

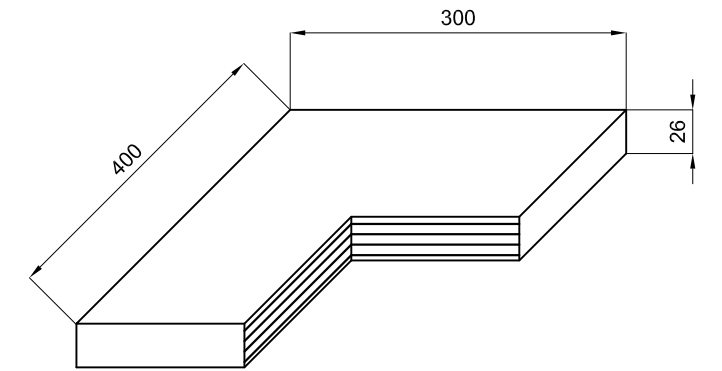
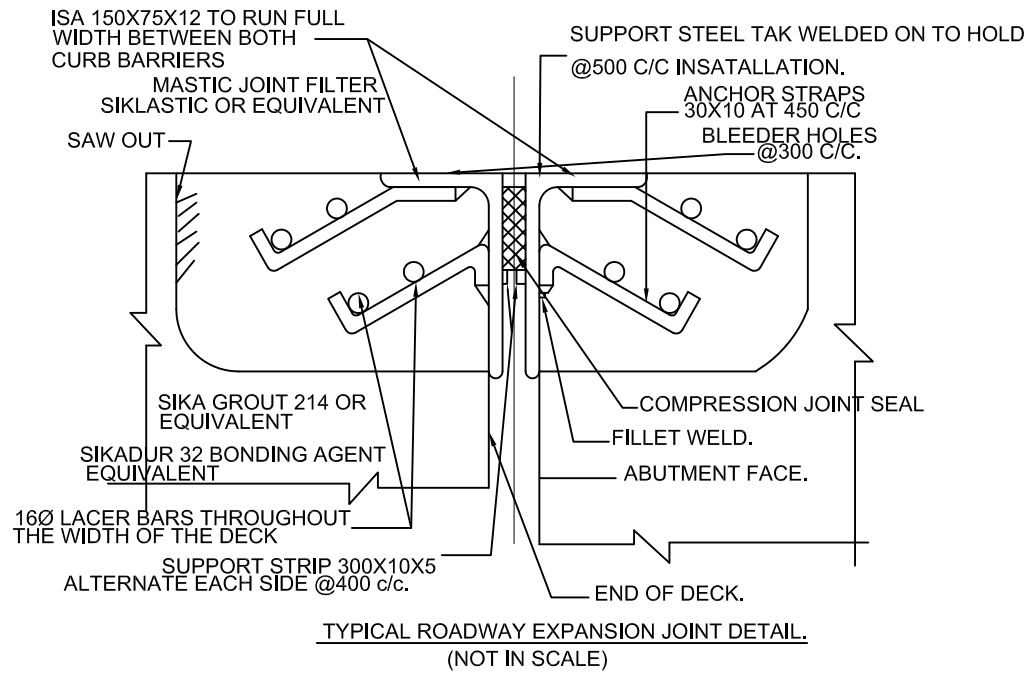
ACCESSORIES (3)



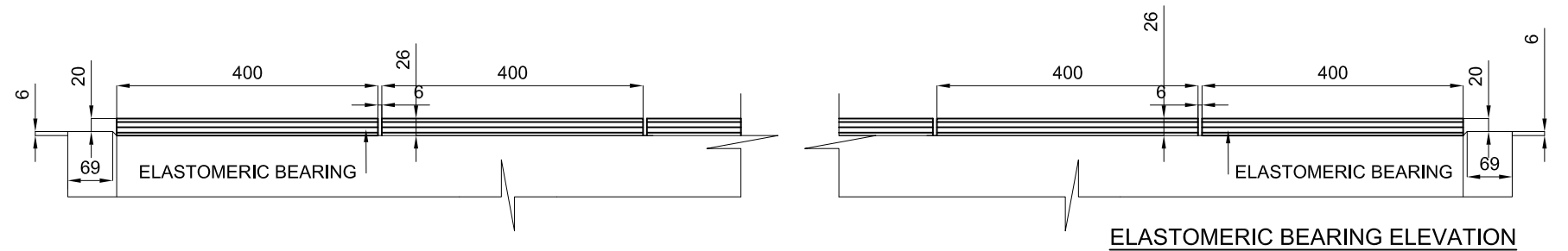
PLAN DETAIL OF DRAINAGE SPOUT AND COLLECTION PIT



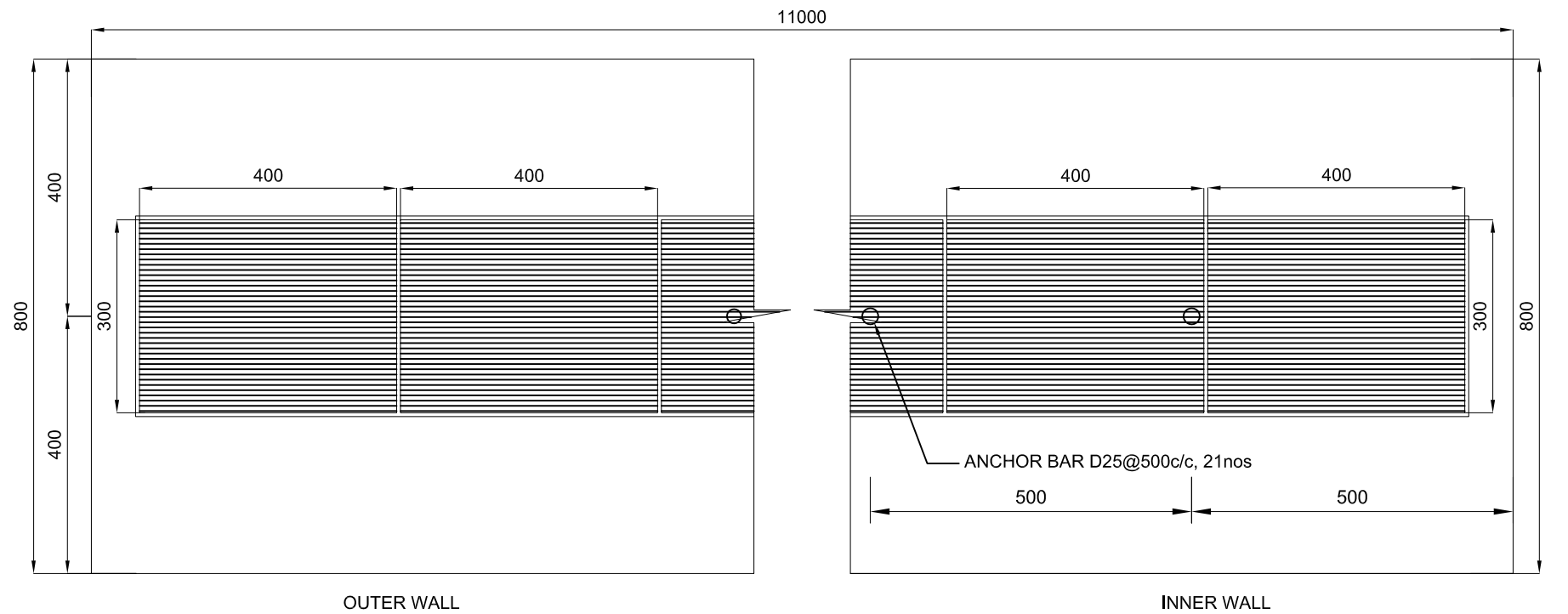
SECTION A-A
SCALE 1:10



SECTIONAL ISOMETRIC VIEW OF ELASTOMERIC BEARING



ELASTOMERIC BEARING ELEVATION



ELASTOMERIC BEARING PLAN

GOVERNMENT OF NEPAL
MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT
DEPARTMENT OF ROADS
CHAKUPAT LALITPUR, KATHMANDU

Support by
JICA EXPERT TEAM
THE PROJECT FOR THE OPERATION
AND MAINTENANCE OF THE
SINDHULI ROAD, PHASE 2

REMARKS:

DESIGNED BY	APPROVED BY	NAME OF BRIDGE	ACCESSORIES (3)
T. Hayakawa		STANDARD DRAWING	
SIGNATURE :		SCALE	DRAWING NO
		1:10	M-3
DATE :	December 2022		

BAR BENDING SCHEDULE OF ACCESSORIES

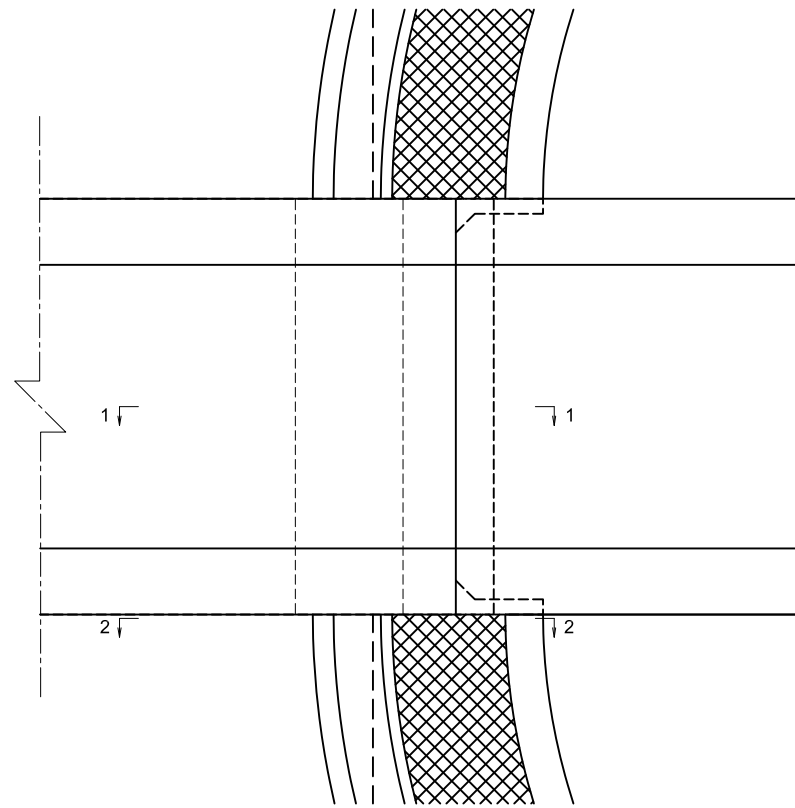
S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
RETURN WALL (PER 10m)							
1	1001		10	1403	6.67	9.4	5.8
2	1002		10	10000	8	80.0	49.4
3	1003		10	10000	2	20.0	12.3
4	1004		10	1545	6.67	10.3	6.4
5	1005		10	10000	8	80.0	49.4
6	1006		10	10000	2	20.0	12.3
RAILINGS (PER 1 nos)							
1	1601		16	2245	2	4.5	7.1
2	1602		16	2245	2	4.5	7.1
3	603		6	657	8	5.3	1.2
RAFT FOUNDATION (PER 10m / ONE SIDE)							
1	1601		16	4534	6.67	30.2	47.7
2	3202		32	10000	11	110.0	694.1

S.N.	Bar Mark	Shape of Bar (Not to Scale) Dimensions are in mm	Dia. of Bars (mm)	Length of Bar as per IS2502 (mm)	No. of Bars	Total Length of Bars (m)	Weight (kg)
RETURN WING WALL (REFERENCE, PER SINGLE PORTION)							
1	2001		20	2937	6	17.6	43.5
2	2002		20	2655 (ave.)	30	79.7	196.9
3	1603		20	2877	6	17.3	42.7
4	1604		20	2595 (ave.)	30	77.9	192.4
5	1605		16	566	8	4.5	7.1
6	1206		12	526	2	1.1	1.0
7	1207		12	6661	2	13.3	11.8
8	2008		20	2053	6	12.3	30.4
9	2009		20	3191	22	70.2	173.4
APPROACH SLAB (REFERENCE, PER SINGLE PORTION)							
1	2001		20	5100	26	132.6	327.5
2	2002		20	4850	17	82.5	203.8
3	2503		25	7350	50	367.5	1414.9
4	1604		16	7350	33	242.6	383.3
5	1205		12	455	96	43.7	38.8
CRADLE (PER SINGLE PORTION)							
1	1601		16	4079	50	204.0	322.3
2	1202		12	7350	6	44.1	39.2

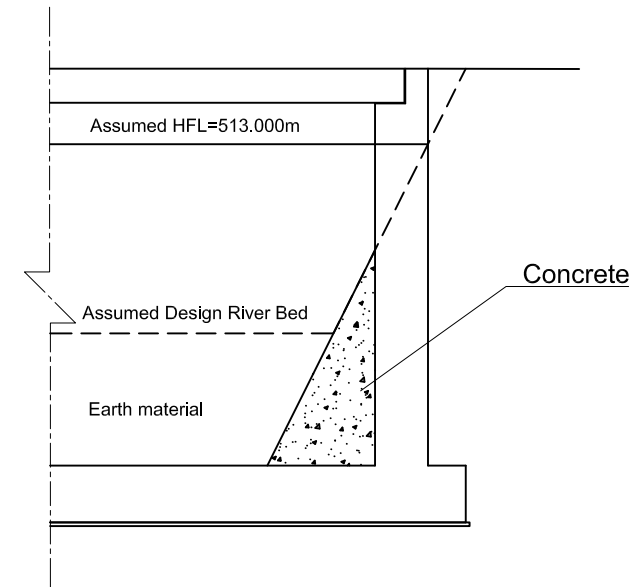
GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU	Support by	REMARKS:	DESIGNED BY		APPROVED BY		NAME OF BRIDGE		BAR BENDING SCHEDULE OF		
	JICA EXPERT TEAM		T. Hayakawa				STANDARD DRAWING		ACCESSORIES		
	THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2						SCALE		DRAWING NO		
			December 2022				NTS		M-4		

RETAINING WALL (REFERENCE)

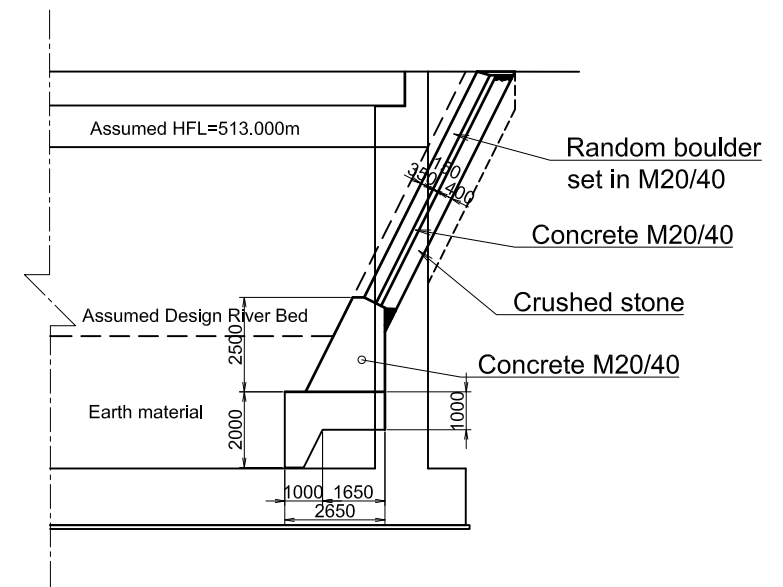
PLAN



1 - 1

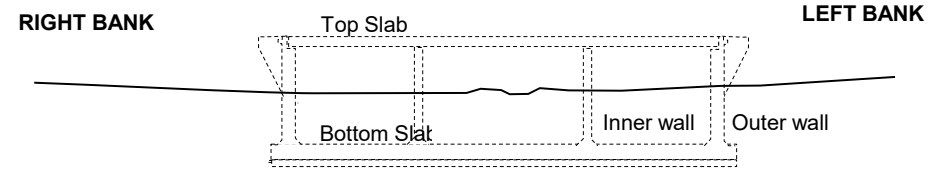


2 - 2



<p>GOVERNMENT OF NEPAL MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT DEPARTMENT OF ROADS CHAKUPAT LALITPUR, KATHMANDU</p>	<p>Support by JICA EXPERT TEAM THE PROJECT FOR THE OPERATION AND MAINTENANCE OF THE SINDHULI ROAD, PHASE 2</p>	<p>REMARKS:</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 15%;"></td> <td style="width: 15%;">DESIGNED BY</td> <td style="width: 15%;">APPROVED BY</td> <td style="width: 20%;">NAME OF BRIDGE</td> <td style="width: 35%;">RETAINING WALL (REFERENCE)</td> </tr> <tr> <td>NAME :</td> <td>T. Hayakawa</td> <td></td> <td>STANDARD DRAWING</td> <td></td> </tr> <tr> <td>SIGNATURE :</td> <td></td> <td></td> <td>SCALE</td> <td>DRAWING NO</td> </tr> <tr> <td>DATE :</td> <td>December 2022</td> <td></td> <td>1:200</td> <td>M-5</td> </tr> </table>		DESIGNED BY	APPROVED BY	NAME OF BRIDGE	RETAINING WALL (REFERENCE)	NAME :	T. Hayakawa		STANDARD DRAWING		SIGNATURE :			SCALE	DRAWING NO	DATE :	December 2022		1:200	M-5
	DESIGNED BY	APPROVED BY	NAME OF BRIDGE	RETAINING WALL (REFERENCE)																			
NAME :	T. Hayakawa		STANDARD DRAWING																				
SIGNATURE :			SCALE	DRAWING NO																			
DATE :	December 2022		1:200	M-5																			

CONSTRUCTION SEQUENCE OF RCSB (REFERENCE)



Before Construction Works

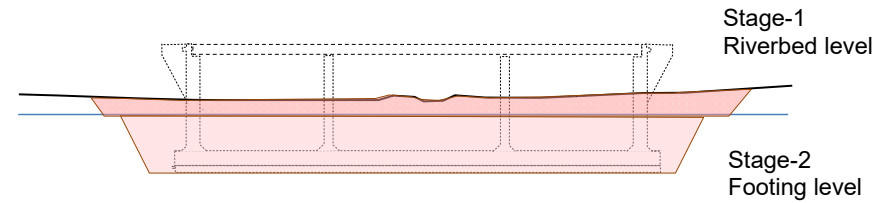


Step-5 Wall Concrete Casting Stage-2.1 (Outer Wall)

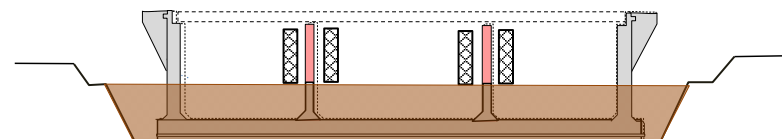
Construction schedule of RCSB (Reference)

Calendar		2021										2022										2023											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Contract Period		Start Date Oct 5										24 months										End Date Oct 5											
Step	Work Item																																
1.	Mobilization	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
2.	Construction of Detour	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
3.	Structure Excavation (stage 1) and River Bed Leveling /Demolition of Existing	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
4.	Structure Excavation (stage 2) with Dewatering	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
5.	Footing Const (Rebar, Form, Concrete)	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
6.	Wall Const part 1 (bottom to riverbed) Abutment and mid wall (Scaffolding, Rebar, Concrete)	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
7.	Backfilling	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
8.	Wall Const part 2 (riverbed to top) Abutment A1	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
9.	Wall Const part 2 (riverbed to top) Abutment A2	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
10.	Wall Const part 2 (riverbed to top) Mid wall W1	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
11.	Wall Const part 2 (riverbed to top) Mid wall W2	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
12.	Supporting for Slab (H=5.8m) and Dismantling	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
13.	Slab Work (Rebar and Concrete)	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
14.	Surfacing and Railing	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
15.	Approach Road	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
16.	River Bank Protection	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															
17.	Demolition of Detour and Site Cleaning	[Gantt bar from Oct 5, 2021 to Oct 5, 2021]																															

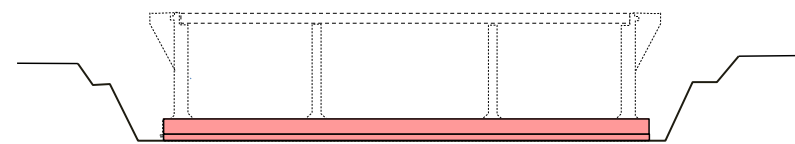
Precondition 1. No construction work inside river is conducted during June to September (rainy season)
2. Efficiency is calculated as 0.75.



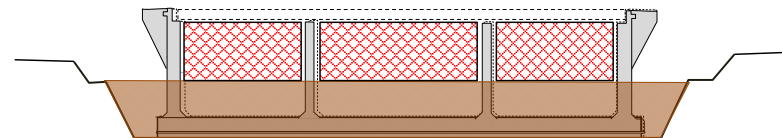
Step-1 Structure Excavation (Stage-1 and Stage-2)



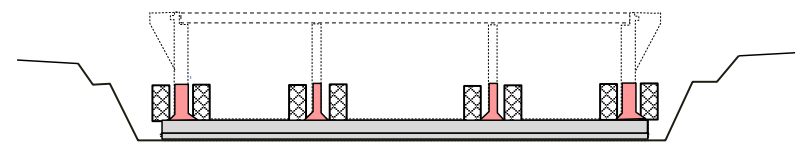
Step-6 Wall Concrete Casting Stage-2.2 (Inner Wall)



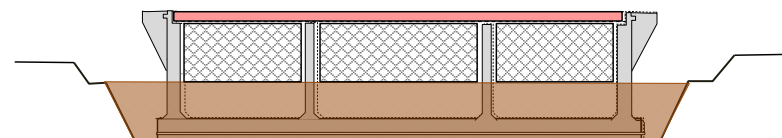
Step-2 Footing Concrete Casting



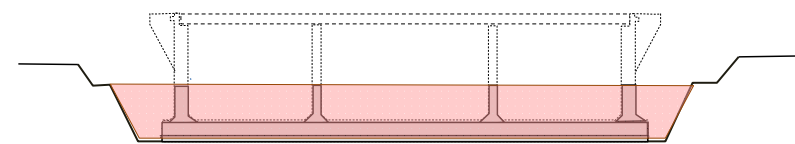
Step-7 Supporting Frame Installation



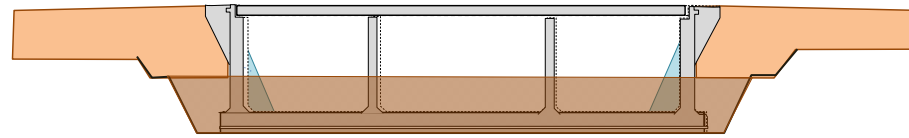
Step-3 Wall Concrete Casting Stage-1 (bottom to riverbed)



Step-8 Slab Concrete Casting



Step-4 Backfilling to Riverbed before Rainy Season



Completion of Construction Works

CLIENT:
GOVERNMENT OF NEPAL
MINISTRY OF PHYSICAL INFRASTRUCTURE AND TRANSPORT
DEPARTMENT OF ROADS
CHAKUPAT LALITPUR, KATHMANDU

Support by
JICA EXPERT TEAM
THE PROJECT FOR THE OPERATION
AND MAINTENANCE OF THE
SINDHULI ROAD, PHASE 2

REMARKS:

DESIGNED BY	APPROVED BY	CONSTRUCTION SEQUENCE OF RCSB (REFERENCE)		
NAME:	T. Hayakawa	SCALE	DRAWING NO	REV. NO
SIGNATURE:		SCALE OUT	M-6	
DATE:	Sep-22			

ANNEX 6

**Structure Analysis for RC
Continuous Slab Bridge**

**CONSTRUCTION OF THREE BRIDGES
(GHYAMPE, MAMTI AND BHYAKURE)
LOCATED BETWEEN CH.111+400 TO CH.119+700
OF BP HIGHWAY**

DESIGN CALCULATION

MAMTI BRIDGE

Name of Bridge	Mamti Bridge
Location	CH. 113+900
Structure Type	RC continuous Slab
Length of Bridge	40 m
Total Structure Height	12 m
Structure Size	
Span Arrangement	3-spans: 12m+16m+12m
Inner Opening Size	11.2mx9.3m+15.2mx9.3m+11.2mx9.3m
Profile	Level
Skew	90°
Horizontal alignment	∞
Sub-structure Type	Cellular Mat Foundation
Foundation Type	Raft Foundation
Wearing course (FH)	Asphalt Concrete 0.050 m ~ 0.075 m
Ground Condition	Gravel Boulder

File Name	BridgeDesignCal-01_Mamti_(RC-con-Slab_12+16+12)_200314_Ver.6
Print Out Data	2020/3/14

**CONSTRUCTION OF THREE BRIDGES
(GHYAMPE, MAMTI AND BHYAKURE)
LOCATED BETWEEN CH.111+400 TO CH.119+700
OF BP HIGHWAY**

DESIGN CALCULATION

CH. 113+900 Mamti Bridge

Contents

1	Design Condition	1
2	Design Load Calculation	6
2-1	Self weight of structure	6
2-2	Dead load on deck slab surface	6
2-3	Live Load Surcharge	7
2-4	Earth Pressure	7
2-5	Footpath Loading	8
2-6	Live Load and Braking Effect	9
3	Coefficient of Foundation Bed Reaction	37
4	Input Data for 2-Dimengion Frame Model	38
4-1	Nodal Point and Frame Data	38
4-2	Elevation of Structure and Frame	39
4-3	Joint Spring	40
4-4	Load Combination and Permissible Stress	41
4-5	Load Combination Cases	42
4-6	Load Data for Dead Load and Erath Pressure	43
4-7	Load Data of Live Load	44
4-8	Combination of Load	48
5	Section Force Arrangement	51
6	Section Check and Rebar Computed for Top and Bottom Slab ..	52
7	Section Check and Rebar Computed for Wall (Column)	82
8	Summary of Section Check and Rebar Computed	127
9	Horizontal Rebar Check	128
10	Return Walls	130
11	Approach Slab	130
12	Reinforcement Arrangement	132
Annex	Design Calculation Output Data by SAP 2000	

6) **Load Combination and Permissible Stress**

IRC: 6-2016 Clause 202.3

Load	2	3	5	10	13	14	18	21
Combination	Dead Load	Live Load	Vehicle Impact	Braking Effort	Earth Pressure	Temperature	Seismic	Permissible Stresses
LC-	G	Q	Q _{im}	F _b	F _{ep}	F _{tc}	F _{eq}	%
I	1	1	1	1	1			100%
IIA	1	1	1	1	1	1		115%
VI	1	0.2	Q x 1	0.2	1		1	150%

Design Case for Stability of Abutment and Sectional Force for Foundation

Load Case I DL + Live Load + Temperature

Load Case VI DL + 20% of Live Load + Seismic ($K_h=0.15$)

7) **Material Unit Weight**

IRC: 21-2000

Reinforced Concrete	$\gamma_c =$	25.0 kN/m ³
Asphalt Concrete	$\gamma_{ac} =$	22.0 kN/m ³
Water	$\gamma_w =$	10.0 kN/m ³
Plane Concrete	=	24.0 kN/m ³
Base Course	=	19.0 kN/m ³
Intensity of Utility Load for Superstructure	=	1.0 kN/m

8) **Back Filling Material Properties**

Back Filling Material	Riverbed sand and gravel	
Unit Weight of Back Filling Soil	$\gamma_{sub} =$	19.0 kN/m ³
Submerged Unit Wt. of Soil	$\gamma_{sub} =$	10.0 kN/m ³
Angle of internal friction of soil	$\Phi =$	32 ° (degree)
Coefficient of Earth Pressure at Rest	$K_0 = 1 - \sin\Phi =$	0.50 Clause 214.1.3
The coefficient of at-rest earth pressure shall be taken as no movement structure such as closed box cell.		
The centre of pressure exerted by the backfill is located at an elevation of 0.33 of the height of the wall.		

9) **Bearing Ground Properties**

Bearing ground Material	Boulder, Gravel and Granular Soil
Soil Density	Very Dense
SPT-N Value	> 30~60
Ground Water Table Elevation	Confirmed

Design for Raft Foundation

Design N-value for spring of foundation base below raft foundation

Mamti SPT-N value = 30 ° (degree)

Located at alluvial fan, sedimental deposit by glandular soil and boulder

10) **Live Load (Q)**

IRC: 6-2016 204

Carriageway Width	=	7.5 m
Combination of Live Load	Number of Lanes for Design Purposes	= 2 Lanes
Load Combination	One lane of Class 70R or two lanes for Class A	
IRC 70R Tracked Vehicle	=	700 kN
IRC 70R Wheeled Vehicle	=	1000 kN
IRC Class-A Train of Vehicle (2 Lane)	=	1080 kN
Refer to figure in Annex-1		

11) Footpath Load IRC: 6-2016 206
 Footpath Width = 1.5 m at both sides
 for effective span of 7.5 m but not exceeding 30 m
 Live load $P = P_1 - (40L - 300)/9$
 for pedestrians $P_1 = 500 \text{ kg/m}^2$
 Effective span $L = 12 \text{ m}$
 $P = 500 - (40 \times 12 - 300)/9 = 480 \text{ kg/m}^2 = 4.8 \text{ kN/m}^2$

12) Braking Effect (Fb) IRC 6-2016 211.2
 Longitudinal Forces Percentage of the Train Load = 20 %

13) Live Load Surcharge IRC 6-2016 214.1.1.3
 Live load surcharge shall be applied on abutments and retaining walls

14) Vertical Impact Effect (Qim) IRC 6-2016 208
 for IRC 70R Tracked Vehicle
 10% up to a span of 40m = 10%
 for IRC 70R Wheeled Vehicle
 RC bridges, 25% up to span of 12m and Fig. 3.6 for spans exceeding 12m
 12 m Impact at 12 m = 25%
 16 m Impact at 16 m = 20%
 for IRC Class A for impact factor fraction for reinforced concrete bridges
 $I = A / (B + L) = 4.5 / (6.0 + L)$ L = length of span
 12 m Impact at 12 m = 25%
 16 m Impact at 16 m = 20%

15) Seismic Load
 IS1893 (Part1) Criteria for Earthquake Resistant Design - General Provisions and Buildings
 IS1893 (Part3) Criteria for Earthquake Resistant Design - Bridge and Retaining walls
 IRC 6-2016 Section: II Loads and Stress 219.5. 1 Horizontal Seismic Zone
 IRC 6-2016 Section: II Loads and Load Combinations 219.5.1 Horizontal Seismic Zone

Horizontal Seismic Coefficient

Zone Factor
 (Seismic Zone: 5) Z = 0.36
 Importance Factor V: Very Severe
 (Important bridges: 1) I = 1.0
 Response Reduction Factor Normal bridge
 (Superstructure, reinforced concrete 3.0) R = 3.0
 (Column 4.0) R = 4.0
 Response Spectra for
 (Type of Soil: 2) **Medium Soil sites, 10 < N < 30**
 Time Period (S) T = 0.2 s
 For Medium Soil sites
 Average Response Acceleration Coefficient $S_a/g = 2.50$
 Design Horizontal Seismic Coefficient $Z/2 \cdot I/R \cdot S_a/g$
 (Superstructure, reinforced concrete 3.0) $= (0.36/2) \times (1.0/3.0) \times 2.50 = 0.150$
 (Column 4.0) $= (0.36/2) \times (1.0/4.0) \times 2.50 = 0.113$
 Maximum Seismic Coefficient for Seismic Zone V according to IRC: 6-2016
 $K_h = 0.15$

IRC: 6-2016 Section: II Loads and Load Combinations 219.5.2 Live load components
 The horizontal seismic force in the direction perpendicular to the traffic shall be calculated using 20 percent of live load
 The vertical seismic force shall be calculated using 20 percent of live load

16) Design Method

Allowable Stress Design : Serviceability Check

17) Software Used

for RC-continuous Slab bridge

2-Dimensions Frame Analysis Program (Calculation for sectional force and moment)

18) Reference Codes

NS Nepal Road Standard - 2070 (2013)

NS Nepal Bridge Standards - 2067 (2010)

NS Nepal Standard for Deformed Steel Bars and Wires for Concrete Reinforcement

IRC Standard Specifications and Code of Practice for Road and Bridges

Section I - General Features of Design IRC: 5-1998

Section II - Loads and Load Combinations IRC: 6-2017

Section III - Cement Concrete (Plain and Reinforced IRC: 21-2000

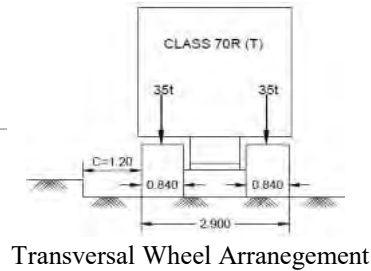
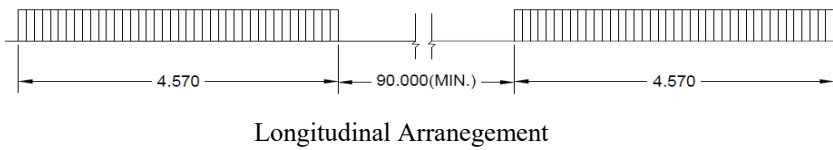
Section VII - Foundation and Substructure IRC: 78-2014

Standard Specifications for Road and Bridge Works - 2075(2018)

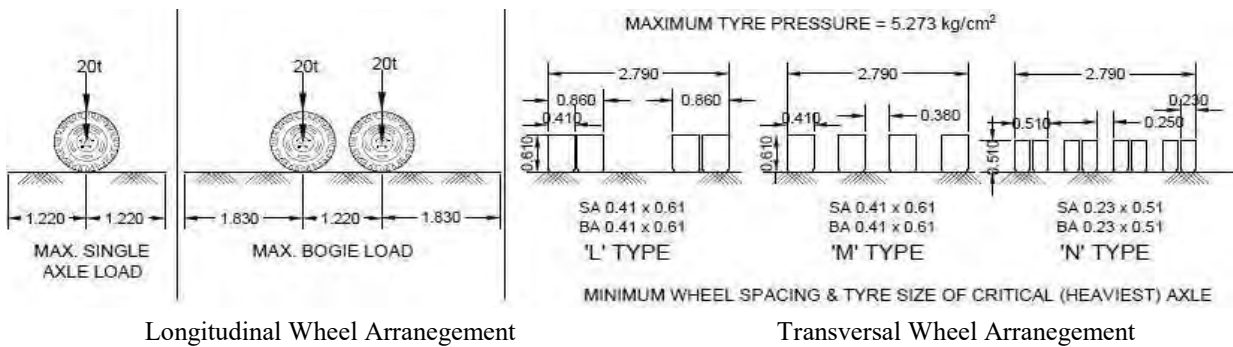
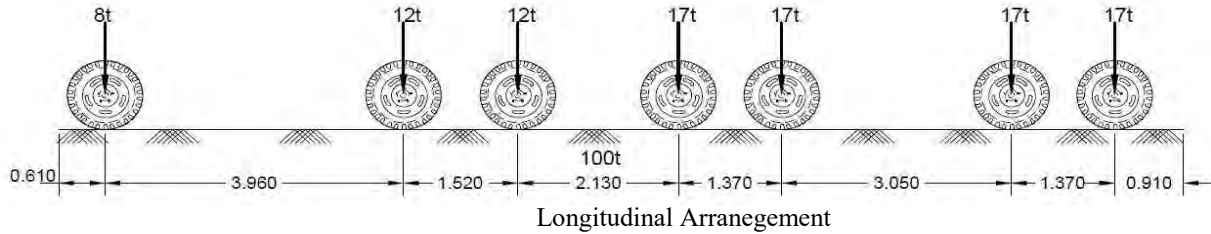
NORMS for Rate Analysis as per Specifications for Road and Bridge Works - 2075 (2018)

***1 Live Load Café for 10) Live Lord**
(1) 70R Tracked Vehicle

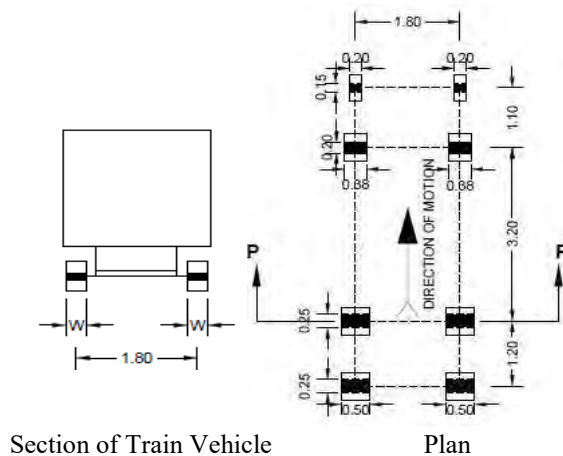
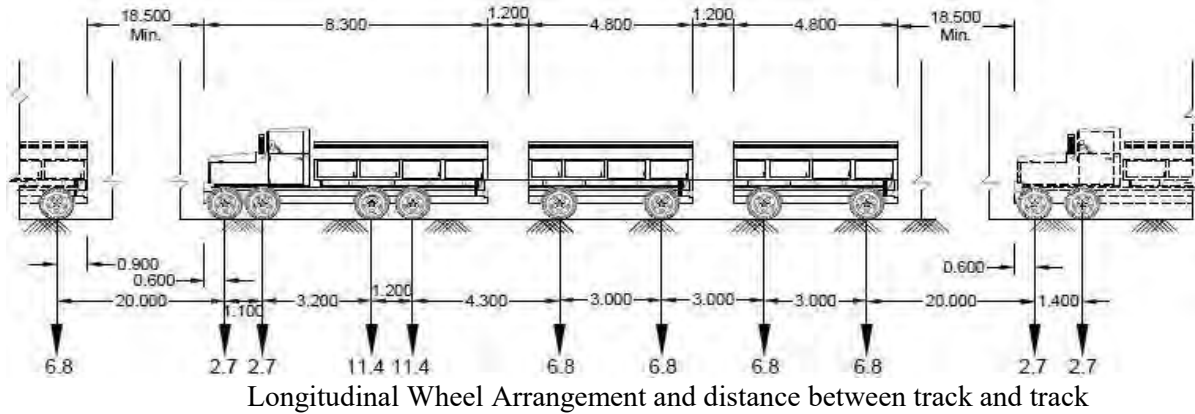
Clause 204.1



(2) 70R Wheeled Vehicle



(3) Class A Train of Vehicles



Live Load Combination

Table 2 Clause 204.3

S.I. No.	Carrigeway Width	Number of lanes for design purposes	Load Combinartion
1)	Less than 5.3 m	1	One lane of Class A considered to occupy 2.3 m. The remaining width of carrigeway shall be loaded with 500 kg/m ¹
2)	5.3 m and above but less than 9.6 m	2	One lane of Class 69R or two lanes for Class A
3)~6)	-	-	-

2 Design Load Calculation

Load Combination and List

Load	2	3	5	10	13	14	18	21
Combination	Dead Load	Live Load	Vehicle Impact	Braking Effort	Earth Pressure	Temperature	Seismic	Permissible Stresses
	G	Q	Q_{im}	F_b	F_{ep}	F_{tc}	F_{eq}	%
I	1	1	1	1	1			100%
IIA	1	1	1	1	1	1		115%
VI	1	0.2	Q x 1	0.2	1		1	150%

List of the Load and horizontal force for Input Data

- | | | | |
|-----|-----------------------------------|-----|--------------------------------|
| 1 | Self weight of structure | 2-1 | Self weight of structure |
| 2 | Dead load on deck slab surface | 2-2 | Dead load on deck slab surface |
| 3 | Live Load Surcharge | 2-3 | Live Load Surcharge |
| 4 | Earth Pressure | 2-4 | Earth Pressure |
| 5 | Footpath Loading | 2-5 | Footpath Loading |
| 6 | Live Load and Braking Effect | 2-6 | Live Load and Braking Effect |
| 1) | 70R Tracked Vehicle-12-70t | | |
| 2) | 70R Tracked Vehicle-16-70t | | |
| 3) | 70R Wheeled Vehicle-12-17t | | |
| 4) | 70R Wheeled Vehicle-16-17t | | |
| 5) | 70R Wheeled Vehicle-12-12t | | |
| 6) | 70R Wheeled Vehicle-16-12t | | |
| 7) | 70R Wheeled Vehicle-12-8t | | |
| 8) | 70R Wheeled Vehicle-16-8t | | |
| 9) | Class A Train of Vehicle-12-11.4t | | |
| 10) | Class A Train of Vehicle-16-11.4t | | |
| 11) | Class A Train of Vehicle-12-6.8t | | |
| 12) | Class A Train of Vehicle-16-6.8t | | |
| 13) | Class A Train of Vehicle-12-2.7t | | |
| 14) | Class A Train of Vehicle-16-2.7t | | |

2-1 Self weight of structure

Calculated in program SAP 2000

2-2 Dead load on deck slab surface (Unsubmerged Case, $\alpha = 1.000$) ES Surcharge (Gravity)

1) Load at Carridgeway Area

	Thick		Unit weight		
Asphalt Concrete	0.075	x	22.00 kN/m ³	=	1.650 kN/m ²
Overlay by AC	0.050	x	22.00 kN/m ³	=	1.100 kN/m ²
Total Unit Weight				=	2.750 kN/m ²

Input data for the program **2.75 kN/m** **DL-Sface-AC**

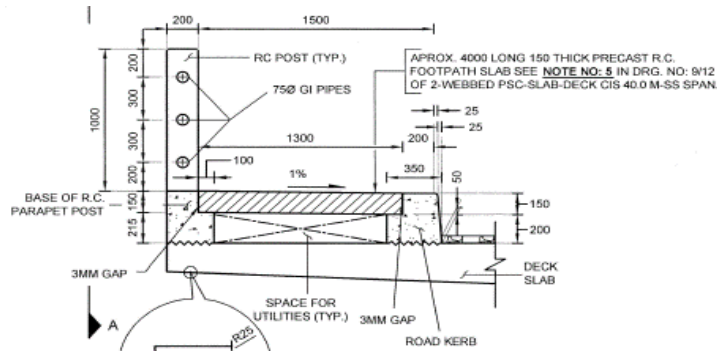
2) Load at Footpath Area

a. Footpath Area

Parapet Post	150 kg/m =	1.50 kN/m	=	1.500 kN/m	
Parapet Post Base	0.300x0.365x	25.00 kN/m ³	=	2.738 kN/m	
Precast Footpath Slab	1.100x0.150x	25.00 kN/m ³	=	4.125 kN/m	
Road Kerb	0.325x0.365x	25.00 kN/m ³	=	2.966 kN/m	
Utility	100 kg/m =	1.00 kN/m	=	1.000 kN/m	
Total Unit Weight				=	12.329 kN/m
Unit Weight	12.329/1.750		=	7.05 kN/m	

b. Footpath Area with footpath loading (width = 1.5m)

Parapet Post	NON	=	0.000 kN/m
Parapet Post Base	0.100x0.365x	25.00 kN/m ³	= 0.913 kN/m
Precast Footpath Slab	1.100x0.150x	25.00 kN/m ³	= 4.125 kN/m
Road Kerb	0.325x0.365x	25.00 kN/m ³	= 2.966 kN/m
Utility	100 kg/m =	1.00 kN/m	= 1.000 kN/m
		Total Unit Weight	= 9.004 kN/m
Unit Weight	9.004/1.500	=	6.00 kN/m DL-Sface-FW



2-3 Live Load Surcharge

Live Load Surcharge at wall

$$WL_2 = K_o \times WL_1 = 0.50 \times 1.2 \times 19.0 = \mathbf{11.400 \text{ kN/m}^2}$$

Coefficient of pressure at rest $K_o = 0.5$

Wet Unit Wt. of Soil $\gamma_t = 19.0 \text{ kN/m}^3$

Equivalent height of earth for live load surcharge as per Clause 714.4, IRC: 78-2014

$$D = 1.2 \text{ m}$$

2-4 Earth Pressure

(Unsubmerged case)

This pressure is the lateral pressure on the outer wall of the bridge from base course and soil.

The pressure on the top of the wall is: (Use K_o = coefficient of pressure at rest.)

$$Wh_1 = K_o \times \{ Wd_1 + (t_{AC} + t_{TS}) \times \gamma_t \} = 0.5 \times \{ 2.750 + (0.050 + 0.550) \times 19.0 \} = 7.1 \text{ kN/m}^2$$

Coefficient of pressure at rest $K_o = 0.5$

Wet Unit Wt. of Soil $\gamma_t = 19.0 \text{ kN/m}^3$

AC wearing course thick = 0.050 m

Top Slab Thickness = 1.100 m

Top Slab thick upper half = 0.550 m

(Note: Centerline of top slab is assumed to be the base point.)

Soil pressure at different height along the culvert wall.

Total height of bridge taken from centerline of top of slab to centerline of bottom slab.

Total Height of the Bridge $d_{OW} = 12.000 \text{ m}$

Top Slab Thickness $d_{TS} = 1.100 \text{ m}$

Height of Wall (with bearing height) $d_{OW} = 9.300 \text{ m}$

Bottom Slab Thickness $d_{BS} = 1.600 \text{ m}$

Height = $9.300 + 1.10 + 1.60 \text{ L97} = 12.000 \text{ m}$

$H_{total} = 9.300 + 1.10 / 2 + 1.60 / 2 = \mathbf{10.650 \text{ m}}$

EP-Both

Point	Point No.	Frame No.	Height m	Thick m	Pressure kN/m ²		
Center of Top Slab	101	207	0		12.3	7.1	= 7.100
	206	206	0.55	0.550	17.1	12.3	= 7.100 + 0.55 x 19.0 x 0.5
	205	205	1.05	0.500	36.1	17.1	= 7.100 + 1.05 x 19.0 x 0.5
	204	204	3.05	2.000	86.4	36.1	= 7.100 + 3.05 x 19.0 x 0.5
	203	203	8.35	5.300	95.9	86.4	= 7.100 + 8.35 x 19.0 x 0.5
	202	202	9.35	1.000	100.7	95.9	= 7.100 + 9.35 x 19.0 x 0.5
	201	201	9.85	0.500	108.3	100.7	= 7.100 + 9.85 x 19.0 x 0.5
Center of Bottom	4		10.65	0.800		108.3	= 7.100 + 10.65 x 19.0 x 0.5
Total				10.650			

2-5 Footpath Loading

IRC: 6-2016 206

for effective span of 7.5 m but not exceeding 30 m

$$\begin{aligned}
 \text{Live load} & \quad P = P_1 - (40L - 300)/9 \\
 \text{for pedestrians} & \quad P^1 = 500.0 \text{ kg/m}^2 = \\
 \text{Effective span} & \quad L = 12.0 \text{ m} \\
 & \quad P = 500 - (40 \times 12 - 300)/9
 \end{aligned}$$

$$= 480 \text{ kg/m}^2 = 4.80 \text{ kN/m}^2$$

2-6 Live Load and Braking Effect

2-6-1 Live Load 70R Tracked Vehicle - Side span 12.0m (70.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Tracked Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	70.0 ton	
Span Location	Side span	Span Length $l_0 =$ 12.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.100 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.840 m	
Calculation	$b_w =$	0.093 m	= $(150+(p-1) \times 57)/1000$ $p =$ 0 ton
	$b_w =$	0.840 m	= $\text{Max}(0.840, 0.093)$
Breadth of Load on slab	$b_l =$	0.940 m	= $0.840 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_l$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.917	
	$\alpha =$	2.174	As per IRC 21-2000 Section 305.16.2 Table

b/L ₀	Simple	Continuous	b/l ₀	Continuous
			0.917	2.174
0.1	0.40	0.40	0	
0.2	0.80	0.80	0	
0.3	1.16	1.16	0	
0.4	1.48	1.44	0	
0.5	1.72	1.68	0	
0.6	1.96	1.84	0	
0.7	2.12	1.96	0	
0.8	2.24	2.08	0	
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0/2 = 6.000 \text{ m}$$

$$b_{ef} = 7.462 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.940$$

$$b_{ef} = 7.462 \text{ m}$$

$$b_{ef}/2 = 3.731 \text{ m}$$

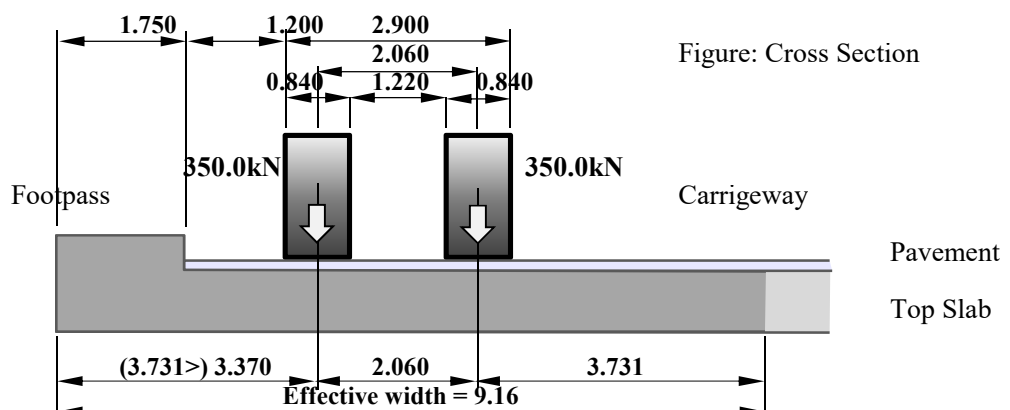
$$> 2.060 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w/2 =$	3.370 m	= $1.750 + 1.200 + 0.840/2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	9.16 m	= $\text{MIN}(3.731, 3.370) + 2.060 + 3.731$
Load	350.0 kN	One side of 70R Tracked Vehicle

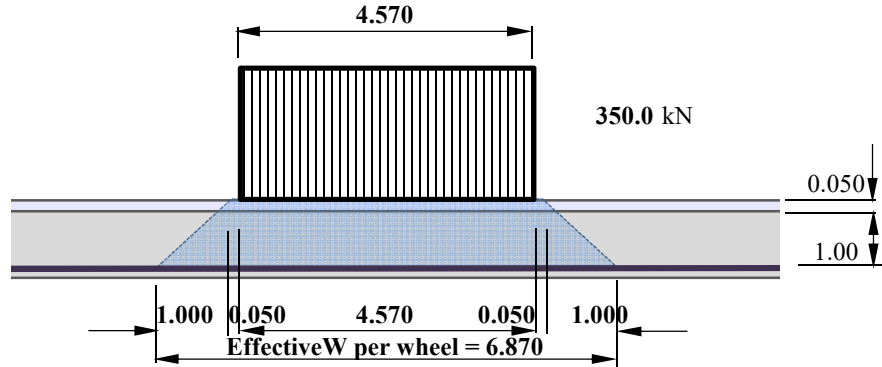


3) Longitudinal Direction

Tyre Contact Length = 4.570 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 4.570 + 2 \times (1.100 + 0.050)$
 = 6.870 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 92.285 m **Not OK Consider Overlap Width**



Impact Factor, $I = 10.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 350 kN
 Effective width = 7.462 m
 Effective length = 6.870 m
 $q = 7.51 \text{ kN/m}^2 = 350.0 \times (1 + 0.100) / (7.462 \times 6.870)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap** 2 Longitudinal = No Overlap
 Load = 700 kN
 Effective width = 9.160 m
 Effective length = 6.870 m
 $q = 12.24 \text{ kN/m}^2 = 350.0 \times 2 \times (1 + 0.100) / (9.160 \times 6.870)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 700 kN = 2×350.0
 Effective width = 9.160 m
 Effective length = 99.155 m = $6.870 + 92.285$
 $q = 1.70 \text{ kN/m}^2 = 700.0 \times 2 \times (1 + 0.100) / (9.160 \times 99.155)$
 Note: **Not Critical**

Total load along s = **84.09 kN/m** = 12.240×6.870

Braking Effect Lo $qi = 2.23 \text{ kN/m}^2 = 20\% \times \text{MAX}(7.51, 12.24, 1.70) / (1 + 10\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	kN/m/m	m	kN/m		
Live Load	LL70RTend1	700	Gravity	12.24	9.160	6.870	84.09
Braking Load	Brak70RTend		X-direction	2.23	9.160	6.870	

2-6 Live Load and Braking Effect

2-6-2 Live Load 70R Tracked Vehicle - Center span 16.0m (70.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Tracked Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	70.0 ton	
Span Location	Center span	Span Length $l_0 =$ 16.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.100 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.840 m	
Calculation	$b_w =$	0.093 m	= $(150+(p-1) \times 57)/1000$ $p =$ 0 ton
	$b_w =$	0.840 m	= $\text{Max}(0.840, 0.093)$
Breadth of Load on slab	$b_1 =$	0.940 m	= $0.840 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1-a/l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.688	
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
			0.688	1.946
0.1	0.40	0.40	0	
0.2	0.80	0.80	0	
0.3	1.16	1.16	0	
0.4	1.48	1.44	0	
0.5	1.72	1.68	0	
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96	0	
0.8	2.24	2.08	0	
0.9	2.36	2.16	0	
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0/2 = 8.000 \text{ m}$$

$$b_{ef} = 8.724 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.940$$

$$b_{ef} = 8.724 \text{ m}$$

$$b_{ef}/2 = 4.362 \text{ m}$$

$$> 2.060 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width $b_{\text{footpath}} = 1.750 \text{ m}$

Outer edge of wheel C = $C = 1.200 \text{ m}$

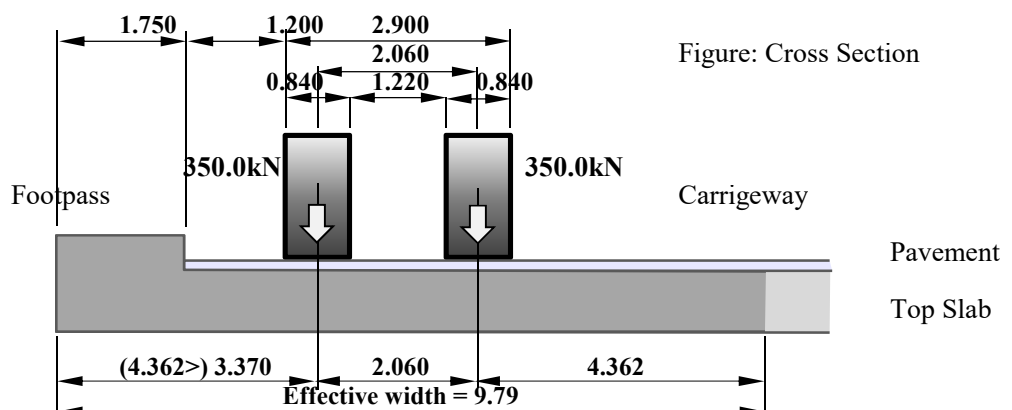
$$b_{\text{footpath}} + C + b_w/2 = 3.370 \text{ m} = 1.750 + 1.200 + 0.840/2$$

As per **IRC 21-2000 Section 305.16.2**

For Overlap

Effective width W = $9.79 \text{ m} = \text{MIN}(4.362, 3.370) + 2.060 + 4.362$

Load **350.0 kN** One side of 70R Tracked Vehicle

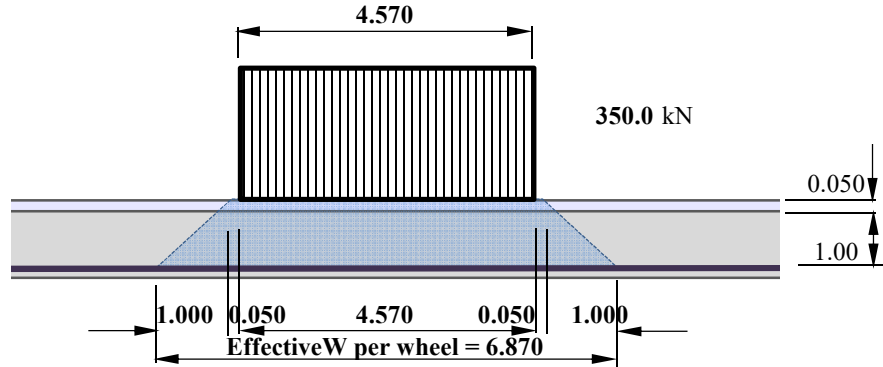


3) Longitudinal Direction

Tyre Contact Length = 4.570 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 4.570 + 2 \times (1.100 + 0.050)$
 = 6.870 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 92.285 m **Not OK Consider Overlap Width**



Impact Factor, $I = 10.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 350 kN
 Effective width = 8.724 m
 Effective length = 6.870 m
 $q = 6.42 \text{ kN/m}^2 = 350.0 \times (1 + 0.100) / (8.724 \times 6.870)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap** 2 Longitudinal = No Overlap
 Load = 700 kN
 Effective width = 9.790 m
 Effective length = 6.870 m
 $q = 11.45 \text{ kN/m}^2 = 350.0 \times 2 \times (1 + 0.100) / (9.790 \times 6.870)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 700 kN = 2×350.0
 Effective width = 9.790 m
 Effective length = 99.155 m = $6.870 + 92.285$
 $q = 1.59 \text{ kN/m}^2 = 700.0 \times 2 \times (1 + 0.100) / (9.790 \times 99.155)$
 Note: **Not Critical**

Total load along s = **78.66 kN/m** = 11.450×6.870

Braking Effect Lo $qi = 2.08 \text{ kN/m}^2 = 20\% \times \text{MAX}(6.42, 11.45, 1.59) / (1 + 10\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	kN/m/m	m	kN/m		
Live Load	LL70RTCen	700	Gravity	11.45	9.790	6.870	78.66
Braking Load	BR 70RTCen		X-direction	2.08	9.790	6.870	

2-6 Live Load and Braking Effect

2-6-3 Live Load 70R Wheeled Vehicle - Side span 12.0m (17.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	17.0 ton	
Span Location	Side span	Span Length $l_0 =$ 12.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.860 m	
Calculation	$b_w =$	0.578 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 8.5 ton
	$b_w =$	0.578 m	$= \text{Min}(0.860, 0.578)$
Breadth of Load on slab	$b_1 =$	0.678 m	$= 0.578 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.917	
	$\alpha =$	2.174	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84		
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 7.200 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.678$$

$$b_{ef} = 7.200 \text{ m}$$

$$b_{ef} / 2 = 3.600 \text{ m}$$

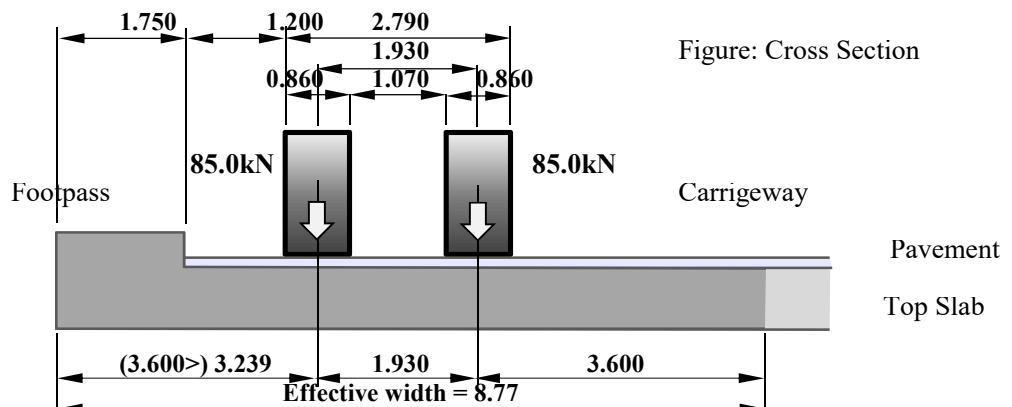
$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.239 m	$= 1.750 + 1.200 + 0.578 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.77 m	$= \text{MIN}(3.600, 3.239) + 1.930 + 3.600$
Load	85.0 kN	One side of 70R Wheeled Vehicle



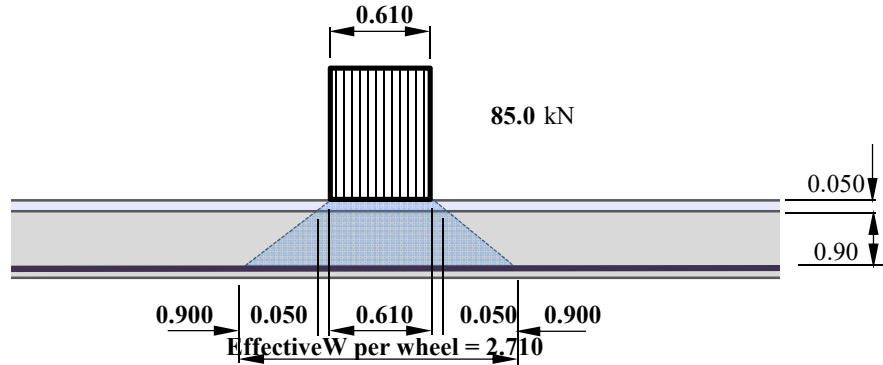
2-6-3 Live Load 70R Wheeled Vehicle - Side span 12.0m (17.0ton)

3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.370 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 85 kN
 Effective width = 7.200 m
 Effective length = 2.710 m
 $q = 5.45 \text{ kN/m}^2 = 85.0 \times (1 + 0.25) / (7.200 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 170 kN
 Effective width = 8.770 m
 Effective length = 2.710 m
 $q = 8.94 \text{ kN/m}^2 = 85.0 \times 2 \times (1 + 0.25) / (8.770 \times 2.710)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 170 kN = 2×85.0
 Effective width = 8.770 m
 Effective length = 4.080 m = $2.710 + 1.370$
 $q = 11.88 \text{ kN/m}^2 = 170.0 \times 2 \times (1 + 0.25) / (8.770 \times 4.080)$
 Note: **Critical**

Total load along span = **48.47 kN/m** = 11.880×4.080

Braking Effect Load $q_i = 1.90 \text{ kN/m}^2 = 20\% \times \text{MAX}(5.45, 8.94, 11.88) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	m	m	kN/m		
Live Load	LL70rWRight1	170	Gravity	11.88	8.770	4.080	48.47
Braking Load	BR 70RWRight1		X-direction	1.90	8.770	4.080	

2-6 Live Load and Braking Effect

2-6-4 Live Load 70R Wheeled Vehicle - Center span 16.0m (17.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	17.0 ton	
Span Location	Center span	Span Length $l_0 =$ 16.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.860 m	
Calculation	$b_w =$	0.578 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 8.5 ton
	$b_w =$	0.578 m	$= \text{Min}(0.860, 0.578)$
Breadth of Load on slab	$b_1 =$	0.678 m	$= 0.578 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.688	
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 8.462 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.678$$

$$b_{ef} = 8.462 \text{ m}$$

$$b_{ef} / 2 = 4.231 \text{ m}$$

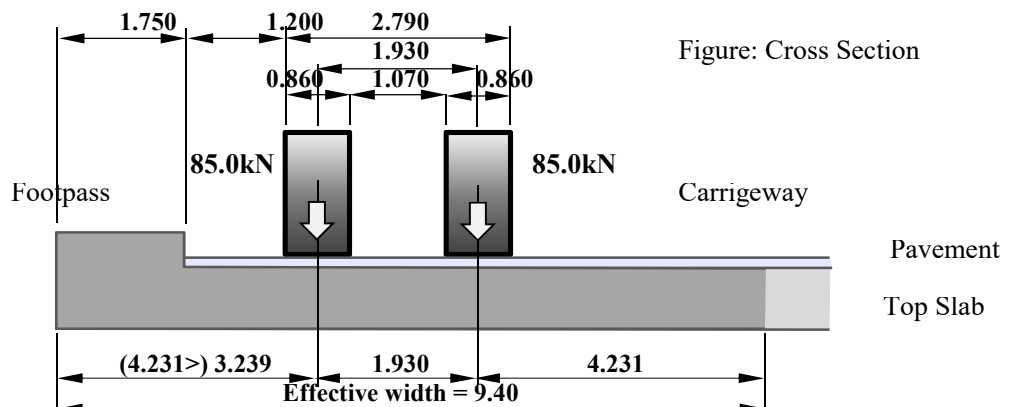
$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.239 m	$= 1.750 + 1.200 + 0.578 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	9.40 m	$= \text{MIN}(4.231, 3.239) + 1.930 + 4.231$
Load	85.0 kN	One side of 70R Wheeled Vehicle



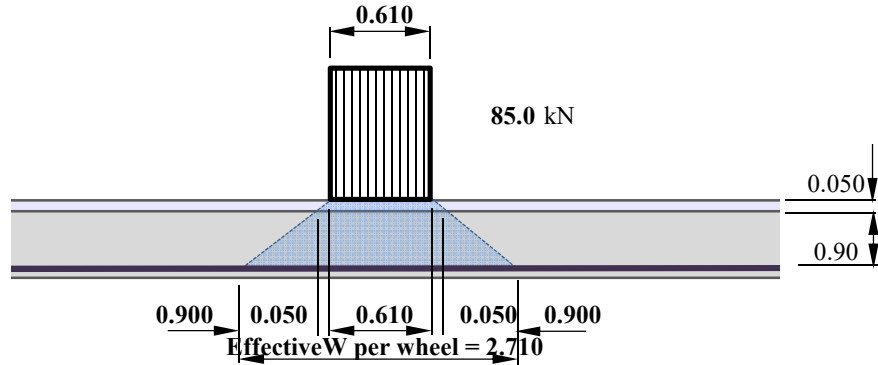
2-6-4 Live Load 70R Wheeled Vehicle - Center span 16.0m (17.0ton)

3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.370 m **Not OK Consider Overlap Width**



Impact Factor, $I = 21.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 85 kN
 Effective width = 8.462 m
 Effective length = 2.710 m
 $q = 4.48 \text{ kN/m}^2 = 85.0 \times (1 + 0.21) / (8.462 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 170 kN
 Effective width = 9.400 m
 Effective length = 2.710 m
 $q = 8.07 \text{ kN/m}^2 = 85.0 \times 2 \times (1 + 0.21) / (9.400 \times 2.710)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 170 kN = 2×85.0
 Effective width = 9.400 m
 Effective length = 4.080 m = $2.710 + 1.370$
 $q = 10.73 \text{ kN/m}^2 = 170.0 \times 2 \times (1 + 0.21) / (9.400 \times 4.080)$
 Note: **Critical**

Total load along span = **43.78 kN/m** = 10.730×4.080

Braking Effect Load $q_i = 1.77 \text{ kN/m}^2 = 20\% \times \text{MAX}(4.48, 8.07, 10.73) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load
		kN	m	m	kN/m
Live Load	LL70rWCen	170 Gravity	10.73	9.400	4.080 43.78
Braking Load	BR 70RWCen	X-directior	1.77	9.400	4.080

2-6 Live Load and Braking Effect

2-6-5 Live Load 70R Wheeled Vehicle - Side span 12.0m (12.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	12.0 ton	
Span Location	Side span	Span Length $l_0 =$ 12.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.000 m	
Calculation	$b_w =$	0.435 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 6 ton
	$b_w =$	0.000 m	$= \text{Min}(0.000, 0.435)$
Breadth of Load on slab	$b_1 =$	0.100 m	$= 0.000 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.917	
	$\alpha =$	2.174	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84		
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 6.622 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.100$$

$$b_{ef} = 6.622 \text{ m}$$

$$b_{ef} / 2 = 3.311 \text{ m}$$

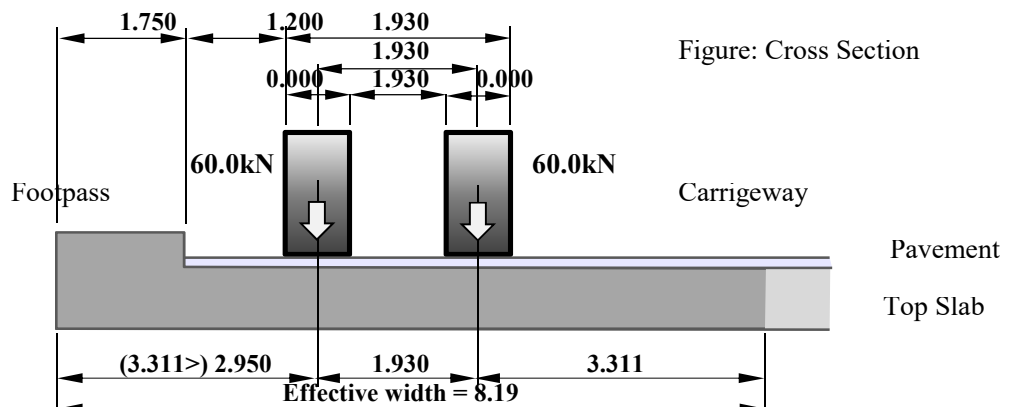
$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	2.950 m	$= 1.750 + 1.200 + 0.000 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.19 m	$= \text{MIN}(3.311, 2.950) + 1.930 + 3.311$
Load	60.0 kN	One side of 70R Wheeled Vehicle



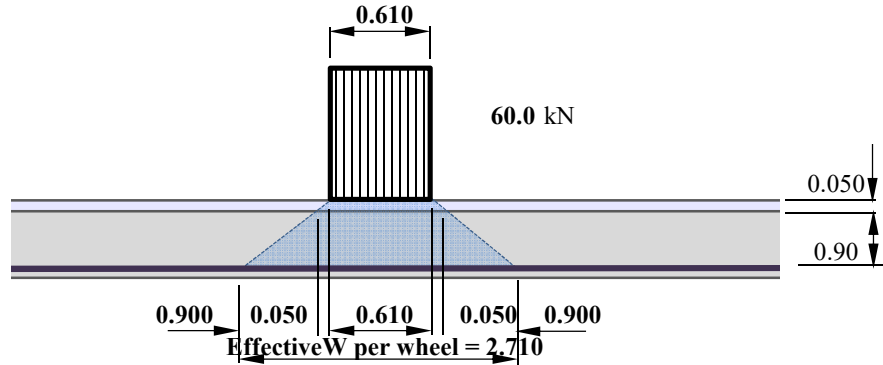
2-6-5 Live Load 70R Wheeled Vehicle - Side span 12.0m (12.0ton)

3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.520 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 60 kN
 Effective width = 6.622 m
 Effective length = 2.710 m
 $q = 4.18 \text{ kN/m}^2 = 60.0 \times (1 + 0.25) / (6.622 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 120 kN
 Effective width = 8.190 m
 Effective length = 2.710 m
 $q = 6.76 \text{ kN/m}^2 = 60.0 \times 2 \times (1 + 0.25) / (8.190 \times 2.710)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 120 kN = 2×60.0
 Effective width = 8.190 m
 Effective length = 4.230 m = $2.710 + 1.520$
 $q = 8.66 \text{ kN/m}^2 = 120.0 \times 2 \times (1 + 0.25) / (8.190 \times 4.230)$
 Note: **Critical**

Total load along span = **36.63 kN/m** = 8.660×4.230

Braking Effect Load $q_i = 1.39 \text{ kN/m}^2 = 20\% \times \text{MAX}(4.18, 6.76, 8.66) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	m	m	kN/m		
Live Load	LL70rWLeft2	120	Gravity	8.66	8.190	4.230	36.63
Braking Load	BR 70RWLeft2		X-direction	1.39	8.190	4.230	

2-6 Live Load and Braking Effect

2-6-6 Live Load 70R Wheeled Vehicle - Center span 16.0m (12.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	12.0 ton	
Span Location	Center span	Span Length $l_0 =$ 16.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.000 m	
Calculation	$b_w =$	0.435 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 6 ton
	$b_w =$	0.000 m	$= \text{Min}(0.000, 0.435)$
Breadth of Load on slab	$b_1 =$	0.100 m	$= 0.000 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.688	
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 7.884 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.100$$

$$b_{ef} = 7.884 \text{ m}$$

$$b_{ef} / 2 = 3.942 \text{ m}$$

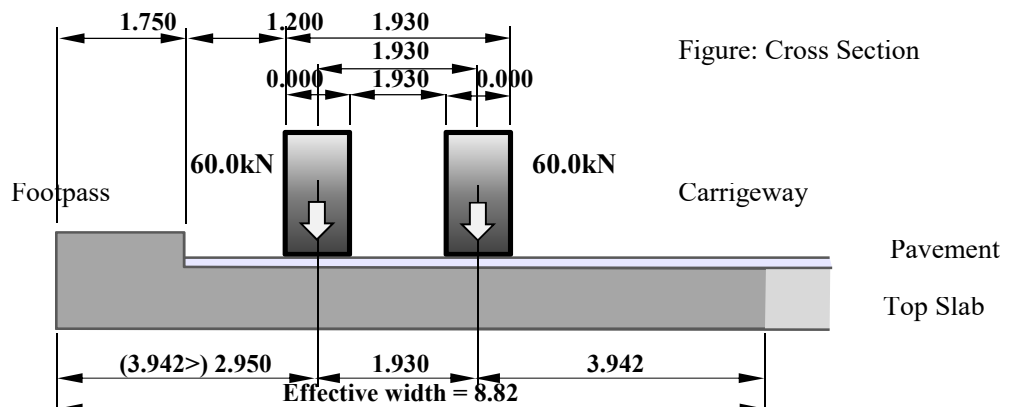
$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	2.950 m	$= 1.750 + 1.200 + 0.000/2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.82 m	$= \text{MIN}(3.942, 2.950) + 1.930 + 3.942$
Load	60.0 kN	One side of 70R Wheeled Vehicle

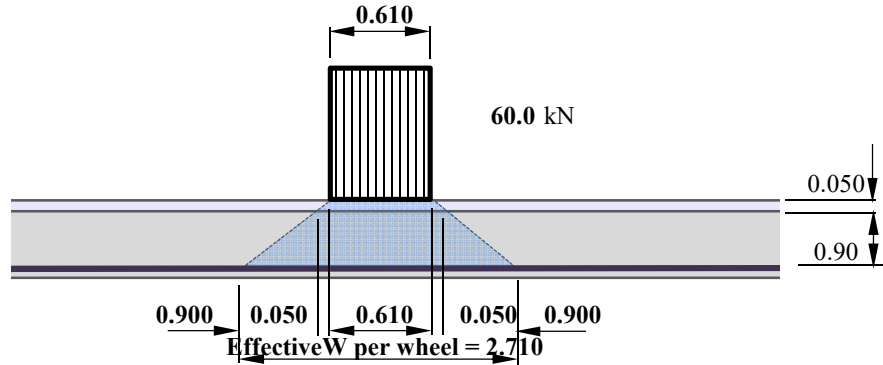


3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.520 m **Not OK Consider Overlap Width**



Impact Factor, $I = 21.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 60 kN
 Effective width = 7.884 m
 Effective length = 2.710 m
 $q = 3.40 \text{ kN/m}^2 = 60.0 \times (1 + 0.21) / (7.884 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 120 kN
 Effective width = 8.820 m
 Effective length = 2.710 m
 $q = 6.07 \text{ kN/m}^2 = 60.0 \times 2 \times (1 + 0.21) / (8.820 \times 2.710)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 120 kN = 2×60.0
 Effective width = 8.820 m
 Effective length = 4.230 m = $2.710 + 1.520$
 $q = 7.78 \text{ kN/m}^2 = 120.0 \times 2 \times (1 + 0.21) / (8.820 \times 4.230)$
 Note: **Critical**

Total load along span = **32.91 kN/m** = 7.780×4.230

Braking Effect Load $q_i = 1.29 \text{ kN/m}^2 = 20\% \times \text{MAX}(3.40, 6.07, 7.78) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	m	m	kN/m		
Live Load	LL70rWLeft2	120	Gravity	7.78	8.820	4.230	32.91
Braking Load	BR 70RWLeft2		X-direction	1.29	8.820	4.230	

2-6 Live Load and Braking Effect

2-6-7 Live Load 70R Wheeled Vehicle - Side span 12.0m (8.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	8.0 ton	
Span Location	Side span	Span Length $l_0 =$ 12.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.000 m	
Calculation	$b_w =$	0.321 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 4 ton
	$b_w =$	0.000 m	$= \text{Min}(0.000, 0.321)$
Breadth of Load on slab	$b_1 =$	0.100 m	$= 0.000 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.917	
	$\alpha =$	2.174	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80	0	
0.3	1.16	1.16	0	
0.4	1.48	1.44	0	
0.5	1.72	1.68	0	
0.6	1.96	1.84	0	
0.7	2.12	1.96	0	
0.8	2.24	2.08	0	
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 6.622 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.100$$

$$b_{ef} = 6.622 \text{ m}$$

$$b_{ef} / 2 = 3.311 \text{ m}$$

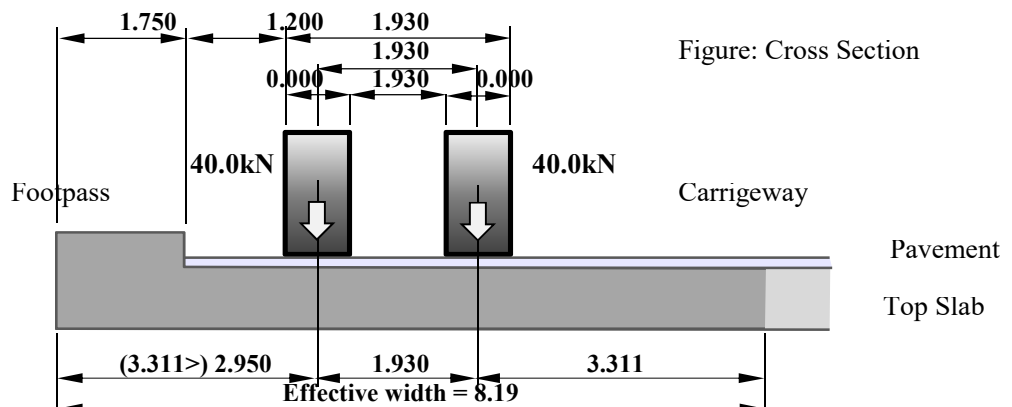
$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	2.950 m	$= 1.750 + 1.200 + 0.000 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.19 m	$= \text{MIN}(3.311, 2.950) + 1.930 + 3.311$
Load	40.0 kN	One side of 70R Wheeled Vehicle



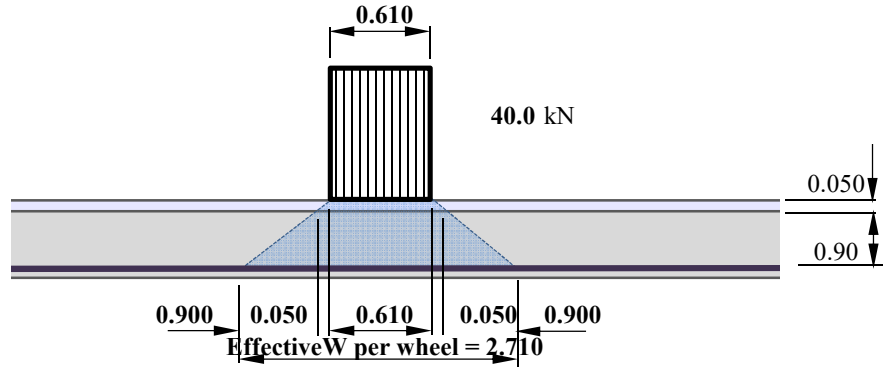
2-6-7 Live Load 70R Wheeled Vehicle - Side span 12.0m (8.0ton)

3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 3.960 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 40 kN
 Effective width = 6.622 m
 Effective length = 2.710 m
 $q = 2.79 \text{ kN/m}^2 = 40.0 \times (1 + 0.25) / (6.622 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 80 kN
 Effective width = 8.190 m
 Effective length = 2.710 m
 $q = 4.51 \text{ kN/m}^2 = 40.0 \times 2 \times (1 + 0.25) / (8.190 \times 2.710)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 80 kN = 2×40.0
 Effective width = 8.190 m
 Effective length = 6.670 m = $2.710 + 3.960$
 $q = 3.66 \text{ kN/m}^2 = 80.0 \times 2 \times (1 + 0.25) / (8.190 \times 6.670)$
 Note: **Not Critical**

Total load along span = 12.22 kN/m = 4.51×2.710

Braking Effect Load $q_i = 0.72 \text{ kN/m}^2 = 20\% \times \text{MAX}(2.79, 4.51, 3.66) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL70rWRight1	80	Gravity	4.51	8.190	2.710	12.22
Braking Load	BR 70RWRight1		X-direction	0.72	8.190	2.710	

2-6 Live Load and Braking Effect

2-6-8 Live Load 70R Wheeled Vehicle - Center span 16.0m (8.0ton)

Live Load Distribution as per width

1) Load Combination

Load Case	70R Wheeled Vehicle	As per IRC 21-2000 Section 305.4.2
Wheel load	8.0 ton	
Span Location	Center span	Span Length $l_0 =$ 16.0 m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m	
Thickness of AC (Wearing)	=	0.050 m	
Span Width	b =	11.000 m	
Breadth of Tyre by given	$b_w =$	0.000 m	
Calculation	$b_w =$	0.321 m	$= (150 + (p-1) \times 57) / 1000$ $p =$ 4 ton
	$b_w =$	0.000 m	$= \text{Min}(0.000, 0.321)$
Breadth of Load on slab	$b_1 =$	0.100 m	$= 0.000 + 2 \times 0.050$
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2
for,	$b/l_0 =$	0.688	
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 7.884 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.100$$

$$b_{ef} = 7.884 \text{ m}$$

$$b_{ef} / 2 = 3.942 \text{ m}$$

$$> 1.930 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width $b_{\text{footpath}} = 1.750 \text{ m}$

Outer edge of wheel C = $C = 1.200 \text{ m}$

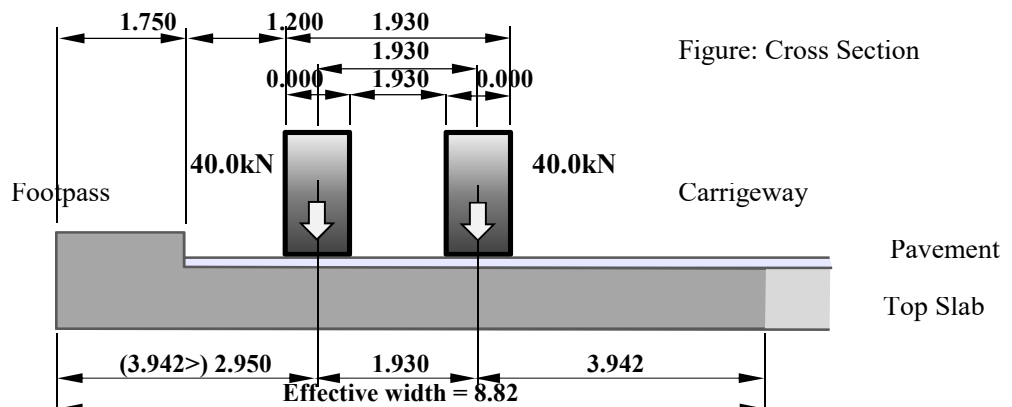
$$b_{\text{footpath}} + C + b_w / 2 = 2.950 \text{ m} = 1.750 + 1.200 + 0.000/2$$

As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width $W = 8.82 \text{ m} = \text{MIN}(3.942, 2.950) + 1.930 + 3.942$

Load **40.0 kN** One side of 70R Wheeled Vehicle



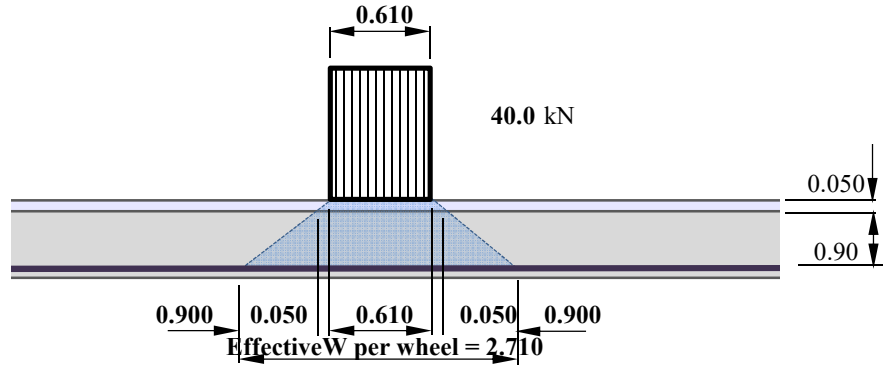
2-6-8 Live Load 70R Wheeled Vehicle - Center span 16.0m (8.0ton)

3) Longitudinal Direction

Tyre Contact Length = 0.610 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.610 + 2 \times (1.000 + 0.050)$
 = 2.710 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 3.960 m **Not OK Consider Overlap Width**



Impact Factor, $I = 21.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 40 kN
 Effective width = 7.884 m
 Effective length = 2.710 m
 $q = 2.27 \text{ kN/m}^2 = 40.0 \times (1 + 0.210) / (7.884 \times 2.710)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 80 kN
 Effective width = 8.820 m
 Effective length = 2.710 m
 $q = 4.05 \text{ kN/m}^2 = 80.0 \times 2 \times (1 + 0.210) / (8.820 \times 2.710)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 80 kN = 2×40.0
 Effective width = 8.820 m
 Effective length = 6.670 m = $2.710 + 3.960$
 $q = 3.29 \text{ kN/m}^2 = 80.0 \times 2 \times (1 + 0.210) / (8.820 \times 6.670)$
 Note: **Not Critical**

Total load along span = **10.98 kN/m** = 4.050×2.710

Braking Effect Load $q_i = 0.67 \text{ kN/m}^2 = 20\% \times \text{MAX}(2.27, 4.05, 3.29) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL CI ALeft2	80	Gravity	4.05	8.820	2.710	10.98
Braking Load	BR CI ALeft2		X-directior	0.67	8.820	2.710	

2-6 Live Load and Braking Effect

2-6-9 Live Load Class A Train of Vehicle - Side span 12.0m (11.4ton)

Live Load Distribution as per width

1) Load Combination

Load Case	Class A Train of Vehicle As per IRC 21-2000 Section 305.4.2		
Wheel load	11.4 ton		
Span Location	Side span	Span Length	$l_0 = 12.0$ m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m		
Thickness of AC (Wearing)	=	0.050 m		
Span Width	b =	11.000 m		
Breadth of Tyre by given	$b_w =$	0.500 m		
Calculation	$b_w =$	0.418 m	$= (150 + (p-1) \times 57) / 1000$	$p = 5.7$ ton
	$b_w =$	0.418 m	$= \text{Min}(0.500, 0.418)$	
Breadth of Load on slab	$b_1 =$	0.518 m	$= 0.418 + 2 \times 0.050$	
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2	
for,	$b/l_0 =$	0.917		
	$\alpha =$	2.174	As per IRC 21-2000 Section 305.16.2 Table	

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84		
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 7.040 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.518$$

$$b_{ef} = 7.040 \text{ m}$$

$$b_{ef} / 2 = 3.520 \text{ m}$$

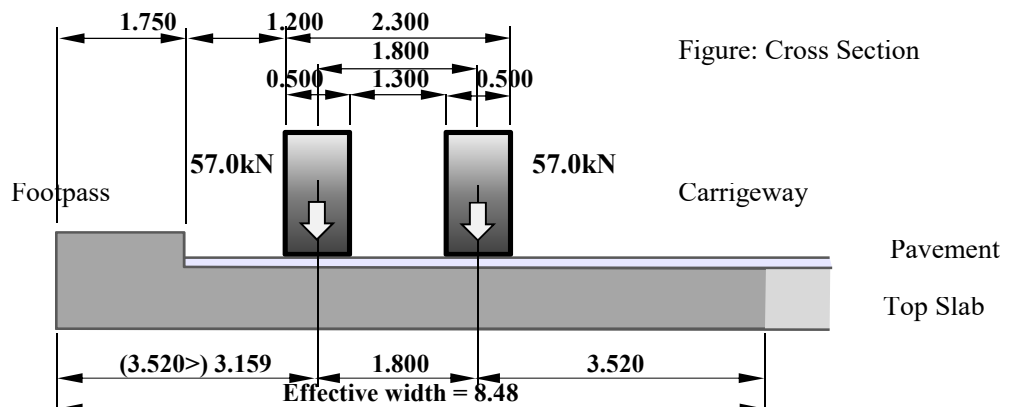
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.159 m	$= 1.750 + 1.200 + 0.418 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.48 m	$= \text{MIN}(3.520, 3.159) + 1.800 + 3.520$
Load	57.0 kN	One side of Class A Train of Vehicle



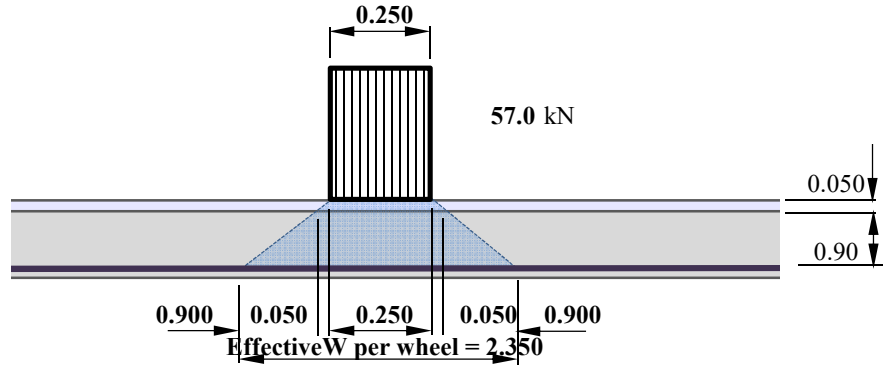
2-6-9 Live Load Class A Train of Vehicle - Side span 12.0m (11.4ton)

3) Longitudinal Direction

Tyre Contact Length = 0.250 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.250 + 2 \times (1.000 + 0.050)$
 = 2.350 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.200 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 57 kN
 Effective width = 7.040 m
 Effective length = 2.350 m
 $q = 4.31 \text{ kN/m}^2 = 57.0 \times (1 + 0.25) / (7.040 \times 2.350)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 114 kN
 Effective width = 8.480 m
 Effective length = 2.350 m
 $q = 7.15 \text{ kN/m}^2 = 57.0 \times 2 \times (1 + 0.25) / (8.480 \times 2.350)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 114 kN = 2×57.0
 Effective width = 8.480 m
 Effective length = 3.550 m = $2.350 + 1.200$
 $q = 9.47 \text{ kN/m}^2 = 114.0 \times 2 \times (1 + 0.25) / (8.480 \times 3.550)$
 Note: **Critical**

Total load along span = **33.62 kN/m** = 9.470×3.550

Braking Effect Load $q_i = 1.52 \text{ kN/m}^2 = 20\% \times \text{MAX}(4.31, 7.15, 9.47) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL CI ALeft2	114	Gravity	9.47	8.480	3.550	33.62
Braking Load	BR CI ALeft2		X-directior	1.52	8.480	3.550	

2-6 Live Load and Braking Effect

2-6-10 Live Load Class A Train of Vehicle - Center span 16.0m (11.4ton)

Live Load Distribution as per width

1) Load Combination

Load Case	Class A Train of Vehicle As per IRC 21-2000 Section 305.4.2		
Wheel load	11.4 ton		
Span Location	Center span	Span Length	$l_0 = 16.0$ m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m		
Thickness of AC (Wearing)	=	0.050 m		
Span Width	b =	11.000 m		
Breadth of Tyre by given	$b_w =$	0.500 m		
Calculation	$b_w =$	0.418 m	$= (150 + (p-1) \times 57) / 1000$	$p = 5.7$ ton
	$b_w =$	0.418 m	$= \text{Min}(0.500, 0.418)$	
Breadth of Load on slab	$b_1 =$	0.518 m	$= 0.418 + 2 \times 0.050$	
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2	
for,	$b/l_0 =$	0.688		
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table	

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 8.302 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.518$$

$$b_{ef} = 8.302 \text{ m}$$

$$b_{ef} / 2 = 4.151 \text{ m}$$

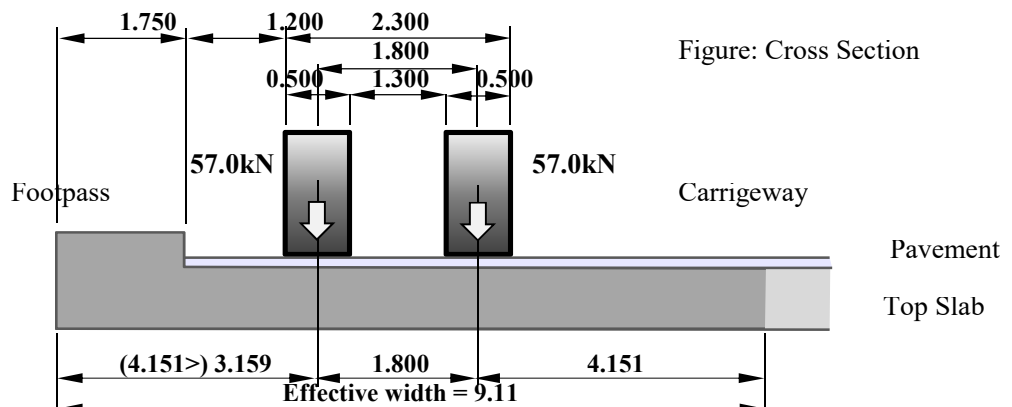
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.159 m	$= 1.750 + 1.200 + 0.418 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	9.11 m	$= \text{MIN}(4.151, 3.159) + 1.800 + 4.151$
Load	57.0 kN	One side of Class A Train of Vehicle

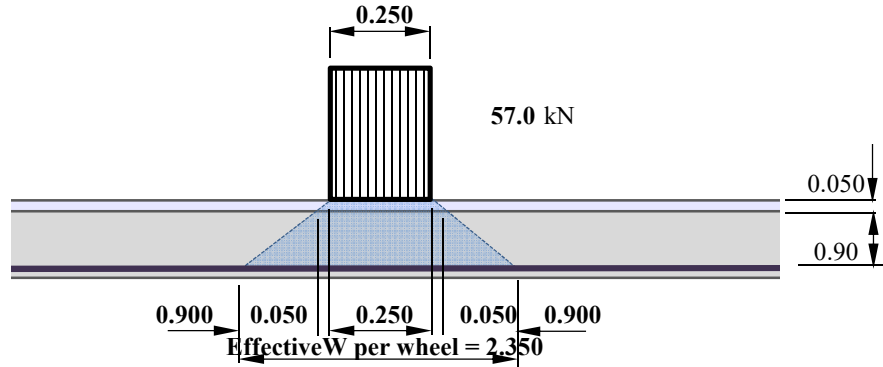


3) Longitudinal Direction

Tyre Contact Length = 0.250 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.250 + 2 \times (1.000 + 0.050)$
 = 2.350 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.200 m **Not OK Consider Overlap Width**



Impact Factor, $I = 20.5\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 57 kN
 Effective width = 8.302 m
 Effective length = 2.350 m
 $q = 3.52 \text{ kN/m}^2 = 57.0 \times (1 + 0.205) / (8.302 \times 2.350)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 114 kN
 Effective width = 9.110 m
 Effective length = 2.350 m
 $q = 6.42 \text{ kN/m}^2 = 57.0 \times 2 \times (1 + 0.205) / (9.110 \times 2.350)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 114 kN = 2×57.0
 Effective width = 9.110 m
 Effective length = 3.550 m = $2.350 + 1.200$
 $q = 8.50 \text{ kN/m}^2 = 114.0 \times 2 \times (1 + 0.205) / (9.110 \times 3.550)$
 Note: **Critical**

Total load along span = **30.18 kN/m** = 8.500×3.550

Braking Effect Load $q_i = 1.41 \text{ kN/m}^2 = 20\% \times \text{MAX}(3.52, 6.42, 8.50) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL Cl Acen	114	Gravity	8.50	9.110	3.550	30.18
Braking Load	BR Cl Acen		X-directior	1.41	9.110	3.550	

2-6 Live Load and Braking Effect

2-6-11 Live Load Class A Train of Vehicle - Side span 12.0m (6.8ton)

Live Load Distribution as per width

1) Load Combination

Load Case **Class A Train of Vehicle** As per IRC 21-2000 Section 305.4.2
 Wheel load **6.8 ton**
 Span Location **Side span** Span Length $l_0 = 12.0$ m

2) Transverse Direction

Thickness of Top Slab = **1.000** m
 Thickness of AC (Wearing) = **0.050** m
 Span Width $b = 11.000$ m
 Breadth of Tyre by given $b_w = 0.380$ m
 Calculation $b_w = 0.287$ m $= (150 + (p-1) \times 57) / 1000$ $p = 3.4$ ton
 $b_w = 0.287$ m $= \text{Min}(0.380, 0.287)$
 Breadth of Load on slab $b_1 = 0.387$ m $= 0.287 + 2 \times 0.050$
 $b_{ef} = \alpha \cdot a \cdot (1 - a / l_0) + b_1$ As per IRC 21-2000 Section 305.16.2
 for, $b/l_0 = 0.917$
 $\alpha = 2.174$ As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80	0	
0.3	1.16	1.16	0	
0.4	1.48	1.44	0	
0.5	1.72	1.68	0	
0.6	1.96	1.84	0	
0.7	2.12	1.96	0	
0.8	2.24	2.08	0	
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 6.909 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.387$$

$$b_{ef} = 6.909 \text{ m}$$

$$b_{ef} / 2 = 3.455 \text{ m}$$

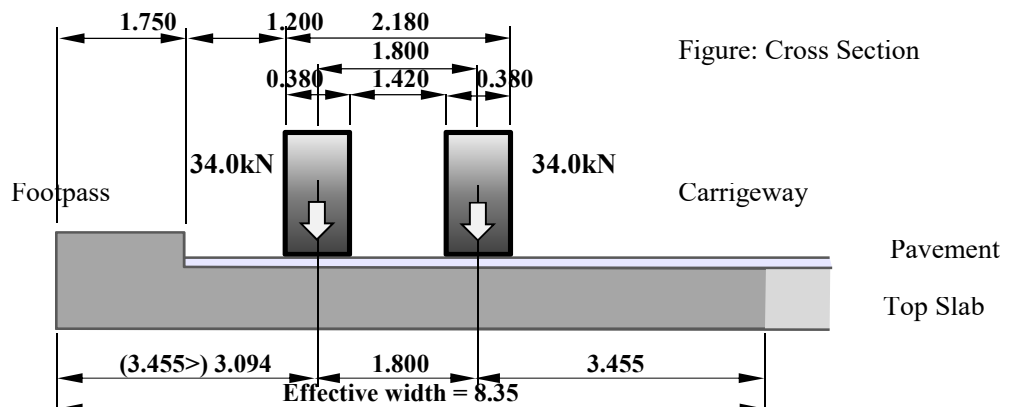
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width $b_{\text{footpath}} = 1.750$ m
 Outer edge of wheel C = $C = 1.200$ m
 $b_{\text{footpath}} + C + b_w / 2 = 3.094$ m $= 1.750 + 1.200 + 0.287/2$
 As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width $W = 8.35$ m $= \text{MIN}(3.455, 3.094) + 1.800 + 3.455$
 Load **34.0 kN** One side of Class A Train of Vehicle



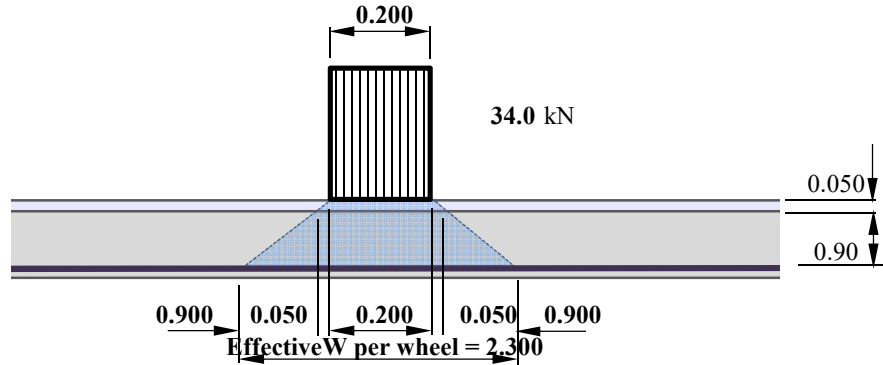
2-6-11 Live Load Class A Train of Vehicle - Side span 12.0m (6.8ton)

3) Longitudinal Direction

Tyre Contact Length = 0.200 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.200 + 2 \times (1.000 + 0.050)$
 = 2.300 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 3.000 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 34 kN
 Effective width = 6.909 m
 Effective length = 2.300 m
 $q = 2.67 \text{ kN/m}^2 = 34.0 \times (1 + 0.25) / (6.909 \times 2.300)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 68 kN
 Effective width = 8.350 m
 Effective length = 2.300 m
 $q = 4.43 \text{ kN/m}^2 = 34.0 \times 2 \times (1 + 0.25) / (8.350 \times 2.300)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 68 kN = 2×34.0
 Effective width = 8.350 m
 Effective length = 5.300 m = $2.300 + 3.000$
 $q = 3.84 \text{ kN/m}^2 = 68.0 \times 2 \times (1 + 0.25) / (8.350 \times 5.300)$
 Note: **Not Critical**

Total load along span = **10.19 kN/m** = 4.43×2.300

Braking Effect Load $q_i = 0.71 \text{ kN/m}^2 = 20\% \times \text{MAX}(2.67, 4.43, 3.84) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL CI ALeft2	68	Gravity	4.43	8.350	2.300	10.19
Braking Load	BR CI ALeft2		X-directior	0.71	8.350	2.300	

2-6 Live Load and Braking Effect

2-6-12 Live Load Class A Train of Vehicle - Center span 16.0m (6.8ton)

Live Load Distribution as per width

1) Load Combination

Load Case	Class A Train of Vehicle As per IRC 21-2000 Section 305.4.2		
Wheel load	6.8 ton		
Span Location	Center span	Span Length	$l_0 = 16.0$ m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m		
Thickness of AC (Wearing)	=	0.050 m		
Span Width	b =	11.000 m		
Breadth of Tyre by given	$b_w =$	0.380 m		
Calculation	$b_w =$	0.287 m	$= (150 + (p-1) \times 57) / 1000$	$p = 3.4$ ton
	$b_w =$	0.287 m	$= \text{Min}(0.380, 0.287)$	
Breadth of Load on slab	$b_1 =$	0.387 m	$= 0.287 + 2 \times 0.050$	
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2	
for,	$b/l_0 =$	0.688		
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table	

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 8.171 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.387$$

$$b_{ef} = 8.171 \text{ m}$$

$$b_{ef} / 2 = 4.086 \text{ m}$$

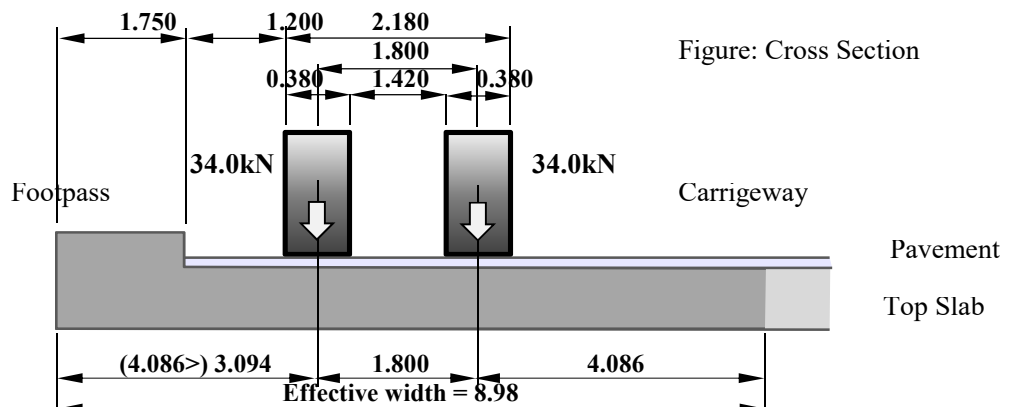
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.094 m	$= 1.750 + 1.200 + 0.287/2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.98 m	$= \text{MIN}(4.086, 3.094) + 1.800 + 4.086$
Load	34.0 kN	One side of Class A Train of Vehicle



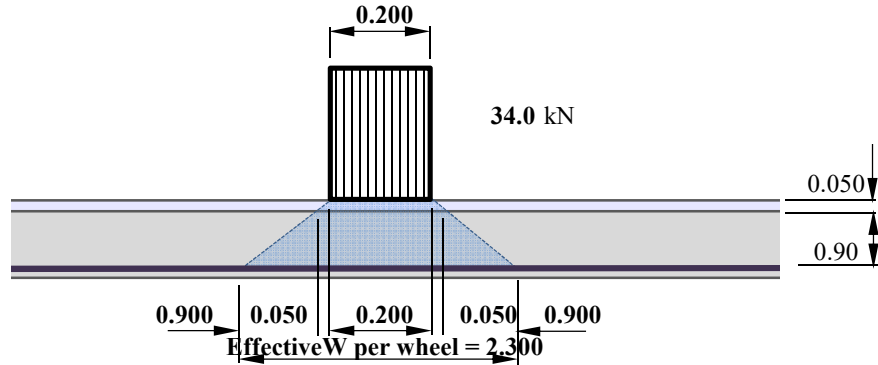
2-6-12 Live Load Class A Train of Vehicle - Center span 16.0m (6.8ton)

3) Longitudinal Direction

Tyre Contact Length = 0.200 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.200 + 2 \times (1.000 + 0.050)$
 = 2.300 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel < 3.000 m **Not OK Consider Overlap Width**



Impact Factor, $I = 20.5\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 34 kN
 Effective width = 8.171 m
 Effective length = 2.300 m
 $q = 2.18 \text{ kN/m}^2 = 34.0 \times (1 + 0.205) / (8.171 \times 2.300)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 68 kN
 Effective width = 8.980 m
 Effective length = 2.300 m
 $q = 3.97 \text{ kN/m}^2 = 34.0 \times 2 \times (1 + 0.205) / (8.980 \times 2.300)$
 Note: **Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 68 kN = 2×34.0
 Effective width = 8.980 m
 Effective length = 5.300 m = $2.300 + 3.000$
 $q = 3.44 \text{ kN/m}^2 = 68.0 \times 2 \times (1 + 0.205) / (8.980 \times 5.300)$
 Note: **Not Critical**

Total load along span = 9.13 kN/m = 3.970×2.300

Braking Effect Load $q_i = 0.66 \text{ kN/m}^2 = 20\% \times \text{MAX}(2.18, 3.97, 3.44) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

		Load	Effective width	Effective length	Total Load		
		kN	m	m	kN/m		
Live Load	LL Cl Acen	68	Gravity	3.97	8.980	2.300	9.13
Braking Load	BR Cl Acen		X-direction	0.66	8.980	2.300	

2-6 Live Load and Braking Effect

2-6-13 Live Load Class A Train of Vehicle - Side span 12.0m (2.7ton)

Live Load Distribution as per width

1) Load Combination

Load Case **Class A Train of Vehicle** As per IRC 21-2000 Section 305.4.2
 Wheel load **2.7 ton**
 Span Location **Side span** Span Length $l_0 = 12.0$ m

2) Transverse Direction

Thickness of Top Slab = **1.000** m
 Thickness of AC (Wearing) = **0.050** m
 Span Width $b = 11.000$ m
 Breadth of Tyre by given $b_w = 0.200$ m
 Calculation $b_w = 0.170$ m $= (150 + (p-1) \times 57) / 1000$ $p = 1.35$ ton
 $b_w = 0.170$ m $= \text{Min}(0.200, 0.170)$
 Breadth of Load on slab $b_1 = 0.270$ m $= 0.170 + 2 \times 0.050$
 $b_{ef} = \alpha \cdot a \cdot (1 - a / l_0) + b_1$ As per IRC 21-2000 Section 305.16.2
 for, $b/l_0 = 0.917$
 $\alpha = 2.174$ As per IRC 21-2000 Section 305.16.2 Table

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.917	2.174
0.2	0.80	0.80	0	
0.3	1.16	1.16	0	
0.4	1.48	1.44	0	
0.5	1.72	1.68	0	
0.6	1.96	1.84	0	
0.7	2.12	1.96	0	
0.8	2.24	2.08	0	
0.9	2.36	2.16	0.917	2.174
2.0	3.00	2.60	0	

Distance of the center of gravity : a

$$a = l_0 / 2 = 6.000 \text{ m}$$

$$b_{ef} = 6.792 \text{ m} = 2.174 \times 6.0 \times (1 - 6.0/12.0) + 0.270$$

$$b_{ef} = 6.792 \text{ m}$$

$$b_{ef} / 2 = 3.396 \text{ m}$$

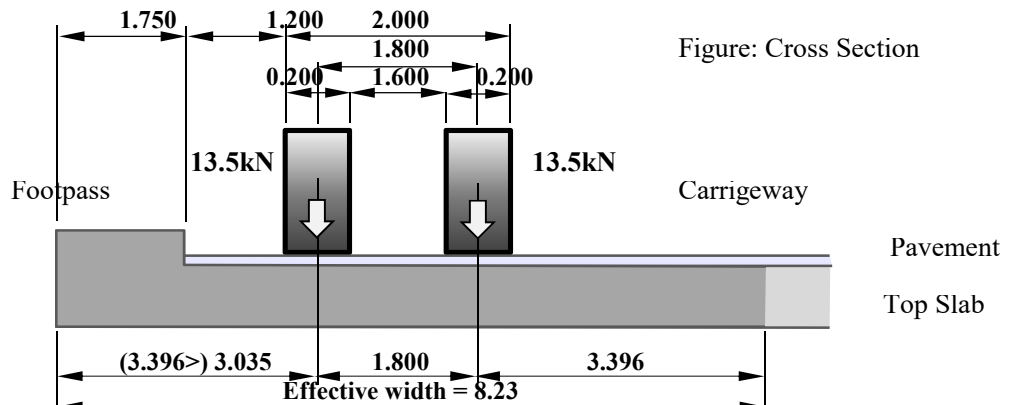
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width $b_{\text{footpath}} = 1.750$ m
 Outer edge of wheel C = $C = 1.200$ m
 $b_{\text{footpath}} + C + b_w / 2 = 3.035$ m $= 1.750 + 1.200 + 0.170/2$
 As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width $W = 8.23$ m $= \text{MIN}(3.396, 3.035) + 1.800 + 3.396$
 Load **13.5 kN** One side of Class A Train of Vehicle



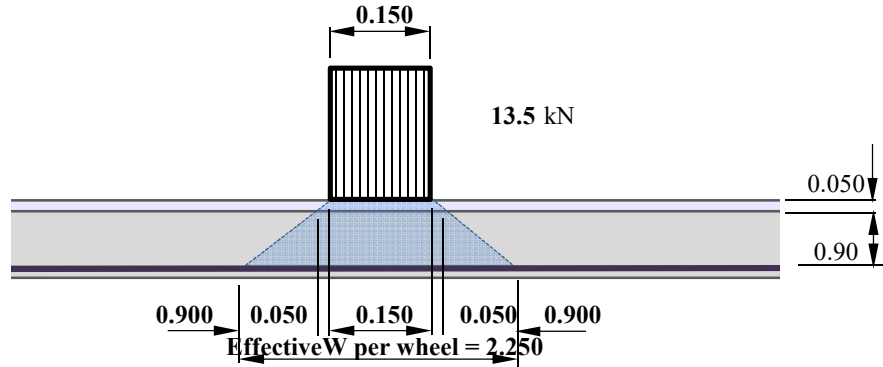
2-6-13 Live Load Class A Train of Vehicle - Side span 12.0m (2.7ton)

3) Longitudinal Direction

Tyre Contact Length = 0.150 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.150 + 2 \times (1.000 + 0.050)$
 = 2.250 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.100 m **Not OK Consider Overlap Width**



Impact Factor, $I = 25.0\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 14 kN
 Effective width = 6.792 m
 Effective length = 2.250 m
 $q = 1.10 \text{ kN/m}^2 = 13.5 \times (1 + 0.25) / (6.792 \times 2.250)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 27 kN
 Effective width = 8.230 m
 Effective length = 2.250 m
 $q = 1.82 \text{ kN/m}^2 = 13.5 \times 2 \times (1 + 0.25) / (8.230 \times 2.250)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 27 kN = 2×13.5
 Effective width = 8.230 m
 Effective length = 3.350 m = $2.250 + 1.100$
 $q = 2.45 \text{ kN/m}^2 = 27.0 \times 2 \times (1 + 0.25) / (8.230 \times 3.350)$
 Note: **Critical**

Total load along span = **8.21 kN/m** = 2.450×3.350

Braking Effect Load $q_i = 0.39 \text{ kN/m}^2 = 20\% \times \text{MAX}(1.10, 1.82, 2.45) / (1 + 25\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load	
		kN	kN/m/m	m	m	kN/m	
Live Load	LL CI ALeft2	27	Gravity	2.45	8.230	3.350	8.21
Braking Load	BR CI ALeft2		X-directior	0.39	8.230	3.350	

2-6 Live Load and Braking Effect

2-6-14 Live Load Class A Train of Vehicle - Center span 16.0m (2.7ton)

Live Load Distribution as per width

1) Load Combination

Load Case	Class A Train of Vehicle As per IRC 21-2000 Section 305.4.2		
Wheel load	2.7 ton		
Span Location	Center span	Span Length	$l_0 = 16.0$ m

2) Transverse Direction

Thickness of Top Slab	=	1.000 m		
Thickness of AC (Wearing)	=	0.050 m		
Span Width	b =	11.000 m		
Breadth of Tyre by given	$b_w =$	0.200 m		
Calculation	$b_w =$	0.170 m	$= (150 + (p-1) \times 57) / 1000$	$p = 1.35$ ton
	$b_w =$	0.170 m	$= \text{Min}(0.200, 0.170)$	
Breadth of Load on slab	$b_1 =$	0.270 m	$= 0.170 + 2 \times 0.050$	
	$b_{ef} = \alpha \cdot a (1 - a / l_0) + b_1$		As per IRC 21-2000 Section 305.16.2	
for,	$b/l_0 =$	0.688		
	$\alpha =$	1.946	As per IRC 21-2000 Section 305.16.2 Table	

b/l ₀	Simple	Continuous	b/l ₀	Continuous
0.1	0.40	0.40	0.688	1.946
0.2	0.80	0.80		
0.3	1.16	1.16		
0.4	1.48	1.44		
0.5	1.72	1.68		
0.6	1.96	1.84	0.688	1.946
0.7	2.12	1.96		
0.8	2.24	2.08		
0.9	2.36	2.16		
2.0	3.00	2.60		

Distance of the center of gravity : a

$$a = l_0 / 2 = 8.000 \text{ m}$$

$$b_{ef} = 8.054 \text{ m} = 1.946 \times 8.0 \times (1 - 8.0/16.0) + 0.270$$

$$b_{ef} = 8.054 \text{ m}$$

$$b_{ef} / 2 = 4.027 \text{ m}$$

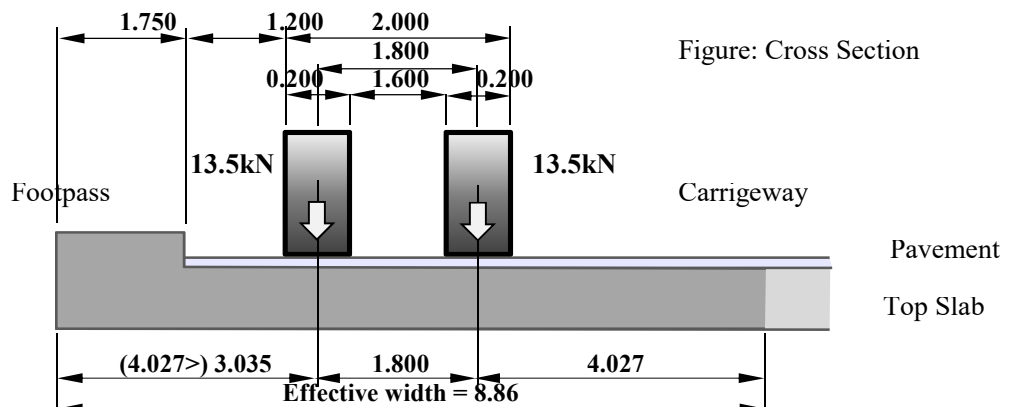
$$> 1.800 \text{ m} \quad \text{Distance between wheel and wheel}$$

Not OK Consider Overlap Width

Footpath width	$b_{\text{footpath}} =$	1.750 m	
Outer edge of wheel C =	C =	1.200 m	
	$b_{\text{footpath}} + C + b_w / 2 =$	3.035 m	$= 1.750 + 1.200 + 0.170 / 2$
			As per IRC 21-2000 Section 305.16.2

For Overlap

Effective width W =	8.86 m	$= \text{MIN}(4.027, 3.035) + 1.800 + 4.027$
Load	13.5 kN	One side of Class A Train of Vehicle



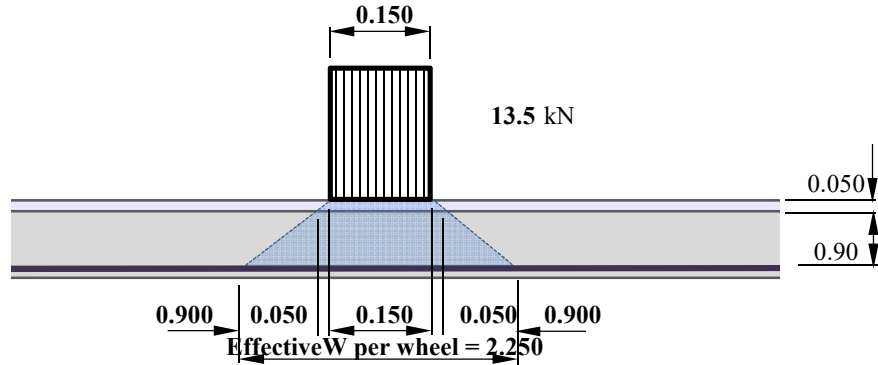
2-6-14 Live Load Class A Train of Vehicle - Center span 16.0m (2.7ton)

3) Longitudinal Direction

Tyre Contact Length = 0.150 m As per IRC: 6-2016 Section 204.1.1
 Effective W per wheel $B = 0.150 + 2 \times (1.000 + 0.050)$
 = 2.250 m As per IRC: 21-2000 Section 305.16.3

Check for Overlap of the Next Wheel

Distance of next wheel > 1.100 m **Not OK Consider Overlap Width**



Impact Factor, $I = 20.5\%$ Span upto 40m As per IRC 6-2016 Section 208.3

Unit Weight Load

1) Transverse Tyre 1 = No Overlap Longitudinal = No Overlap
 Load = 14 kN
 Effective width = 8.054 m
 Effective length = 2.250 m
 $q = 0.90 \text{ kN/m}^2 = 13.5 \times (1 + 0.205) / (8.054 \times 2.250)$
 Note: **Not Critical**

2) Transverse Tyre 2 = **Overlap 2** Longitudinal = No Overlap
 Load = 27 kN
 Effective width = 8.860 m
 Effective length = 2.250 m
 $q = 1.63 \text{ kN/m}^2 = 13.5 \times 2 \times (1 + 0.205) / (8.860 \times 2.250)$
 Note: **Not Critical**

3) Transverse Type both = **Overlap** Longitudinal = **Overlap**
 Load = 27 kN = 2×13.5
 Effective width = 8.860 m
 Effective length = 3.350 m = $2.250 + 1.100$
 $q = 2.19 \text{ kN/m}^2 = 27.0 \times 2 \times (1 + 0.205) / (8.860 \times 3.350)$
 Note: **Critical**

Total load along span = 7.34 kN/m = 2.190×3.350

Braking Effect Load $q_i = 0.36 \text{ kN/m}^2 = 20\% \times \text{MAX}(0.90, 1.63, 2.19) / (1 + 21\%)$
 As per IRC 6-2016 Section 211.2

			Load	Effective width	Effective length	Total Load
			kN	m	m	kN/m
Live Load	LL CI ALeft2	Gravity	27	8.860	3.350	7.34
Braking Load	BR CI ALeft2	X-direction	0.36	8.860	3.350	

4 Input Data for 2-Dimengion Frame Model

(Input Data)

Spring support of ground for raft foundation

Reactions from earth were considered as spring supports, calculated using the below formula. Reaction coefficients are shown in below.

< Vertical Coefficient of Raft Foundation Bed Reaction (Square Footing) >		
Case I	- % of Sand higher than Cohesive Soil	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-1/2}$
Case II	- Equal % of Sandy and Cohesive Soil	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-3/4}$
Case III	- % of Cohesive Soil higher than Sand	$K_v = K_{v0} \left(\frac{B_v}{0.3} \right)^{-1}$

$$K_{v0} = \frac{1}{0.3} \times \alpha \times E_0$$

Hence, α : the method of calculation E_0 , the correction factor

E_0 : Modulus of Elasticity of soil (kN/m²)

α = 1 (Case of using N value in normal condition)

N-value = 30 ° (Assumed)

E_0 = 2800 x N = 2800x30 = 84000 kN/m²

K_{v0} = 1/0.3 x 84000 x 1 = 280000 kN/m³

Total Width of bottom Slab (B) = B = 44.2 m

Length (transverse) of bottom slab (L) = L = 11.0 m

B_v If B>L, $B_v = \text{Sqrt}(B \times L)$; If B<L, $B_v = \text{Sqrt}(B \times B)$

$$= 44.2^{(1/2)} \times 11.0 = 22.0 \text{ m}$$

K_v Case I = 280,000x(22.0/0.3)^(-1/2) = 32,697 kN/m³

Case II = 280,000x(22.0/0.3)^(-3/4) = 11,173 kN/m³

Case III = 280,000x(22.0/0.3)⁽⁻¹⁾ = 3,818 kN/m³

Our Soil Case = Case II

Hence,

for Unit Length = (only if B < L)

Soil Case = Case II

$K_v (B \times L) = K_v = 11173 \text{ kN/m}^3$

Distributing $K_v(B \times L)$ along three nodes on the base of raft foundation, used in SAP Model

Coefficient	Nodal Point	L m	Spring Value of Subgrade Reaction	
			Formula	kN/m
K_v	1-4, 33~36	0.7	$11173 \times 0.7 =$	7,000
	5~32	2.0	$11173 \times 2.0 =$	22,000
K_h	36	-	(Infinitely rigid)	10000000000

4 Input Data for 2-Dimengion Frame Model

4-1 Nodal Point and Frame Data

(1) Nodal Point

Point	X	Y	Point	X	Y
1	0.00	0	101	2.10	10.650
2	0.50	0	102	14.10	10.650
3	1.00	0	103	30.10	10.650
4	2.10	0	104	42.10	10.650
5	2.50	0	201	2.10	0.800
6	3.00	0	202	2.10	1.300
7	5.00	0	203	2.10	2.300
8	7.00	0	204	2.10	7.600
9	9.20	0	205	2.10	9.600
10	11.20	0	206	2.10	10.100
11	13.20	0	301	14.10	0.800
12	13.70	0	302	14.10	1.300
13	14.10	0	303	14.10	2.300
14	14.50	0	304	14.10	7.600
15	15.00	0	305	14.10	9.600
16	17.00	0	306	14.10	10.100
17	19.00	0	401	30.10	0.800
18	21.00	0	402	30.10	1.300
19	23.20	0	403	30.10	2.300
20	25.20	0	404	30.10	7.600
21	27.20	0	405	30.10	9.600
22	29.20	0	406	30.10	10.100
23	29.70	0	501	42.10	0.800
24	30.10	0	502	42.10	1.300
25	30.50	0	503	42.10	2.300
26	31.00	0	504	42.10	7.600
27	33.00	0	505	42.10	9.600
28	35.00	0	506	42.10	10.100
29	37.20	0			
30	39.20	0			
31	41.20	0			
32	41.70	0			
33	42.10	0			
34	43.20	0			
35	43.70	0			
36	44.20	0			

Check **44.20**

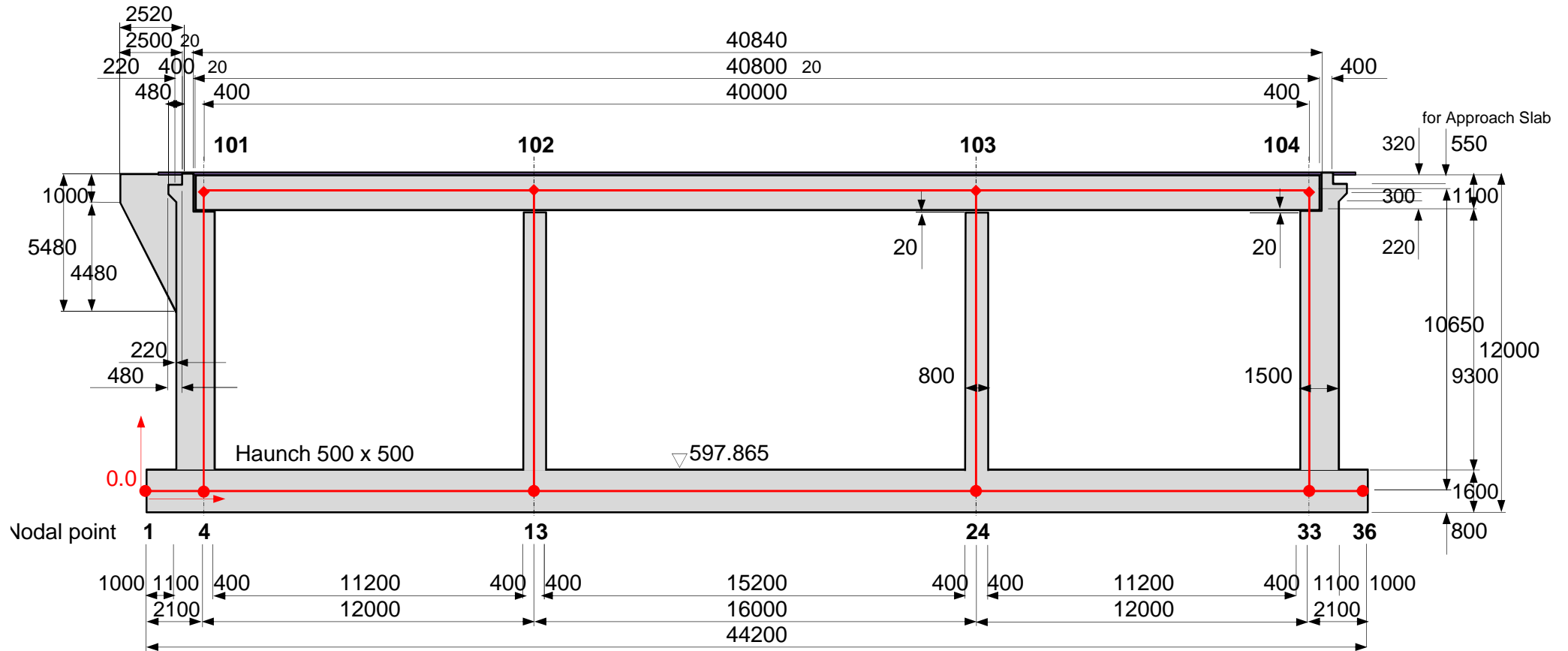
(2) Frame

Frame	Joint-I	Joint-J	Length	Frame	Joint-I	Joint-J	Length
1	1	2	0.50	101	101	102	12.000
2	2	3	0.50	102	102	103	16.000
3	3	4	1.10	103	103	104	12.000
4	4	5	0.40	201	4	201	0.800
5	5	6	0.50	202	201	202	0.500
6	6	7	2.00	203	202	203	1.000
7	7	8	2.00	204	203	204	5.300
8	8	9	2.20	205	204	205	2.000
9	9	10	2.00	206	205	206	0.500
10	10	11	2.00	207	206	101	0.550
11	11	12	0.50	301	13	301	0.800
12	12	13	0.40	302	301	302	0.500
13	13	14	0.40	303	302	303	1.000
14	14	15	0.50	304	303	304	5.300
15	15	16	2.00	305	304	305	2.000
16	16	17	2.00	306	305	306	0.500
17	17	18	2.00	307	306	102	0.550
18	18	19	2.20	401	24	401	0.800
19	19	20	2.00	402	401	402	0.500
20	20	21	2.00	403	402	403	1.000
21	21	22	2.00	404	403	404	5.300
22	22	23	0.50	405	404	405	2.000
23	23	24	0.40	406	405	406	0.500
24	24	25	0.40	407	406	103	0.550
25	25	26	0.50	501	33	501	0.800
26	26	27	2.00	502	501	502	0.500
27	27	28	2.00	503	502	503	1.000
28	28	29	2.20	504	503	504	5.300
29	29	30	2.00	505	504	505	2.000
30	30	31	2.00	506	505	506	0.500
31	31	32	0.50	507	506	104	0.550
32	32	33	0.40				
33	33	34	1.10				
34	34	35	0.50				
35	35	36	0.50				

4-2 Elevation of Structure and Frame

Size of RC Concrete Slab on Raft Base

Span Arrangement		12.00	+	14.00	+	12.00	m
First Span	1st Cell	L = 11.20	m	x	H = 9.30	m	
Center Span	2nd Cell	L = 15.20	m	x	H = 9.30	m	
End Span 2	3rd Cell	L = 11.20	m	x	H = 9.30	m	



4-3 Joint Spring

Joint	X	Li m	L average m	U1 kN/m	U3 kN/m	
1	0.00	0.25	0.67		7,000	
2	0.50	0.50				7,000
3	0.50	0.80				7,000
4	1.10	0.75				7,000
5	0.40	0.45				7,000
6	0.50	1.25				7,000
7	2.00	2.00	2.07		22,000	
8	2.00	2.10				22,000
9	2.20	2.10				22,000
10	2.00	2.00				22,000
11	2.00	1.25	0.76		7,000	
12	0.5	0.45				7,000
13	0.40	0.40				7,000
14	0.40	0.45				7,000
15	0.50	1.25				7,000
16	2.00	2.00	2.03		22,000	
17	2.00	2.00				22,000
18	2.00	2.10				22,000
19	2.20	2.10				22,000
20	2.00	2.00				22,000
21	2.00	2.00				22,000
22	2.00	1.25	0.76		7,000	
23	0.50	0.45				7,000
24	0.40	0.40				7,000
25	0.40	0.45				7,000
26	0.50	1.25				7,000
27	2.00	2.00	2.07		22,000	
28	2.00	2.10				22,000
29	2.20	2.10				22,000
30	2.00	2.00				22,000
31	2.00	1.25	0.67		7,000	
32	0.50	0.45				7,000
33	0.40	0.75				7,000
34	1.10	0.80				7,000
35	0.50	0.50				7,000
36	0.50	0.25			1.E+10	7,000

4-4 Load Combination and Permissible Stress

IRC 6-2014 Clause 202.3

Load Combination	2	3	5	10	13	14	18	21	Analysis
	Dead Load	Live Load	Vehicle Impact	Braking	Earth Pressure	Temperature	Seismic	Permissible Stresses	
	(G)	(Q)	(Q _{im})	(F _b)	(F _{ep})	(F _{tc})	(F _{eq})	(%)	
I	1	1	1	1	1			100%	
IIA	1	1	1	1	1	1		115%	N.A. *
IIIA	1	1	1	1	1	1		133%	N.A. *
VI	1	0.2	Q x 1	0.2	1		1	150%	

note. *: IIA and IIIA with temperature load are not required to design due to isolated superstructure of top slab

Marks			Direction Load Case	Service		Seismic		
				LC-I		LC-VI		
					Impact		Impact	
	Permissible Stress			100%		150%		
G	Dead Load	Body	Gravity	1		1		
G	Dead Load	Surface	AC pavement	Gravity	1	1		
G	Dead Load	Surface	Footway	Gravity				
Fep	Earth Pressure		Longitudinal	1		1		
Q	Live Load (LL)	70R Tracked	Gravity	1		0.2		
		70R Wheeled	Gravity	1		0.2		
		Class A Track(s)	2 lanes	Gravity	1		0.2	
		Class A Track(s)	2 lanes	Gravity	1		0.2	
Qim	Live Load Vertical Impact	70R Tracked	Gravity	1	LL x 10%	LL x 1	LL x 10%	
		70R Wheeled	Gravity	1	LL x 25%	LL x 1	LL x 25%	
		Class A Track(s)	2 lanes	Gravity	1	LL x 25%	LL x 1	LL x 25%
		Class A Track(s)	1 lanes	Gravity	1	LL x 25%	LL x 1	LL x 25%
Fb	Braking Effect	70R Tracked	Longitudinal	1	LL x 20%	0.2	LL x 20%	
		70R Wheeled	Longitudinal	1	LL x 20%	0.2	LL x 20%	
		Class A Track(s)	2 lanes	Longitudinal	1	LL x 20%	0.2	LL x 20%
		Class A Track(s)	1 lanes	Longitudinal	1	LL x 20%	0.2	LL x 20%
Q	Footpath Load		Gravity	1		0.2		
Feq	Seismic		Longitudinal			1		

4-5 Load Combination Cases

	Loaded on		Input to SAP2000	Direction	Case	Load Pattern
Dead Load	Body		Automatically	Gravity	DC	DC
Dead Load	AC pavement & overlay	w/o Footpath load	Case-1	Gravity	DL-Sface-AC	DL-Sface-AC
Dead Load	Footpath	with Footpath load	Case-2	Gravity	DL-Sface-FW	DL-Sface-FW
Earth Pressure	both side of outer wall			Longitudinal (x)	EP-Both	EP-Both
Live Load	70R Tracked	on side span		Gravity	L-1-7T-Side	L-1-7T-Side
		on center span			L-2-7T-Cent	L-2-7T-Cent
	70R Wheeled	on one side span			L-3-7W-Side	L-3-7W-Side
		on one side span-2			L-4-7W-Side2	L-4-7W-Side2
		on center span			L-5-7W-Cent	L-5-7W-Cent
	Class A (by 2 lane)	on center span-2			L-6-7W-Cent2	L-6-7W-Cent2
		on center span-3			L-7-7W-Cent3	L-7-7W-Cent3
		on one side span			L-8-CA-Side	L-8-CA-Side
		on both side span			L-9-CA-Side2	L-9-CA-Side2
		on center span			L-10-CA-Cent	L-10-CA-Cent
Braking Effect	70R Tracked	on side span		Longitudinal (x)	B-1-7T-Side	B-1-7T-Side
		on center span			B-2-7T-Cent	B-2-7T-Cent
	70R Wheeled	on one side span			B-3-7W-Side	B-3-7W-Side
		on one side span-2			B-4-7W-Side2	B-4-7W-Side2
		on center span			B-5-7W-Cent	B-5-7W-Cent
	Class A (by 2 lane)	on center span-2			B-6-7W-Cent2	B-6-7W-Cent2
		on center span-3			B-7-7W-Cent3	B-7-7W-Cent3
		on one side span			B-8-CA-Side	B-8-CA-Side
		on both side span			B-9-CA-Side	B-9-CA-Side
		on center span			B-10-CA-Cent	B-10-CA-Cent
Footpath Load	70R Tracked	on side span		Gravity	F-1-Side	F-1-Side
		on center span			F-2-Cent	F-2-Cent
	70R Wheeled	on one side span			F-3-Side	F-3-Side
		on one side span-2			F-4-Side2	F-4-Side2
		on center span			F-5-Cent	F-5-Cent
	Class A (by 2 lane)	on center span-2			F-6-Cent2	F-6-Cent2
		on center span-3			F-7-Cent3	F-7-Cent3
		on one side span			F-8-Side	F-8-Side
		on both side span			F-9-Side2	F-9-Side2
		on center span			F-10-Cent	F-10-Cent
Earthquake Load			input Parameter	Longitudinal (x)	EQ	EQ

4-6 Load Data for Dead Load and Erath Pressure

Input Dat

(1) Dead Load: Surface Load on Top Slab

Frame Text	LoadPat Text	Dir	RelDistA Uitless	RelDistB Uitless	AbsDistA m	AbsDistB m	FOverLA kN/m	FOverLB kN/m
101	DL-Sface-AC	Gravity	0	1			2.75	2.75
102	DL-Sface-AC	Gravity	0	1			2.75	2.75
103	DL-Sface-AC	Gravity	0	1			2.75	2.75
101	DL-Sface-FW	Gravity	0	1			6.00	6.00
102	DL-Sface-FW	Gravity	0	1			6.00	6.00
103	DL-Sface-FW	Gravity	0	1			6.00	6.00

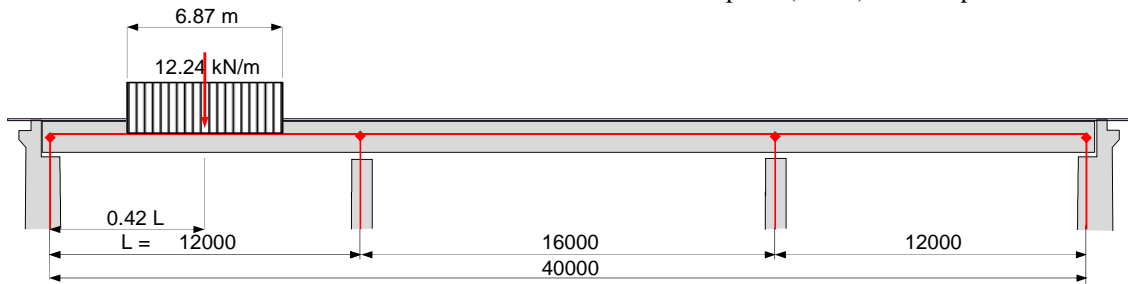
(2) Earth Presure to Outer Walls

Frame Text	LoadPat Text	Dir	RelDistA Uitless	RelDistB Uitless	AbsDistA m	AbsDistB m	FOverLA kN/m	FOverLB kN/m
201	EP-Both	X	0	1			108.3	100.7
202	EP-Both	X	0	1			100.7	95.9
203	EP-Both	X	0	1			95.9	86.4
204	EP-Both	X	0	1			86.4	36.1
205	EP-Both	X	0	1			36.1	17.1
206	EP-Both	X	0	1			17.1	12.3
207	EP-Both	X	0	1			12.3	7.1
501	EP-Both	X	0	1			-108.3	-100.7
502	EP-Both	X	0	1			-100.7	-95.9
503	EP-Both	X	0	1			-95.9	-86.4
504	EP-Both	X	0	1			-86.4	-36.1
505	EP-Both	X	0	1			-36.1	-17.1
506	EP-Both	X	0	1			-17.1	-12.3
507	EP-Both	X	0	1			-12.3	-7.1

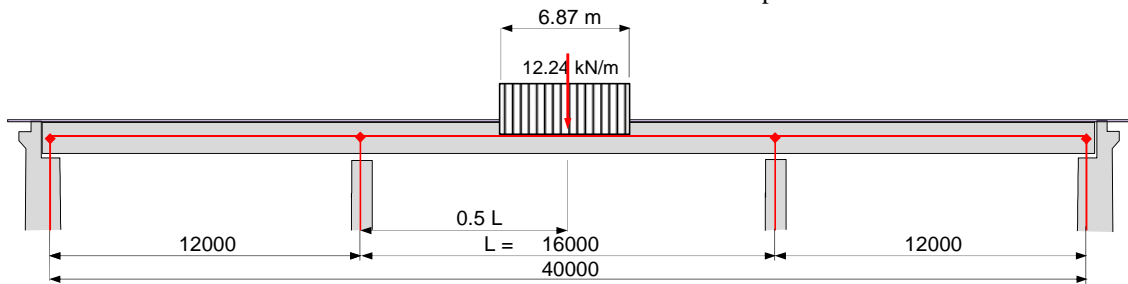
4-7 Load Data of Live Load

Live Load Case	Live Load	Load Condition	LoadPat
1	Live Load - 1 70R-T	M-Max at first span: max load at moment max point (0.42L) of side span Load at moment max point (0.42L) of side span	L-1-7T-Side
2	Live Load - 2 70R-T	M-Max at center of center span Load at center of center span	L-2-7T-Cent
3	Live Load - 3 70R-W	M-Max 2-17ton axles at first span Max 3rd & 4th axles at moment max point (0.42L) of first span	L-3-7W-Side
4	Live Load - 4 70R-W	M-Max 2-17ton axles at end span Max 3rd & 4th axles at moment max point (0.42L) of end span	L-4-7W-Side2
5	Live Load - 5 70R-W	M-Max 2-17ton axles at center of center span Max 3rd & 4th axles at center of center span	L-5-7W-Cent
6	Live Load - 6 70R-W	M-Max 3rd 17ton axle at center of center span Max 3rd axles at center of center span	L-6-7W-Cent2
7	Live Load - 7 70R-W	Shear-Max at edge of center span Max 4th axles at end of center span	L-7-7W-Cent3
8	Live Load - 8 Class A	M-Max 2nd axles of 1st Train at first span and 2nd Train 1st Train at first span 2nd Train at end span	L-8-CA-Side
9	Live Load - 9 Class A	M-Max 2nd axles of 1st Train at end span and 2nd Train 1st Train at first span 2nd Train at end span	L-9-CA-Side2
10	Live Load - 10 Class A	M-Max 2nd axles at center span One Train at center of center span	L-10-CA-Cent

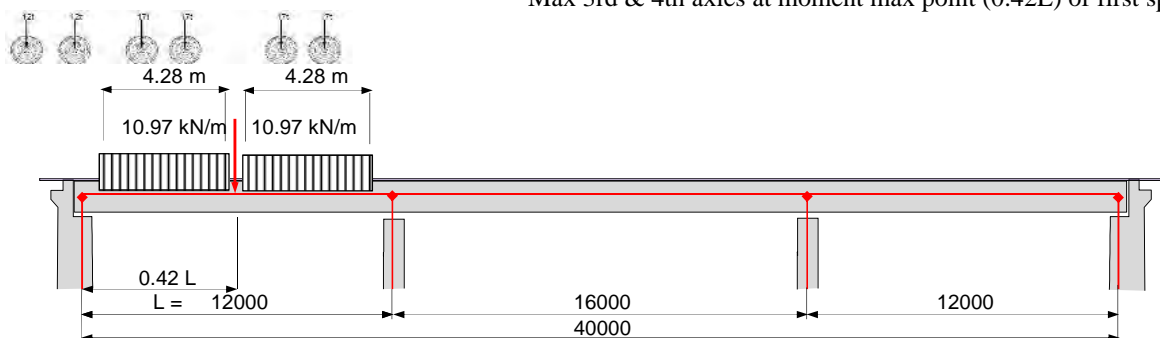
- 1 Live Load - 1 70R-T L-1-7T-Side** M-Max at first span: max load at moment max point (0.42L) of side span ;
Load at moment max point (0.42L) of side span



- 2 Live Load - 2 70R-T L-2-7T-Cent** M-Max at center of center span
Load at center of center span

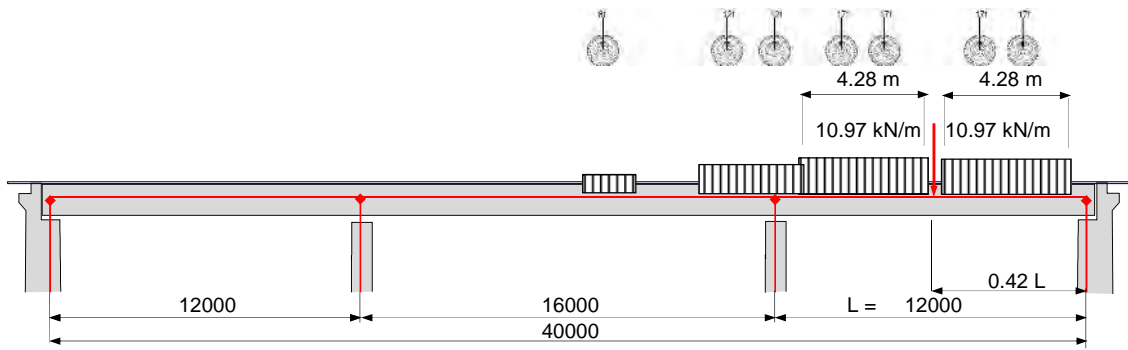


- 3 Live Load - 3 70R-W L-3-7W-Side** M-Max 2-17ton axles at first span
Max 3rd & 4th axles at moment max point (0.42L) of first span



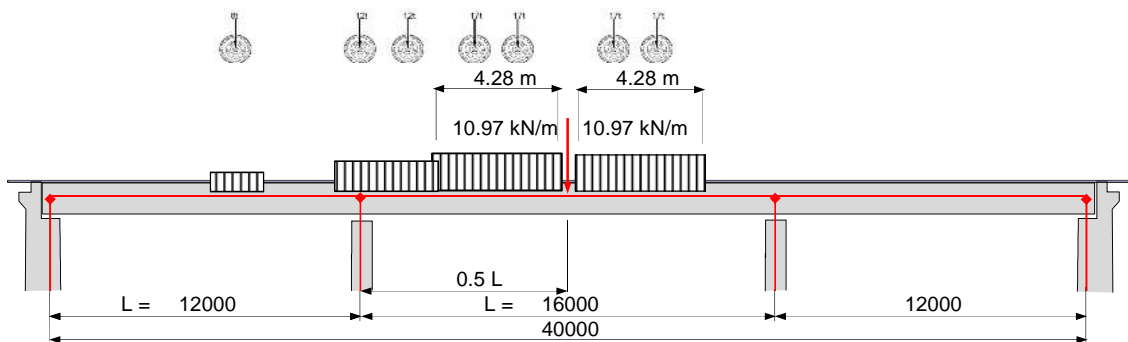
4 Live Load - 4 70R-W L-4-7W-Side2

M-Max 2-17ton axles at end span
 Max 3rd & 4th axles at moment max point (0.42L) of end span



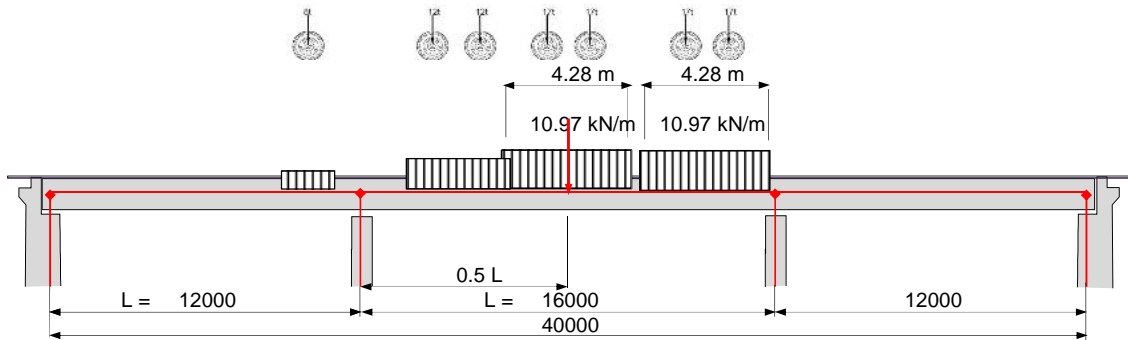
5 Live Load - 5 70R-W L-5-7W-Cent

M-Max 2-17ton axles at center of center span
 Max 3rd & 4th axles at center of center span



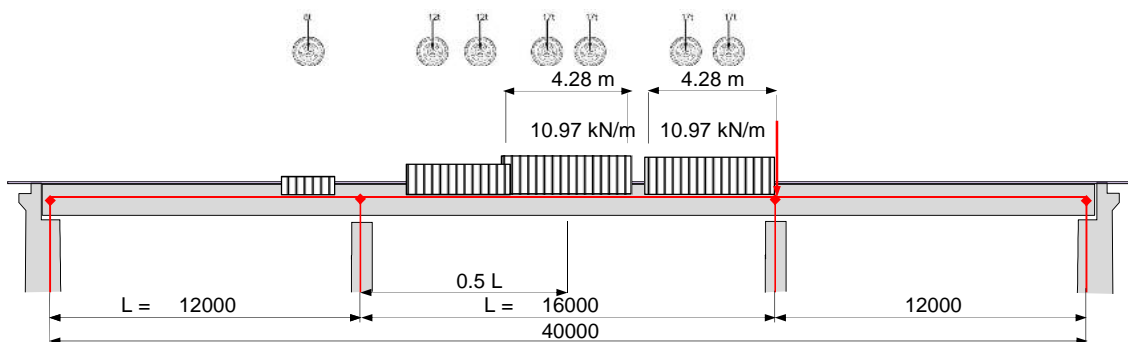
6 Live Load - 6 70R-W L-6-7W-Cent2

M-Max 3rd 17ton axle at center of center span
 Max 3rd axles at center of center span



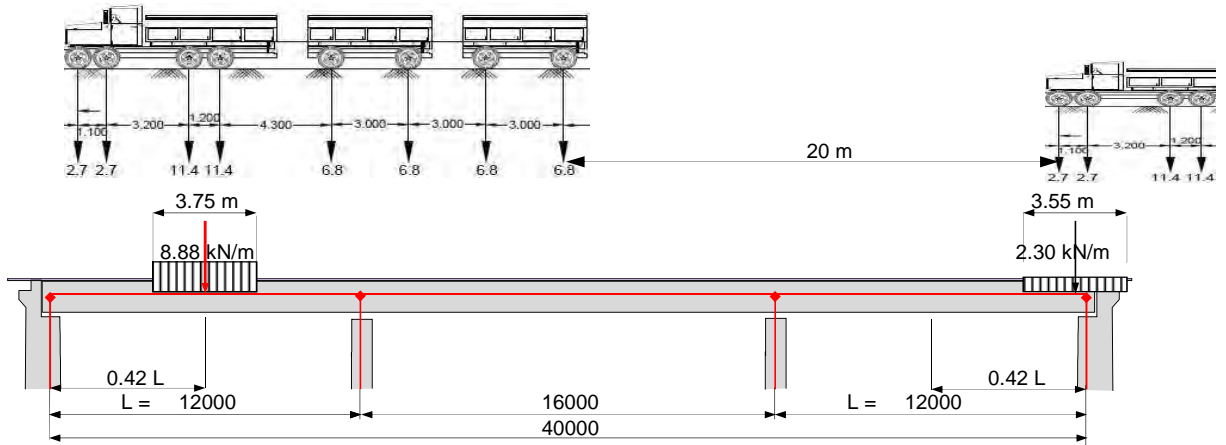
7 Live Load - 7 70R-W L-7-7W-Cent3

Shear-Max at edge of center span
 Max 4th axles at end of center span



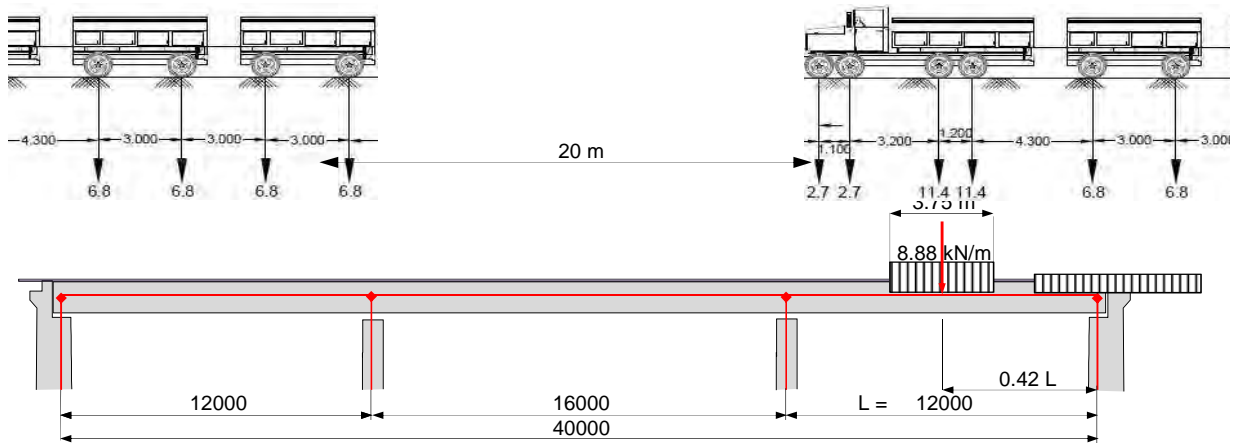
8 Live Load - 8 Class A L-8-CA-Side

M-Max 2nd axles of 1st Train at first span and 2nd Train
1st Train at first span
2nd Train at end span



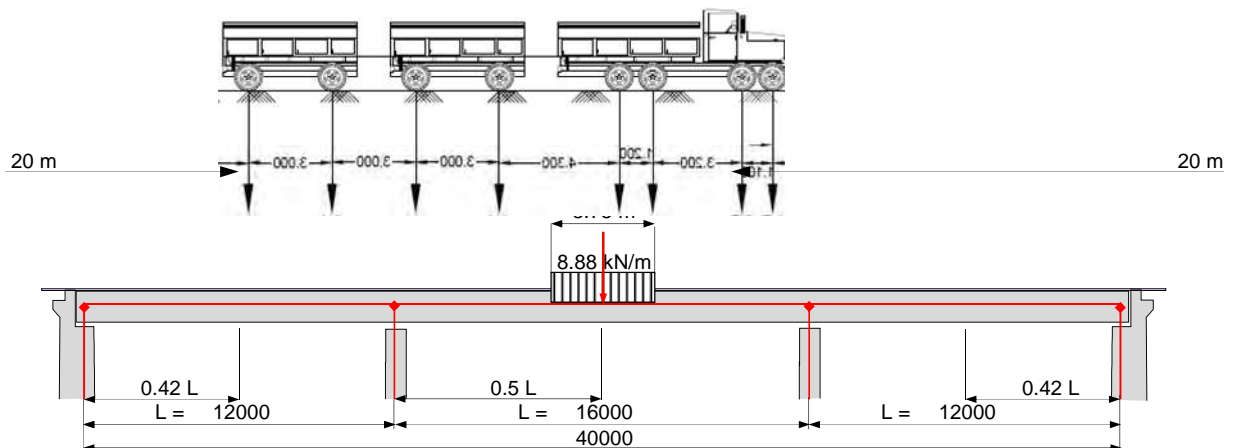
9 Live Load - 9 Class A L-9-CA-Side2

M-Max 2nd axles of 1st Train at end span and 2nd Train
1st Train at first span
2nd Train at end span



10 Live Load - 10 Class A L-10-CA-Cent

M-Max 2nd axles at center span
One Train at center of center span



Input Data

(1) Live Load

Live Load (70R-T, 70R-W, Class A) without Impact

(2) Braking Effect (Direction X)

(3) Footpass Load (under Footpath area)

Case	Live Load	Condition	Frame	LoadPat	AbsDistA	AbsDistB	FOverLA FOverLB	Frame	LoadPat	AbsDistA	AbsDistB	FOverLA FOverLB	Frame	LoadPat	AbsDistA	AbsDistB	FOverLA FOverLB
			Text	Text	m	m	kN/m	Text	Text	m	m	kN/m	Text	Text	m	m	kN/m
1	70R-T	M-Max at first span	101	L-1-7T-Side	1.605	8.475	12.24	101	B-1-7T-Side	1.605	8.475	2.23	101	F-1-Side	0	10.8	4.8
														103	F-1-Side	1.2	12.0
2	70R-T	M-Max at center span	102	L-2-7T-Cent	4.565	11.435	12.24	102	B-2-7T-Cent	4.565	11.435	2.23	102	F-2-Cent	3.2	12.8	4.8
3	70R-W	M-Max 2-17ton load at first span 4th & 5th axles at 0.42L	101	L-3-7W-Side	0	0.785	8.18	101	B-3-7W-Side	0	0.785	1.31	101	F-3-Side	0	10.8	4.8
			101	L-3-7W-Side	0.690	4.970	10.97	101	B-3-7W-Side	0.690	4.970	1.76	103	F-3-Side	1.2	12.0	4.8
			101	L-3-7W-Side	5.110	9.390	10.97	101	B-3-7W-Side	5.110	9.390	1.76					
4	70R-W	M-Max 2-17ton load at end span at first span 4th & 5th axles at 0.42L	102	L-4-7W-Side2	10.315	13.225	4.15	102	B-4-7W-Side2	10.315	13.225	0.66	101	F-4-Side	0	10.8	4.8
			102	L-4-7W-Side2	14.275	16.000	8.18	102	B-4-7W-Side2	14.275	16.000	1.31	103	F-4-Side	1.2	12.0	4.8
			103	L-4-7W-Side2	0	2.705	8.18	103	B-4-7W-Side2	0	2.705	1.31					
			103	L-4-7W-Side2	2.610	6.890	10.97	103	B-4-7W-Side2	2.610	6.890	1.76					
			103	L-4-7W-Side2	7.030	11.310	10.97	103	B-4-7W-Side2	7.030	11.310	1.76					
5	70R-W	M-Max 2-17ton load at cent spa at center span 4th & 5th axles at center of center span	101	L-5-7W-Cent	7.355	12.000	4.15	101	B-5-7W-Cent	7.355	12.000	0.66	102	F-5-Cent	3.2	12.8	4.8
			102	L-5-7W-Cent	0	-1.735	4.15	102	B-5-7W-Cent	0	-1.735	0.66					
			102	L-5-7W-Cent	-0.685	3.745	8.18	102	B-5-7W-Cent	-0.685	3.745	1.31					
			102	L-5-7W-Cent	3.650	7.930	10.97	102	B-5-7W-Cent	3.650	7.930	1.76					
			102	L-5-7W-Cent	8.070	12.350	10.97	102	B-5-7W-Cent	8.070	12.350	1.76					
6	70R-W	M-Max 3rd 17ton axle at center span center of cent span	101	L-6-7W-Cent2	9.565	12.000	4.15	101	B-6-7W-Cent2	9.565	12.000	0.66	102	F-6-Cent	3.2	12.8	4.8
			102	L-6-7W-Cent2	0	0.475	4.15	102	B-6-7W-Cent2	0	0.475	0.66					
			102	L-6-7W-Cent2	1.525	5.955	8.18	102	B-6-7W-Cent2	1.525	5.955	1.31					
			102	L-6-7W-Cent2	5.860	10.140	10.97	102	B-6-7W-Cent2	5.860	10.140	1.76					
			102	L-6-7W-Cent2	10.280	14.560	10.97	102	B-6-7W-Cent2	10.280	14.560	1.76					
7	70R-W	S-Max at cent span Edge of 4th at end of cent span	101	L-7-7W-Cent3	11.005	12.000	4.15	101	B-7-7W-Cent3	11.005	12.000	0.66	102	F-7-Cent	0.0	16.0	4.8
			102	L-7-7W-Cent3	0	1.915	4.15	102	B-7-7W-Cent3	0	1.915	0.66					
			102	L-7-7W-Cent3	2.965	7.395	8.18	102	B-7-7W-Cent3	2.965	7.395	1.31					
			102	L-7-7W-Cent3	7.300	11.580	10.97	102	B-7-7W-Cent3	7.300	11.580	1.76					
			102	L-7-7W-Cent3	11.720	16.000	10.97	102	B-7-7W-Cent3	11.720	16.000	1.76					
8	Class A	M-Max 2nd axles at first span 1st Train at first span	101	L-8-CA-Side	3.160	6.910	8.88	101	B-8-CA-Side	3.160	6.910	1.42	101	F-8-Side	0	10.8	4.8
			101	L-8-CA-Side	10.185	12.000	4.03	101	B-8-CA-Side	10.185	12.000	0.64	103	F-8-Side	1.2	12.0	4.8
			102	L-8-CA-Side	0	0.685	4.03	102	B-8-CA-Side	0.000	0.685	0.64					
		102	L-8-CA-Side	4.185	6.685	4.03	102	B-8-CA-Side	4.185	6.685	0.64						
		103	L-8-CA-Side	9.710	12.000	2.30	103	B-8-CA-Side	9.710	12.000	0.37						
9	Class A	M-Max 2nd axles at end span 1st Train at first span	101	L-9-CA-Side2	1.308	3.808	4.03	101	B-9-CA-Side2	1.308	3.808	0.64	101	F-9-Side	0	10.8	4.8
			101	L-9-CA-Side2	7.308	9.808	4.03	101	B-9-CA-Side2	7.308	9.808	0.64	103	F-9-Side	1.2	12.0	4.8
		2nd Train at end span	103	L-9-CA-Side2	0.832	4.382	2.30	103	B-9-CA-Side2	0.832	4.382	0.37					
			103	L-9-CA-Side2	5.083	8.833	8.88	103	B-9-CA-Side2	5.083	8.833	1.42					
10	Class A	M-Max 2nd axils at center span One Train at center span	101	L-10-CA-Cent	6.300	8.800	4.03	101	B-10-CA-Cent	6.300	8.800	0.64	102	F-10-Cent	3.2	12.8	4.8
			102	L-10-CA-Cent	0.300	2.800	4.03	102	B-10-CA-Cent	0.300	2.800	0.64					
			102	L-10-CA-Cent	6.075	9.825	8.88	102	B-10-CA-Cent	6.075	9.825	1.42					
			103	L-10-CA-Cent	10.525	14.075	2.30	103	B-10-CA-Cent	10.525	14.075	0.37					

4-8 Combination of Load

(1) Combination of Service Load Condition (LC Case-I)

1) S-1~S-10 at Carridgeway Area

Combo Name	Combo Type	CaseName	Scale Factor	add Impact	Remarks
S-1	Liner Add	DC	1		
S-1		DL-Suface-AC	1		
S-1		EP-Both	1		
S-1		L-1-7T-Side	1.1	10%	add 10 % of impact
S-1		B-1-7T-Side	1		
<hr/>					
S-2	Liner Add	DC	1		
S-2		DL-Suface-AC	1		
S-2		EP-Both	1		
S-2		L-2-7T-Cent	1.1	10%	add 10 % of impact
S-2		B-2-7T-Cent	1		
<hr/>					
S-3	Liner Add	DC	1		
S-3		DL-Suface-AC	1		
S-3		EP-Both	1		
S-3		L-3-7W-Side	1.25	25%	add 25 % of impact
S-3		B-3-7W-Side	1		
<hr/>					
S-4	Liner Add	DC	1		
S-4		DL-Suface-AC	1		
S-4		EP-Both	1		
S-4		L-4-7W-Side2	1.25	25%	add 25 % of impact
S-4		B-4-7W-Side2	1		
<hr/>					
S-5	Liner Add	DC	1		
S-5		DL-Suface-AC	1		
S-5		EP-Both	1		
S-5		L-5-7W-Cent	1.25	25%	add 25 % of impact
S-5		B-5-7W-Cent	1		
<hr/>					
S-6	Liner Add	DC	1		
S-6		DL-Suface-AC	1		
S-6		EP-Both	1		
S-6		L-6-7W-Cent2	1.25	25%	add 25 % of impact
S-6		B-6-7W-Cent2	1		
<hr/>					
S-7	Liner Add	DC	1		
S-7		DL-Suface-AC	1		
S-7		EP-Both	1		
S-7		L-7-7W-Cent3	1.25	25%	add 25 % of impact
S-7		B-7-7W-Cent3	1		
<hr/>					
S-8	Liner Add	DC	1		
S-8		DL-Suface-AC	1		
S-8		EP-Both	1		
S-8		L-8-CA-Side	1.25	25%	add 25 % of impact
S-8		B-8-CA-Side	1		
<hr/>					
S-9	Liner Add	DC	1		
S-9		DL-Suface-AC	1		
S-9		EP-Both	1		
S-9		L-9-CA-Side2	1.25	25%	add 25 % of impact
S-9		B-9-CA-Side	1		
<hr/>					
S-10	Liner Add	DC	1		
S-10		DL-Suface-AC	1		
S-10		EP-Both	1		
S-10		L-10-CA-Cent	1.25	25%	add 25 % of impact
S-10		B-10-CA-Cent	1		

2) S-11~S-20 at Footpath Area (with footpath loading)

Combo Name	Combo Type	CaseName	Scale Factor	add Impact	Remarks
S-11	Liner Add	DC	1		
S-11		DL-Suface-FW	1		
S-11		EP-Both	1		
S-11		L-1-7T-Side	1.1	10%	add 10 % of impact
S-11		B-1-7T-Side	1		
S-11		F-1-Side	1		
<hr/>					
S-12	Liner Add	DC	1		
S-12		DL-Suface-FW	1		
S-12		EP-Both	1		
S-12		L-2-7T-Cent	1.1	10%	add 10 % of impact
S-12		B-2-7T-Cent	1		
S-12		F-2-Cent	1		
<hr/>					
S-13	Liner Add	DC	1		
S-13		DL-Suface-FW	1		
S-13		EP-Both	1		
S-13		L-3-7W-Side	1.25	25%	add 25 % of impact
S-13		B-3-7W-Side	1		
S-13		F-3-Side	1		
<hr/>					
S-14	Liner Add	DC	1		
S-14		DL-Suface-FW	1		
S-14		EP-Both	1		
S-14		L-4-7W-Side2	1.25	25%	add 25 % of impact
S-14		B-4-7W-Side2	1		
S-14		F-4-Side2	1		
<hr/>					
S-15	Liner Add	DC	1		
S-15		DL-Suface-FW	1		
S-15		EP-Both	1		
S-15		L-5-7W-Cent	1.25	25%	add 25 % of impact
S-15		B-5-7W-Cent	1		
S-15		F-5-Cent	1		
<hr/>					
S-16	Liner Add	DC	1		
S-16		DL-Suface-FW	1		
S-16		EP-Both	1		
S-16		L-6-7W-Cent2	1.25	25%	add 25 % of impact
S-16		B-6-7W-Cent2	1		
S-16		F-6-Cent	1		
<hr/>					
S-17	Liner Add	DC	1		
S-17		DL-Suface-FW	1		
S-17		EP-Both	1		
S-17		L-7-7W-Cent3	1.25	25%	add 25 % of impact
S-17		B-7-7W-Cent3	1		
S-17		F-7-Cent	1		
<hr/>					
S-18	Liner Add	DC	1		
S-18		DL-Suface-FW	1		
S-18		EP-Both	1		
S-18		L-8-CA-Side	1.25	25%	add 25 % of impact
S-18		B-8-CA-Side	1		
S-18		F-8-Side	1		
<hr/>					
S-19	Liner Add	DC	1		
S-19		DL-Suface-FW	1		
S-19		EP-Both	1		
S-19		L-9-CA-Side2	1.25	25%	add 25 % of impact
S-19		B-9-CA-Side	1		
S-19		F-9-Side2	1		
<hr/>					
S-20	Liner Add	DC	1		
S-20		DL-Suface-FW	1		
S-20		EP-Both	1		
S-20		L-10-CA-Cent	1.25	25%	add 25 % of impact
S-20		B-10-CA-Cent	1		
S-20		F-10-Cent	1		

(2) Combination of Seismic Condition (LC Case-VI)

1) S-1~S-10 at Carridgeway Area

Combo Name	Combo Type	CaseName	Scale Factor	add Impact	Remarks
Q-1	Liner Add	DC	1		
Q-1		DL-Surface-AC	1		
Q-1		EP-Both	1		
Q-1		L-1-7T-Side	0.22	10%	add 10 % of impact
Q-1		B-1-7T-Side	0.2		
Q-1		EQ	1		
Q-2	Liner Add	DC	1		
Q-2		DL-Surface-AC	1		
Q-2		EP-Both	1		
Q-2		L-2-7T-Cent	0.22	10%	add 10 % of impact
Q-2		B-2-7T-Cent	0.2		
Q-2		EQ	1		
Q-3	Liner Add	DC	1		
Q-3		DL-Surface-AC	1		
Q-3		EP-Both	1		
Q-3		L-3-7W-Side	0.25	25%	add 25 % of impact
Q-3		B-3-7W-Side	0.2		
Q-3		EQ	1		
Q-4	Liner Add	DC	1		
Q-4		DL-Surface-AC	1		
Q-4		EP-Both	1		
Q-4		L-4-7W-Side2	0.25	25%	add 25 % of impact
Q-4		B-4-7W-Side2	0.2		
Q-4		EQ	1		
Q-5	Liner Add	DC	1		
Q-5		DL-Surface-AC	1		
Q-5		EP-Both	1		
Q-5		L-5-7W-Cent	0.25	25%	add 25 % of impact
Q-5		B-5-7W-Cent	0.2		
Q-5		EQ	1		
Q-6	Liner Add	DC	1		
Q-6		DL-Surface-AC	1		
Q-6		EP-Both	1		
Q-6		L-6-7W-Cent2	0.25	25%	add 25 % of impact
Q-6		B-6-7W-Cent2	0.2		
Q-6		EQ	1		
Q-7	Liner Add	DC	1		
Q-7		DL-Surface-AC	1		
Q-7		EP-Both	1		
Q-7		L-7-7W-Cent3	0.25	25%	add 25 % of impact
Q-7		B-7-7W-Cent3	0.2		
Q-7		EQ	1		
Q-8	Liner Add	DC	1		
Q-8		DL-Surface-AC	1		
Q-8		EP-Both	1		
Q-8		L-8-CA-Side	0.25	25%	add 25 % of impact
Q-8		B-8-CA-Side	0.2		
Q-8		EQ	1		
Q-9	Liner Add	DC	1		
Q-9		DL-Surface-AC	1		
Q-9		EP-Both	1		
Q-9		L-9-CA-Side2	0.25	25%	add 25 % of impact
Q-9		B-9-CA-Side	0.2		
Q-9		EQ	1		
Q-10	Liner Add	DC	1		
Q-10		DL-Surface-AC	1		
Q-10		EP-Both	1		
Q-10		L-10-CA-Cent	0.25	25%	add 25 % of impact
Q-10		B-10-CA-Cent	0.2		
Q-10		EQ	1		

2) S-11~S-20 at Footpath Area (with footpath loading)

Combo Name	Combo Type	CaseName	Scale Factor	add Impact	Remarks
Q-11	Liner Add	DC	1		
Q-11		DL-Surface-FW	1		
Q-11		EP-Both	1		
Q-11		L-1-7T-Side	0.22	10%	add 10 % of impact
Q-11		B-1-7T-Side	0.2		
Q-11		F-1-Side	0.2		
Q-11		EQ	1		
Q-12	Liner Add	DC	1		
Q-12		DL-Surface-FW	1		
Q-12		EP-Both	1		
Q-12		L-2-7T-Cent	0.22	10%	add 10 % of impact
Q-12		B-2-7T-Cent	0.2		
Q-12		F-2-Cent	0.2		
Q-12		EQ	1		
Q-13	Liner Add	DC	1		
Q-13		DL-Surface-FW	1		
Q-13		EP-Both	1		
Q-13		L-3-7W-Side	0.25	25%	add 25 % of impact
Q-13		B-3-7W-Side	0.2		
Q-13		F-3-Side	0.2		
Q-13		EQ	1		
Q-14	Liner Add	DC	1		
Q-14		DL-Surface-FW	1		
Q-14		EP-Both	1		
Q-14		L-4-7W-Side2	0.25	25%	add 25 % of impact
Q-14		B-4-7W-Side2	0.2		
Q-14		F-4-Side2	0.2		
Q-14		EQ	1		
Q-15	Liner Add	DC	1		
Q-15		DL-Surface-FW	1		
Q-15		EP-Both	1		
Q-15		L-5-7W-Cent	0.25	25%	add 25 % of impact
Q-15		B-5-7W-Cent	0.2		
Q-15		F-5-Cent	0.2		
Q-15		EQ	1		
Q-16	Liner Add	DC	1		
Q-16		DL-Surface-FW	1		
Q-16		EP-Both	1		
Q-16		L-6-7W-Cent2	0.25	25%	add 25 % of impact
Q-16		B-6-7W-Cent2	0.2		
Q-16		F-6-Cent	0.2		
Q-16		EQ	1		
Q-17	Liner Add	DC	1		
Q-17		DL-Surface-FW	1		
Q-17		EP-Both	1		
Q-17		L-7-7W-Cent3	0.25	25%	add 25 % of impact
Q-17		B-7-7W-Cent3	0.2		
Q-17		F-7-Cent	0.2		
Q-17		EQ	1		
Q-18	Liner Add	DC	1		
Q-18		DL-Surface-FW	1		
Q-18		EP-Both	1		
Q-18		L-8-CA-Side	0.25	25%	add 25 % of impact
Q-18		B-8-CA-Side	0.2		
Q-18		F-8-Side	0.2		
Q-18		EQ	1		
Q-19	Liner Add	DC	1		
Q-19		DL-Surface-FW	1		
Q-19		EP-Both	1		
Q-19		L-9-CA-Side2	0.25	25%	add 25 % of impact
Q-19		B-9-CA-Side	0.2		
Q-19		F-9-Side2	0.2		
Q-19		EQ	1		
Q-20	Liner Add	DC	1		
Q-20		DL-Surface-FW	1		
Q-20		EP-Both	1		
Q-20		L-10-CA-Cent	0.25	25%	add 25 % of impact
Q-20		B-10-CA-Cent	0.2		
Q-20		F-10-Cent	0.2		
Q-20		EQ	1		

(3) Combination of Envelope

Combo Name	CaseName combination	Scale Factor	Case
S-envelope	S-1	1	Service Load (LC I) condition at Carridgeway Area
S-envelope	S-2	1	
S-envelope	S-3	1	
S-envelope	S-4	1	
S-envelope	S-5	1	
S-envelope	S-6	1	
S-envelope	S-7	1	
S-envelope	S-8	1	
S-envelope	S-9	1	
S-envelope	S-10	1	
S2-envelope	S-11	1	Service Load (LC I) condition at Footpath Area with footpath loading
S2-envelope	S-12	1	
S2-envelope	S-13	1	
S2-envelope	S-14	1	
S2-envelope	S-15	1	
S2-envelope	S-16	1	
S2-envelope	S-17	1	
S2-envelope	S-18	1	
S2-envelope	S-19	1	
S2-envelope	S-20	1	
Q-envelope	Q-1	1	Seismic Load condition (LC VI) at Carridgeway Area
Q-envelope	Q-2	1	
Q-envelope	Q-3	1	
Q-envelope	Q-4	1	
Q-envelope	Q-5	1	
Q-envelope	Q-6	1	
Q-envelope	Q-7	1	
Q-envelope	Q-8	1	
Q-envelope	Q-9	1	
Q-envelope	Q-10	1	
Q2-envelope	Q-11	1	Seismic Load condition (LC VI) at Footpath Area with footpath loading
Q2-envelope	Q-12	1	
Q2-envelope	Q-13	1	
Q2-envelope	Q-14	1	
Q2-envelope	Q-15	1	
Q2-envelope	Q-16	1	
Q2-envelope	Q-17	1	
Q2-envelope	Q-18	1	
Q2-envelope	Q-19	1	
Q2-envelope	Q-20	1	

5 Section Force Arrangement

Section Force Arrangement from Output Data by SAP 2000

SN	Frame Position	Load Position	Sectional Force	Member	Service Condition (with Live) Load Comb. I						Seismic Condition Load Comb. IV						B mm	H mm	Check for Bending for			Shear Reinf. Req for Stirrups		
					Frame	x	Case	A (P)	S (V2)	M(M3)	Frame	x	Case	A (P)	S (V2)	M(M3)			Cover	Dia	ctc.	Dia	low	ctc.
					no.	m	-	kN	kN	kN-m	no.	m	-	kN	kN	kN-m			mm	mm	mm	mm	nos.	mm
1	Top slab at Center/Carriageway	End span Load	Positive BM-Max	Slab	101	4.5	S-3	149.3	2.6	468.5	101	4.5	Q-4	45.6	12.6	363.0	1000	1100	75	25	125	12	2	200
2	Top slab at Center/Footpath	End span Load	Positive BM-Max	Slab	101	4.5	S-13	148.0	6.7	568.3	101	4.5	S-13	148.0	6.7	568.3	1000	1100	75	25	125	12	2	200
3	Top slab at Inwall/Carriageway	End span Load	Negative BM-Max	Slab	102	16	S-5	166.7	331.0	796.1	102		S-15	148.4	370.4	885.8	1000	1100	75	25	115	12	2	200
4	Top slab at Inwall/Footpath	Center span load	Negative BM&Shear-Max	Slab	102	16	S-15	170.0	380.0	907.8	102	16	Q-15	153.5	319.2	961.8	1000	1100	75	25	115	12	2	200
5	Bottom slab at Outwall	End span load	Negative B-Max	Slab	4		S-3	473.4	386.9	1083.0	4		Q-3	691.8	500.5	3080.3	1000	1600	75	32	125	12	2	200
6	Bottom slab at Side span center	End span load	Positive B-Max	Slab	6		S-3	473.4	272.1	756.3	6		Q-3	691.8	432.8	2638.7	1000	1600	75	32	125	12	2	200
7	Bottom slab at Side span center	End span load	Shear Max	Slab	6	2	S-13	474.6	369.6	108.5	6	2	Q-13	691.3	520.6	1672.4	1000	1600	75	32	125	12	2	200
8	Bottom slab at Inwall	End span load	Negative BM-Max	Slab	13		S-15	467.1	434.0	1073.4	13		Q-15	772.4	483.8	1492.1	1000	1600	75	32	125	12	2	200
9	Bottom slab at center	End span Load	Positive BM-Max	Slab	18		S-14	480.7	50.7	754.8	18		Q-14	775.1	12.7	630.8	1000	1600	75	32	125	12	2	200
10	Bottom slab at Inwall2	End span load	Negative BM-Max	Slab	24		S-15	466.5	372.4	1018.1	24		Q-15	848.1	481.3	994.1	1000	1600	75	32	125	12	2	200
11	Outer wall Base	End span Load	Positive BM-Max	Wall/Column	201		S-3	602.1	473.4	813.5	201		Q-3	562.7	691.8	3014.0	1000	1500	75	32	120	12	2	200
12	Outer wall Base	End span Load	Positive BM-Max	Wall/Column	201		S-4	529.2	472.3	802.0	201		Q-4	548.1	691.5	3011.7	1000	1500	75	32	120	12	2	200
13	Outer wall Base	Center span load	Positive BM-Max	Wall/Column	201		S-7	516.4	463.9	712.3	201		Q-7	545.5	689.9	2993.8	1000	1500	75	32	120	12	2	200
14	Outer wall 2 Base	End span Load	Positive BM-Max	Wall/Column	501		S-3	529.6	459.4	665.3	501		Q-3	509.7	233.5	1616.0	1000	1500	75	32	120	12	2	200
15	Outer wall 2 Base	End span Load	Positive BM-Max	Wall/Column	501		S-4	580.3	454.2	609.0	501		Q-4	519.9	232.4	1627.3	1000	1500	75	32	120	12	2	200
16	Outer wall 2 Base	Center span load	Positive BM-Max	Wall/Column	501		S-5	514.5	446.8	530.5	501		Q-5	506.7	230.9	1643.0	1000	1500	75	32	120	12	2	200
17	Inner wall Base	End span Load	Positive BM	Wall/Column	301		S-3	763.9	7.1	75.5	301		Q-3	655.6	84.1	828.6	1000	800	75	25	125	12	2	200
18	Inner wall Base	End span Load	Positive BM-Max	Wall/Column	301		S-4	685.1	6.9	73.6	301		Q-4	639.9	84.0	828.2	1000	800	75	25	125	12	2	200
19	Inner wall Base	Center span load	Positive BM	Wall/Column	301		S-7	777.1	6.2	66.0	301		Q-7	658.3	83.9	826.7	1000	800	75	25	125	12	2	200

6 Section Check and Rebar Computed for Top and Bottom Slab

1 Top slab at Center/Carriageway - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1100	75	25	125	1013

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-149.3	-2.6	468.5	-45.6	-12.6	363.0

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(468.5 \times 1000 \times 1000) / (1.326 \times 1000)\} = 594 \text{ mm}$
	594 < d = 1013 mm, OK
Seismic =	$= \text{SQRT}\{(363.0 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 427 \text{ mm}$
	427 < d = 1013 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1100 mm
Effective depth of member: d	$= 1100 - 75 - 1/2 \times 25 =$	1013 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= 468.5 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) =$	2137 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= 363.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) / 1.5 =$	1103 mm ²

Actual area of steel provided:
 Used re-bar diameter = 25 mm
 Area of re-bar: Ar = 490.9 mm²
 Used re-bar spacing: s = 125 mm
 $A_s = B/s \times Ar = 1,000/125 \times 490.9 = 3927 \text{ mm}^2$
 At Service **3927 > 2137 mm², OK**
 At Seismic **3927 > 1103 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0039} = 3927 / (1000 \times 1013)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

0.12 < 0.39 < 4.0 %, OK

IRC 21: 2000 - 303.4

$s_{\max} = 150 \text{ mm}$
 Provided Spacing, S provided = 125 mm

Using	25 mm ϕ.	125 mm max. center to center spacing	OK
--------------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static $V_u = 2.6 \text{ kN}$
Seismic $V_{ue} = 12.6 \text{ kN}$
Seismic(S) $V_u(e) = 12.6/1.5 = 8.4 \text{ kN}$

Seismic(S) $V_u = 8.4 \text{ KN}$
 $B = 1000 \text{ mm}$
 $d = 33 \text{ mm}$

Shear Stress $\tau_v \quad \tau_v = V_u/Bd = (8.4 \times 1000) / (1000 \times 33) = 0.255 \text{ MPa}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0039 \times 100 = 0.390 \%$

Design Axial Force

Seismic(S) $P_u = 149.3 \text{ kN}$
 $f_{ck} = 30 \text{ MPa}$
 $H = 1100 \text{ mm}$

$A_g = B \times H = 1000 \times 1100 = 1E+06 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.275 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor, $d = 1 + 5P / (A_g \times f_{ck})$
 $= 1 + (5 \times 149.3 \times 1000) / (1100000 \times 30) = 1.02$

1.02 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = $0.275 \times 1.02 = 0.281$ MPa
Seismic(S) **$\tau_c = 0.281 > 0.255$ N/mm², OK**
Not Req. Stirrup
 Permissible Shear Stress in Concrete = **0.275** MPa

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.390 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.390	0.275
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups not required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = $0.255 - 0.281 = -0.026$ MPa
 $V_{us} = (V - \tau_c \times b \times d) = -0.026 \times 1000 \times 1013 / 1000 = -26.3$ kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

$\emptyset v V_s$ required = -26.3 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = $113.1 \times 2 \times 500 \times 205 / (-26.3 \times 1000) = -881.58$ mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1013.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual $V_s = (113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9$ kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y) = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6$ mm²
 A_v provided = $2 \times 113.1 = 226.2$ mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 $A_{vmin} = 221.6$ mm²
 A_v , provided = $2 \times 113.1 = 226.2$ mm²
 $226.2 > 221.6$ mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

2 Top slab at Center/Footpath - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1100	75	25	125	1013

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-148.0	-6.7	568.3	-148.0	-6.7	568.3

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(568.3 \times 1000 \times 1000) / (1.326 \times 1000)\} = 655 \text{ mm}$
	655 < d = 1013 mm, OK
Seismic =	$= \text{SQRT}\{(568.3 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 535 \text{ mm}$
	535 < d = 1013 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1100 mm
Effective depth of member: d	$= 1100 - 75 - 1/2 \times 25 =$	1013 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= 568.3 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) =$	2592 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= 568.3 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) / 1.5 =$	1728 mm ²

Actual area of steel provided:

Used re-bar diameter	=	25 mm
Area of re-bar: Ar	Ar =	490.9 mm ²
Used re-bar spacing: s	s =	125 mm
A _s = B/s x Ar	= 1,000/125x490.9 =	3927 mm ²
At Service	3927 > 2592 mm², OK	
At Seismic	3927 > 1728 mm², OK	

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0039} = 3927 / (1000 \times 1013)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.39 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	125 mm

Using	25 mm φ.	125 mm max. center to center spacing	OK
-------	-----------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	6.7 kN
Seismic	V _{ue} =	6.7 kN
Seismic(S)	V _{u(e)} = 6.7/1.5 =	4.5 kN

Seismic(S)	V _u =	4.5 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ _v	τ _v = V _u /Bd	= (4.5x1000)/(1000x33) =	0.136 MPa
Percentage area of tension steel, 100A _{st} /bd		= 0.0039x100 =	0.390 %

Design Axial Force

Seismic(S)	P _u =	148.0 kN
	f _{ck} =	30 MPa
	H =	1100 mm

$$A_g = B \times H$$

$$= 1000 \times 1100 = 1E+06 \text{ mm}^2$$

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete	=	0.275 MPa
--------------------------------------	---	-----------

IRC 21: 2000 - Table 12B

Shear strength increment factor, **d = 1+5P/(A_g x f_{ck})**

$$= 1 + (5 \times 148.0 \times 1000) / (1100000 \times 30) = 1.02$$

1.02 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.275x1.02 = 0.281 MPa
Seismic(S) **$\tau_c = 0.281 > 0.136 \text{ N/mm}^2$, OK**
Not Req. Stirrup
 Permissible Shear Stress in Concrete = **0.275 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.390 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.390	0.275
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups not required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 0.136-0.281 = -0.145 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = -0.145x1000x1013/1000 = -146.9 kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -146.9 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500 \text{ MPa}$
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(-146.9x1000) = -157.83 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1013.0/2, 300) = 300 \text{ mm}$

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415 \text{ MPa}$
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

3 Top slab at Inwall/Carriageway - End span Load - Negative BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1100	75	25	115	1013

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-166.7	331.0	-796.1	-148.4	-370.4	-885.8

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(-796.1 \times 1000 \times 1000) / (1.326 \times 1000)\} = 775 \text{ mm}$
	775 < d = 1013 mm, OK
Seismic =	$= \text{SQRT}\{(-885.8 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 667 \text{ mm}$
	667 < d = 1013 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1100 mm
Effective depth of member: d	$= 1100 - 75 - 1/2 \times 25 =$	1013 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= -796.1 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) =$	3630 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= -885.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) / 1.5 =$	2693 mm ²

Actual area of steel provided:

Used re-bar diameter	=	25 mm
Area of re-bar: Ar	Ar =	490.9 mm ²
Used re-bar spacing: s	s =	115 mm
A _s = B/s x Ar	= 1,000/115x490.9 =	4269 mm ²
At Service	4269 > 3630 mm², OK	
At Seismic	4269 > 2693 mm², OK	

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0042} = 4269 / (1000 \times 1013)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.42 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	115 mm

Using	25 mm φ.	115 mm max. center to center spacing	OK
-------	-----------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	331.0 kN
Seismic	V _{ue} =	370.4 kN
Seismic(S)	V _{u(e)} = 370.4/1.5 =	246.9 kN

Seismic(S)	V _u =	246.9 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ _v	τ _v = V _u /Bd	= (246.9x1000)/(1000x33) =	7.482 MPa
Percentage area of tension steel, 100A _{st} /bd		= 0.0042x100 =	0.420 %

Design Axial Force

Seismic(S)	P _u =	166.7 kN
	f _{ck} =	30 MPa
	H =	1100 mm

$$A_g = B \times H = 1000 \times 1100 = 1E+06 \text{ mm}^2$$

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete	=	0.284 MPa
--------------------------------------	---	-----------

IRC 21: 2000 - Table 12B

Shear strength increment factor, d = 1+5P/(A_g x f_{ck})	= 1+(5x166.7x1000)/(1100000x30) =	1.03
	1.03 < 1.5, OK	Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.284x1.03 = 0.293 MPa
Seismic(S) **t c = 0.293 < 7.482, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.284 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.420 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.420	0.284
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 7.482-0.293 = 7.189 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 7.189x1000x1013/1000 = 7282.5 kN

Provide Shear Reinforcement

ϕV_s required = 7282.5 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) $\sigma_{co} = 205$ MPa
 Spacing Required = 113.1x2x500x205/(7282.5x1000) = 3.18 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1013.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

4 Top slab at Inwall/Footpath - Center span load - Negative BM&Shear-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1100	75	25	115	1013

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-170.0	380.0	-907.8	-153.5	319.2	-961.8

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(-907.8 \times 1000 \times 1000) / (1.326 \times 1000)\} = 827 \text{ mm}$
	827 < d = 1013 mm, OK
Seismic =	$= \text{SQRT}\{(-961.8 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 695 \text{ mm}$
	695 < d = 1013 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1100 mm
Effective depth of member: d	$= 1100 - 75 - 1/2 \times 25 =$	1013 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= -907.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) =$	4140 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= -961.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1013) / 1.5 =$	2924 mm ²

Actual area of steel provided:

Used re-bar diameter	=	25 mm
Area of re-bar: Ar	Ar =	490.9 mm ²
Used re-bar spacing: s	s =	115 mm
A _s = B/s x Ar	= 1,000/115x490.9 =	4269 mm ²
At Service	4269 > 4140 mm², OK	
At Seismic	4269 > 2924 mm², OK	

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0042} = 4269 / (1000 \times 1013)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.42 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	115 mm

Using	25 mm ϕ.	115 mm max. center to center spacing	OK
-------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	380.0 kN
Seismic	V _{ue} =	319.2 kN
Seismic(S)	V _{u(e)} = 319.2/1.5 =	212.8 kN

Seismic(S)	V _u =	212.8 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ_v $\tau_v = V_u / Bd$ = (212.8x1000)/(1000x33) = **6.448 MPa**

Percentage area of tension steel, 100A_{st}/bd = 0.0042x100 = **0.420 %**

Design Axial Force

Seismic(S)	P _u =	170.0 kN
	f _{ck} =	30 MPa
	H =	1100 mm

A_g = B x H = 1000x1100 = **1E+06 mm²**

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = **0.284 MPa**

IRC 21: 2000 - Table 12B

Shear strength increment factor, **d = 1+5P/(A_g x f_{ck})**

= 1+(5x170.0x1000)/(1100000x30) = **1.03**

1.03 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.284x1.03 = 0.293 MPa
Seismic(S) **t c = 0.293 < 6.448, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.284 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.420 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.420	0.284
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 6.448-0.293 = 6.155 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 6.155x1000x1013/1000 = 6235 KN

Provide Shear Reinforcement

ϕV_s required = 6235.0 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) $\sigma_{co} = 205$ MPa
 Spacing Required = 113.1x2x500x205/(6235.0x1000) = 3.72 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1013.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

5 Bottom slab at Outwall - End span load - Negative B-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-473.4	386.9	1083.0	-691.8	500.5	3080.3

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	f _y =	500 MPa
Permissible flexural tensile stress	σ _{st} =	240 MPa
Permissible direct compressive stress	σ _{so} =	205 MPa

Concrete Grade

Permissible compressive stress	f _{ck} =	30.0 MPa
Permissible direct compressive stress	σ _{co} =	7.5 MPa
Permissible flexural compressive stress	σ _c =	10.0 MPa
Basic permissible tensile stress	σ _t =	0.67 MPa
Maximum permissible shear stress	τ _{max} =	2.2 MPa

Design of Data:

Modular ratio	m =	10
Neutral axis depth factor, n = (mσ _c)/(mσ _c +σ _{st})	n =	10 x 10 / (10 x 10 + 240) = 0.294
Lever arm factor	j = (1-n/3) =	1 - 0.294 / 3 = 0.902
Moment of resistance coefficient	R = 1/2 x n x j x σ _c	
	= 1/2 x 0.294 x 0.902 x 10 =	1.326 MPa

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = SQRT {M/(RxB)}	
Service =	= SQRT {(1,083.0x1000x1000)/(1.326x1000)} = 904 mm
	904 < d = 1509 mm, OK
Seismic =	= SQRT {(3,080.3x1000x1000)/(1.5x1.326x1000)} = 1244 mm
	1,244 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	=	1600 mm
Effective depth of member: d	= 1600-75-1/2x32 =	1509 mm
Service: Area of tension reinforcement req. = M _u /(σ _{st} x j x d)		
Seismic	= 1083.0x1000x1000/(240x0.902x1509) =	3315 mm ²
Seismic: Area of tension reinforcement req. = M _{ue} /(σ _{st} x j x d)/1.5		
Seismic	= 3,080.3x1000x1000/(240x0.902x1509)/1.5 =	6286 mm ²

Actual area of steel provided:

Used re-bar diameter	=	32 mm
Area of re-bar: Ar	Ar =	804.2 mm ²
Used re-bar spacing: s	s =	125 mm
$A_s = B/s \times Ar$	$= 1,000/125 \times 804.2 =$	6434 mm ²
	At Service	6434 > 3315 mm², OK
	At Seismic	6434 > 6286 mm², OK

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{min} = \boxed{0.0012}$$

$$\rho_{max} = 4\% \text{ of } b_t \times d$$

$$\rho_{max} = \boxed{0.0400}$$

$$\rho_{use} = \boxed{0.0043} = 6434 / (1000 \times 1509)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.43 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	125 mm

Using 32 mm ϕ . 125 mm max. center to center spacing OK

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	386.9 kN
Seismic	V _{ue} =	500.5 kN
Seismic(S)	V _{u(e)} = 500.5/1.5 =	333.7 kN

Seismic(S)	V _u =	333.7 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ_v $\tau_v = V_u / Bd$ $= (333.7 \times 1000) / (1000 \times 33) =$ **10.112 MPa**

Percentage area of tension steel, $100A_{st}/bd$ $= 0.0043 \times 100 =$ **0.430 %**

Design Axial Force

Seismic(S)	P _u =	473.4 kN
	$f_{ck} =$	30 MPa
	H =	1600 mm

$A_g = B \times H$ $= 1000 \times 1600 =$ **2E+06 mm²**

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete $=$ **0.288 MPa**

IRC 21: 2000 - Table 12B

Shear strength increment factor, $d = 1 + 5P / (A_g \times f_{ck})$

$= 1 + (5 \times 473.4 \times 1000) / (1600000 \times 30) =$ **1.05**

1.05 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **t c = 0.302 < 10.112, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 10.112-0.302 = 9.810 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 9.810x1000x1509/1000 = 14803 KN

Provide Shear Reinforcement

ϕV_s required = 14803.3 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(14803.3x1000) = 1.57 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

6 Bottom slab at Side span center - End span load - Positive B-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-473.4	272.1	756.3	-691.8	432.8	2638.7

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	f _y =	500 MPa
Permissible flexural tensile stress	σ _{st} =	240 MPa
Permissible direct compressive stress	σ _{so} =	205 MPa

Concrete Grade

Permissible compressive stress	f _{ck} =	30.0 MPa
Permissible direct compressive stress	σ _{co} =	7.5 MPa
Permissible flexural compressive stress	σ _c =	10.0 MPa
Basic permissible tensile stress	σ _t =	0.67 MPa
Maximum permissible shear stress	τ _{max} =	2.2 MPa

Design of Data:

Modular ratio	m =	10
Neutral axis depth factor, n = (mσ _c)/(mσ _c +σ _{st})	n =	10 x 10 / (10 x 10 + 240) = 0.294
Lever arm factor	j = (1-n/3) =	1 - 0.294 / 3 = 0.902
Moment of resistance coefficient	R = 1/2 x n x j x σ _c	
	= 1/2 x 0.294 x 0.902 x 10 =	1.326 MPa

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = SQRT {M/(RxB)}	
Service =	= SQRT {(756.3x1000x1000)/(1.326x1000)} = 755 mm
	755 < d = 1509 mm, OK
Seismic =	= SQRT {(2,638.7x1000x1000)/(1.5x1.326x1000)} = 1152 mm
	1,152 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	=	1600 mm
Effective depth of member: d	= 1600-75-1/2x32 =	1509 mm
Service: Area of tension reinforcement req. = M _u /(σ _{st} x j x d)		
Seismic	= 756.3x1000x1000/(240x0.902x1509) =	2315 mm ²
Seismic: Area of tension reinforcement req. = M _{ue} /(σ _{st} x j x d)/1.5		
Seismic	= 2,638.7x1000x1000/(240x0.902x1509)/1.5 =	5385 mm ²

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **t c = 0.302 < 8.745, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 8.745-0.302 = 8.443 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 8.443x1000x1509/1000 = 12741 KN

Provide Shear Reinforcement

ϕV_s required = 12740.5 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(12740.5x1000) = 1.82 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

7 Bottom slab at Side span center - End span load - Shear Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-474.6	369.6	108.5	-691.3	520.6	1672.4

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	f _y =	500 MPa
Permissible flexural tensile stress	σ _{st} =	240 MPa
Permissible direct compressive stress	σ _{so} =	205 MPa

Concrete Grade

Permissible compressive stress	f _{ck} =	30.0 MPa
Permissible direct compressive stress	σ _{co} =	7.5 MPa
Permissible flexural compressive stress	σ _c =	10.0 MPa
Basic permissible tensile stress	σ _t =	0.67 MPa
Maximum permissible shear stress	τ _{max} =	2.2 MPa

Design of Data:

Modular ratio	m =	10
Neutral axis depth factor, n = (mσ _c)/(mσ _c +σ _{st})	n =	10 x 10 / (10 x 10 + 240) = 0.294
Lever arm factor	j = (1-n/3) =	1 - 0.294 / 3 = 0.902
Moment of resistance coefficient	R = 1/2 x n x j x σ _c	
	= 1/2 x 0.294 x 0.902 x 10 =	1.326 MPa

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = SQRT {M/(RxB)}	
Service =	= SQRT {(108.5x1000x1000)/(1.326x1000)} = 286 mm
	286 < d = 1509 mm, OK
Seismic =	= SQRT {(1,672.4x1000x1000)/(1.5x1.326x1000)} = 917 mm
	917 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	=	1600 mm
Effective depth of member: d	= 1600-75-1/2x32 =	1509 mm
Service: Area of tension reinforcement req. = M _u /(σ _{st} x j x d)		
Seismic	= 108.5x1000x1000/(240x0.902x1509) =	332 mm ²
Seismic: Area of tension reinforcement req. = M _{ue} /(σ _{st} x j x d)/1.5		
Seismic	= 1,672.4x1000x1000/(240x0.902x1509)/1.5 =	3413 mm ²

Actual area of steel provided:

Used re-bar diameter	=	32 mm
Area of re-bar: Ar	Ar =	804.2 mm ²
Used re-bar spacing: s	s =	125 mm
A _s = B/s x Ar	= 1,000/125x804.2 =	6434 mm ²
	At Service	6434 > 332 mm², OK
	At Seismic	6434 > 3413 mm², OK

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0043} = 6434 / (1000 \times 1509)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.43 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	125 mm

Using	32 mm φ.	125 mm max. center to center spacing	OK
-------	-----------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	369.6 kN
Seismic	V _{ue} =	520.6 kN
Seismic(S)	V _{u(e)} = 520.6/1.5 =	347.1 kN

Seismic(S)	V _u =	347.1 KN
	B =	1000 mm
	d =	33 mm

Shear Stress τ_v $\tau_v = V_u / Bd$ = (347.1x1000)/(1000x33) = **10.518 MPa**

Percentage area of tension steel, 100A_{st}/bd = 0.0043x100 = **0.430 %**

Design Axial Force

Seismic(S)	P _u =	474.6 kN
	f _{ck} =	30 MPa
	H =	1600 mm

A_g = B x H = 1000x1600 = **2E+06 mm²**

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = **0.288 MPa**

IRC 21: 2000 - Table 12B

Shear strength increment factor, **d = 1+5P/(A_g x f_{ck})**

= 1+(5x474.6x1000)/(1600000x30) = **1.05**

1.05 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **t c = 0.302 < 10.518, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 10.518-0.302 = 10.216 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 10.216x1000x1509/1000 = 15416 KN

Provide Shear Reinforcement

ϕV_s required = 15415.9 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(15415.9x1000) = 1.50 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

8 Bottom slab at Inwall - End span load - Negative BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-467.1	434.0	1073.4	-772.4	483.8	1492.1

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	f _y =	500 MPa
Permissible flexural tensile stress	σ _{st} =	240 MPa
Permissible direct compressive stress	σ _{so} =	205 MPa

Concrete Grade

Permissible compressive stress	f _{ck} =	30.0 MPa
Permissible direct compressive stress	σ _{co} =	7.5 MPa
Permissible flexural compressive stress	σ _c =	10.0 MPa
Basic permissible tensile stress	σ _t =	0.67 MPa
Maximum permissible shear stress	τ _{max} =	2.2 MPa

Design of Data:

Modular ratio	m =	10
Neutral axis depth factor, n = (mσ _c)/(mσ _c +σ _{st})	n =	10 x 10 / (10 x 10 + 240) = 0.294
Lever arm factor	j = (1-n/3) =	1 - 0.294 / 3 = 0.902
Moment of resistance coefficient	R = 1/2 x n x j x σ _c	
	= 1/2 x 0.294 x 0.902 x 10 =	1.326 MPa

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = SQRT {M/(RxB)}	
Service =	= SQRT {(1,073.4x1000x1000)/(1.326x1000)} = 900 mm
	900 < d = 1509 mm, OK
Seismic =	= SQRT {(1,492.1x1000x1000)/(1.5x1.326x1000)} = 866 mm
	866 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	=	1600 mm
Effective depth of member: d	= 1600-75-1/2x32 =	1509 mm
Service: Area of tension reinforcement req. = M _u /(σ _{st} x j x d)		
Seismic	= 1073.4x1000x1000/(240x0.902x1509) =	3286 mm ²
Seismic: Area of tension reinforcement req. = M _{ue} /(σ _{st} x j x d)/1.5		
Seismic	= 1,492.1x1000x1000/(240x0.902x1509)/1.5 =	3045 mm ²

Actual area of steel provided:

Used re-bar diameter	=	32 mm
Area of re-bar: Ar	Ar =	804.2 mm ²
Used re-bar spacing: s	s =	125 mm
A _s = B/s x Ar	= 1,000/125x804.2 =	6434 mm ²
	At Service	6434 > 3286 mm², OK
	At Seismic	6434 > 3045 mm², OK

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0043} = 6434 / (1000 \times 1509)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.43 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	125 mm

Using	32 mm φ.	125 mm max. center to center spacing	OK
-------	-----------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	434.0 kN
Seismic	V _{ue} =	483.8 kN
Seismic(S)	V _{u(e)} = 483.8/1.5 =	322.5 kN

Seismic(S)	V _u =	322.5 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ_v $\tau_v = V_u / B d$ = (322.5x1000)/(1000x33) = **9.773 MPa**

Percentage area of tension steel, 100A_{st}/bd = 0.0043x100 = **0.430 %**

Design Axial Force

Seismic(S)	P _u =	467.1 kN
	f _{ck} =	30 MPa
	H =	1600 mm

A_g = B x H = 1000x1600 = **2E+06 mm²**

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = **0.288 MPa**

IRC 21: 2000 - Table 12B

Shear strength increment factor, **d = 1+5P/(A_g x f_{ck})**

= 1+(5x467.1x1000)/(1600000x30) = **1.05**

1.05 < 1.5, OK Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **t c = 0.302 < 9.773, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 9.773-0.302 = 9.471 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 9.471x1000x1509/1000 = 14292 KN

Provide Shear Reinforcement

ϕV_s required = 14291.7 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(14291.7x1000) = 1.62 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

9 Bottom slab at center - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-480.7	-50.7	-754.8	-775.1	12.7	-630.8

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(-754.8 \times 1000 \times 1000) / (1.326 \times 1000)\} = 755 \text{ mm}$
	755 < d = 1509 mm, OK
Seismic =	$= \text{SQRT}\{(-630.8 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 563 \text{ mm}$
	563 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1600 mm
Effective depth of member: d	$= 1600 - 75 - 1/2 \times 32 =$	1509 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= -754.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1509) =$	2311 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= -630.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1509) / 1.5 =$	1287 mm ²

Actual area of steel provided:

Used re-bar diameter	=	32 mm
Area of re-bar: Ar	=	804.2 mm ²
Used re-bar spacing: s	=	125 mm
A _s = B/s x Ar	=	1,000/125x804.2 = 6434 mm ²
	At Service	6434 > 2311 mm², OK
	At Seismic	6434 > 1287 mm², OK

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0043} = 6434 / (1000 \times 1509)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.43 < 4.0 %, OK

S _{max}	=	150 mm
Provided Spacing, S provided	=	125 mm

Using 32 mm φ. 125 mm max. center to center spacing OK

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static	V _u =	50.7 kN
Seismic	V _{ue} =	12.7 kN
Seismic(S)	V _{u(e)} = 12.7/1.5 =	8.5 kN

Seismic(S)	V _u =	8.5 kN
	B =	1000 mm
	d =	33 mm

Shear Stress τ _v	τ _v = V _u /Bd				
Percentage area of tension steel, 100A _{st} /bd	= (8.5x1000)/(1000x33) =	0.258 MPa	= 0.0043x100 =	0.430 %	

Design Axial Force

Seismic(S)	P _u =	480.7 kN
	f _{ck} =	30 MPa
	H =	1600 mm
	A _g = B x H	= 1000x1600 = 2E+06 mm ²

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete	=	0.288 MPa
--------------------------------------	---	-----------

IRC 21: 2000 - Table 12B

Shear strength increment factor, d = 1+5P/(A _g x f _{ck})		
	= 1+(5x480.7x1000)/(1600000x30) =	1.05
	1.05 < 1.5, OK	Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **tc = 0.302 > 0.258 N/mm², OK**
Not Req. Stirrup
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups not required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 0.258-0.302 = -0.044 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = -0.044x1000x1509/1000 = -66.4 kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -66.4 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(-66.4x1000) = -349.18 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

6 Section Check and Rebar Computed for Top and Bottom Slab

10 Bottom slab at Inwall2 - End span load - Negative BM-Max

1) Force and Design Condition

B	H	Cover	Re-bar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1600	75	32	125	1509

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-466.5	372.4	1018.1	-848.1	481.3	994.1

Section Specification and Design Assumption

Reinforcing Bar Grade

Permissible flexural tensile stress	$f_y =$	500 MPa
Permissible flexural tensile stress	$\sigma_{st} =$	240 MPa
Permissible direct compressive stress	$\sigma_{so} =$	205 MPa

Concrete Grade

Permissible compressive stress	$f_{ck} =$	30.0 MPa
Permissible direct compressive stress	$\sigma_{co} =$	7.5 MPa
Permissible flexural compressive stress	$\sigma_c =$	10.0 MPa
Basic permissible tensile stress	$\sigma_t =$	0.67 MPa
Maximum permissible shear stress	$\tau_{max} =$	2.2 MPa

Design of Data:

Modular ratio	$m =$	10
Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$	$n =$	$10 \times 10 / (10 \times 10 + 240) = 0.294$
Lever arm factor	$j = (1 - n/3) =$	$1 - 0.294 / 3 = 0.902$
Moment of resistance coefficient	$R = \frac{1}{2} \times n \times j \times \sigma_c$	$= 1/2 \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$

2) Check for Bending Moment (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$	
Service =	$= \text{SQRT}\{(1,018.1 \times 1000 \times 1000) / (1.326 \times 1000)\} = 876 \text{ mm}$
	876 < d = 1509 mm, OK
Seismic =	$= \text{SQRT}\{(994.1 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 707 \text{ mm}$
	707 < d = 1509 mm, OK

Area of reinforcement required,

Overall depth of member	$=$	1600 mm
Effective depth of member: d	$= 1600 - 75 - 1/2 \times 32 =$	1509 mm
Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$		
Seismic	$= 1018.1 \times 1000 \times 1000 / (240 \times 0.902 \times 1509) =$	3117 mm ²
Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$		
Seismic	$= 994.1 \times 1000 \times 1000 / (240 \times 0.902 \times 1509) / 1.5 =$	2029 mm ²

Design shear strength of concrete, τ_c = 0.288x1.05 = 0.302 MPa
Seismic(S) **t c = 0.302 < 9.724, Not OK**
Stirrups required
 Permissible Shear Stress in Concrete = **0.288 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

100Ast/bd (1)	M-30 (4)	Tension Steel 0.430 %	Design shear Strength of Con. N/mm ²
0.15	0.20		
0.25	0.23	0.430	0.288
0.50	0.31		
0.75	0.37		
1.00	0.41		
1.25	0.45		

Thus Shear stirrups required. IRC 21: 2000 - 304.7.1.4
 Minimum τ_v = 9.724-0.302 = 9.422 MPa
 $V_{us} = (V - \tau_c \times b \times d)$ = 9.422x1000x1509/1000 = 14218 KN

Provide Shear Reinforcement

ϕV_s required = 14217.8 kN
 Dia. of re-bar used = 12 mm
 Area of re-bar = 113.1 mm²
 No. of leg = 2
 $f_y = 500$ MPa
 Permissible Direct Compression stress (σ_{co}) = 205 MPa
 Spacing Required = 113.1x2x500x205/(14217.8x1000) = 1.63 mm
 Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6
 $s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed
 IRC 21: 2000- 304.7.1.5
 $s_{max} = \text{MIN}(1509.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = (113.1x2x205x1000/200)/1000 = 231.9 kN
 $f_y \leq 415$ MPa
 $A_{vmin} = 0.4 \cdot b \cdot s / (0.87 \cdot f_y)$
 = 0.4x1000x200/(0.87x415) = 221.6 mm²
 A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm
 Dia. of re-bar Used = 12 mm
 Area of Bar = 113.1 mm²
 No. of Leg = 2 nos.
 A_{vmin} = 221.6 mm²
 A_v , provided = 2x113.1 = 226.2 mm²
226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

7 Section Check and Rebar Computed for Wall (Column)

11 Outer wall Base - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-602.1	473.4	813.5	-562.7	691.8	3014.0

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(813.5 \times 1000 \times 1000) / (1.326 \times 1000)\} = 783 \text{ mm}$

783 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(3,014.0 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 1231 \text{ mm}$

1,231 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $813.5 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 2667 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $3,014.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 6588 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 2667 mm², OK**
 At Seismic **6702 > 6588 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.48 < 4.0 %, OK

s_{max} = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm φ.	120 mm max. center to center spacing	OK
--------------	-----------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 473.4 kN
Seismic V_{ue} = 691.8 kN
Seismic(S) Vu(e) = 691.8/1.5 = 461.2 kN

Seismic(S) Vu = **461.2 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = V_u/Bd = (461.2 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.327 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) P_u = 602.1 kN
 f_{ck} = 30 MPa
 H = 1500 mm

$A_g = B \times H = 1,000 \times 1,500 = 2E+06 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 602.1 \times 1000)/(1500000 \times 30) = 1.07$

1.07 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, $\tau_c = 0.304 \times 1.07 = 0.325 \text{ MPa}$

Seismic(S) $\tau_c = 0.325 < 0.327, \text{ Not OK}$

Stirrups required

Permissible Shear Stress in Concrete = **0.304 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups required.

IRC 21: 2000 - 304.7.1.4

Minimum $\tau_v = 0.327 - 0.325 = 0.002 \text{ MPa}$

$V_{us} = (V - \tau_c \times b \times d) = 0.002 \times 1000 \times 1,409.0 / 1000 = 2.82 \text{ kN}$

Provide Shear Reinforcement

ϕV_s required = 2.82 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500 \text{ MPa}$

Permissible Direct Comp. stress (σ_{co}) = 205 MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (2.82 \times 1000) = 8221.81 \text{ mm}$

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300 \text{ mm}$

OK, Stirrup spacing less than maximum allowed

Actual $V_s = (113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9 \text{ kN}$
 $f_y \leq 415 \text{ MPa}$

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$

$A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6 \text{ mm}^2$

A_v provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ = 221.6 mm²

A_v , provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	602.1 kN
	Moment, Mue	Mue =	813.5 kN-m
	Eccentricity, e	$e = 813.5/602.1 =$	1.35 m
Seismic	Axial Thrust, Pu at Middle	=	562.7 kN
	Moment, Mue	Mue =	3014.0 kN-m
	Eccentricity, e	$e = 3,014.0/562.7 =$	5.36 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000 / (1,500/2) =$	5E+08 mm ³
Therefore, direct stress, σ_{co} , cal	$\sigma_{co} = 602.1 \times 1000 / 1,687,200 =$	0.35 MPa
Bending compressive stress, σ_c , cal	$\sigma_c = 813.5 \times 10^6 / 506,712,000 =$	1.60 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.35 / (1.5 \times 10.0) + 1.60 / (1.5 \times 7.5) = 0.17$$

0.17 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.60 - 0.35 = 1.25 \text{ MPa}$$

$$= 0.25 \times (1.60 + 0.350) = 0.49 \text{ MPa}$$

1.25 > 0.49 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.60 - 0.35 = 1.25 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{1.25 < 3.45 \text{ N/mm}^2, \text{OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.60 + 0.35 = 1.95 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.95 < 15.0 \text{ N/mm}^2, \text{OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\text{Pitch of lateral tie} < \text{least lateral dimension of column} = 1500 \text{ mm}$$

$$< 12 \times \text{dia of smallest longitudinal bar} = 12 \times 32 = 384 \text{ mm etc.}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

12 Outer wall Base - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-529.2	472.3	802.0	-548.1	691.5	3011.7

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(802.0 \times 1000 \times 1000) / (1.326 \times 1000)\} = 778 \text{ mm}$

778 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(3,011.7 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 1231 \text{ mm}$

1,231 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $802.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 2629 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $3,011.7 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 6583 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 2629 mm², OK**
 At Seismic **6702 > 6583 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.48 < 4.0 %, OK

s_{max} = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm ϕ .	120 mm max. center to center spacing	OK
-------	----------------	--------------------------------------	----

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 472.3 kN
Seismic Vu(e) = 691.5 kN
Seismic(S) Vu(e) = 691.5/1.5 = 461.0 kN

Seismic(S) Vu = **461.0 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = V_u/Bd = (461.0 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.327 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) Pu = 529.2 kN
 f_{ck} = 30 MPa
 H = 1500 mm

$A_g = B \times H = 1,000 \times 1,500 = 2E+06 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 529.2 \times 1000)/(1500000 \times 30) = 1.06$

1.06 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, $\tau_c = 0.304 \times 1.06 = 0.322 \text{ MPa}$

Seismic(S) $\tau_c = 0.322 < 0.327, \text{ Not OK}$

Stirrups required

Permissible Shear Stress in Concrete = **0.304 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups required.

IRC 21: 2000 - 304.7.1.4

Minimum $\tau_v = 0.327 - 0.322 = 0.005 \text{ MPa}$

$V_{us} = (V - \tau_c \times b \times d) = 0.005 \times 1000 \times 1,409.0 / 1000 = 7.05 \text{ kN}$

Provide Shear Reinforcement

ϕV_s required = 7.05 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500 \text{ MPa}$

Permissible Direct Comp. stress (σ_{co}) = 205 MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (7.05 \times 1000) = 3288.72 \text{ mm}$

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300 \text{ mm}$

OK, Stirrup spacing less than maximum allowed

Actual $V_s = (113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9 \text{ kN}$
 $f_y \leq 415 \text{ MPa}$

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$
 $A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6 \text{ mm}^2$

A_v provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ = 221.6 mm²

A_v , provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	529.2 kN
	Moment, Mue	Mue =	802.0 kN-m
	Eccentricity, e	$e = 802.0/529.2 =$	1.52 m
Seismic	Axial Thrust, Pu at Middle	=	548.1 kN
	Moment, Mue	Mue =	3011.7 kN-m
	Eccentricity, e	$e = 3,011.7/548.1 =$	5.49 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000 / (1,500/2) =$	5E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 529.2 \times 1000 / 1,687,200 =$	0.31 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 802.0 \times 10^6 / 506,712,000 =$	1.58 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.31 / (1.5 \times 10.0) + 1.58 / (1.5 \times 7.5) = 0.17$$

0.17 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.58 - 0.31 = 1.27 \text{ MPa}$$

$$= 0.25 \times (1.58 + 0.310) = 0.47 \text{ MPa}$$

1.27 > 0.47 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.58 - 0.31 = 1.27 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\quad \mathbf{1.27 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.58 + 0.31 = 1.89 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\quad \mathbf{1.89 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\text{Pitch of lateral tie} < \text{least lateral dimension of column} = 1500 \text{ mm}$$

$$< 12 \times \text{dia of smallest longitudinal bar} = 12 \times 32 = 384 \text{ mm etc.}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

13 Outer wall Base - Center span load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-516.4	463.9	712.3	-545.5	689.9	2993.8

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(712.3 \times 1000 \times 1000) / (1.326 \times 1000)\} = 733 \text{ mm}$

733 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(2,993.8 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 1227 \text{ mm}$

1,227 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $712.3 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 2335 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $2,993.8 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 6543 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 2335 mm², OK**
 At Seismic **6702 > 6543 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK
GOOD for Maximum Ratio, OK
0.12 < 0.48 < 4.0 %, OK

IRC 21: 2000 - 303.4

smax = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm ϕ.	120 mm max. center to center spacing	OK
--------------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 463.9 kN
Seismic V_{ue} = 689.9 kN
Seismic(S) Vu(e) = 689.9/1.5 = 459.9 kN

Seismic(S) Vu = **459.9 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = V_u/Bd = (459.9 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.326 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) P_u = 516.4 kN
 f_{ck} = 30 MPa
 H = 1500 mm
 $A_g = B \times H = 1,000 \times 1,500 = 2E+06 \text{ mm}^2$

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 516.4 \times 1000)/(1500000 \times 30) = 1.06$

1.06 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, $\tau_c = 0.304 \times 1.06 = 0.322 \text{ MPa}$

Seismic(S) $\tau_c = 0.322 < 0.326, \text{ Not OK}$

Stirrups required

Permissible Shear Stress in Concrete = **0.304 MPa**

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups required.

IRC 21: 2000 - 304.7.1.4

Minimum $\tau_v = 0.326 - 0.322 = 0.004 \text{ MPa}$

$V_{us} = (V - \tau_c \times b \times d) = 0.004 \times 1000 \times 1,409.0 / 1000 = 5.64 \text{ kN}$

Provide Shear Reinforcement

ϕV_s required = 5.64 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500 \text{ MPa}$

Permissible Direct Comp. stress (σ_{co}) = 205 MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (5.64 \times 1000) = 4110.90 \text{ mm}$

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300 \text{ mm}$

OK, Stirrup spacing less than maximum allowed

Actual $V_s = (113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9 \text{ kN}$
 $f_y \leq 415 \text{ MPa}$

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$
 $A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6 \text{ mm}^2$

A_v provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ = 221.6 mm²

A_v , provided = $2 \times 113.1 = 226.2 \text{ mm}^2$

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	516.4 kN
	Moment, Mue	Mue =	712.3 kN-m
	Eccentricity, e	$e = 712.3/516.4 =$	1.38 m
Seismic	Axial Thrust, Pu at Middle	=	545.5 kN
	Moment, Mue	Mue =	2993.8 kN-m
	Eccentricity, e	$e = 2,993.8/545.5 =$	5.49 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000 / (1,500/2) =$	5E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 516.4 \times 1000 / 1,687,200 =$	0.30 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 712.3 \times 10^6 / 506,712,000 =$	1.40 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.30 / (1.5 \times 10.0) + 1.40 / (1.5 \times 7.5) = 0.15$$

0.15 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.40 - 0.30 = 1.10 \text{ MPa}$$

$$= 0.25 \times (1.40 + 0.30) = 0.43 \text{ MPa}$$

1.10 > 0.43 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.40 - 0.30 = 1.10 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{1.10 < 3.45 \text{ N/mm}^2, \text{OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.40 + 0.30 = 1.70 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.70 < 15.0 \text{ N/mm}^2, \text{OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pitch of lateral tie} &< \text{least lateral dimension of column} = 1500 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 < 12 \times \text{dia of smallest longitudinal bar} &= 12 \times 32 = 384 \text{ mm etc.}
 \end{aligned}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

14 Outer wall 2 Base - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-529.6	-459.4	-665.3	-509.7	-233.5	1616.0

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(-665.3 \times 1000 \times 1000) / (1.326 \times 1000)\} = 708 \text{ mm}$

708 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(1,616.0 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 901 \text{ mm}$

901 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $-665.3 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 2181 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $1,616.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 3532 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 2181 mm², OK**
 At Seismic **6702 > 3532 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK
GOOD for Maximum Ratio, OK
0.12 < 0.48 < 4.0 %, OK

IRC 21: 2000 - 303.4

smax = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm ϕ .	120 mm max. center to center spacing	OK
-------	----------------	--------------------------------------	----

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 459.4 kN
Seismic Vue = 233.5 kN
Seismic(S) Vu(e) = 233.5/1.5 = 155.6 kN

Seismic(S) Vu = **155.6 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = Vu/Bd = (155.6 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.110 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) Pu = 529.6 kN
 f_{ck} = 30 MPa
 H = 1500 mm

$A_g = B \times H = 1,000 \times 1,500 = 2E+06 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 529.6 \times 1000)/(1500000 \times 30) = 1.06$

1.06 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, τ_c = $0.304 \times 1.06 = 0.322$ MPa
Seismic(S) **tc= 0.322 > 0.110 N/mm², OK**

Permissible Shear Stress in Concrete = **0.304** MPa
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = $0.110 - 0.322 = -0.212$ MPa

$V_{us} = (V - \tau_c \times b \times d) = -0.212 \times 1000 \times 1,409.0 / 1000 = -298.71$ kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -298.71 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500$ MPa

Permissible Direct Comp. stress (σ_{co}) = 205 MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (-298.71 \times 1000) = -77.62$ mm

Used Spacing, $s = 200$ mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = $(113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$

$A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6$ mm²

A_v provided = $2 \times 113.1 = 226.2$ mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, $s = 200$ mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min} = 221.6$ mm²

A_v , provided = $2 \times 113.1 = 226.2$ mm²

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	529.6 kN
	Moment, Mue	Mue =	665.3 kN-m
	Eccentricity, e	$e = 665.3/529.6 =$	1.26 m
Seismic	Axial Thrust, Pu at Middle	=	509.7 kN
	Moment, Mue	Mue =	1616.0 kN-m
	Eccentricity, e	$e = 1,616.0/509.7 =$	3.17 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000/(1,500/2) =$	5E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 529.6 \times 1000/1,687,200 =$	0.31 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 665.3 \times 10^6/506,712,000 =$	1.31 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.31/(1.5 \times 10.0) + 1.31/(1.5 \times 7.5) = 0.14$$

0.14 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.31 - 0.31 = 1.00 \text{ MPa}$$

$$= 0.25 \times (1.31 + 0.31) = 0.41 \text{ MPa}$$

1.00 > 0.41 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.31 - 0.31 = 1.00 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{1.00 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.31 + 0.31 = 1.62 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.62 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pitch of lateral tie} &< \text{least lateral dimension of column} = 1500 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 < 12 \times \text{dia of smallest longitudinal bar} &= 12 \times 32 = 384 \text{ mm etc.}
 \end{aligned}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

15 Outer wall 2 Base - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-580.3	-454.2	-609.0	-519.9	-232.4	1627.3

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(-609.0 \times 1000 \times 1000) / (1.326 \times 1000)\} = 678 \text{ mm}$

678 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(1,627.3 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 905 \text{ mm}$

905 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $-609.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 1997 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $1,627.3 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 3557 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 1997 mm², OK**
 At Seismic **6702 > 3557 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.48 < 4.0 %, OK

s_{max} = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm ϕ .	120 mm max. center to center spacing	OK
-------	----------------	--------------------------------------	----

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 454.2 kN
Seismic Vu(e) = 232.4 kN
Seismic(S) Vu(e) = 232.4/1.5 = 154.9 kN

Seismic(S) Vu = **154.9 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = V_u/Bd = (154.9 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.110 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) Pu = 580.3 kN
 f_{ck} = 30 MPa
 H = 1500 mm
 $A_g = B \times H = 1,000 \times 1,500 = 2E+06 \text{ mm}^2$

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 580.3 \times 1000)/(1500000 \times 30) = 1.06$

1.06 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, τ_c = $0.304 \times 1.06 = 0.322$ MPa
Seismic(S) **tc= 0.322 > 0.110 N/mm², OK**

Permissible Shear Stress in Concrete = **0.304** MPa
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = $0.110 - 0.322 = -0.212$ MPa

$V_{us} = (V - \tau_c \times b \times d) = -0.212 \times 1000 \times 1,409.0 / 1000 = -298.71$ kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -298.71 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500$ MPa

Permissible Direct Comp. stress (σ_{co}) = 205 MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (-298.71 \times 1000) = -77.62$ mm

Used Spacing, $s = 200$ mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s = $(113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$

$A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6$ mm²

A_v provided = $2 \times 113.1 = 226.2$ mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, $s = 200$ mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min} = 221.6$ mm²

A_v , provided = $2 \times 113.1 = 226.2$ mm²

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	580.3 kN
	Moment, Mue	Mue =	609.0 kN-m
	Eccentricity, e	$e = 609.0/580.3 =$	1.05 m
Seismic	Axial Thrust, Pu at Middle	=	519.9 kN
	Moment, Mue	Mue =	1627.3 kN-m
	Eccentricity, e	$e = 1,627.3/519.9 =$	3.13 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000 / (1,500/2) =$	5E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 580.3 \times 1000 / 1,687,200 =$	0.34 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 609.0 \times 10^6 / 506,712,000 =$	1.20 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.34 / (1.5 \times 10.0) + 1.20 / (1.5 \times 7.5) = 0.13$$

0.13 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.20 - 0.34 = 0.86 \text{ MPa}$$

$$= 0.25 \times (1.20 + 0.34) = 0.39 \text{ MPa}$$

0.86 > 0.39 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.20 - 0.34 = 0.86 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{0.86 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.20 + 0.34 = 1.54 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.54 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\text{Pitch of lateral tie} < \text{least lateral dimension of column} = 1500 \text{ mm}$$

$$< 12 \times \text{dia of smallest longitudinal bar} = 12 \times 32 = 384 \text{ mm etc.}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

16 Outer wall 2 Base - Center span load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	1500	75	32	120	1409

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-514.5	-446.8	-530.5	-506.7	-230.9	1643.0

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(-530.5 \times 1000 \times 1000) / (1.326 \times 1000)\} = 633 \text{ mm}$

633 < d = 1409 mm, OK

Seismic = $\text{SQRT}\{(1,643.0 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 909 \text{ mm}$

909 < d = 1409 mm, OK

Area of reinforcement required,

Overall depth of member = 1500 mm

Effective depth of member: $d = 1500 - 75 - 1/2 \times 32 = 1409 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $-530.5 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) = 1739 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $1,643.0 \times 1000 \times 1000 / (240 \times 0.902 \times 1,409.0) / 1.5 = 3591 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 32 mm
 Area of rebar: Ar = 804.2 mm²
 Used rebar spacing: s = 120 mm
 $A_s = B/s \times Ar = 1000/120 \times 804.2 = 6702 \text{ mm}^2$
 At Service **6702 > 1739 mm², OK**
 At Seismic **6702 > 3591 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0048} > 2/(1,000 \times 1,409.0)$$

GOOD for Minimum Ratio, OK
GOOD for Maximum Ratio, OK
0.12 < 0.48 < 4.0 %, OK

IRC 21: 2000 - 303.4

smax = 150 mm
 Provided Spacing, S provided = 120 mm

Using	32 mm ϕ .	120 mm max. center to center spacing	OK
-------	----------------	--------------------------------------	----

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 446.8 kN
Seismic V_{ue} = 230.9 kN
Seismic(S) Vu(e) = 230.9/1.5 = 154.0 kN

Seismic(S) Vu = **154.0 kN**
 B = 1000 mm
 d = 1409.0 mm

Shear Stress $\tau_v = V_u/Bd = (154.0 \times 1000)/(1000 \times 1,409.0) = \mathbf{0.109 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0048 \times 100 = 0.480 \%$

Design Axial Force

Seismic(S) P_u = 514.5 kN
 f_{ck} = 30 MPa
 H = 1500 mm

A_g = B x H = 1,000 x 1,500 = 2E+06 mm²
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.304 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P/(A_g \times f_{ck})$
 $= 1 + (5 \times 514.5 \times 1000)/(1500000 \times 30) = 1.06$

1.06 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, τ_c = $0.304 \times 1.06 = 0.322$ MPa
Seismic(S) **tc= 0.322 > 0.109 N/mm², OK**

Permissible Shear Stress in Concrete = **0.304** MPa
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.480 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23	0.480	0.304
	0.50	0.31		
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = $0.109 - 0.322 = -0.213$ MPa

$V_{us} = (V - \tau_c \times b \times d) = -0.213 \times 1000 \times 1,409.0 / 1000 = -300.12$ kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

$\emptyset v V_s$ required = -300.12 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500$ MPa

Permissible Direct Comp. stress (σ_{co}) $\sigma_{co} = 205$ MPa

Spacing Required = $113.1 \times 2 \times 500 \times 205 / (-300.12 \times 1000) = -77.25$ mm

Used Spacing, $s = 200$ mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(1,409.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s $V_s = (113.1 \times 2 \times 205 \times 1000 / 200) / 1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4 \times b \times s / (0.87 \times f_y)$

$A_{vmin} = 0.4 \times 1000 \times 200 / (0.87 \times 415) = 221.6$ mm²

A_v provided = $2 \times 113.1 = 226.2$ mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, $s = 200$ mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ $A_v = 221.6$ mm²

A_v provided = $2 \times 113.1 = 226.2$ mm²

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	514.5 kN
	Moment, Mue	Mue =	530.5 kN-m
	Eccentricity, e	$e = 530.5/514.5 =$	1.03 m
Seismic	Axial Thrust, Pu at Middle	=	506.7 kN
	Moment, Mue	Mue =	1643.0 kN-m
	Eccentricity, e	$e = 1,643.0/506.7 =$	3.24 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	1.50 m
Ratio of effective length to lateral dimension of pier	$= 10.98/1.50 =$	7.32 m

7.32 < 12 m, Short Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0048 \times 100 \times 2 =$	0.96 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 1.50/100 =$	1.500 m ²
Net area of concrete, Ac	$Ac = (1-0.960/100) \times 1.50/100 =$	1.486 m ²
X-sectional area of steel, As	$As = 0.960 \times 1.500 \times 1000 \times 1000/100 =$	14400 mm ²
Equivalent Area of Concrete	$= 1.49 \times 10^6 + (1.5 \times 10^{-1}) \times 14400 =$	2E+06 mm ²
Equivalent Moment of Inertia	$= 1000 \times 1500^3/12 + (1.5 \times 10^{-1}) \times 14400 (1500/2 - 50)^2 =$	4E+11 mm ⁴
Section modulus, Z	$= 380,034,000,000/(1,500/2) =$	5E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 514.5 \times 1000/1,687,200 =$	0.30 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 530.5 \times 10^6/506,712,000 =$	1.04 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.30/(1.5 \times 10.0) + 1.04/(1.5 \times 7.5) = 0.12$$

0.12 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 1.04 - 0.30 = 0.74 \text{ MPa}$$

$$= 0.25 \times (1.04 + 0.30) = 0.34 \text{ MPa}$$

0.74 > 0.34 N/mm², Not OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 1.04 - 0.30 = 0.74 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\quad \mathbf{0.74 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 1.04 + 0.30 = 1.34 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\quad \mathbf{1.34 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 14400 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 32/4 = 8 \text{ mm}
 \end{aligned}$$

$$\text{Pitch of lateral tie} < \text{least lateral dimension of column} = 1500 \text{ mm}$$

$$< 12 \times \text{dia of smallest longitudinal bar} = 12 \times 32 = 384 \text{ mm etc.}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

17 Inner wall Base - End span Load - Positive BM

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	800	75	25	125	713

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-763.9	7.1	75.5	-655.6	84.1	828.6

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $= \text{SQRT}\{(75.5 \times 1000 \times 1000) / (1.326 \times 1000)\} = 239 \text{ mm}$

239 < d = 713 mm, OK

Seismic = $= \text{SQRT}\{(828.6 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 645 \text{ mm}$

645 < d = 713 mm, OK

Area of reinforcement required,

Overall depth of member = 800 mm

Effective depth of member: $d = 800 - 75 - 1/2 \times 25 = 713 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $= 75.5 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) = 489 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $= 828.6 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) / 1.5 = 3579 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 25 mm
 Area of rebar: Ar = 490.9 mm²
 Used rebar spacing: s = 125 mm
 $A_s = B/s \times Ar = 1000/125 \times 490.9 = 3927 \text{ mm}^2$
 At Service **3927 > 489 mm², OK**
 At Seismic **3927 > 3579 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0055} \times 927 / (1,000 \times 713.0)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.55 < 4.0 %, OK

smax = 150 mm
 Provided Spacing, S provided = 125 mm

Using	25 mm ϕ.	125 mm max. center to center spacing	OK
--------------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 7.1 kN
Seismic Vue = 84.1 kN
Seismic(S) Vu(e) = 84.1/1.5 = 56.1 kN

Seismic(S) Vu = **56.1 kN**
 B = 1000 mm
 d = 713.0 mm

Shear Stress $\tau_v = \tau_v = Vu/Bd = (56.1 \times 1000) / (1000 \times 713.0) = \mathbf{0.079 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0055 \times 100 = 0.550 \%$

Design Axial Force

Seismic(S) Pu = 763.9 kN
 f_{ck} = 30 MPa
 H = 800 mm

$A_g = B \times H = 1,000 \times 800 = 800,000 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.322 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P / (A_g \times f_{ck})$
 $= 1 + (5 \times 763.9 \times 1000) / (800,000 \times 30) = 1.16$

1.16 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.322x1.16 = 0.374 MPa
Seismic(S) **tc= 0.374 > 0.079 N/mm2, OK**

Permissible Shear Stress in Concrete = **0.322 MPa**
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.550 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23		
	0.50	0.31	0.550	0.322
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = 0.079-0.374 = -0.295 MPa

$V_{us}=(V-\tau_cxbxd)$ = -0.295x1000x713.0/1000 = -210.34 kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -210.34 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

f_y = 500 MPa

Permissible Direct Comp. stress(σ_{co}) σ_{co} = 205 MPa

Spacing Required = 113.1x2x500x205/(-210.34x1000) = -110.23 mm

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

s_{max} = Min(d/2, 300mm) Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

s_{max} = = MIN(713.0/2, 300) = 300 mm

OK, Stirrup spacing less than maximum allowed

Actual V_s $V_s = (113.1x2x205x1000/200)/1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4*b*s/(0.87*f_y)$

$A_{vmin} = 0.4x1000x200/(0.87x415) = 221.6$ mm²

A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ $A_v = 221.6$ mm²

A_v , provided = 2x113.1 = 226.2 mm²

226.2 > 221.6 mm2, OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	763.9 kN
	Moment, Mue	Mue =	75.5 kN-m
	Eccentricity, e	$e = 75.5/763.9 =$	0.10 m
Seismic	Axial Thrust, Pu at Middle	=	655.6 kN
	Moment, Mue	Mue =	828.6 kN-m
	Eccentricity, e	$e = 828.6/655.6 =$	1.26 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	0.80 m
Ratio of effective length to lateral dimension of pier	$= 10.98/0.80 =$	13.73 m

13.73 > 12 m, Long Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0055 \times 100 \times 2 =$	1.10 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 0.80/100 =$	0.800 m ²
Net area of concrete, Ac	$Ac = (1 - 1.100/100) \times 0.80/100 =$	0.791 m ²
X-sectional area of steel, As	$As = 1.100 \times 0.800 \times 1000 \times 1000/100 =$	8800 mm ²
Equivalent Area of Concrete	$= 0.79 \times 10^6 + (1.5 \times 10 - 1) \times 8800 =$	9E+05 mm ²
Equivalent Moment of Inertia	$= 1000 \times 800^3/12 + (1.5 \times 10 - 1) \times 8800 (800/2 - 50)^2 =$	6E+10 mm ⁴
Section modulus, Z	$= 57,758,666,667/(800/2) =$	1E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 763.9 \times 1000/914,400 =$	0.83 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 75.5 \times 10^6/144,396,667 =$	0.52 MPa

Check

	$f_{ck} =$	30 Mpa
i) Combined stress=	$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$	
	$= 0.83/(1.5 \times 10.0) + 0.52/(1.5 \times 7.5) =$	0.11
		0.11 < 1.0, OK
ii) Condition for tensile stresses to be within limit,	$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$	
	$= 0.52 - 0.83 =$	-0.31 MPa
	$= 0.25 \times (0.52 + 0.830) =$	0.34 MPa
		-0.31 < 0.34 N/mm², OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 0.52 - 0.83 = -0.31 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{-0.31 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 0.52 + 0.83 = 1.35 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.35 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 8800 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 25/4 = 6.25 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pitch of lateral tie} &< \text{least lateral dimension of column} = 800 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 < 12 \times \text{dia of smallest longitudinal bar} &= 12 \times 25 = 300 \text{ mm etc.}
 \end{aligned}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

18 Inner wall Base - End span Load - Positive BM-Max

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	800	75	25	125	713

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-685.1	6.9	73.6	-639.9	84.0	828.2

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(R \times B)\}$

Service = $\text{SQRT}\{(73.6 \times 1000 \times 1000) / (1.326 \times 1000)\} = 236 \text{ mm}$

236 < d = 713 mm, OK

Seismic = $\text{SQRT}\{(828.2 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 645 \text{ mm}$

645 < d = 713 mm, OK

Area of reinforcement required,

Overall depth of member = 800 mm

Effective depth of member: $d = 800 - 75 - 1/2 \times 25 = 713 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $73.6 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) = 477 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $828.2 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) / 1.5 = 3577 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 25 mm
 Area of rebar: Ar = 490.9 mm²
 Used rebar spacing: s = 125 mm
 $A_s = B/s \times Ar = 1000/125 \times 490.9 = 3927 \text{ mm}^2$
 At Service **3927 > 477 mm², OK**
 At Seismic **3927 > 3577 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$$\rho_{\min} = 0.12\% \text{ of } b_t \times d$$

$$\rho_{\min} = \boxed{0.0012}$$

$$\rho_{\max} = 4\% \text{ of } b_t \times d$$

$$\rho_{\max} = \boxed{0.0400}$$

$$\rho_{\text{use}} = \boxed{0.0055} \times 927 / (1,000 \times 713.0)$$

GOOD for Minimum Ratio, OK

GOOD for Maximum Ratio, OK

IRC 21: 2000 - 303.4

0.12 < 0.55 < 4.0 %, OK

s_{max} = 150 mm
 Provided Spacing, S provided = 125 mm

Using	25 mm ϕ.	125 mm max. center to center spacing	OK
--------------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 6.9 kN
Seismic Vu(e) = 84.0 kN
Seismic(S) Vu(e) = 84/1.5 = 56.0 kN

Seismic(S) Vu = **56.0 kN**
 B = 1000 mm
 d = 713.0 mm

Shear Stress $\tau_v = \tau_v = Vu/Bd = (56.0 \times 1000) / (1000 \times 713.0) = \mathbf{0.079 \text{ MPa}}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0055 \times 100 = 0.550 \%$

Design Axial Force

Seismic(S) Pu = 685.1 kN
 f_{ck} = 30 MPa
 H = 800 mm

$$A_g = B \times H = 1,000 \times 800 = 800,000 \text{ mm}^2$$

IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.322 MPa

IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P / (A_g \times f_{ck})$
 $= 1 + (5 \times 685.1 \times 1000) / (800,000 \times 30) = 1.14$

1.14 < 1.5, OK

Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.322x1.14 = 0.367 MPa
Seismic(S) $\tau_c = 0.367 > 0.079$ N/mm², OK

Permissible Shear Stress in Concrete = **0.322 MPa**
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.550 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23		
	0.50	0.31	0.550	0.322
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = 0.079-0.367 = -0.288 MPa

$V_{us} = (V - \tau_c x b x d)$ = -0.288x1000x713.0/1000 = -205.34 kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -205.34 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

f_y = 500 MPa

Permissible Direct Comp. stress (σ_{co}) σ_{co} = 205 MPa

Spacing Required = 113.1x2x500x205/(-205.34x1000) = -112.91 mm

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(713.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s $V_s = (113.1x2x205x1000/200)/1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4*b*s/(0.87*f_y)$

$A_{vmin} = 0.4x1000x200/(0.87x415) = 221.6$ mm²

A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ $A_v = 221.6$ mm²

A_v , provided = 2x113.1 = 226.2 mm²

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	685.1 kN
	Moment, Mue	Mue =	73.6 kN-m
	Eccentricity, e	$e = 73.6/685.1 =$	0.11 m
Seismic	Axial Thrust, Pu at Middle	=	639.9 kN
	Moment, Mue	Mue =	828.2 kN-m
	Eccentricity, e	$e = 828.2/639.9 =$	1.29 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	0.80 m
Ratio of effective length to lateral dimension of pier	$= 10.98/0.80 =$	13.73 m

13.73 > 12 m, Long Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0055 \times 100 \times 2 =$	1.10 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 0.80/100 =$	0.800 m ²
Net area of concrete, Ac	$Ac = (1 - 1.100/100) \times 0.80/100 =$	0.791 m ²
X-sectional area of steel, As	$As = 1.100 \times 0.800 \times 1000 \times 1000/100 =$	8800 mm ²
Equivalent Area of Concrete	$= 0.79 \times 10^6 + (1.5 \times 10 - 1) \times 8800 =$	9E+05 mm ²
Equivalent Moment of Inertia	$= 1000 \times 800^3/12 + (1.5 \times 10 - 1) \times 8800 \times (800/2 - 50)^2 =$	6E+10 mm ⁴
Section modulus, Z	$= 57,758,666,667/(800/2) =$	1E+08 mm ³
Therefore, direct stress, $\sigma_{co, cal}$	$\sigma_{co} = 685.1 \times 1000/914,400 =$	0.74 MPa
Bending compressive stress, σ_c, cal	$\sigma_c = 73.6 \times 10^6/144,396,667 =$	0.50 MPa

Check

i) Combined stress= $f_{ck} = 30 \text{ Mpa}$

$$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$$

$$= 0.74/(1.5 \times 10.0) + 0.50/(1.5 \times 7.5) = 0.10$$

0.10 < 1.0, OK

ii) Condition for tensile stresses to be within limit,

$$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$$

$$= 0.50 - 0.74 = -0.24 \text{ MPa}$$

$$= 0.25 \times (0.50 + 0.740) = 0.31 \text{ MPa}$$

-0.24 < 0.31 N/mm², OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 0.50 - 0.74 = -0.24 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\mathbf{-0.24 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 0.50 + 0.74 = 1.24 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\mathbf{1.24 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 8800 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 25/4 = 6.25 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 \text{Pitch of lateral tie} &< \text{least lateral dimension of column} = 800 \text{ mm}
 \end{aligned}$$

$$\begin{aligned}
 < 12 \times \text{dia of smallest longitudinal bar} &= 12 \times 25 = 300 \text{ mm etc.}
 \end{aligned}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

7 Section Check and Rebar Computed for Wall (Column)

19 Inner wall Base - Center span load - Positive BM

1) Force and Design Condition

B	H	Cover	Rebar Φ	Space ctc.	d
mm	mm	mm	mm	mm	mm
1000	800	75	25	125	713

Service Load Condition			Seismic Condition		
P _u (A)	V _u (V2)	M _u	P _u (A)	V _{ue}	M _{ue}
kN	kN	kN-m	kN	kN	kN-m
-777.1	6.2	66.0	-658.3	83.9	826.7

Section Specification and Design Assumption

Reinforcing Bar Grade

Fe500

Permissible flexural tensile stress $f_y = 500$ MPa

Permissible flexural tensile stress $\sigma_{st} = 240$ MPa

Permissible direct compressive stress $\sigma_{so} = 205$ MPa

Permissible compressive stress of concrete

M-30

Permissible compressive stress $f_{ck} = 30.0$ MPa

Permissible direct compressive stress $\sigma_{co} = 7.5$ MPa

Permissible flexural compressive stress $\sigma_c = 10.0$ MPa

Basic permissible tensile stress $\sigma_t = 0.67$ MPa

Maximum permissible shear stress $\tau_{max} = 2.2$ MPa

Design of Data

Modular ratio $m = 10$

Neutral axis depth factor, $n = (m\sigma_c) / (m\sigma_c + \sigma_{st})$
 $n = \frac{10 \times 10}{(10 \times 10 + 240)} = 0.294$

Lever arm factor $j = (1 - n/3) = 1 - 0.294 / 3 = 0.902$

Moment of resistance coefficient

$$R = \frac{1}{2} \times n \times j \times \sigma_c$$

$$= \frac{1}{2} \times 0.294 \times 0.902 \times 10 = 1.326 \text{ MPa}$$

2) Check for Bending (by single reinforcement method)

Depth of section required = $\text{SQRT}\{M/(RxB)\}$

Service = $= \text{SQRT}\{(66.0 \times 1000 \times 1000) / (1.326 \times 1000)\} = 223 \text{ mm}$

223 < d = 713 mm, OK

Seismic = $= \text{SQRT}\{(826.7 \times 1000 \times 1000) / (1.5 \times 1.326 \times 1000)\} = 645 \text{ mm}$

645 < d = 713 mm, OK

Area of reinforcement required,

Overall depth of member = 800 mm

Effective depth of member: $d = 800 - 75 - 1/2 \times 25 = 713 \text{ mm}$

Service: Area of tension reinforcement req. = $M_u / (\sigma_{st} \times j \times d)$

Seismic = $= 66.0 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) = 428 \text{ mm}^2$

Seismic: Area of tension reinforcement req. = $M_{ue} / (\sigma_{st} \times j \times d) / 1.5$

Seismic = $= 826.7 \times 1000 \times 1000 / (240 \times 0.902 \times 713.0) / 1.5 = 3571 \text{ mm}^2$

Actual area of steel provided:
 Used rebar diameter = 25 mm
 Area of rebar: Ar = 490.9 mm²
 Used rebar spacing: s = 125 mm
 $A_s = B/s \times Ar = 1000/125 \times 490.9 = 3927 \text{ mm}^2$
 At Service **3927 > 428 mm², OK**
 At Seismic **3927 > 3571 mm², OK**

3) Check for Reinforcement Ratio:

IRC 21: 2000 - 305.19

$\rho_{min} = 0.12\% \text{ of } b_t \times d$
 $\rho_{min} = 0.0012$
 $\rho_{max} = 4\% \text{ of } b_t \times d$
 $\rho_{max} = 0.0400$
 $\rho_{use} = 0.0055 \times 927 / (1,000 \times 713.0)$

GOOD for Minimum Ratio, OK
GOOD for Maximum Ratio, OK
0.12 < 0.55 < 4.0 %, OK

IRC 21: 2000 - 303.4

smax = 150 mm
 Provided Spacing, S provided = 125 mm

Using	25 mm ϕ.	125 mm max. center to center spacing	OK
--------------	---------------------------------	---	-----------

4) Check For Shear: Using IRC 21: 2000

IRC 21: 2000 - 304.7

Design Shear Force

Static Vu = 6.2 kN
Seismic Vue = 83.9 kN
Seismic(S) Vu(e) = 83.9/1.5 = 55.9 kN

Seismic(S) Vu = **55.9 kN**
 B = 1000 mm
 d = 713.0 mm

Shear Stress $\tau_v = Vu/Bd = (55.9 \times 1000) / (1000 \times 713.0) = 0.078 \text{ MPa}$
 Percentage area of tension steel, $100A_{st}/bd = 0.0055 \times 100 = 0.550 \%$

Design Axial Force

Seismic(S) Pu = 777.1 kN
 f_{ck} = 30 MPa
 H = 800 mm

$A_g = B \times H = 1,000 \times 800 = 800,000 \text{ mm}^2$
 IRC 21: 2000 - 304.7.1.3.3

Permissible Shear Stress in Concrete = 0.322 MPa
 IRC 21: 2000 - Table 12B

Shear strength increment factor $d = 1 + 5P / (A_g \times f_{ck})$
 $= 1 + (5 \times 777.1 \times 1000) / (800,000 \times 30) = 1.16$
1.16 < 1.5, OK
 Not exceeding 1.5

Design shear strength of concrete, τ_c = 0.322x1.16 = 0.374 MPa
Seismic(S) $\tau_c = 0.374 > 0.078$ N/mm², OK

Permissible Shear Stress in Concrete = **0.322 MPa**
Not req. stirrup

Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	100Ast/bd (1)	M-30 (4)	Tension Steel 0.550 %	Design shear Strength of Con. N/mm ²
	0.15	0.20		
	0.25	0.23		
	0.50	0.31	0.550	0.322
	0.75	0.37		
	1.00	0.41		
	1.25	0.45		

Thus Shear stirrups not required.

IRC 21: 2000 - 304.7.1.4

Minimum τ_v = 0.078-0.374 = -0.296 MPa

$V_{us} = (V - \tau_c x b x d)$ = -0.296x1000x713.0/1000 = -211.05 kN

No Shear Reinf. Req. DISCARD SHEAR CALC. BELOW

ϕV_s required = -211.05 kN

Dia. of rebar used = 12 mm

Area of rebar = 113.1 mm²

No. of leg = 2 nos.

$f_y = 500$ MPa

Permissible Direct Comp. stress (σ_{co}) $\sigma_{co} = 205$ MPa

Spacing Required = 113.1x2x500x205/(-211.05x1000) = -109.86 mm

Used Spacing, s = 200 mm

IRC 21: 2000- 304.7.1.6

$s_{max} = \text{Min}(d/2, 300\text{mm})$ Max. stirrup space. Allowed

IRC 21: 2000- 304.7.1.5

$s_{max} = \text{MIN}(713.0/2, 300) = 300$ mm

OK, Stirrup spacing less than maximum allowed

Actual V_s $V_s = (113.1x2x205x1000/200)/1000 = 231.9$ kN
 $f_y \leq 415$ MPa

$A_{vmin} = 0.4*b*s/(0.87*f_y)$

$A_{vmin} = 0.4x1000x200/(0.87x415) = 221.6$ mm²

A_v provided = 2x113.1 = 226.2 mm²

GOOD, Stirrups OK for Minimum Requirement

Used Spacing, s = 200 mm

Dia. of Rebar Used = 12 mm

Area of Bar = 113.1 mm²

No. of Leg = 2 nos.

$A_{v,min}$ $A_v = 221.6$ mm²

A_v , provided = 2x113.1 = 226.2 mm²

226.2 > 221.6 mm², OK

Stirrups Using	12 mm dia.	200 mm space.	OK
-----------------------	-------------------	----------------------	-----------

5) Check for Walls as Column: Using IRC 21: 2000- 306

The Abutment section will be designed for the Case A and the section adequacy will be checked for both the cases. As the moment of inertia of the Abutment along Y-Y axis is greater than along X-X axis, the design needs to be done for stresses along the X-X axis only.

At Seismic Condition

Seismic	Axial Thrust, Pu at Middle	Pu =	777.1 kN
	Moment, Mue	Mue =	66.0 kN-m
	Eccentricity, e	$e = 66.0/777.1 =$	0.08 m
Seismic	Axial Thrust, Pu at Middle	=	658.3 kN
	Moment, Mue	Mue =	826.7 kN-m
	Eccentricity, e	$e = 826.7/658.3 =$	1.26 m
	Length of pier, L	L =	9.150 m

Check for Column Type

Effective length of column, le	$le = 1.2 \times L = 9.150 =$	10.98 m
Lateral Dimension, D (H)	D =	0.80 m
Ratio of effective length to lateral dimension of pier	$= 10.98/0.80 =$	13.73 m

13.73 > 12 m, Long Column

Minimum area of steel	=	0.80 %
Maximum area of steel	=	6.00 %
Assume percentage area of steel	$= 0.0055 \times 100 \times 2 =$	1.10 %
Gross area of concrete, Ag	$Ag = 1000/1000 \times 0.80/100 =$	0.800 m ²
Net area of concrete, Ac	$Ac = (1 - 1.100/100) \times 0.80/100 =$	0.791 m ²
X-sectional area of steel, As	$As = 1.100 \times 0.800 \times 1000 \times 1000/100 =$	8800 mm ²
Equivalent Area of Concrete	$= 0.79 \times 10^6 + (1.5 \times 10 - 1) \times 8800 =$	9E+05 mm ²
Equivalent Moment of Inertia	$= 1000 \times 800^3/12 + (1.5 \times 10 - 1) \times 8800 \times (800/2 - 50)^2 =$	6E+10 mm ⁴
Section modulus, Z	$= 57,758,666,667/(800/2) =$	1E+08 mm ³
Therefore, direct stress, σ_{co} , cal	$\sigma_{co} = 777.1 \times 1000/914,400 =$	0.84 MPa
Bending compressive stress, σ_c , cal	$\sigma_c = 66.0 \times 10^6/144,396,667 =$	0.45 MPa

Check

	$f_{ck} =$	30 Mpa
i) Combined stress=	$(\sigma_{co,cal}/\sigma_{co}) + (\sigma_{c,cal}/\sigma_c)$	
	$= 0.84/(1.5 \times 10.0) + 0.45/(1.5 \times 7.5) =$	0.10
		0.10 < 1.0, OK
ii) Condition for tensile stresses to be within limit,	$(\sigma_{c,cal} - \sigma_{co,cal}) \leq 0.25 \times (\sigma_{c,cal} + \sigma_{co,cal})$	
	$= 0.45 - 0.84 =$	-0.39 MPa
	$= 0.25 \times (0.45 + 0.84) =$	0.32 MPa
		-0.39 < 0.32 N/mm², OK

$$\begin{aligned}
 (\sigma_{c,cal} - \sigma_{co,cal}) &\leq 0.75 \times \text{7-day modulus of rupture of concrete} \\
 \text{7-day modulus of rupture of concrete} &= 1.5 \times 0.56 \times \text{SQRT}(f_{ck}) \\
 &= \text{ROUNDDOWN}\{1.5 \times 0.56 \times \text{SQRT}(30)\} = 4.60 \text{ MPa} \\
 &= 0.45 - 0.84 = -0.39 \text{ MPa} \\
 &= 0.75 \times 4.60 = 3.45 \text{ MPa} \\
 &\quad \mathbf{-0.39 < 3.45 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

$$\begin{aligned}
 \text{iii) Resultant compressive stress} &= 0.45 + 0.84 = 1.29 \text{ MPa} \\
 &= 1.5 \times 10.0 = 15.0 \text{ MPa} \\
 &\quad \mathbf{1.29 < 15.0 \text{ N/mm}^2, \text{ OK}}
 \end{aligned}$$

Thus provide both side of wall layers of steel giving reinforcement area of = 8800 mm²

Design for Lateral Tie

$$\begin{aligned}
 \text{Diameter of lateral tie should be greater than } \Phi_L/4 \\
 \Phi_L/4 &= 25/4 = 6.25 \text{ mm}
 \end{aligned}$$

$$\text{Pitch of lateral tie} < \text{least lateral dimension of column} = 800 \text{ mm}$$

$$< 12 \times \text{dia of smallest longitudinal bar} = 12 \times 25 = 300 \text{ mm etc.}$$

Provide $\Phi 10 @ 300 \text{ mm etc.}$

8 Summary of Section Check and Rebar Computed

1) Section Check and Reinforcement Computed (IRC)

Check Location		Check for Bending Moment						Check for Shear Strength of Concrete			
		Main Rebar Arrangement	at Service (I)		at Seismic (IV)		at Service (I or IV)		by Shear Strength Stress	Stirrups	Stirrup Arrangement
			Stress	Ratio	Stress	Ratio	Stress	Ratio			
1	Top slab at Center/Carriageway - End span Load - Positive B-Max	Φ 25 mm - ctc. 125 mm	3927 > 2137 mm ² , OK	54%	3927 > 1103 mm ² , OK	28%	0.12 < 0.39 < 4.0 %, OK	10%	tc = 0.281 > 0.255 N/mm ² , OK	Not Req. Stirrup	Φ 12 mm - ctc. 200 mm
2	Top slab at Center/Footpath - End span Load - Positive B-Max	Φ 25 mm - ctc. 125 mm	3927 > 2592 mm ² , OK	66%	3927 > 1728 mm ² , OK	44%	0.12 < 0.39 < 4.0 %, OK	10%	tc = 0.281 > 0.136 N/mm ² , OK	Not Req. Stirrup	Φ 12 mm - ctc. 200 mm
3	Top slab at Inwall/Carriageway - End span Load - Negative B-Max	Φ 25 mm - ctc. 115 mm	4269 > 3630 mm ² , OK	85%	4269 > 2693 mm ² , OK	63%	0.12 < 0.42 < 4.0 %, OK	11%	t c = 0.293 < 7.482, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
4	Top slab at Inwall/Footpath - Center span load - Negative B&Shear-Max	Φ 25 mm - ctc. 115 mm	4269 > 4140 mm ² , OK	97%	4269 > 2924 mm ² , OK	68%	0.12 < 0.42 < 4.0 %, OK	11%	t c = 0.293 < 6.448, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
5	Bottom slab at Outwall - End span load - Negative B-Max	Φ 32 mm - ctc. 125 mm	6434 > 3315 mm ² , OK	52%	6434 > 6286 mm ² , OK	98%	0.12 < 0.43 < 4.0 %, OK	11%	t c = 0.302 < 10.112, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
6	Bottom slab at Side span center - End span load - Positive B-Max	Φ 32 mm - ctc. 125 mm	6434 > 2315 mm ² , OK	36%	6434 > 5385 mm ² , OK	84%	0.12 < 0.43 < 4.0 %, OK	11%	t c = 0.302 < 8.745, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
7	Bottom slab at Side span center - End span load - Shear Max	Φ 32 mm - ctc. 125 mm	6434 > 332 mm ² , OK	5%	6434 > 3413 mm ² , OK	53%	0.12 < 0.43 < 4.0 %, OK	11%	t c = 0.302 < 10.518, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
8	Bottom slab at Inwall - End span load - Negative B-Max	Φ 32 mm - ctc. 125 mm	6434 > 3286 mm ² , OK	51%	6434 > 3045 mm ² , OK	47%	0.12 < 0.43 < 4.0 %, OK	11%	t c = 0.302 < 9.773, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
9	Bottom slab at center - End span Load - Positive B-Max	Φ 32 mm - ctc. 125 mm	6434 > 2311 mm ² , OK	36%	6434 > 1287 mm ² , OK	20%	0.12 < 0.43 < 4.0 %, OK	11%	tc = 0.302 > 0.258 N/mm ² , OK	Not Req. Stirrup	Φ 12 mm - ctc. 200 mm
10	Bottom slab at Inwall2 - End span load - Negative B-Max	Φ 32 mm - ctc. 125 mm	6434 > 3117 mm ² , OK	48%	6434 > 2029 mm ² , OK	32%	0.12 < 0.43 < 4.0 %, OK	11%	t c = 0.302 < 9.724, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
11	Outer wall Base - End span Load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 2667 mm ² , OK	40%	6702 > 6588 mm ² , OK	98%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.325 < 13.976, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
12	Outer wall Base - End span Load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 2629 mm ² , OK	39%	6702 > 6583 mm ² , OK	98%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.322 < 13.970, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
13	Outer wall Base - Center span load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 2335 mm ² , OK	35%	6702 > 6543 mm ² , OK	98%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.322 < 13.936, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
14	Outer wall 2 Base - End span Load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 2181 mm ² , OK	33%	6702 > 3532 mm ² , OK	53%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.322 < 4.715, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
15	Outer wall 2 Base - End span Load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 1997 mm ² , OK	30%	6702 > 3557 mm ² , OK	53%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.322 < 4.694, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
16	Outer wall 2 Base - Center span load - Positive B-Max	Φ 32 mm - ctc. 120 mm	6702 > 1739 mm ² , OK	26%	6702 > 3591 mm ² , OK	54%	0.12 < 0.48 < 4.0 %, OK	12%	t c = 0.322 < 4.667, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
17	Inner wall Base - End span Load - Positive B	Φ 25 mm - ctc. 125 mm	3927 > 489 mm ² , OK	12%	3927 > 3579 mm ² , OK	91%	0.12 < 0.55 < 4.0 %, OK	14%	t c = 0.374 < 1.700, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
18	Inner wall Base - End span Load - Positive B-Max	Φ 25 mm - ctc. 125 mm	3927 > 477 mm ² , OK	12%	3927 > 3577 mm ² , OK	91%	0.12 < 0.55 < 4.0 %, OK	14%	t c = 0.367 < 1.697, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm
19	Inner wall Base - Center span load - Positive B	Φ 25 mm - ctc. 125 mm	3927 > 428 mm ² , OK	11%	3927 > 3571 mm ² , OK	91%	0.12 < 0.55 < 4.0 %, OK	14%	t c = 0.374 < 1.694, Not OK	Stirrups required	Φ 12 mm - ctc. 200 mm

2) Check for Column (IRC 21: 2000- 306)

Check Location		Type of Member	Check For Column: Using IRC 21: 2000- 306						
			Combined Stress		Condition for tensile stresses to be within limit,	7-day modulus of rupture of concrete		Resultant compressive stress	
			Stress	Ratio	Stress	Stress	Ratio	Stress	Ratio
11	Outer wall Base - End span Load - Positive B-Max	Column	0.17 < 1.0, OK	17%	1.25 > 0.49 N/mm ² , Not OK	1.25 < 3.45 N/mm ² , OK	36%	1.95 < 15.0 N/mm ² , OK	13%
12	Outer wall Base - End span Load - Positive B-Max	Column	0.17 < 1.0, OK	17%	1.27 > 0.47 N/mm ² , Not OK	1.27 < 3.45 N/mm ² , OK	37%	1.89 < 15.0 N/mm ² , OK	13%
13	Outer wall Base - Center span load - Positive B-Max	Column	0.15 < 1.0, OK	15%	1.10 > 0.43 N/mm ² , Not OK	1.10 < 3.45 N/mm ² , OK	32%	1.70 < 15.0 N/mm ² , OK	11%
14	Outer wall 2 Base - End span Load - Positive B-Max	Column	0.14 < 1.0, OK	14%	1.00 > 0.41 N/mm ² , Not OK	1.00 < 3.45 N/mm ² , OK	29%	1.62 < 15.0 N/mm ² , OK	11%
15	Outer wall 2 Base - End span Load - Positive B-Max	Column	0.13 < 1.0, OK	13%	0.86 > 0.39 N/mm ² , Not OK	0.86 < 3.45 N/mm ² , OK	25%	1.54 < 15.0 N/mm ² , OK	10%
16	Outer wall 2 Base - Center span load - Positive B-Max	Column	0.12 < 1.0, OK	12%	0.74 > 0.34 N/mm ² , Not OK	0.74 < 3.45 N/mm ² , OK	21%	1.34 < 15.0 N/mm ² , OK	9%
17	Inner wall Base - End span Load - Positive B	Column	0.11 < 1.0, OK	11%	-0.31 < 0.34N/mm ² , OK	-0.31 < 3.45 N/mm ² , OK	-9%	1.35 < 15.0 N/mm ² , OK	9%
18	Inner wall Base - End span Load - Positive B-Max	Column	0.1 < 1.0, OK	10%	-0.24 < 0.31N/mm ² , OK	-0.24 < 3.45 N/mm ² , OK	-7%	1.24 < 15.0 N/mm ² , OK	8%
19	Inner wall Base - Center span load - Positive B	Column	0.1 < 1.0, OK	10%	-0.39 < 0.32N/mm ² , OK	-0.39 < 3.45 N/mm ² , OK	-11%	1.29 < 15.0 N/mm ² , OK	9%

9 Horizontal Rebar Check

9-1. Distribution Reinforcement check in Top and Bottom Slab:

IRC 21: 305.18 — Distribution Reinforcement in Slab

- Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

- Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area,

but not less than 0.0012:

(a) Distribution reinforcement to resist moment for 0.3 times live load and 0.2 times Dead Load..... Case a

(b) = 0.0012 Case b

1) Top Slab

Minimum Distrib reinforce = 0.0012
 Assume unit width, B = 1000 mm
 Thickness of slab = 1100 mm
 Area of reinforcement required $A_{sreq.} = 0.0012 \times 1000 \times 1100 = 1320 \text{ mm}^2$

This area of steel is equally distributed on each face of the slab, so each face (either top or bottom) will have to have half of the above

required steel area. i.e = 660 mm²

Used re-bar Diameter = 12 mm

Used re-bar Area = 113.1 mm²

Used spacing, sused = 150 mm

Actual area of Steel $A_{sact.} = 753.98 \text{ mm}^2$

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor farther apart than 450 mm.

5 times slab thickness = 5500 mm

Maximum Allowable spacing = 450 mm

OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

FINAL DISTRIBUTION REINFORCING IN TOP SLAB:
--

Using 12 mm diameter @ of 150 mm max. spacing OK
--

2) Bottom Slab

Minimum Distrib reinforce = 0.0012
 Assume unit width, B = 1000 mm
 Thickness of slab = 1600 mm
 Area of reinforcement required $A_{sreq.} = 0.0012 \times 1000 \times 1600 = 1920 \text{ mm}^2$

This area of steel is equally distributed on each face of the slab, so each face (either top or bottom) will have to have half of the above

required steel area. i.e = 960 mm²

Used re-bar Diameter = 16 mm

Used re-bar Area = 201.06 mm²

Used spacing, sused = 175 mm

Actual area of Steel $A_{sact.} = 1148.9 \text{ mm}^2$

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor farther apart than 450 mm.

5 times slab thickness = 8000 mm

Maximum Allowable spacing = 450 mm

OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

9 Horizontal Rebar Check

9-1. Distribution Reinforcement check in Top and Bottom Slab:

IRC 21: 305.18 — Distribution Reinforcement in Slab

- Reinforcement for shrinkage and temperature stresses normal to flexural reinforcement shall be provided in structural slabs where the flexural reinforcement extends in one direction only.

- Area of shrinkage and temperature reinforcement shall provide at least the following ratios of reinforcement area to gross concrete area,

but not less than 0.0012:

(a) Distribution reinforcement to resist moment for 0.3 times live load and
0.2 times Dead Load..... Case a

(b) = 0.0012 Case b

1) Top Slab

Minimum Distrib reinforce = 0.0012
 Assume unit width, B = 1000 mm
 Thickness of slab = 1100 mm
 Area of reinforcement required $A_{sreq.} = 0.0012 \times 1000 \times 1100 = 1320 \text{ mm}^2$

This area of steel is equally distributed on each face of the slab, so each face (either top or bottom) will have to have half of the above

required steel area. i.e = 660 mm²

Used re-bar Diameter = 12 mm

Used re-bar Area = 113.1 mm²

Used spacing, sused = 150 mm

Actual area of Steel $A_{sact.} = 753.98 \text{ mm}^2$

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor farther apart than 450 mm.

5 times slab thickness = 5500 mm

Maximum Allowable spacing = 450 mm

OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

FINAL DISTRIBUTION REINFORCING IN TOP SLAB:
--

Using 12 mm diameter @ of 150 mm max. spacing OK
--

2) Bottom Slab

Minimum Distrib reinforce = 0.0012
 Assume unit width, B = 1000 mm
 Thickness of slab = 1600 mm
 Area of reinforcement required $A_{sreq.} = 0.0012 \times 1000 \times 1600 = 1920 \text{ mm}^2$

This area of steel is equally distributed on each face of the slab, so each face (either top or bottom) will have to have half of the above

required steel area. i.e = 960 mm²

Used re-bar Diameter = 16 mm

Used re-bar Area = 201.06 mm²

Used spacing, sused = 175 mm

Actual area of Steel $A_{sact.} = 1148.9 \text{ mm}^2$

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Shrinkage and temperature reinforcement shall be spaced not farther apart than five times the slab thickness, nor farther apart than 450 mm.

5 times slab thickness = 8000 mm

Maximum Allowable spacing = 450 mm

OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

FINAL DISTRIBUTION REINFORCING IN BOTTOM SLAB:			
Using	16 mm diameter @ of	175 mm max. spacing	OK

3) Outer Walls

Minimum Distrib reinforce =	= 0.0012
Assume unit width, B =	= 1000 mm
Thickness of Wall =	= 1500 mm
Area of reinforcement required $A_{sreq.} =$	$= 0.0012 \times 1000 \times 1500 = 1800 \text{ mm}^2$

- This area of steel is equally distributed on each face of the walls, so each face will have to have half of the above.

required steel area. i.e	= 900 mm^2
Used re-bar Diameter	= 16 mm
Used re-bar Area	= 201.06 mm^2
Used spacing, sused	= 175 mm
Actual area of Steel $A_{sact.}$	= 1148.9 mm^2

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Vertical & horizontal reinforcement shall be spaced not farther apart than three times the wall thickness, nor farther apart than 450 mm.

3 times wall thickness	= 4500 mm
Maximum Allowable spacing	= 450 mm

OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

FINAL DISTRIBUTION REINFORCING IN WALLS:			
Using	16 mm diameter @ of	175 mm max. spacing	OK

4) Inner Walls

Minimum Distrib reinforce	= 0.0012
Assume unit width, B	B = 1000 mm
Thickness of Wall	= 800 mm
Area of reinforcement required $A_{sreq.} =$	$= 0.0012 \times 1000 \times 800 = 960 \text{ mm}^2$

- This area of steel is equally distributed on each face of the walls, so each face will have to have half of the above

required steel area. i.e	= 480 mm^2
Used re-bar Diameter	= 16 mm
Used re-bar Area	= 201.06 mm^2
Used spacing, sused	= 200 mm
Actual area of Steel $A_{sact.}$	= 1005.3 mm^2

Area of steel OK, CHECK THE ALLOWABLE SPACING

- Vertical & horizontal reinforcement shall be spaced not farther apart than three times the wall thickness, nor farther apart than 450 mm.

3 times wall thickness	= 2400 mm
Maximum Allowable spacing	= 450 mm

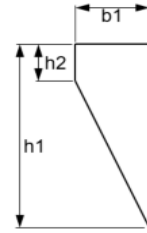
OK, SPACING PROVIDED IS GREATER THAN ALLOWABLE SPACING

FINAL DISTRIBUTION REINFORCING IN WALLS:			
Using	16 mm diameter @ of	200 mm max. spacing	OK

10 Return Walls

Return wall will be monolithic with backwall. They are joined together as shown. The load acting on the wing walls would be earth pressure and is designed to withstand a live load equivalent to surcharge of 1.2 m height of earth fill according to IRC: 78-2000.

b1: cantilever length of return wall	=	2.520 m
h1: base of return wall height	=	5.480 m
h2: tip of return wall height	=	1.000 m
t: thickness of return wall	=	0.400 m



$$\begin{aligned} \text{Average value of earth pressure} &= \frac{1}{2} \gamma_s \times (h_1/2 + h_2/2 + 1.2)^2 \times \tan^2(45 - \Phi/2) \\ &= \frac{1}{2} \times 19.0 \times (5.480/2 + 1.2 + 1.2)^2 \times (\tan(45 - 35/2))^2 = 50.8 \text{ kN} \\ \text{Acting at a distance from wing wall bottom} &= 0.5 \times (5.480 + 1.000)/2 = 1.62 \text{ m} \\ \text{Moment due to earth pressure} &= \{50.8 \times (2.520 - 0.600)^2\} / 2 = 93.6 \text{ kN-m/m} \end{aligned}$$

$$\begin{aligned} \text{Depth required} &= \text{SQRT} \{93.6 \times 1000 \times 1000 / (1.326 \times (0.5 \times (5.48 + 1.0)) \times 1000)\} = 148 \text{ mm} \\ \text{Effective depth provided} &= 0.400 \times 1000 - 50 - 16/2 = 342 \text{ mm} \end{aligned}$$

Thus, provide Φ 16 mm - ctc spacing of 150 mm

$$\begin{aligned} \text{Giving reinforcement area of} &= (\pi \times 16^2 / 4) \times 0.5 \times (5.48 + 1.0) \times (1000 / 150) = 4343 \text{ mm}^2 \\ \text{Area of reinforcement required} &= 93.6 \times 1000 \times 1000 / (240 \times 0.902 \times 342) = 1264 \text{ mm}^2 \end{aligned}$$

Return Wall 4343 > 1264 mm², OK

Return Wall: area of main steel required Φ 16 mm - ctc spacing of 150 mm

Return wing wall: Distribution Reinforcement

$$\begin{aligned} \text{Required area of distribution reinforcement} &= 0.12 \% \text{ of Area} \\ \text{And, as distribution bar, provide } \Phi 10 \text{ mm - ctc spacing of 200 mm} & \\ \text{Giving reinforcement area of} &= (\pi \times 10^2 / 4) \times (1000 / 200 - 1) = 314 \text{ mm}^2 \\ \text{Area of distribution reinforcement req.} &= (0.400 \times 1000 \times 1000 \times 0.12 / 100) / 2 = 240 \text{ mm}^2 \end{aligned}$$

Return Wall for Distribution bar 314 > 240 mm², OK

Return Wall: area of dist. steel required Φ 10 mm - ctc spacing of 200 mm
in the fillet joint, provide Φ 12 mm - ctc spacing of 200 mm

The wing wall would be properly anchored to the abutment, backwall and abutment cap.

11 Approach Slab

IRC: 6-2016 214.2

Reinforced concrete approach slab with 12 mm dia. 150 mm ctc in each direction both at top and bottom as reinforcement in M-30 grade concrete covering the entire width of the roadway, with one end resting on the structure designed to resting on the structure designed to retain earth and extending for a length of not less than 3.5 m into the approach shall be provided

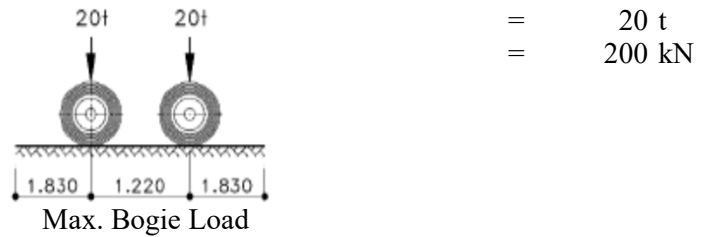
The approach slab is resting over the abutment and the other end supported by the soil underneath.

It should be designed on the basis of elastic base theory, which is complicated. Hence the dimensions and reinforcement is provided as per the standard design practice.

Length of slab =	3.500 m	Width of slab =	7.500 m
thickness of slab =	0.300 m	Self weight /m width	= 0.300x25.0 = 7.5 kN/m ²
Weight of pavement			= 0.075x22.0 = 1.7 kN/m ²
		Total udl =	9.2 kN/m ²

$$\begin{aligned} \text{Max moment in longitudinal Direction due to Self Load} & \\ &= 9.2 \times (3.5 - 0.25 \times 2)^2 / 8 = 10.4 \text{ kN-m/m} \end{aligned}$$

Maximum Bogie Live Load =



$$= 20 \text{ t}$$

$$= 200 \text{ kN}$$

Max moment in longitudinal Direction due to Bogie Load of 200 kN

$$= \{200 \times (3.5 - 0.25 \times 2) / 2 - 200 \times 1.22 / 2\} / 7.5 = 23.7 \text{ kN-m/m}$$

$$= 10.4 + 23.7 = 34.1 \text{ kN-m/m}$$

Effective depth provided (length-covering-half of re-bar) = 300 - 50 - 12 / 2 = 244 mm

Effective depth of slab required = $\text{SQRT}\{M / (R_x b)\}$
 $= \text{SQRT}\{34.1 \times 1000 \times 1000 / (1.326 \times 1000)\} = 160 \text{ mm}$

Approach slab: Effective depth of re-bar 160 < 244 mm, OK

Thus, provide Φ 12 mm - ctc spacing of 150 mm

Giving reinforcement area of = $(\pi \times 12^2 / 4) \times (1000 / 150) = 792 \text{ mm}^2$

Area of reinforcement required = $34.1 \times 1000 \times 1000 / (240 \times 0.902 \times 244) = 646 \text{ mm}^2$

Approach slab: Area of reinforcement required 792 > 646 mm², OK

Thus, provide Φ 12 mm - ctc spacing of 150 mm

Maximum moment transverse direction IRC: 21-305.18

$$= 0.2 \times 10.4 + 0.3 \times 23.7 = 9.2 \text{ kN-m/m}$$

Effective depth of approach slab required = $\text{SQRT}\{M / (R_x b)\}$

$$= \text{SQRT}\{9.2 \times 1000 \times 1000 / (1.326 \times 1000)\} = 83 \text{ mm}$$

Effective depth provided = 244 - 12 = 232 mm

Permissible Flexural Tensile stress (σ_{st}) = 240 MPa

$$j = 0.902$$

Area of reinforcement required = $9.2 \times 1000 \times 1000 / (240 \times 0.902 \times 232) = 183 \text{ mm}^2$

Thus, provide Φ 12 mm - ctc spacing of 150 mm

Giving an Steel Area of = $(\pi \times 12^2 / 4) \times (1000 / 150) = 792 \text{ mm}^2$

And, as distribution bar, provide Φ 12 mm - ctc spacing of 150 mm

Maximum shear force = $9.2 \times 3.5 / 2 + 200 / 7.5 = 42.8 \text{ kN/m}$

Shear stress = $42.8 \times 1000 / (232 \times 1000) = 0.184 \text{ MPa}$

Percentage area of steel = $100 \times 792 / (232 \times 1000) = 0.341 \%$

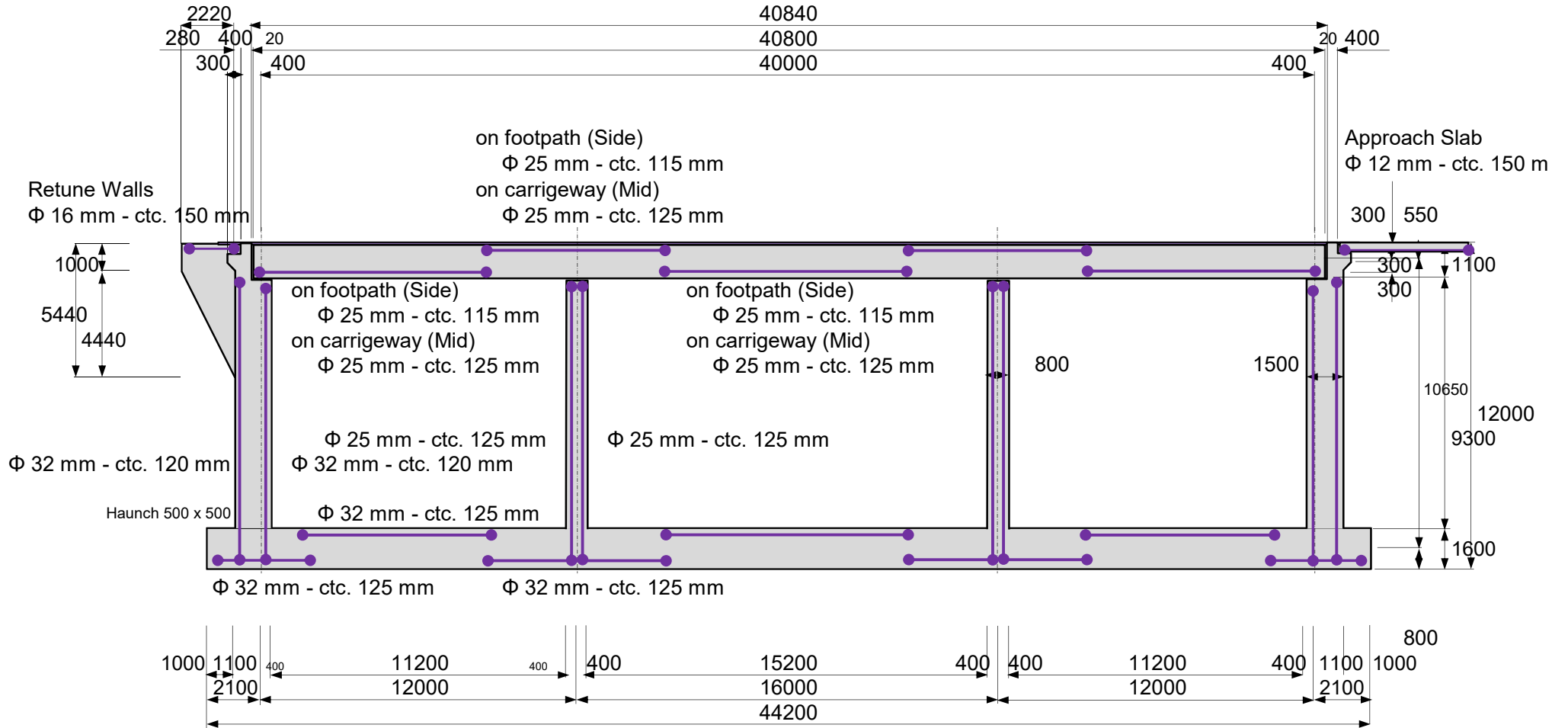
Permissible Shear Stress in Concrete IRC: 21-2000 Clause 304.7.1.3.3. Table 12B

M-30	Area of steel 100A _s /bd	shear stgh. MPa
	0.15	0.20
	0.25	0.23
	0.50	0.31
	0.75	0.37
	0.341	0.259

Permissible shear strength of concrete = 0.259 MPa

Approach slab: Shear stress of concrete 0.184 < 0.259 MPa, OK

12 Reinforcement Arrangement





नेपाल सरकार
भौतिक पूर्वाधार तथा यातायात मन्त्रालय
सिंहदरबार, काठमाण्डौ

वि.पी. राजमार्ग अन्तर्गत १११+००० कि.मि. देखि ११९+५०० कि.मि. सम्म पर्ने घ्याम्पे खोला पुल (४० मि.),माम्ती खोला पुल (४० मि.) र भ्याकुरे खोला पुल (४० मि.) निर्माण कार्यको संक्षिप्त वातावरणीय अध्ययन प्रतिवेदन काभ्रेपलान्चोक र सिन्धुली जिल्ला, बागमती प्रदेश



पेश गरिएको निकाय

भौतिक पूर्वाधार तथा यातायात मन्त्रालय
सिंहदरबार, काठमाण्डौ, नेपाल
फोन नं : +९७७-१-४२११७३२
फ्याक्स नं : +९७७-१-४२११७२०
ई-मेल : info@mopit.gov.np
वेबसाइट : www.mopit.gov.np

मार्फत

भू-वातावरण तथा सामाजिक शाखा
सडक विभाग, चाकुपाट, ललितपुर
फोन नं : +९७७-१-५००५५२०
फ्याक्स नं : +९७७-१-५५२९१०६
ई-मेल : gesuunit@dor.gov.np
वेबसाइट : www.dor.gov.np

प्रस्तावक

सुर्यविनायक-धुलिखेल, धुलिखेल-सिन्धुली-
बर्दिबास सडक आयोजना
मिनभवन, काठमाडौं, नेपाल
फोन नं : +९७७-१-४४८०६०४
फ्याक्स नं : +९७७-१-४४८०६०४
ई-मेल : sddsbrp@gmail.com.np

परामर्शदाता

ग्रुप अफ इन्जिनियर्स कन्सोर्टियम (प्रा) लि (GEC)
श्रीमार्ग, पुल्चोक, ललितपुर
फोन नं : +९७७-१-५५४३९७९
फ्याक्स नं : +९७७-१-५५४९३८२
ई-मेल : groupofengineers.gec@gmail.com
वेबसाइट : www.gec.com.np

वैशाख २०७९

कार्यकारी सारंस

१.० आयोजनाको परिचय

वि.पी. राजमार्ग अन्तर्गत १११+००० कि.मि. देखि ११९+७०० कि.मि. सम्म पर्ने घ्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोलामा पुल निर्माण र एप्रोच सडक स्तरोन्नति गर्ने कार्यको प्रस्तावक नेपाल सरकार, भौतिक पूर्वाधार तथा यातायात मन्त्रालय, सडक विभाग अन्तर्गत पर्ने सुर्यबिनायक – धुलिखेल, धुलिखेल – सिन्धुली – बर्दिबास सडक आयोजना रहेको छ।

राष्ट्रिय राजमार्ग बर्दिबास-सिन्धुली-खुर्कोट-धुलिखेल सडक (वि.पी. राजमार्ग) को कोड नं. रा.रा.- १३ (NH13) रहेको छ। यस राजमार्गले पूर्वी तराईलाई काठमाण्डौसँग जोड्ने भएकोले, यो देशकै एउटा महत्वपूर्ण राजमार्ग पनि हो। यस राजमार्गको कुल लम्बाई १६० कि.मि. रहेको छ, र यस सडक खण्डले अरनिको राजमार्गमा पर्ने धुलिखेललाई पूर्व-पश्चिम राजमार्गको बर्दिबास सँग जोड्छ। यो राजमार्ग मार्च २०१५ मा जापान सरकारको सहयोगमा निर्माण सम्पन्न भएको थियो।

प्रस्तावित घ्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल हेरेकको ४०मी.लम्बाई र ११ मी. चौडाईको हुनेछ। तिनै वटा पुलमा ७.५० मी. (३.७५ मी.* २) को क्यारिज वे र ३ मी.(१.५ मी.दाँया/ बाँया) को फुटपाथ बनाइनेछ। साथै घ्याम्पे खोलामा ७५ मी. , माम्ती खोलामा १६१ मी. र भ्याकुरे खोलामा ८० मी. कुल लम्बाई (दुवै तर्फ) को पहुँच सडक (Asphalt Concrete) निर्माण गरिनेछ।

२.० प्रस्तावको उद्देश्य र सान्दर्भिकता

यस प्रस्तावको मुख्य उद्देश्य वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि. सम्म पर्ने घ्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा दुई तर्फी क्षमताको ४० मी.लम्बाईको पक्की पुल र एप्रोच सडक बनाउने हो। यी पुलहरूको डिजाइन जाइका आयोजना कार्यालयको प्राविधिक सहयोगमा प्रस्तावकले प्रचलित निर्देशिका र मापदण्ड अवलम्बन गरि तयार गरेको छ। प्रस्तावित पुलहरू दुई तर्फी र पहुँच मार्ग कालो पत्रे (asphalt concrete) गर्ने गरि डिजाइन गरिएको छ।

प्रस्तावित राजमार्गको स्तरोन्नति कार्यले आयोजनाले यातायात संचालनमा सहजता प्रदान गर्दछ। वि.पी. राजमार्ग अन्तर्गत पर्ने घ्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा कजवेमात्र भएको कारण सवारीसाधन तथा सर्वसाधारणहरू लाई वर्षातको समयमा निकै असहज परिस्थिति सिर्जना भैरहेको छ। वर्षायाममा खोलाको सतह बढेर यातायातनै ठप्प हुने गरेको छ। यस कारण प्रस्तावित पुल निर्माणले यातायात सुविधामा निकै सहज हुनेछ। प्रस्ताव कर्यन्वयनले भएपछि वि.पी. राजमार्गबाट हुने यात्रालाई सहजीकरण गर्नेछ। साथै यस प्रस्तावको कार्यन्वयनले, आयोजना क्षेत्र, प्रदेश नं. १ र २ का समग्र जिल्लाहरू र देशको नै आर्थिक-सामाजिक उन्नतिमा योगदान पुर्याउनेछ। यस कारण एप्रोच सडकको स्तरोन्नति र पुल निर्माण कार्यले यातायातमा सहजता हुनेछ।

३.० संक्षिप्त वातावरणीय अध्ययनको उद्देश्य, सान्दर्भिकता र अध्ययन विधि

३.१ संक्षिप्त वातावरणीय अध्ययनको उद्देश्य

यस आयोजनाको कार्यान्वयनले सामाजिक, आर्थिक, जैविक, प्राकृतिक वातावरणहरूमा पर्ने प्रभाव आँकलन गरि सकारात्मक प्रभावको बढोत्तरी र नकारात्मक प्रभावहरूको न्यूनीकरण गर्न आवश्यक वातावरणीय व्यवस्थापन योजना तयार गर्नु नै संक्षिप्त वातावरणीय अध्ययनको प्रमुख उद्देश्य हो। यस आयोजनाको संक्षिप्त वातावरणीय अध्ययनको उद्देश्यहरू यस प्रकार छन्:



- ❖ आयोजना प्रभावित क्षेत्रको भौतिक वातावरण, जैविक वातावरण, आर्थिक-सामाजिक-साँस्कृतिक वातावरण, रासायनिक वातावरण सम्बन्धि वस्तुगत अवस्थाको तथ्यांक/सूचना संकलन गर्ने।
- ❖ आयोजना कार्यान्वयन गर्दा भौतिक वातावरण, जैविक वातावरण, आर्थिक-सामाजिक-साँस्कृतिक वातावरण, रासायनिक वातावरणमा पर्न सक्ने प्रभावहरू पत्ता लगाउने, आंकलन गर्ने, तथा मूल्यांकन गर्ने।
- ❖ सकारात्मक प्रभाव बढोत्तरी तथा नकारात्मक पभाव न्यूनीकरण गर्न व्यवहारिक र स्थान विशिष्ट उपायहरू पत्ता लगाई कार्यान्वयन गर्ने।
- ❖ वातावरण व्यवस्था कार्ययोजना तथा वातावरणीय अनुगमन योजना तयार गरी कार्यान्वयन गर्ने।
- ❖ आयोजना कार्यान्वयनका लागि संक्षिप्त वातावरणीय अध्ययन गरे पुग्छ / पुग्दैन भन्ने निश्चित गर्ने।

३.२ संक्षिप्त वातावरणीय अध्ययनको सान्दर्भिकता

प्रस्तावित सडक खण्ड र तीनवटै पुलहरू वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि.को दुरीमा अवस्थित रहेको छ। वातावरण संरक्षण नियमावली २०७७ को अनुसूची-१ को ड (१) बमोजिम २५० मिटर सम्म लम्बाईको पुल निर्माण गर्नु भन्दा पहिले संक्षिप्त वातावरणीय अध्ययन गर्नुपर्ने कानूनी प्रावधान रहेको र सडक खण्ड १० कि.मी. भन्दा कम रहेकोले वातावरणीय अध्ययन एकै प्याकेजमा गर्नु वाञ्छनीय छ। संक्षिप्त वातावरणीय अध्ययनको लागि आवश्यक कार्यसूची भौतिक पूर्वाधार तथा यातायात मन्त्रालय द्वारा मिति २०७८/०२/३१ गते स्वीकृत भएको थियो।

यसका साथै यस पुल राष्ट्रिय निकुञ्ज, संरक्षण क्षेत्र, वन्यजन्तु आरक्ष, मध्यवर्ति क्षेत्र तथा कुनै पनि वातावरणीय संवेदनशील क्षेत्रभित्र पर्ने भएकोले परियोजना कार्यान्वयन गर्दा संक्षिप्त वातावरणीय अध्ययन गरे पुग्ने देखिन्छ। यस अवस्थामा प्रस्तावित आयोजनाको कार्यान्वयन हेतु संक्षिप्त वातावरणीय अध्ययन पर्याप्त हुन्छ।

३.३ अध्ययन विधि

अध्ययन विधि अन्तर्गत डेस्क अध्ययन, स्थलगत अध्ययन तथा म्याट्रीक्स प्रणालीद्वारा वातावरणीय प्रभावको पहिचान गरि संक्षिप्त वातावरणीय अध्ययन गरिएको छ। डेस्क अध्ययनमा आवश्यक तथ्याङ्क सङ्कलन कार्यका लागि सन्दर्भ सामग्रीको पुनरावलोकन, सम्बन्धित प्रकाशित वा अप्रकाशित सामग्री/प्रतिवेदनको पुनरावलोकन, सर्वेक्षण कार्यका लागि आवश्यक प्रश्नावलीको तयारी, स्थलगत पैदल सर्भेक्षण (Walkover survey), प्रत्यक्ष अवलोकन, मुख्य जानकार व्यक्तिसंग अन्तर्वार्ता (Key Informant Interview), तथा सामुहिक छलफल लगायतका कार्य गरिएको छ। तथ्यांक संकलनको लागि वातावरणीयविज्ञ, समाजशास्त्री, वनस्पतिविद् र वातावरणीय इन्जिनियरको टोलीले वि.सं. २०७८/०५/१८ देखि वि.सं. २०७८/०६/२४ सम्म आयोजना क्षेत्र स्थलगत भ्रमण गरेका थिए। उक्त टोलीले आयोजना क्षेत्रमा पैदल सर्वेक्षण गरी भौतिक, जैविक र सामाजिक-आर्थिक र साँस्कृतिक वातावरण अवलोकन गरेका थिए। आयोजना क्षेत्रको वातावरणीय र सामाजिक अवस्थाको बारेमा विभिन्न आधारभूत तथ्याङ्क र जानकारी संकलन गरियो।

यसै गरि मिति २०७८-०५-२५ गते रोशी गाउँपालिका -११, माम्ती भीमसेन मन्दिर मा सार्वजनिक सुनुवाई कार्यक्रम आयोजना गरिएको थियो। सार्वजनिक सुनुवाई कार्यक्रममा ५२ जना व्यक्तिको उपस्थित रहेको थियो। यसका साथै वातावरण संरक्षण नियमावली २०७७ को नियम (७) अनुसार स्थानीय तहको कार्यालय, सरोकारवाला संघ-संस्था लगायत सार्वजनिक स्थानहरू जस्तै गाउँपालिका भवन, सम्बन्धित वडा कार्यालयको भवन, प्रहरीचौकी, स्वास्थ्य चौकी, विद्यालय, लगायतका सार्वजनिक स्थानमा सात (७) दिन भित्र लिखित सुझाव उपलब्ध गराउन अनुसूची ३ बमोजिमको ढाँचामा सूचना टाँस गरी मुचुल्का तयार गरिएको थियो र सोही बमोजिमको सूचना मिति २०७८/०६/०६ गते सिन्धुली जिल्लाबाट प्रकाशित हुने राष्ट्रिय दैनिक पत्रिका "सिन्धुली सौगात" बाट प्रकाशन गरिएको थियो।



४.० विद्यमान वातावरणीय अवस्था

४.१ भौतिक वातावरण

प्रस्तावित क्षेत्र बागमती प्रदेशको पहाडी भेगमा पर्दछ। यी पुलहरू सिन्धुली र काभ्रेपलाञ्चोक जिल्लामा अवस्थित हुनेछन्। उक्त पुल निर्माण क्षेत्र वरपर मुख्य रूपमा खोलाले बगाएर ल्याएका ढुंगा, माटो प्रसस्त रूपमा देख्न सकिन्छ। हाल खोलाको सतह र विद्यमान सडक करिब बीच १५-३० मि. को अन्तर रहेको छ। अन्य समय भन्दा वर्षायाममा अविरल वर्षाको कारण पुल नरहेको अवस्थामा सडकबाट नै पानी बग्ने हुदा सडकहरू घन्टौंसम्म बन्द रहने सम्भावना बढि रहन्छ। आयोजना क्षेत्रको वार्षिक वर्षा ८८७ मि.मि. रहेको छ। निर्माण क्षेत्र भूकम्पको दृष्टिकोणले मध्यम किसिम जोखिम रहेको पाइन्छ।

४.२ जैविक वातावरण

प्रस्तावित आयोजना उपोष्ण मौसमी क्षेत्रमा पर्दछ। सिमल (*Bombax cebia*), उत्तिस (*Alnus nepalensis*), सिरिस (*Albizia procera*), खिर्रो (*Sapium insigne*), महुवा (*Engelhardia spicata*), बिलाउने (*Maesa chisia*), रक्चन (*Daphniphyllum himalense*), चुलेत्रो (*Brasaiopsis hainla*) आदिको बाहुल्यता रहेको उक्त क्षेत्रमा पुल निर्माणको क्रममा कुनै पनि काट्न नपर्ने देखिन्छ। आयोजना क्षेत्रहरू वस्ती नजिकै भएकाले वन्यजन्तुहरूको वासस्थान आयोजना क्षेत्र भन्दा केहि पर रहेको छ। स्थानीयहरूसंगको छलफल अनुसार आयोजना क्षेत्र वरपर न्याउरी मुसा, स्याल, रातो बादर, दुम्सी, मृग आदि जस्ता वन्य जन्तुहरू पाइन्छन्। चराहरूको सन्दर्भमा आयोजना क्षेत्र वरपर काग, परेवा, भंगेरा, चिवे, ढुकुर, कोइली आदि प्रजातीका चराहरू पाइन्छन्।

४.३ सामाजिक आर्थिक तथा सांस्कृतिक वातावरण

जातीय हिसाबले तामांग, ब्राह्मण, क्षेत्री, नेवार, मगर आदिको बाहुल्यता रहेको उक्त क्षेत्रमा शिक्षा, स्वास्थ्य र संचारको राम्रो प्रबन्ध रहेको छ। आयोजना क्षेत्रमा नेपाल विद्युत प्राधिकरणको विद्युतको पहुँच रहेको छ। खाना पकाउनका लागि ग्यास तथा दाउराको प्रयोग हुने गर्दछ। त्यस्तै आयोजना क्षेत्रमा एन्सेल, नमस्ते जस्ता सेवा प्रदायकहरूले संचार सुविधा प्रदान गरिरहेका छन्।

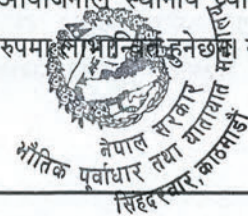
कृषि यस क्षेत्रको मुख्य पेशा रहेको छ। समथर फाँट तथा टारहरूमा धान, मकै, गहु तथा आलु जस्ता खाद्यबालीको राम्रो उत्पादन हुने गरेको पाइन्छ। यस क्षेत्रको आर्थिक भार कृषि र व्यापारले धानेको देखिन्छ। कृषि बाहेक रेमिट्यान्स, नोकरी र व्यवसायले पनि केहि आर्थिक भारबोकेको पाइन्छ। पसल, होटल र घरेलु व्यापारमा व्यवसायी संलग्न भएको पाइन्छ।

५.० आयोजनाका प्रभावहरू

आयोजना कार्यान्वयन हुदाँ आयोजना क्षेत्रको वातावरणमा सकारात्मक र नकारात्मक दुवै प्रकारको प्रभाव हुने देखिन्छ।

५.१ सकारात्मक प्रभावहरू

सकारात्मक प्रभावमा निर्माण गतिविधिले सम्भवतः आयोजना क्षेत्रमा आर्थिक गतिविधिहरू बढाउछ। आयोजना क्षेत्रमा कामदारहरूको आगमनले विशेष रूपमा उपभोग वस्तुहरूको आपूर्तिको लागि स्थानीय रूपमा उब्जिएको तरकारीहरू र होटल र रेस्टुरेन्ट/चिया स्टल व्यवसायहरू आर्थिक गतिविधिहरूको मुख्य क्षेत्र हुनेछन्। आयोजना निर्माण सम्बन्धि गतिविधिहरूको कारण आर्थिक गतिविधिमा वृद्धि भइ यी क्षेत्रहरू लाभान्वित हुनेछन्। आयोजनाले स्थानीय व्यक्तिहरूलाई सीप अनुरूप रोजगारीको अवसर प्रदान गर्दछ। यो आयोजनाले स्थानीय व्यक्तिहरू प्रतक्ष्य रूपमा लाभान्वित हुनेछन्। साथै ध्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल निर्माणले यातायातमा सहज हुन्छ।



५.२ नकारात्मक प्रभावहरू

त्यस्तै नकारात्मक प्रभावमा पुल निर्माण तथा सडक सुधारको क्रममा भित्ताहरू काट्टा बढ्न जाने भू-क्षयको जोखिम, त्यस्तै गिट्टी, बालुवाहरू उत्खनन गर्दा निम्तिन सक्ने वातावरणीय प्रभाव, आयोजनाका मेसिनरी तथा सवारीसाधन संचालन गर्दा हुने वायु तथा ध्वनि प्रदुषण, पुलको जग खन्दा निस्कने ढुंगा तथा माटोको व्यवस्थापनको चुनौती, कामदारहरूबाट निस्काशित फोहोरमैलाले गर्ने प्रभाव, अवैध चोरी शिकारी, सामाजिक कलह, पेशागत स्वास्थ्य तथा सुरक्षाका सवालहरू आदि पर्दछन्।

६.० वैकल्पिक विश्लेषण

यस आयोजनाको संक्षिप्त वातावरणीय अध्ययनका क्रममा आयोजना पद्धति, आयोजना स्रोत, प्रविधि, संचालन विधि, संचालन समय, कच्चा पदार्थहरू, वातावरणीय व्यवस्थापनका पक्षहरू, आयोजना कार्यान्वयनका जोखिम पक्षहरू आदि विकल्पहरूको विश्लेषण गरिएको छ।

७.० सकारात्मक प्रभाव बढोत्तरीका उपायहरू

निर्माणका क्रममा संलग्न हुने कामदारहरूलाई स्थानीय रूपमा उब्जिएको तरकारीहरू र उपयोगयोग्य बस्तुहरू नजिकको बजार वाट खरिद गर्न प्रेरित गरिनेछ। पुल निर्माण गर्ने क्रममा स्थानीय कामदारहरू लाई बढी प्राथमिकता दिईनेछ। साथै स्थानीयहरूको शिप विकास गर्न तालिमको व्यवस्था गरिनेछ।

८.० नकारात्मक प्रभावहरू न्यूनीकरणका उपायहरू

● भौतिक वातावरण

आयोजना कार्यान्वयनको क्रममा उत्सर्जित रासायनिक पदार्थहरू तथा त्यससंग मिसिएर आएको फोहोरहरूलाई उचित रूपमा संकलन गर्ने तथा भण्डारण गर्ने, काम गर्ने कर्मचारी र कामदारहरूलाई उचित शौचालयको व्यवस्था मिलाउने र खुला दिशा मुक्त गराउने, बाटोको धुलो न्यूनीकरणका लागि हरेक दिन बिहान पानी छर्कने, वन नोकशान हुनवाट बचाउनको लागि खाना पकाउनका निम्ति एल.पी.जी सिलिन्डरको व्यवस्था गरिनेछ। इलेक्ट्रोम्याग्नेटिक प्रभाव कम गर्न सम्पूर्ण पोलहरू अर्थिग गरिनेछ। आयोजनाको निर्माण र संचालन चरण अन्तर्गत भौतिक वातावरणीयमा पर्ने प्रभावको न्यूनीकरणका लागत आयोजनाको निर्माण लागतमा समावेश गरिएको छ।

● जैविक वातावरण

आयोजना कार्यान्वयनद्वारा हुने नकारात्मक प्रभावको न्यूनीकरण तथा सकारात्मक प्रभावको अभिवृद्धिका लागि विभिन्न न्यूनीकरणका उपायहरू अवलम्बन गरिनेछ। निर्माणको लागि कुनै पनि रुख कटान गरिने छैन। वन्यजन्तुको आवास र आवागमनमा बाधा कम गर्न निर्माण क्षेत्रमा चेतावनी चिन्हहरू राखिनेछ।

● सामाजिक आर्थिक तथा सांस्कृतिक वातावरण

रोजगारीको क्रममा र रोजगारी तथा ज्याला वितरणका क्रममा लैंगिक विभेद गरिने छैन। स्थानीयहरूलाई उनीहरूको सांस्कृतिक, धार्मिक स्थलहरू लगायत महिलाहरूलाई आदर गर्ने खालका विभिन्न जनचेतनामुलक कार्यक्रमहरू संचालन गरिनेछ।

कामदारहरू तथा कर्मचारीहरूलाई रातिको समयमा आयोजनाको क्याम्पिन बाहिर निस्कनु परेमा व्यवस्थापकको अनुमति लिनुपर्ने व्यवस्था गरिएको छ। स्थानीय तथा राज्यको कामदारहरूलाई उनीहरूको कार्य रूपमा पालना गर्न



लगाइने छ। निर्माणका क्रममा कामदारहरू र कर्मचारीहरूलाई पेशागत स्वास्थ्यमा पतिकुल प्रभाव न्यूनीकरणका विकल्पहरू बारेमा सुचित गराइनेछ। त्यसको व्यवस्था निर्माण व्यावासायी र कम्पनीले गराउनुअर्ने हुन्छ। प्राथमिक उपचारका लागि आवश्यक पर्ने सम्पूर्ण औषधि एवं उपकरणहरू क्याम क्षेत्र र निर्माण क्षेत्रमा उपलब्ध गराइनेछ। सरसफाई सम्बन्धि विभिन्न खालका कार्यक्रमहरू संचालन गरिनेछ। प्रदुषण कम गर्नका लागि निस्किएका ठोस फोहोर, उत्खनन गर्दा निस्किएका माटोहरूको उचित व्यवस्थापन गरिनेछ। विद्युत प्रसारण लाइनको अधिकार क्षेत्र साथै महत्वपूर्ण स्थानहरूमा होर्डिंग बोर्ड लगाइनेछ।

१.० वातावरणीय व्यवस्थापन कार्ययोजना वातावरणीय अनुगमन योजना

वातावरणीय प्रभाव न्युनिकरण गर्नका लागि यस प्रतिवेदनमा विभिन्न उपायहरू एवम निरीक्षण कार्यलाई प्रभावकारी र व्यवस्थित बनाउनका लागि वातावरणीय व्यवस्थापन योजना निर्माण गरिएको छ। यस योजनाले प्रत्येक वातावरणीय सूचकहरू, कार्यान्वयन गराउने संस्था, निरीक्षण गर्ने संस्था, कार्यान्वयनको समय तथा आवश्यक आर्थिक व्यवस्थापनका विषयहरूलाई स्पष्ट रूपमा प्रस्तुत गरिएको छ। यस आयोजना द्वारा त्यस क्षेत्रमा कार्यरत सरकारी, सम्बन्धित संस्था, गाउँपालिका, वडा कार्यालय, जिल्ला समन्वय समिति, समुदायमा आदारित संस्था तथा गैरसरकारी संस्थाहरू तथा स्थानीय सरोकारवालाहरूसंग आयोजनाको कस्तो सम्बन्ध रहने तथा कसरी समन्वय गर्ने भन्ने विषयलाई समेत मध्यनजर गरिएको छ।

यस आयोजनाको वातावरणीय अनुगमनका लागि चार लाख दश हजार (ने.रु. ४,१०,०००) बजेट प्रस्ताव गरिएको छ।

१०.० निष्कर्ष

संक्षिप्त वातावरणीय अध्ययनबाट पहिचान गरिएका अधिकांश प्रभावहरूलाई न्यूनीकरण गरि स्वीकारयोग्य बनाउनको लागि आर्थिकरूपमा प्रभावकारी देखाइएको छ। आयोजनाको निर्माण चरणमा सामान्य श्रमिकका रूपमा काम गर्ने कामदारहरूले डकमी काम तथा पर्खाल लगाउने जस्ता कामहरू सिकन सक्ने छन्। दक्ष जनशक्तिहरूसँगको सुपरिवेक्षणमा निर्माण कार्यमा संलग्न भई काम गर्न पाउँदा नयाँ तथा शिप विहिन ज्यालादारी मजदुरहरूले निर्माण सम्बन्धि कार्य अनुभव वाट आफ्नो सिप, दक्षता तथा क्षमता अभिवृद्धि गर्ने अवसर पाउँदछन।

वि.पी. राजमार्ग अन्तर्गत पर्ने ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा हाल कजवेमात्र भएको कारण सवारीसाधन तथा सर्वसाधारणहरूलाई वर्षातको समयमा निकै असहज परिस्थिति सिर्जना भैरहेको छ। वर्षायाममा खोलाको सतह बढेर यातायातनै ठप्प हुने गरेको छ। यस कारण प्रस्तावित पुलहरू दुई तर्फी र पहुँच मार्ग कालो पत्रे बनाएपछि यातायात सुविधामा निकै सहज हुनेछ। साथै प्रस्तावित भ्याकुरे खोला पुल, माम्ती खोला पुल, र ध्याम्पे खोला पुल निर्माणबाट नजिकका बजारहरू जस्तै नेपालथोक, माम्ती, मंगलटारमा होटेल, चियापसल जस्ता व्यवसाय चलाई स्थानीय पैसा आर्जन गर्न पनि सक्दछन। त्यस्तै स्थानीय पसलहरूको समान बिक्रिमा वृद्धि तथा खाने उपज जस्तै तरकारी, दुध तथा मासुहरूको पनि खपत बढनेछ। जसको कारण स्थानीय स्तरमा आर्थिक गतिविधिमा वृद्धि हुनेछ। स्थानीयहरूले निर्माण कार्य सम्बन्धि रोजगारीका अवसरहरू प्राप्त गर्नेछन। यस लगाएत वर्षायाममा पानीको उचित निकास, सवारीसाधन आवतजावतमा सहजीकरण आदि जस्ता सकारात्मक प्रभावहरू देखा पर्छन। माथिका तथ्यहरूका आधारमा संक्षिप्त वातावरणीय अध्ययन प्रतिवेदनमा प्रस्ताव गरिएको न्यूनीकरणका उपायहरू जस्तै रिटेनिंग संरचना निर्माण, चेक ड्याम र छेकबाँधको निर्माण, फोहोरमैलाको उचित व्यवस्थापन, पहुँच सडकको दाँया/बायाँ वृक्षारोपण आदि र वातावरणीय व्यवस्थापन योजना अनुसार कार्यान्वयन गर्ने गरि आयोजना संचालन गर्न उपयुक्त देखिन्छ।



विषय सुची

कार्यकारी सारंस	I
१.०. प्रतिवेदन तयार गर्ने व्यक्ति वा संस्थाको नाम र ठेगाना	१
१.१ प्रस्तावक	१
१.२ परामर्शदाता	१
२.० प्रस्ताव	३
२.१ आयोजनाको परिचय	३
२.२ आयोजनाको सान्दर्भिकता	३
२.३ आयोजनाको उद्देश्यहरु	३
२.४ संक्षिप्त वातावरणीय अध्ययनको सान्दर्भिकता	४
२.५ संक्षिप्त वातावरणीय अध्ययनको उद्देश्यहरु	४
२.६ भू-उपयोगमा पर्ने प्रभाव	४
२.७ आयोजनाको लागि कटान गर्नु पर्ने रुखको विवरण	५
२.८ आयोजनाले प्रभाव पर्ने घरधुरी र जनसंख्याको सन्क्षिप्त विवरण	५
३.० प्रस्तावको विस्तृत विवरण	६
३.१ प्रस्तावको किसिम	६
३.२ आयोजना क्षेत्रको नक्सा	६
३.३ आयोजनाको मुख्य विशेषताहरु	१०
३.४ आयोजनाको लागि जग्गा आवश्यकता	१२
३.५ आयोजनाको लागि आवश्यक निर्माण सामग्री	१२
३.६ आयोजनाको लागि आवश्यक पर्ने इन्धन	१३
३.७ आयोजनाको लागि आवश्यक जनशक्ति	१३
३.८ आयोजना क्षेत्र निर्धारण	१३
३.९ आयोजनाका सहायक सुविधाहरु निर्धारण	१४



३.९.१ कामदार शिविर तथा भण्डारण क्षेत्र	१४
३.१० निर्माण प्रविधि	१५
३.११ निर्माण तालिका	१५
३.१२ अध्ययन विधि	१७
३.१२.१ संक्षिप्त वातावरणीय अध्ययनका लागि आवश्यक सूचना/तथ्यांक	१७
३.१२.२ तथ्याङ्क संकलनको विधि	१९
३.१२.३ सार्वजनिक सुनुवाई तथा सार्वजनिक सूचना:	२१
३.१२.४ तथ्यांक विश्लेषण:	२४
३.१३ आयोजनाको विद्यमान वातावरणीय अवस्था	२६
३.१३.१ भौतिक वातावरण	२६
३.१३.२ जैविक वातावरण	२८
३.१३.३ सामाजिक, आर्थिक र साँस्कृतिक वातावरण	२८
३.१४ प्रतिवेदन तयार गर्दा विचार गर्नु पर्ने नीति, एन, नियम, निर्देशिका तथा अन्तर्राष्ट्रिय सन्धि सम्झौताहरु	३१
३.१४.१ नेपालको संविधान	३१
३.१४.२ नीति, ऐन, नियमावली, निर्देशिका, सन्धि तथा सम्झौता	३१
३.१४.३ मापदण्ड	४९
४. प्रस्ताव कार्यान्वयन गर्दा वातावरणमा पर्ने खास प्रभाव	५१
४.१ सकारात्मक प्रभावहरु	५१
४.१.१ निर्माण चरण	५१
४.१.२ संचालन चरण	५२
४.२ नकारात्मक प्रभावहरु	५३
४.२.१ भौतिक वातावरण	५३
४.२.२ जैविक वातावरण	५६
४.२.३ सामाजिक आर्थिक र साँस्कृतिक वातावरण	५७
५.० प्रस्ताव कार्यान्वयनका विकल्प	६०
५.१ आयोजनास्थल	६०
५.२ वैकल्पिक डिजाइन	६०



५.३ प्रविधि र सञ्चालन विधि, समय तालिका, प्रयोग हुने कच्चा पदार्थ:	६०
५.४ वन प्रयोग नगर्ने वा कम गर्ने	६०
६.० वातावरणीय व्यवस्थापन योजना	६१
६.१ वातावरणीय व्यवस्थापनका लागि जिम्मेवार निकायहरू:.....	६१
६.२ वातावरण व्यवस्थापन योजना (ध्याम्पे खोला पुल)	६२
६.३ वातावरण व्यवस्थापन योजना (माम्ती खोला पुल)	७१
६.४ वातावरण व्यवस्थापन योजना (भ्याकुरे खोला पुल).....	८२
७.० प्रस्तावको कार्यन्वयनगर्दा अनुगमन गर्नु पर्ने विषय	९२
७.१ अनुगमनका सूचकहरू	९२
७.२ अनुगमन सम्बन्धि विवरण	९३
७.३ अनुगमन र न्युनिकरणको खर्चको विवरण:	९४
८. निष्कर्ष	९५
सन्दर्भ सामाग्रीहरू.....	९६

अनुसूचीहरू	
अनुसूची १:	स्वीकृत कार्यसूचीको पत्र
अनुसूची २ :	स्वीकृत कार्यसूची
अनुसूची ३:	आयोजना स्थलको गुगल नक्शा र सडक संजाल नक्शा र अवस्थिति नक्शा
अनुसूची ४:	आयोजनाको विस्तृत नक्शाकन सहितको स्थलिकृत नक्शा
अनुसूची ५:	सार्वजनिक सुनुवाइको सूचना
अनुसूची ६:	सार्वजनिक सुनुवाइको विवरण
अनुसूची ७:	सार्वजनिक सूचना
अनुसूची ८:	सिफारिस पत्र
अनुसूची ९:	तस्बिरहरू
अनुसूची १०:	स्व-धोषणा पत्र



चित्रहरुको सुची:

चित्र नं. ३.१:	आयोजना स्थल	७
चित्र नं. ३.२:	आयोजना स्थल सम्मको पहुँचमार्ग	९
चित्र नं. ३.३:	सार्वजनिक छलफल	२१
चित्र नं. ३.४:	सार्वजनिक सुनिवाईको तस्बिरहरु	२३
चित्र नं. ३.५:	सुचना टाँसको तस्बिर	२४



तालिकाहरूको सूचि

तालिका १.१:	संक्षिप्त वातावरणीय अध्ययनमा संलग्न व्यक्तिहरू	२
तालिका २.१:	आयोजनाका लागि आवश्यक पर्ने जग्गाको बिस्तृत विवरण	४
तालिका ३.१:	स्थानीय प्रशासनिक क्षेत्रहरूको विवरण	६
तालिका ३.२:	आयोजना स्थलको पहुँच विवरण	८
तालिका ३.३:	आयोजनाको मुख्य विशेषताहरू	१०
तालिका ३.४ :	निर्माण सामग्रीको विवरण	१२
तालिका ३.५:	आयोजनाको लागि आवश्यक पर्ने इन्धनको विवरण	१३
तालिका ३.६ :	जनशक्ति आवश्यकताको विवरण	१३
तालिका ३.७:	कामदार शिविरको विवरण	१४
तालिका ३.८:	आयोजनाको निर्माण तालिका	१६
तालिका ३.९:	जल, जमिन तथा वायु प्रदूषणको अवस्था तिनिहरूको स्रोत तथा पार्न सक्ने असर	१७
तालिका ३.१०:	वनस्पति तथा वन्यजन्तुको अवस्था तिनिहरूको स्रोत तथा पार्न सक्ने असर	१८
तालिका ३.११:	तथ्यांक संकलन विधि संक्षेप	१९
तालिका ३.१२:	सार्वजनिक सुनुवाईको उपस्थित	२२
तालिका ३.१३:	सुनुवाई कार्यक्रममा उठेका रायसुझाव तथा उपायहरू	२२
तालिका ३.१४:	प्रभाव पहिचान म्याट्रिक्स	२५
तालिका ३.१५:	प्रभाव महत्व	२५
तालिका ३.१६:	वायु गुणस्तर सूचांक र PM2.5 तथ्याङ्क	२७
तालिका ३.१७:	प्रसारण लाईनको विभिन्न स्थानमा मापन गरिएको ध्वनिको स्तर	२७
तालिका ३.१८:	आयोजना प्रभावित जिल्लाहरूको जनसांख्यिकीय विवरण	२९
तालिका ३.१९:	प्रभावित क्षेत्रको जनसाङ्ख्यिक विवरण	२९
तालिका ३.२०:	जातिय विवरण	३०
तालिका ३.२१:	आयोजनासँग सम्बन्धित दफा, नियम, निर्देशिका, मापदण्ड, सन्धि, सम्झौता	३१
तालिका ३.२२	एम्बियन्ट एयर क्वालिटी मानक, २०१२	५०
तालिका ३.२३:	ध्वनी गुणस्तरको राष्ट्रिय मानक, २०६९	५०
तालिका ४.१	अनुकूल प्रभावहरूको सारांश	५३
तालिका ४.२:	भौतिक वातावरणमा पर्ने प्रभावहरूको सारांश	५६
तालिका ४.३:	जैविक वातावरणमा पर्ने प्रभावहरूको सारांश	५८
तालिका ४.४:	सामाजिक आर्थिक र सांस्कृतिक वातावरणमा पर्ने प्रभावहरूको सारांश	५९
तालिका ६.१ :	सकारात्मक प्रभावको बढोतरीका क्रियाकलापहरू(ध्याम्पे खोला पुल)	६३
तालिका ६.२ :	नकारात्मक प्रभावको न्यूनीकरणका उपायहरू(ध्याम्पे खोला पुल)	६५
तालिका ६.३	सकारात्मक प्रभावको बढोतरीका क्रियाकलापहरू(माम्ती खोला पुल)	७१
तालिका ६.४	नकारात्मक प्रभावको न्यूनीकरणका उपायहरू(माम्ती खोला पुल)	७४
तालिका ६.५	सकारात्मक प्रभावको बढोतरीका क्रियाकलापहरू(भ्याकुरे खोला पुल)	८१
तालिका ६.६	नकारात्मक प्रभावको न्यूनीकरणका उपायहरू(भ्याकुरे खोला पुल)	८४
तालिका ७.१:	अनुगमन सूचकहरू	९२



तालिका ७.२:	प्रभाव क्षेत्रहरूको अनुगमन, सूचक, तरिका तथा समय तालिका	९३
तालिका ७.३:	अनुगमन र न्युनिकरणको अनुमानित लागत	९४



१.०. प्रतिवेदन तयार गर्ने व्यक्ति वा संस्थाको नाम र ठेगाना

१.१ प्रस्तावक

वि.पी. राजमार्ग अन्तर्गत १११+००० कि.मि. देखि ११९+७०० कि.मि. सम्म पर्ने घ्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल निर्माण र एग्रोच सडक स्तरोन्नति गर्ने कार्यको प्रस्तावक नेपाल सरकार, भौतिक पूर्वाधार तथा यातायात मन्त्रालय, सडक विभाग अन्तर्गत पर्ने सुर्यबिनायक – धुलिखेल, धुलिखेल – सिन्धुली – बर्दिबास सडक आयोजना रहेको छ। प्रस्तावको संक्षिप्त वातावरणीय अध्ययन प्रतिवेदन सडक विभाग, भु-वातावरण तथा सामाजिक शाखा हुँदै भौतिक पूर्वाधार तथा यातायात मन्त्रालयमा पेश भै स्वीकृति हुने कानुनी प्राबधान रहेको छ।

प्रस्तावकको नाम र ठेगाना तल उल्लेख गरिएको छ।

प्रस्तावकको नाम तथा ठेगाना

नेपाल सरकार, भौतिक पूर्वाधार तथा यातायात मन्त्रालय, सडक विभाग
सुर्यबिनायक -धुलिखेल, धुलिखेल- सिन्धुली-बर्दिबास सडक आयोजना,
मिनभवन, काठमाडौं

फोन नं.: ०१-४४८०६०४

फ्याक्स नं.: ०१-४४८०६०४

ईमेल: sddsbrp@gmail.com

प्रस्तावक सुर्यबिनायक -धुलिखेल, धुलिखेल- सिन्धुली-बर्दिबास सडक आयोजनाले घ्याम्पे खोला पुल निर्माणको लागि निर्माण कम्पनी प्यासिफिक इंजिनियरिंग कम्पनी प्रा.लि. सँग मिति २०७८-०६-१३ मा करार सम्झौता(करार संकेत नं: SDSBR-33701132-2077/78-027) गरेको हो। त्यसैगरी प्रस्तावकले माम्ती खोला पुल निर्माणको लागि निर्माण कम्पनी जयविष्णु-ईम्यान्यल-गौरीमाइ जे.भी. सँग मिति २०७८-०६-१२ मा करार सम्झौता(करार संकेत नं: SDSBR-33701132-2077/78-02८) गरेको हो। साथै प्रस्तावकले भ्याकुरे खोला पुल निर्माणको लागि निर्माण कम्पनी जयविष्णु-ईम्यान्यल-गौरीमाइ जे.भी. सँग मिति २०७८-०६-१२ मा करार सम्झौता (करार संकेत नं: SDSBR-33701132-2077/78-029) गरेको हो।

१.२ परामर्शदाता

प्रस्तावकको तर्फबाट ग्रुप अफ इंजिनियर्स कन्सर्टियम (GEC) लाई प्रस्तावित आयोजनाको संक्षिप्त वातावरणीय अध्ययनको प्रतिवेदनको तयारीको लागि जिम्मेवारी दिइएको छ। ग्रुप अफ इंजिनियर्स कन्सर्टियमले प्रस्तावित आयोजनाको संक्षिप्त वातावरणीय अध्ययन गर्ने सम्बन्धमा मिति २०७७/०५/१६ मा सम्झौता गरे पश्चात् भौतिक पूर्वाधार तथा यातायात मन्त्रालयबाट संक्षिप्त वातावरणीय अध्ययनको कार्यसूची वि.स. २०७८/२/२१ मा स्वीकृत गरेको थियो।

सम्पर्क ठेगाना:

नाम: ग्रुप अफ इंजिनियर्स कन्सर्टियम (GEC)

ठेगाना: पुलचोक, ललितपुर

फोन नं.: ०१-५५४३९७९

फ्याक्स नं.: ०१-५५४९३८२

ईमेल : groupofengineers.gec@gmail.com



संक्षिप्त वातावरणीय अध्ययन तयार गर्न संलग्न विज्ञहरुको विवरण देहाय बमोजिमक तालिका १.१ मा प्रस्तुत गरिएको छ।
तालिका १.१:संक्षिप्त वातावरणीय अध्ययनमा संलग्न व्यक्तिहरु

क्र.स.	नाम	पद	योग्यता	कार्य अनुभव (वर्ष)	वातावरणीय अध्ययन कार्य गरेको संख्या
१.	रमनकला मजाकोटी	वातावरण विज्ञ/टोली प्रमुख	वातावरण विज्ञानमा स्नातकोत्तर	८	१५
२.	भरत प्रसाद बन्जारा	इन्जिनियर	सिभिल ईन्जिनियरिंगमा स्नातकोत्तर	११	१४
३.	दिनेश आचार्य	समाजशास्त्री	समाज शास्त्रमा स्नातक	१५	१२
४.	शिलानाथ झा	वनस्पति विज्ञ	वनस्पति शास्त्रमा स्नातकोत्तर	१५	१७
५.	सुमन थापा	जलस्रोत विज्ञ	जलाधार एवम् जलस्रोत विज्ञानमा स्नातकोत्तर	११	१३
६.	रुविन थापा	वातावरण इन्जिनियर, संयोजक	वातावरण ईन्जिनियरिंगमा स्नातक	६	२१



२.० प्रस्ताव

२.१ आयोजनाको परिचय

राष्ट्रिय राजमार्ग बर्दिवास-सिन्धुली-खुर्कोट-धुलिखेल सडक (वि.पी. राजमार्ग) को कोड नं. रा.रा.- १३ (NH13) रहेको छ। यस राजमार्गले पूर्वी तराईलाई काठमाण्डौसँग जोड्ने भएकोले, यो देशकै एउटा महत्वपूर्ण राजमार्ग पनि हो । यस राजमार्गको कुल लम्बाई १६० कि.मि. रहेको छ, र यस सडक खण्डले अरनिको राजमार्गमा पर्ने धुलिखेललाई पुर्व-पश्चिम राजमार्गको बर्दिबास सँग जोड्छ। यो राजमार्ग वि.सं. २०५१ मा जापान सरकारको सहयोगमा निर्माण सम्पन्न भएको थियो।

“सिन्धुली सडकको संचालन तथा मर्मत चरण-२” अन्तर्गत वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि. सम्म रहेका ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा पुल निर्माण र एप्रोच सडक स्तरोन्नति कार्यका लागि प्रस्तावक सुर्यबिनायक – धुलिखेल, धुलिखेल – सिन्धुली – बर्दिबास सडक आयोजना, मिनभवन, काठमाडौं यस प्रस्तावलाई कार्यान्वयन गर्ने निकाय हो। प्रस्तावक कार्यान्वयन पछि प्रस्तावित पुलहरू र एप्रोच सडक डबल लेन स्तरीय (Double Lane Standard) हुनेछ।

प्रस्तावित ध्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल ४०मी . लम्बाई र ११ मी. चौडाईको हुनेछ। तिनै वटा पुलमा ७.५० मी. (३.७५ मी.* २) को क्यारिज वे र ३ मी.(१.५ मी.दुवै तर्फ) को फुटपाथ बनाइनेछ। साथै ध्याम्पे खोलामा ७५ मी. , माम्ती खोलामा १६१ मी. र भ्याकुरे खोलामा ८० मी. लम्बाई (दुवै तर्फ) को पहुँच सडक (Asphalt Concrete) निर्माण गरिनेछ।

२.२ आयोजनाको सान्दर्भिकता

प्रस्तावित राजमार्गको स्तरोन्नति कार्यले आयोजनाले यातायात संचालनमा सहजता प्रदान गर्दछ। वि.पी. राजमार्ग अन्तर्गत पर्ने ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा कजवेमात्र भएको कारण सवारीसाधन तथा सर्वसाधारणहरूलाई वर्षातको समयमा निकै असहज परिस्थिति सिर्जना भैरहेको छ। वर्षायाममा खोलाको सतह बढेर यातायातनै ठप्प हुने गरेको छ। यस कारण प्रस्तावित पुल निर्माणले यातायात सुविधामा निकै सहज हुनेछ। प्रस्तावित सडक खण्डको ध्याम्पे खोला पुल सिन्धुली जिल्लाको सुनकोशी गा.पा. वडा नं. १, माम्ती खोला पुल र भ्याकुरे खोला पुल काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा.वडा नं. ११ मा पर्दछ। हाल अवस्थित कजवे वर्षायाममा आइरहने बाढीका कारण क्षयीकरण भई सडकमार्गमा समेत प्रभाव पारिरहेको र खास गरि वर्षायाममा यस राजमार्गमा केहि मिनेट देखि केहि घण्टासम्म सवारी आवागमनमा अवरोध हुने गरेको छ। प्रस्ताव कर्यन्वयनले भएपछि वि.पी. राजमार्गबाट हुने यात्रालाई सहजीकरण गर्नेछ। साथै यस प्रस्तावको कार्यान्वयनले, आयोजना क्षेत्र, प्रदेश नं. १ र २ का समग्र जिल्लाहरू र देशको नै आर्थिक-सामाजिक उन्नतिमा योगदान पुर्याउनेछ। यस कारण एप्रोच सडकको स्तरोन्नति र पुल र पहुँच सडकको निर्माण कार्यले यातायातमा सहजता हुनेछ।

२.३ आयोजनाको उद्देश्यहरू

यस प्रस्तावको मुख्य उद्देश्य वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि. सम्म पर्ने ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा दुई तर्फी क्षमताको पक्की पुल र एप्रोच सडक बनाई हालको ट्राफिक अबरोधलाई व्यवस्थापन गर्नु हो । यी पुलहरूको डिजाइन जाइका आयोजना कार्यालय को प्राविधिक सहयोगमा प्रस्तावकले प्रचलित



निर्देशिका र मापदण्ड अवलम्बन गरि तयार गरेको छ । प्रस्तावित पुलहरू दुई तर्फि र पहुँच मार्ग कालो पत्रे (asphalt concrete) गर्ने गरि डिजाइन गरिएको छ ।

२.४ संक्षिप्त वातावरणीय अध्ययनको सान्दर्भिकता

प्रस्तावित सडक खण्ड र तीनवटै पुलहरू वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि.को दुरीमा अवस्थित रहेको छ । वातावरण संरक्षण नियमावली २०७७ को अनुसूची-१को ड (१) बमोजिम २५० मिटर सम्म लम्बाईको पुल निर्माण गर्नु भन्दा पहिले संक्षिप्त वातावरणीय अध्ययन गर्नुपर्ने कानूनी प्रावधान रहेको र सडक खण्ड १० कि.मी. भन्दा कम रहेकोले वातावरणीय अध्ययन एकै प्याकेजमा गर्नु वाञ्छनीय छ ।

यसका साथै यस पुल राष्ट्रिय निकुञ्ज, संरक्षण क्षेत्र, वन्यजन्तु आरक्ष, मध्यवर्ति क्षेत्र तथा कुनै पनि वातावरणीय संवेदनशील क्षेत्रभित्र नपर्ने भएकोले परियोजना कार्यान्वयन गर्दा संक्षिप्त वातावरणीय अध्ययन गरे पुग्ने देखिन्छ । यस अवस्थामा प्रस्तावित आयोजनाको कार्यान्वयन हेतु संक्षिप्त वातावरणीय अध्ययन पर्याप्त हुन्छ ।

२.५ संक्षिप्त वातावरणीय अध्ययनको उद्देश्यहरू

यस आयोजनाको कार्यान्वयनले सामाजिक, आर्थिक, जैविक, प्राकृतिक वातावरणहरूमा सकारात्मक वा नकारात्मक प्रभाव पर्ने हुँदा, ती प्रभावहरूको आँकलन गरि सकारात्मक प्रभावको बढोत्तरी र नकारात्मक प्रभावहरूको न्यूनीकरण गर्न आवश्यक वातावरणीय व्यवस्थापन योजना तयार गर्नु नै संक्षिप्त वातावरणीय अध्ययनको प्रमुख उद्देश्य हो । यस आयोजनाको संक्षिप्त वातावरणीय अध्ययनको विशिष्ट उद्देश्यहरू यस प्रकार छन्:

- ❖ आयोजना प्रभावित क्षेत्रको भौतिक वातावरण, जैविक वातावरण, आर्थिक-सामाजिक-साँस्कृतिक वातावरण, रासायनिक वातावरण सम्बन्धि वस्तुगत अवस्थाको तथ्यांक/सूचना संकलन गर्ने।
- ❖ आयोजना कार्यान्वयन गर्दा भौतिक वातावरण, जैविक वातावरण, आर्थिक-सामाजिक-साँस्कृतिक वातावरण, रासायनिक वातावरणमा पर्ने सक्ने प्रभावहरू पत्ता लगाउने, आँकलन गर्ने, तथा मूल्यांकन गर्ने ।
- ❖ सकारात्मक प्रभाव बढोत्तरी तथा नकारात्मक प्रभाव न्यूनीकरण गर्न व्यवहारिक र स्थान विशिष्ट उपायहरू पत्ता लगाई कार्यान्वयन गर्ने ।
- ❖ वातावरण व्यवस्था कार्ययोजना तथा वातावरणीय अनुगमन योजना तयार गरी कार्यान्वयन गर्ने ।
- ❖ निर्णयकर्तालाई आयोजना निर्माण तथा कार्यान्वयन गर्नुपूर्व वातावरणीय प्रभाव र प्रभाव न्यूनीकरणका उपायहरूको बारेमा पूर्वसूचना दिने ।
- ❖ आयोजना कार्यान्वयनका लागि संक्षिप्त वातावरणीय अध्ययन गरे पुछ / पुग्दैन भन्ने निश्चित गर्ने ।

२.६ भू-उपयोगमा पर्ने प्रभाव

तालिका २.१: आयोजनाका लागि आवश्येक पर्ने जग्गाको बिस्तृत विवरण

आयोजनाको अवयवको विवरण	निजि जमिन (हे.)		सरकारी जमिन (हे.)		कुल (हे.)	जमिन
	अस्थायी	स्थायी	अस्थायी	स्थायी		
ध्याम्पे खोला पुल						



पहुँच सडक, पुल axis र river training	०	०	०	०.२४८	०.२४८	स्थायी जग्गा प्रस्तावकले आफ्नो स्वामित्वमा लिईसकेको
भण्डारण क्षेत्र	०	०	०.०४	०.०	०.०४	
शिविर क्षेत्र	०	०	०.०८	०.०	०.०८	
कुल			०.१२	०.२४८	०.३६८	
माम्ती खोला पुल						
पहुँच सडक, पुल axis र river training	०	०	०	०.२५७	०.२५७	स्थायी जग्गा प्रस्तावकले आफ्नो स्वामित्वमा लिईसकेको
भण्डारण क्षेत्र	०	०	०.०८	०.०	०.०८	
शिविर क्षेत्र	०	०	०.०६	०.०	०.०६	
कुल			०.१४	०.२५७	०.३९७	
भ्याकुरे खोला पुल						
पहुँच सडक, पुल axis र river training	०	०	०	०.२५३	०.२५३	स्थायी जग्गा प्रस्तावकले आफ्नो स्वामित्वमा लिईसकेको
भण्डारण क्षेत्र	०	०	०.०५	०.०	०.०५	
शिविर क्षेत्र	०	०	०.०७	०.०	०.०७	
कुल			०.१२	०.२५३	०.३७३	

श्रोत: क्षेत्र निरीक्षण, २०२२

२.७ आयोजनाको लागि कटान गर्नु पर्ने रुखको विवरण

प्रस्ताव गरिएको ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोला पुल र एग्रोच सडकको निर्माणको लागि कुनै पनि रुख काटनु पर्ने देखिदैन।

२.८ आयोजनाले प्रभाव पर्ने घरधुरी र जनसंख्याको सन्क्षिप्त विवरण

प्रस्ताव गरिएको ध्याम्पे खोला, माम्ती खोला र भ्याकुरे खोला पुल निर्माणको लागि प्रभावित घर धुरी र जनसंख्या छैनन्।



३.० प्रस्तावको विस्तृत विवरण

३.१ प्रस्तावको किसिम

प्रस्तावित आयोजना वि.पी. राजमार्गको १११+४०० कि.मि. देखि ११९+७०० कि.मि. सम्म पर्ने घ्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा पक्कि पुल र एप्रोच सडक निर्माण गर्नु हो। प्रस्तावित आयोजनाको प्रस्तावक नेपाल सरकार, भौतिक पूर्वाधार तथा यातायात मन्त्रालय, सडक विभाग अन्तर्गत पर्ने सुर्यबिनायक – धुलिखेल, धुलिखेल – सिन्धुली – बर्दिबास सडक आयोजना रहेको छ।

३.२ आयोजना क्षेत्रको नक्सा

प्रस्तावित आयोजना अन्तर्गत तीनवटा पुलहरू बागमती प्रदेशमा पर्दछन् जसमध्ये घ्याम्पे खोला पुल सिन्धुली जिल्लाको सुनकोशी गा.पा. वडा नं. १, माम्ती खोला पुल काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. वडा नं. १२ र भ्याकुरे खोला पुल काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. वडा नं. ११ मा पर्दछ। प्रस्तावित घ्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल निर्माण कार्यमा नेपाल सरकारको लगानी रहेको छ। प्रस्तावित आयोजनाको निर्माण कार्य भौतिक पूर्वाधार तथा यातायात मन्त्रालय, सडक विभाग अन्तर्गत सुर्यबिनायक – धुलिखेल, धुलिखेल-सिन्धुली- बर्दिबास सडक आयोजनाद्वारा कार्यान्वयन गरिनेछ। “सिन्धुली सडकको संचालन तथा मर्मत चरण-२” को कार्यान्वयन हुनु पूर्व सन् २०१७ मा गरिएको एक सर्वेक्षणले यी तिन वटा पुलहरूको निर्माणको आवश्यकता औंलाएको थियो। वि.पी. राजमार्ग अन्तर्गत १११+४०० कि.मि. देखि ११९+७०० कि.मि. भित्र पर्ने घ्याम्पे खोला पुल, माम्ती खोला पुल र भ्याकुरे खोला पुल भौगोलिक हिसाबले पहाडी भू-भागमा पर्दछन्।

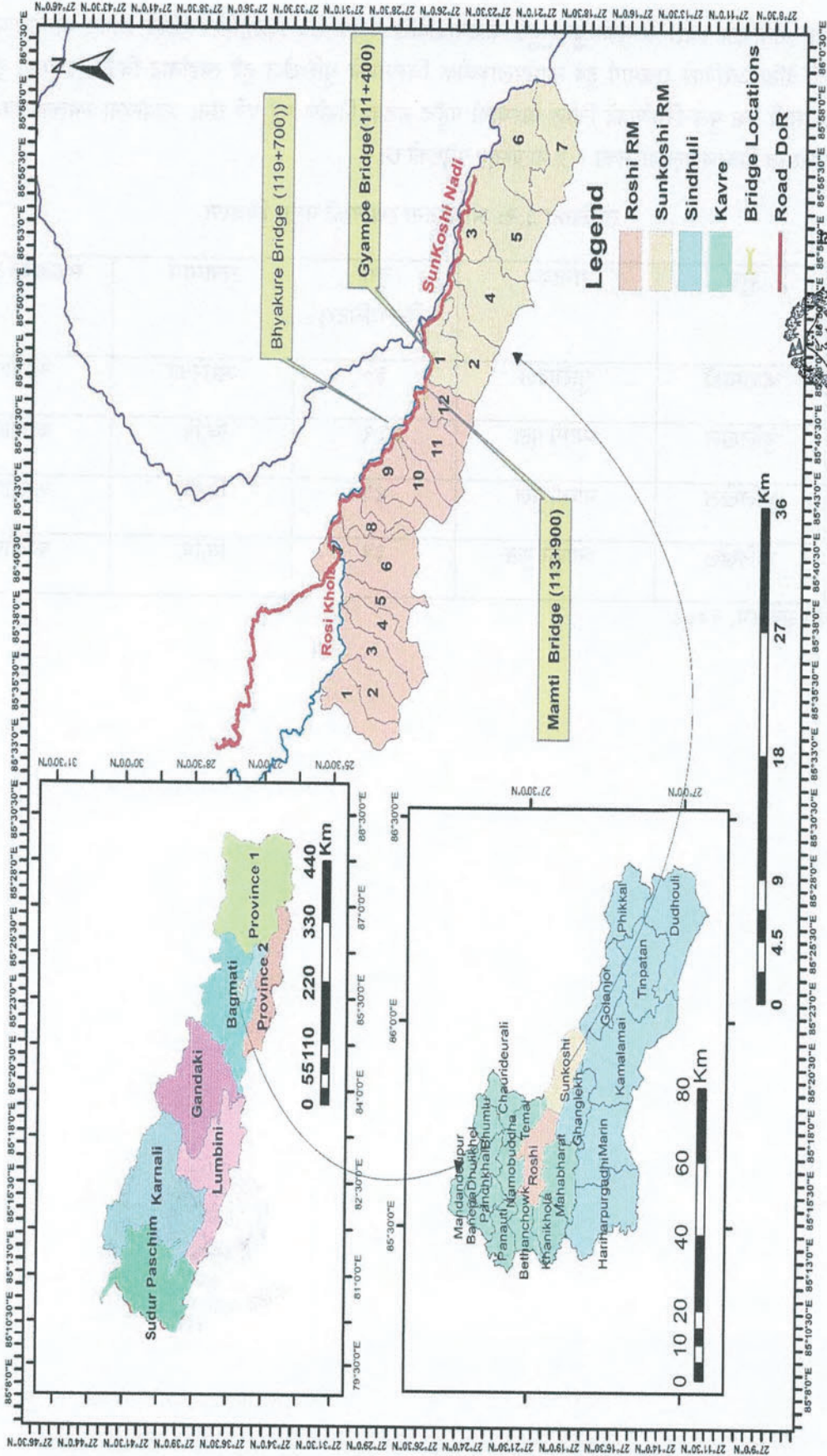
यस आयोजनाको स्थानीय प्रशासनिक क्षेत्रहरूको विवरण तालिका ३.१ मा दिइएको छ। साथै, प्रस्तावित आयोजनास्थल तथा आयोजना प्रभावित क्षेत्र चित्र नं. ३.१ मा देखाइएको छ।

तालिका ३.१: स्थानीय प्रशासनिक क्षेत्रहरूको विवरण

अवस्थिति	घ्याम्पे खोला पुल	माम्ती खोला पुल	भ्याकुरे खोला पुल
प्रदेश	बागमती	बागमती	बागमती
जिल्ला	सिन्धुली	काभ्रेपलाञ्चोक	काभ्रेपलाञ्चोक
गाउँपालिका/नगरपालिका	सुनकोशी, वडा नं. १	रोशी, वडा नं. १२	रोशी, वडा नं. ११
सडकको नाम	बी. पी. राजमार्ग	बी. पी. राजमार्ग	बी. पी. राजमार्ग
सडक प्रारम्भ – अन्त्य स्थान	धुलिखेल – बर्दिबास	धुलिखेल – बर्दिबास	धुलिखेल – बर्दिबास
पुलको चेनेज	१११ + ४००	११३ + ९००	११९ + ७००
जिपिएस	३८१७७४.८१ पूर्व, ३०३५४०४.९४ उत्तर	३७९६९४.४३ पूर्व, ३०३६२०७.९२ उत्तर	३७६५६४.०० पूर्व, ३०३९०६००० उत्तर

श्रोत : स्थलगत अध्ययन, २०७८





चित्र नं. ३.१ आयोजना स्थल

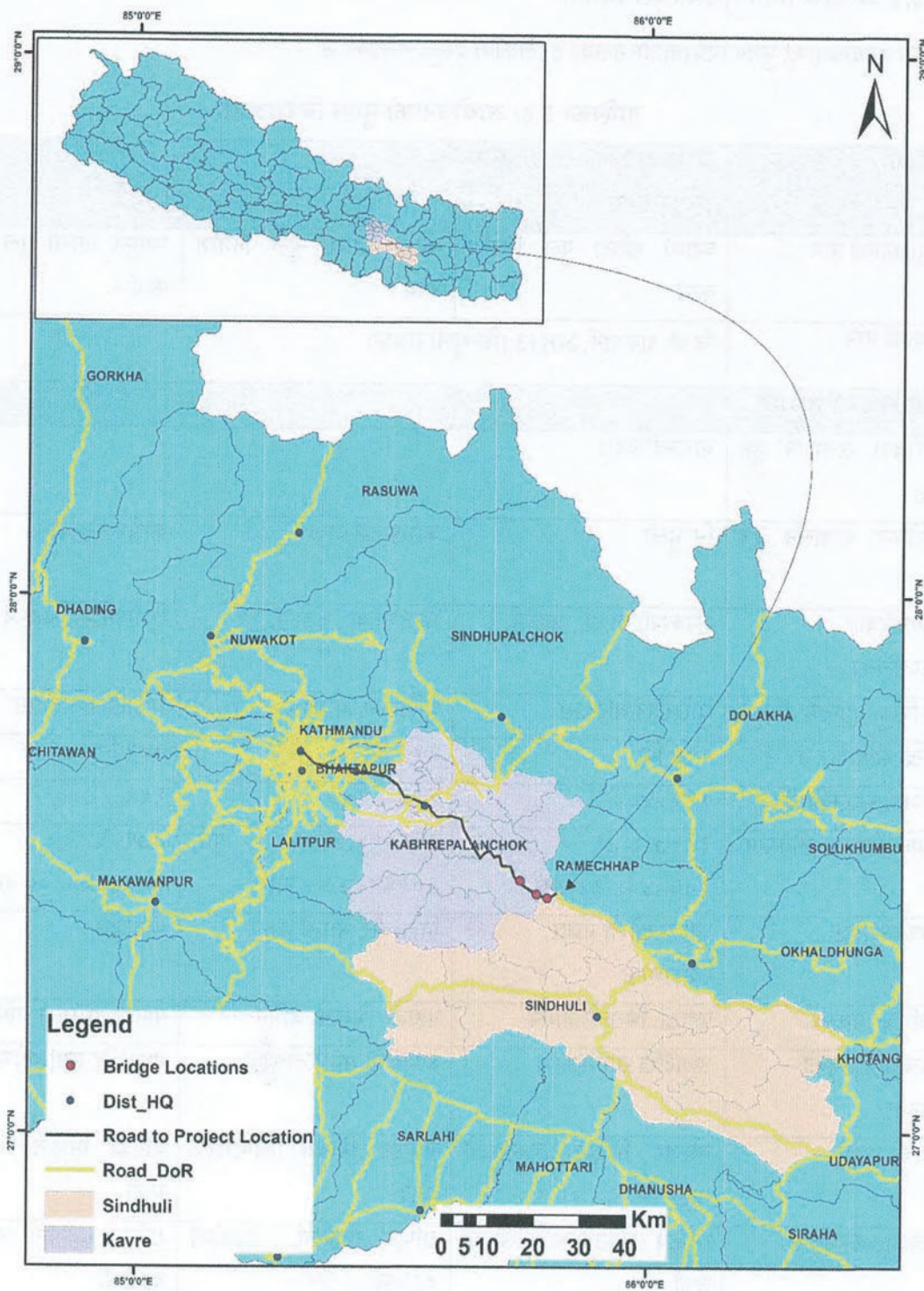
प्रस्तावित आयोजना स्थल सम्मको कुल दुरी काठमाडौँदेखि करिब ८० किलोमिटर रहेको छायास आयोजना स्थल काठमाडौँ देखि अरनिको राजमार्ग हुँदै काभ्रेपलाञ्चोक जिल्लाको धुलिखेल हुँदै त्यहाँबाट वि.पि. राजमार्ग हुँदै पुग्न सकिन्छ। साथै यस पुल निर्माणको निम्ति अस्थायी पहुँच सडक निर्माण गर्नु पर्ने छैन। आयोजना स्थलसम्मको पहुँच मार्गको विस्तृत विवरण तल तालिका ३.२ मा प्रस्तुत गरिएको छ।

तालिका ३.२: आयोजना स्थलको पहुँच विवरण

क्र.सं.	सुरु	गन्तव्य	दूरी (किलोमिटर)	राजमार्ग	सडकको प्रकार
१	काठमाडौँ	धुलिखेल	३०	अरनिको	कालोपत्रे
२	धुलिखेल	घ्याम्पे पुल	४९	वि.पि.	कालोपत्रे
३	धुलिखेल	माम्ती पुल	४३	वि.पि.	कालोपत्रे
४	धुलिखेल	भ्याकुरे पुल	३९	वि.पि.	कालोपत्रे

स्रोत: क्षेत्र सर्वेक्षण, २०७८





चित्र ३.२: आयोजना स्थल सम्मको पहुँचमार्ग



३.३ आयोजनाको मुख्य विशेषताहरू

यस आयोजनाको मुख्य बिशेषताहरू तलको तालिकामा प्रस्तुत गरिएको छः

तालिका ३.३: आयोजनाको मुख्य विशेषताहरू

विवरण	आयोजनाका मुख्य विशेषताहरू		
आयोजनाको नाम	ध्याम्पे खोला पुल निर्माण कार्य	माम्ती खोला पुल निर्माण कार्य	भ्याकुरे खोला पुल निर्माण कार्य
सडकको नाम	बि.पी. राजमार्ग, NH13 (सिन्धुली सडक)		
भौगोलिक अवस्थिति			
आयोजना संचालन हुने प्रदेश	बागमती प्रदेश		
आयोजना संचालन हुने जिल्ला	सिन्धुली	काभ्रेपलाञ्चोक	काभ्रेपलाञ्चोक
गाउँपालिका/नगरपालिका	सुनकोशी गा.पा., वडा नं. १	रोशी गा.पा., वडा नं. १२	रोशी गा.पा., वडा नं. ११
शुरु बिन्दु/अन्तिम बिन्दु	धुलिखेल/बर्दिवास	धुलिखेल/बर्दिवास	धुलिखेल/बर्दिवास
समुन्द्री सतहबाट उचाई	५९४ मि.	६१२ मि.	७०१ मि.
पुल रहने स्थानको चेनेज	१११+४००	११३ + ९००	११९ + ७००
पुलको जीपीएस लोकेसन	३८१७७४.८१ पूर्व, ३०३५४०४.९४ उत्तर	३७९६९४.४३ पूर्व, ३०३६२०७.९२ उत्तर	३७६५६४.०० पूर्व, ३०३९०६०.०० उत्तर
प्रमुख बस्तीहरू	ध्याम्पे खोला बजार, नेपालथोक	तिलाचौर, माम्ती बजार	मंगलटार
भौगर्भिक अवस्था	पहाडी भिरालो जमिन	पहाडी भिरालो जमिन	पहाडी भिरालो जमिन
जलवायु/मौसमको अवस्था	उष्णदेखि समसितोष्ण	उष्णदेखि समसितोष्ण	उष्णदेखि समसितोष्ण
माटोको प्रकार	बोल्डर मिश्रित चिम्टाईलो माटो	बोल्डर मिश्रित चिम्टाईलो माटो	बोल्डर मिश्रित चिम्टाईलो माटो
सडक/पुलको प्रकार	राष्ट्रिय राजमार्ग/आरसीसी दुई तर्फी	राष्ट्रिय राजमार्ग /आरसीसी दुई तर्फी	राष्ट्रिय राजमार्ग /आरसीसी दुई तर्फी
राजमार्ग /सहायक राजमार्ग कोड; पुल नम्बर	NH13	NH13	NH13
सडकको विद्यमान सतह	कालोपत्रे	कालोपत्रे	कालोपत्रे
क्रस सेक्सन			
क्षेत्राधिकार (राईट अफ वे	५० मि. (सडकको बीच रेखा	५० मि. (सडकको बीच रेखा	५० मि. (सडकको बीच रेखा



- आर.ओ.डब्लु.)	बाट दाँया बाँया दुबैतिर २५/२५ मिटर)	बाट दाँया बाँया दुबैतिर २५/२५ मिटर)	बाट दाँया बाँया दुबैतिर २५/२५ मिटर)
डिजाइन गति	४० कि.मि. प्रति घण्टा	४० कि.मि. प्रति घण्टा	४० कि.मि. प्रति घण्टा
पुलको लम्बाई	४० मि.	४० मि.	४० मि.
पुलको स्पानको लम्बाई	४० मि.	१२ मि., १६ मि., १२ मि.	४० मि.
पुलको जम्मा चौडाई	११ मि.	११ मि.	११ मि.
पहुँच सडकको लम्बाई	३१.५ मी.(नेपालथोक तर्फ) ४३.५ मी.(धुलिखेल तर्फ)	११५ मी.(नेपालथोक तर्फ) ४६ मी.(धुलिखेल तर्फ)	४३.५ मी.(नेपालथोक तर्फ) ३६.५ मी.(धुलिखेल तर्फ)
पहुँच सडकको स्तर	Asphalt Concrete	Asphalt Concrete	Asphalt Concrete
पुलको क्यारिज वे	७.५०मि.(३.७५ मि. X २)	७.५० मि.(३.७५मि. X २)	७.५० मि.(३.७५ मि. X २)
फुटपाथ	३ मि. (१.५ मि. दुवै तर्फ)	३ मि (१.५ मि. दुवै तर्फ)	३ मि. (१.५ मि. दुवै तर्फ)
माथिल्लो भागको संरचना प्रकार (Type of superstructure)	मानक नक्सांकन अनुसार निर्माणस्थलमा नै तयार गरिने PC Post-tensioned 2-Webbed-Slab (३ मि. गहिराइ), ४० मिटर एकल स्पान, Reverse T-shape RC Abutment x 2	मानक नक्सांकन अनुसार निर्माण स्थलमा नै तयार गरिने आरसी कन्टिनियस स्ल्याब, १२ मि. + १६ मि. + १२ मि. स्पान,	मानक नक्सांकन अनुसार निर्माण स्थलमा नै तयार गरिने PC Post-tensioned 2-Webbed-Slab (३ मि. मोटाइ), ४० मिटर एकल स्पान, Reverse T-shape RC Abutment x 2
अबुटमेन्टको प्रकार	रिभर्स टि - सेप आरसी अबुटमेन्ट X २	रिभर्स टि - सेप आरसी अबुटमेन्ट X २	रिभर्स टि - सेप आरसी अबुटमेन्ट X २
जगको प्रकार र गहिराइ	आइसोलेटेड (स्प्रेड फुटिङ), ५.९ मि. गहिराइ	राफ्ट फाउन्डेसन (स्प्रेड फुटिङ), ५ मि. गहिराइ, १.६ मि. मोटाइ	अइसोलेटेड फाउन्डेसन (स्प्रेड फुटिङ), ५.६ मि. गहिराइ, १.६ मि. मोटाइ
डिजाइन डिस्चार्ज	४०८ घ.मि. प्रति सेकेन्ड	३५८ घ.मि. प्रति सेकेन्ड	४३१ घ.मि. प्रति सेकेन्ड
असर पर्ने पानीको रेखीय बाटो (Effective Linear waterway)	३८ मि.	३८ मि.	३८ मि.
डीजाइन गति	४० कि.मि. प्रति घण्टा	४० कि.मि. प्रति घण्टा	४० कि.मि. प्रति घण्टा
संरचनाहरू			
कंक्रीट सुपरस्टक्चर	३०२ घ.मि.	५१० घ.मि.	३०२ घ.मि.
कंक्रीट सबस्टक्चर	३७२ घ.मि.	८४१ घ.मि.	३७२ घ.मि.
कंक्रीट जगमा (लिन कंक्रीट)	२५ घ. मि.	५० घ. मि.	२५ घ. मि.
ग्याबियन	३,८०० घ.मि.	३,८०० घ.मि.	३,८०० घ.मि.



गर्न सकिन्छ वा बनेपा, धुलिखेल र काठमाडौँवाट आयात गर्न पनि सकिन्छ। ठुलो गिट्टी र मसिना गिट्टी (बालुवा) आयोजना स्थल नजिक रोशी खोलामा रहेका क्रसरहरु सँग खरिद गरिनेछ। निर्माण सामग्रीहरुको ढुवानी सबै अवस्थित वि.पि. राजमार्ग बाटै गरिनेछ।

३.६ आयोजनाको लागि आवश्यक पर्ने इन्धन

त्यसैगरी पुल निर्माण कार्यका लागि ९०,००० लिटर डिजेल आवश्यक पर्ने अनुमान गरिएको छ र यो इन्धन निर्माण सामग्रीको ढुवानी, निर्माण मेसिनरी संचालन तथा जेनेरेटर संचालनको लागि प्रयोग हुनेछ। आयोजनाको लागि आवश्यक पर्ने इन्धनको विवरण निम्नअनुसार रहेको छ।

तालिका ३.५: आयोजनाको लागि आवश्यक पर्ने इन्धनको विवरण

स.न.	इन्धनको किसिम	श्रोत मात्रा	इकाई	अनुमानित कार्बोन उत्सर्जन	कैफियत
१.	डिजेल	९०,०००	लिटर	२६२.५५ टन कार्बोन डाईअकसाईड बराबर	

३.७ आयोजनाको लागि आवश्यक जनशक्ति

प्रस्तावित आयोजना कार्यान्वयनको क्रममा दक्ष, अदक्ष जनशक्तिको आवश्यकता पर्नेछ। स्थानीय जनशक्तिलाई उनीहरुको सीप र योग्यताको आधारमा रोजगारीको अवसर दिईने छ। माम्ती खोला पुल निर्माण अबधिभर कुल १०,३५३ कामदार दिन जनशक्ति आवश्यक पर्ने देखिन्छ जसमध्ये २,२३३ दक्ष कामदार दिन र ८,१२० अदक्ष कामदार दिन आवश्यक देखिन्छ। भ्याकुरे खोला पुल निर्माण अबधिभर कुल ९०९५ कामदार दिन जनशक्ति आवश्यक पर्ने देखिन्छ जसमध्ये १,९६५ दक्ष कामदार दिन र ७,१४० अदक्ष कामदार दिन आवश्यक देखिन्छ। त्यसैगरी घ्याम्पे खोला पुल निर्माण अबधिभर कुल ७,९७० कामदार दिन जनशक्ति आवश्यक पर्ने देखिन्छ जसमध्ये १,७२० दक्ष कामदार दिन र ६,२५० अदक्ष कामदार दिन आवश्यक देखिन्छ।

तालिका ३.६ : जनशक्ति आवश्यकताको विवरण

क्र.सं.	जनशक्ति	माम्ती	घ्याम्पे	भ्याकुरे	इकाई
१.	दक्ष	२,२३३	१,७२०	१,९६५	कामदार दिन
२.	अदक्ष	८,१२०	६,२५०	७,१४०	कामदार दिन
	कुल	१०,३५३	७,९७०	९,०९५	कामदार दिन

३.८ आयोजना क्षेत्र निर्धारण

संक्षिप्त वातावरण अध्ययनको लागि आयोजना निर्माण र संचालनको कारण प्रभावित क्षेत्रलाई आयोजना क्षेत्रको रूपमा परिभाषित गरिएको छ। यी क्षेत्रहरूमा दुई जिल्लाका दुई गाँउपालिकाको विभिन्न वार्डहरू समावेश छन्। आयोजना प्रभाव क्षेत्र निम्न रूपमा परिभाषित गरिएको छ:



● प्रत्यक्ष प्रभाव क्षेत्र (DIA)

प्रस्तावित आयोजनाका लागि पुल निर्माण हुने क्षेत्रको बीच भागबाट १०० मि. दुरीको अर्धब्यासमा चारै तिरको क्षेत्रलाई प्रत्यक्ष प्रभाव क्षेत्र का रूपमा लिईएकोछ । यस अन्तर्गत आयोजनाका विभिन्न संरचनाहरू जस्तै: सडक पंक्ति, कामदार शिविर, उत्खनन क्षेत्र, खानी क्षेत्र, अलकत्रा तताउने क्षेत्र, निर्माण सामाग्री थुपार्ने क्षेत्र, बिग्रन व्यवस्थापन क्षेत्र, क्रसर संचालन क्षेत्र आदिलाई पर्दछ । यस बमोजिम यस संक्षिप्त वातावरणीय अध्ययनको प्र.प्र.क्षे.मा काभ्रेपलाञ्चोक जिल्ला रोशी गा.पा. को वडा नं. ११ र १२ साथै सिन्धुली जिल्ला सुनकोशी गा.पा. को वडा नं. १ हुन। यस आयोजनाका लागि कामदार शिविर, उत्खनन क्षेत्र, खानी क्षेत्र, अलकत्रा तताउने क्षेत्र, निर्माण सामाग्री थुपार्ने क्षेत्र, व्यवस्थापन क्षेत्र उल्लेखित वडा भित्रनै रहने छ।

● अप्रत्यक्ष प्रभाव क्षेत्र (IIA)

पुल निर्माण वरपर, प्रत्यक्ष प्रभाव क्षेत्रको छेउमा पर्ने भागहरू र आयोजना कार्यान्वयन गर्दा हुने गतिविधिहरूद्वारा अप्रत्यक्ष रूपमा प्रभावित हुने गर्दछन्। अप्रत्यक्ष प्रभाव क्षेत्रको रूपमा प्रत्यक्ष प्रभाव क्षेत्रको १०० मी. अर्धब्यासमा पर्न आउने क्षेत्र पर्दछन् । यस बमोजिम यस संक्षिप्त वातावरणीय अध्ययनको अ.प्र.क्षे. मा काभ्रेपलाञ्चोक जिल्ला रोशी गा.पा. को वडा नं. ११ र १२ मुख्य रूपमा र सोहि गा.पा. का अन्य वडाहरू पर्दछ । त्यसैगरी अ.प्र.क्षे. अन्तर्गत सिन्धुली जिल्ला सुनकोशी गा.पा. को वडा नं. १ मुख्य रूपमा र सोहि गा.पा.को अन्य वडाहरू पर्दछन् ।

● समग्र प्रभाव क्षेत्र (ZoI)

समग्र प्रभाव क्षेत्र अन्तर्गत रोशी गाउँपालिका र सुनकोशी गाउँपालिका पर्दछन ।

३.९ आयोजनाका सहायक सुविधाहरू निर्धारण

३.९.१ कामदार शिविर तथा भण्डारण क्षेत्र

कामदार शिविरको व्यवस्थाको लागि निर्माण व्यवसायी जिम्मेवार हुनेछ। वातावरणीय मापदण्ड पालना गरि शिविरहरू निर्माण क्षेत्र वरपर राप्ररी व्यवस्थित गरिनेछ। निर्माण कार्य एकसाथ विभिन्न ठाउँमा हुने भएकोले कुनै पनि स्थायी शिविर निर्माण गरिने छैन। निर्माण व्यवसायीले आयोजना क्षेत्र वरपरको गाउँ तथा बस्ती (माम्ती बजार, नेपालथोक, मंगलटार)मा श्रमिकका लागि घर भाडामा लिनेछ। अन्य आकस्मिक समयका लागि निर्माण व्यवसायीले कामदारलाई टेन्टको व्यवस्था गर्नेछ। आयोजना क्षेत्र नजिकको रहेका खुला क्षेत्र निर्माण सामग्री भण्डारणको लागि प्रयोग गरिनेछ। तथापि आयोजनाले ३ वटा पुल निर्माणको लागि सामग्री भण्डारणको लागि कुल ०.१७ हे. अस्थायी सरकारी जमिन प्रस्ताव गरिएको छ। भण्डारण क्षेत्र सडकमा गुड्ने सवारीसाधनलाई असर पार्ने तवरले गरिने छैन।

तालिका ३.७: कामदार शिविरको विवरण

स्थान	शिविर रहने सम्भावित स्थान	भण्डारण रहने सम्भावित स्थान	जग्गाको किसिम	कैफियत
भ्याकुरे खोला	२७°२८'१०.५१" N ८५°४५'०३.६८" E	२७°२८'११.०२" N ८५°४५'०१.४१" E	सरकारी जग्गा	



	६९८ मी. उचाई	६९८ मी. उचाई		
माम्ती खोला	२७° २६' ४२.३८" N ८५° ४६' ५६.६३" E ६१० मी. उचाई	२७° २६' ३८.९८" N ८५° ४६' ५७.४०" E ६०४ मी. उचाई	सरकारी जग्गा	
घ्याम्पे खोला	२७° २६' १३.१८" N ८५° ४८' १५.०९" E ५९१ मी. उचाई	२७° २६' १३.६२" N ८५° ४८' १४.५३" E ५८९ मी. उचाई	सरकारी जग्गा	

३.१० निर्माण प्रविधि

पुल निर्माण र एप्रोच सडकको स्तरोन्नतिको कार्य मेसिनमा आधारित प्रविधिलाई प्राथमिकता दिईनेछ । स्तरोन्नतिको बिधिमा स्थल खालीगर्ने, मिलाउने, सम्याउने र भर्ने जस्ता कार्यहरू मानिस आफैले गर्दछन मानिसले गर्न सम्भव नभएका र प्रभावकारी नहुने कार्यहरू मेसिन द्वारा गरिनेछ । निर्माण प्रविधिले वातावारंमा सकारात्मक र नकारात्मक दुवै प्रकारको प्रभाव पर्दछ। स्तरोन्नतिको दृष्टिकोणले स्थानीय वातावरणमा न्यूनतम क्षेति गर्ने देखिन्छ।

३.११ निर्माण तालिका

प्रस्तावित आयोजना २४ महिनामा सम्पन्न गर्ने योजना रहेको छ । तालिका ३.८ मा आयोजनाको बिस्तृत जानकारी दिईएको छ ।



३.१२ अध्ययन विधि

३.१२.१ संक्षिप्त वातावरणीय अध्ययनका लागि आवश्यक सूचना/तथ्यांक

अध्ययन विधि अन्तर्गत डेस्क अध्ययन, स्थलगत अध्ययन तथा म्याट्रीक्स प्रणालीद्वारा वातावरणीय प्रभावको पहिचान गरि संक्षिप्त वातावरणीय अध्ययन गरिएको छ। डेस्क अध्ययनमा आवश्यक तथ्याङ्क सङ्कलन कार्यका लागि सन्दर्भ सामग्रीको पुनरावलोकन, सम्बन्धित प्रकाशित वा अप्रकाशित सामग्री/प्रतिवेदनको पुनरावलोकन, सर्वेक्षण कार्यका लागि आवश्यक प्रश्नावलीको तयारी, स्थलगत पैदल सर्वेक्षण (Walkover survey), प्रत्यक्ष अवलोकन, मुख्य जानकार व्यक्तिसंग अन्तर्वार्ता (Key Informant Interview), तथा सामुहिक छलफल लगायतका कार्य गरिएको छ। तथ्यांक संकलनको लागि वातावरणीयविज्ञ, समाजशास्त्री, वनस्पतिविद् र वातावरणीय इन्जिनियरको टोलीले वि.सं. २०७८/०५/२० देखि वि.सं. २०७८/०५/२२ सम्म आयोजना क्षेत्र स्थलगत भ्रमण गरेका थिए। उक्त टोलीले आयोजना क्षेत्रमा पैदल सर्वेक्षण गरी भौतिक, जैविक र सामाजिक-आर्थिक र सांस्कृतिक वातावरण अवलोकन गरेका थिए। आयोजना क्षेत्रको वातावरणीय र सामाजिक अवस्थाको बारेमा विभिन्न आधारभूत तथ्याङ्क र जानकारी संकलन गरियो।

भौतिक वातावरण

यो प्रस्ताव कार्यान्वयन हुने क्षेत्रहरूमा नमूना क्षेत्रहरूको छनौट गरी ती स्थानहरूको सर्वेक्षण गरिएको थियो। यसरी अध्ययन गर्ने/भ्रमण गर्ने काममा स्थानीय जनताहरूसँग त्यस क्षेत्रको माटो, चट्टान, जलाधार क्षेत्र, भू-क्षय हुने क्षेत्र, हावापानी, खोलानालामा पानीको अवस्था र प्रस्ताव कार्यान्वयनबाट प्रत्यक्ष पर्न सक्ने भौतिक असरहरूका बारेमा समूहगत रूपमा छलफल गरी प्रस्ताव कार्यान्वयन गर्दा पर्न सक्ने प्रभाव आदि बारेमा जानकारी संकलन गर्ने कार्य गरिएको थियो।

- ❖ फिजियोग्राफी र टोपोग्राफी: प्रस्ताव कार्यान्वयन हुने स्थानको फिजियोग्राफी तथा टोपोग्राफि उचाइमा हुने परिवर्तन, भू-परिवर्तन, भू-बनोटमा हुने परिवर्तन
- ❖ भू-गर्भ तथा माटो: पुल निर्माण हुने स्थानको भू-बनोट, माटोको प्रकार, भूकम्पीय जोखिमको संवेदनशीलता, खोला, खोल्सी तथा सतह नालाको अवस्थिति
- ❖ हावापानी: पुल निर्माण स्थलको हावापानी, वर्षातको अवस्था, मौसम अवस्था इत्यादि
- ❖ पानीढल तथा खोल्सा-खोल्सी: नदी तथा यसका सहायक खोलाहरू र तिनीहरूको प्रकार, सडकमा पर्ने खोलाहरूका बारेमा जानकारी
- ❖ भू-उपयोग: पुल निर्माण वरपरको भू-बनोट तथा भू-बनोटमा भईरहेको परिवर्तन, जमिनको प्रयोगको अवस्था, भू-क्षयको हालको अवस्था र नियन्त्रणका उपायहरूका बारेमा अध्ययन
- ❖ प्रदूषण: योजना कार्यान्वयनबाट उत्पन्न हुन सक्ने जल प्रदूषण, वायु प्रदूषण, रासायनिक प्रदूषण र न्यूनीकरणका उपायहरूको अध्ययन

तालिका ३.९: जल, जमिन तथा वायु प्रदूषणको अवस्था तिनिहरूको स्रोत तथा पार्न सक्ने असर

बिषय	विवरण
भौगर्भिक अध्ययन	यो प्रस्ताव कार्यान्वयन हुने क्षेत्रहरूमा मुख्य क्षेत्रहरूको नक्सा अध्ययन, गुगल अर्थ तस्वीरहरूको अध्ययन, भौगर्भिक नक्शाहरूको अध्ययन गरी उक्त स्थानहरूको सर्वेक्षण गरिएको छ। यसरी अध्ययन भ्रमण गर्ने काममा स्थानीय जनताहरूसँग त्यस क्षेत्रको माटो, चट्टानको उपलब्धताबारे अध्ययन गरी स्थलगत जानकारी लिइएको छ।



	त्यसैगरी भू-क्षय हुनसक्ने क्षेत्र, पुलको भौगोलिक अवस्था र संभावित असरहरूबारे स्थानीय जनताहरूसँग छलफल तथा स्थलगत अध्ययन गरिएको थियो।
खोला/नालाको अध्ययन	प्रस्तावित खोलाहरूको अध्ययन र अवस्था र पुल बन्ने section मा नदिको Profile (Gradient, Channel Width, Discharge, Velocity) बारेमा अध्ययन गरिएको थियो।
मौसम र हावापानी सम्बन्धि अध्ययन	मौसम र हावापानी सम्बन्धि अध्ययन द्वितीय स्रोतहरूबाट गरिएको छ।
फोहोरमैला मापन	फोहोरमैला मापनको लागि स्थलगत अध्ययनका क्रममा अनुमान गरीएको थियो।
हावाको गुणस्तर मापन	द्वितीय स्रोतहरूबाट तथ्यांक संकलन गरेर
स्याम्पलिङ्ग क्षेत्र	प्रस्तावित क्षेत्र भित्र

जैविक वातावरण

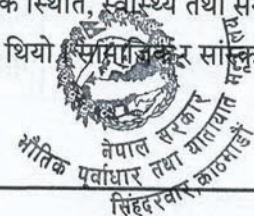
अध्ययन टोलीले सम्बन्धित स्थानमा भ्रमण गरी प्रस्ताव कार्यान्वयन हुने क्षेत्रमा पाइने वन्य जन्तु, वनस्पति र सुक्ष्म जीवाणुको सम्बन्धमा आवश्यक प्राथमिक जानकारी संकलन गरेका थिए। सो क्रममा प्रत्यक्ष रूपमा भेटिएका पद चिन्ह, विस्टा, आवाज आदिबाट जिवजन्तुको पहिचान गरी तिनको टिपोट गरिएको थियो।

तालिका ३.१०: वनस्पति तथा वन्यजन्तुको अवस्था तिनिहरूको स्रोत तथा पार्न सक्ने असर

बिषय	विवरण
वनस्पति/वन्यजन्तु सम्बन्धि तथ्यांक संकलन	प्रस्ताव क्षेत्रको वन, वनस्पति र वन्यजन्तुहरूको अध्ययन, वाक ओभर सर्भे, अवलोकन र प्रश्नावली सर्वेक्षणद्वारा गरिएको थियो। प्रमुख सूचनादाता अन्तर्वार्ताद्वारा प्रस्ताव क्षेत्रमा प्रस्तावको कार्यान्वयनबाट हुनसक्ने असरहरू र आवश्यक न्यूनीकरणका उपायहरूकोबारे जानकारी दिइएको थियो भने चेकलिस्ट र प्रश्नावलीद्वारा जैविक वातावरणको विस्तृत जानकारी लिइएको थियो।
वनस्पतिहरूको अवस्थिति र वृक्षारोपणको अवस्था	प्रस्ताव क्षेत्रको नदी किनाराहरू भ्रमण गरी तटबन्द र वृक्षारोपणको अवस्था अध्ययन अवलोकन गरिएको थियो। प्रमुख सूचनादाता अन्तर्वार्ताद्वारा तथा तिनकै सहभागितामा स्थलगत भ्रमण गरी आवश्यक परामर्श लिई, प्रस्ताव क्षेत्रमा प्रस्तावको कार्यान्वयनबाट नदीको किनारामा तथा बस्तीमा परिरहेको र पर्न सक्ने असरहरू र आवश्यक न्यूनीकरणका उपायहरूको बारे जानकारी लिइएको थियो।

सामाजिक, आर्थिक, सांस्कृतिक वातावरण

आयोजना कार्यान्वयन हुने क्षेत्रको सामाजिक, आर्थिक, सांस्कृतिक वातावरण सम्बन्धी तथ्याङ्क संकलन गर्न लक्षित समुहसँगको छलफल, सूचनादाता सर्वेक्षण विधिको प्रयोग गरिएको थियो। प्रस्ताव कार्यान्वयन हुने क्षेत्रको घरधुरीको पारिवारिक विवरण, पेशा, बसोबास, भू-स्वामित्व, कृषि तथा पशुपालन, शैक्षिक स्थिति, स्वास्थ्य तथा सरसफाई, वार्षिक आमदानी, श्रोतको उपयोग सम्बन्धी विवरण जस्ता जानकारी संकलन गरिएको थियो। सामाजिक र सांस्कृतिक वातावरण सम्बन्धि तथ्यांक संकलनमा तलका बिधि अपनाइएको थियो।



- सूचनादातासँगको अन्तर्वार्ता
- श्रमिकहरूसँग अन्तर्वार्ता
- लक्षित समूहसँग छलफल
- सार्वजनिक सुनुवाई

३.१२.२ तथ्याङ्क संकलनको विधि

यस आयोजनाको संक्षिप्त वातावरणीय अध्ययन प्रतिवेदन तयार गर्दा अपनाईएको तथ्यांक संकलनका विधिहरू निम्न अनुसार हुनेछन्:

तालिका ३.११: तथ्यांक संकलन विधि संक्षेप

मापदण्ड	तथ्याङ्क संकलन विधि	कैफियत
भौतिक वातावरण		
हावापानी (वर्षा तथा तापक्रम)	जल तथा मौसम विज्ञान विभाग	नजिकको हावापानी मापन केन्द्रको तापक्रम तथा वर्षाको तथ्याङ्क विश्लेषण
खोलानालाको अध्ययन	जल तथा मौसम विज्ञान विभाग	खोला, खोलिस तथा नदीको विश्लेषण
वायुको गुणस्तर	एयर स्याम्पलर वाद्वितीय स्रोत	पुलको सुरु विन्दु, तथा अन्त विन्दु, मुख्य मानव वस्ति
ध्वनिको प्रदुषण	ध्वनि मापन मिटर (Noise meter) वा द्वितीय स्रोत	पुलको सुरु विन्दु, तथा अन्त विन्दु, मुख्य मानव वस्ति
ढलान स्थिरता (Slope Stability)	भू-क्षय तथा पहिरो जाने स्थानको सूचि तयार	जि.पि.एस.को सहायतामा भू-क्षय तथा पहिरो जान सक्ने स्थानको पहिचान
परियोजनाका सुविधाहरू	सूचि तथा चेकलिस्ट	परियोजनालाई आवश्यक पर्ने सुविधाहरूको विवरण (Construction camps, Stockpiling sites etc)
जैविक वातावरण		
वनस्पति	जम्मा गणना, सूचि तयार तथा स्थानीय समुदायसँग छलफल	पुलको किनारमा भएका रुख तथा वनस्पति नेपाल सरकार, IUCN र CITES को संरक्षित वर्ग अनुसार वर्गिकरण
वन्यजन्तु	पद चिन्ह तथा दोस्रो स्रोत को अध्ययन, स्थानिय समुदाय सँग	त्यसरी संकलन गरेको वन्यजन्तुको तथ्यांकलाई नेपाल सरकार, IUCN र CITES को संरक्षित वर्ग

	परामर्श गर्ने	अनुसार वर्गिकरण गरिएको
वनको प्रकार	वनको प्रकारको सूचि तयार गर्ने, स्थानीय समुदाय सँग परामर्श गर्ने	पुलको किनारामा भएका वनहरूको प्रकार छुट्याईएको
सामाजिक-आर्थिक तथा सांस्कृतिक वातावरण		
जनसांख्यिक जानकारी	क्षेत्र सर्वेक्षण	प्रभावित घरधुरीको सम्पूर्ण जनसांख्यिकीय विवरण संकलन
सांस्कृतिक तथा पुरातात्विक क्षेत्र	सूचि तयार तथा स्थानीय समुदाय सँग परामर्श गर्ने र जि.पि.एस. को सहायतामा सभे गर्ने	सांस्कृतिक तथा पुरातात्विक सम्पदाहरूको जि.पि.एस.को सहायतामा निर्देशांक (Coordinates) संकलन
सार्वजनिक सवाल तथा मुद्दाहरू	लक्षित समुह छलफल, स्थानीय सँगको परामर्श, सिफारीस पत्र	सम्पूर्ण सार्वजनिक सवाल तथा मुद्दाहरू संकलन

● सन्दर्भ सामग्रीको अध्ययन

प्रतिवेदन तयार गर्ने क्रममा सम्बन्धित उद्देश्य प्राप्तिका लागि अध्ययन टोलीले विशेष गरी नेपाल सरकारका प्रचलित नीति, ऐन, नियम तथा निर्देशिकाहरू जस्तै राष्ट्रिय वन नीति २०७५, वातावरण संरक्षण ऐन २०७६, वातावरण संरक्षण नियमावली २०७७, स्थानीय शासन सञ्चालन ऐन २०७४ र वन ऐन २०७६, राष्ट्रिय वातावरणीय प्रभाव मूल्याङ्कन निर्देशिका २०५०, संक्षिप्त वातावरणीय अध्ययन कार्यसूची र प्रतिवेदनको दिग्दर्शन, भू-उपयोग निती २०६९, साथै यस आयोजनासँग सम्बन्धित हुन सक्ने अन्य उपलब्ध लेख रचना र सामग्रीहरू समेतको पुनरावलोकन गरिएको छ।

सम्बन्धित निकायहरूले प्रकाशन गरेका विभिन्न सन्दर्भ सामाग्रीहरू जस्तै राष्ट्रिय वातावरण प्रभाव मूल्यांकन निर्देशिका २०५०, वातावरणीय तथा सामाजिक व्यवस्थापन संरचना २०७०, राष्ट्रिय आर्थिक जनगणना २०७५ समेत सूचीकरण गरी संक्षिप्त वातावरणीय अध्ययन गर्ने सिलसिलामा विस्तृत अध्ययन गरिएको छ। त्यस्तै गरी, आयोजनासँग सम्बन्धित तर अप्रकाशित सन्दर्भ सामाग्रीहरूको समेत अध्ययन गरिएको थियो। त्यस्ता प्रकाशन हुन बाँकि सामग्रीहरूमा विस्तृत परियोजना प्रतिवेदन (DPR), स्थालाकृति (topography) र गुगल नक्साहरू, पूर्व-सम्भाव्यता अध्ययन प्रतिवेदन, सम्भाव्यता अध्ययन प्रतिवेदन आदि पर्दछन्। यी सामाग्रीहरू संकलन तथा सूचिकृत गरी संक्षिप्त वातावरणीय अध्ययन गर्ने क्रममा बिस्तृत अध्ययन गरिएको थियो।

● चेकलिस्ट र घरधुरी सर्वेक्षण प्रश्नावली तयारी:

प्रस्ताव कार्यान्वयन हुने स्थानहरूको सामाजिक, आर्थिक तथा अन्य सूचनाहरू गाउँपालिकाबाट प्रकाशित हुने वा भएका मुखपत्रहरूबाट प्राप्त गरिएका सूचनाहरूको सत्य तथ्य मिलान गर्न स्थानीय स्तरमा ठिक छ कि छैन जाँच गर्न नियमानुसार आवश्यक पर्ने बुँदाहरू समेट्ने गरी प्रश्नावली तथा चेकलिस्ट तयार गरी प्रयोग गरिएको थियो।

● स्थलगत अध्ययन कार्य:



संक्षिप्त वातावरणीय अध्ययन गर्ने क्रममा स्थलगत अध्ययन गर्दा भौतिक, जैविक, आर्थिक-सामाजिक-साँस्कृतिक, रासायनिक वातावरणका विभिन्न पक्षहरूको तथ्यांक संकलन गर्न अपनाएको विभिन्न अध्ययन विधि स्पष्ट रूपमा दिईएको छ। स्थलगत अध्ययनमा निम्न कार्यहरू गरिएको थियो :

● **लक्षित समुह छलफल(Focus Group Discussion-FGD):**

लक्षित समुह छलफल गर्नुको मुख्य उद्देश्य स्थानीय वासिन्दाहरूलाई प्रस्तावको बारेमा विस्तृत विवरण बताउनुको साथै प्रस्ताव कार्यान्वयनबाट पर्न सक्ने प्रभावको बारेमा जानकारी गराउनु हो। लक्षित समुह छलफलबाट परियोजना प्रतिको समुदायको धारणा संकलन गरिएको थियो। यस छलफलबाट प्राप्त राय सुझाव, सवालहरूलाई प्राथमिकताका साथ प्रतिवेदनमा समावेश गरीएको छ।

● **मुख्य सूचनादाता अन्तर्वार्ता (Key Informants Interview-KII):**

पूल निर्माणको असर क्षेत्रभित्र रहेका विभिन्न मुख्य सूचकसँग अन्तर्वार्ता गरीएको थियो। यसको मुख्य उद्देश्य त्यस क्षेत्रका जनताको धारणा संकलन गर्नुका साथै उनीहरूको अपेक्षा अवगत भै सोहि अनुसार आयोजना तयार गर्नु पनि हो। यस अन्तर्गत गाउँपालिका अध्यक्ष, वडा अध्यक्ष, शिक्षक, बुद्धिजीवि, पत्रकार, स्थानीय नेतृत्व, राजनीतिक पार्टीका व्यक्तित्व लगायत त्यस समाजमा विकासका क्षेत्रमा लागिरहेका भद्र भलाधि रहेका थिए।

● **सार्वजनिक छलफल (Public Discussion):**

आयोजना कार्यान्वयन हुने स्थलमा स्थलगत अध्ययनको शिलशिलामा विभिन्न चरणमा स्थानीय समुदायहरूको राय तथा सार्वजनिक सवाल र मुद्दाहरू संकलन गरिएको थियो। त्यस्ता छलफल र परामर्शबाट संकलित सुझाव तथा रायहरूलाई संक्षिप्त वातावरणीय अध्ययन प्रतिवेदनमा समावेश गरिएको छ।



चित्र ३.३: सार्वजनिक छलफल

३.१२.३ सार्वजनिक सुनुवाई तथा सार्वजनिक सूचना:

संक्षिप्त वातावरणीय अध्ययन प्रतिवेदन तयारीको शिलशिलामा वातावरण संरक्षण नियमावलीको २०७७ को (६) बमोजिम सार्वजनिक सुनुवाई गरिएको थियो। सार्वजनिक सुनुवाई सम्बन्धि सूचना मिति २०७८/०५/२० गते बनेपा, काभ्रे वाट प्रकाशित हुने साप्ताहिक पत्रिका “मध्यमार्ग” वाट प्रकाशन गरिएको थियो। मिति २०७८/०५/२५ गते शुक्रबार का

दिन काभ्रेपलान्चोक जिल्ला वडा नः ११ को माम्ती खोला नजिक माम्ती भीमसेन मन्दिर मा सार्वजनिक सुनुवाई कार्यक्रम आयोजना गरिएको थियो । सार्वजनिक सुनुवाई कार्यक्रममा ५२ जना व्यक्तिको उपस्थित रहेको थियो ।

तालिका ३.१२ : सार्वजनिक सुनुवाईको उपस्थित

क्र.स.	सहभागीको प्रकार	सहभागीको संख्या	
		महिला	पुरुष
१.	वडा/ नगरपालिका प्रतिनिधि	१	८
२.	सरोकारवाला संस्था	२	६
३.	सर्वसाधारण	९	२६
	कुल	१२	४०

तालिका ३.१३: सुनुवाई कार्यक्रममा उठेका रायसुझाव तथा उपायहरू

क्र.स.	उठाइएको मुद्दाहरू	स्थान	उपायहरू
१	तत्काल सुचारु गर्नको लागि सम्बन्धित निकायलाई जानकारी गराउनुपर्ने ।	रोशी गाउँपालिका- ११, माम्ती भीमसेन मन्दिर, काभ्रेपलान्चोक	आयोजना निर्माण गर्नु पूर्व सम्बन्धित सबै निकायलाई जानकारी गराईनेछ ।
२	एकै चोटी गाडी आउने र जान सक्ने निर्माण गर्ने ।		निर्माण गरिने पुलको चौडाई ११ मी. भएको एकै चोटी २ ओटा गाडी आउन जान सक्ने छ ।
३	वातावरणीय अध्ययन गर्दा स्थानीय जेष्ठ नागरिकहरूको रायसुझाव लिने ।		स्थानीय जेष्ठ नागरिकहरू सँग समन्वय गरि वातावरणीय अध्ययन गरिएको छ ।
४	महाभारत हरियो क्षेत्र भएकोले यस क्षेत्रमा प्रतेक वर्ष पानीले बाढीले क्षति पुगेको देखिन्छ ।		वातावरणीय अध्ययन पुरा गरि पुल निर्माणमा छिटो काम गरि बाढी वाट हुने क्षति कम गरिनेछ ।
५	आयोजनामा स्थानीयको शिप अनुसारका रोजगारी पाउने पर्ने देखिन्छ।		स्थानीयलाई उनीहरूको दक्षता अनुसार रोजगारी दिइनेछ।





चित्र ३.४ : सार्वजनिक सुनिवाइको तस्बिरहरु

सार्वजनिक सुनुवाईबाट प्राप्त रायसुझावहरू संलग्न गरी सं.वा.अ. प्रतिवेदन तयारी गर्ने सिलसिलामा वातावरण संरक्षण नियमावली २०७७ को नियम (७) अनुसार स्थानीय तहको कार्यालय, सरोकारवाला संघ-संस्था लगायत सार्वजनिक स्थानहरू जस्तै गाउँपालिका भवन, सम्बन्धित वडा कार्यालयको भवन, प्रहरीचौकी, स्वास्थ्य चौकी, विद्यालय, लगायतका सार्वजनिक स्थानमा सात (७) दिन भित्र लिखित सुझाव उपलब्ध गराउन अनुसूची ३ बमोजिमको ढाँचामा सूचना टाँस गरी मुचुल्का तयार गरिएको थियो र सोही बमोजिमको सूचना मिति २०७८/०६/०६ गते सिन्धुली जिल्लावाट प्रकाशित हुने राष्ट्रिय दैनिक पत्रिका “सिन्धुली सौगात” वाट प्रकाशन गरिएको थियो ।



चित्र ३.५: सूचना टाँसको तस्बिर

सूचना टाँसको पत्रहरू तथा मुचुल्काहरू अनुसूची ७ मा राखिएको छ ।

३.१२.४ तथ्यांक विश्लेषण:

प्रस्तावित क्षेत्रको विशेष अध्ययन गर्दा गरिएको विश्लेषणबाट आएका प्रथम र दोस्रो क्रममा भएका तथ्याङ्क तथा जानकारीलाई सँक्षिप्तिकरण गरी आवश्यकता अनुसार तालिकामा राखी प्रतिवेदनको उपयुक्त भागमा समावेश गरिएको छ। तसर्थ प्राप्त जानकारीहरूबाट (सन्दर्भ सामाग्री तथा फिल्डको अनुगमन पुनरावलोकन बाट प्राप्त) प्रस्ताव कार्यान्वयन गर्दा हुने सम्भाव्य अनुकूल र प्रतिकूल असरहरूको पहिचान गरी त्यसको जैविक, भौतिक, सामाजिक आर्थिक गरी तीन शीर्षक अन्तर्गत छुट्याई प्रभाव अनुमान तथा मूल्याङ्कन गरियो। यसरी प्रभाव मूल्याङ्कन गर्दा राष्ट्रिय वातावरणीय प्रभाव मूल्याङ्कन निर्देशिका, २०५० अनुरूप प्रभावहरूलाई त्यसको प्रकृति, आकार, विस्तार र अवधि मा वर्गीकरण गरि मूल्याङ्कन गरिएको थियो। तत्पश्चात् प्रभावहरूलाई न्यूनिकरण गर्न मितव्ययी तथा व्यवहारिक उपायहरूको पहिचान गरि यस प्रतिवेदनमा उल्लेख गरिएको छ।

प्राप्त सूचना तथा जानकारीको आधारमा आयोजना कार्यन्वयनले पार्न सक्ने प्रभावका आधार, प्रभावको प्रकृति, प्रभावको परिमाण, प्रभावको सीमा र प्रभावको समयावधिका आधारमा विश्लेषण गरिएको छ । प्रभावका प्रकारमा भौतिक, जैविक, सांस्कृतिक तथा आर्थिक-सामाजिक पर्दछन् भने यी प्रभावका प्रकृति प्रत्यक्ष वा अप्रत्यक्ष गरी दुई प्रकारका हुनेछन् । अर्थात् कतिपय परिणाम प्रत्यक्ष र कतिपय परिणाम अप्रत्यक्ष रूपमा देखिएका छन् । प्रभावका परिणाम उच्च, मध्यम र न्यून गरि तिन प्रकारका हुने भएकोले त्यसै अनुसार विश्लेषण गरिएको छ । प्रभावहरू कुन तहसम्म जान सक्छ भन्ने बुझ्नको लागि तिनीहरूको स्थलगत, क्षेत्रिय र स्थानीयरूपमा देखिने प्रभावलाई हेरिएको छ । त्यस्तै कतिपय प्रभावहरू छोटो

समयको लागि सक्रिय हुन्छन त कतिपय प्रभाव दिर्घकालिन हुन्छन् । यसैले प्रभाव छोटो समय, वा लामो वा मध्यम समय के को लागि हो त्यो विश्लेषण गरिएको छ।

तालिका ३.१४: प्रभाव पहिचान म्याट्रिक्स

परिमाण		हद		अवधि	
उच्च (H)	६०	क्षेत्रीय (R)	६०	दीर्घकालीन (LT)	२०
मध्यम (M)	२०	स्थानीय (L)	२०	मध्यकालीन (MT)	१०
निम्न (L)	१०	स्थलगत (Ss)	१०	अल्पकालीन (ST)	५

स्रोत: राष्ट्रिय वातावरण प्रभाव मुल्याङ्कन दिशानिर्देश, २०५०

तालिका ३.१५: प्रभाव महत्व

क्र.स.	स्कोर	वर्णन
१	< ४५	कम महत्वपूर्ण
२	४५ - ७५	महत्वपूर्ण
३	> ७५	अत्यधिक महत्वपूर्ण

तथ्यांक विश्लेषण गर्नको लागि मुख्यतः माइक्रोसफ्ट एक्सल र वर्ड सफ्टवेर प्रयोग गरिएको छ साथै नक्सांकन गर्न र स्थानहरु स्थानाकृत गर्न गुगल अर्थ र जिआइएस प्रयोग गरिएको छ ।



३.१३ आयोजनाको विद्यमान वातावरणीय अवस्था

आयोजना क्षेत्रको भौतिक, जैविक, सामाजिक-आर्थिक-साँस्कृतिक र रासायनिक वातावरणको विद्यमान अवस्थाको अध्ययनका लागि आयोजना स्थलको स्थलगत भ्रमण गरिएको थियो। साथै समग्र प्रभाव क्षेत्र अन्तर्गत रोशी गा.पा. र सुनकोशी गा.पा. मा सम्पर्क गरि उपलब्ध सन्दर्भ सामग्रीहरू संकलन गरिएको थियो। साथै, यी गाउँपालिकाहरूले तयार गरेका गाउँपालिकाको पाश्चिमा, केन्द्रीय तथ्यांक विभागको राष्ट्रिय जनगणना २०६८ लगायतका प्रकाशित प्रतिवेदन र दस्तावेज अध्ययन गरी निम्न बमोजिम आधारभूत विवरणहरू प्रस्तुत गरिएको छ।

३.१३.१ भौतिक वातावरण

• स्थालाकृति (टोपोग्राफि)

आयोजना स्थल रहेको काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. र सिन्धुली जिल्लाको सुनकोशी गा.पा. महाभारत पहाड को उच्च भू-भाग देखी समथल फेदीसम्म फैलिएको छ। भौगोलिक नक्शामा सिन्धुली जिल्लाको अवस्थिती २६°५५' देखी २७°२२' उत्तरी अक्षांशसम्म र ८५°१५' देखी ८६°२५' पूर्वी देशान्तर सम्मको फैलावटमा रहेको छ भने समुद्र सतहबाट न्यूनतम १६८ मि. देखि अधिकतम २७९७ उचाई सम्म भू-धरातल रहेको छ। भौगोलिक नक्शामा काभ्रेपलाञ्चोक जिल्लाको अवस्थिती २७°२१' देखी २७°८५' उत्तरी अक्षांशसम्म र ८५°२४' देखी ८५°४९' पूर्वी देशान्तर सम्मको फैलावटमा रहेको छ भने समुद्र सतहबाट न्यूनतम ३१८ मि. देखि अधिकतम ३०१८ उचाई सम्म भू-धरातल रहेको छ। प्रस्तावित तीनवटै पुल निर्माण आयोजनाहरू महाभारत पहाड श्रृङ्खलाको फेदी भएर बग्ने रोशी खोलाको दाँया तर्फको तटिय भेगमा पर्दछन्।

• जलवायु र वर्षा

प्रस्तावित आयोजना उपोष्ण मौसमी क्षेत्रमा पर्दछ। यस स्थलको न्यूनतम तापक्रम ४°C र अधिकतम तापक्रम ३३°C सम्म पुग्दछ र कुल औसत बार्षिक वर्षा ८८७ मि.मि. रहेको छ।(स्रोत: जल तथा मौसम विभाग)

• भौगर्भिक विवरण

भौगर्भिक बनोटका आधारमा समग्र नेपाललाई सात वटा प्रकारमा बिभाजन गरिएको छ। भौगर्भिक नक्शाकनमा सिन्धुली जिल्ला लेसर हिमालय जोन, हायर हिमालय जोनर शिवालिक जोनमा फैलिएको छ भने काभ्रेपलाञ्चोक जिल्ला लेसर हिमालय जोन र हायर हिमालय जोनमा फैलिएर रहेको छ। प्रारम्भिक अध्ययन गर्दा भौगर्भिक नक्शाकनका आधारमा प्रस्तावित आयोजना लेसर हिमालय जोनमा पर्ने देखिन्छ। यस क्षेत्रमा बोल्डर मिश्रित चिम्टाईलो माटो पाइन्छ भने सेडिमेन्टरी र मेटासेडिमेन्टरी प्रकारका चट्टान पाइन्छ।

• भूकम्पीय विवरण (सेस्मिसिटी)

इन्डियन प्लेट निरन्तर युरासियन प्लेट तीर बार्षिक १८ देखी २० मि.मि. का दरले सरिरहेको (स्रोत: एडल एट अल, २०१२) र उक्त स्थानान्तरणका कारण इन्डियन प्लेट र युरासियन प्लेटको जोर्तीमा हुने घर्षणले गर्दा नेपाल भूकम्पको उच्च जोखिम क्षेत्रमा पर्दछ।



● खोला/खोलिसको विवरण

प्रस्तावित आयोजना अन्तर्गत घ्याम्पे, माम्ती र भ्याकुरे तीनवटा खोलाहरूमा पुल निर्माण कार्य गर्नु रहेको छ । तीनवटै खोलाहरू महाभारत श्रृङ्खलाको उच्च स्थानबाट उत्तरतर्फ बगेका छन् र रोशी खोलामा मिसिएका छन् । तीनवटै खोलाहरू खहरे खोला हुन त्यसैले सुख्खा मौसममा पानीको बहाव नभएता पनि वर्षातको समयमा बाडीको उच्च जोखिम देखिन्छ । वर्षायाममा अधिकतम पानीको बहाव भएको समयमा डिस्चार्ज घ्याम्पे खोलाको ४०८ घ.मि. प्रति सेकेन्ड, माम्ती खोलाको ३५८ घ.मि. प्रति सेकेन्ड र भ्याकुरे खोलाको ४३१ घ.मि. प्रति सेकेन्ड रहेको छ ।

● वायु र ध्वनिको गुणस्तर

प्रस्तावित आयोजना ग्रामिण क्षेत्रमा अवस्थित छ जहाँ मानव वस्तीहरू छरिएर रहेका छन्। आयोजनास्थल वरपर कुनै पनि उद्योग कलकारखाना छैनन्। सवारी साधनको आवतजावत, खाना पकाउन प्रयोग गरिने दाउराको, वायु प्रदुषणको कारक देखिन्छ। आयोजनाको पुल रहने स्थानको वायु नमुनाको विवरण तालिका ६.१ मा प्रस्तुत गरिएको छ।

तालिका ३.१६: वायु गुणस्तर सूचांक र PM2.5 तथ्याङ्क

क्र.स.	नमुना स्थान	वायु गुणस्तर सूचांक	PM 2.5 (ug/m3)
१	भ्याकुरे	५३	११
२	माम्ती	५७	१४
३	घ्याम्पे	४९	१०

आयोजना क्षेत्रमा सवारीसाधन, खोला, चराचुरुङ्गी तथा जनावर बाहेक मानव निर्मित ध्वनि सिमित रहेको छ। ध्वनिस्तर मापन गरिएको स्थानहरूको विवरण तालिका ६.२ मा देखाइएको छ। आयोजना स्थलमा मापन गरिएको ध्वनि स्तर ग्रामिण क्षेत्र राष्ट्रिय ध्वनिस्तर मापदण्ड, २०६९ ४५ dBA भन्दा कम रहेको छ।

तालिका ३.१७: विपी राजमार्गको विभिन्न स्थानमा मापन गरिएको ध्वनिको स्तर

क्र.स.	मापन स्थल	स्तर (dBA)
१	भ्याकुरे खोला	४६
२	माम्ती खोला	५३
३.	घ्याम्पे खोला	५०

● भू-उपयोग तथा प्रयोगको विवरण

आयोजना स्थल रहेको काभ्रेपलाञ्चोक जिल्लाको कुल क्षेत्रफल १,४०,४८६ हे. रहेकोमा ३६,४४२ हे. कृषियोग्य जमिन र ७३,८०१ हे. जंगल क्षेत्र रहेको छ । सिन्धुली जिल्लाको कुल क्षेत्रफल २,४७,७०९ हे. रहेकोमा ३९,४८४ हे. कृषियोग्य जमिन र १,७८,१३० हे. जंगल क्षेत्र रहेको छ ।

आयोजना स्थल रहेको काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. र सिन्धुली जिल्लाको सुनकोशी गा.पा. अधिकतम ग्रामिण भेग भएको भएतापनि यस क्षेत्रमा भएको वि.पी. रागमार्गका कारण राजमार्गको दाँया बाँया क्षेत्रमा बस्ती बिकास बढ्दो पाइन्छ । उच्च पहाडी क्षेत्रबाट हुने बसाँइसराइका कारण कृषियोग्य जमिनमा बस्तीको बिकास तीव्र भएको पाइन्छ । आयोजनास्थलको ५०० मि. अर्धव्यास क्षेत्रभित्र पर्ने मंगलटार, नेपालथोक, चौकिडाडाँडा बजार व्यापारिक केन्द्रका रूपमा बिकसित भइरहेको छ ।



● जलवायु तथा मौसमको विवरण

समग्र प्रभावित क्षेत्रमा पर्ने काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. र सिन्धुली जिल्लाको सुनकोशी गा.पा. क्षेत्रको हावापानीमा निकै विविधता पाउन सकिन्छ। यस क्षेत्रमा उष्ण, उपोष्ण र समसितोष्ण हावापानी पाइन्छ। समसितोष्ण जलवायु महाभारत क्षेत्रका करिब १२०० मि. देखी माथि उचाईमा रहेको भागमा पाईन्छ जसमा हिउँदमा केहि जाडो र अन्य समयमा न्यानो हावापानी रहन्छ। उपोष्ण जलवायु ६०० मि. देखी माथि १२०० मि. सम्मका चुरे क्षेत्रमा पाईन्छ। सिन्धुली जिल्लामा औषत बर्षा १४२० मि.मि., औषत तापक्रम ५.३ देखि २८.३ सेन्टिग्रेड रहेको छ। समग्र प्रभावित क्षेत्रमा पर्ने नेपालथोकको औषत बर्षा ८८७ मि.मि., जुलाई महिनाको औषत उच्च बर्षा २९६.३ मि.मि. र नोभेम्बर महिनाको औषत न्यून बर्षा ९ मि.मि. रहेको छ।

● सार्वजनिक सम्पत्ति

आयोजना स्थल र निर्माण स्थलमा सार्वजनिक सम्पत्ति, भौतिक संरचनाहरू नपर्ने देखिन्छ। प्रारम्भिक अध्ययनमा तीन वटै पुल निर्माण स्थलको तल्लो तटिय क्षेत्र रोशी खोलाको बगर क्षेत्रबाट ५०० मि. दुरीमा पर्ने भएकोले सार्वजनिक र नीजि सम्पत्तिको स्थानान्तरण वा क्षतिपुर्ति व्यहोर्नुपर्ने देखिदैन।

३.१३.२ जैविक वातावरण

प्रस्तावित आयोजना स्थल र प्रभावित क्षेत्र पर्यावरणीय रूपमा संवेदनशील क्षेत्रहरू: संरक्षित क्षेत्र, मध्यवर्ती क्षेत्र, सिमसार क्षेत्र भित्र पर्दैन। प्रस्तावित पुल निर्माण गर्ने क्षेत्रमा उपोष्ण र समसितोष्ण हावापानी पाईन्छ। आयोजना निर्धारण गरेको प्रत्यक्ष र अप्रत्यक्ष प्रभाव क्षेत्र भित्र कुनै पनि वन क्षेत्र नपरेता पनि वरपर पाइने वनस्पतिहरूमा उत्तीस, सिसौ, चिलाउने पाइन्छ। यसैगरी प्रभावित क्षेत्रमा काग, चिल, परेवा, सुगा, भंगेरा प्रजातिका चराचुरूगीहरू पाइन्छन भने जिवजन्तुहरूमा चितुवा, बर्देल, बाँदर, मृग पाइन्छ। घ्याम्पे खोला, माम्ती खोला र भ्याकुरे खोलामा माछा नपाईएता पनि नजिकै रहेको रोशी खोलामा असला माछा, तिते माछा, कत्ले माछा आदि पाइन्छन्।

३.१३.३ सामाजिक, आर्थिक र साँस्कृतिक वातावरण

● जनसंख्या

राष्ट्रिय जनगणना २०६८ अनुसार काभ्रेपलाञ्चोक जिल्लाको कुल जनसंख्या ३,८१,९३७ रहेको छ भने सिन्धुली जिल्लाको कुल जनसंख्या २,९६,१९२ रहेको छ। लिङ्गका आधारमा काभ्रेपलाञ्चोक जिल्लाको कुल जनसंख्याको ४७.८९ प्रतिशत पुरुष र ५२.१० प्रतिशत महिला रहेका छन् भने सिन्धुली जिल्लाको कुल जनसंख्याको ३१.५२ प्रतिशत पुरुष र ६८.४७ प्रतिशत महिला रहेका छन्।

तालिका ३.१८: आयोजना प्रभावित जिल्लाहरूको जनसांख्यिकीय विवरण

विवरण	काभ्रेपलाञ्चोक	सिन्धुली
क्षेत्रफल	१३९६ वर्ग कि.मि.	२४९१ वर्ग मि.
कुल जनसंख्या	३८१९३७	२९३१७३
पुरुष	१८२९३६	१३९४०१
महिला	१९९००१	१५३७७२
कुल घरधुरी	८०६५१	५७५४४
औसत परिवार	४.७३	५.०९४



जनघनत्वो	२७३.५९	११७.६९
Sex Ratio (Males per 100 Females)	९१.९२	९०.६५
नगरपालिका/गाउँपालिका	६/७	२/७
मुख्य जातजाति	तामांग, ब्राह्मण, क्षेत्रि, नेवार, मगर, कामी	तामांग, ब्राह्मण, क्षेत्रि, नेवार, मगर, कामी
धर्म	हिन्दु, बुद्धिस्ट, क्रीसचियन,	हिन्दु, बुद्धिस्ट, क्रीसचियन,
भाषा	नेपाली, तामांग, नेवारी, मगर	नेपाली, तामांग, नेवारी, मगर

स्रोत: राष्ट्रिय जनसंख्या तथा घरधुरी सर्वेक्षण, २०११

तालिका ३.१९: प्रभावित क्षेत्रको जनसाङ्ख्यिक विवरण

जिल्ला	गा.पा./न.पा.	घरधुरी	जनसंख्या	पुरुष	महिला
काभ्रेपलाञ्चोक	रोशी गा.पा.	५,८९६	२८,७४६	१३,५३१	१५,२१५
सिन्धुली	सुनकोशी गा.पा.	४,५५७	२१,४७३	९,९८८	११,४८५

स्रोत: राष्ट्रिय जनसंख्या तथा घरधुरी सर्वेक्षण, २०११

काभ्रेपलाञ्चोक जिल्लामा मुख्य जातजातीमा तामाङ ३४.०१ प्रतिशत, ब्राम्हण २१.५३ प्रतिशत रहेका छन् भने सिन्धुली जिल्लामा तामाङ २८.८७ प्रतिशत, मगर १४.९ प्रतिशत रहेका छन्। प्रभावित क्षेत्र रहेको जिल्लामा हिन्दु धर्मावलम्बिको बाहुल्यता रहेको छ जसमा काभ्रेपलाञ्चोक जिल्लामा ८२.५७ प्रतिशत र सिन्धुली जिल्लामा ६८.५६ प्रतिशत देखिन्छ। साक्षरताको तथ्यांकमा काभ्रेपलाञ्चोक जिल्लामा ६९.८ प्रतिशत र सिन्धुली जिल्लामा ७०.०० प्रतिशत साक्षरता रहेको छ।

- घर, जग्गा र उत्पादन, आम्दानी र आम्दानीको श्रोत, पेशा व्यवसाय, उपलब्ध सुविधाहरु आदिको विवरण

प्रभावित क्षेत्रमा पर्ने काभ्रेपलाञ्चोक जिल्लाको रोशी गा.पा. र सिन्धुली जिल्लाको सुनकोशी गा.पा. का अधिकांश भूभाग मध्य पहाडी क्षेत्रमा पर्दछ र पहाडको फेदीमा रहेका केहि समथर भागहरुमा धान खेती गर्ने गरिएको पाइन्छ। अधिकांश ग्रामिण भेगमा कच्चि प्रकारका घरहरु छन् भने वि.पी. राजमार्ग छेउमा बसेका नयाँ बस्तीहरु मंगलटार, नेपालथोक, कटुन्जे, रामटार क्षेत्रमा अर्ध शहरीकरण र व्यापारिक क्रियाकलापहरु बढ्दो पाइन्छ। दुबै गा.पा.का सबै वडाहरुमा बिद्युत सेवा पुगेको छ र सञ्चारका लागि नेपाल टेलिकम, एनसेल, स्पार्ट सेलको नेटवर्कहरु उपलब्ध छन्। काभ्रेपलाञ्चोक जिल्लामा ५७० पूर्व प्राथमिक, १००६ आधारभुत, २८४ माध्यामिक बिद्यालयहरु छन् भने एउटा विश्वबिद्यालय रहेको छ। त्यसैगरि सिन्धुली जिल्लामा ४११ पूर्व प्राथमिक, ७५६ आधारभुत, १६३ उच्च माध्यामिक बिद्यालयहरु छन्।

- व्यापार व्यवसाय आदिको अवस्था

यस क्षेत्रका बासिन्दाहरुको मुख्य पेशा कृषि रहेको छ र अन्य पेशाका रूपमा बैदेशिक रोजगार, आन्ध्रियत नेपाल र भारतका मुख्य शहरहरुमा रोजगारीका लागि जाने रहेको छ।



- आदिवासी/जनजाति, जोखिममा रहेको जनसंख्याको समुह प्रभावित क्षेत्रमा तामाङ जातिको बाहुल्यता रहेको छ भने ब्राम्हण, क्षेत्रि, मगर, दलित र माझि जाति पनि रहेका छन्।

तालिका ३.२०: जातिय विवरण

जातीय समुह	रोशी गाउँपालिका	सुनकोशी गाउँपालिका
तामाङ्ग	३४%	२७%
ब्राम्हण	२२%	८%
क्षेत्रि	१३%	१४%
नेवार	१३%	६%
मगर	४%	१५%
कामी	२%	५%
सार्की	२%	४%
दनुवार	२%	६%
दमाई	१%	४%
अन्य	६%	१३%

स्रोत: राष्ट्रिय जनसंख्या तथा घरधुरी सर्वेक्षण, २०११

- साँस्कृतिक विवरण

बौद्ध धर्मावलम्बिको बाहुल्यता रहेको प्रभावित क्षेत्रमा मनाइने मुख्य चाडपर्वहरूमा ल्होसार, दशैं, तिहार शिवरात्री रहेका छन्। यस क्षेत्रमा रहेको कुशेश्वर महादेव मन्दिरमा शिव रात्रीमा ठुलो मेला लाग्ने गरेको छ।

- उद्योग र व्यापार

आयोजना क्षेत्रको मुख्य व्यापार केन्द्र बनेपा र धुलिखेल हुन्। आयोजना क्षेत्र र यसको छेउछाउमा ठुला उद्योग रहेका छैनन्।

- आयोजना वरपरका वस्तीहरू

आयोजना स्थलबाट नजिकका वस्तीहरूमा माम्ती बजार, दुम्जा, ढुंगोटार, मंगलटार, तिलाचौर आदि हुन्।

