3.4 Future Traffic Demand on Proposed Bypasses

3.4.1 Procedures

(1) Necessity of Application of Simulation Model

Reviewing other feasibility study reports and referring to a study guideline prepared by the IRC in "Traffic Studies for Planning Bypasses Around Towns", no traffic simulation models were suggested for the estimation of diversion traffic to new bypasses. The basic methodologies of these studies are, at first, to identify local traffic and through traffic (potential divertible traffic) from a present O-D table and then all or some portion of the through traffic were assumed to divert to a new bypass with a certain diversion rate. These stepwise manual method, however, is appropriate in a single and simple bypass case.

For this study, such method as explained above is not suitable because of the following reasons :

The proposed ten (10) bypasses have different characteristics each other in terms of types such as a semi-ring road with 2-3 interchanges, long parallel type, shorter or longer than existing National Highways, congestion degree at a city centre, widening plans of existing National Highways and etc. In these situations, it may not be impossible but is very time consuming and difficult work to apply the manual O-D pair wise procedure.

In case of a Toll bypass, the manual method will not be able to easily estimate the effects of levying various toll fees on vehicles.

(2) Traffic Assignment Model

The traffic simulation model adopted in this study is an iterative capacity-constraint assignment method. A typical flow chart for this method is shown in Figure 3-2.

A minimum travel time was adopted as a criterion when select possible travel routes for particular O-D pair traffic. Each O-D pair components were divided into 5 portions of 20% O-D traffic and assigning the first 20% O-D traffic to the minimum travel time route in the road network. Then the travel speed of each link is adjusted based on the Q-V formula (a relationship between traffic volume Q and travel speed V). Under the altered conditions of travel speed, the new minimum travel time route is searched and the second 20% of O-D traffic is assigned to the new route. Above process is repeated 5 times until 100% of O-D traffic is assigned to each route and until all O-D pairs traffic are

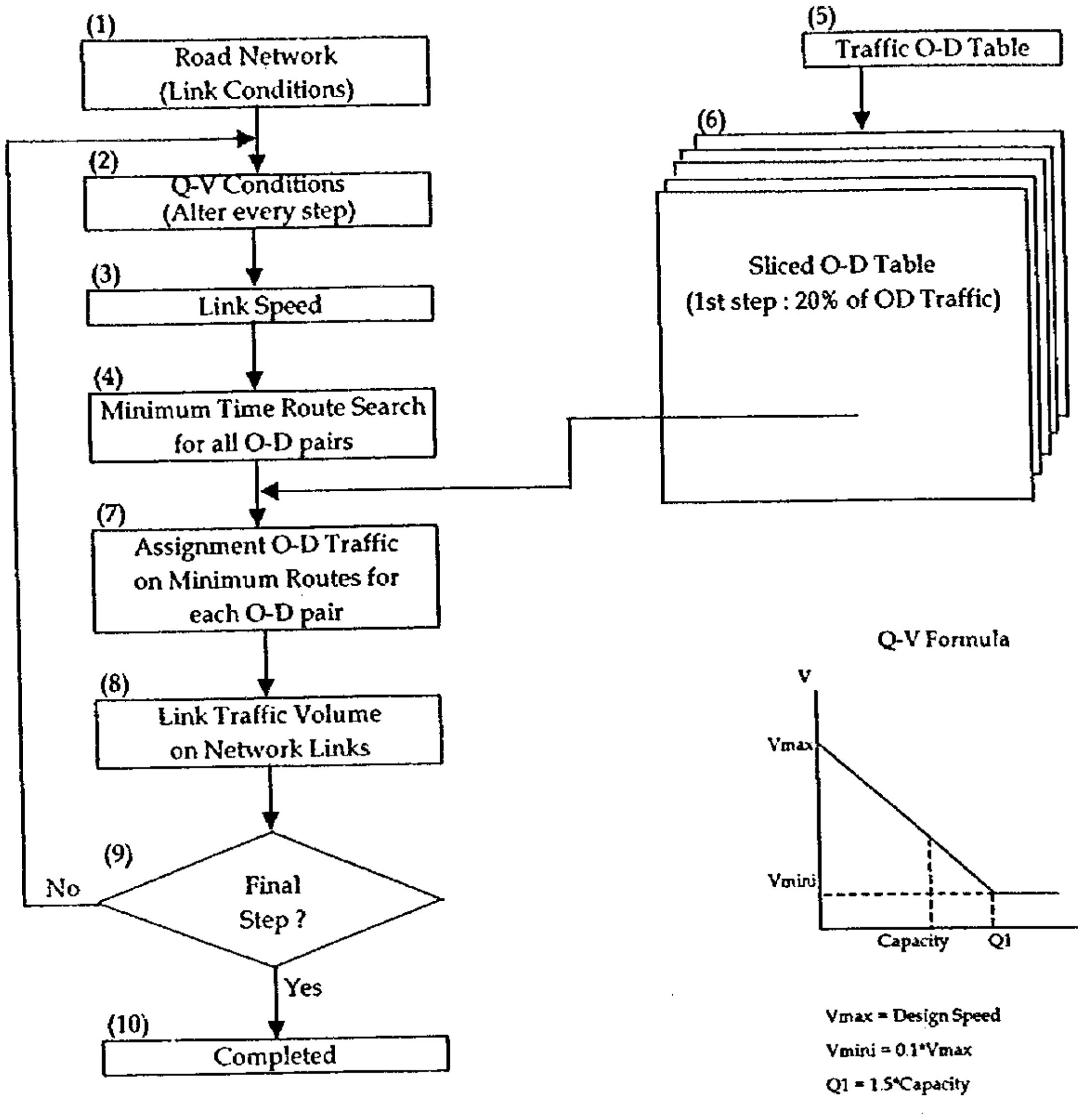


Figure 3-2 Flow Diagram for Traffic Assignment Method

assigned to the road network. The accumulated traffic of 5 repetitions results in the traffic volumes of each road link. (The above parameters of 20% and 5 times are not fixed ones. Those are decided depending on the situations such as, for example, 10% and 10 times repetitions. In case of large urban road network which consists of many alternative routes for each O-D pair traffic, it will be better to repeat 10 times assignment with 10% of O-D pair traffic.)

A similar traffic assignment procedure was applied recently to the Faridabad-Noida-Ghaziabad (F-N-G) Expressway Project (Phase II).

3.4.2 Input Information

The only one shortcoming of the traffic assignment method is that the model requires much information to be input as listed below :

(1) Road Network information

The traffic zoning systems should be prepared for each influence area of each proposed bypass in accordance with the road network. Then links of each road section are to be attached the link information such as link length, road classification, number of lanes, daily capacity and design speed.

(2) Speed - Flow Relation (Q-V Formula)

The Q-V formula is a tool to adjust the travel speed depending on the assigned traffic volume. It is basically specified when the design speed and daily capacity are given. There are many variations of Q-V formulas. In order to decide the Q-V formula for this study, the results of the speed survey were reviewed and the relationship between traffic volume and distribution of the journey speed (including delay) was examined. Although the relationship above was not observed clearly, the study adopted the Q-V formulas illustrated in Figure 3-3.

(3) Design Capacity and Design Speed

According to the "Geometric Design Standards for Rural (Non - Urban) Highways (IRC:73-1980)", the figures of daily capacity of two-lane National Highways are given as 10,000 PCU/day and 20,000 - 30,000 PCU/day for dual four-lane roads. On the other hand, IRC-26 has suggested the design service volume of 15,000 - 17,250 PCU/day for two-lane road. In this study, the following figures were prepared :

1) Two-lane National Highways (Design speed : 80 km/hr.)

- Built-up Area (city centre area and suburbs : inside of bypasses)

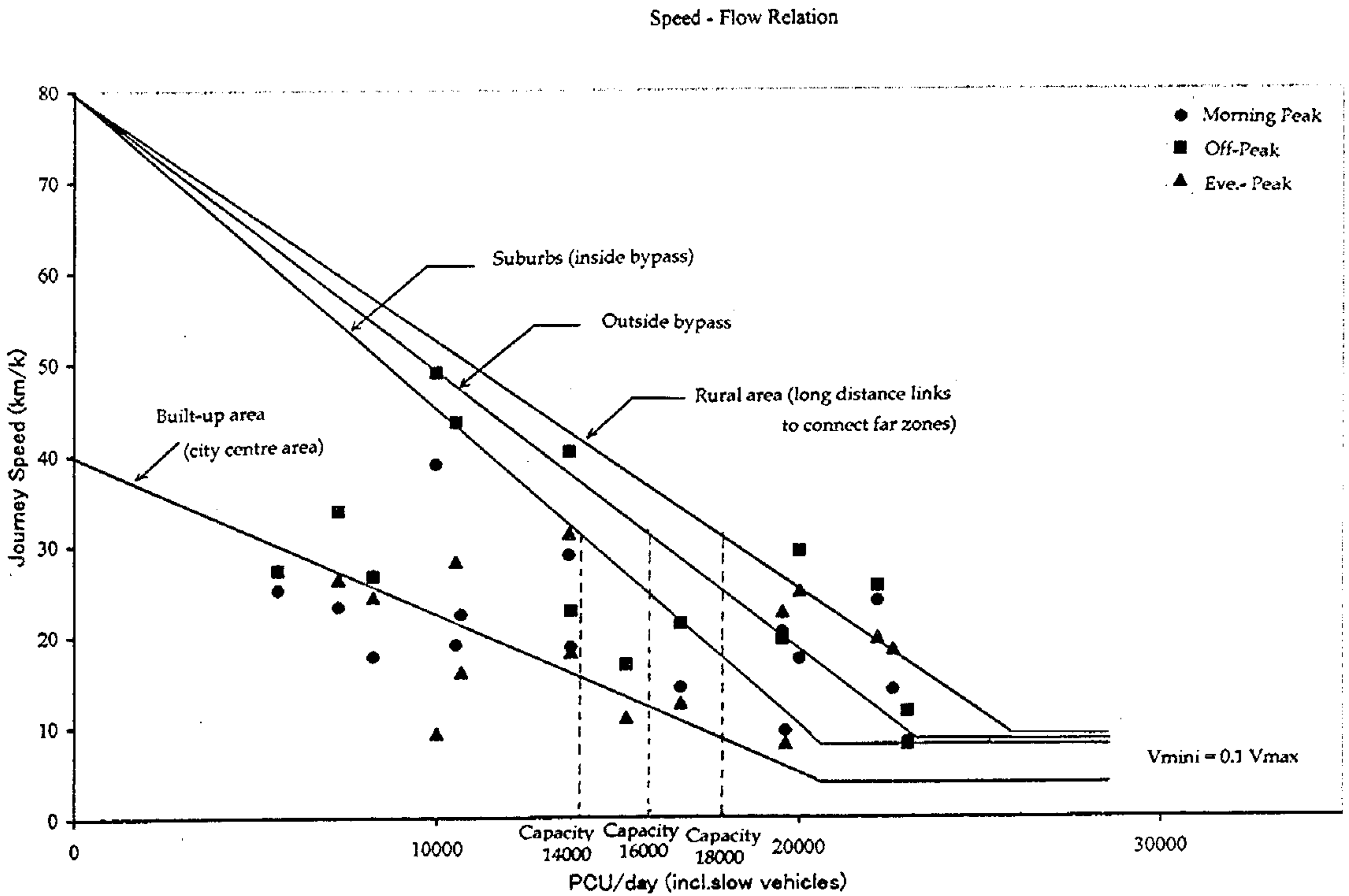


Figure 3-3 Q-V Formula (Speed - Flow Relation)

(2,500 PCU /hour for both directions) x (100/K) x 0.7 (adjustment factor by roadside development) x 0.8 (LOS) = 14,000 PCU/day

- Outside of bypasses

(2,500 PCU/hour for both directions) x (100/K) x 0.8 (adjustment factor by roadside development) x 0.8 (LOS) = 16,000 PCU/day

- Rural areas

(2,500 PCU/hour for both directions) x (100/K) x 0.9 (adjustment factor by roadside development) x 0.8 (LOS) = 18,000 PCU/day

2) Four-lane access controlled bypasses (Design speed : 100 km/hr.)

(2,200 PCU/hour/lane) x (5000/KxD) x (No. of lanes 4) x 0.9 x 0.8 =52,800 PCU/day

K : Peak hour ratio = 10 % (average)
D : Major directional traffic ratio at peak hour = 60 % (average)
LOS : Level of Service

(4) Toll rates and Travel Time Values

a) Toll Rates

In case of a Toll Bypass, the charged toll fees are converted into extra travel costs in terms of travel time and Total Travel Cost (TTC) including toll fees are expressed as generalised cost shown below :

$$TTC = t + F/w$$

here, TTC : total travel cost (in terms of time)
t : travel time
w: value of travel time (Rs./hour)
F: toll fees (in Rs.)

The level of toll rate is usually decided depending on the amount of total benefits accruing from the implementation of the project. Therefore, it may be different by each toll bypass.

The Cabinet Committee on Infrastructure (CCI) have approved in June 1997 the maximum toll rate to be charged on vehicles on existing roads which are widened from 2-lane to 4-lane as follows :

- Car/Jeep/Van — Rs. 0.40 per km
- Light Commercial Vehicle — Rs. 0.70 per km

• Truck and Bus	Rs. 1.40 per km
• Heavy Construction Machinery	Rs. 3.00 per km

Furthermore, it has indicated that the above toll rates would be reviewed periodically by the Government after every three years referring to the whole sale price index.

At the same time, the MOST has been authorised to levy higher rates of toll than the above rates for expressways, major bridges, tunnels and new bypasses (with rates ranging from Rs. 0.8 per km for cars/vans to Rs. 3.5 per km for heavy construction machinery).

It was decided for this study to apply the toll rate of Rs.1.0 per km in 1997 for cars, by referring to other recent studies on bypasses and expressways. Then the toll rates for other vehicle types were assumed to follow the same proportions of toll rates approved by the CCI (except for two wheeler) as shown below :

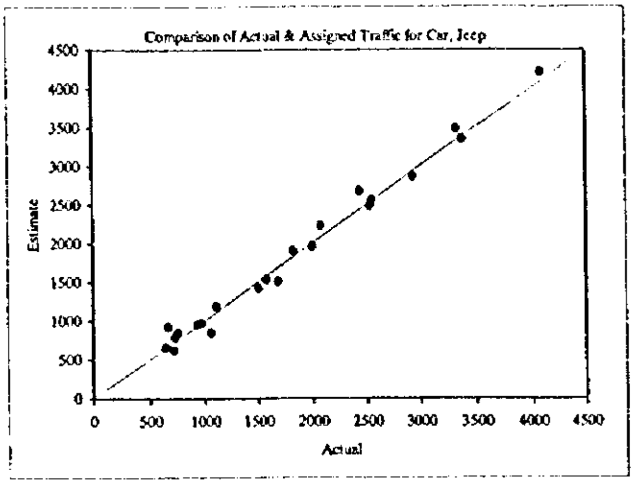
Car/Jeep/Van	Rs. 1.00 per km
Light Commercial Vehicle	Rs. 1.75 per km
Truck and Bus	Rs. 3.50 per km
Heavy construction machinery	Rs. 7.50 per km
Two wheeler (as half of cars)	Rs. 0.50 per km

b) Travel Time Values

The travel time values by vehicle type were estimated based on the time values of passengers and commodities transported as shown in the chapter of economic analysis.

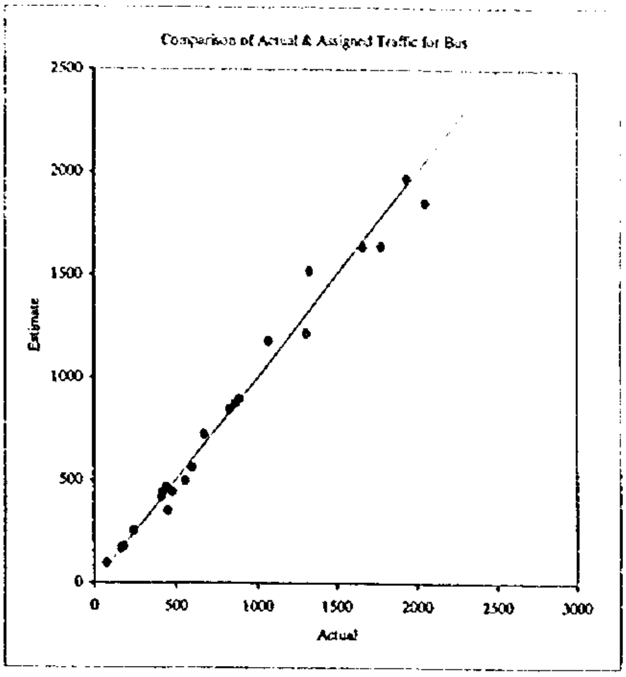
3.4.3 Validity of Traffic Assignment Procedure

In order to confirm the validity of the traffic assignment method, present O-D tables and road network information, it is necessary to conduct a simulation tests of traffic assignment and to compare the estimated traffic volumes with the actual traffic data (traffic count data in 1997). This check work is important to guarantee the reliability of future traffic demand forecast. The present O-D tables were assigned to the present road network and re-produced (estimated) traffic volumes of 1997 on road links were compared with actual traffic data. The results of these tests are illustrated in Figure 3-4 to Figure 3-7. The figures indicate that the traffic assignment model satisfactorily re-produces and replicates observed traffic volumes.



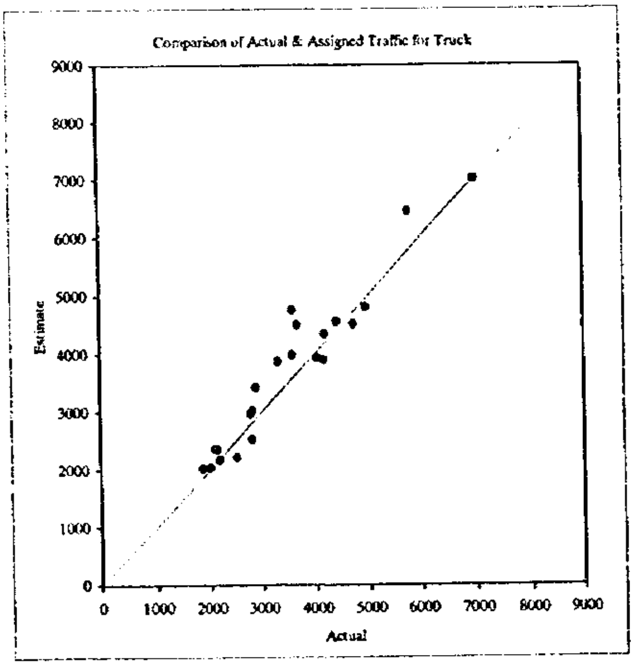
R = 0.993

Figure 3-4 Comparison of Actual & Assigned Traffic for Car, Jeep



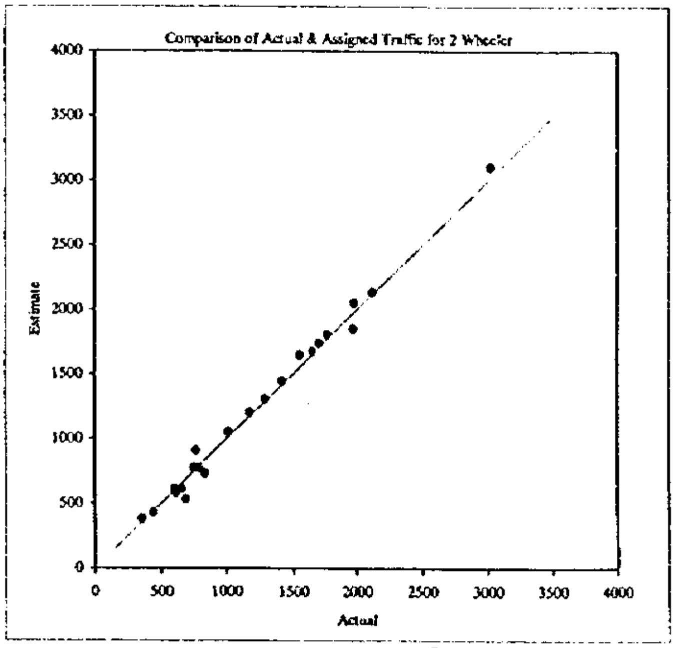
R = 0.991

Figure 3-5 Comparison of Actual & Assigned Traffic for Bus



R = 0.961

Figure 3-6 Comparison of Actual & Assigned Traffic for Truck



R = 0.995

Figure 3-7 Comparison of Actual & Assigned Traffic for Two Wheeler

3.4.4 Results of Future Traffic Demand Forecast

Future O-D tables were assigned to the road network, both "with" and "without" the proposed bypasses. The results of total 40 runs of assignment (10 bypasses x 2 target years x 2 cases of with and without projects) are given in Table 3-10. The following comments are added from the results :

- Each 2-lane National Highway will reach its capacity in next 5 - 6 years.
- Regarding the Vijayawada bypass, the main direction of traffic demand is along the NH 5 (from/to Eluru to/from Chilakalerupet via Vijayawada). Therefore, when the section of Eluru - Vijayawada on the NH 5 has congested, some potions of traffic will divert to the Bypass and flow in to NH5 via NH9. This is a reason why the traffic will increase at the section of NH9 in with bypass case (in 2012). At the same time, this result indicates the requirement of extension of the Vijayawada bypass to the NH5 by crossing the Krishna River.
- In the case of a ring road type such as Bhopal and Bareilly bypasses with interchanges at major radiant roads, traffic other than through traffic will also partly use the bypasses as detour routes to avoid congested sections of existing roads to/from city centres.
- The Patna bypass will attract the diversion traffic not only from NH30 but also from other roads which would be insisted to take long detour routes because of inconvenient long waiting at one-way crossing of Sone river through the existing old narrow bridge.

Table 3-10 Future Traffic Projection

(PCU/day)

No.	Bypass	Year	Case							
			Without Bypass		With Bypass					
			National Highway		National Highway		Bypass			
			N(W)	S (E)	N(W)	S (E)	N(W)	Centre	S(E)	
1	Bareilly	2002	32,285	31,456	22,221	19,319	18,441	21,025	12,138	
		*(v/c)	2.02	1.97	1.39	1.21	0.35	0.40	0.23	
		2012	60,541	59,064	25,891	22,920	35,949	82,575	36,144	
		(v/c)	3.78	3.69	1.62	1.43	0.68	1.56	0.68	
2	Patna	2002	14,779	14,973	6,033	6,356	18,095	18,095		
		(v/c)	1.06	1.07	0.43	0.45	0.34	0.34		
		2012	25,360	25,576	8,937	14,582	26,191	26,191		
		(v/c)	1.81	1.83	0.64	1.04	0.50	0.50		
3	Keonjhar	2002	11,122	11,284	9,394	9,557	1,728			
		(v/c)	0.79	0.81	0.67	0.68	0.03			
		2012	18,346	18,641	12,625	12,919	5,722			
		(v/c)	1.31	1.33	0.90	0.92	0.11			
4	Balugaon	2002	14,596	13,877	12,052	11,333	2,544			
		(v/c)	1.04	0.99	0.86	0.81	0.05			
		2012	24,506	23,319	11,681	10,494	12,825			
		(v/c)	1.75	1.67	0.83	0.75	0.24			
5	Vijayawada (**)	2002	22,957	39,590	18,700	35,332	4,258			
		(v/c)	0.56	0.97	0.46	0.86	0.08			
		2012	42,092	72,824	59,581	39,817	33,007			
		(v/c)	1.03	1.78	1.45	0.97	0.63			
6	Kannur	2002	24,279	19,641	16,201	11,575	8,078			
		(v/c)	1.35	1.40	0.90	0.83	0.15			
		2012	44,743	36,218	33,586	17,112	19,121			
		(v/c)	2.49	2.59	1.87	1.22	0.36			
7	Nandura	2002	19,117	18,123	5,593	4,598	13,525			
		(v/c)	1.06	1.01	0.31	0.26	0.26			
		2012	34,791	32,960	10,160	8,329	24,631			
		(v/c)	1.93	1.83	0.56	0.46	0.47			
8	Khamgaon	2002	22,430	23,269	6,057	8,766	16,374	14,504		
		(v/c)	1.40	1.45	0.38	0.55	0.31	0.27		
		2012	40,909	42,500	10,308	15,687	30,601	26,813		
		(v/c)	2.56	2.66	0.64	0.98	0.58	0.51		
9	Bhopal	2002	14,968	28,463	14,313	14,801	3,320	1,442	7,256	13,666
		(v/c)	1.07	2.03	1.02	1.06	0.06	0.03	0.14	0.26
		2012	32,099	53,974	14,941	19,136	25,715	20,647	27,281	34,838
		(v/c)	2.29	3.86	1.07	1.37	0.49	0.39	0.52	0.66
10	Gwalior	2002	31,674	37,098	18,206	23,628	13,471			
		(v/c)	1.76	2.06	1.01	1.31	0.26			
		2012	63,654	74,551	36,475	47,613	27,177			
		(v/c)	3.54	4.14	2.03	2.65	0.51			

Note: (*v/c) : Traffic Volume / Capacity Ratio

(**) : assuming four-lane widening of NH5 and NH9 at Vijayawada sections

N(W) : North link (West link)

S(E) : South link (East link)

Centre : Centre link

3.4.5 Toll Elasticity of Traffic Demands

Toll elasticity of traffic demands on proposed bypass was estimated for the two cases changing the toll rate by 50% down and 50% up from the base rate. As the base toll rate was applied equally to each bypass, the effects of changes of the base rate were observed in various forms depending on the characteristics of each bypass (congestion on existing National Highways and bypasses, alignment and length of bypasses, etc.). The toll elasticity of traffic demands is defined as below and summarised in Table 3-11 (in this estimation, traffic demands are calculated as total vehicle-km per day on bypasses).

Toll Elasticity of Traffic Demands = [Changes in Traffic Demands (%)]/[Changes in Toll Rate (%)]

The explanations of the results are given below :

(1) Bareilly Bypass

The traffic demands on the Bareilly Bypass in 2002 will be still under capacity (refer to Table 3-10) but the traffic volume on the National Highway 24 will exceed its capacity even in the case of base toll rate with proposed bypass. The traffic demands will easily increase when the toll rates go down in these situations. The same tendency is observed in 2012. The toll elasticity of traffic demands is less than unity for the both target years. When the elasticity is less than 1 at a given toll rate and demand, decrease (increase) in toll rate is accompanied by a less proportional increase (decrease) in traffic demands and total toll revenues will decrease (increase). This is the case of inelastic demands. The elasticity is very low especially in the case of upward change (+50%) of toll rate because of congestion of existing NH24.

(2) Patna Bypass

The traffic demands on the Patna Bypass will remain at the same level even if the toll rate goes down in by 50% from the base rate in 2002. Because about 80% of the through traffic already diverted to the bypass in the base toll rate case, and because of its 50 km of length and traffic on the National Highway 30 will be under the capacity in the base case of 2002, 50% decrease of toll rate will not result in increase of traffic demands in 2002.

(3) Keonjhar Bypass

The Keonjhar Bypass has the alignment longer than the National Highway 6 and comparatively low traffic volume among the proposed ten bypasses in 2002. In these circumstance, traffic demands on the bypass will sensitively vary depending on the toll level. All traffic demands will easily return to the existing National Highway when the toll rate goes up by 50%. On the other hand, two times of traffic demands will be attracted to the bypass if the burden of toll charge is reduced by 50%. This is an elastic demand case and the toll revenues will increase (decrease) when the toll rate goes down (goes up). On the other hand, in 2012, the traffic demands will not decrease even if the toll rate is increased because the traffic volume on the National Highway 6 will be nearly its capacity in the base case.

(4) Balugaon Bypass

The same situation as the Keonjhar Bypass will occur to the Balugaon Bypass in 2002. However, as the traffic volume on the National Highway 5 will still be under capacity in 2012, a 50% down of the toll rate will attract no additional traffic demands to the bypass.

(5) Vijayawada Bypass

As the National Highway 5 at Vijayawada sections is scheduled to be widened to four lanes, traffic demands on the toll bypass are not so high in 2002. However, if the toll rate is set to the lower level than the base rate, large traffic demands will increase in 2002 because divertible traffic is comparatively high at this section. In 2012, although the traffic volume on the existing NH5 will exceed its capacity, traffic demands on the bypass will decrease if the toll rate changes upward by 50% because the length of the bypass is comparatively long (28.1 km).

(6) Kannur Bypass

The Kannur Bypass is the most inelastic demand case among the proposed ten bypasses. All through traffic will divert to the bypass in the base toll rate case both for the year 2002 and 2012. Therefore, no additional traffic on the bypass will appear even if the toll rate goes down in 2002 and 2012. At the same time, as traffic volumes on the National Highway 17 will reach/exceed its capacity in 2002 and 2012, it will not easy to return to the existing National Highway even if the toll rate goes up by 50% in 2002 and 2012. Therefore, the completely inelastic situations will be observed as far as the toll changes within a range of +50%up and -50% down are concerned.

(7) Nandura Bypass

Although the Nandura Bypass has a short cut alignment, a higher toll rate will result in the decrease of traffic demands on the bypass as the traffic volume on the National Highway 6 is under the capacity in 2002. In 2012, as the traffic volume on NH6 will increase and because of short cut alignment of the bypass, 50% of increase of toll rate will not result in the decrease of traffic demands on the bypass.

(8) Khamgaon Bypass

The traffic volume on both the National Highway 6 at Khamgaon sections and the proposed bypass will not reach their capacity in 2002 and 2012 (except for the south section of NH6 in 2012 with congestion rate of 0.98). In addition, the alignment of the bypass has a longer distance than the existing highway. Therefore, the traffic demands on the bypass will change in accordance with downward and upward changes of the toll rate.

(9) Bhopal Bypass

The toll elasticity of traffic demands of the Bhopal Bypass is very low in both 2002 and 2012 because of its alignment (ring road type, far from the city centre) and congestion of the existing National Highway 12.

(10) Gwalior Bypass

Although the traffic demands on the National Highway 3 will exceed its capacity in base toll rate case in 2002 and 2012, a 50% of upward change of the toll rate will result in decrease of the traffic demands on the bypass because of the long length of the bypass (26.0 km). However, the toll elasticity for upward change in 2012 will be very small (only 0.01).

Table 3-11 Estimation of Traffic Demand Elasticity by Toll Rate

No.	Bypass		2002 Toll Rate -50%	2002 Toll Rate Base Rate	2002 Toll Rate +50%	2012 Toll Rate -50%	2012 Toll Rate Base Rate	2012 Toll Rate +50%
1	Bareilly	Vehicle-km/day	302,459	218,522	217,629	778,924	633,068	604,618
		Changes in Veh.-km	+38.4%	-	-0.4%	+23.0%	-	-4.5%
		Elasticity	0.77	-	0.01	0.46	-	0.09
2	Patna	Vehicle-km/day	390,383	390,383	301,154	656,698	562,275	512,785
		Changes in Veh.-km	0	-	-22.9%	+16.8%	-	-8.8%
		Elasticity	0.00	-	0.46	0.34	-	0.18
3	Keonjhar	Vehicle-km/day	12,580	6,299	0	31,476	20,987	20,987
		Changes in Veh.-km	+99.7%	-	-100.0%	+50.0%	-	0.0%
		Elasticity	1.99	-	2.00	1.00	-	0.00
4	Balugaon	Vehicle-km/day	28,952	14,476	0	73,042	73,042	55,348
		Changes in Veh.-km	+100.0%	-	-100.0%	0.0%	-	-24.3%
		Elasticity	2.00	-	2.00	0.00	-	0.49
5	Vijayawada	Vehicle-km/day	141,902	44,274	22,137	422,972	402,752	241,787
		Changes in Veh.-km	+220.5%	-	-50.0%	+5.0%	-	-40.0%
		Elasticity	4.41	-	1.00	0.10	-	0.80
6	Kannur	Vehicle-km/day	44,800	44,800	44,800	113,786	113,786	113,786
		Changes in Veh.-km	0.0%	-	0.0%	0.0%	-	0.0%
		Elasticity	0.00	-	0.00	0.00	-	0.00
7	Nandura	Vehicle-km/day	42,835	34,272	25,702	78,317	62,656	62,656
		Changes in Veh.-km	+25.0%	-	-25.0%	+25.0%	-	0.0%
		Elasticity	0.50	-	0.50	0.50	-	0.00
8	Khamgaon	Vehicle-km/day	79,360	64,450	58,133	145,308	121,208	116,430
		Changes in Veh.-km	+23.2%	-	-9.7%	+19.9%	-	-3.9%
		Elasticity	0.46	-	0.19	0.40	-	0.08
9	Bhopal	Vehicle-km/day	177,000	165,735	163,478	667,669	636,795	617,245
		Changes in Veh.-km	+6.8%	-	-1.4%	+4.9%	-	-3.1%
		Elasticity	0.14	-	0.03	0.10	-	0.06
10	Gwalior	Vehicle-km/day	173,602	131,924	90,194	350,220	268,164	266,188
		Changes in Veh.-km	+31.6%	-	-31.6%	+30.6%	-	-0.7%
		Elasticity	0.63	-	0.63	0.61	-	0.01

Pre-Feasibility Study

Chapter 4
Design Standards

4 Design Standards

4.1 Design Concept and Methodology

4.1.1 General

At the Pre-Feasibility Study, a design concept, methodology and design standard were established. These should be consistent for whole period of the project. The ten bypasses in the Pre-Feasibility Study were as shown in Table 4-1.

Table 4-1 Ten Bypasses in Pre-Feasibility Study

No.	Name of Bypass	Distance (km)	State	National Highway to be Connected
1	Bareilly	31.1	Uttar Pradesh	NH24
2	Patna	49.8	Bihar	NH30
3	Keonjhar	8.5	Orissa	NH6
4	Balugaon	15.4	Orissa	NH5
5	Vijayawada	28.1	Andhra Pradesh	NH5,NH9
6	Kannur	11.1	Kerala	NH17
7	Nandura	6.4	Maharashtra	NH6
8	Khamgaon	10.9	Maharashtra	NH6
9	Bhopal	40.3	Madhya Pradesh	NH12
10	Gwalior	26.0	Madhya Pradesh	NH3

4.1.2 Basic Concept of Design

a. Adopt the route alignment alternatives prepared by MoST/PWD basically, through discussions with MoST/PWD and ground reconnaissance by the Study Team, to confirm major controls, on the sites;

b. Assume the bypasses will be dual 2-lane highway with full control of access and function as a toll-way;

c. Avoid as much as possible densely populated areas to minimise the relocation;

d. Avoid as much as possible areas where conservation and protection of environmental conditions apply;

e. Set the route alignment so as to minimise structures like bridges/viaducts, culverts and high retaining walls;

f. Design the route alignment with least earthwork; and

g. Apply larger horizontal and vertical curves in the design, because of the design works based on the scale of 1: 50,000 topographic map. These design elements will be modified properly according to future additional information.

4.1.3 Design Methodology

a. Review the alignments proposed by PWD, where they have;

b. Visit the bypass sites and confirm the project conditions including major controls by discussions with PWD, and convey the ground reconnaissance;

c. Establish the design standard, geometric, structural and drainage, to be adopted for the design of throughway based on IRC standard, referring to AASHTO standard of United States and JRSO of Japan. These countries have experienced the expressway-era for many years and keeping valuable data for the expressway traffic management, including record of traffic accidents and desirable structures for safety and comfort of drivers;

d. Study of full control of access system of the bypass taking consideration of Indian conditions; and

e. Finalisation of the design drawing and the quantities for the Pre-Feasibility Study.

4.2 Geometric Design Standard for Throughway

4.2.1 General

(1) General

The Indian Road Congress (IRC) has established and maintained a comprehensive road design standard for ordinary roads, which carries various kind of vehicles from low speed animal drawn vehicles to high speed motor vehicles.

As the bypasses are intended to build as full control of access and provide high level of service, the Study Team prepared and submitted a draft geometric design standard report at the middle of June 1997, and MoST agreed with some modifications. Major design elements are described below and Table 4-5 summaries the design standard to be applied to the project.

(2) Publications Referred

a) IRC: "Pocketbook for Highway Engineers (First Revision 1995)"

b) IRC: Special Publication No. 20, "Manual for Survey, Investigation, and Preparation of Road Projects"

c) IRC: 73-1980 "Geometric Design Standards for Rural (Non-urban) Highways"

d) IRC: 62-1976 "Guidelines for Control of Access on Highways"

e) AASHTO: "A Policy on Geometric Design of Highways and Streets, 1994"

f) JRA: "Japan Road Structure Ordinance (JRSO)"

g) JHPC: "Design Manual Vol. 4: Geometric Design Standard"

(3) Design Vehicle

According to IRC: 3-1983 "Dimensions and Weight of Road Design Vehicles", the Study Team proposed to apply the dimensions of length: 18.00 m; width: 2.50 m; height: 4.20 m, and the maximum gross weight: 52.20 ton; maximum axle weight: 18.00 ton.

(4) Design Speed

The most important criteria in determining the design speed is the highway classification and the intended function of the proposed highway. Other factors to be considered are topography (plain, rolling, mountain or steep) and land use on the roadsides. As the bypasses are National Highway and located at plain terrain, respectively, the Study Team proposed to employ a 100 km/hr as design speed.

4.2.2 Cross-Sectional Elements

(1) Road Land Width, Building Lines and Control Lines

The Study Team proposed to apply following values; road land width is 80 m, overall width between building lines is 100 m and overall width between control lines is 150 m, considering the design speed and the land use conditions along the project areas.

Eighty (80) meters of road land width (Right-Of-Way) was derived from considering the width of the service road which runs both sides of the through traffic.

(2) Width of Carriageway

According to IRC standard, 3.5 m wide per lane for multi-lane carriageway and it makes 7.0 m wide for dual 2-lane highway.

The Study Team proposed to adopt 7 m width of the carriageway, this width allows up to 53,000 pcus.

(3) Width of Outer Shoulder

Appropriate shoulder width for a 100 km/hr design was studied referring AASHTO and JRSO, then the dimension of 2.5 m wide of paved shoulder and 1.00 m of earthen shoulder was proposed by the Study Team and agreed by MOST.

(4) Width of Median Shoulder

Since raised median with barrier-type curbing was determined to be adopted the bypass, the width of median shoulder was studied and proposed to apply a 0.75 m wide by the Study Team. MoST had discussed the width internally and instructed to apply a 0.70 m median shoulder.

(5) Median

Median type was discussed between MoST and the Study Team. MOST had understood the concept of median type in high-speed highway, but insisted that in case of applying flat median, people would cross the bypass easily and it increases serious traffic accidents, as special consideration to be paid here in India.

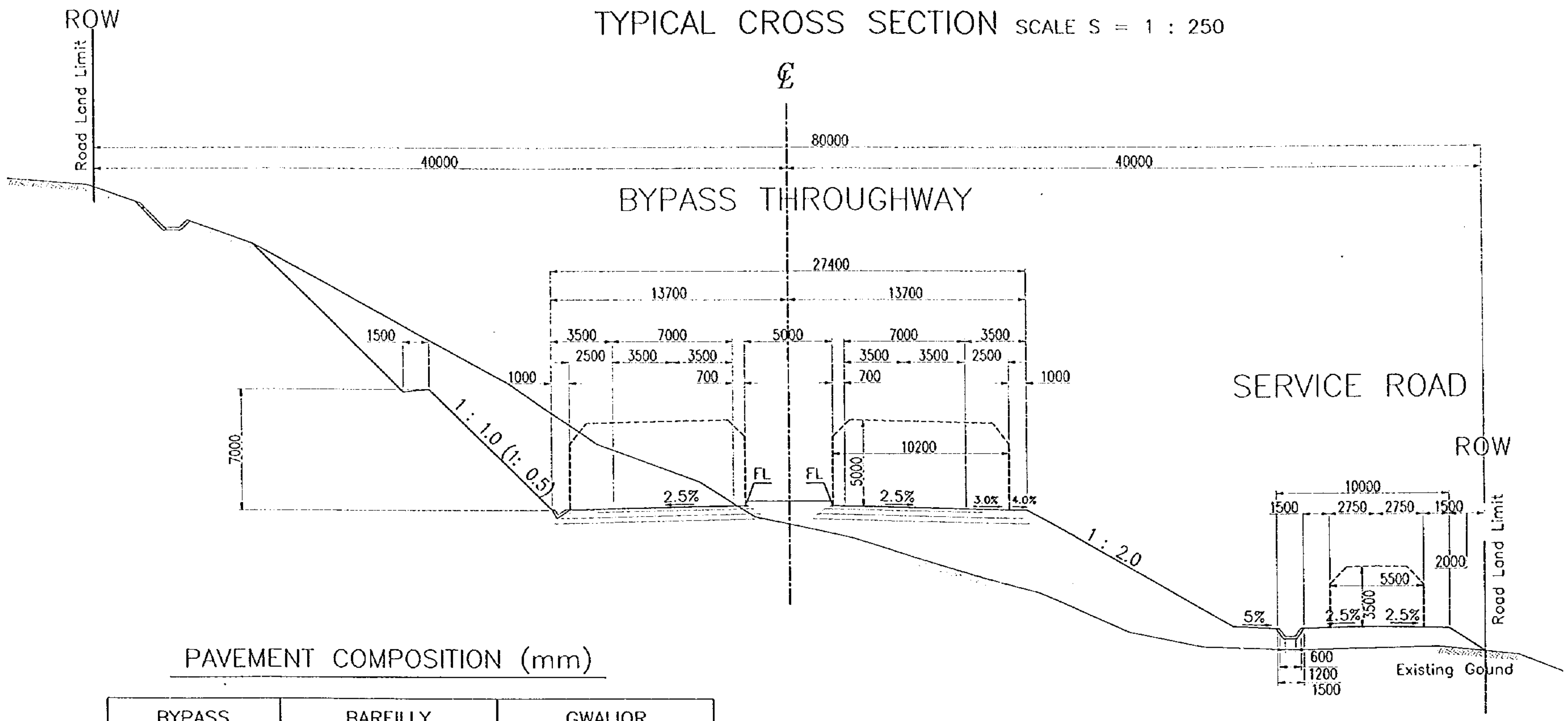
The Study Team accepted to apply the raised median with keeping wide median shoulder for horizontal clearance to the barrier-type curb.

(6) Roadway Width

Summarising overall cross-sectional elements described above, total width of roadway is 27.40 m both for fill and cut section.

4.2.3 Typical Cross Section

The typical cross section to be applied to the bypass is shown in Figure 4-1.



PAVEMENT COMPOSITION (mm)

BYPASS	BAREILLY	GWALIOR
AC	40	40
DBM	160	160
WMM	300	300
GSB	300	300
TOTAL	800	800

NOTE:
1) Cut slope is 1:0.5 in rock section in Gwalior Bypass

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) THE FEASIBILITY STUDY ON NATIONAL HIGHWAY BYPASSES IN INDIA	DWG TITLE : TYPICAL CROSS SECTION OF THROUGHWAY	DWG SCALE : S = 1 : 250	DWG NO. : B-1

Figure 4-1 Typical Cross Section

4.2.4 Horizontal Alignment

(1) Minimum Radius of Horizontal Curve

On a horizontal curve, the centrifugal force is balanced by the combined effects of superelevation and side friction. The basic equation for this condition of equilibrium is:

$$R = \frac{V^2}{127(e + f)}$$

where:

V = vehicle speed in km/h (100)

e = superelevation ratio in meter in meter (0.07)

f = coefficient of side friction between vehicle tires and pavement (0.15)

R = radius in meters

Based on this equation, a 360 m radius is the minimum for a 100 km/hr design speed.

(2) Superelevation

Superelevation required on horizontal curves should be calculated from the following formula. This assumes that centrifugal force corresponding to three-fourth the design speed in balanced by superelevation and rest counteracted by side friction:

$$e = \frac{V^2}{225 \cdot R}$$

where:

e = superelevation in meter per meter,

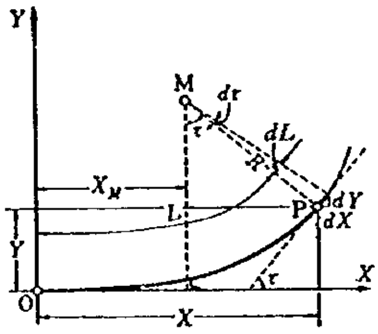
V = speed in km/h, and

R = radius in meters

In plain and rolling terrain, the superelevation value should be kept limited to seven per cent. The minimum radius of curve, which does not require superelevation is 1,800 m.

(3) Transition Curves

The Study Team proposed to adopt the Euler's spiral curves as transition curves, which are known as Clothoide and expressed in the following formulas.



$$R = \frac{A^2}{L} = \frac{A}{l} = \frac{L}{2\tau} = \frac{A}{\sqrt{2\tau}}$$

$$L = \frac{A^2}{R} = \frac{A}{r} = 2\tau R = A\sqrt{2\tau}$$

$$\tau = \frac{L}{2R} = \frac{L^2}{2A^2} = \frac{A^2}{2R^2}$$

$$A^2 = LR = \frac{L^2}{2\tau} = 2\tau R^2$$

$$A = \sqrt{RL} = l \cdot R = L \cdot r = \frac{L}{\sqrt{2\tau}} = \sqrt{2\tau} \cdot R$$

$$X = L\left(1 - \frac{L^2}{40R^2} + \frac{L^4}{3456R^4} - \frac{L^6}{599040R^6} + \cdots\cdots\right)$$

$$Y = \frac{L^2}{6R}\left(1 - \frac{L^2}{56R^2} + \frac{L^4}{7040R^4} - \frac{L^6}{1612800R^6} + \cdots\cdots\right)$$

$$\Delta R = Y + R\cos\tau - R$$

$$X_M = X - R\sin\tau$$

$$T_K = Y \operatorname{cosec}\tau$$

$$T_L = X - Y\cot\tau$$

$$S_0 = Y \operatorname{cosec}\sigma$$

Figure 4-2 Clothoide Spiral Formula

4.2.5 Vertical Alignment

(1) Gradients

Regarding values of gradients, the Study Team proposed to adopt the same values as IRC standard as follows, which for a 100 km/hr design speed;

Table 4-2 Gradients for Roads (plain or rolling terrain)

Element	Type	Value
Gradients	Ruling Limiting Exceptional	3.3 % 5.0 % 6.7 %
Vertical Curve	Minimum Length	60 m
Minimum Gradients for Drainage	Lined Unlined	0.3 % 1.0 %

(2) Critical Length of the Gradient

IRC indicates the maximum gradients but the critical length. The Study Team proposed to apply critical length of the gradients, which is common in other countries, as shown in Table 4-3.

Table 4-3 Critical Length of the Gradient (100 km/hr)

Absolute Maximum Gradients (%)	Critical Length (m)
Less than 3.3	No Limit
4	700
5	500
6	400

(4) Vertical Curves

In order to have simple configurations, vertical curves of quadratic parabolic type were proposed for the design. The length of convex vertical curves is determined by the sight or stopping distance, while the length of concave vertical curves is related to night visibility generated by the vehicles lights, drainage control and comfort level along the curve.

(5) Minimum Radius of Vertical Curves

The Study Team proposed to apply this expression for the design of the vertical curves addition to the IRC, and the radiuses proposed are as shown in Table 4-4.

Table 4-4 Radius of Vertical Curves (100 km/hr)

Summit Curves		Valley Curves	
Absolute Minimum Radius (m)	Desirable Minimum Radius (m)	Absolute Minimum Radius (m)	Desirable Minimum Radius (m)
6,500	10,000	3,000	4,500

4.2.6 Lateral and Vertical Clearances at Underpasse

According to IRC: 54-1974 "Lateral and Vertical Clearances at Underpasses for Vehicular Traffic", the Study Team proposed to apply that the lateral clearance at underpasses is 10.20 m for entire width of paved surface, and the vertical clearance is 5.00 m from the finished level of the paved surface.

4.2.7 Established Design Standard

Established geometric design standard is summarised in Table 4-5.

Table 4-5 Established Geometric Design Standard

		Design Elements	Type/Value	Remarks	Reference
1		Road Classification	National Highway		IRC
2		Terrain	Plain	0-10 % slope	IRC
3		Design Speed (km/h)	100		IRC
4	Vehicle	Dimension (WxHxL, m)	2.50x4.2x18.0		IRC
		Weight (Gross, ton)	52.2		IRC
		Weight (Axle, ton)	18.0		IRC
5	Cross-Sectional Elements	Overall Width between Control Lines (m)	150		
		Overall Width between Building Lines (m)	100		IRC modified
		Road Land Width (m)	80		IRC modified
		Roadway Width (m)	27.00	Dual 2-lane	---
		Carriageway Width(m)	7.00	2@3.5	IRC
		Outer Shoulder Paved Width (m)	2.50		AASHTO/JRSO
		Outer Shoulder Earthen Width (m)	1.00		JRSO
		Inner Shoulder Paved Width (m)	0.70		JRSO
		Median Width (m)	5.00	Flat type	AASHTO/JRSO
		Crossfall			
		Carriageway (%)	2.50		IRC
		Outer Shoulder Paved (%)	2.50		IRC
		Outer Shoulder Earthen (%)	4.00		IRC
		Inner Shoulder Paved (%)	2.50		same as carriadgeway
		Median (%)	3.00		
		Slope of Earthworks			
		Fill	V : H = 1:2		
		Cut	V : H = 1:1 (0.5)		( ) Value for Rock
6	Sight Distance	Driver's Eye Height (m)	1.20		IRC
		Height of Object for Stopping Distance (m)	0.15		IRC
		Safe Stopping Sight Distance (m)	180		IRC
		Intermediate Sight Distance (m)	360		IRC
		Overtaking Sight Distance (m)	640		IRC
7	Horizontal Alignment	Horizontal Curve			
		Minimum Radii of Horizontal Curve (m)	360		IRC
		Minimum Curve Length (m)	150		IRC
		Superelevation			
		Maximum Superelevation (%)	7.00		IRC
		Minimum Radii w/o Superelevation (m)	1800		IRC
		Maximum Slope of Superelevation	1/200		AASHTO
		Transition Curve			
		Spiral Type	Clothoid		
		Minimum Radii w/o Transition (m)	2000		IRC
8	Vertical Alignment	Gradients			
		Ruling (%)	3.3		IRC
		Limiting (%)	5.0		IRC
		Exceptional (%)	6.7		IRC
		Critical Length of Gradients			
		For 3.3 %	no limit		IRC
		For 4.0 % (m)	700		JRSO
		For 5.0 % (m)	500		JRSO
		For 6.0 % (m)	400		JRSO
		Vertical Curve			
		Minimum Length of Vertical Curve (m)	60		IRC
		Minimum Radius of Vertical Curve			
		Summit Curve (m)	10000(6500)	( )Absolute Minimum	AASHTO/JRSO
		Valley Curve (m)	4500(3000)	( )Absolute Minimum	AASHTO/JRSO
		Minimum Gradients for Drainage			
		Lined (%)	0.50		IRC
		Unlined (%)	1.00		IRC
9		Lateral Clearance (m)	10.20	all paved width	
		Vertical Clearance (m)	5.00		IRC

4.3 Pavement Design Criteria

4.3.1 General

As the flexible pavement structure is commonly applied to the National Highway, and the advantages in construction method and in maintenance treatment are well accepted. The Study Team proposed to adopt the flexible pavement to the project bypasses. IRC has a guideline "IRC: 37-1984, Guidelines for the Design of Flexible Pavements", which is tentative yet but generally used as a basis of the pavement design in India.

For the pre-feasibility study, the Study Team proposed to apply uniform pavement design, thickness and composition, equally for all ten bypasses because that the design of a flexible pavement involves the interplay of several variables such as the wheel loads, climate, terrain and subgrade conditions, and these factors are difficult to evaluate for each bypass, at this moment.

4.3.2 Design Method

The IRC standard recommends design method to be a modification of the California Bearing Ratio (CBR) Method indicated in the previous edition of AASHTO. The Study Team applied this method to the pavement design of the project.

IRC had revised and established an additional thickness combination blocks of pavement structures in 1993.

4.3.3 Traffic Analysis and Determination of Design MSAL

Future traffic projection for commercial vehicles for all ten bypasses is shown in Table 4-6.

Table 4-6 Future Traffic Projection for Commercial Vehicles

No.	Bypass	Year 2002		Total	Year 2012		Total	Growth
		Bus	Truck	(A)	Bus	Truck	(B)	Rate(%/yr)
1	Bareilly	739	2,764	3,503	2,322	7,955	10,277	11.36%
2	Patna	762	4,458	5,220	1,060	6,502	7,562	3.78%
3	Keonjhar	18	501	519	56	660	716	3.27%
4	Balugaon	46	764	810	223	3,859	4,082	17.55%
5	Vijayawada	638	3,781	4,419	1,712	10,087	11,799	10.32%
6	Kannur	436	1,628	2,064	1,222	3,456	4,678	8.53%
7	Nandura	312	3,881	4,193	539	7,088	7,627	6.17%
8	Khamgaon	250	4,929	5,179	470	7,954	8,424	4.98%
9	Bhopal	454	3,217	3,671	1,243	7,842	9,085	9.48%
10	Gwalior	118	4,132	4,250	230	8,315	8,545	7.23%

According to the IRC standard, the design of dual two-lane carriageway roads should be based on 75 per cent of the numbers of commercial vehicles in each direction. Therefore, the design traffic volume recalculated as shown in Table 4-7.

Table 4-7 Design Traffic Volume

No.	Bypass	Year 2002		Total (A)	Design Traffic (B:75% of A)	Directional Traffic (C)
		Bus	Truck			
1	Bareilly	739	2,764	3,503	2,627	1,314
2	Patna	762	4,458	5,220	3,915	1,958
3	Keonjhar	18	501	519	389	195
4	Balugaon	46	764	810	608	304
5	Vijayawada	638	3,781	4,419	3,314	1,657
6	Kannur	436	1,628	2,064	1,548	774
7	Nandura	312	3,881	4,193	3,145	1,572
8	Khamgaon	250	4,929	5,179	3,884	1,942
9	Bhopal	454	3,217	3,671	2,753	1,377
10	Gwalior	118	4,132	4,250	3,188	1,594

According to the IRC standard, 3.00 was assigned as the tentative VDF value. On the basis of the traffic projection and the vehicle damage factor, tentative cumulative equivalent standard Axle Loads in Millions (MSAL) for each bypass were calculated in as shown in Table 4-8.

Table 4-8 Million Equivalent Standard Axle Loads (MSAL)

No.	Bypass	Directional Traffic (C)	Growth Rate(%/yr)	Design Life	VDF	MSAL
1	Bareilly	1,314	22.84%	10	3.00	43
2	Patna	1,958	14.47%	10	3.00	42
3	Keonjhar	195	13.91%	10	3.00	4
4	Balugaon	304	29.67%	10	3.00	14
5	Vijayawada	1,657	21.69%	10	3.00	51
6	Kannur	774	19.71%	10	3.00	22
7	Nandura	1,572	17.11%	10	3.00	39
8	Khamgaon	1,942	15.80%	10	3.00	45
9	Bhopal	1,377	20.77%	10	3.00	41
10	Gwalior	1,594	18.28%	10	3.00	42

The design MSAL value was determined as 50 for the pre-feasibility study.

4.3.4 Composition of the Pavement

Table 4-9 shows the revised IRC table in 1993.

Table 4-9 Revised IRC Table in 1993

Cumulative Standard Axles Million (MSAL)	Thickness of Component Layers		
	Surfacing (X)	Base (Y)	Sub-base (Z)
30-50	40 AC + 130 DBM = 170	300	(T-470) Minimum Thickness 300
50-75	40 AC + 150 DBM = 190	300	(T-490) Minimum Thickness 300
75-100	40 AC + 160 DBM = 200	300	(T-500) Minimum Thickness 300

Based on the design MSAL, the total depth of the pavement to be applied was determined as 790 mm with the composition shown in Table 4-10.

Table 4-10 Pavement Composition

No.	Depth (mm)	Acc. Depth (mm)	Sign	Description
1	40	40	AC	Asphalt Concrete
2	150	190	DBM	Dense Bituminous
3	300	490	WMM	Wet Mix Macadam
4	300	790	GSB	Granular Sub-Base

4.4 Design Standard and Criteria of Structures

4.4.1 Concept and Methodology of Structure Design

The objective of structural planning is to estimate the required cost for structures of each bypass.

The procedure of structural planning is as follows:

i) Establish design standard and criteria

ii) Identify the existing facilities which cross the proposed bypass

iii) Assign the required clearance for classified facilities

iv) Plan of the structure for classified facilities

The existing facilities were classified in three main categories, "Road", "Railway", and "Water Channel". Then the "Typical Structure" was designed for each categorised facility, and quantities were estimated.

Structural design was conducted considering domestic conditions of construction, current site conditions, and both of Japanese and Indian specification for road bridge.

4.4.2 Basic Concept of Design Standard and Criteria

4.4.2.1 General

- Standard type structures in India are generally applied in the Project.
- Considering the procurement, values defined in Indian specification were employed for features and allowable strength of materials.
- Regarding natural conditions like hydrology and seismic force, Indian specifications were applied.

4.4.2.2 Design Standard Applied

Design standard applied in this phase is shown from Table 4-11 to Table 4-13 below.

Table 4-11 Design Standard (References)

References		Authority
Japanese Specification	- Specification for Highway Bridge (JRA) - JIS A5313 & JIS A5319 for Pre-cast Concrete Girder	Japan Road Association
Indian Specification	- IRC:5-1985 Standard Specifications and Code of Practice for Road Bridge(Section-I, General Features of Design) - IRC:6-1966 Standard Specifications and Code of Practice for Road Bridge(Section-II, Loads and Stresses) - IRC:78-1983 Standard Specification and Code of Practice for Road Bridges(Section-VII, Foundation and Substructure) - IRC:54-1974 Lateral and Vertical Clearances at Underpasses for Vehicle Traffic - IRC:73-1980 Geometric Design Standards for Rural (Non-Urban) Highways - IRC:3-1983 Dimensions and Weights of Road Design Vehicle - IRC Special Publication No.13 Guideline for the Design of Small Bridges and Culverts	Indian Road Congress
	- Pocketbook for Bridge Engineers (Published by IRC, 1995) - Standard Plans for Highway Bridges (R.C.C. T-beam and slab Superstructure) - Standard Plans for Highway Bridges (Pre stressed Concrete beams & R.C.C. slab type Superstructure) - Addendum to Ministry's Technical Circulars and Directives on National Highways and Centrally Sponsored Road & Bridge Projects, August 1988 to December 1992	Ministry of Surface Transport (Road Wing)

Table 4-12 Design Standard (Loads & Forces)

Items	Description	Reference & Remarks
(1)Combination of Loads and Forces	Combination is defined with considering IRC & JSHB	IRC:6-1966, Clause 202.3 IRC:78-1983,Clause 706.2.1 JSHB: I, Clause 2.2
(2)Dead Load	Unit Weight described in Indian Standard is applied	IRC:6-1966, Clause 205
(3)Live Load	- Japanese B-type live load - Indian Class AA tracked and wheeled vehicle - Indian Class A train of vehicles - Indian Class 70R tracked and wheeled vehicle	JSHB: I, Clause 2.1.3 IRC:6-1966, Clause 207
(4)Impact	Assign adequate force with reference to Live Load	JSHB:I, Clause 2.1.4 IRC:6-1966, Clause 211
(5)Earth Pressure	Japanese method (based on Coulomb's theory) is applied to estimate. * Including live load surcharge	JSHB: I, Clause 2.1.7 IRC:6-1966, Clause 217
(6)Earthquake (Seismic Force)	Indian Standard is applied	IRC:6-1966, Clause 222
(7)Buoyancy	Considered	JSHB: I, Clause 2.1.8 IRC:6-1966, Clause 216

Notes: IRC: Specification or Publication of Indian Road Congress
JSHB: Japanese Specification for Highway Bridge

Table 4-13 Design Standard (Materials)

Items	Description	Reference & Remarks
(2)Concrete (RC) (PC)	Indian Standard is applied. Adoption of controlled concrete having 28days works cube strength of 200kg/cm^2 (M20 or higher quality required)	IRC:21-1987, Clause 302.6 IRC:18-1985, Clause 4&7 PB, Clause 4.11.9.1
(3)Reinforcement Bar	Indian Standard is applied. Mild steel bars having a permissible tensile stress of 1,250kg/cm2 and deformed bars having a permissible tensile stress of 1,900kg/cm2 have been adopted (S240 for Mild steel bar) (S415 for Deformed bar)	IRC:21-1987, Clause 302 PB, Clause 4.11.9.1
(4)PC Strand	Indian Standard is applied.	IRC:21-1987, Clause 8

Notes: IRC: Specification or Publication of Indian Road Congress
JSHB: Japanese Specification for Highway Bridge
PB: Pocketbook for Bridge Engineer (IRC & MOST)

4.4.2.3 Design Method

"Allowable stress design method" was applied to the project, as that both Japanese and Indian standard employ it as common structure analysis method.

Table 4-14 shows permissible increase in stresses for each combination of loads and forces in IRC, and this percentage is totally same with those defined in Japanese Specifications of Highway Bridges:

Table 4-14 Permissible Increase in Stresses (Criteria: IRC Specification)

Combination of Loads and Forces	Case - I	Case - II	Reference
Permissible Increase in Stresses	Nil	50%	IRC:6-1966, Clause 203

Note: Case-I Dead Load + Live Load + Impact + Earth Pressure (+ Buoyancy)
Case-II Dead Load + Earth Pressure + Seismic Force (+ Buoyancy)

4.4.2.4 Typical Cross Section of Throughway

Three types of cross section were planned, the first is for earthwork section, the second is for the structure shorter than 100m (Bridge Section; Type- I), and the third is for the structure longer than 100m (Bridge Section; Type- II).

(1) Earthwork Section

Typical cross section of earthwork section is shown in Figure 4-1.

(2) Bridge Section (Type - I)

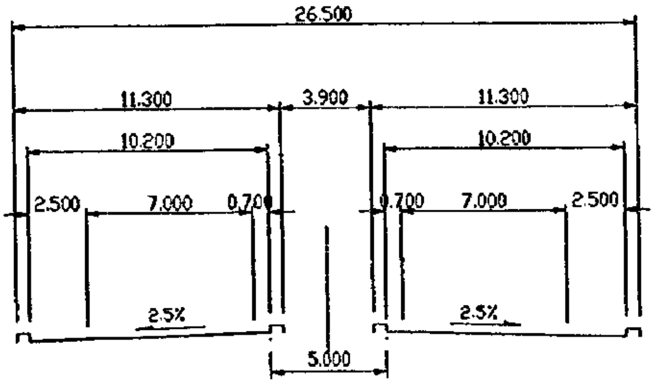


Figure 4-3 Cross section of Bridge / Viaduct, Type I (Length < 100m)

(3) Bridge Section (Type - II)

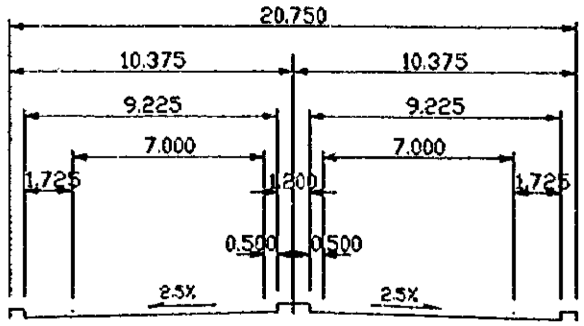


Figure 4-4 Cross section of Bridge / Viaduct, Type II (Length ≧ 100m)

4.4.2.5 Required Clearance

(1) Road

Non-urban road is classified in IRC:73-1980, and required clearance of each classified road is defined in IRC:54-1974.

Table 4-15 Required Clearance of Road

Classification	Lateral Clearance (m)	Vertical Clearance (m)	Reference
National and State Highway	12.0	5.0	IRC:73-1980 IRC:54-1974
Major and Other District Road	9.0	5.0	
Village Road	7.5	5.0	

(2) Railway

Required clearance of railway was discussed and confirmed by Ministry of Railway, and shown in the following table:

Table 4-16 Required Clearance of Railway

Classification	Lateral Clearance (m)	Vertical Clearance (m)	
Broad Gauge 1track	4.720	Electrified	5.870
		Non-Electrified	5.030
Broad Gauge 2track	9.445	Electrified	5.870
		Non-Electrified	5.030
Broad Gauge 3track	14.170	Electrified	5.870
		Non-Electrified	5.030
Broad Gauge 4track	18.895	Electrified	5.870
		Non-Electrified	5.030
Meter Gauge 1track	4.270	Non-Electrified	3.810
Meter Gauge 2track	7.470	Non-Electrified	3.810

(3) Water Channel

Required vertical clearance of water channel is defined above highest flood level (H.F.L.) with afflux, and in IRC5-1985, Clause 106:

Table 4-17 Required Clearance of Water Channel

Discharge (m^3/sec)	Minimum vertical clearance (mm)
Upto 0.3	150
Above 0.3 and upto 3	450
Above 3 and upto 30	600
Above 30 and upto 300	900
Above 300 and upto 3,000	1,200
Above 3,000	1,500

Note: About other required vertical clearance, no part of metallic bearing shall be at a height less than 500mm above the design H.F.L. taking into account the afflux.

4.4.2.6 Design Condition of Substructure

(1) Earth Covering above Footing

Earth covering above footing is classified by crossing facilities.

a) Road and Railway

For viaduct over Road or Railway, minimum earth covering is defined as 1.0m from existing ground level.

b) Water Channel

Top of footings of bridge over Water Channel, is defined to be placed below maximum depth of scour (hereafter, M.D.S.).

M.D.S. is the depth below highest flood level upto the estimated scoured river bed level. Estimate method to estimate M.D.S. is described in clause 104. ~ 110 of IRC:5-1985, and in this phase, assumed M.D.S. was applied for each classified Water Channel.

(2) Required Offset of Abutment

Required offset of abutment is also classified by crossing facilities.

a) Road

In principle, abutment must setback from required lateral clearance, and, in addition, taking into account the allowance of 0.5m for the guard rail installation in front of abutment, the required offset from edge of carriageway was decided 3.0m.

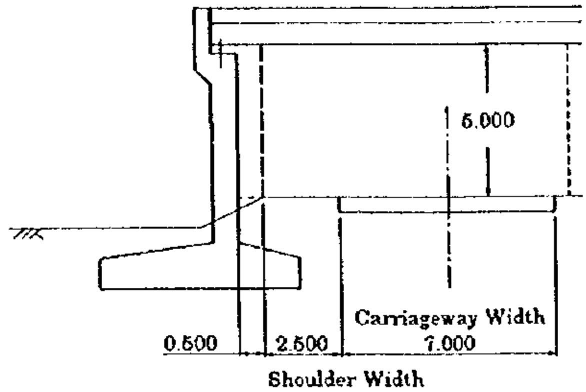


Figure 4-5 Required Offset of Abutment from Edge of Carriageway (National & State Highway)

b) Railway

Required offset of abutment was estimated as 2.5m considering the following as shown in Figure 4-6.

- not to affect the ballast during the excavation works
- not to place the footing of substructure under ballast
- keep the required lateral clearance of railway

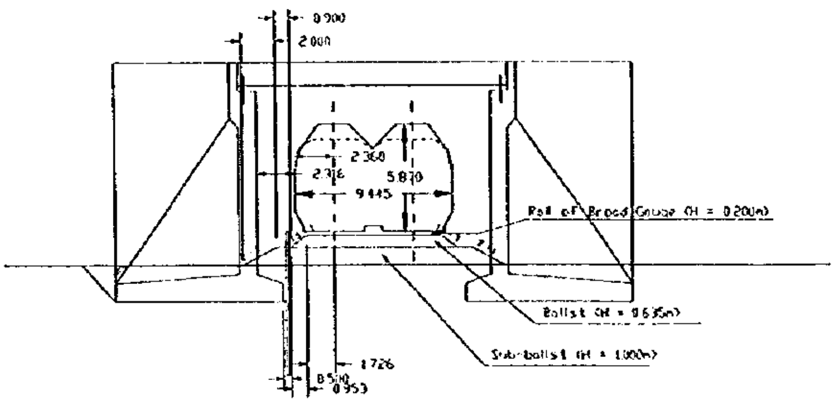


Figure 4-6 Required Offset of Abutment from Railway Clearance

c) Water Channel

Required offset of abutment for the bridge over river is defined as corresponding to the maximum depth of scour and cross section of water channel at crossing point. In this phase, abutment wall is desirable to keep away from inside of embankments not to obstruct water flow.

4.4.2.7 Design Condition of Foundations

(1) General

Geological characteristics and the depth of bearing strata of each site was assessed by site condition, and foundation type was classified by the depth of bearing strata.

Applicable types of foundation is in the following Table 4-18:

Table 4-18 Applicable types of Foundation

Type	Depth of Bearing Strata
Spread Foundation	Depth less than 5.0m
Well Foundation	Depth 5.0m to 10.0m
Pile Foundation	Depth more than 10.0m

Spread Foundation was applied to the depth is less than 5.0m from ground level, and well foundation is to more than 5.0m, but less than 10.0m. Cast-in-situ Pile (Dia.1,000mm) is applied to the depth is more than 10.0m, and it is to be friction pile in the case bearing strata is deeper than 25.0m.

4.4.2.8 Design Condition of Culverts

(1) Earth Covering

Minimum required earth covering above top slab was defined as 50cm. This is because subsliding of back-filling earth might harm smooth traffic if earth covering above culvert is less.

4.4.3 Classification of Crossing Facilities

4.4.3.1 General

Facilities which cross the proposed bypass are classified into three main categories, i) Road, ii) Railway, and iii) Water Channel.

Identification of facilities were carried out by utilising topographic map of 1:50,000 published by Survey of India.

Clarification and classification were conducted based on the collected information through the site reconnaissance. Obtained data from the State PWD Staff also contributed to clarify the present condition and possible future scheme of major facilities.

Summary of the classification is shown in the following table.

4.4.3.2 Road

Table 4-19 Classification of Road

Legend on Topo-Map	Comment	Remarks	Class in Project
①	ROAD:METALLED	• Road open to vehicle passage. • Continuous line indicates paved road, and broken line non-paved • Larger width between two lines indicates a more important road.	Road-HW
①	ROAD:UNMETALLED		Road-HW
②	ROAD:METALLED		Road-DR
②	ROAD:UNMETALLED		Road-DR
③	ROAD:METALLED		Road-VR
③	ROAD:UNMETALLED		Road-VR
④	CART TRACK	• Track or path which is availabe to passage of carriage	Road-CT
⑤	PACK TRACK	• Track or path which is availabe to passage of cattle	Road-PT
⑥	FOOT PATH	• Track or path which is availabe to passage of pedestrian	Road-FP

Road in Rural Area is categorised into 3 classes in IRC:73-1980, i.e., 1)National and State Highway, 2)Major and Other District Road, and 3)Village Road. Required clearance for each classified road is defined in IRC: 54-1974.

4.4.3.3 Railway

Table 4-20 Classification of Railway

Legend	Comment	Remarks	Class in Project
①	BROAD GAUGE DOUBLE TRACK	Railway which has broad gauge, double track	*need to certify scheme of each railway which crosses bypass
②	BROAD GAUGE SINGLE TRACK	Railway which has broad gauge, single track	
③	OTHER GAUGE DOUBLE TRACK	Railway which has narrow gauge or meter gauge, double track	
④	OTHER GAUGE SINGLE TRACK	Railway which has narrow gauge or meter gauge, single track	

Following information was provided from Ministry of Railway in India:

- Major railways currently with broad gauge will be multiplied track in their future scheme, and
- All railways currently with narrow and metre gauge will be upgraded to single broad gauge in their future scheme.

4.4.3.4 Water Channel

Table 4-21 Classification of Water Channel

Legend		Comment	Remarks	Class in Project
①		River bank	River which flows perennially	Water Channel RV-1
②		River bank	River which flows non-perennially (no stream in dry season)	Water Channel RV-2
③		River bank	River which flows perennially	Water Channel RV-3
④		River bank	River which flows non-perennially (no stream in dry season)	Water Channel RV-4
⑤		Single-line stream (Large)	Stream which flows perennially	Water Channel S-1
⑥		Single-line stream (Large)	Stream which flows non-perennially (no stream in dry season)	Water Channel S-2
⑦		Single-line stream (Small)	Stream which flows perennially	Water Channel S-3
⑧		Single-line stream (Small)	Stream which flows non-perennially (no stream in dry season)	Water Channel S-4

Rivers are classified into 4 classes, based on their width and their being perennial or non-perennial. "Perennial" means flowing through the year, and "non-perennial" means there is no flow in the dry season.

RV-1 & RV-2 represent Large Rivers having width more than 100m. RV-1 is perennial, and RV-2 is non-perennial.

Only Sone River in Patna Bypass was classified as the categories, RV-1. According to the State PWD, a new bridge design, which was proposed to construct at the downstream of the existing one, was once prepared. This previous design gives the design discharge, design flood level, and geological data. These design output were fully utilised for the establishment of the structural planning of this Study. Details of Sone River Bridge was presented in next chapter 5, "Preliminary Design of the Bypasses".

RV-3 & RV-4 represent Medium Rivers having width more than 20m, but less than 100m. RV-3 is perennial, and RV-4 is non-perennial. Most of canals belong to this classification.

Single-line stream has various scales of channel width, depth of waterbed, height of embankment. They are classified according to their width and catchment area.

S-1 & S-2 are large size streams. S-1 is perennial, and S-2 is non-perennial.

S-3 & S-4 are narrow size streams. S-3 is perennial, and S-4 is non-perennial.

4.4.4 Required Clearance

Clearance of individual classified facility was summarised below:

4.4.4.1 Road

Table 4-22 Required Clearance of Classified Road

<table>
<tr><th colspan="5">Classification & Clearance of Project</th><th colspan="3">Classification of IRC:73-1980 & 54-1974</th><th rowspan="2">Remarks</th></tr>
<tr><th>Class in Project</th><th colspan="2">Lateral Clearance</th><th colspan="2">Vertical Clearance</th><th>Classification</th><th>Lateral Clearance</th><th>Vertical Clearance</th></tr>
<tr><td rowspan="2">Road-HW</td><td colspan="2" rowspan="2">12.0 m</td><td colspan="2" rowspan="2">5.0 m</td><td>National Highway & State Highway</td><td>12.0 m</td><td>5.0 m</td><td rowspan="2">Same as IRC</td></tr>
<tr><td></td><td>12.0 m</td><td>5.0 m</td></tr>
<tr><td rowspan="2">Road-DR</td><td colspan="2" rowspan="2">9.0 m</td><td colspan="2" rowspan="2">5.0 m</td><td>Major District Road & Other District</td><td>9.0 m</td><td>5.0 m</td><td rowspan="2">″</td></tr>
<tr><td></td><td>9.0 m</td><td>5.0 m</td></tr>
<tr><td rowspan="2">Road-VR</td><td rowspan="2">*1
7.5 m</td><td rowspan="2">*2
4.0 m</td><td rowspan="2">*3
5.0 m</td><td rowspan="2">*4
3.5 m</td><td>Village Road</td><td>7.5 m</td><td>5.0 m</td><td rowspan="5">Defined with considering Present Condition</td></tr>
<tr><td></td><td>7.5 m</td><td>5.0 m</td></tr>
<tr><td>Road - CT</td><td colspan="2" rowspan="3">2.5 m</td><td colspan="2" rowspan="3">2.5 m</td><td colspan="3">Not Defined</td></tr>
<tr><td>Road - PT</td><td colspan="3">Not Defined</td></tr>
<tr><td>Road - FP</td><td colspan="3">Not Defined</td></tr>
</table>

*Minimum Lateral Clearance = Roadway Width IRC:73-1980
*Vertical Clearance in Rural Area = 5.0m IRC:54-1974
*1 (Road-VR) : Individual Road which has possibility of upgrading in future
*2 (Road-VR) : Individual Road which does not have possibility of upgrading in future

"Road - HW" and "Road - DR" are recognised as major road categories, (detailed description is in IRC:73-1980). Required clearances for these are defined to have the same figures as the IRC specification.

When the cross-angle is skewed, longitudinal distance was applied as the required lateral clearance for the design purpose.

The longitudinal distance was estimated by the following equation:

Required Lateral Clearance

= Lateral Clearance / sin 45digree = 1.41 x Lateral Clearance

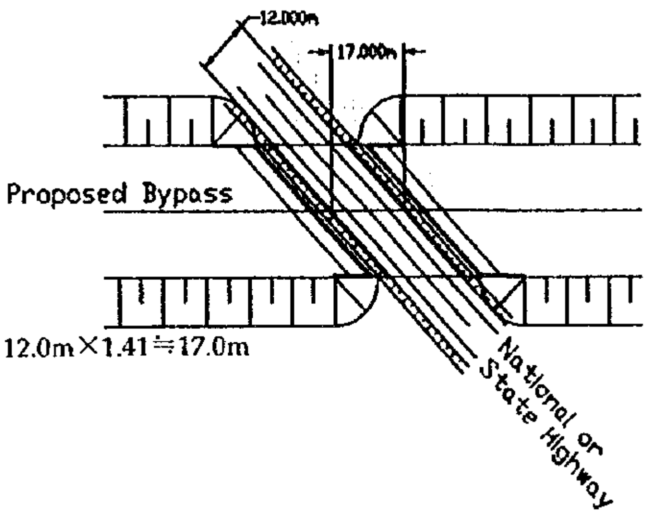


Figure 4-7 Lateral Clearance of Highway with skew

From the viewpoint of cost savings, the reduced clearance for "Road - VR" was proposed by the Study Team and approved by the MOST, as the clearance of exceptional case. Reduced clearance was applied to the crossing village road when it has no future scheme of upgrading broadly.

Table 4-23 Two types of Clearance for Road - VR

	Lateral Clearance	Vertical Clearance	Remarks
Typical	7.5m	5.0m	Same as IRC:54-1974
Exceptional	4.0m	3.5m	

"Road - CT", "Road - PT", and "Road - FP" are generally not supposed to cater the vehicle traffic. Its clearance is not defined in the IRC specification.

Judging from the finding from the site reconnaissance, lateral and vertical clearance in this project were proposed as 2.5m, respectively.

4.4.4.2 Railway

The lateral and vertical clearance for the railways are specified by Ministry of Railways as summarised in the following table.

Table 4-24 Lateral and Vertical Clearance for Railway

Classification of Ministry of Railways				Classification And Clearance in project				Remarks
Condition	Lateral Clearance	Vertical Clearance (categorised by Traction)		Condition	Lateral Clearance	Vertical Clearance		
Broad Gauge Double Track	9.445 m	Electrified	5.870 m	Broad Gauge 2track	9.445 m	Electrified	5.870 m	
		Non-Electrified	5.030 m			Non-Electrified	5.030 m	
Broad Gauge Single Track	4.720 m	Electrified	5.870 m	Broad Gauge 3track	14.170 m	Electrified	5.870 m	
		Non-Electrified	5.030 m			Non-Electrified	5.030 m	
Meter Gauge Double Track	7.470 m	Non-Electrified	3.610 m	Broad Gauge 4track	18.895 m	Electrified	5.870 m	
Meter Gauge Single Track	4.270 m					Non-Electrified	5.030 m	

Summary of present conditions and scheme of individual railway lines which cross the bypass is shown in the Table 4-25.

Table 4-25 Present Condition and Scheme of individual Railways

Proposed Bypass Which Has Railway crossing	Present Condition	Scheme of Ministry of Railways & classification in Project	Lateral Clearance	Vertical Clearance	Remarks
Bareilly Bypass	Meter Gauge 2track, Non-Electrified	Broad Gauge 2track, Non-Electrified	9.445 m	5.030 m	• To consider Clearance, Height of Ballast is needed to considered, and to be added to clearance shown on this table
Vijayawada Bypass	Broad Gauge 2track, Electrified	Broad Gauge 4track, Electrified	18.895 m	5.870 m	
Kannur Bypass	Broad Gauge 2track, Non-Electrified	Broad Gauge 3track, Electrified	14.170 m	5.870 m	
Bhopal Bypass	Broad Gauge 2track, Non-Electrified	Broad Gauge 4track, Electrified	18.895 m	5.870 m	
Gwalior Bypass	Narrow Gauge 1track, Non-Electrified	Broad Gauge 2track, Non-Electrified	9.445 m	5.030 m	

4.4.4.3 Water Channel

Table 4-26 Width and Vertical Clearance for Water Channel

Classification & Clearance of Project				Remarks
Class in Project	Comment	Waterway Width	Vertical Clearance	
Water Channel RV-1	River bank(perennial, large)	Each River Width	Defined for Each River	Defined each channel by site-Survey Result & Topo Map
Water Channel RV-2	River bank (non-perennial, large)			As above
Water Channel RV-3	River bank(perennial, medium)		0.60m from Highest Flood Level	As above
Water Channel RV-4	River bank (non-perennial, medium)			As above
Water Channel S-1	Single-line stream (perennial, wide)	20 m	-	Defined by site-survey Result
Water Channel S-2	Single-line stream (non-perennial, wide)			As above
Water Channel S-3	Single-line stream (perennial, narrow)	5 m	-	As above
Water Channel S-4	Single-line stream (non-perennial, narrow)			As above

Waterway width and vertical clearance of Water Channel RV-1 & RV-2 were determined based on site survey, information from PWD, and prevision survey data, if available.

Freeboard (vertical clearance) of 60cm, above the design flood level, was proposed for these Water Channel RV-3 & RV-4.

For Water Channel S-1, S-2, S-3, and S-4, the average waterway width and depth were estimated based on the site survey results as shown in Table 4-26.

4.4.5 Applicable Structure Types

4.4.5.1 Span Arrangement of Structures

Applicable type of superstructure and culvert was defined considering the recommended superstructure type of India and Japan which depend on the span length.

Table 4-27 Applicable Types for Span Length

Effective Span Length (m)	Applicable Structure Types
1m ~ 5m	Culvert - Box
6m ~ 10m	RC - Slab
11m ~ 19m	RC - T beam
15m ~ 25m	PC - Hollow Slab (Post - tension, site product)
25m ~ 45m	PC - I beam (Post - tension, site product)

The advantage of PC - Hollow Slab is its low height of beam, and short construction period. This type was applied to the specific crossing facilities where the lower finishing level of the proposed bypass, or where the shorter construction period is required.

4.4.5.2 Superstructures

Individual superstructure was designed one by one for each location where the viaduct or bridge is required. The total bridge length is rounded off by 1m.

4.4.5.3 Substructures

Applicable types of substructure was decided depending upon the height as listed below:

Table 4-28 Applicable Types of Substructure

Type		Applicable Height (m)
Abutment	Inverted T - Type	Upto 15m
	Buttressed Type	Above 15m
Pier	Wall Type	Above 5m and upto 30m

4.4.5.4 Foundations

Table 4-29 shows the applicable types of foundation.

Table 4-29 Applicable Types of Foundation

Type	Depth of Bearing Strata (m)
Spread Foundation	Depth less than 5.0m
Well Foundation (open caisson)	Depth 5.0m to 10.0m
Pile Foundation (cast-in-situ, Diameter = 1,000mm)	Depth more than 10.0m

Note: In case bearing strata is deeper than 25.0m from existing ground level, pile is to be friction pile.

With reference of IRC:78-1983, foundation placed in waterway must be deep type foundation, and pile foundation is prohibited to apply because of its unreliablity against scour. In those cases, well foundation was applied in this study.

4.4.5.5 Culverts

Culverts were designed for road and water channel, taking into account the required lateral/vertical clearance.

4.4.6 Application of Structures

4.4.6.1 Applicable Structures for Classified Crossing Facilities

Application of structures for the proposed bypasses are summarised in Table 4-30, Table 4-31, and Table 4-32.

Table 4-30 Classification of Applicable Structures (Roads)

Crossing Facility	Structure	Composition
Road-HW	Road Over Bridge	Superstructure: RC - T beam (2@13.0=26.0m) (2@19.0=38.0m) - skewed Substructure: Inverse T - Type Abutment (H=10.0m), Wall Type Pier (H=8.0m) Foundation: Individually Designed
Road-DR	Road Over Bridge	Superstructure: RC - T beam (1@11.0=11.0m) (1@17.0=17.0m) - skewed Substructure: Inverse T - Type Abutment (H=10.0m) Foundation: Individually Designed
	Crossing Over Bridge	Superstructure: RC - T beam (2@17.0=34.0m,W=8.0m) Substructure: Inverse T - Type Abutment (H=10.0m) Wall Type Pier (H=8.0m) Foundation: Individually Designed
Road-VR	Culvert - Box	Internal width: 4.0m Internal height: 3.5m
	Crossing Over Bridge	Superstructure: RC - T beam (2@17.0=34.0m,W=4.0m) Substructure: Inverse T - Type Abutment (H=10.0m) Wall Type Pier (H=8.0m) Foundation: Individually Designed
Road-CT,PT,&FP	Culvert - Box	Internal width: 2.5m Internal height: 2.5m

Table 4-31 Classification of Applicable Structures (Railways)

Crossing Facility	Structure	Composition
Railway 2track	Railway Over Bridge	Superstructure: PC - Hollow (1@16.0=16.0m) (1@25.0=25.0m) - skewed Substructure: Buttressed Type Abutment (H=15.0m) Foundation: Individually Designed
Railway 3track	Railway Over Bridge	Superstructure: PC - Hollow (1@20.0=20.0m) PC - I beam (1@28.0=28.0m) - skewed Substructure: Buttressed Type Abutment (H=15.0m) Foundation: Individually Designed
Railway 4track	Railway Over Bridge	Superstructure: PC - Hollow (1@25.0=25.0m) PC - I beam (1@36.0=36.0m) - skewed Substructure: Buttressed Type Abutment (H=15.0m) Foundation: Individually Designed

Table 4-32 Classification of Applicable Structures (Water Channels)

Crossing Facility	Structure	Composition
Water Channel RV-3&4	Bridge	Superstructure: RC - T beam (2@15.0=30.0m) ~ (4@15.0=60.0m) * Number of Span was designed individually. Substructure: Inverse T - Type Abutment (H=7.0m) Foundation: Individually Designed
Water Channel S-1&2	Culvert - Box	Internal width: 2.5m Number of Cell: 3 Internal height: 2.5m
Water Channel S-3&4	Culvert - Pipe	Diameter: 1.0m Number of Pipe: 2

4.4.6.2 Individually Designed Structures

For combination of multiple crossing facilities, applicable structure was individually designed at each point.

Individual design was also attempted for the structure which design condition was not defined with the feature of its crossing facilities.

Individually designed structures are described in next chapter, and they are shown in Table 4-33.

Table 4-33 Individually Designed Structures

Type of Structure	Applied Bypass	Crossing Facilities
1.Over Bridge (PC Hollow,22.0+25.0+22.0=69.0m)	Bareilly Bypass	State Highway - 37 Railway
2.Bridge over Sone River (PC Extra-dosed Bridge) (98.70+8@148.05+98.70=1,381.80m)	Patna Bypass	Sone River
3.Over Bridge (PC - I beam, 9@45.0=405.0m)	Kannur Bypass	Village Road Railway

Pre-Feasibility Study

Chapter 5
Preliminary Design of the Bypasses

5. Preliminary Design of the Bypasses

5.1 Bareilly Bypass

5.1.1 General

The original alignment of Bareilly Bypass was drawn by State PWD in 1993. Subsequently, the MoST has approved the alignment. The JICA Study Team adopted the alignment in this Pre-Feasibility Study.

5.1.2 Major Controls

The district of Bareilly, although lying not far from the lower ranges of the Himalayas, is located in a gentle sloping plain. There are no topographical obstructions in the proposed alignment. However, the area of the proposed bypass route encounters some villages and local manufacturers of bricks. Airforce aerodrome is located in the north east of Bareilly city. The major control points were listed in Table 5-1.

Table 5-1 Major Controls of Bareilly Bypass

No.	Approx. Sta.	Description	Requirements
1	0+000	NH24	To secure smooth connection
2	5+100	Village(Pardhauli)	To be avoided
3	7+000	Village(Ata)	To be avoided
4	7+800	Deorania River	Bridge
5	9+080	SH37	Bridge
6	9+120	Railway	Bridge
7	13+720	SH33	Bridge
8	14+240	Nakatia River	Deorania River
9	15+500	Village(Mahoranian)	To be avoided
10	23+560	MDR	Bridge
11	25+000	Village(Chainpur)	To be avoided
12	31+100	NH24	To secure smooth connection

5.1.3 Proposed Alignment

The starting point of the bypass is Km. 235 of NH24, from where the proposed alignment takes an east bound direction. Around Sta. 5+100, on the north side of Pardhauli village, there is a gentle curve to the right. Thereafter, the alignment passes encountered Bibiapur village and Ata village in a straight line. A small river, the Deorania river, is before the bypass reaches SH37 crossing at the north of Belwa village.

A metre gauge railway runs parallel to SH37. The proposed alignment crosses over

SH37 and after crossing SH37, the Bypass passes the aerodrome and several villages in a straight alignment. At the crossing with SH33, a viaduct should be planned.

The alignment crosses Nakatia River at 500 m east from SH33. The river width at this location is narrow and well protected by high banks.

Subsequently, the alignment has a right curve at an angle of approximately 80 degrees, and after the curve, the alignment continues to the southern direction. The section from Major District Road to the ending point of NH24 is connected by a straight line. The ending point is Km. 259 on NH24. The proposed horizontal and vertical alignment was summarised in Tables 5-2 and 5-3.

Table 5-2 Summary of Horizontal Alignment

Design Element	Length (m)	Ratio (%)
Tangent	28,525.1	92
Curve	2,179.7	7
Spiral (Clothoide)	400.0	1
Total	31,104.8	100

Table 5-3 Summary of Vertical Alignment

Grade (%)	Length (m)	Ratio (%)
G <= 0.3	24,204.8	78
0.3< G <=1.0	3,000.0	10
1.0< G <=2.0	3,900.0	12
Total	31,104.8	100

5.1.4 Major Structures

(1) Major Structures

Major structures proposed were summarised in Table 5-4, including two viaducts for crossing SH37 and SH33, where interchanges will be allocated.

Table 5-4 Major Structures of Bareilly Bypass

No.	Approx. Sta.	Description	Type	Span Arrangement (m)
1	7+800	Deorania	RC-T	4@15=60
2	8+800	SH37	RC-T	2@13=26
3	9+080	Railway, SH37	PC-Hollow	4@16=64
4	13+720	SH33	RC-T	2@119=38
5	14+240	Nakatia	RC-T	4@15=60

Figure 5-1 indicates general view of throughway viaduct proposed at the point over SH-37(STA = 9+080) and railway(STA = 9+120).

(2) Summary of Structures

Table 5-5 summarises the proposed structures in the Bareilly Bypass. Total length of throughway bridges is 233 m and the total length of the Culvert-box is 1,031m.

Table 5-5 Summary of Structures in Bareilly Bypass

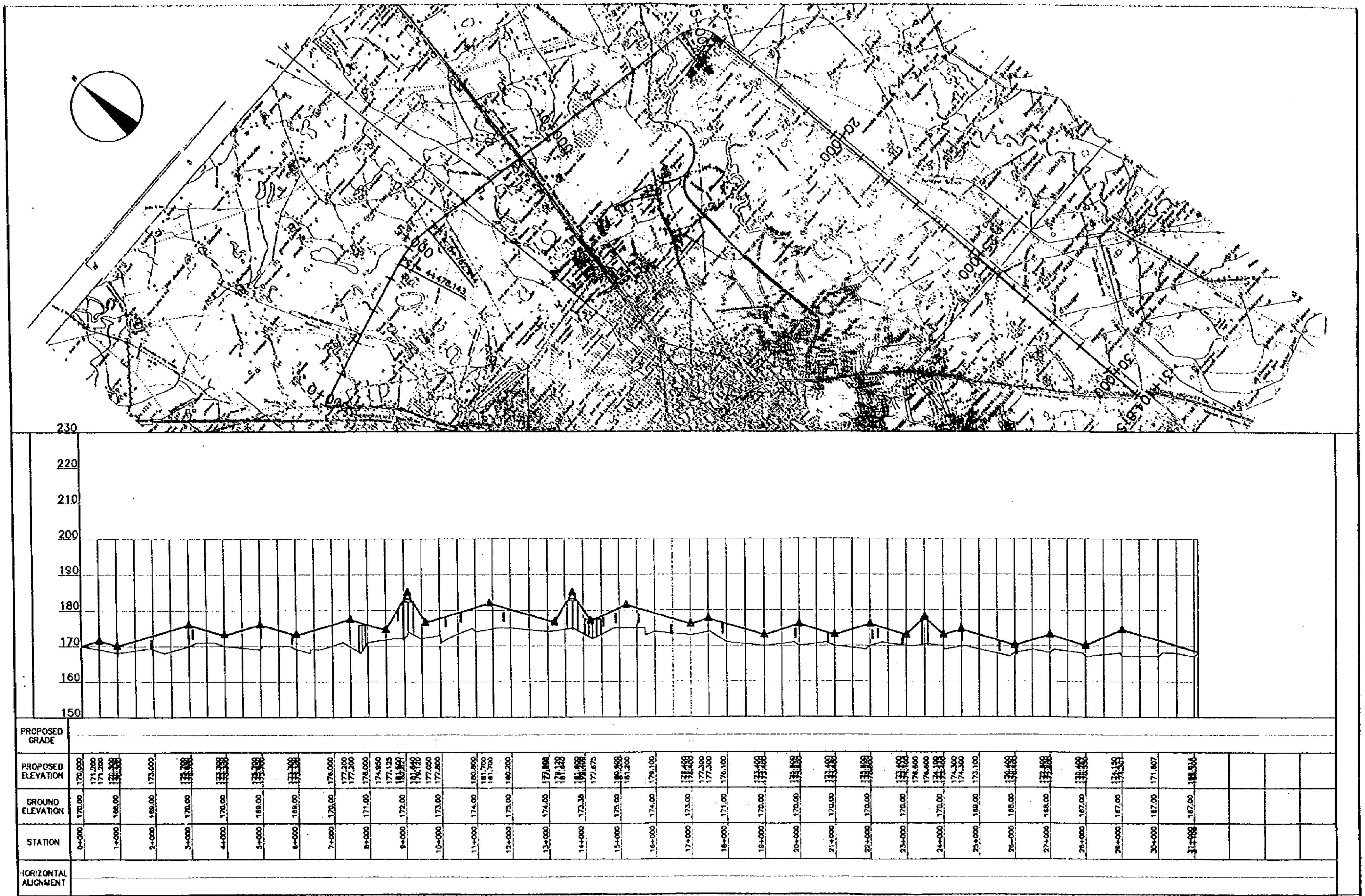
Type	Length (m)
Large Bridge (L>200m)	0
Medium&Short Bridge (200m>L)	233
Throughway Bridge Total	233
Culvert-box (L)	32
Culvert-box (S)	999
Culvert-box Total	1,031

5.1.5 Major Quantities

Major quantities of proposed bypass in the Pre-Feasibility Study was summarised in Table 5-6.

Table 5-6 Major Quantities of Bareilly Bypass

Item	Unit	Amount
Bypass Length	km	31.1
Earthwork Section	km	30.9
Structural Section	km	0.2
Earthwork Balance	m^3	-4,411,000
Fill	m^3	4,411,000
Cut	m^3	
Concrete	m^3	20,700
HYSD	ton	2,740
PC Strand	ton	24
Pavement		
AC	m^3	19,200
DBM	m^3	96,900
WMM	m^3	222,500
GSB	m^3	217,900



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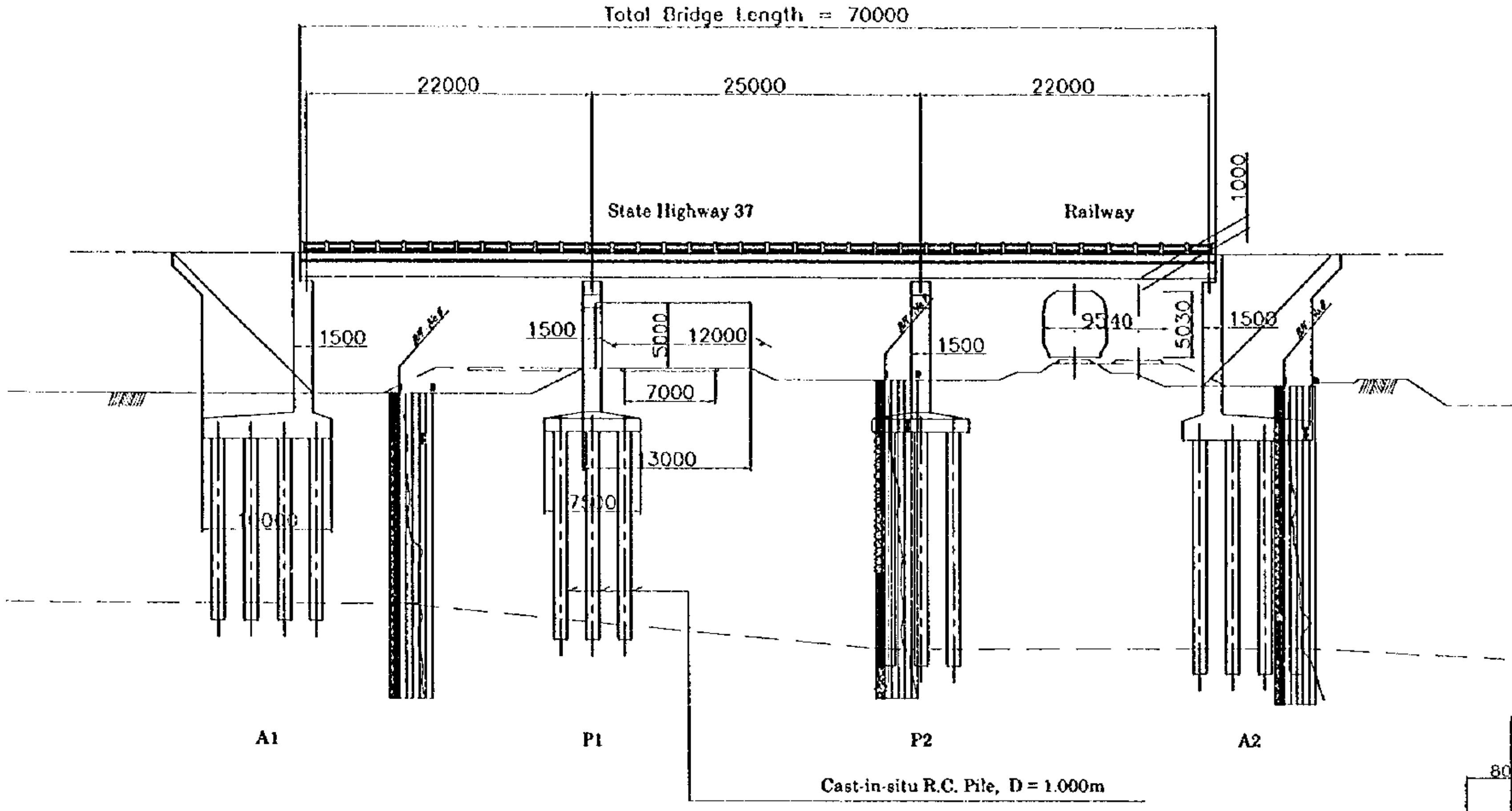
THE FEASIBILITY STUDY ON NATIONAL HIGHWAY BYPASSES IN INDIA

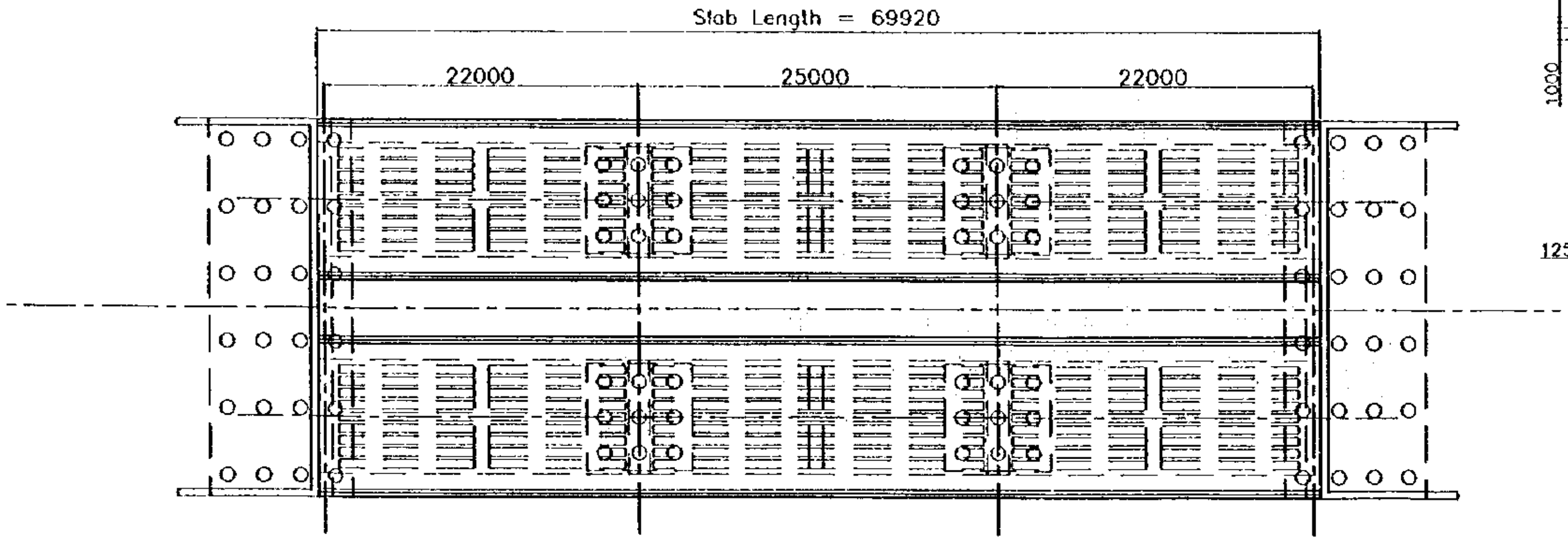
DWG TITLE : BAREILLY BYPASS: PLAN & PROFILE

DWG SCALE : H = 1 : 100,000 V = 1 : 1,000

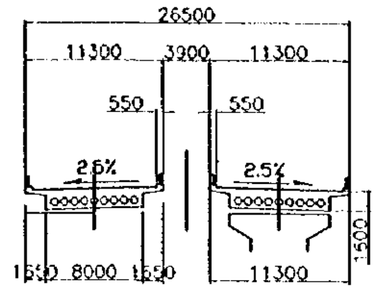
DWG NO. : 001



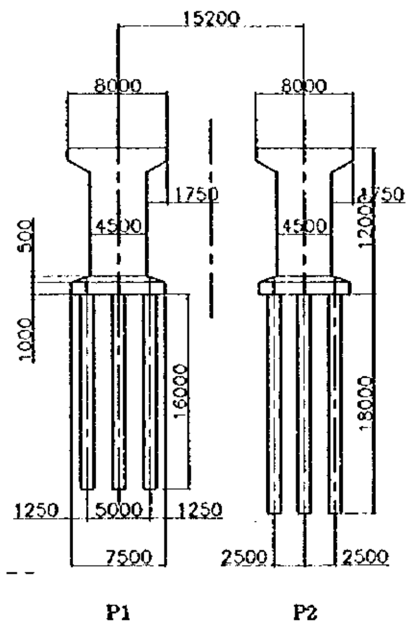
Side View Scale 1:600



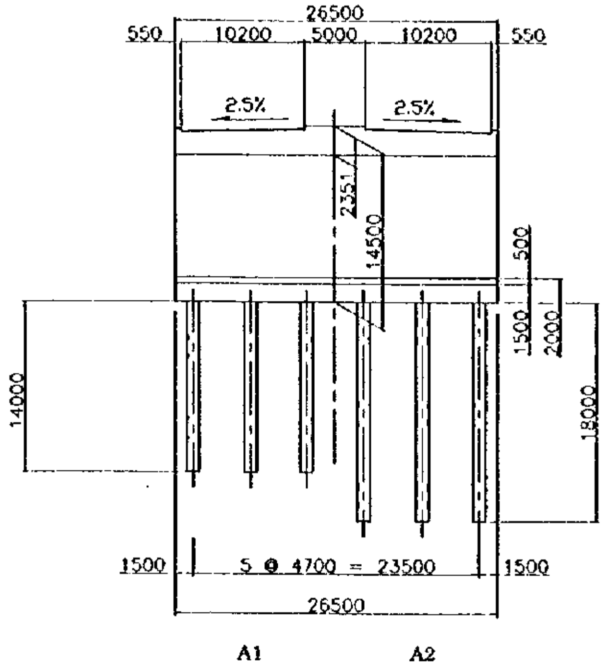
Plan Scale 1:600



Superstructure Cross Section Scale 1:600
(PC Hollow Slab 22.0 + 25.0 + 22.0 = 69.0m)



Pier Scale 1:600



Abutment Scale 1:600

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FIGURE 5-1 Over Bridge of Bareilly Bypass

5.2 Preliminary Design of Patna Bypass

5.2.1 General

Patna Bypass was originally proposed by State PWD to ease the traffic congestion of NH30 which traverses the main Arrah town, Danapur Military Cantoment Area and northern part of Patna town, since eastern part of the Patna Bypass has already been built for approximately 20 kms. as phase I & II.

Regarding remaining portion which is expected to connect Arrah and down south of Patna, say phase III, after several times of surveys/investigations, an alternative route report was submitted to MOST, and the south-most alternative route was approved by MOST in 1989. The route starts from Km. 116, Anet Junction, of NH 30 newly constructed at the southern fringe of the Arrah city area and passes nearly 4.5 kms upstream of the existing Sone Bridge at Koilwar and ends to Km 179, Chitcohra Junction, of NH30 in connection with the existing bypass. After approval of route by MOST, no further detailed survey/investigation work has done yet.

In the Pre-Feasibility Study, the approved route was reviewed and a project alignment was proposed by the Study Team, through discussions with MOST/PWD and site reconnaissance. The details of the proposed alignment was described below:

5.2.2 Major Controls

The project area locates on flood plain of both the Ganga and the Sone River. The project bypass starts at the elevation of 62 and ends at the elevation of 44, in distance of 50 kms approximately. The Highest Food Level of the Sone River was assumed as the elevation of 59 based on the flood record of the river. Roadside area, on the south of existing railway, is plain agricultural land, with sporadic hamlets here and there. Major control points along the project route was summarised in Table 5-7.

5.2.3 Proposed Alignment

As there are no serious and strict restriction along the route, the horizontal alignment was formulated with applying larger curves, which are not required any transitions and superelevations.

Table 5-7 Major Controls of Patna Bypass

No.	Approx. Sta.	Description	Requirements
1	0+000	NH30, Anet JC	To secure smooth connection
2	2+400	Ara Canal	Bridge
3	9+000	NH30	Bridge
4	12+700	Village(Bahiara)	To be avoided
5	13+000 14+350	Sone River	Bridge
6	15+000	Village(Bindaul)	To be avoided
7	23+450	MDR	Bridge
8	33+000	Village(Naubatpur)	To be avoided
9	36+100	Patna Canal	Bridge
10	43+000	Villages	To be avoided
11	49+839	NH30, Chitcohra JC	To secure smooth connection

Regarding vertical alignment, the grade and vertical curves were defined to clear the vertical controls, required from structural planning. As section between the beginning point (Sta. 0+000) and the Major District Road (Sta. 23+450) was assumed as a flood area, the finished level was designed higher than 60, which is one metre above the HFL. The project area has very flat topography, therefore minimum 0.3 % of longitudinal grade was applied to secure the drainage capacity. The proposed horizontal and vertical alignment was summarised in Tables 5-8 and 5-9.

Table 5-8 Summary of Horizontal Alignment

Design Element	Length (m)	Ratio (%)
Tangent	32,025.1	64
Curve	17,813.6	36
Spiral (Clothoide)	-----	
Total	49,838.7	100

Table 5-9 Summary of Vertical Alignment

Grade (%)	Length (m)	Ratio (%)
G = 0.3	33,638.7	67
0.3< G <=1.0	14,000.0	29
1.0< G <=2.0	1,800.0	4
Total	49,838.7	100

5.2.4 Major Structures

(1) The Sone Bridge

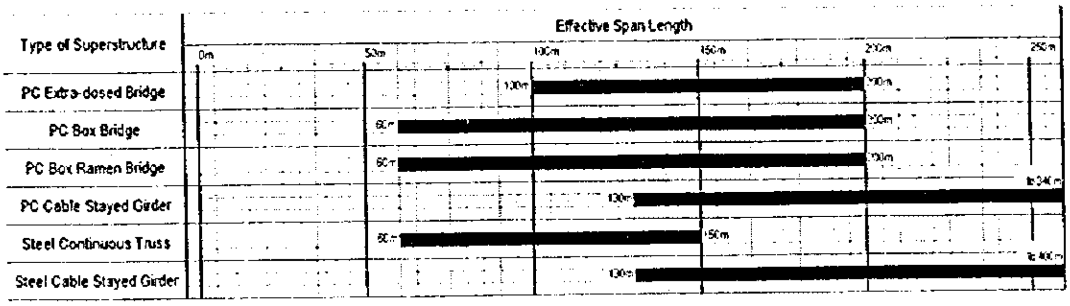
The State PWD had once prepared the new Sone River bridge design at the downstream of the existing bridge by their own feasibility study. Based on their study, Sone River has following characteristics:

River Width(in their planning site):	1,200m
Average River Flow:	36,600m³/sec
Highest Flood Level:	58.9m
Depth of Bearing Stratum:	30 m (below the riverbed)

Total length of proposed bridge was 1,381.800m(= 28 @ 49.350m) which is based on the multiple span length with the existing pier columns, according to the Indian regulation that the piers to be newly built nearby the existing, shall not disturb the river flow for the safety of the existing bridge.

Applicable types of Superstructure are shown in the following Table 5-10.

Table 5-10 Applicable Types of Superstructure for Effective Span Length



The Study Team proposed following two types as alternatives and comparison study was carried out:

Alternative-A: PC Extra-dosed Bridge

Alternative-B: PC Box Ramen Bridge

This is because PC superstructure is commonly planned and applied for the road bridge across large river in India.

Span arrangement of each alternative is defined with the following reason.

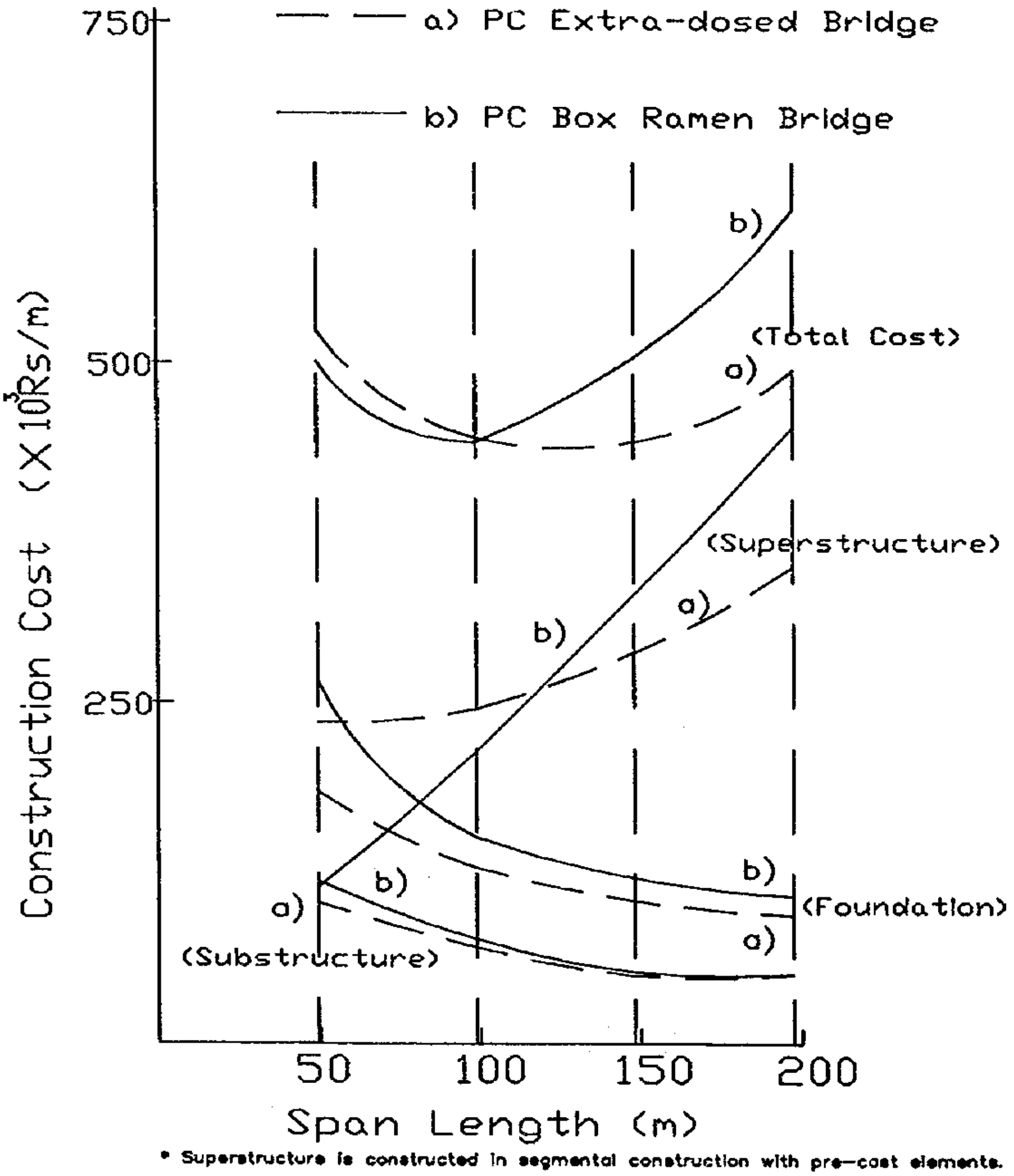
- span is to be multiple length of existing bridge (49.350m)
- most economical span arrangement for each bridge type is applied and that is decided with comparison of construction cost

The relations of cost and span arrangement of each type of bridge are shown in Figure 5-2, and defined span arrangement is in the following:

Alternative-A: PC Extra-dosed Bridge
(with span arrangement of 98.700m + 8 @ 148.050m + 98.700m = 1,381.800m)

Alternative-B: PC Box Ramen Bridge
(with span arrangement of 14 @ 98.700m = 1,381.800m)

Figure 5-3 shows the general side view and span arrangement of these two alternatives, and the comparison study is described in Table 5-11 .



* Superstructure is constructed in segmental construction with pre-cast elements.

Figure 5-2 Relation of Cost and Span Arrangement

(2) Summary of Structures

Table 5-12 summarises the proposed structures in Patna Bypass. Total length of throughway bridges is 1,703m and the total length of the Culvert-box is 377 m.

Table 5-11 Summary of Structures in Patna Bypass

Type	Length (m)
Sone Bridge	1,382
Large Bridge (L>200m)	0
Medium&Short Bridge (200m>L)	310
Throughway Bridge Total	1,692
Culvert-box (L)	192
Culvert-box (S)	185
Culvert-box Total	377

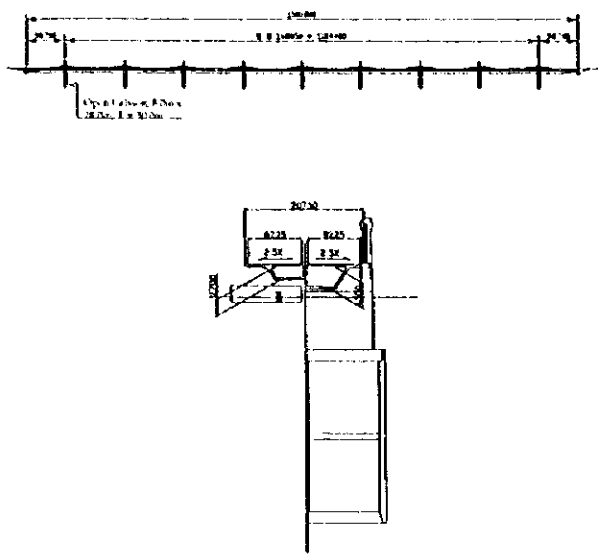
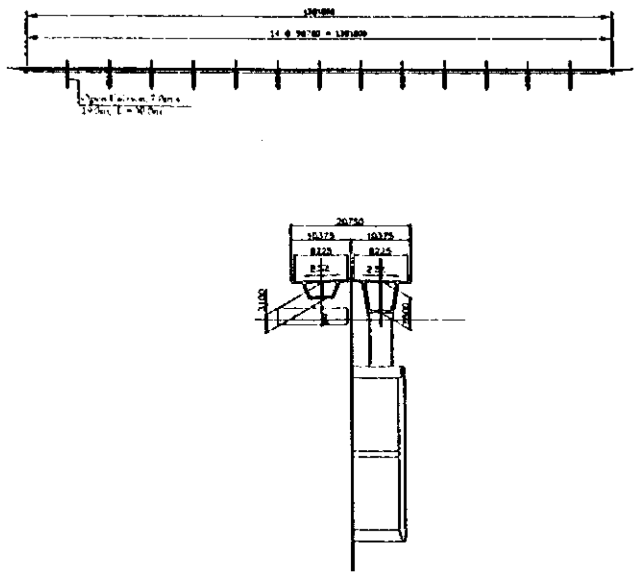
5.2.5 Major Quantities

Major quantities of proposed bypass in the Pre-Feasibility Study was summarised in Table 5-13.

Table 5-12 Major Quantities of Patna Bypass

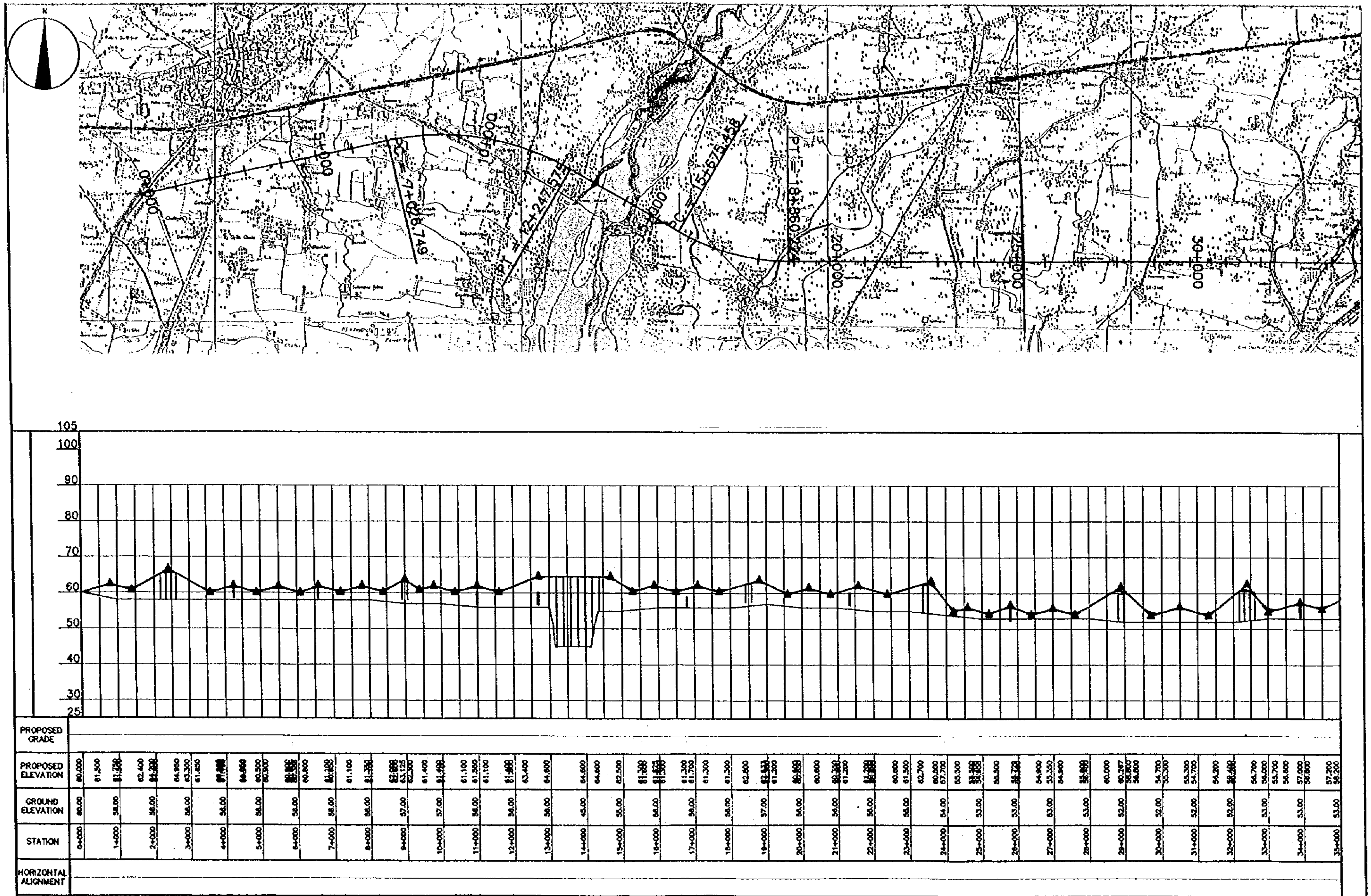
Item	Unit	Amount
Bypass Length	km	49.9
Earthwork Section	km	48.2
Structural Section	km	1.7
Earthwork Balance	m^3	- 4,493,000
Fill	m^3	4,513,000
Cut	m^3	20,000
Concrete	m^3	76,600
HYSD	ton	11,000
PC Strand	ton	1,300
Pavement		
AC	m^3	29,900
DBM	m^3	151,100
WMM	m^3	347,000
GSB	m^3	338,400

Table 5-13 Comparison Study of Sone Bridge Alternatives

	General Side View & Cross Section	Construction Cost	Construction Period	Superstructure	Substructure	Foundation	
Alternative - A PC Extra-dosed Bridge (98.700+8@148.050+98.700=1,381.800m)		Foundation: 176.8 Substructure 172.1 Superstructure 1,439.5 Total 1,788.4 *Saddle structure which is settled in tower and steel structure, and stay cable are to be imported.	43.0 months *Period is shorter than Alternative - B, because of less number of foundation and substructure.	There is no experience in India, however construction is not so difficult. Careful procedure is required about saddle structure settlement in the tower Employment of foreign consultant or adviser for supervising is desirable.	Substructure is constructed in typical method of construction in India. There are no difference in these two alternatives about construction procedure, only size and number are different. During rainy season, construction is interrrupted.	Foundation is planned with open caisson. It is standard foundation type in large river in India, and certificated in IRC specification. Soil of river bed is clay, and Lowest Flood Level in dry season is above 2~3m above river bed. Some earthwork to establish coffering island is required as temporary works.	Superior to Alternative - B about construction period, and almost same evaluation about construction cost. This will be first extra-dosed bridge in India, so it is desirable to settle special committee, or employ foreign experienced contractor or engineer.
Alternative - B PC Box Ramen Bridge (14@98.700=1,381.800m)		Foundation: 202.9 Substructure 248.6 Superstructure 1,233.2 Total 1,684.7 *All material and equipment is available to be domestically procured.	47.5 months *Period is longer than Alternative - A, because of more number of foundation and substructure.	Typical type of superstructure for long bridge in India.			Typical type of structure in India, but inferior about construction period.

Segmental construction with pre-cast elements is desirable for construction method of superstructure for both alternatives. This is to make construction period shorter.

The study team recommend Alternative - A, " PC Extra-dosed Bridge".



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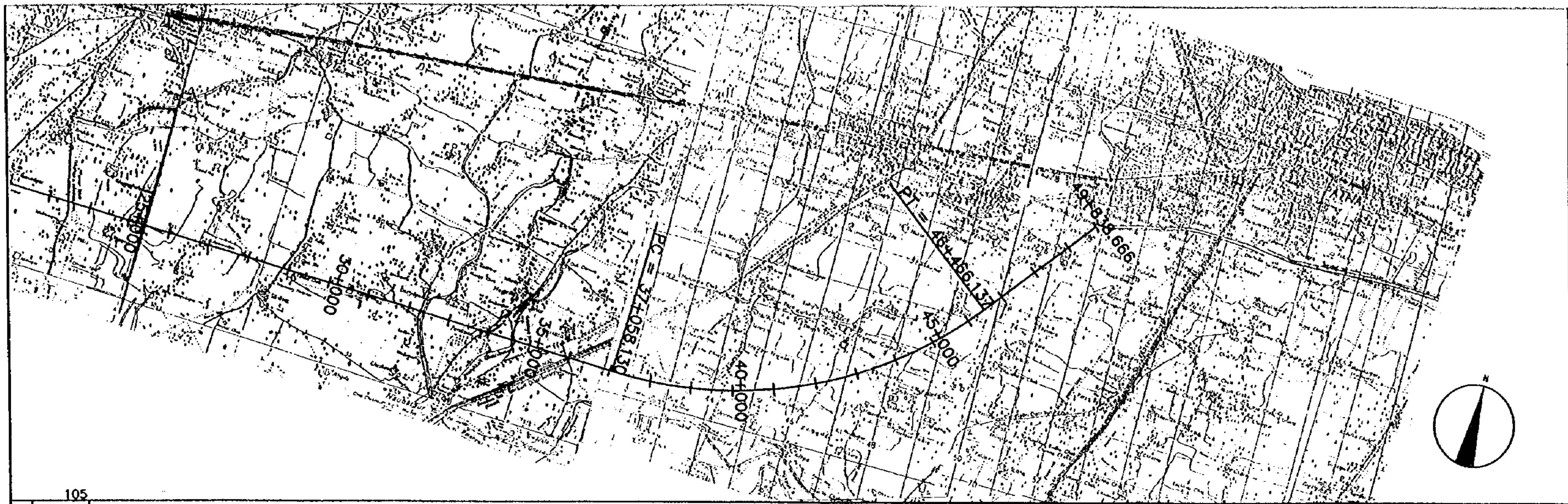

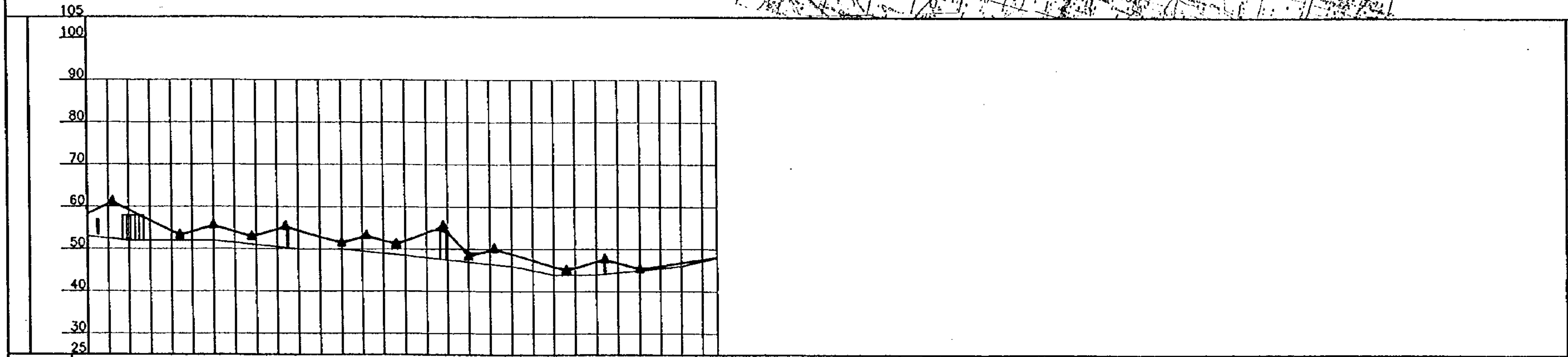

PROPOSED GRADE																
PROPOSED ELEVATION	58.200	58.700 [illegible]	54.200	53.800 54.700 55.150	54.700 53.800 53.400	[illegible] 54.400	52.300 51.850	52.300 [illegible]	52.300 [illegible]	51.900 49.425	49.200 [illegible]	45.900	45.900 [illegible]	46.800 46.200 45.640	45.759 46.832	48.116
GROUND ELEVATION	53.00	52.00	52.00	52.00	51.00	50.00	50.00	49.00	48.00	47.00	46.00	44.00	44.00	45.00	46.00	
STATION	35+000	36+000	37+000	38+000	39+000	40+000	41+000	42+000	43+000	44+000	45+000	46+000	47+000	48+000	49+000	49+838
HORIZONTAL ALIGNMENT																

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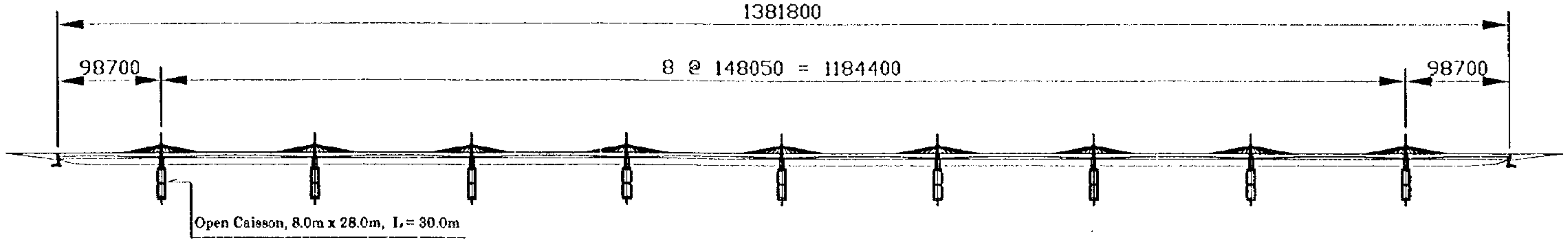
DWG NO. : 002 (2/2)

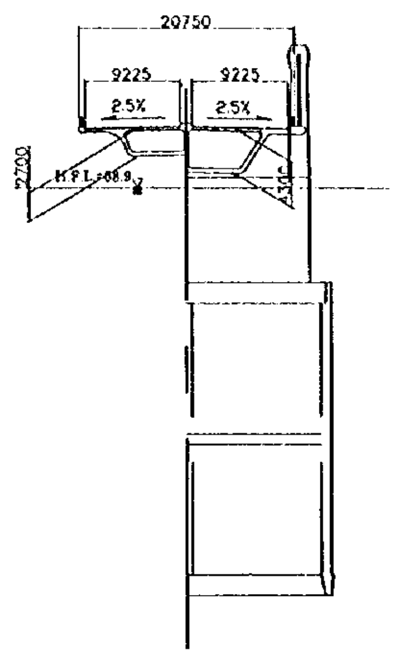
Alternative-A: PC Extra-dosed Bridge (98,700+8@148,050+98,700=1,381,800)

Side View Scale 1:5,000



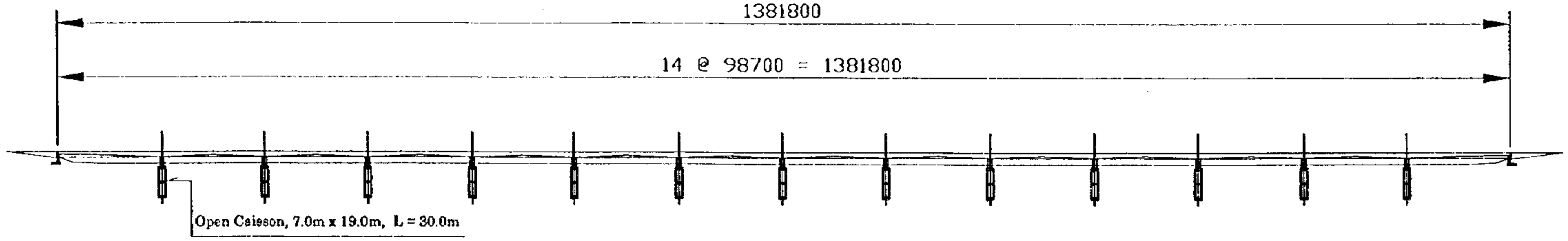
Cross Section Scale 1:700

(Center Span) (Above Pier)



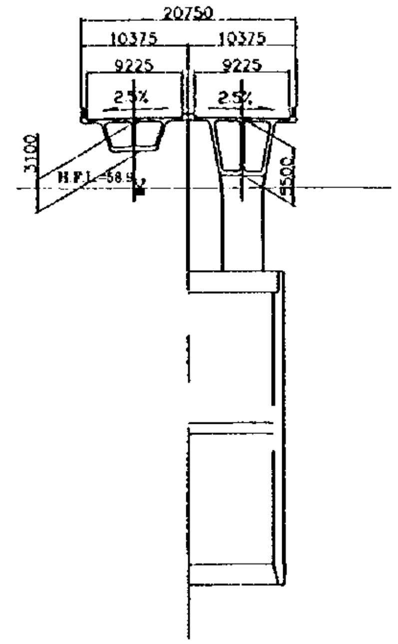
Alternative-B: PC Box Ramen Bridge (14@98,700=1,381,800)

Side View Scale 1:5,000



Cross Section Scale 1:700

(Center Span) (Above Pier)



Girder Soffit is to be 1.5m above the Highest Flood Level (H.F.L.) = 58.9m for both alternatives.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA) THE FEASIBILITY STUDY ON NATIONAL HIGHWAY BYPASSES IN INDIA	FIGURE 5-3 Alternatives for newly-established Bridge over Sone River

5.3 Preliminary Design of Keonjhar Bypass

5.3.1 General

Six (6) kms. stretch of NH6 located in Keonjhar town, from Km. 349 to Km. 355, is a very crowded and congested with problems of ribbon development. It is a virtual bottleneck on NH6. There is no scope for free and uninterrupted passage of vehicles, leave alone the prospect of widening to four lanes, the necessity for which should arise in the near future to cater to the ever increasing growth in traffic volume.

5.3.2 Major Controls

There is no major control for the horizontal alignment except a new railway construction project near the starting point. The railway line is being laid in the North South direction with at-grade crossing on NH6. The major control points are listed in Table 5-14.

Table 5-14 Major Controls of Keonjhar Bypass

No.	Approx. Sta.	Description	Requirements
1	0+000	NH6	To secure smooth connection
2	1+000	Railway	To be avoided
3	2+800	Village(Gamaria)	To be avoided
4	4+800	River	Bridge
5	6+020	SH11	Bridge
6	8+505	NH6	To secure smooth connection

5.3.3 Proposed Alignment

The section from starting point to Sta. 2+500 is parallel to the newly constructed railway line with a gentle left curve. Near Sta. 2+800, a big left curved alignment was required to change the direction to the south-west up to the end point.

Regarding the vertical alignment, the difference of elevation between the beginning point and the end point is about 15 metres with a gradually increasing slope. However, the section of Sta. 2+000 to Sta. 3+000 is at a slightly lower elevation due to some streams, and will be a fill section with 4-6 metres high. At the crossing with SH11, a viaduct bridge was proposed for a grade separation.

The proposed horizontal and vertical alignment was summarised in Tables 5-15 and 5-16.

Table 5-15 Summary of Horizontal Alignment

Design Element	Length (m)	Ratio (%)
Tangent	6,706.6	79
Curve	957.7	11
Spiral (Clothoide)	833.3	10
Total	8,497.6	100

Table 5-16 Summary of Vertical Alignment

Grade (%)	Length (m)	Ratio (%)
G <= 0.3	3,497.6	41
0.3< G <=1.0	4,200.0	50
1.0< G <=2.0	800.0	10
Total	8,497.6	100

5.3.4 Major Structures

(1) Major Structures

Major structures in Keonjhar Bypass were summarised in Table 5-17.

Table 5-17 Major Structures of Keonjhar Bypass

No.	Approx. Sta.	Description	Type	Span Arrangement (m)
1	4+800	River	RC-T	2@15=30
2	6+020	SH11	RC-T	2@13=26

(2) Summary of Structures

Table 5-18 summarises the proposed structures in Keonjhar Bypass. Total length of throughway bridges is 56 m and the total length of the Culvert-box is 133 m.

Table 5-18 Summary of Structures in Keonjhar Bypass

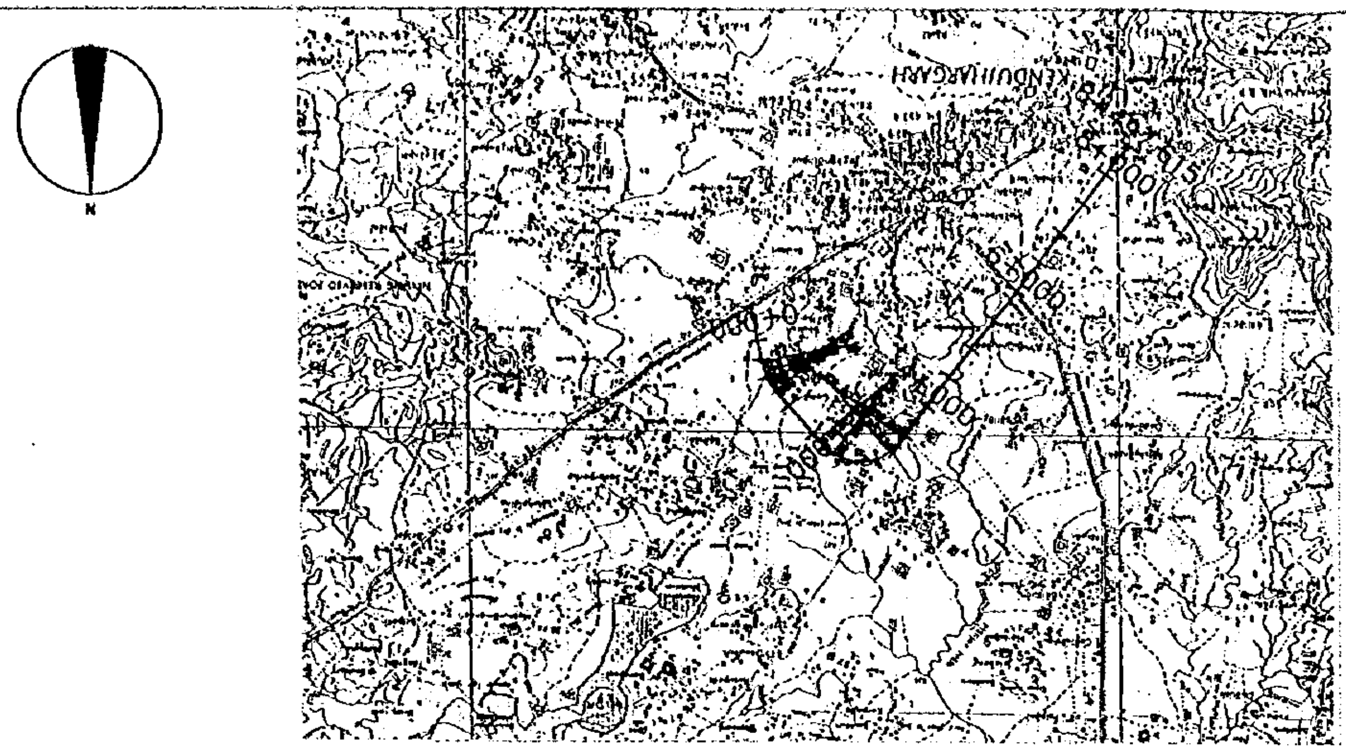
Type	Length (m)
Large Bridge (L>100m)	0
Medium&Short Bridge (100m>L)	56
Throughway Bridge Total	56
Culvert-box (L)	96
Culvert-box (S)	37
Culvert-box Total	133

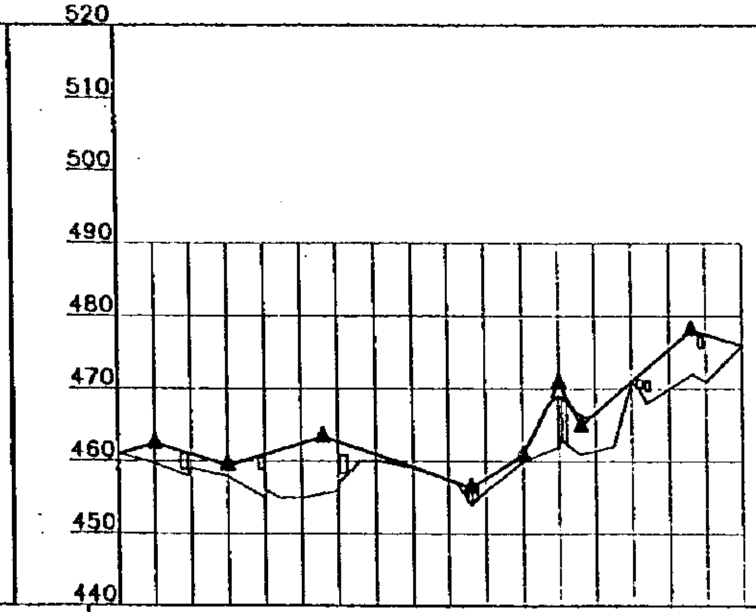
5.3.5 Major Quantities

Major quantities of proposed bypass in this Pre-Feasibility Study was summarised in Table 5-19.

Table 5-19 Major Quantities of Keonjhar Bypass

Item	Unit	Amount
Bypass Length	km	8.5
Earthwork Section	km	8.4
Structural Section	km	0.1
Earthwork Balance	m^3	-762,000
Fill	m^3	762,000
Cut	m^3	
Concrete	m^3	6,500
HYSD	ton	800
Pavement		
AC	m^3	5,300
DBM	m^3	26,700
WMM	m^3	61,200
GSB	m^3	59,700





PROPOSED GRADE																		
PROPOSED ELEVATION	461.000	462.200 462.200	461.000	458.800 458.800	461.000		463.100 [illegible]		458.200		456.750 457.043 [illegible]	459.936 [illegible] 466.660		471.060		477.220 [illegible]	476.000	
GROUND ELEVATION	461.00		458.00		455.00		458.00		458.00		456.00		462.00	471.00		471.00		
STATION	0+000		1+000		2+000		3+000		4+000		5+000		6+000	7+000		8+000	8+498	
HORIZONTAL ALIGNMENT																		

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DWG NO. : 003

5.4 Preliminary Design of Balugaon Bypass

5.4.1 General

Three kilo-metres stretch of NH5, from Km. 326 to Km. 329, inside Balugaon town is seriously crowded and congested, especially at the peak hours, and is beset with problems of ribbon development. It is a virtual bottleneck on NH5. There is no scope for free and uninterrupted passage of vehicles, let alone the prospect of widening to four lanes, the necessity for which would arise in the near future to cater to the ever-growing traffic volume. The width of the Right of Way available inside Balugaon town for NH5 is only 12 metres.

5.4.2 Major Controls

There are two level crossings with railway at Km. 323 and Km. 337 on either side of Balugaon. These pose a big problem for fast and safe movement of vehicles. Presently, each level crossing is being closed a minimum of 75 times per day, causing traffic interruption of nearly 12 hours per day, which is a colossal loss to the nation due to vehicle detention.

To obviate the problems of traffic interruptions and delay caused in traffic movement, it is proposed Balugaon Bypass to start from Km. 322 on NH5, and run on the left side of the existing highway up to Km. 337. The maximum separation distance is about two kms. from NH5. The major control points were listed in Table 5-20.

Table 5-20 Major Controls of Balugaon Bypass

No.	Approx. Sta.	Description	Requirements
1	0+000	NH5	To secure smooth connection
2	1+500	Village(Tutipara)	To be avoided
3	5+600	ODR	Bridge
4	8+000	Village(Bishundihi)	To be avoided
5	9+470	River	Bridge
6	15+400	NH5	To secure smooth connection

5.4.3 Proposed Alignment

The alignment has three curves. First curve at Sta. 1+600 is a gentle right hand curve. After that, it is parallel to the railway line up to the crossing to the ODR which is connected to the town centre of Balugaon. Second curve is at Sta. 8+200 and the third is at Sta. 14+500, and are both curves to the right.

Regarding the vertical alignment, the control point was identified at only for a crossing of ODR. The grade to be applied is 2.0 % for the approach of a bridge over

ODR. The minimum grade of the Bypass was 0.3 % for drainage of road surface water.

The proposed horizontal and vertical alignment was summarised in Tables 5-21 and 5-22. Developed drawings and design parameters were attached at the end of this section.

Table 5-21 Summary of Horizontal Alignment

Design Element	Length (m)	Ratio (%)
Tangent	13,918.0	90
Curve	457.1	3
Spiral (Clothoide)	1,025.0	7
Total	15,400.1	100

Table 5-22 Summary of Vertical Alignment

Grade (%)	Length (m)	Ratio (%)
G <= 0.3	9200.0	60
0.3< G <=1.0	4400.1	28
1.0< G <=2.0	1800.0	12
Total	15400.1	100

5.4.4 Major Structures

(1) Major Structures

Major structures proposed were summarised in Table 5-23.

Table 5-23 Major Structures of Balugaon Bypass

No.	Approx. Sta.	Description	Type	Span Arrangement (m)
1	5+600	MDR	RC-T	1@11=11
2	9+470	River	RC-T	4@15=60

(2) Summary of Structures

Table 5-24 summarises the structural planning in Balugaon Bypass. Total length of throughway bridges is 71 m and the total length of the Culvert-box is 296 m.

Table 5-24 Summary of Structures in Balugaon Bypass

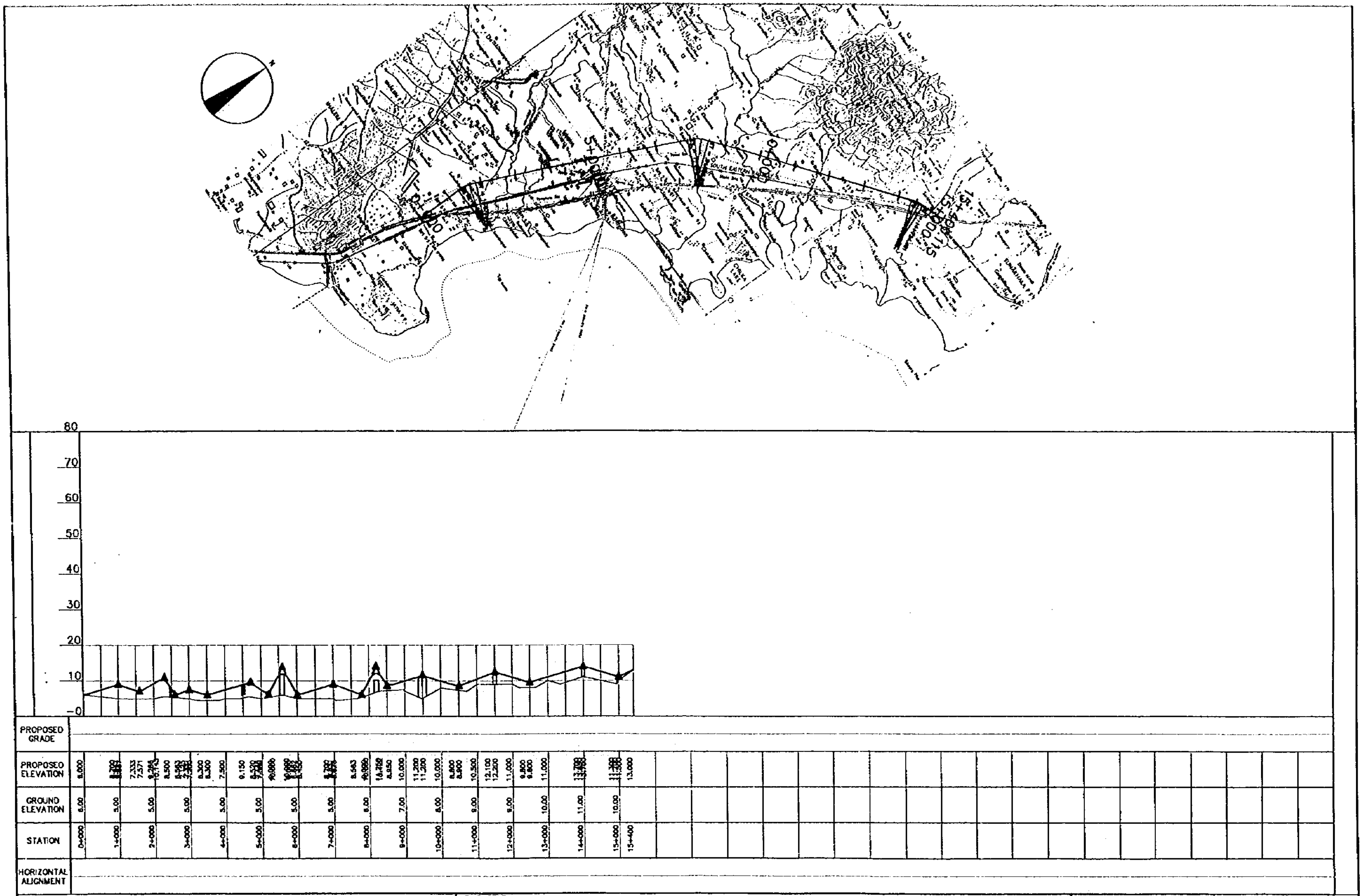
Type	Length (m)
Large Bridge (L>100m)	0
Medium&Short Bridge (100m>L)	71
Throughway Bridge Total	71
Culvert-box (L)	0
Culvert-box (S)	296
Culvert-box Total	296

5.4.5 Major Quantities

Major quantities of proposed bypass in this Pre-Feasibility Study was summarised in Table 5-25.

Table 5-25 Major Quantities of Balugaon Bypass

Item	Unit	Amount
Bypass Length	km	15.4
Earthwork Section	km	15.3
Structural Section	km	0.1
Earthwork Balance	m^3	-245,000
Fill	m^3	245,000
Cut	m^3	
Concrete	m^3	6,700
HYSD	ton	900
Pavement		
AC	m^3	9,500
DBM	m^3	48,000
WMM	m^3	110,000
GSB	m^3	107,400



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