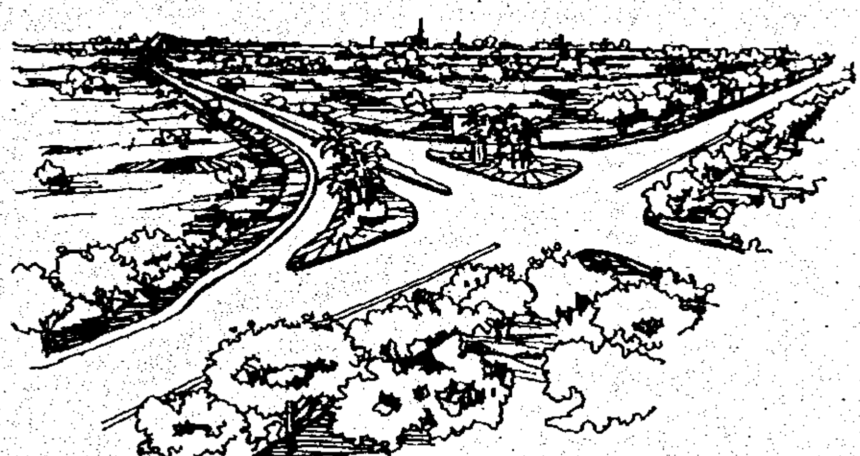
CHAPTER 6

PRELIMINARY ENGINEERING DESIGN



CHAPTER 6 PRELIMINARY ENGINEERING DESIGN

6.1 Design Criteria

6.1.1 Design Criteria for Highway

(1) Introduction

Since the geometric design standard of National Highways and urban streets must reflect the desired goals targeted by the Government of Bangladesh, it is preferable to apply uniform standards through the country if these are available.

A Policy on Geometric Design of Highways and Streets published by AASHTO has been widely referred to make framework of geometric design standard in Bangladesh as well as many other countries, even though each criteria of design control may be discussed within such framework to reflect characteristics of traffic as well as physical and natural conditions in each country or region.

The Road Materials and Standards Study Bangladesh (hereinafter called "RMSS") was prepared in June 1994 under financial assistance from European Economic Community, and it successfully revealed such characteristics in Bangladesh. On the other hand, Japan also has made efforts to revise its own standard for the sake of warranting public investment and to develop several criteria from experiences.

It is a matter of fact that amenity or good performance brought by a new road is recognized not in the design stage but in the operation after opening to the public. On the contrary, good performance could be expected not only by good engineering practice itself but also both education to drivers and enforcement against illegal users may be required.

(2) Definition of Terms

The following technical terms as defined are commonly used (refer to Fig. 6.1.1).

Roadway: the portion of a highway, including shoulder, for vehicular use.

Traveled Way: the portion of the roadway for the movement of vehicles, exclusive of shoulders.

Shoulder: the portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use and lateral support of subbase, base, and surface courses.

Hard Shoulder is the portion to be paved or surface treated.
Soft Shoulder is the portion to be covered by sod or turf.

Marginal Strip: the portion of the shoulder and the same pavement structure of the traveled way extended, usually 0.25 m - 0.3 m. This is also the space for road marking at both ends of traveled way.

Median: the portion of a divided highway separating the traveled way for traffic inopposing directions. The Median Width is expressed as the dimension between edges of each through traveled way and includes the inner shoulders, if any.

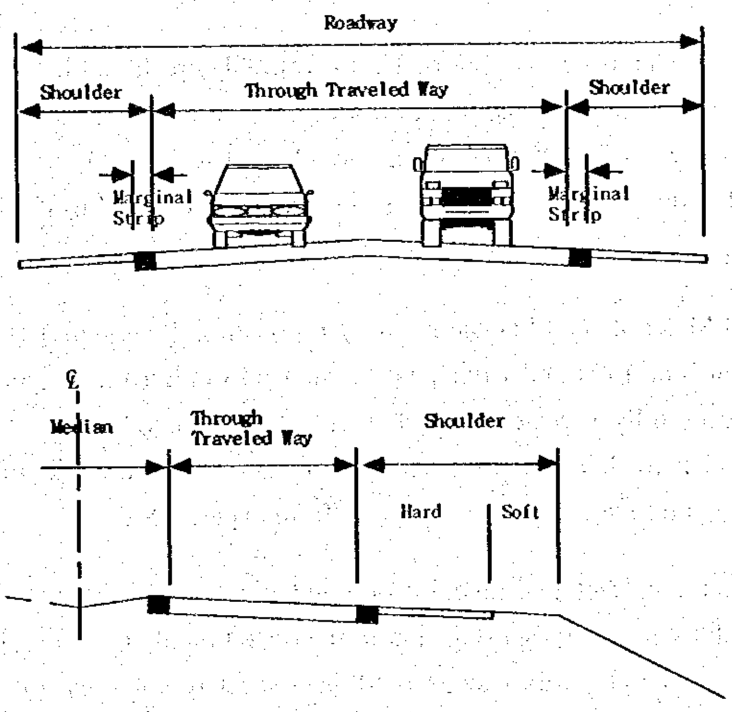


Fig. 6.1.1 Configuration of Road Structure

(3) Geometric Design Criteria for the Southern Section of Khulna Bypass (SSKB)

1) Functional Classification as a Design Type

Since the Southern Section of Khulna Bypass is planned to substitute congested Rupsa Ferry and a part of existing National Highway No. 7 in the downtown Khulna, it is designated as Urban Arterial Street with the primary road function of mobility and the priority given to motorized vehicles.

2) Design Vehicle

The physical characteristics of vehicles and proportions of variously sized vehicles using urban street are positive controls in geometric design. For the purpose of geometric design, each design vehicle has larger physical dimensions and larger minimum turning radius than those of almost all vehicles in its class.

Three general classes of vehicles have been selected, namely Passenger Car, Truck and Semitrailer. The Passenger Car class includes sedan, wagon, van and pick-up, while the Truck class includes bus, single-unit truck and so forth. The Semitrailer class represents truck tractor-semitrailer combination, especially for targeting 40 ft container transport.

Taking into consideration similar vehicular size and composition to Japan, the same design vehicles as shown in Fig. 6.1.2 are applied to the study, and the Semitrailer class is to apply to "Through Traveled Way", the Truck to "Major At-grade Intersection", and the Passenger Car to "Minor At-grade Intersection", standing on the economical yet practical viewpoint.

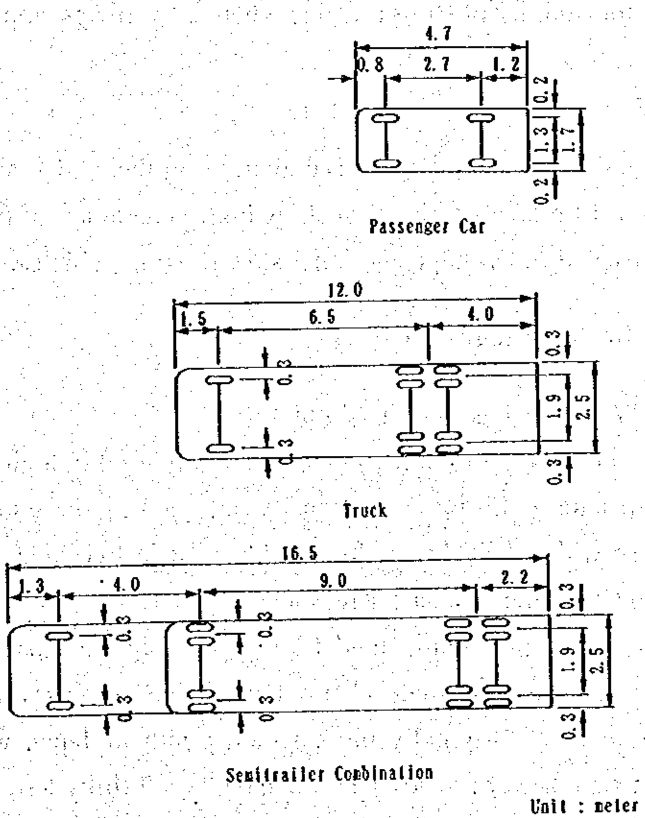


Fig. 6.1.2 Design Combination

3) Design Speed

Design speed is the maximum safe speed that can be maintained over a specified section of road when conditions are so favorable that design features of road govern. The design speed is to be determined logically with respect to the terrain, adjacent land use, type of road and the design speed of adjoining section.

The design speed selected will directly affect many geometric elements, namely horizontal and vertical alignments, sight distance, provision of superelevation, etc. Other features such as traveled way width and roadside clearances are also influenced by design speed but to a lesser degree.

The followings may warrant the design speed of 60 km/h applied to the Southern Section of Khulna Bypass;

i) Six (6) at-grade intersections are planned intermittently in 10 km stretch;
ii) No passing or overtaking control will be enforced on the Rupsa Bridge and its approach sections covering approximately 1.5 km long; and
iii) A toll plaza of barrier-gate type on the through traveled way is planned in the vicinity of Rupsa Bridge where all vehicles stop for paying toll.

4) Grade

The grade of 3% prevails in Bangladesh on the bridge approach section because of the traffic characteristics such as high percentage of over-laden trucks, trucks and buses of old vintage and other slow moving vehicles.

5) Cross Section Elements

<u>Lane Width for Fast-moving Vehicles</u>
Lane widths of 2.7 m to 3.75 m are generally used in highways through the world. 3.75 m lane width is internationally accepted as the widest possible lane width because wider than this width would result in two-lane use for one lane, which should be avoided for safety reasons.
The regulated maximum standard lane width in the Japanese road regulation was historically narrower than other countries due to the severe terrain and economic requirements. Originally the standard width in Japan was 3.50 m for Class-1 (flat terrain, heavy traffic), Class-2 and Class-3 (hilly terrain, medium traffic), and 3.25 m for Class-4 (mountainous terrain, less traffic).

In Bangladesh, 7.5 m wide 2-lane Carriageway is regulated as most high-type highways, and it is equivalent to 7.0 m wide 2-lane Traveled Ways with marginal strips at both sides (0.25 m + 3.5 m x 2 + 0.25 m).
The lane width of 3.50 m is applied to the Study, and it is sure this width accords with that of regulated Carriageway for National Highway in Bangladesh.

Track for Slow-moving Vehicles

One of the salient features of the traffic characteristics in the Study Area is a large number of slow-moving vehicles such as motor bikes and auto-rickshaws. As the mixture of such slow-moving vehicles with fast-moving vehicles may reduce the traffic capacity as well as traffic safety, it is preferable to separate them from fast-moving vehicles. Therefore, the track for the slow-moving vehicles is planned to be contiguous to the fast-moving traveled way.
Fig. 6.1.3 illustrates dimensions of auto-rickshaw, which is 1.2 m wide 2.4 m long.

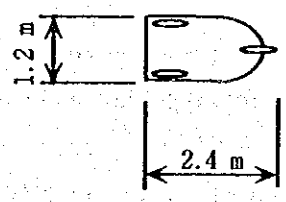


Fig. 6.1.3 Dimensions of Auto-rickshaw

The slow-moving track is assumed to require 2.5 m wide on the embankment section because one auto-rickshaw could manage to pass by even though another stuck or out-of-order auto-rickshaw blocks the track. The slow-moving track may be reduced up to 2.0 m on the Rupsa Bridge from economical viewpoint where a stuck or out-of-order auto-rickshaw should share the space for pedestrian to stop.

Shoulder Width on Embankment

Considering the functions of the shoulder together with land acquisition condition and service level as National Highway, 2.5 m outer shoulders and 1.0 m inner shoulders are recommended in the Study.

Median Width on Embankment

The median width of 5.5 m including 1.0 m inner shoulder at both sides is recommended to the Study. The median is to provide a recovery area for out-of-control vehicles, provide a stopping area in case of emergencies, allow the space for auxiliary lane for right-turning and U-turning, construction of piers of grade separation structures and overhead pedestrian crossing facilities, drainage at section with superelevation, minimize headlight glare or anti-glare facilities on horizontal curves, provide width for future lanes and so forth.

6) Crossfall of Traveled Way and Shoulder

A crossfall of 2 percent is adopted as a standard on the urban street, considering the advantage in rapidly draining the pavement during rainstorms as well as comfort of drivers.
A crossfall of 4 percent is adopted for the treated outer shoulders in order to use them effectively for surface rainwater flow.
Normal crown arrangement is applied to the roads except at sections with superelevation.

7) Type of Pavement

Considering the ease of construction and maintenance, the economical and functional viewpoints, flexible type pavement is selected generally for the urban street. The flexible type pavement agrees with the RHD's policy to utilize the existing pavement as much as possible as a component of the total structure of pavement where overlay method is applicable.
A rigid type pavement is used at the toll plaza to prevent damage to the pavement caused by oil and repeated wheel loads in regulated paths at toll booths.

8) Horizontal and Vertical Clearances

Horizontal Clearance
Each case of horizontal clearance limit illustrated in Fig. 6.1.4 indicates at least 0.25 m additional clearance beyond the outer edge of the shoulder except in the stretch where a 2.5 m wide Slow-moving Track is provided for the urban street.

Vertical Clearance
RHD has decided that 4.9 m headroom for the National Highway and 4.6 m for crossing feeder roads are the applicable standards.

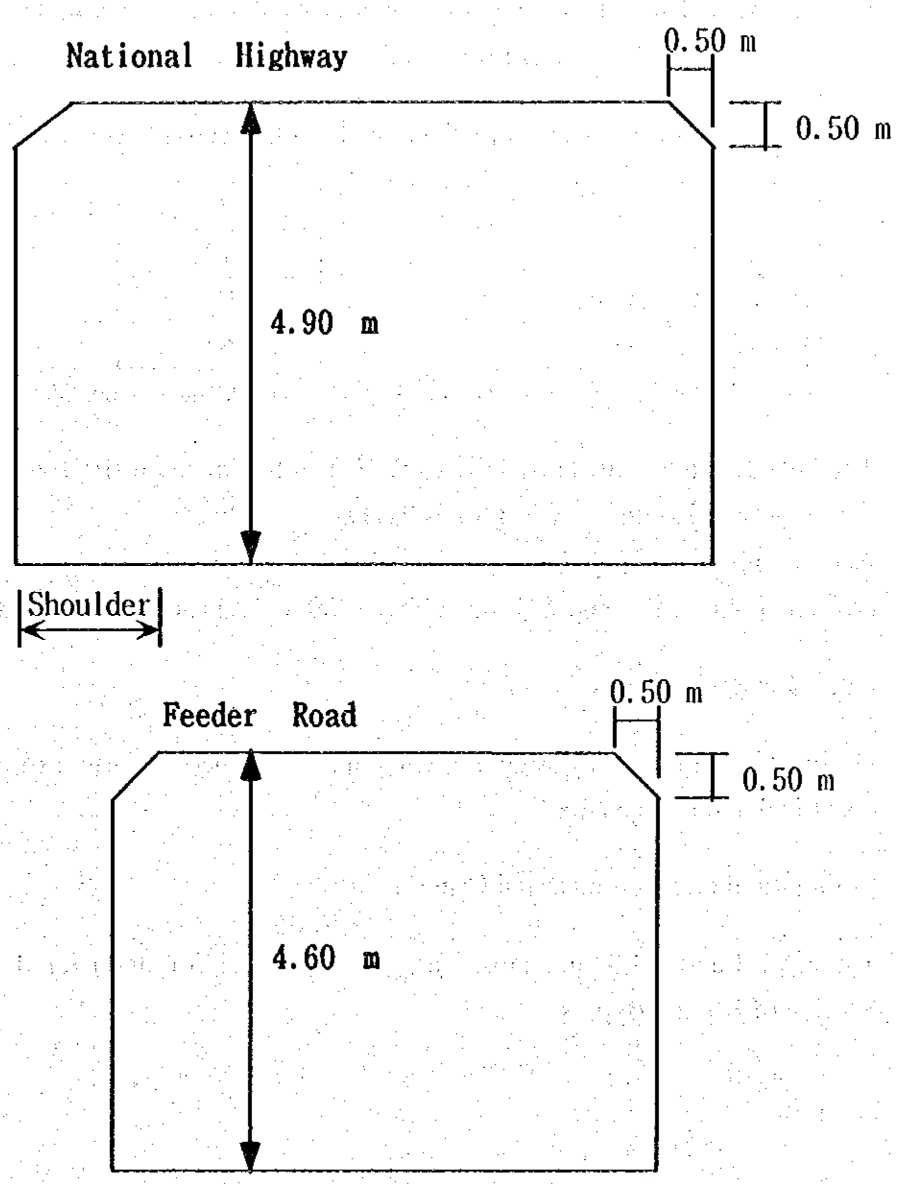


Fig. 6.1.4 Horizontal and Vertical Clearances

9) Navigation Clearance for the Rupsa River

Navigation clearance beneath the Bridge is appropriately reserved to provide space vertically and horizontally for letting design vessel pass safely even on high water level. It is also pointed out that navigation clearance is not only dependent on maximum vessel in the past but also related to managerial policy of the river such as future development along the river and salvaging allowance.
Navigation clearance of rivers in Bangladesh is controlled under the jurisdiction of Bangladesh Inland Water Transport Authority (BIWTA). The Rupsa River

has already had specified navigation clearances as summarized in Table 6.1.1 by the document which the BIWTA replied officially to the RHD's questionnaire.

Table 6.1.1 Navigation Clearance for the Rupsa River (Class I)

	Navigation Clearance	
	in Feet	in Meters
Horizontal Clearance	250	76.22
Vertical Clearance	60	18.30

Note: The vertical clearance shall be kept above the Standard High Water Level.

The BIWTA also replied officially to RHD that the Standard High Water Level in the vicinity of Khulna City is 3.00 m PWD.
Accordingly, the navigation clearance of 60ft x 250 ft is to be kept at the river crossing point of the Rupsa Bridge above 3.00 m PWD at the center of the river.

10) Other Design Elements

Design criteria of other design elements are determined according to discussions described in the Appendix.

11) Summary of Geometric Design Criteria

Table 6.1.2 and 6.1.3 summarize the geometric design criteria for the Southern Section of Khulna Bypass.

Table 6.1.2 Summary of Geometric Design Criteria for the Southern Section of Khulna Bypass

Item	Unit	Design Criteria
1 Design Speed	km/h	60
2 Through Traveled Lane Width	m	3.5
3 Slow-moving Track	m	2.5 (2.0)
4 Outer Shoulder Width	m	2.5 (0.0)
5 Inner Shoulder Width	m	1.0 (0.0)
6 Crossfall of Traveled Way	%	2
7 Crossfall of Outer Shoulder	%	4
8 Crossfall of Inner Shoulder	%	4
9 Type of Pavement	-	Asphaltic Concrete
10 Maximum Superelevation	%	3
11 Minimum Radius	m	160
12 Maximum Grade	%	3
13 Stopping Sight Distance	m	85
14 Minimum Vertical Curve Length	m	Refer to Table 6.1.3
15 Minimum Horizontal Curve Length	m	100* or 700/θ
16 Minimum Transition Curve Length	m	50
17 Minimum Parameter of Clothoid Curve	m	80
18 Sharpest Curve without Transition Curve	m	500
19 Sharpest Curve without Superelevation	m	950
20 Maximum Relative Slope for Superelevation Runoff	-	1/140

Notes :

1. θ shows intersecting angle in degree for horizontal curve (min. 2 degrees).
2. The figure with * shows absolute value in case that θ is more than 7 degrees .
3. The figure in parenthesis shows value for the Rupsa Bridge.

Table 6.1.3 Minimum Vertical Curve Length

Algebraic Difference in Grade (%)	On Crest Curve			On Sag Curve		
	Rider Comfort	Sight Dictence	Adopted Value	Rider Comfort	Sight Dictence	Adopted Value
6	50	99	99	50	97	97
5.5	50	90	90	50	89	89
5	50	82	82	50	81	81
4.5	50	74	74	50	73	73
4	50	66	66	50	65	65
3.5	50	57	57	50	57	57
3	50	49	50	50	49	50
2.5	50	41	50	50	40	50
2	50	33	50	50	32	50
1.5	50	25	50	50	24	50
1	50	16	50	50	16	50
0.5	50	8	50	50	8	50

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1 Design Speed	km/h	60
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6	50	99	99	50	97	97
5.5	50	90	90	50	89	89
5	50	82	82	50	81	81
4.5	50	74	74	50	73	73
4	50	66	66	50	65	65
3.5	50	57	57	50	57	57
3	50	49	50	50	49	50
2.5	50	41	50	50	40	50
2	50	33	50	50	32	50
1.5	50	25	50	50	24	50
1	50	16	50	50	16	50
0.5	50	8	50	50	8	50

6.1.2 Design Criteria for Bridges

6.1.2.1 Geometric Requirements

(1) Bridge Cross-section

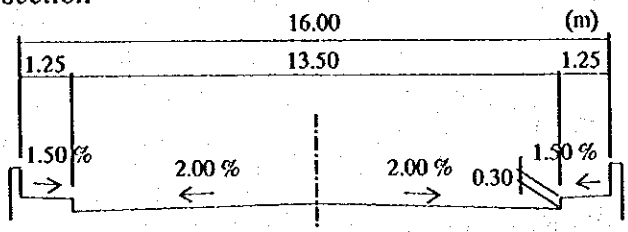


Fig. 6.1.5 Cross-section for Rupsa Bridge

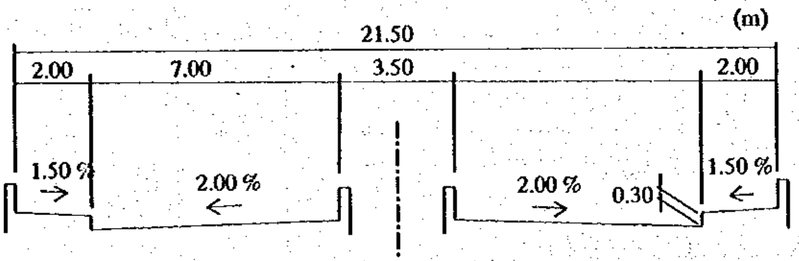


Fig. 6.1.6 Cross-section for Canal Bridges

(2) Alignment Horizontal: Bridge shall cross the river straight and at right angle to flow.

Vertical: Apply the profile slope of 3% with a vertical curve of 100 m at center of the river based on the road geometrical design.

(3) Navigation Clearance: A 76.22 m wide x 18.30 m high clearance above SHWL = 3.00 m PWD at the center of the river shall be secured. The minimum span length required from the navigation, will be about 100 m as shown in Fig. 6.1.7.

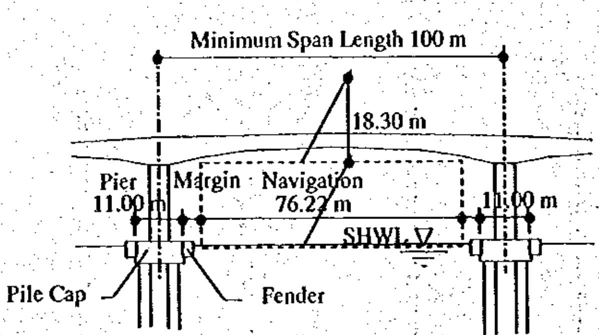


Fig. 6.1.7 Navigation Clearance and Minimum Span Length

(4) Length of Main Bridge: Main bridge shall cover the entire river width and some marginal space be provided for future possible bank erosion. See Section 6.4.4-Hydrological Recommendation.

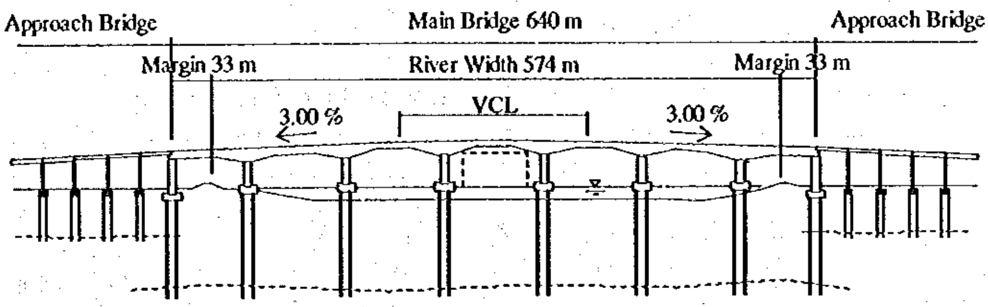


Fig. 6.1.8 Main Bridge Length

6.1.2.2 Design Loads and Environment Condition

(1) Live Load (Vehicle Traffic Load)

- Standard Live Load: 100% HS20-44 in accordance with AASHTO Division-I, Article 3.7.1.
- Alternate Military Load: be compared to HS20-44 in accordance with AASHTO Division-I, Article 3.7.4.

(2) Public Utility Loads

- Electric Lines, Telecommunication Lines and Gas Pipes (for residential use) are scheduled on the bridge. Their spaces are to be secured between girders and in total 400 kg considered.
- Water Pipes are not scheduled.

(3) Bridge Railing: Combination of traffic and pedestrian type of railing is adopted.

(4) River Water Levels: Water levels of 100 years return period is adopted.

High Water Level: 3.77 m PWD

Low Water Level: -1.26 m PWD

(5) River Current Velocity: The maximum velocity surveyed in the Study is adopted.

Vc = 2.3 m/sec

(6) River Bed Variation: From Section 6.4.2.1-Pier Scouring Study,

Channel Degradation Depth	5.0 m
Local Scour Depth	10.0 m
Total Scour Depth	15.0 m

(7) Wind Load

Basic Wind Velocity: $V_{Z=10}$ = 238 km/hr at 10 m height in accordance with National Building Code Bangladesh, Table 6.2.8.

Design wind pressure is estimated by the following process.

Design Wind Velocity: $V_D = 2.5 * V_o * (V_{Z=10}/V_B) * \ln(Z/Z_o) = 271$ km/hr

where, Base Wind Velocity V_B = 161 km/hr (100 mile/hr)

in accordance with AASHTO Division-I, Article 3.15.

Bridge Height Z (m)

Friction Velocity V_o = 13.21 km/hr (8.21 mile/hr in open country)

Friction Length Z_o = 0.070 m (0.23 ft in open country)

Base Wind Pressure: P_B = 2.394 kN/m^2 (50 lbf/ft^2)

coresponding to V_B = 161 km/hr (100 mile/hr)

Design Wind Pressure: $P_D = P_B * (V_D/V_B)^2$ (kN/m^2)

(8) Temperature Change and Humidity: based on the meteorological data of Khulna.

Temperature Change 7 ~ 38 °C Mean 26 °C

Average Humidity 70 %

(9) Boat Collision Load

The following collision loads are considered to provide the resistance similar to the level of Jamuna and Paksey Bridges

- On Substructure : Ps = 5000 kN

Analysis : $Ps = 61.17 * (DWT)^{1/2} * V$ from AASHTO Vessel Collision, Article 2.17.

where, Ps = Equivalent static vessel impact force (kN)

DWT = Deadweight tonnage of vessel (ton)

V = Vessel impact velocity (knot)

DWT(ton) \ V(knot)	5	10	15	
10	1000	1900	2900	(kN)
50	2200	4300	6500	
100	3100	6100	9200	
150	3700	7500	11200	
200	4300	8700	13000	
250	4800	9700	14500	
300	5300	10600	15900	

- On Superstructure : Ps = 500 kN

(10) Earthquake

Seismic Acceleration Coefficient: A = 0.075 Zone I
in accordance with National Building Code, Bangladesh Fig. 6.2.10.

Seismic Performance Category: SPC = A
in accordance with AASHTO Division-IA, Article 3.4.

Design Requirement: No structural seismic analysis is required except the design of connection and bearing support length in accordance with AASHTO Division-IA, Article 4.2.

Horizontal Force for Connection Design = 0.20 * (Tributary Weight)
in accordance with AASHTO Division-IA, Article 5.2.

6.1.2.3 Loads Combination and Design Limit

(1) Load Combination

The design load combination is generally based on AASHTO Division-I, Table 3.22.1A. The following supplements are made specific to design of the Project bridges.

- Any overload provision is not specified by RHD in accordance with to AASHTO Division-I, Article 3.5.
- Centrifugal Force (CF) and Ice Pressure (ICE) are not applicable.
- Boat Collision Load (BC) will not be combined with Live Load nor with Wind Load.

(2) Serviceability Limit State

- Tolerable Settlement: Maximum angular distortion between adjacent foundations shall be limited to 0.004 for continuous structures in accordance with AASHTO Division-I, Article 4.11.3.3.
- Tolerable Horizontal displacement: 50 mm (2.0 inches) is adopted as vertical displacement is considered small in accordance with AASHTO Division-I, Article 4.12.3.2.2.

6.2 Highway Engineering Design

6.2.1 Design of Roadway

(1) Design Section, Traffic Capacity and Required Number of Lanes

The design section of the Southern Section of Khulna Bypass (SSKB) is determined to be one (1) due to the following features;

- The terrain is flat through the stretch;
- The land use along the route remains unchanged; and
- The traffic demand varies within comparatively small range.

To determine the required number of traffic lanes in a design section, the capacity of project road must be determined based on future traffic characteristics. The concept and methodology used for the analysis are based on the "Highway Capacity Manual" of the Highway Research Board, USA and "Road Design Standard" of Japan. The design capacity is presented in the Appendix.

The traffic demand for the year 2015 is forecasted in Chapter 3, and Table 6.2.1 summarizes the design traffic volume in each segment.

Table 6.2.1 Design Traffic Volume in Each Segment

	Khulna-Sakthira Rd. - Batiaghata Rd.	Batiaghata Rd. - Rupsa Bridge	Rupsa Bridge - Jabusa Rd.	Jabusa Rd. - Khulna-Mongla Rd.
Design Traffic (pcu/day)	6,700	14,400	18,500	16,900

Fig. 6.2.1 presents relationship between traffic capacity of the planned cross section and the traffic volume. Judging from the figure, it is obvious that undivided 2-lane roadway has enough capacity for the traffic in 2015.

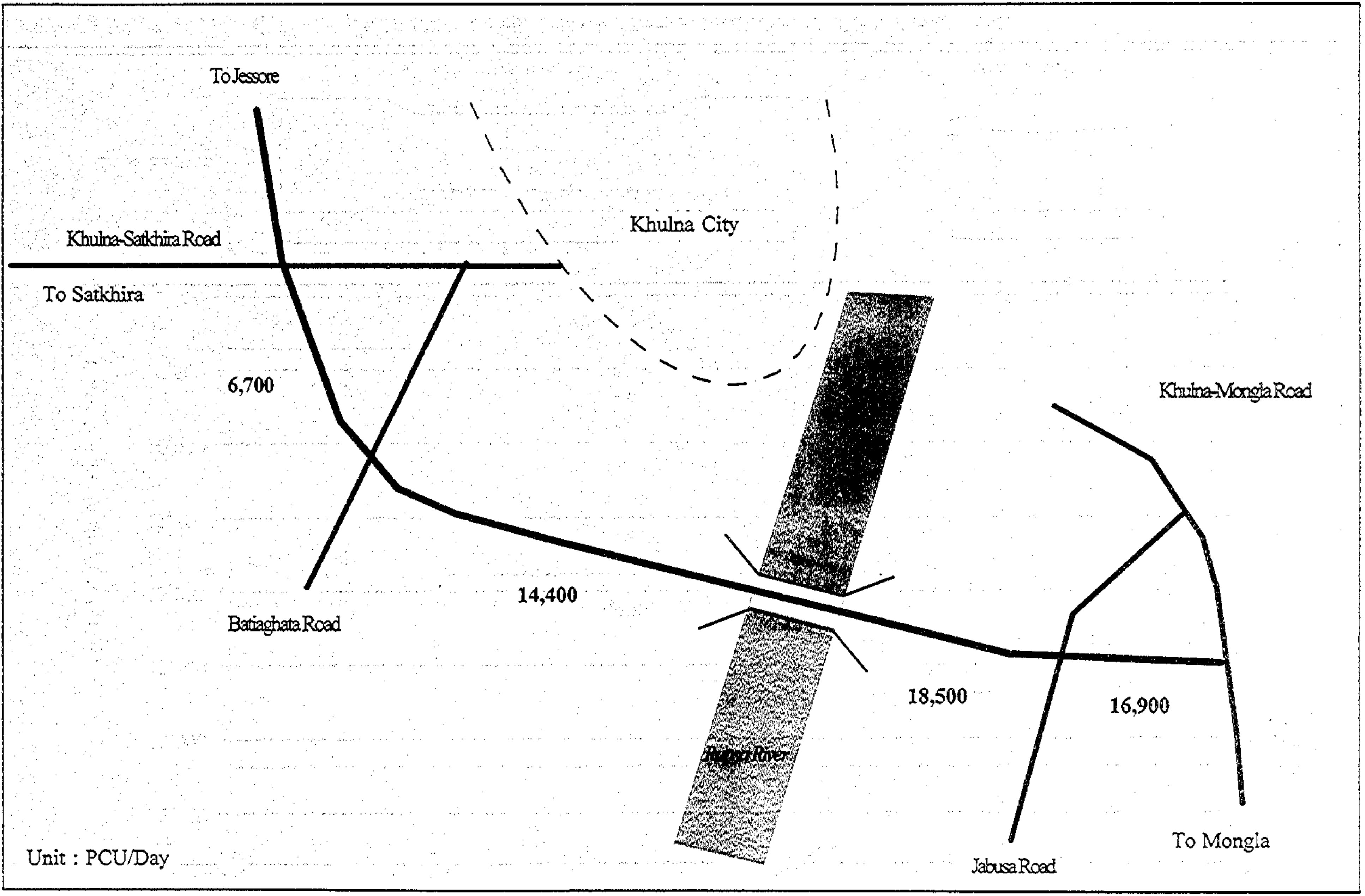


Fig. 6.2.1 (1) Traffic Volume of SSKB

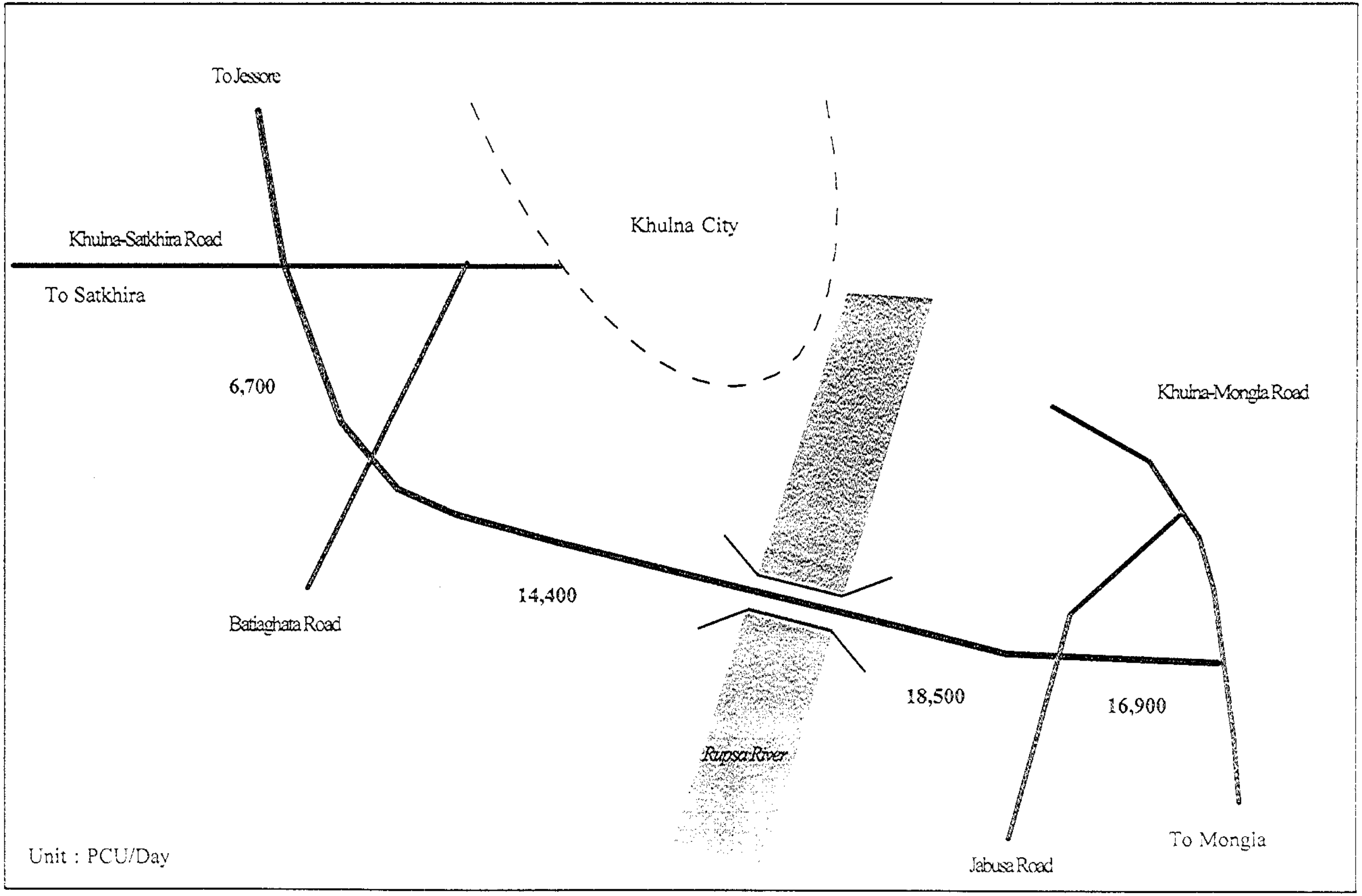


Fig. 6.2.1 (1) Traffic Volume of SSKB

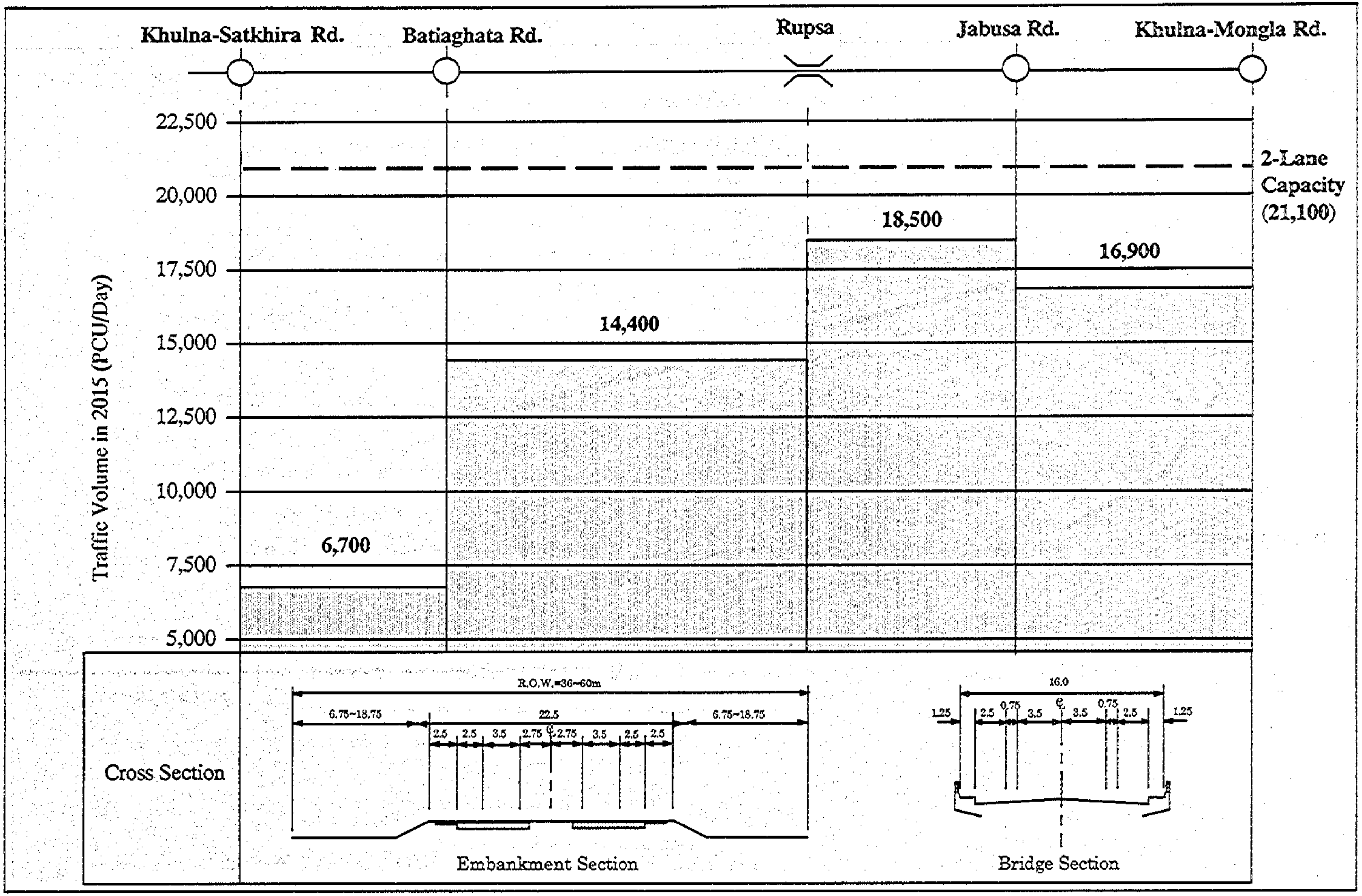


Fig. 6.2.1 (2) Comparison with Traffic Capacity and Traffic Volume of SSKB

(2) Cross Sectional Configurations

Fig. 6.2.2 shows the proposed typical cross section for the Rupsa Bridge based on the selected scheme of Phase 1 Study.

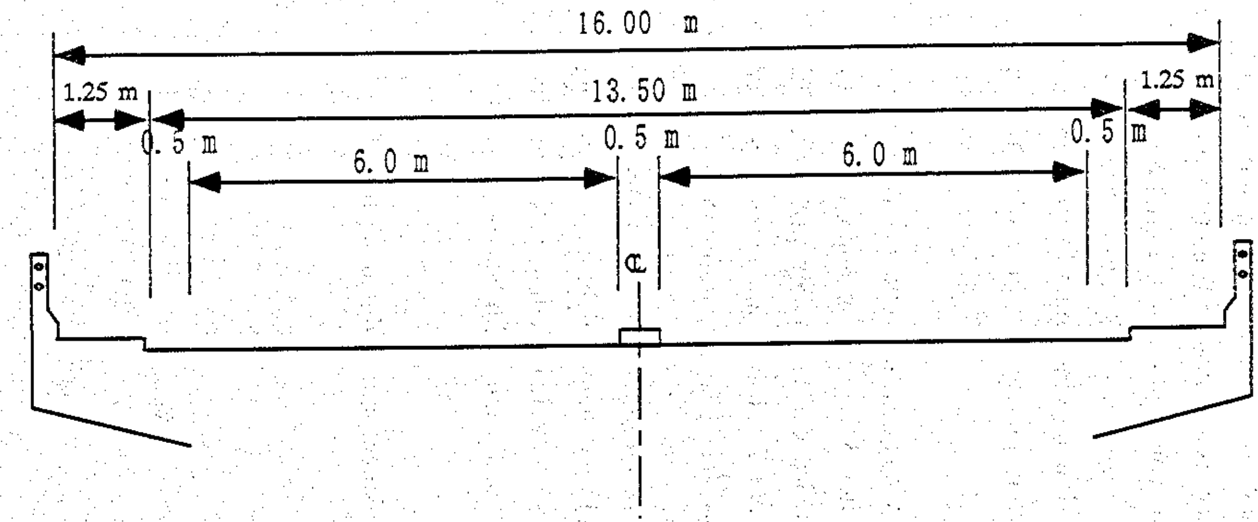
The proposed cross sectional configuration has following advantages and justifications made by Phase 1 Study;

i) Rupsa Bridge is located in the urbanized area of Khulna and major users are expected local commuters although major benefits are brought from transport cost savings of heavy trucks and long distance buses on regional and arterial road. It is necessary to deliberate transport means for citizens such as auto-rickshaws and motorcycles, and accordingly separated slow-moving tracks accommodate commuters as well as contribute traffic safety and steady flow of traffic on through traveled ways.

ii) Number of trucks and buses of quite an old vintage with overloaded or shortage of horsepower make it justify to adopt flatter 3% grade in approach section because mixed traffic of slow-moving vehicles causes mainly present traffic congestion taken place on National Highway No. 7. It is desirable that separated slow-moving vehicles enhance traffic safety as well as smooth traffic flow.

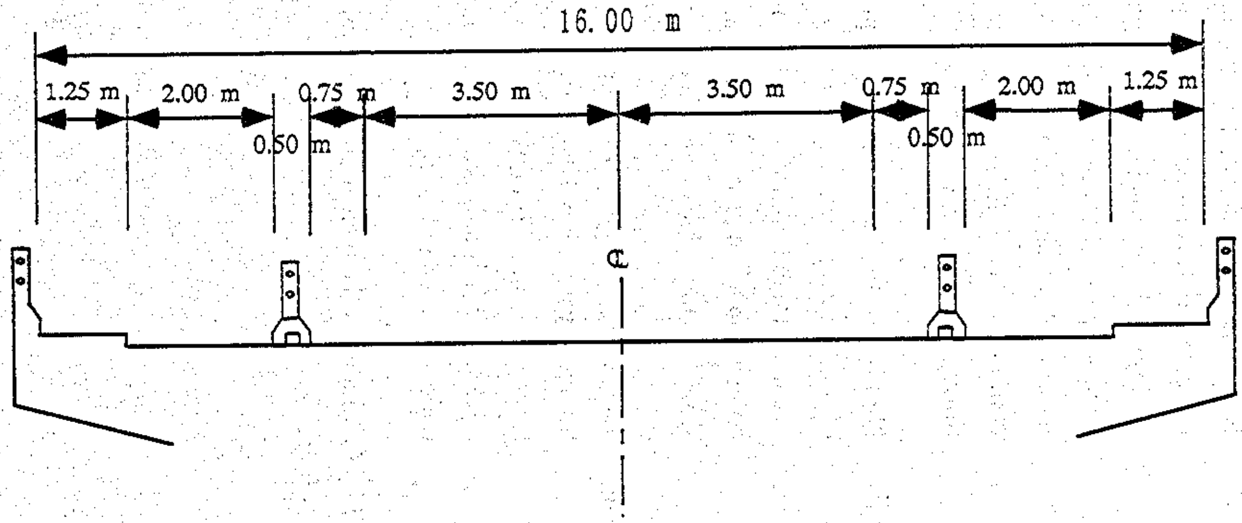
iii) This cross sectional configuration has remarkable advantage to expand 2-lane traveled ways up to 4-lane just in case that traffic demand might increase beyond forecasted one. Total width of roadway is 13.5 m wide including 2 slow-moving tracks, and it is still practical to modify it divided 4-lane with lane width of 3 m wide as shown in Fig. 6.2.2.

Fig. 6.2.3 shows the typical cross sections of embankment and bridge other than Rupsa Bridge.



Proposed Rupsa Bridge

Divided 4-lane



Proposed Rupsa Bridge

2-lane Two-way with
Slow-moving Tracks

Fig. 6.2.2 Proposed Rupsa Bridge and its Variation

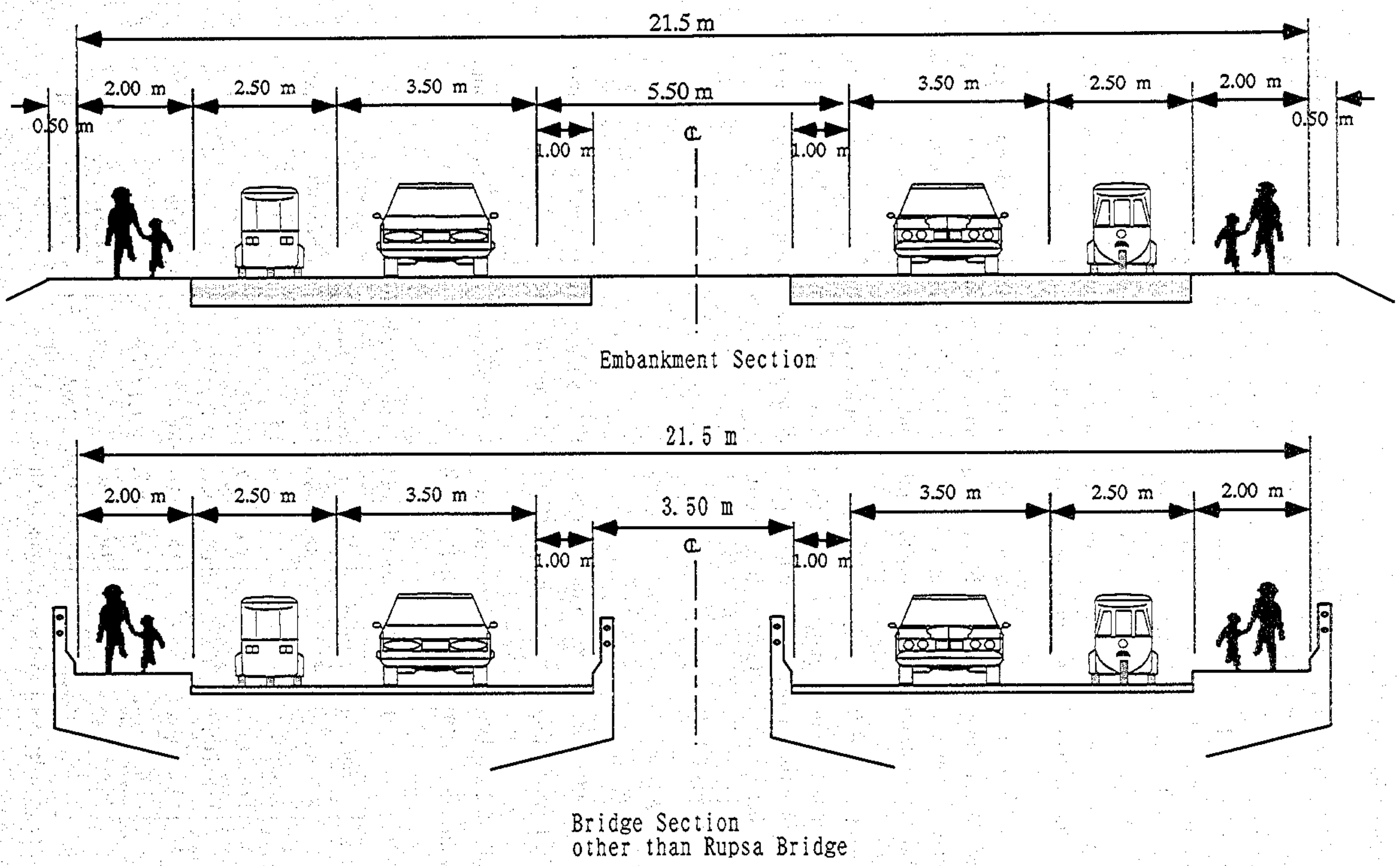


Fig. 6.2.3 Typical Cross Sections of Embankment and Bridges other than Rupsa Bridge

(3) Road Embankment Structure

Salient features related to road construction in the study area are flat terrain, high ground water level and no quarry. Accordingly, it is actual yet common practice that fill materials for road embankment are of common excavation which usually gets soil from both road sides within ROW, so-called "side borrow", or borrow materials of which a contractor purchases top soil from land owners or from their own borrow pits. Road embankment structure comprises of lower road bed and upper road bed, together with horizontal sand drain beneath lower road bed where surcharge embankment is required. Sub-grade is a part of upper road bed and fill materials should be selected carefully provided that required strength (Design CBR) could not be kept.

According to the investigation in the study area, fill material from side borrow and river bed deposits may be applicable, of which tenure is deemed governmental. On the contrary, top soil purchased by a contractor through private land owners is found sometimes low quality such as organic soil or mixed with grass/crop roots.

Therefore, road ROWs are proposed two, namely 36 m (120ft) wide and 60 m. The former is the same width as that of the northern section of Khulna Bypass and the minimum required width where land use along the route is developed, and the latter is desirable to keep earthwork well-balanced.

6.2.2 Design of At-grade Intersection

(1) General

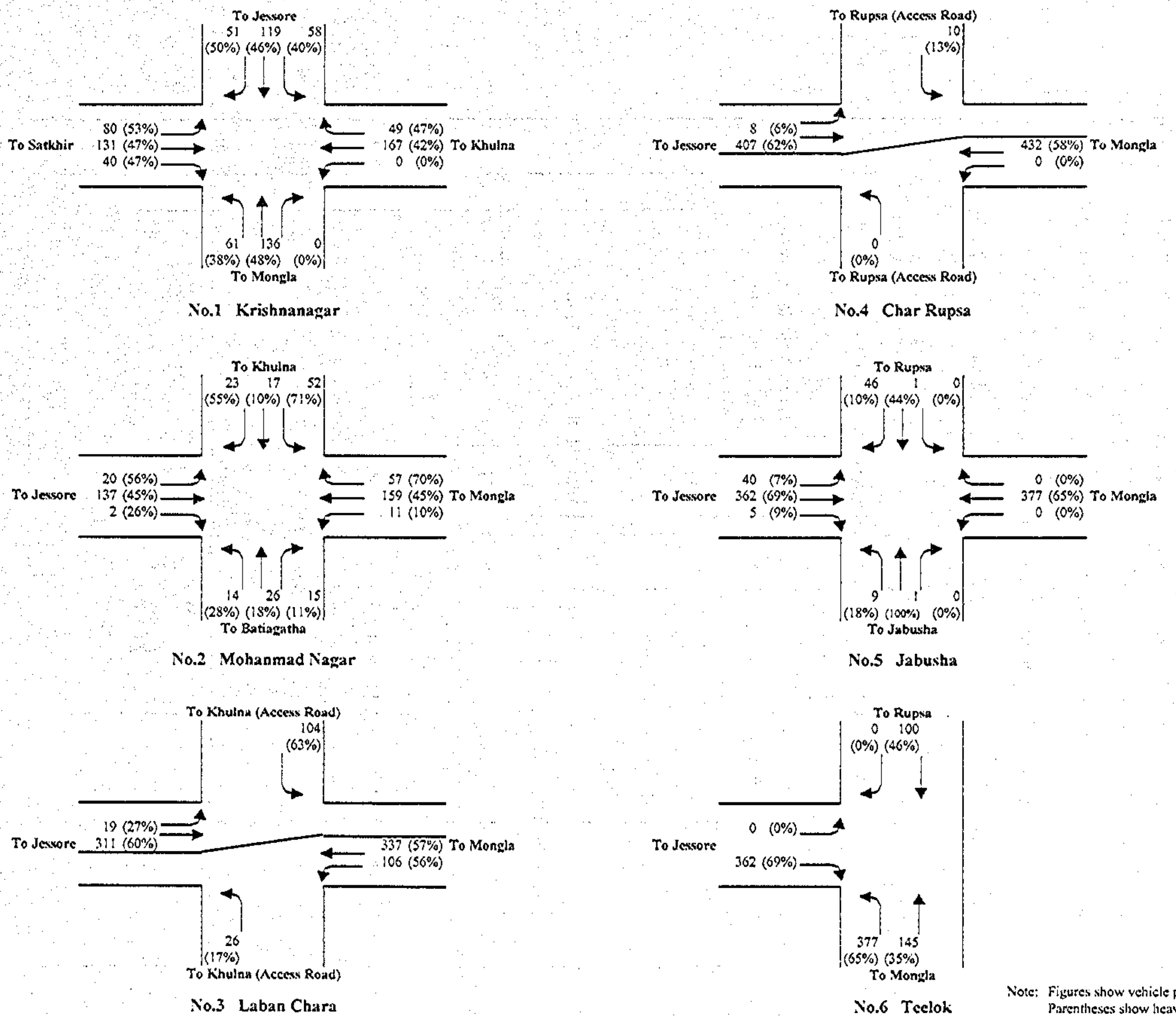
The Southern Section of Khulna Bypass (SSKB) is planned to connect to local roads, which are existing as well as planning in the study area to collect/distribute traffic.

Table 6.2.2 is tabulated the location of at-grade intersections, and hourly traffic volume by direction in 2015 are shown in Fig. 6.2.4.

Table 6.2.2 Location of At-grade Intersections

No.	Name of Intersection	Name of Intersecting Streets	Station
1	Krishnanagar	Khulna-Satkhira Road	Sta. 0+000
2	Mohanmad Nagar	Batiagatha Road	Sta.1+614
3	Loban Chara-1	Western Dyke Road	Sta. 6+271
	Loban Chara-2	(Half-cloverleaf Type IC)	
4	Char Rupsa-1	Eastern Dyke Road	Sta. 6+849
	Char Rupsa-2	(Half-cloverleaf Type IC)	
5	Jabusha	Jabusha Road	Sta. 8+515
6	Teelok	Khulna-Mongla Road	Sta. 10+044

Note : Station denotes the value on the route of Alternative-1.



Note: Figures show vehicle per hour
Parentheses show heavy vehicle rate

Fig. 6.2.4 Volume by Direction by Hour in 2015

(2) Methodology

The concept used for the intersection capacity analysis is based on the "Highway Capacity Manual of Highway Research Board 1985, U.S.A.". However, some adjustments were made to reflect local conditions based on the results of studies obtained by "Highway Research Board, Japan", since much resemblance is found in types and sizes of vehicles and in operating conditions in Bangladesh and Japan.

The work flow of the intersection capacity analysis is presented in Fig. 6.2.5.

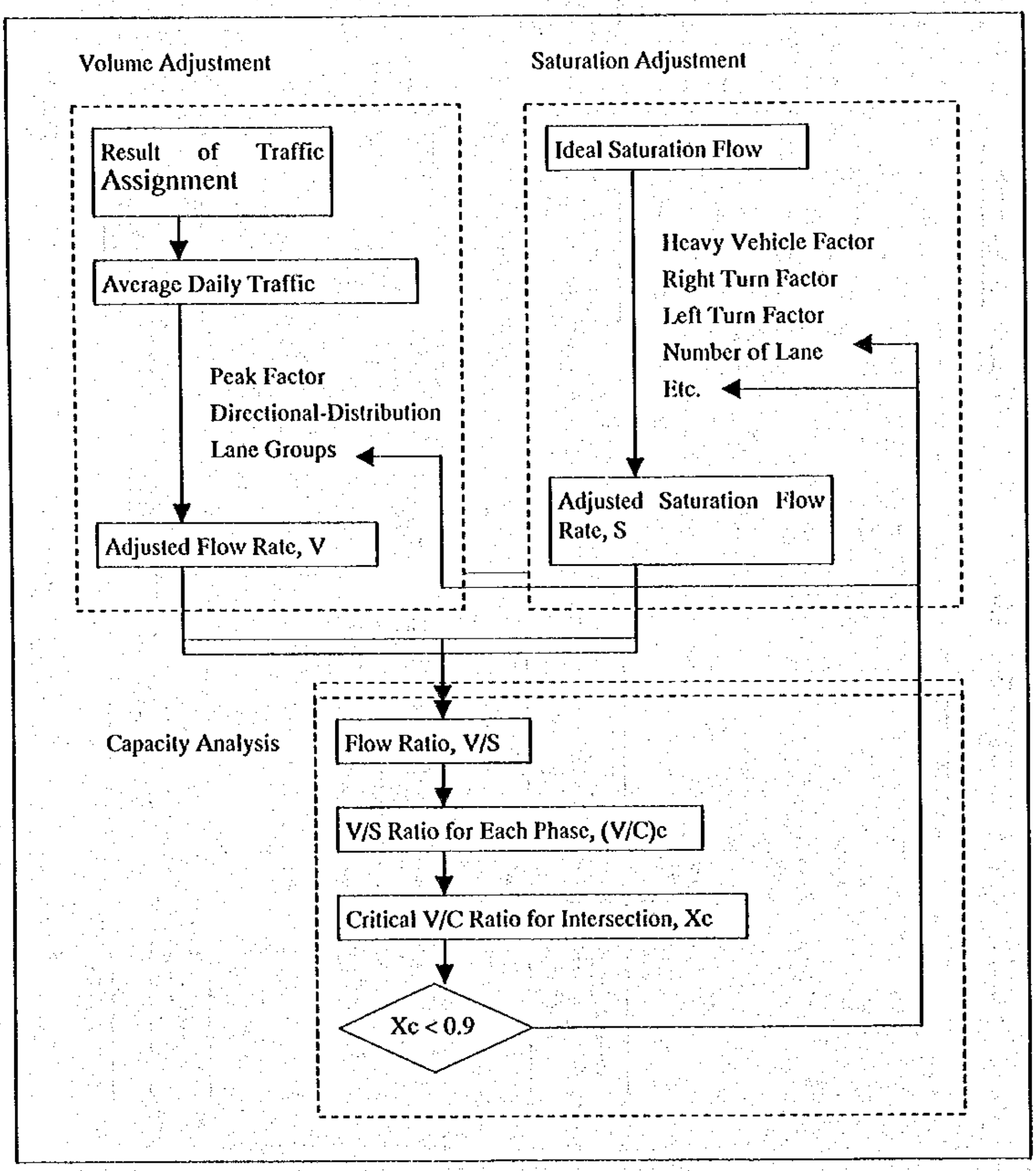


Fig. 6.2.5 Flow Chart of Intersection Capacity Analysis

(3) Typical Types of At-grade Intersection

Typical types of at-grade intersection are 3-leg intersection (T-type Intersection) and 4-leg intersection. More than 4 legs and Roundabout (Rotary) intersections are deemed impractical as far as channelization is planned.

A Half-cloverleaf type interchange (IC) is planned to be formed at No. 3 : Loban Chara and No. 4 : Char Rupsa due to no direct connection brought by grade separation structure of Rupsa Bridge, and accordingly two 3-leg intersections are required to provide access to the SSKB.

Table 6.2.3 shows planned types of intersection adopted to each intersection.

Table 6.2.3 Type of At-grade Intersections

No.	Name of Intersection	Type of Intersection
1	Krishnanagar	3-Leg (4-Leg in future)
2	Mohanmad Nagar	4-Leg
3	Loban Chara-1 Loban Chara-2	3-Leg (Half Cloverleaf IC)
4	Char Rupsa-1 Char Rupsa-2	3-Leg (Half Cloverleaf IC)
5	Jabusha	4-Leg
6	Teelok	3-Leg

(4) Description of Intersection Planning

1) 3-Leg Intersection

This intersection is T-type in the shape, and right-turn or left-turning auxiliary lane is normally provided in case of channelization with traffic signals as shown in Fig. 6.2.6. In case of no provision of auxiliary lane, it takes place often that stopping right-turning vehicles for pedestrian make following vehicles stuck.

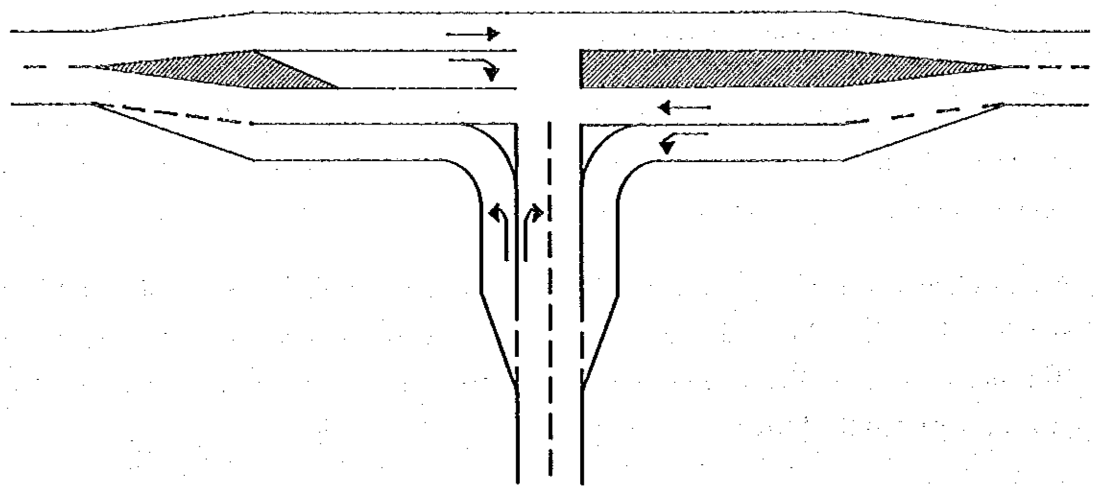


Fig. 6.2.6 Typical Shape of T-type Intersection

At 2-lane to 2-lane intersection, left-turning heavy vehicles such as trucks and buses are apt to violate opposite lane on egress. Stopping line at intersection should be designed properly in case that heavy vehicles are expected to turn into crossing roads.

The critical V/C ratio for 3-leg intersection is 0.68 at most where the heaviest traffic volume is forecasted at No. 6 : Teelok Intersection.

2) 4-Leg Intersection

4-leg intersection has more conflict points than 3-leg intersection, and lane for through traffic is apt to share with right-turning or left-turning. Right-turning auxiliary lane should be provided on the SSKB as shown in Fig. 6.2.7. This channelization plan has advantages for through traffic at both direction from viewpoint of traffic safety because signal phase allocation usually allow to pass both through traffic at the same time and right-turning traffic should wait at the auxiliary lane to turn occasionally in the intervals. Left-turning traffic may share lane with through traffic in case that volume is forecasted modest.

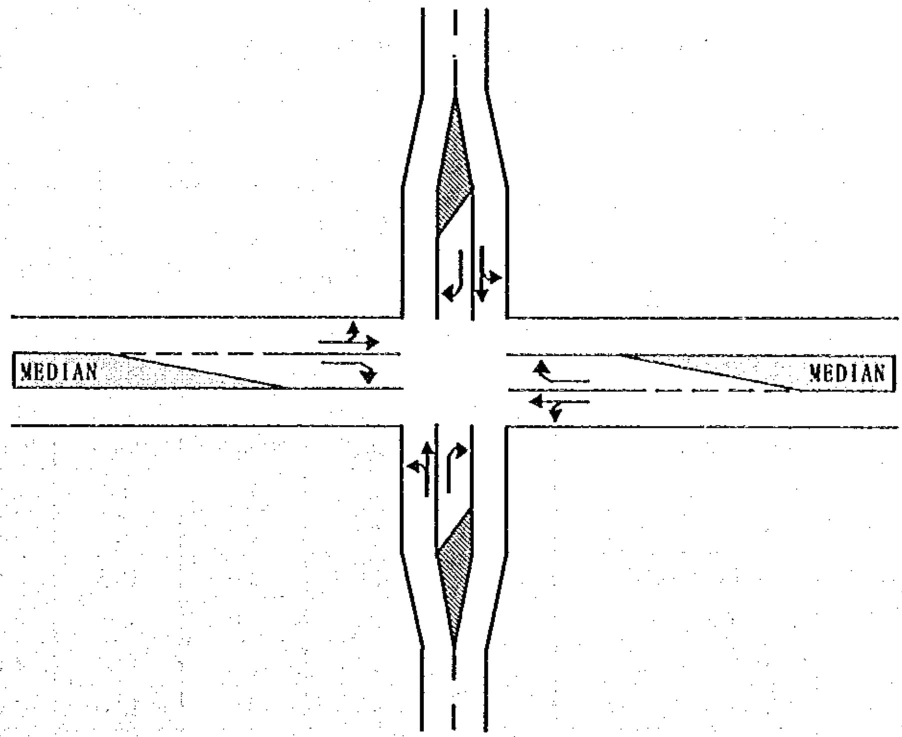


Fig. 6.2.7 Typical Shape of 4-Leg Intersection

The critical V/C ratio for 4-leg intersection is 0.49 at most where the heaviest traffic volume is forecasted at No. 1 : Krishnanager Intersection.

6.2.3 Design of Road Crossing Structures and Road Drainage

(1) Road Crossing Structures

1) General

The study area is flat terrain and is protected by Rupsa River embankment of which regulators control the entrances and outlets of all flows to keep water level. Surface storm water runoff is properly designed as storm water runoff from the catchment areas are drained off through controlled regulators. There exist many waterways such as tributary rivers, irrigation channels, urban drains and ponds/reservoirs. The SSKB is planned to cross the Rupsa river as well as these waterways to maintain necessary discharge capacity so as to keep opening horizontally and vertically by structures. Simultaneously, such road crossing structure control a horizontal alignment of the SSKB, and accordingly road embankment height is also affected.

Based on site investigations and technical clarification with agencies concerned, specified location and type of structures other than Rupsa Bridge are tabulated in Table 6.2.4.

Table 6.2.4 Location and Type of Road Crossing Structure

(1) Canal Bridges

Station	Name	Unit	Length	Span	Remarks
1+850	Hatia River	M	90	3	PC I-Girder
9+340	Molonghata Canal	M	30	1	PC I-Girder

Note : Station denotes the value on the route of Alternative-1.

(2) Box Culverts

Station	Name	Unit	Length	Height	Width	Remarks
2+218	Alutala Canal	M	25	1.5	4.0	2-Cell
2+759	Aralia Canal	M	27	2.0	7.5	3-Cell
3+658	Narikal Baria Canal	M	36	5.0	16.5	3-Cell
4+525	Karate Canal	M	23	2.0	4.0	2-Cell
4+643	Laurir Canal	M	23	3.5	14.0	4-Cell
4+881	Moyur Canal	M	23	4.0	12.0	3-Cell
5+265	Khetra Canal	M	23	4.0	12.0	3-Cell
5+495	Malekana Canal	M	30	2.0	12.5	5-Cell
8+861	Besar Canal	M	30	4.0	8.0	2-Cell

Note : Station denotes the value on the route of Alternative-1.

2) Irrigation

Pipe culverts are to be installed where road embankment interrupt water flow of irrigation. Therefore, 1.2m diameter pipe culvert is planned to be installed at 100m intervals for equalizing difference between potential head of upstream and of downstream.

3) River/Canal

Because the canals are interconnected, the water level remains same everywhere within the enclosed area. By interviewing the local people, it is established that Standard High Water Level (S.H.W.L.) is 1.9m +PWD in the west and 1.6m +PWD in the east side of the Rupsa river.

Fig. 6.2.8 shows cross sections of waterway and dimensions of crossing structures

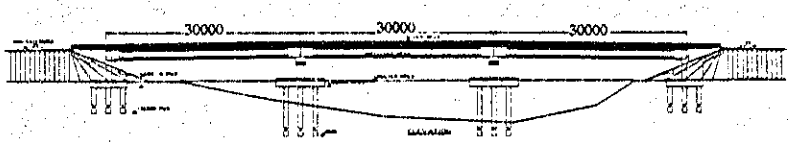
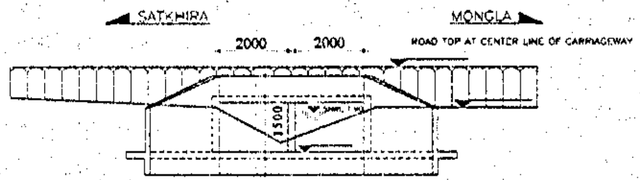
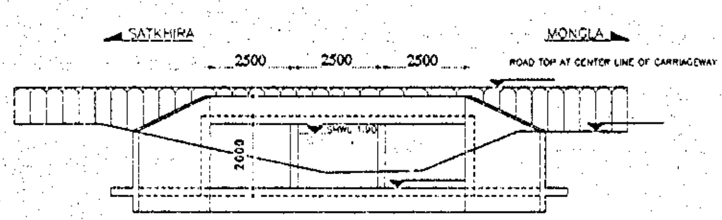
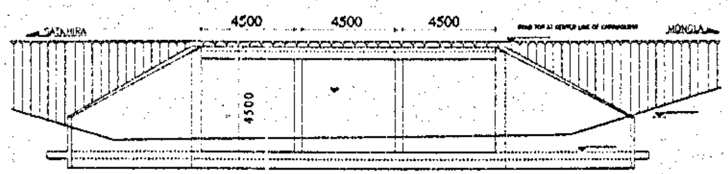
No.	River/Canal	Cross Section	Chainage	Free Board (m)	Head Loss (%)	Remarks
1	Hatia River		STA.1 +847.6	4.50	23.0	
2	Alutala Khal		STA.2 +218.5	0.30	20.0	
3	Aralia Khal		STA.2 +760.5	0.30	20.0	
4	Narikal Baria Khal		STA.3 +660.0	1.80	30.0	

Fig. 6.2.8 (1) Dimensions of Crossing Structures

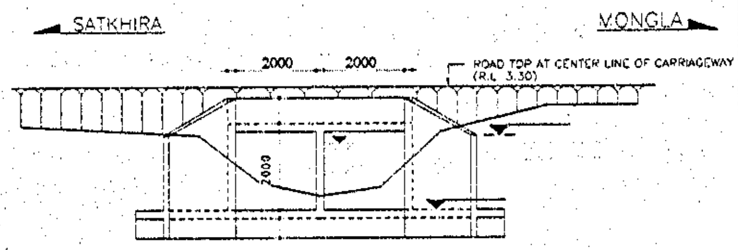
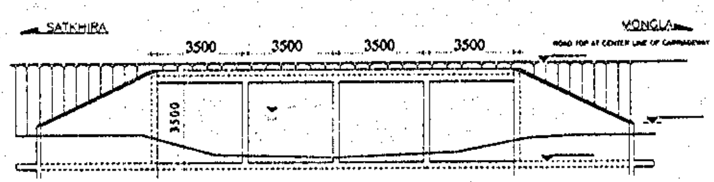
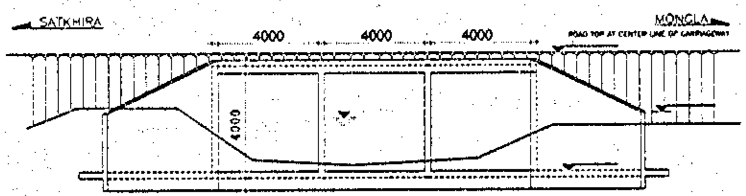
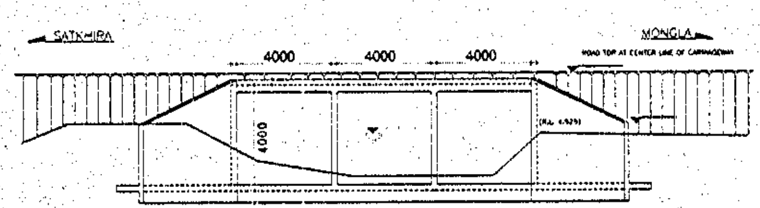
No.	River/Canal	Cross Section	Chainage	Free Board	Head Loss	Remarks
5	Karate Khal		STA.4 +525.0	0.30	20.0	
6	Laurir Khal		STA.4 +643.0	1.80	20.0	
7	Moyur Khal		STA.4 +882.0	1.80	24.0	
8	Khetra Khal		STA.5 +266.5	1.80	13.0	

Fig. 6.2.8 (2) Dimensions of Crossing Structures

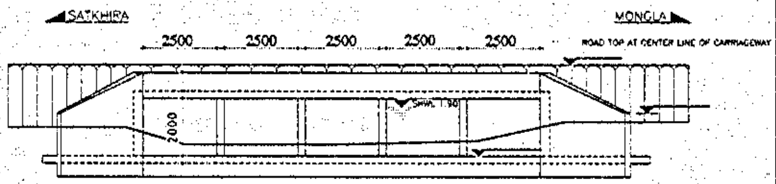
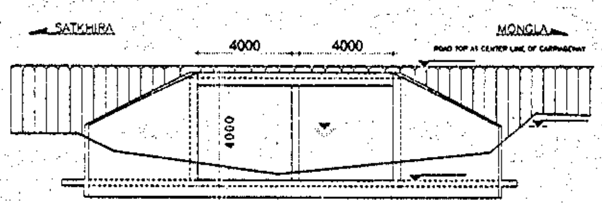
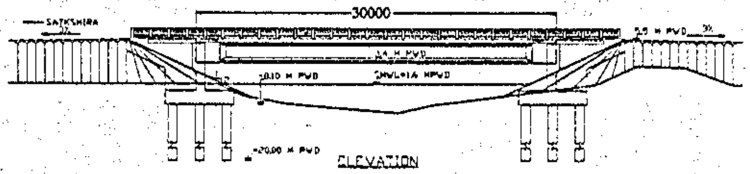
No.	River/Canal	Cross Section	Chainage	Free Board	Head Loss	Remarks
9	Melekana Khal		STA.5 +495.5	0.30	8.0	
10	Besar Khal		STA.8 +860.5	1.80	20.0	
11	Gupi Nadi River		STA.9 +339.0	1.80	0.0	

Fig. 6.2.8 (3) Dimensions of Crossing Structures

(2) Road Drainage

1) General

Surface water disposal consists of road surface drainage and roadside drainage. Namely, road surface drainage is set for removing rainfall from road surface quickly, because of keeping to drive safety in rain and protecting pavement structure from water. On the other hand, roadside drainage is set for guiding to the river or canal, because of protection from floods.

2) Road Surface Water

Two road drainage systems are studied, namely normal crossfall section and sections with superelevation or with access road where storm water is apt to retain at lower portion or catchment area become large enough to be intercepted.

At the normal crossfall section, neither ditch nor pipe culvert is provided as storm water may drain naturally on the slope of embankment up to roadside drainage.

At the sections with superelevation or with access road, ditch is installed in the median or outer separation due to interception of converged road surface water and storm water is guided to roadside drainage through pipe culverts. Inverted bottom level is to be set keeping discharge capacity of pipe culvert up to 80%.

Inlet or catchbasin should be placed at the following points:

i) The sag point on the road profile,
ii) The points accessible to existing waterways,
iii) Not more than 50m intervals

3) Roadside Drainage

Roadside drainage should make full use of the space after embankment material is excavated by side borrow. The roadside drainage that is deemed having enough discharge capacity should connect to the existing canal or river.

6.2.4 Design of Pavement

Prevailing pavement works in the study area is carried out by a manpower-oriented method that a flexible pavement consists of sand bed overlaid by brick flat soiling as sub-base course, base course laden with bricks (Herring bone bond) or of water bound Macadam and surface dressing with semi-grouted premixed seal coat, while a rigid pavement is of Herring bone bond overlaid by Portland cement concrete. However, Khulna-Mongla Road of which pavement structure comprises 5cm thick wearing course, 8cm binder, 10cm water bound Macadam base course and 25cm sub-base course has performed good durability against daily traffic of 1,000 - 1,500 veh./day including 70% heavy vehicles. Main factors for such good durability are pointed out as follows;

1) The level of sub-grade is located above ground water level;
2) The roadbed embankment is settled sufficiently so as to distribute axle loads appropriately; and
3) Total structure number may be good enough against cumulative equivalent single axle loads.

Since the SSKB is designated as a major arterial road to accommodate considerable road transport comprising heavy vehicles such as large buses and trucks including truck tractor-semitrailer combination targeting 40 ft container transport in future, the pavement structure should be designed properly to perform well durability as modern design methods demonstrated by experimental tests or past performance.

However, there exist ambiguous factors in the study area such as cumulative equivalent single axle loads during design life stemmed from future traffic volume and its axle load distribution, roadbed resilient modulus and coefficient of relative strength to structure number.

It is recommended that the pavement design procedures prevailing in Japan are adopted to the study from following technical viewpoints;

1) Natural conditions such as high ground water level and annual rainfall are similar; and

2) Loading conditions of heavy vehicles and their axle load distribution are deemed equivalent.

According to traffic demand forecast presented in Chapter 3, design traffic of heavy vehicles are in between 1,000 and 3,000 veh./day, which means the road classification is C and it is required to secure Total Structure Number of 32 and Surface Thickness of 15 cm.

Since Design CBR is expected 4 due to the post evaluation of Khulna-Mongla Road, the pavement structure is proposed as follows.

Plant-mixed Asphalt Concrete Surface :Wearing & Binder Course	15cm
Asphalt Treated Base Course	10cm
Mechanically Stabilized Base Course	15cm
Sand Sub-base Course	35cm

6.2.5 Design of Road Supporting Facilities

The objectives of the road supporting facilities are to maintain smooth and safe traffic flow as well as to ensure the benefits of the users.

Following road supporting facilities are considered:

- Traffic Signs
- Traffic Markings
- Road Lighting
- Slow-moving Track
- Traffic Barriers
- Toll Gate
- Bus Stop
- Pedestrian Crossing Facilities
- Traffic Signals

(1) Traffic Signs

Traffic signs are one of the traffic control devices which are used to regulate, warn or guide road users. Traffic signs should meet following four (4) requirements:

i) to fulfill an important need
ii) to command attention
iii) to convey a clear, simple meaning
iv) to give adequate time for proper response

Three kinds of signs are designated, namely, regulatory signs, warning signs and guide signs to assist traffic safety and for the convenience of users.

1) Regulatory Signs

Regulatory signs inform road users of traffic law or regulations and indicate the applicability of legal requirements that would not otherwise be apparent.

Regulatory signs are generally circular, rectangular, triangle, lozenge, inverted triangle in shape.

2) Warning Signs

Warning signs are used when it is deemed necessary to warn traffic of existing or potentially hazardous conditions on or adjacent to a road.

Warning signs are generally lozenge in shape, however, there are a few which are rectangular. The colors shall be black symbols and borders of yellow background.

3) Guide Signs

Guide signs convey to drivers information such as destination and distance, service facilities and route confirmation. These signs play an important role in informing drivers in advance of correct traffic lane for making an exit or entry at merging/diverging points.

Guide signs generally consist of destination sign, directional sign and distance sign.

(2) Traffic Markings

Traffic markings include all traffic lines (both longitudinal and transverse), symbols, words, object marks, delineators, cones or other devices, except signs that are applied or attracted to the pavement or mounted at the side of the road to guide traffic or warn of an obstruction.

Road markings are particularly important to help in regulating traffic, warning or guiding road users. All road markings, like other traffic control devices should be uniform in design, position and application so that they may be recognized and understood immediately by all road users. Furthermore, all markings on road should be reflective.

Most of the traffic markings are painted on pavement and can be divided into the following types:

i) Longitudinal lines
ii) Transverse lines
iii) Other markings

A longitudinal line consists of either a solid line or a broken line or a combination of both marked in the direction of travel. The dimensions of longitudinal lines are shown in the manual. The thickness of longitudinal lines should be 3 mm to 5 mm when applied by hot application and 1.0 mm to 1.5 mm by cold application.

Transverse lines are marked across the road and are generally associated with intersection. They should be wider than longitudinal lines because of avoiding narrowing view caused by low angle. They shall be of non-skid materials and shall protrude 5 mm above the level of road surface.

Other markings are included diagonal and chevron markings, words, numerals and symbols which are painted on pavements to convey guiding, warning or regulatory message to drivers. They should be elongated in the direction of traffic movement in order that they may be legible at the maximum distance.

Post delineators are one of the traffic markings which are effective aid for night time driving. The purpose of delineators is to indicate the road alignment. Post delineators are simply reflector units mounted on suitable supports and reflector units usually are made of glass, plastic or reflective sheeting. Post mounted delineators are beneficial for horizontal curves over five (5) degree.

The road markings shall be white and yellow only for some auxiliary areas according to the manual.

(3) Road Lighting

Lighting may improve safety of road traffic and the ease and comfort of operation thereon. Statistics indicate that night time accident rate is higher than that during day time hours, which to a large extent may be attributed to impaired visibility. There is evidence that in urban area and suburban area, where there are concentration of pedestrians, fixed source lighting tends to reduce accidents.

The recommended standard for road lighting and its application will be described as follows:

Description	Bridge, At-grade Intersection, Merging/Diverging	Toll Plaza
Design Illumination Intensities	15 lux	20 lux
Selection of Luminaries	Semi Cut-off type	Flood Light
Light Source : Sodium Lamp	Low Pressure	High Pressure
Ballast	Constant wattage and high-power-factor type	Power-factor correction, current limiting and low wattage losses type
Lighting Columns	Height : 13 m, Slope Angle : < 5°	25 m high-mast
Foundation	Base plate type	Base plate type

(4) Slow-moving Track

Rupsa Bridge is located in the urbanized area of Khulna and major users are expected local commuters although major benefits are brought from transport cost savings of heavy trucks and long distance buses on regional and arterial road. It is necessary to deliberate transport means for citizens such as auto-rickshaws and motorcycles. On the contrary, one of the salient features of the traffic characteristics in the study area is a large number of slow-moving vehicles such as motor bikes and auto-rickshaws. As the mixture with such slow-moving vehicles may reduce the traffic capacity as well as traffic safety, it is preferable to separate them from fast-moving vehicles.

Therefore, the track for the slow-moving vehicles is planned to be contiguous to the fast-moving traveled way. Additional track for slow-moving vehicles is provided in the stretch where a considerable volume of auto-rickshaws, motorcycles and so forth are estimated, as the slow-moving track may contribute traffic safety and steady flow of traffic.

Separated slow-moving track is provided because no passing/overtaking on the traveled way is allowed on Rupsa Bridge.

(5) Traffic Barriers

Traffic barriers are classified into basic groups of longitudinal and crash cushions according to functions. Longitudinal traffic barriers perform by redirecting errant vehicles away from the roadside hazard. Crash cushion barriers function primarily by decelerating errant vehicles to a stop. This study only considers longitudinal traffic barriers.

There are three types of traffic barriers systems, rigid, semi-rigid and flexible. The rigid barriers do not deflect on impact, resistance is achieved through the combined flexure and tensile strength of rail in the semi-rigid, and the flexible undergo considerable dynamic deflection on impact.

Traffic barrier warrants are delineated in terms of geometry and location of roadside features and traffic volume is also a decision factor for the case of median barriers. Height and slope of embankment and roadside obstacles are principal features.

Guard rails are planned to be installed at the following locations:

1) High embankment sections (H>3.0 m)
2) Bridge and box culvert approaches
3) Box culvert wing walls and bridge piers
4) Guide signs

For being clear of roadside obstacles such as bridge piers or permanent buildings, a 10m long installation adjacent to the traveled way is recommended as the minimum.

(6) Toll Gate

In the planning and design of the toll gate, considerations have to be made regarding the road, topographical and other conditions as well as the system for the control and operation of road. The system of toll collection has to be studied at the same time.

1) Toll Levying System

The flat tariff system is adopted because a toll is imposed only on Rupsa Bridge.

2) Determination of Number of Lanes at a Toll Plaza

Number of booths to be provided at a toll plaza for the year 2015 is determined from traffic volume (interval of arrival), service time per vehicle and service level provided (planned length of queue).

Two (2) lanes are required based on the basic hourly traffic volume (620 veh./hr), the service time per vehicle (8 second) and the service level (3 veh./lane), and additional one lane at the center is provided as reversible lane for high peak hours because commuter traffic might increase beyond forecast.

3) Geometric Structure at Toll Plaza

The width composition of lane and island is 3.0m and 2.0m respectively. Refuge islands of 30m long standard type provide a foundation for toll booths and protection from approaching vehicles.

The vertical gradient is below 2% in principle, and the range to be governed this criteria is 100m long on both sides of toll gate.

The toll gate portion is of cement concrete pavement and the range is 50m on both sides of toll gate.

(7) Bus Stop

Most of area within the sub-corridor of the Southern Section of Khulna Bypass (SSKB) will be developed into residential, commercial and industrial areas, so that there will be many bus routes on the sub-corridor of the SSKB in future. The provision of exclusive space for buses to stop is required in order to avert disturbing traffic flow.

A stopping space of 15m long and 3m wide together with taper of 24m long is sufficient for one (1) large bus to stop with minimum disturbance to other vehicles on the through traveled way.

The location of bus stops is determined in accordance with the following criteria:

1) Places close to pedestrian crossing facilities because bus users usually return to the same place, but on the opposite side.
2) Places where enough space for the provision of bus bay is available within the R.O.W.
3) Places where the stopping and starting movement of buses are unlikely to be interfered with by vehicles from minor accesses.

(8) Pedestrian Crossing Facilities

There are two types of facilities, at-grade crossing painted on the pavement surface and elevated pedestrian bridge. No underpass by box culvert is planned because of security and flooding problems.

As a general policy it is proposed that pedestrian crossing facilities are located at approximately 500m interval where high pedestrian demand is forecasted. Additional crossing facilities will be provided later where land adjacent to the SSKB is still substantially undeveloped.

The criteria for selection of pedestrian bridge location are that existing demand will arise from the public facilities such as school, market, hospital and other public buildings.

(9) Traffic Signals

Traffic signals provide for the orderly movement of traffic at-grade intersections to reduce the likelihood of collisions.

In installation of traffic signal in order for drivers to respond effectively to these basic requirements has to be considered:

1) The amount of light researching the driver's eye.
2) The position of signal in the driver's field of view.
3) The ratio of signal-to-background contrast.
4) The amount of competing information sources (visual clutter or "noise").
5) The degree to which the appearance of signal is expected.
6) The degree to which the precise location of signal is known.
7) The degree to which the message conform to the driver's knowledge and expectations.

Generally, the precise location should consider the lateral and vertical angles of sight toward signal as determined by;

1) typical driver's eye position;
2) vertical design; and
3) vertical, longitudinal and lateral position of signal face.

The recommended locations for various types of traffic signals are shown in Table 6.2.5.

Table 6.2.5 Locations for Various Types of Traffic Signals

Type of Traffic Signal	Location	
Overhead type (Mast arm mounted)	On the left side of traffic on the roadway	
Post or Pole mounted signal type for vehicles and pedestrians	On the roadway	Each side of pedestrian crossings
	On the roadway entering	Left side of pedestrian crossings
	On the median	Each side of pedestrian crossings

6.3 Bridge Engineering Design

6.3.1 Rupsa Main Bridge

6.3.1.1 Substructure Design

(1) Pier Structural Type

Piles are required from the soft ground condition as shown in Fig. 6.3.1, the soil boring logs and subsoil profile across the Rupsa River.

Three types of pier, where positions of pile cap differs, are compared as shown in Table 6.3.1. Evaluation factors are construction cost, period, and scouring effect. The table shows that pile cap position above water level (pile bent type) is recommended due to its structural characteristic, safety of construction, and most of all the construction cost, which is more economical among other options.

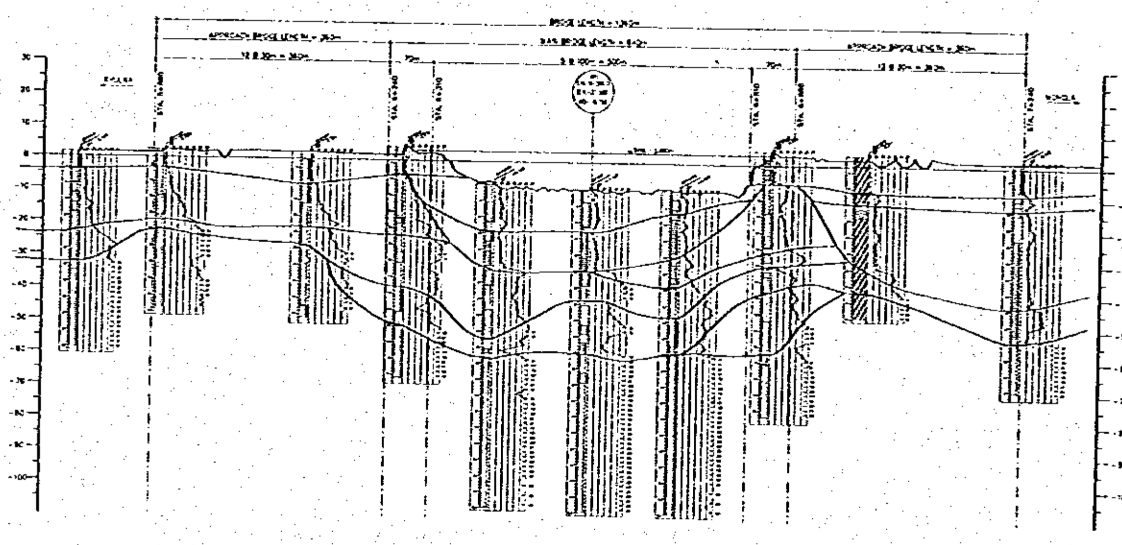
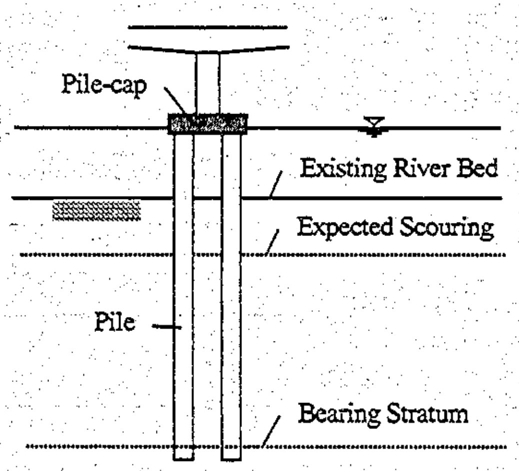
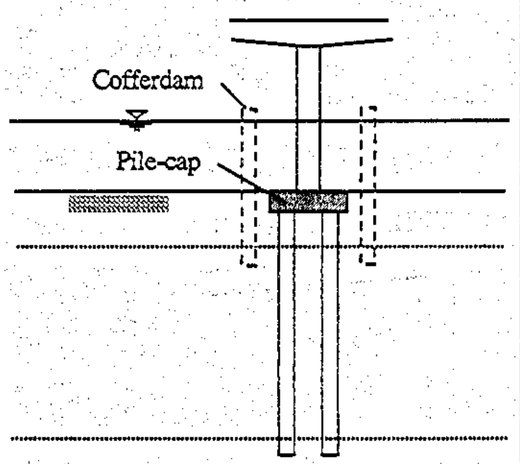
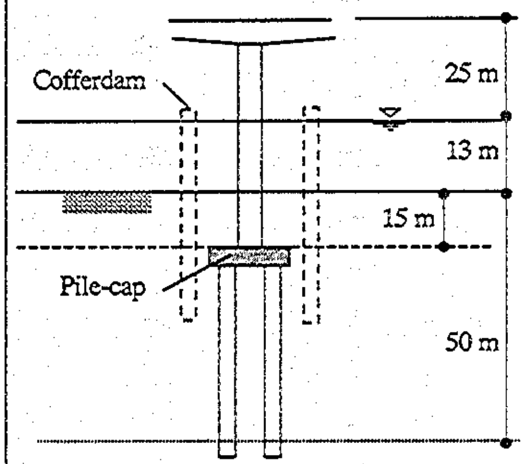


Fig. 6.3.1 Soil Boring Logs and Subsoil Profile across the Rupsa River

Table 6.3.1 Comparison of Pier Types

Type	Pile-cap above Water Level (Pile Bent)	Pile-cap below Existing River Bed	Pile-cap below Estimated Scouring Level
Position of Pile-Cap			
Scouring Effect	Scouring depth is the smallest, because only the piles disturb the flow and cause the scouring. △	Deeper than Pile bent type, because the pile-cap affects scouring. ×	Non affected. ○
Construction Period	Shortest ○	Middle △	Long ×
Construction Cost	Lowest cost because of no need for preparing cofferdam. ○	Medium cost because of need for deep cofferdam. △	Highest cost because of need for deeper cofferdam. ×
Estimation	Recommended		

(2) Pile Type and Size

According to the subsoil investigation, bearing strata lie at a depth of about 50m below the riverbed. For such a deep range, RC precast driven pile is not possible. RC bored pile is commonly used in Bangladesh. Tubular steel pile is also a possible option for the bridge. The size of pile is determined by geotechnical, structural and serviceability requirement. The design pile types are shown in Fig. 6.3.2.

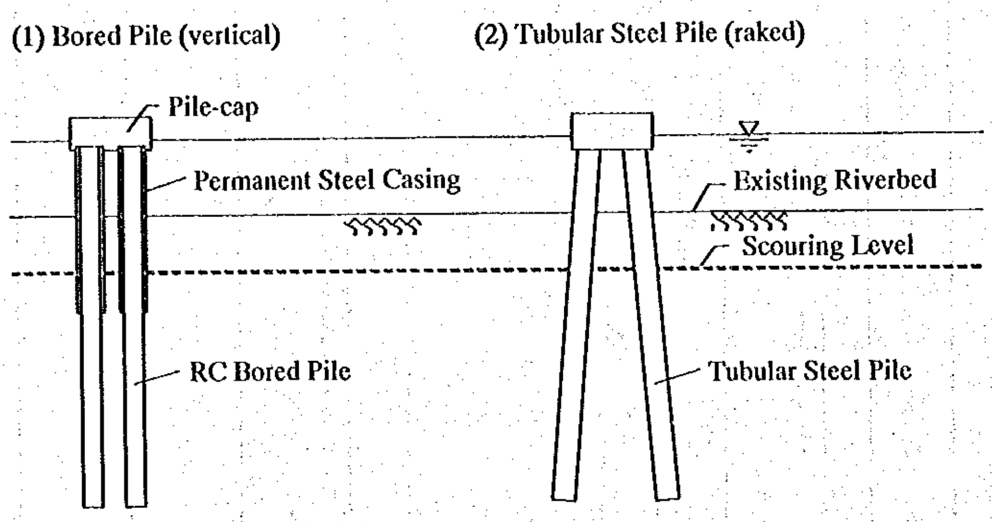


Fig. 6.3.2 Pile Types

The two types of piles are designed and economically compared for the diameters ranging from 1.5 to 3.0 m under the constant reaction forces of a common superstructure, 7-span continuous PC box girder. Wind load and temperature change are the governing forces in transverse and longitudinal direction respectively. Fig. 6.3.3 shows the construction cost of substructure per pier for different pile types and diameters. Unit rates were taken from the report for the Phase 1 Study and amended according to the hearing from contractors specialized in piling.

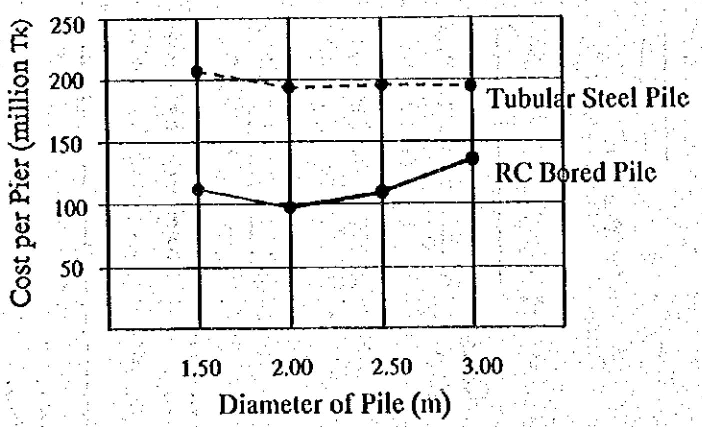


Fig. 6.3.3 Cost Comparison of Pile Type and Size

From the figure, the RC bored pile of diameter 2.00 m is the most economical, but the diameter needs as deep as 100 m of construction to ensure geotechnical capacity. Therefore, in design, the diameter of 2.50 m, for which requires a less construction depth of 75 m, is finally decided for more reliable construction though it is a little costlier.

The cost of a pier using tubular steel piles comes much higher than that of using RC bored piles. Because, the cost portion of driving equipment in case of tubular steel piles is very high about 25 % of the total piling cost, although very little number of piles only 32 piles for diameter 2.50 m or 48 piles for diameter 2.00 m are scheduled. On the other hand, the equipment cost of RC bored piles is small so that the construction cost per bored pile is insignificant.

6.3.1.2 Superstructure Design

(1) Girder Type and Construction Method

At the Phase 1 Stage of the Study, a conventional PC box-girder was recommended as the most suitable type of superstructure for the main bridge. Here at this stage an extradosed PC box -girder, relatively a new technique, is to be introduced additionally as an option to the conventional one, and is studied especially from economic point of view.

A conventional PC box-girder bridge usually holds prestressing tendons inside the box section for the whole length. But on the other hand, the new type is equipped with the cables outside the box section in area of negative moment of the girder, where the cables are diagonally supported by pylons placed on intermediate piers. These exposed cables enable the prestressed section more efficient by increasing eccentricity to the prestressing force. This type of bridge looks like a cable stayed girder bridge at a glance because of the set of the diagonal cable and the pylons, and also its characteristics are positioned in-between conventional PC box-girder and cable stayed PC box-girder bridge in general.

The specialty of the new type over the conventional one is not only on the construction cost of the main bridge, but also the merits of the extradosed is that it can reduce the depth-to-span ratio, which allows to lower the superelevation and thus save the overall bridge length including the approach bridge.

Balanced cantilever segmental technique will be the most suitable method for erecting either type of PC box-girder bridges. This allows the navigation beneath the bridge even during the erection.

Cast-in-place segmental method is preferred to precasting method for the rather small construction volume of the main bridge. The precast segment method requires vast yards and facilities within a certain reach of the site where precast blocks are prepared and stockpiled until the erection. This kind of capital investment may meet the demands for such long bridges as Jamuna and Paksey, where the facilities may be repetitively taken advantage.

(2) Cross-sectional Design of PC Girder

A single cell box cross-section with inclined webs is recommended for a conventional PC box girder. Because, the single cell is the most efficient and the lightest cross-section compared with a multi-cell box. Also, the inclined webs give an esthetic view. It is of a great importance for a long span bridge to minimize self-weight of the superstructure. Cross-section with fewer webs is favorable for segmental construction work at site.

However, an extradosed PC girder requires a double-cell box section, which has an additional web in the middle, resulting from a wider deck required in order to anchor the outer diagonal cables.

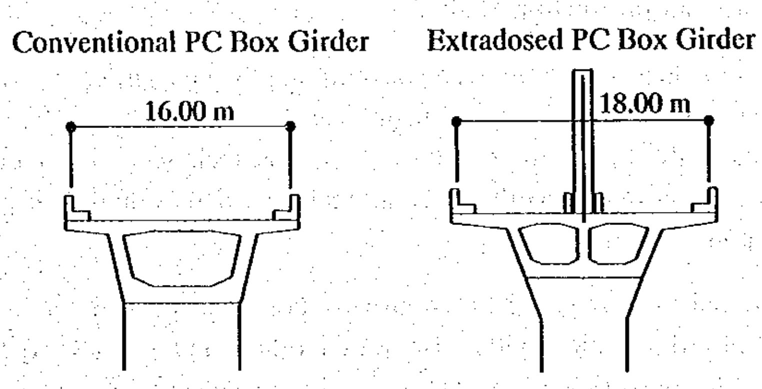


Fig. 6.3.4 Typical Cross-sections of PC Box Girders

(3) Longitudinal Design of Girder and Supporting Details

A continuous span arrangement is recommended. Reduction of number of expansion joints will not only improve rider comfort and economize the maintenance cost, but also the continuous beam is more structurally reasonable than that of simply supported. Moreover the continuity of the beam provides more degrees of freedom in selecting construction method. A continuous PC girder is suitable to the aforesaid balanced cantilever segmental construction method.

There are several options of continuous support that may be applied to the structure for the project or in other word, condition of connecting superstructure with substructure, and their combination, as shown in Fig. 6.3.5.

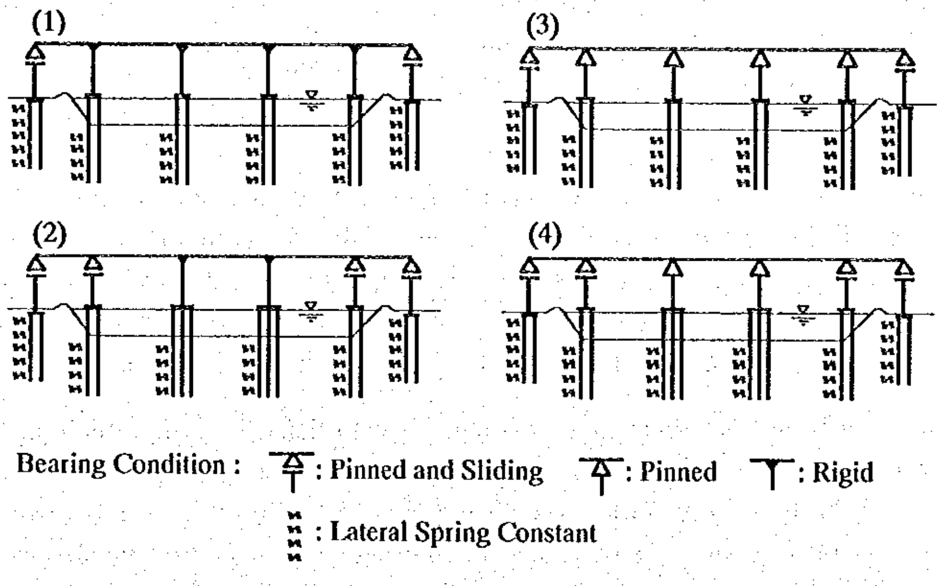


Fig. 6.3.5 Longitudinal Bridge Structural Models

"Rigid" connection will transfer bending moment, axial force and also shear force, on the other hand "pinned" will not transfer bending moment only, and "sliding" neither bending moment nor shearing force.

Regarding the forces working perpendicular to the structure such as wind force, there is no significant difference among these options.

The remarkable effect of these different connections will appear when the structure receives longitudinal forces, namely temperature changes or earthquake. Earthquake is fortunately insignificant in Khulna. The degree to which the structure has to be burdened with will depend on the constraints at the connections, length of bridge and temperature change.

Generally a structure having higher degrees of indeterminate can distribute the load into number of members, thus each element will share the forces evenly. Option (1) has the highest degrees, and (4) the lowest.

Also from viewpoints of initial and maintenance cost, the more the members are constrained at joints, the more economical, or that is to say bearing devices that help to release the constraints are expensive and may require maintenance in the future. In this case only two sets of elastomeric bearings are installed at the both end piers.

Moreover as the bridge is to be erected by the balanced cantilever method mentioned before, the main girder must be fixed temporarily to a column to maintain the balance during erection, if the bridge connection other than "rigid type" is adopted.

The option (1), the rigid frame structure, is the best among others so far mentioned. Notwithstanding the advantages accompanied with the rigid frame structure, there may be some problems that have to be verified by structural analysis before making decision on the structural type.

When the option receives expansion/contraction corresponding 7~38 °C as specified, it will behave accordingly, and especially the column base may have forces such as horizontal forces and bending moment which proportion the substructures. If the foundations can be designed against these forces within a reasonable and acceptable scale, (1) will be the best solution of the structural types.

In case that beams are short enough compared with the tall and flexible columns, shearing force and bending moment working at the base of the column should be small and the foundation structure resisting against the forces may be reasonable and acceptable in scale. As the Rupsa main bridge is planned to have slender and flexible pile bents for the substructures, the rigid frame structure is very much expected to be realized if other situations allow.

The structural analysis conducted by the Study Team resulted in reasonable number and diameter of piles for the intermediate piers, they consist of six piles of 2.50 m in diameter for a substructure, and that is in a scale reasonable enough.

The rigid frame type (1) was selected as recommended because of the economy, convenience for maintenance and during erection, and also the high performance due to the structural indeterminacy.

(4) Pier Protection against Boat Collision

Besides the bridge design against the boat collision load prescribed in Section 6.1.2.2-Design Loads and Environment Condition, a physical protection directly located on the pilecaps (such as fender made of concrete and timber) will be provided to alleviate collision impact on the piers to some extent as well as for decoration of the pilecaps.

The illustration shown in Fig. 6.3.6 is a type of fender in design.

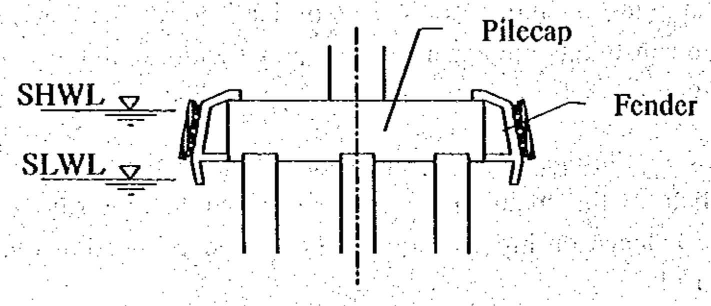


Fig. 6.3.6 Pier Protection Fender

(5) Alternatives of Superstructure

Herein the conclusions described so far are arranged:

a) The main bridge length is 640 m, and the main spans have to be 100 m or longer in order to accommodate navigation clearance.

b) Conventional and extradosed continuous PC box-girder types are compared.

c) Either type of the PC girders will be constructed by a cast-in-place balanced cantilevered erection method.

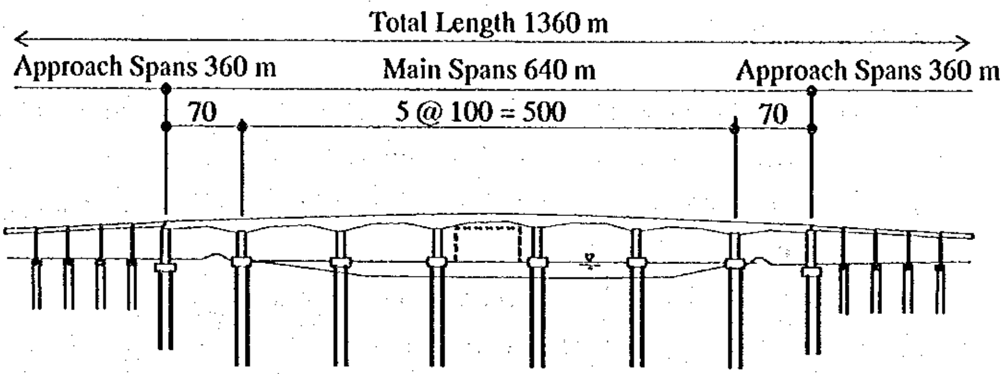
d) A single cell with inclined webs forms a cross-section of the conventional PC girder, and double-cell for the extradosed girder.

e) All the piers except the end piers are fixed rigidly to the superstructure; thus the super- and substructure form a rigid frame structure.

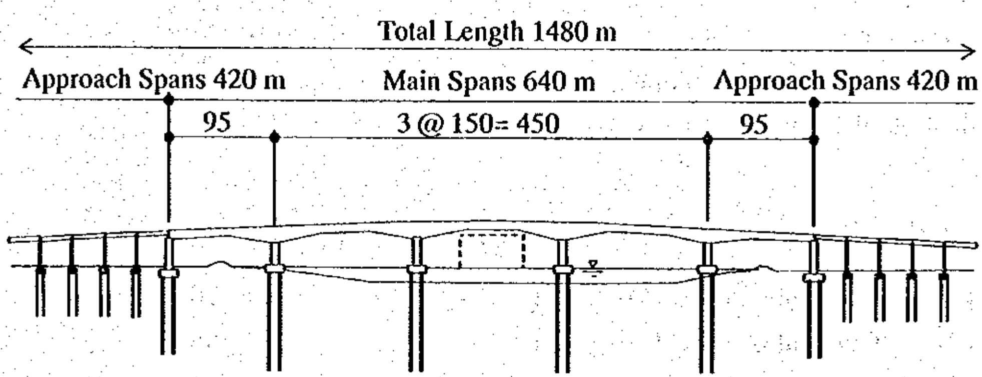
According to the conclusions mentioned above. The following options were established, studied and compared. The result is reported in Section 10.1.2-Evaluation of Bridge Alternatives.

Option	Girder Type	Number of Spans	Span Length (m)
(1)	Conventional PC Box-girder	7	70+5@100+70
(2)	Conventional PC Box-girder	5	95+3@150+95
(3)	Extradosed PC Box-girder	5	95+3@150+95
(4)	Extradosed PC Box-girder	4	120+2@200+120

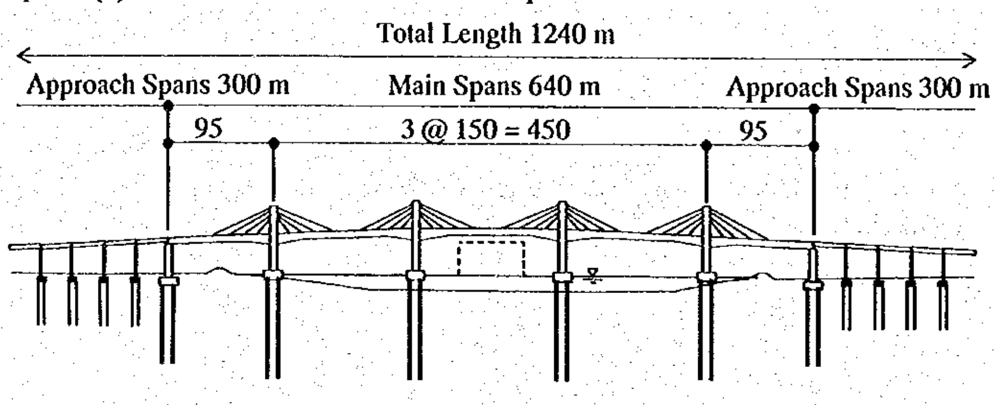
Option (1) : Conventional PC Box Girder 7 Spans



Option (2) : Conventional PC Box Girder 5 Spans



Option (3) : Extradosed PC Box Girder 5 Spans



Option (4): Extradosed PC Box Girder 4 Spans

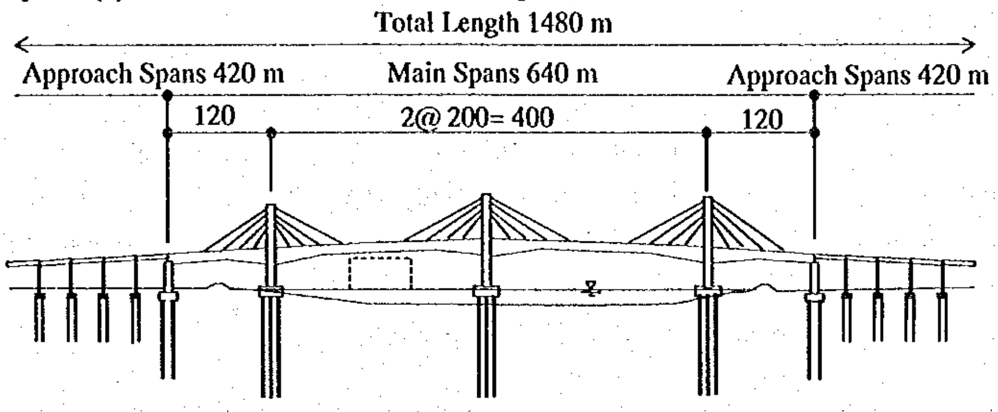


Fig. 6.3.7 Bridge Alternatives

6.3.2 Approach Bridge

(1) Pier Type

Structurally the most common types of pier are (1) Solid wall type, (2) Hammerhead type, (3) Multiple Column type and (4) Pile bent type. Among these multiple column type is the most common in Bangladesh. It is suitable also for the approach spans of the Rupsa Bridge because of its structural frame action against the transverse forces. Besides, the height of the tallest pier is 15 m that is much more than the economical height for other three types.

Regarding the cross section of column, square section is selected because it is more effective in terms of structural capacity than circular section, particularly when designed to resist moment.

Unlike conventional pier, no intermediate bracing is used because the height of the piers varies along the bridge axis and the existence of bracing at different level for different piers will seriously affect the uniformity of appearance.

(2) Abutment Type

In general abutments cover two basic categories: pile bents or spill through abutment and gravity types or full (closed) abutments. The closed design prevents the approach embankment from spilling out in front of the structure while the pile bent abutment allows the embankment slope to spill out in front of it. An intermediate solution is a partially closed abutment that allows a portion of embankment slope in front of the structure and it is quite common in Bangladesh.

The wing wall is normally parallel to the roadway. It is designed as cantilever with abutment wall and pilecap requiring no additional foundation for it. Structure of this type is also adopted for the Rupsa Bridge because of its satisfactory performance so far in Bangladesh. Besides it is more economical than full closed abutment and requires less maintenance than spill through abutment.

Safe back fill height and the corresponding cost are the decisive factors to decide the abutment height where the ground is soft. The soil boring logs show the existence of very soft soil having SPT 0 to 5 up-to a depth of 4 to 5 m at west approach and from a depth of 6 to 9 m at east approach of the bridge. From this information, it is understood that pre-consolidation will be necessary. The surcharge load and duration are studied in Chapter 4.2.9- Settlement and Stability of Embankment and therefore the height of abutment is limited to 5.5 m.

(3) Pile Type and Size

The soil boring logs show the bearing strata lying at a depth of 25 m to 55 m. For this range of depth RC precast driven pile is not possible and decision in favor of RC bored pile is obvious because other alternative i.e. steel pile is much more expensive. Besides, RC bored pile is quite common in Bangladesh.

The soil boring logs also show that the top soil is too soft to retain the pressure of fresh concrete and hence permanent steel casing may be necessary for a depth of 10 to 12 m. As the permanent casing is very expensive, attempt is made to keep the number of piles as low as eight only. The size of pile is determined from the geo-technical, structural and serviceability requirement of the structure. A diameter of 0.90 m is designed.

(4) Standard Girder Type and Arrangement

Prestressed concrete girder is selected in preference to RC girder because of the fact that the RC girder is often found to be cracked in maximum stress zone. Besides the RC girder will result in short span and clumsy looking bridge because of having to many piers.

In design of PC girder, only the AASHTO's standard section is considered in order to promote standardization of design and construction practice which will help in reduction of bridge costs. As practice in Bangladesh, cast insitu RC deck composite with the PC girder is selected for the approach bridges. The deck is designed to have a thickness of 0.20 m assuming support on seven girders spaced at a center to center distance of 2.40 m.

(5) Standard Span Length

To find the most economical span length for the approach bridges, both superstructure and the substructure are designed for different span length ranging from 20 m to 35 m.

Fig. 6.3.8 shows the graph of total cost of bridge per m length for different span length. This estimate is based on the unit rate taken from the Phase 1 Study report, considering the market price. The graph shows that 30 m is the most economical length of span and the approach bridges are designed on this basis.

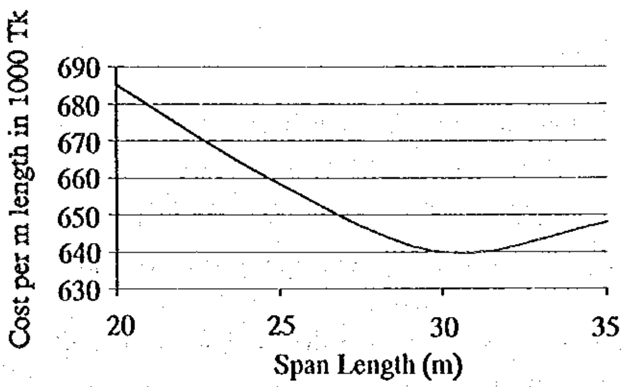


Fig. 6.3.8 Comparison of Cost for PC Girder Bridge

(6) Deck Continuity Design

Deck continuity design is adopted to reduce the number of expansion joints. Maximum continuity length that can be allowed without expansion joint is studied for temperature variation of 7~38 °C and found that only two joints are necessary on either boundary pier between the main bridge and the approach bridges. For this study all the girders are assumed pinned with the supports including abutment through elastomeric bearing as shown in Fig. 6.3.9. Exception is only the boundary piers where expansion is allowed. Piers being connected with the superstructure by pin will allow rotation and share the longitudinal forces with each other.

Abutment is also considered pinned to avoid expansion bearing over it. Because, maintenance of this expansion bearing is difficult and abutments are often found to be propped against superstructure due to filling up of gaps by dirt. So, it is better not to have any expansion gap over abutment.

As shown in Fig. 6.3.9, deck is cast against the edge of deck of the adjacent span, having dowel connection with each other at their mid-depth.

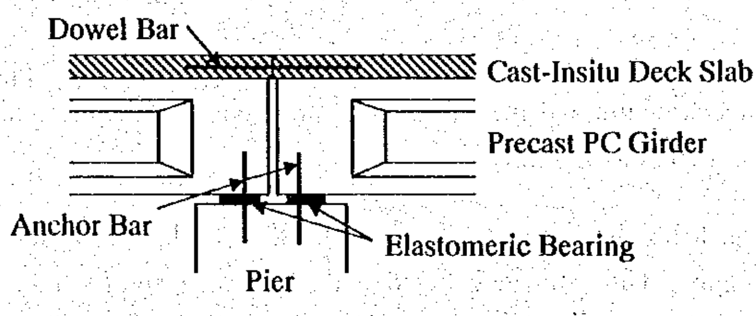


Fig. 6.3.9 Deck Continuity Detail

Analysis shows that the piers can accommodate the thermal expansion/contraction of an entire 360 m long approach bridge and hence no expansion joint is allowed other than two on the two boundary piers.

6.3.3 Canal Bridges and Culverts

(1) Design High Water Level and Required Clearance

All the canals crossing the proposed approach road to the Rupsa Bridge fall within the area surrounded by flood embankment. Most of the canals are connected with each other and their final confluence point is the Rupsa River where their flow is regulated by sluice gate. The source of water is mainly the local rainfall and occasionally the Rupsa River at the time of high tide if the gate is open. Even if there is intense rainfall within the enclosed area, the floodwater does not stand because it can easily be drained out to the river by opening the gate during low tide. Unless the gate is open, there is practically no flow of water in the canal.

Because the canals are interconnected, the water level remains same everywhere within the canal system. Based on the site survey including interviewing the local people, the following design SHWLs (standard high water levels) are established:

West Bank of the Rupsa River: 1.90 m PWD
East Bank of the Rupsa River: 1.60 m PWD

Regarding the requirement of freeboard, following three different classes are established based on the canal water traffic survey:

Water Traffic	Freeboard provided (m)	Structures falling under category
No navigation	0.30	4 Culverts
Small boat	1.80	5 Culverts & Molonghata Bridge
Boat with sail	3.50 (*1)	Hatia Bridge

Note *1: Same freeboard as that of the existing Gallamari Bridge located at upstream of the Hatia Canal.

(2) Bridge over Hatia Canal

The approach road crosses this canal making a skew angle of 84 degree. The bank to bank distance is 71 m along the bridge axis. A 90-m long bridge is provided having three spans of 30 m each. The span length being same as that of viaduct is considered an advantage because same shutter and same launching method can be used here. The abutment and the pier head are kept perpendicular to bridge axis for simplicity both in design and construction. But the pile rows of piers are kept parallel to the flow of water to minimize the width of obstruction. The type of abutment is same as the abutment of the Rupsa approach bridges. Transition slabs are provided behind the abutments for smooth plying of vehicle.

The depth of water is about 7 m at pier location. Keeping the pilecap below the bed level will be expensive and time consuming and hence the bottom of pilecap of pier is kept at low water level. 0.90 m diameter RC bored piles same in size as that of the approach bridges are used for pier because the work is to be done in water. Once the bored piles are used for piers, the same type is also used for abutments.

The vertical grade of bridge and the road approaching it are designed for 100 m sight distance and 3 % grade. A freeboard of 3.5 m is provided above SHWL in the middle span only.

(3) Bridge over Molonghata Canal

Bank to bank distance across this canal is 33 m. A 30-m long single span bridge is provided here. Thus using the PC girder of same length and cross section everywhere in the approach bridges and the canal bridges will ultimately reduce the total project cost.

Providing 30 m opening in 33-m wide waterway, the channel is constricted by 3 m, but it does not matter because the flow is regulated by sluice gate of size much less than the opening provided. Abutment and pile types are same as those of the bridge over the Hatia Canal. Transition slabs are provided behind the abutments for smooth plying of vehicle.

Like the other canal bridge, the vertical grade of bridge and the road approaching it are designed for 100 m sight distance and 3 % grade. A freeboard of 1.8 m is provided above SHWL.

(4) Culvert Design

In total nine sites are selected for box culverts. Out of these three are skew by 70 to 80 degree angle. The width of culverts covers the full width of road embankment. The invert level is placed at least 0.30 m below the lowest bed level. Where there is navigation, 1.8 m freeboard is provided or otherwise 0.3 m freeboard is considered sufficient. Wherever the normal road level goes above the deck of culvert, fill is allowed on deck or otherwise the road level is raised to accommodate base and surfacing course on deck. Transition slabs are provided in front and the rear of culverts for smooth plying of vehicle. Wing wall is designed to integrate with the abutment wall for the sake of economy and better performance. Protective aprons are provided at both ends of culverts.