3.5 Construction Planning and Cost Estimates

3.5.1 Construction Planning

(1) Procurement of Material

The major construction materials to be used under the project based on the outcome of the preliminary design are summarized in the table below. Materials that are available locally are to be used as much as possible and imported materials are to be used in cases where the quality and quantities of materials available locally cannot be guaranteed. Imported materials can come through Chittagong Port and transported on the National Highway No. 1 or by sea to the construction site.

Table 3.5-1 Material Procurement

No.	Material	Source	Main Use
1	Cement	Local	Bridge
2	Aggregate and Sand	Local (Dinajpur, Sylet) and/or Import (Southeast Asia, Middle East)	Bridge
3	Re-Bar	Local	Bridge
4	Embankment Material	Local (Sylet, Dredged soil) and/or Import (Southeast Asia, Middle East)	Road
5	PVD	Import	Road
6	Bitumen	Import	Road
7	Base and Subbase course	Local (Dinajpur, Sylet) and/or Import (Southeast Asia , Middle East)	Road
8	Steel Pile Sheet Piles	Import	Bridge
9	Steel Girders	Import	Bridge

Source: JICA Survey Team

(2) Preparatory Work and Temporary Work

Before commencement of the construction works, topographic surveys, installation of temporary fences and gates, acquisition of permits and preparation of required documents such as shop drawings and construction plans shall be prepared by the Contractor. Other temporary works which are considered necessary are:

- Temporary site offices and accommodation in the temporary yard,
- Temporary roads for transporting equipment and materials

The Contractor will undertake the following works in the temporary yard:

- Storage and welding of steel sheet piles
- Production of ready-mixed concrete at batching plant
- Production of asphalt at asphalt plant
- Processing and storage of rebar and formwork
- Assembling of steel box girders
- Manufacturing and storage of PC-I girders
- Storage of heavy equipment and other equipment

For selection of the temporary yards, the location and geographical conditions should be carefully examined in consideration of the possible effects of floods and storm surges. Where necessary, the temporary yard should be filled up to a height above flood levels and it should be compacted to bear the load of heavy machinery and vehicular traffic. Furthermore, the temporary yard shall be enclosed by a fence, and necessary measures taken to ensure that trespassers do not enter into the yard.

The locations of the temporary yards need to be determined in consideration of the following factors:

- Transportation method and transport time from national/regional highways to temporary yard
- Transportation method and transportation time from temporary yard to each respective construction site
- Required size and duration of use
- Safety aspects

The required area of the temporary yard for the construction work is summarized in the table below. This is based on the assumption that the construction would be divided into three (3) packages, which is the current tentative plan that will be reviewed during the detailed design stage.

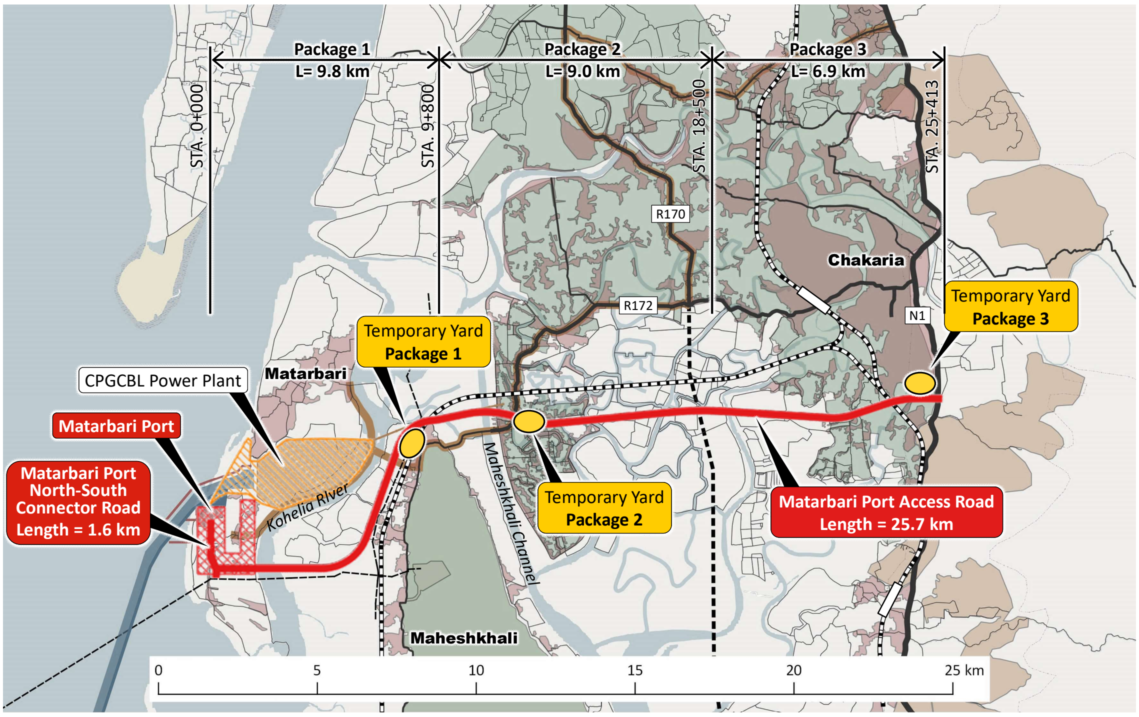
Table 3.5-2 Required Area for Temporary Construction Yard (ha)

Item	Package 1	Package 2	Package 3	Total
Stock Yard of Temporary Materials (Sheet Piles, etc.)	1.0	2.0	1.0	4.0
Stock Yard of Superstructure Material (Steel Box Girder, PC Girder)	0.2	0.9	0.7	1.8
Workplace for Formwork and Rebar	0.1	0.3	0.3	0.7
Heavy Machinery, Equipment and Materials	1.0	1.5	1.7	4.3
Asphalt and Concrete Plants	1.0	1.0	1.0	3.0
Office and Accommodations	0.5	0.8	0.9	2.2
Total	3.9	6.6	5.6	16.0

Source: JICA Survey Team

Considering the above areas, the following locations are proposed as temporary yards:

- Package 1: In Uttar Nalbila around Maheshkhali Hill (approximately 3.9 ha)
- Package 2: In Badharkhali near R172 (approximately 6.6 ha)
- Package 3: In Fashiakhali near the intersection of the project road and N1 (approximately 5.6 ha)



Source: JICA Survey Team

Figure 3.5-1 Temporary Construction Yard

(3) Road works

1) Preparatory Works

The first step will be to remove any obstacles, vegetation and top soil by use of backhoes and dump trucks. The vegetation and topsoil could be cleared in such a manner that they are used for protecting the embankment slopes. Also, since the road will be mainly constructed in salt farms or rice fields, it can be assumed that the ground condition of the existing ground is loose. In such a case, it is necessary to construct temporary drainages and/or temporary roads so that construction vehicles are able to move in a smooth manner. After removing the obstacles and leveling the ground, it is necessary to provide a certain degree of gradient that allows for natural drainage.

2) Temporary Roads and Drainages Works

After completing preparatory works, the next step will be to construct temporary drainages and temporary roads. Temporary drainage will be located on both sides of the temporary road so that water is drained away from the existing ground. For areas surrounded by the temporary roads, where necessary, the residual water from the salt farm areas will be drained using pumps or any other means. Excavated soil will be used as part of vegetation on the temporary road embankment slopes. The temporary roads should have a width of between 8 to 15 m and are to be used as part of the service road in their final state.

3) Soft Ground Improvement Works

For improving the soft ground condition to support embankment works, the following three (3) types of soft ground treatment are recommended:

- Excavation and replacement with suitable materials
- Consolidating and dewatering by applying a surcharge with Prefabricated Vertical Drains (PVDs)
- Application of the sand compaction piles (SCPs) method

Excavation and replacement method shall be used where the thickness of soft ground layers are less than 3 m. The excavated materials will be reused as topsoil to embankment slopes. The consolidation and dewatering method shall be applied where the thickness of soft ground is over 3 m. The compaction method shall be used only where consolidation and dewatering may not achieve the required settlement within the target construction period due to existing ground conditions such as sections near bridge abutments and box culverts.

4) Embankment Works (Filled up Ground and Subgrade)

The embankment shall be raised to a predetermined height successively while compacting each layer horizontally to a predetermined thickness from the lowest part, which is normally at 30 cm intervals maximum. This procedure necessitates a drainage gradient. The embankment materials shall conform to the specifications and will be transported via N1 or R172. The embankment works shall be constructed under close monitoring of the water content ratio in accordance with the specifications. When the target height is attained, the temporary road is converted to a permanent embankment section. In some sections, this embankment shall be used as a surcharge load for PVD consolidation.

Dredged soil and sand are to be used as embankment fill material. The desirable property of embankment fill material is "coarse grained soils more than 50% retained on or above the 0.075 mm sieve". The dredged soils, which are expected to be available near the project site, are "fine grain mixed sand (coarse grain content > 50%, 5% ≤ fine grain content < 15%, gravel content < 5%)". These results indicate that the material could be used as embankment fill. During the detailed design stage, it is necessary to select candidate locations where material sourcing through dredging will be undertaken so that the embankment fill material is procured from the project site.

However, since the embankment surface is sand it will be susceptible to erosion and therefore, necessary to: i) apply suitable clay or fine grainy gravel onto the surface of the embankment slopes or ii) install slope protection in order to prevent erosion. For the former case, the thickness of the suitable fill material should be 30 cm or more perpendicular to the surface as the minimum thickness necessary for growth of vegetation, and should preferably be 2 to 3 m width for compaction by machinery. Fine grainy gravel for protection is difficult to source from the vicinity of the project site, and needs to be procured from Sylhet or another country. The excavated clay material could be used as the top layer but its reinforcement would be necessary in that case.

During the construction stage, temporary drainages including vertical ones should be provided at certain intervals to prevent erosion of the embankment by rainfall.

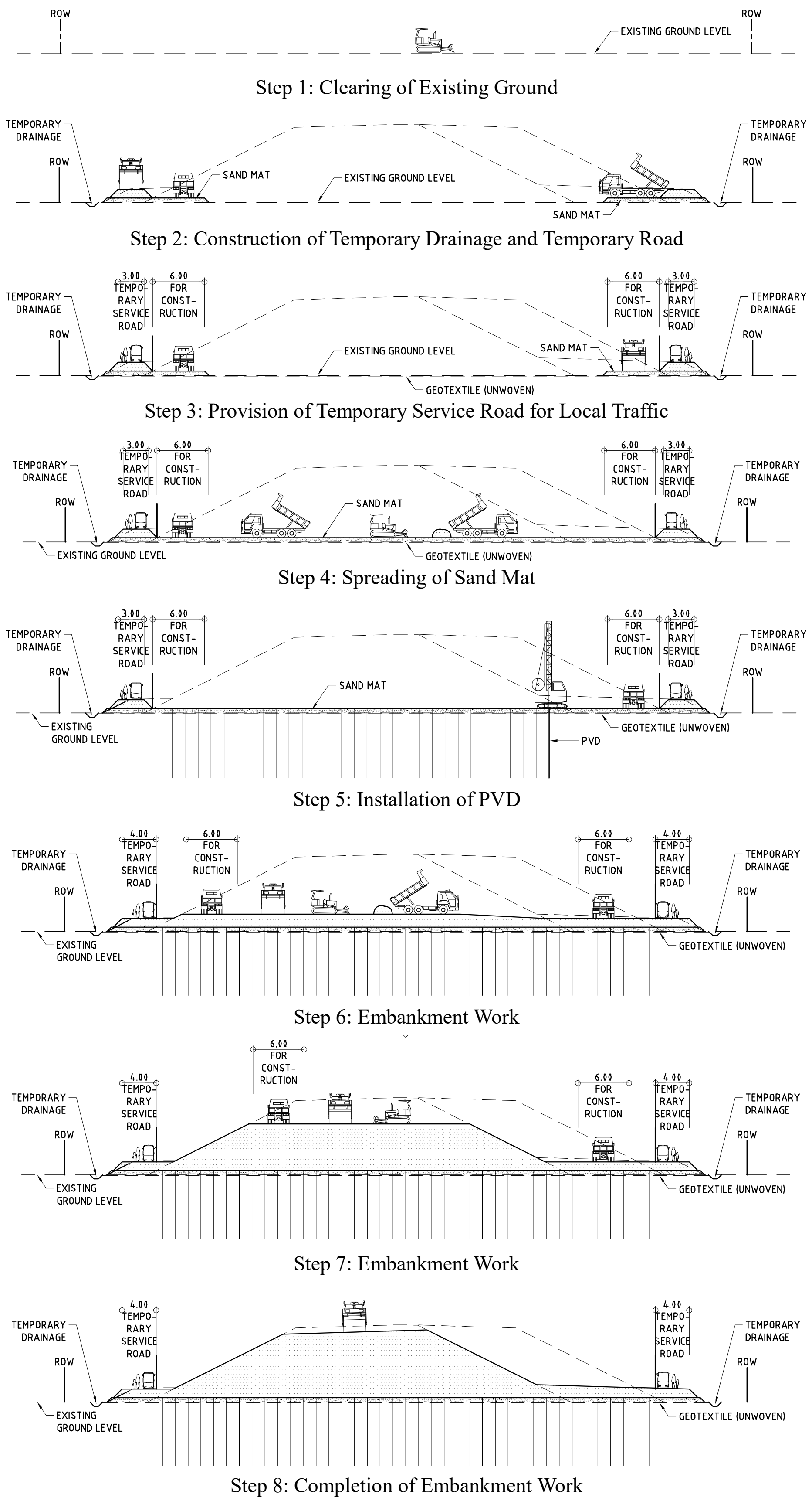
5) Subbase and Base Course Works

From the point at which the embankment works are completed or when residual settlement minimal, the sub base and base course works may commence after the leveling and cleaning of the embankment surface. The compaction should progress in layers and when the material is dry, the water content ratio should be adjusted to an optimum percentage by sprinkling water.

6) Asphalt Pavement Works

The asphalt required will be produced from the temporary yard during construction and the temperature control measures should be strictly adhered to during primary and secondary placement.

In order to adequately bear the loads from heavy vehicles travelling from/to the proposed Matarbari Port, polymer modified asphalt concrete should be used. In addition, semi-flexible pavements should be used at intersections where the pavement structure is expected to experience extra loads due to deceleration and acceleration of vehicles.



Source: JICA Survey Team

Figure 3.5-2 Example of Construction Procedure for Road Works

(4) Bridge works

1) Temporary works

Temporary Bridge

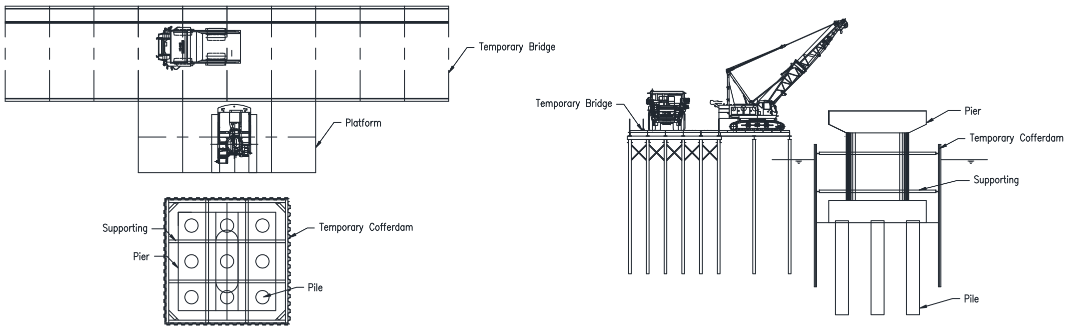
A temporary bridge and work platform will be installed considering the influence of flood/ storm surges during the construction works and to aid movement of heavy equipment. The installation of these facilities will follow the following sequence: pile driving, girder support, road decking panel support and bridge/platform decking panel. These temporary bridges are to be used not only for bridge construction work but also for embankment works on the other side of rivers.

Temporary Cofferdam

Since the river water level is high even in dry season and the existing ground is soft, a temporary cofferdam will be required for construction of the abutments and piers.

After construction of the cast-in-place concrete piles, steel sheet piles will be installed. Thereafter, the soil inside of cofferdam is excavated by a backhoe and removed to a predetermined place by a dump truck. The excavated soil can later be used for backfilling around structures or road embankment works.. In case of water ingress into the cofferdam, a submersible pump can be used for dewatering..

Regarding temporary bridges and cofferdams, the specifications of steel sheet piles will be reviewed at detailed design stage, and a suitable construction method will be proposed based the site conditions.



Plan View Front View

Source: JICA Survey Team

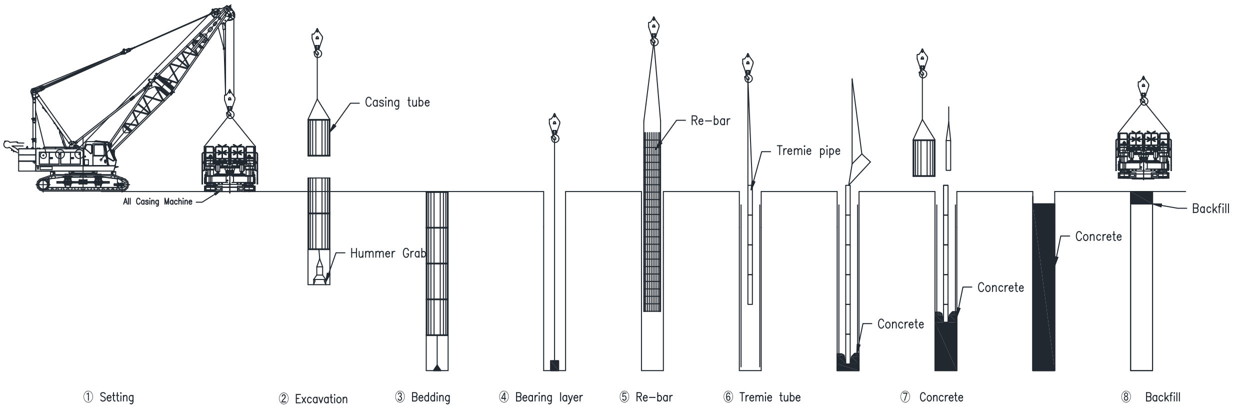
Figure 3.5-3 Temporary Works

2) Foundation works

Cast-in-place Concrete Piles

Same as the other bridge construction projects in Bangladesh, cast-in-place concrete piles were adopted from the viewpoint of material availability and easiness of construction. In this project, cast-in-place piling using all casing method was selected.

During all casing method, the casing tube is pressed into the soil while swinging or rotating, and the soil inside of the tube is excavated using a grab hammer. After excavation, slime treatment is done using a grab hammer and a settling bucket. Re-bars and tremie pipes are then installed and concrete casting proceeds. The tremie tubes are then pulled out sequentially as concrete casting proceeds. A more comprehensive review will be done at detailed design stage for the pile construction method to be adopted for the works.

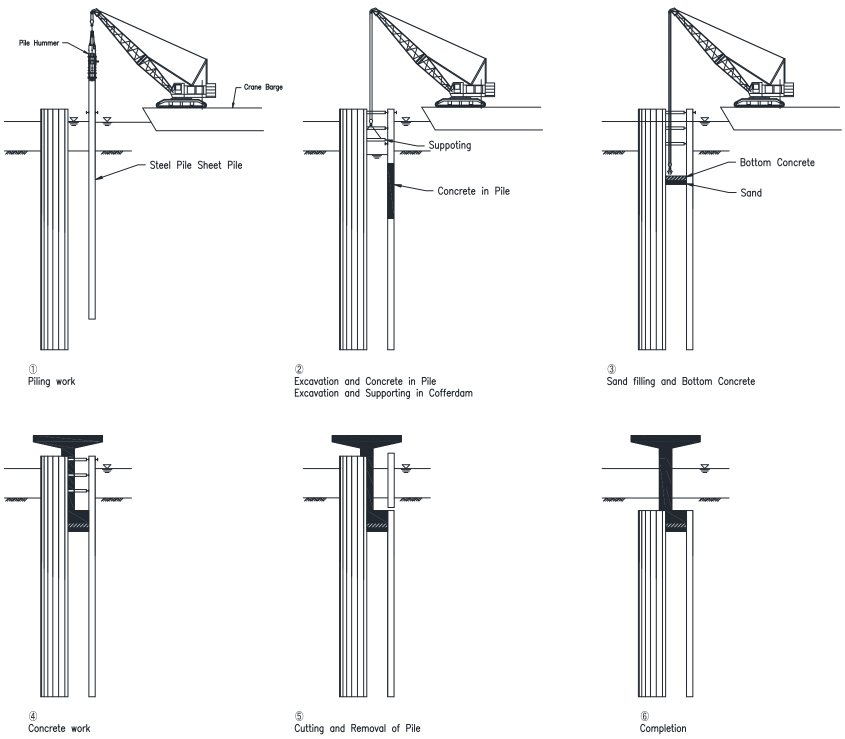


Source: JICA Survey Team

Figure 3.5-4 Cast-in-place Concrete Piles

<u>Steel Pipe Sheet Pile</u>

The installation guides and steel pipe sheet piles will be installed using a crane barge on water. Selection of the pile driving hammer is done in consideration of the soil condition, the required bearing capacity, the diameter, the length, etc. After driving the steel pipe sheet piles, the soil inside of the piles is excavated and pile concrete cast. Cofferdam works such as drainage, supporting and excavation are then executed. Pier concrete is then cast. On completion of the substructure works, steel pipe sheet pile trimming is then done.

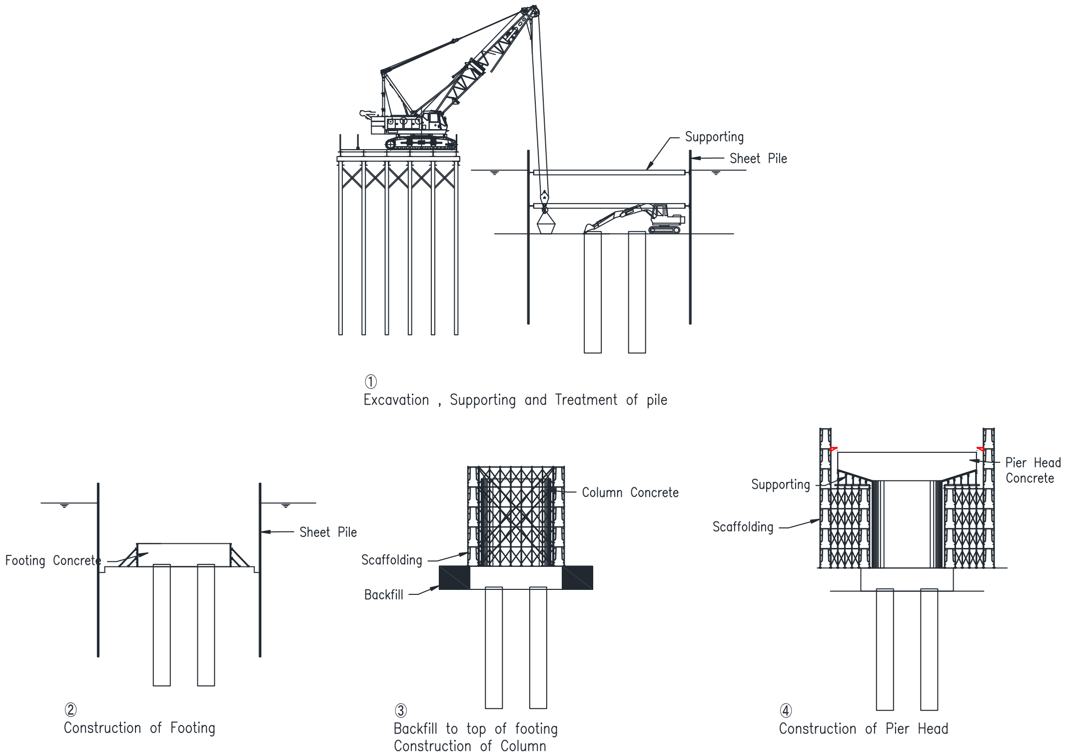


Source: JICA Survey Team

Figure 3.5-5 Steel Pipe Sheet Pile

3) Sub Structures (Abutments and Piers)

When excavation and bedding are completed, crushed stone will be spread and compacted, and leveling concrete placed. Then reinforcement bars, formwork and support/ scaffolding will be installed, and thereafter main concrete casted.



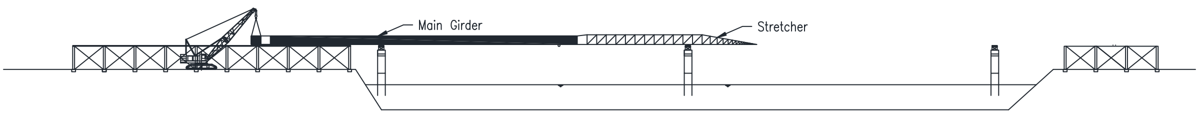
Source: JICA Survey Team

Figure 3.5-6 Substructure

4) Super Structure (Steel Box Girders and PC-I Girders)

<u>Steel Box Girders</u>

Since at the project site the water levels of the river and the channel will be high even in dry season, installation of a bent to allow access of a truck crane inside the river is difficult.. For this reason, the launching girder erection method was adopted for this project. During pier construction, steel box girders will be manufactured at a factory situated outside the project site and then after transported to the construction site. On completion of construction of the bridge piers and installation of the bents, assembling the stretcher will proceed and subsequently the box girders will be connected and sent gradually to the piers.

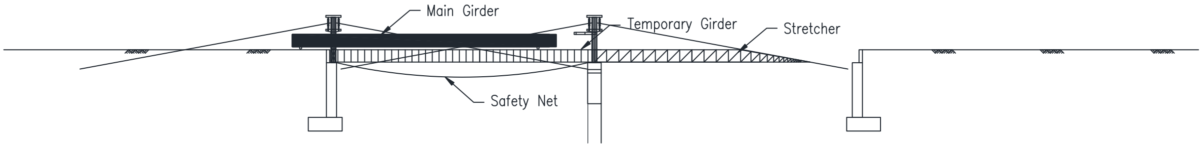


Source: JICA Survey Team

Figure 3.5-7　Erection of Steel Box Girders

PC-I Girders

As earlier described relating to the high water levels and the difficulties anticipated in bent installation to allow truck crane access to the river, for this project preference was given to the girder construction method by temporary erection. The PC-I girders will be produced at a temporary yard or on-site during construction works for the abutments and piers. The temporary erection girders and the stretcher will be assembled and erected behind the abutment, the PC-I girders will then be moved by rail over the temporary erection girder gradually to the piers.



Source: JICA Survey Team

Figure 3.5-8 Erection of PC-I Girders

(5) Construction Schedule

1) Determination of Operation Rate

Before preparation of the construction schedule, the operation rate of work will be set as shown in the table 3.5-3 below. Based on the rainfall records during the past 5 years and the daily normal rainfall records published by Bangladesh Meteorological Department, the operation rate was calculated as 1.39 (workable in 72% of days) in the dry season and not workable during the rainy season due to the expected number of rainy days (daily rainfall of 10 mm or more) and public holidays.

The number of rainy days from June to August ranges between 18 to 22 days per month for the past 5 years and 30 to 31 days per month for the record of daily normal rainfall. Therefore, road and bridge construction will proceed normally during dry season, and consolidation settlement promoted in rainy season.

Table 3.5-3 Operation Rate

2011.Junuary～2016.December

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
Rainy Days (>10mm/day)	①	0	1	1	3	11	18	22	18	10	7	1	1	93	
Public holiday	②	4	4	5	4	4	5	4	5	4	4	5	4	52	
Nation holiday	③	0	1	2	2	2	4		3	2	1	1	2	20	
Overlap	④						1			1	1			3	
Total	⑤=②+③-④	4	5	7	6	6	8	4	8	5	4	6	6	69	
Duplicate nonoperation days	⑥=①*⑤÷⑦	0.0	0.2	0.2	0.6	2.1	4.8	2.8	4.6	1.7	0.9	0.2	0.2	18.3	
Calendar day	⑦	31	28	31	30	31	30	31	31	30	31	30	31	365	
Nonoperation days	⑧=①+⑤-⑥	4.0	5.8	7.8	8.4	14.9	21.2	23.2	21.4	13.3	10.1	6.8	6.8	143.7	
Operation days	⑨=⑦-⑧	27.0	22.2	23.2	21.6	16.1	8.8	7.8	9.6	16.7	20.9	23.2	24.2	221.3	
Operation Rate	⑩=⑨÷⑦	0.87	0.79	0.75	0.72	0.52	0.29	0.25	0.31	0.56	0.67	0.77	0.78	**0.61**	
Dry season Operation Rate		Dry season								Dry season				**0.72**	**→1÷0.72≒1.39**
Rainy season Operation Rate							Rainy season							**0.28**	

Normal Daily Rainfall

Item		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	
Rainy Days (>10mm/day)	①	0	0	0	1	11	30	31	31	11	5	1	0	121	
Public holiday	②	4	4	5	4	4	5	4	5	4	4	5	4	52	
Nation holiday	③	0	1	2	2	2	4		3	2	1	1	2	20	
Overlap	④						1			1	1			3	
Total	⑤=②+③-④	4	5	7	6	6	8	4	8	5	4	6	6	69	
Duplicate nonoperating days	⑥=①*⑤÷⑦	0.0	0.0	0.0	0.2	2.1	8.0	4.0	8.0	1.8	0.6	0.2	0.0	24.9	
Calendar day	⑦	31	28	31	30	31	30	31	31	30	31	30	31	365	
Nonoperating days	⑧=①+⑤-⑥	4.0	5.0	7.0	6.8	14.9	30.0	31.0	31.0	14.2	8.4	6.8	6.0	165.1	
Operating days	⑨=⑦-⑧	27.0	23.0	24.0	23.2	16.1	0.0	0.0	0.0	15.8	22.6	23.2	25.0	199.9	
Operating Rate	⑩=⑨÷⑦	0.87	0.82	0.77	0.77	0.52	0.00	0.00	0.00	0.53	0.73	0.77	0.81	**0.55**	
Dry season Operating Rate		Dry season								Dry season				**0.73**	**→1÷0.72≒1.36**
Rainy season Operating Rate							Rainy season							**0.00**	

Source: JICA Survey Team

3.6 Implementation Plan

3.6.1 Implementation Strategy (Phased Construction)

The road component will follow a phase construction approach as is the case with the port. A 4-lane carriageway will be necessary in foreseeable future but a 2-lane carriageway would be enough for least until 10 years after the opening of Matarbari Port. However, for land acquisition purposes, the entire 4-lane carriageway road corridor needs to be secured at the initial stage to avoid settlement along the road.

Land acquisition for the port component will be undertaken for only the area necessary at the initial stage. Considering that the estimated future traffic volume in 2026 was calculated as 6,601 PCU/day or 3,153 vehicles/day based on the maximum capacity of the proposed Matarbari Port at the initial stage (JICA's loan funded), a 2-lane would be sufficient for the anticipated traffic generated from Matarbari Port, CPGCBL's power plant and the diverted traffic from the adjoining roads.

However, with the cargo demand in Bangladesh expected to rise rapidly, the second phase the expansion of the Matarbari Port would be necessary soon after its opening. Considering that the estimated future traffic volume in 2035 is 12,103 PCU/day or 5,655 vehicles/day based on an assumption of increased port demand, a 4-lane carriageway would be necessary soon after 2035. Unlike Port developments, road developments tend to attract more human settlements along the road because of the access convenience. For this reason, the need for a total road corridor acquisition at the outset is emphasized as part of the Matarbari Port Development Project.

Taking into account the above, implementation of the project under a phased construction is recommended as in the following order:

<u>Initial Stage</u>

- Land acquisition to cover the 4-lane carriage way width necessary for future development;
- Embankment works will cover the 2-lane carriageway width necessary at the initial stage but the remaining lanes necessary for the second stage will also be filled to form a gentle slope in order to protect the embankment against the frequent flooding and prevent informal settlements;
- Pavement and bridge construction shall be for 2-lanes only. Therefore the size of the bridge substructures should be accommodated within the width of the superstructures;
- Box culverts will be constructed to accommodate a 2-lane carriageway on the embankment.

<u>Second Stage</u>

- Before construction works for the second stage commence, consolidation settlement of embankment should have progressed significantly;
- Embankment filling for the remaining portion will be undertaken;
- Pavement and bridge construction works for the remaining 2-lanes will be embarked on;
- Box culverts under the embankment will be extended to provide for 4-lanes over the embankment.

3.6.2 Scope of the Project

The road component of the Matarbari Port Development Project includes construction of the following:
- Matarbari Port Access Road (road length: 25.7 km, 2-lane)
- Matarbari Port North-South Connector Road (road length: 1.6 km, 4-lane)

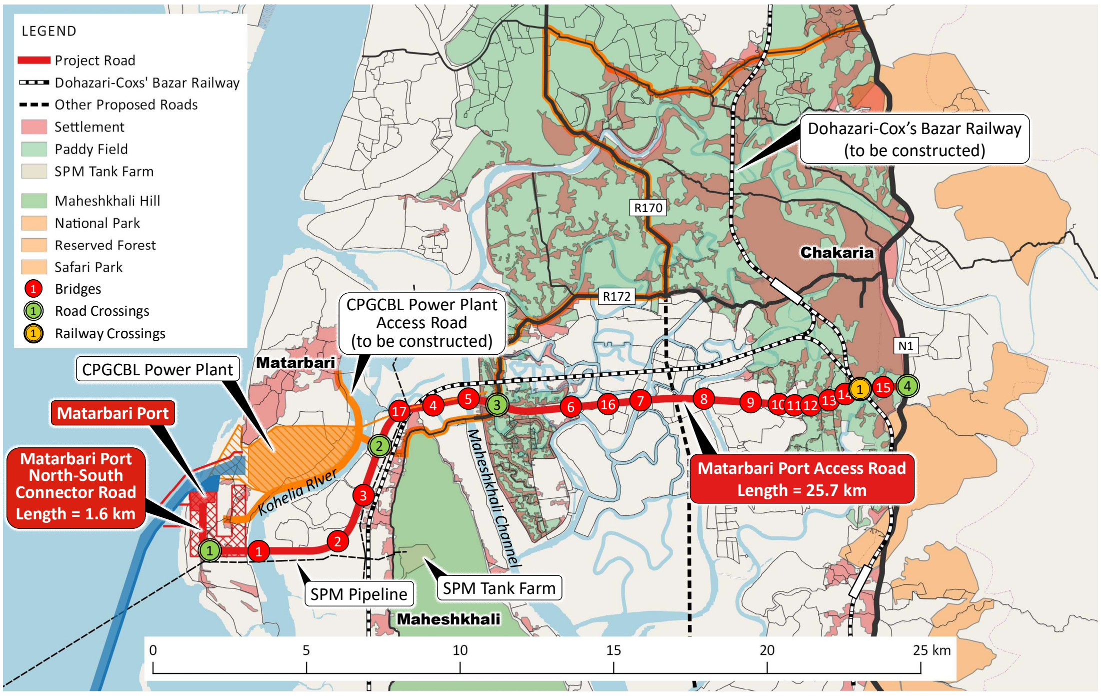
As described in the section 3.4, preliminary design for the selected route of the project road was undertaken. Based on the preliminary design, the scope of the project was determined as follows:

Matarbari Port Access Road

- Road length: 25.7 km
- Number of lanes: 2-lane (at initial stage, to be widened to 4-lane in future)
- Number of bridges: 17 (total 7,104 m)
- Number of intersections: 4 (3 at-grades, 1 grade separated)
- Installation of traffic signal: 1 (at the intersection with N1)
- Number of railway crossing: 1 (at-grade, Dohazari-Cox's Bazar Railway), Rail Spur Line to Matarbari is not considered at this stage
- Number of box culverts: 4 for roadway underpasses, 40 for pedestrian underpasses, 169 for channels
- Soft soil improvement: Replacement, surcharge with PVD, sand compaction pile
- Pavement type: Polymer modified asphalt concrete, semi-flexible pavement (only at intersections)

Matarbari Port North-South Connector Road

- Road length: 1.6 km
- Number of lanes: 4-lane
- Number of box culverts: 1 for roadway, 1 for pedestrian, 11 for channel
- Soft soil improvement: Replacement, preloading with PVD, sand compaction pile



Source: JICA Survey Team

Figure 3.6-1 Project Scope

Table 3.6-1 provides a summary of the intersecting roads and railways. The project road has been planned as a semi-access controlled road and will intersect with only two (2) roads, namely CPGCBL Power Plant Access Road and R172, in between the beginning point and the ending point. The project road will also cross the Dohazari-Cox's Bazar Railway and probably the Rail Spur Line to Matarbari Port whose implementation is currently uncertain.

Table 3.6-1 List of Intersecting Roads/Railways

No.	Station	Road/Railway Name	Cross Angle	Intersection Type
1	0+000	Matarbari Port North-South Connector Road	90°	At-Grade
2	7+727	CPGCBL Power Plant Access Road	85°	At-Grade
3	12+240	R172	-	Grade Separation
4	23+935	Dohazari-Cox's Bazar Railway	64°	At-Grade
5	25+413	N1	90°	At-Grade

Source: JICA Survey Team

Table 3.6-2 summarizes the proposed bridges to be constructed under this project.

Table 3.6-2 List of Bridges

<table>
<tr><th rowspan="2">No.</th><th colspan="2">Station</th><th rowspan="2">Bridge Type</th><th rowspan="2">No of Spans</th><th rowspan="2">Span Arrangement (m)</th><th rowspan="2">Total Length (m)</th><th rowspan="2">River Name</th><th rowspan="2">Remarks</th></tr>
<tr><th>From</th><th>To</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">0+806</td><td rowspan="3">2+040</td><td>PC-I</td><td>11</td><td>11@40m=440m</td><td rowspan="3">1234</td><td rowspan="3">Kohelia River</td><td rowspan="3">BIWTA Class II</td></tr>
<tr><td>Steel Narrow Box Girder</td><td>4</td><td>70m+2@87m+70m =314m</td></tr>
<tr><td>PC-I</td><td>12</td><td>12@40m=480m</td></tr>
<tr><td>2</td><td>4+430</td><td>4+670</td><td>PC-I</td><td>6</td><td>6@40m</td><td>240</td><td>Nonaichnari Khal</td><td>*</td></tr>
<tr><td>3</td><td>6+080</td><td>6+215</td><td>PC-I</td><td>3</td><td>3@45m</td><td>135</td><td></td><td>*</td></tr>
<tr><td>4</td><td>9+890</td><td>10+115</td><td>PC-I</td><td>4</td><td>4@40m</td><td>160</td><td></td><td>*</td></tr>
<tr><td rowspan="3">5</td><td rowspan="3">10+680</td><td rowspan="3">12+154</td><td>PC-I</td><td>11</td><td>11@40=440m</td><td rowspan="3">1474</td><td rowspan="3">Maheshkhali Channel</td><td rowspan="3">BIWTA Class II</td></tr>
<tr><td>Steel Narrow Box Girder</td><td>4</td><td>70m+2@87m+70m =314m</td></tr>
<tr><td>PC-I</td><td>18</td><td>18@40m=720m</td></tr>
<tr><td>6</td><td>14+090</td><td>14+450</td><td>PC-I</td><td>9</td><td>9@40m</td><td>360</td><td>Bura Matamuhuri Khal</td><td></td></tr>
<tr><td>7</td><td>16+490</td><td>16+760</td><td>PC-I</td><td>6</td><td>6@45m</td><td>270</td><td>ditto</td><td></td></tr>
<tr><td>8</td><td>18+550</td><td>18+910</td><td>PC-I</td><td>9</td><td>9@40m</td><td>360</td><td>Matamuhuri</td><td></td></tr>
<tr><td>9</td><td>20+460</td><td>20+580</td><td>PC-I</td><td>3</td><td>3@40m</td><td>120</td><td>Batamani Khal</td><td>*</td></tr>
<tr><td>10</td><td>21+340</td><td>21+430</td><td>PC-I</td><td>2</td><td>2@45m</td><td>90</td><td>ditto</td><td>*</td></tr>
<tr><td>11</td><td>21+530</td><td>21+690</td><td>PC-I</td><td>4</td><td>4@40m</td><td>160</td><td>ditto</td><td>*</td></tr>
<tr><td>12</td><td>21+785</td><td>21+920</td><td>PC-I</td><td>3</td><td>3@45m</td><td>135</td><td>ditto</td><td>*</td></tr>
<tr><td>13</td><td>22+680</td><td>22+840</td><td>PC-I</td><td>4</td><td>4@40m</td><td>160</td><td>Fasiakhali Chara</td><td>*</td></tr>
<tr><td>14</td><td>23+390</td><td>23+550</td><td>PC-I</td><td>4</td><td>4@40m</td><td>160</td><td>ditto</td><td>*</td></tr>
<tr><td>15</td><td>24+455</td><td>24+495</td><td>PC-I</td><td>1</td><td>40m</td><td>40</td><td></td><td></td></tr>
<tr><td>16</td><td>14+640</td><td>15+900</td><td>Steel I Girder</td><td>23</td><td>50m+4@60m+50m x 3 +45m+3@50m+45m</td><td>1,260</td><td></td><td>Soft Ground</td></tr>
<tr><td rowspan="3">17</td><td rowspan="3">9+012</td><td rowspan="3">9+683</td><td>PC-I</td><td>3</td><td>3@45m=135m</td><td rowspan="3">671</td><td rowspan="3"></td><td rowspan="3">LNG Pipeline</td></tr>
<tr><td>Steel Narrow Box Girder</td><td>1</td><td>70m</td></tr>
<tr><td>PC-I</td><td>11</td><td>35m+5@45m+26m +4@45m=466m</td></tr>
</table>

Note: * represents that bridge construction may not be necessary in view of drainage purpose. Further engineering study should be made during the detailed design stage in order to justify the necessity of bridges.
Source: JICA Survey Team

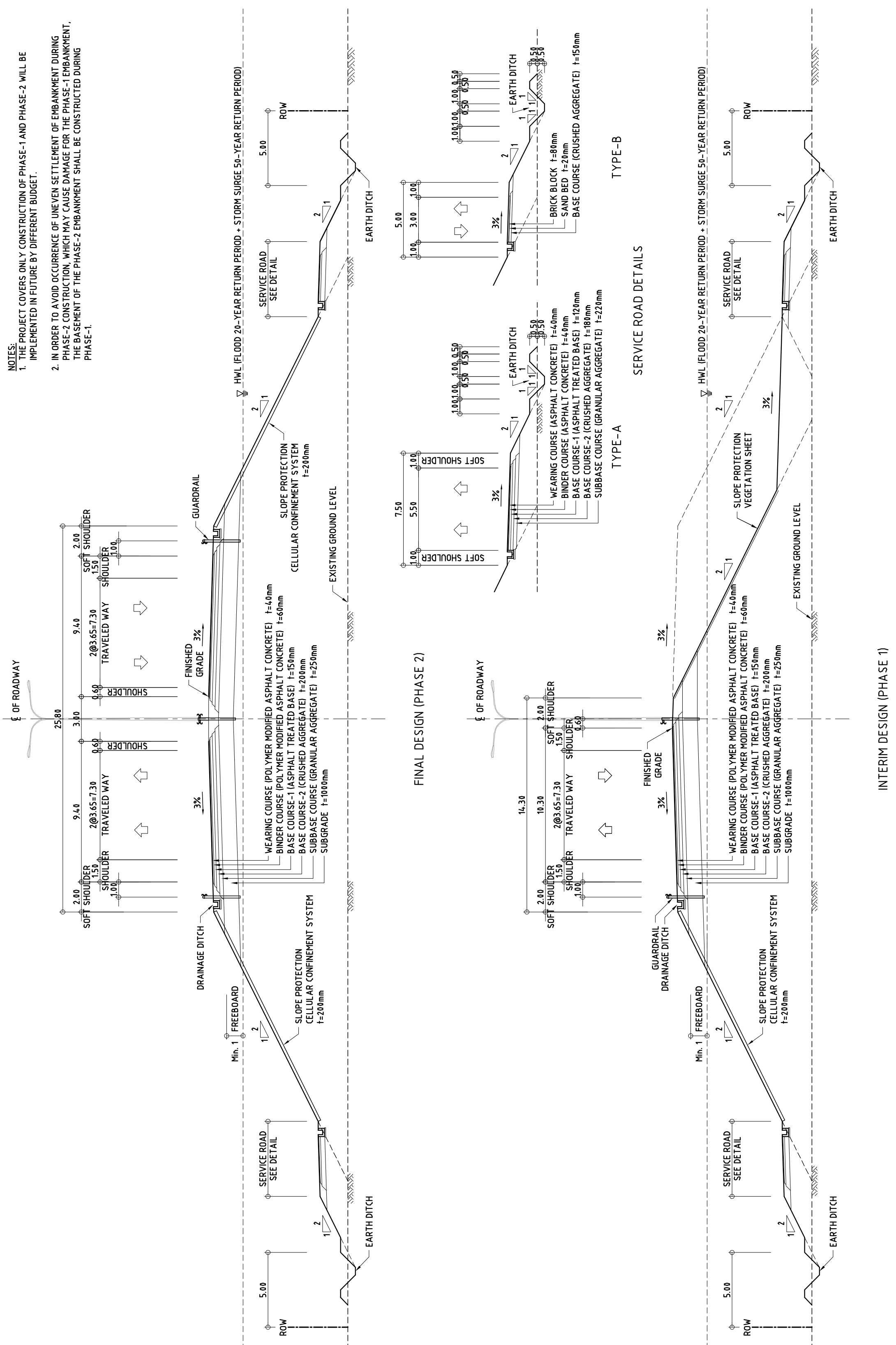


Figure 3.6-2 Typical Cross Section (Embankment Section)

Source: JICA Survey Team

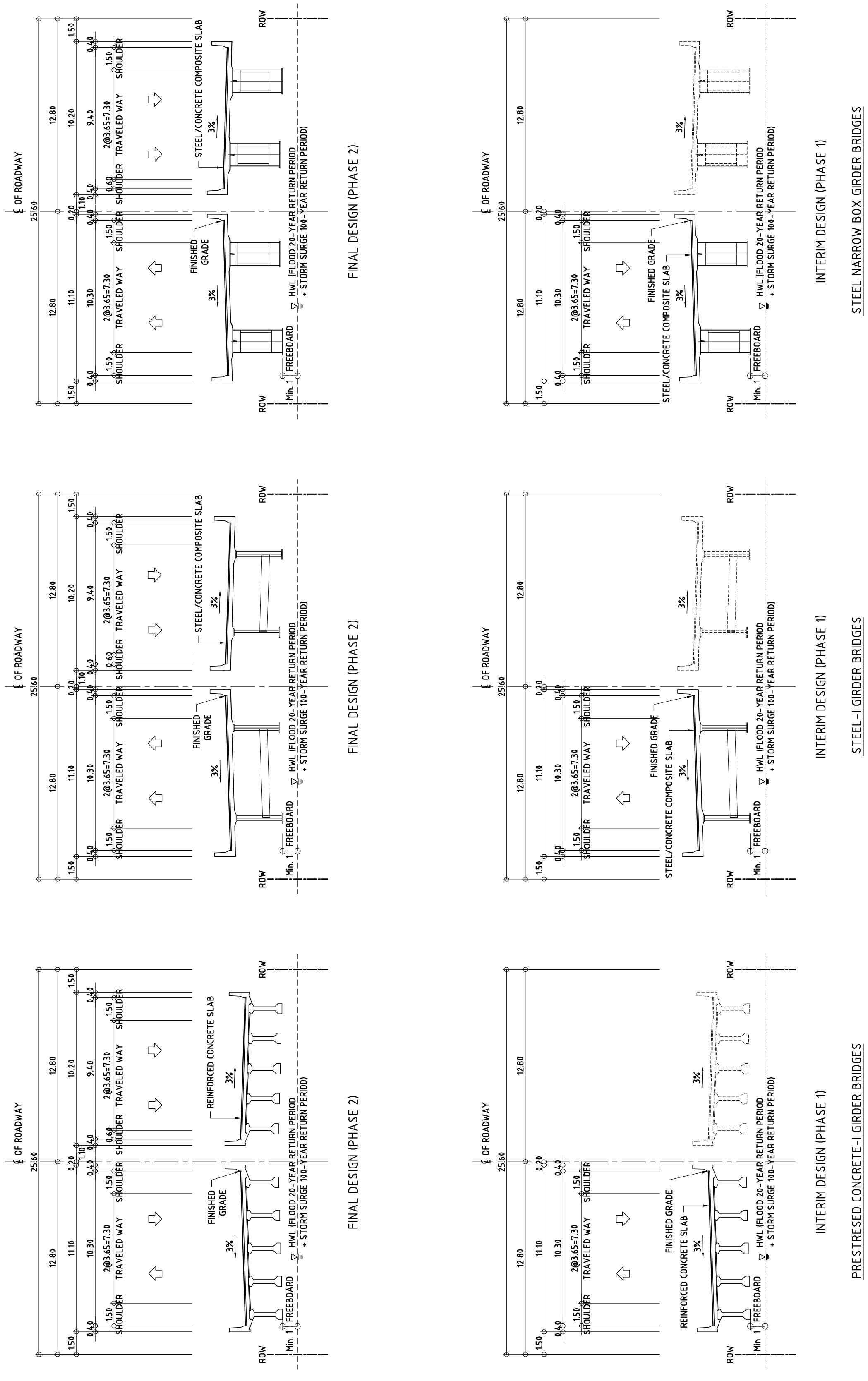


Figure 3.6-3 Typical Cross Section (Bridge Section)

Source: JICA Survey Team

Required Soft Soil Improvements

The filling height of the embankment under the Project ranges from 6.5 m to 12 m. For this reason, soil improvement is required:

- The subsurface layers typically manifest low shear strength which leads to instability of the embankment during construction;
- Consolidation settlement of any embankment ought to be completed within the limited construction period to ensuring port accessibility before opening of the proposed Matarbari Port.

The proposed soft soil improvement methods are listed below (for more details, see Figure 3.6-4):

- Excavation and replacement with suitable materials
- Consolidation and dewatering by applying a surcharge with Prefabricated Vertical Drains (PVDs)
- Compaction using Sand Compaction Piles (SCPs)

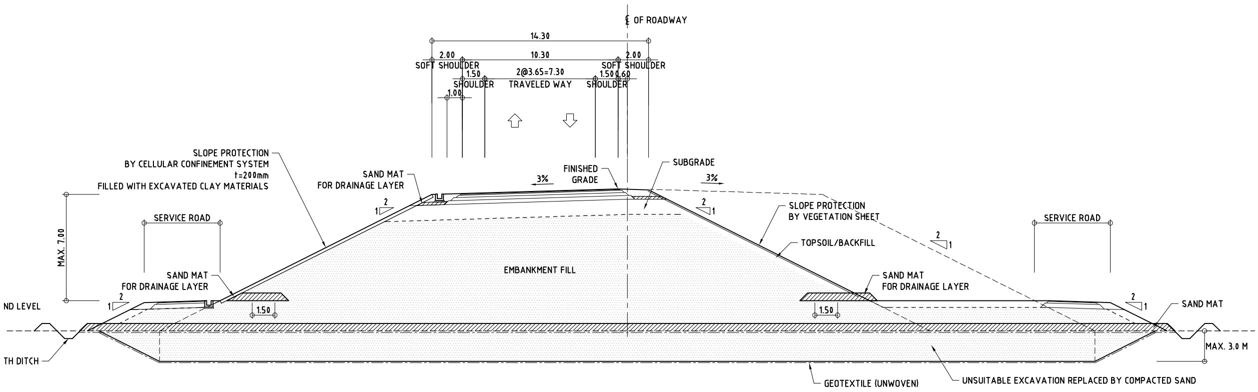
Possibility of Occurrence of Flooding and Storm Surge

As a result of the hydraulic and hydrological study, it was confirmed that the influence of storm surge extend to N1. Whereas, the external forces of a storm surge from the coastal line gradually decrease as it flows up into the inland areas, the damage caused by flash-floods alone inland tends to be greater than at the coastal areas. Therefore, protection measures for the embankment and bridges against the effects of storm surges and/ or the flash floods should be provided.

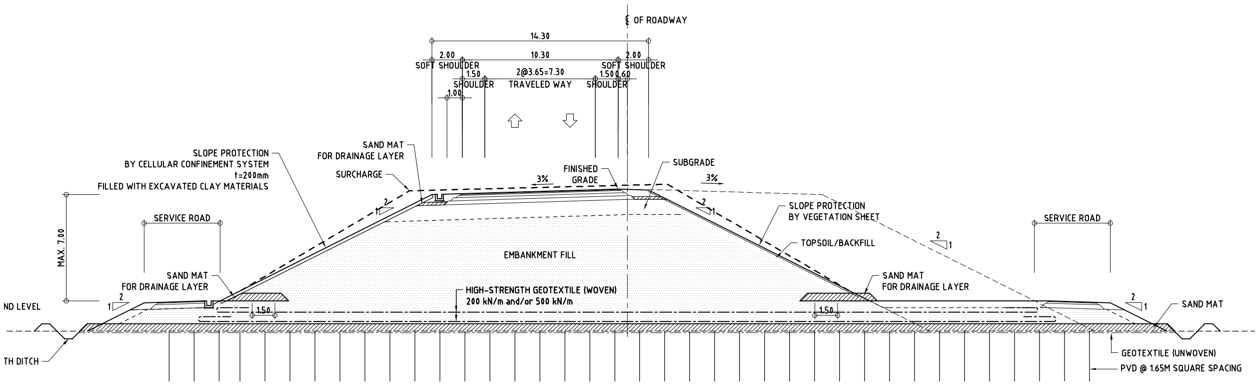
Figure 3.6-5 shows is the water surface elevations given the following flooding situations:

- 20-year flood: for analyzing the possible high water level during construction work;
- 20-year flood and 50-year storm surge: for designing the elevation of the embankment
- 20-year flood and 100-year storm surge: for designing the elevation of bridges

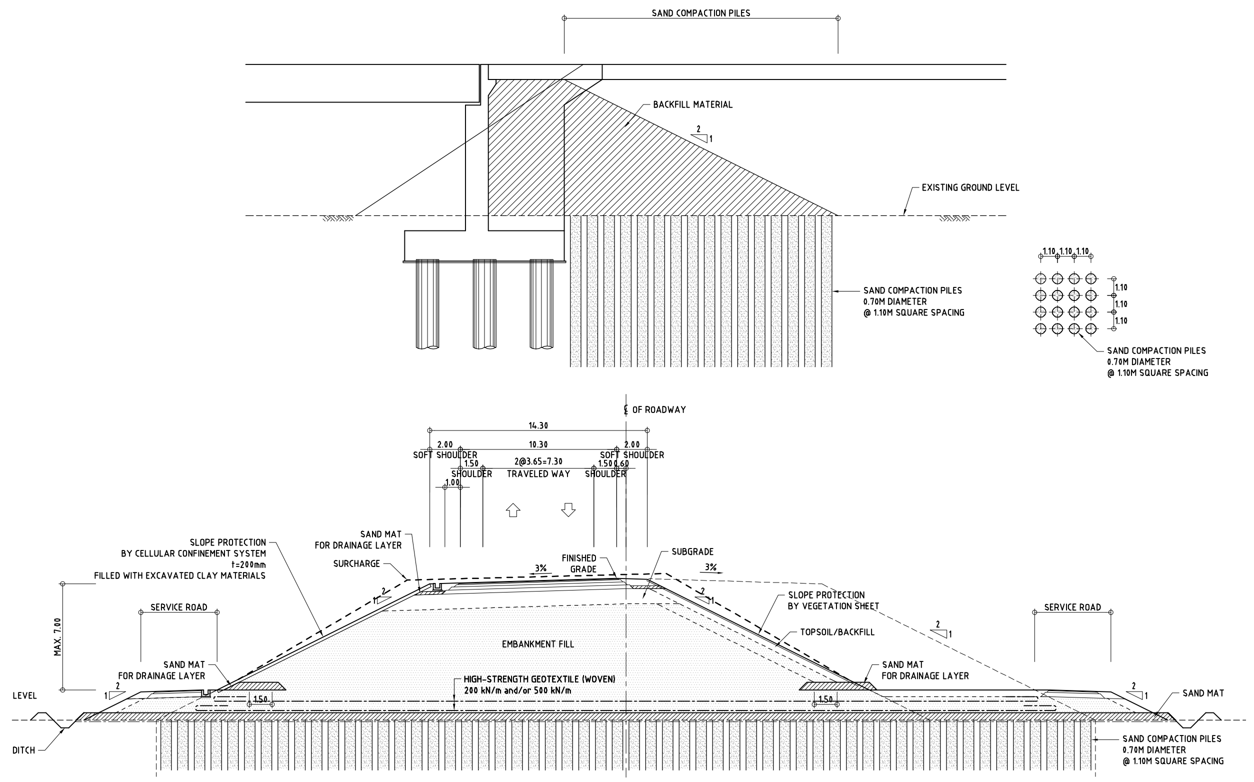
As it can be seen from Figure 3.6-5of "the 20-year flood", the possible high water level during construction work would be 2.0 to 2.5 m above MSL. Whereas the existing ground levels along most of the sections of the project road are lower than the high water level, such flooding situations should be considered for embankment construction. If the proposed service road beside the access road will be constructed higher than the flood level, the construction yard would be able to be dry even during flooding situations.



Excavation and Replacement Method by Suitable Materials



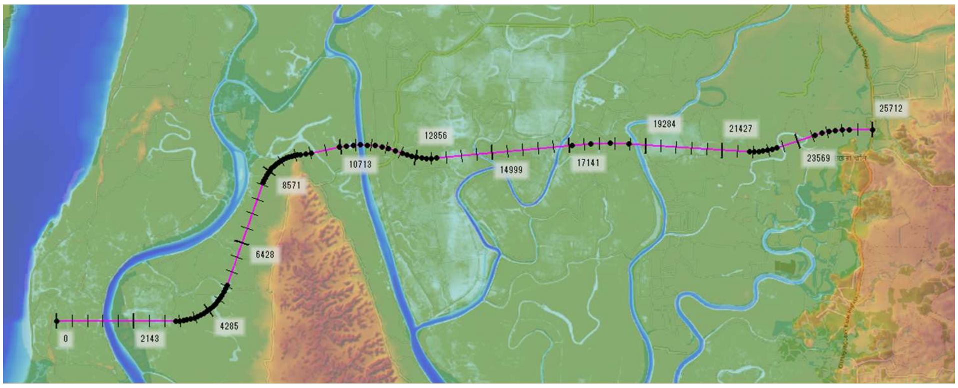
Consolidation and Dewatering Method by Surcharge with PVD



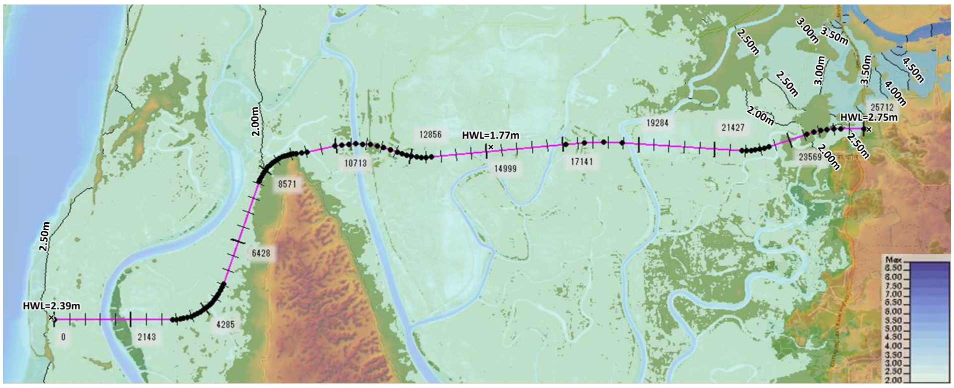
Compaction Method by Sand Compaction Piles

Source: JICA Survey Team

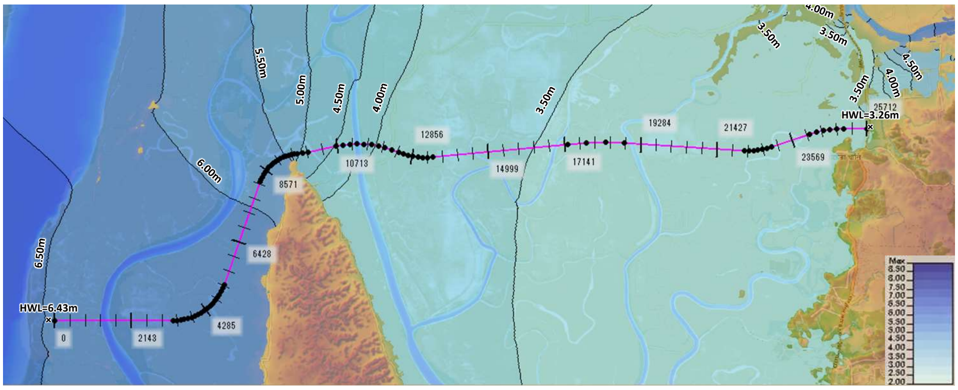
Figure 3.6-4 Soft Soil Improvement Methods



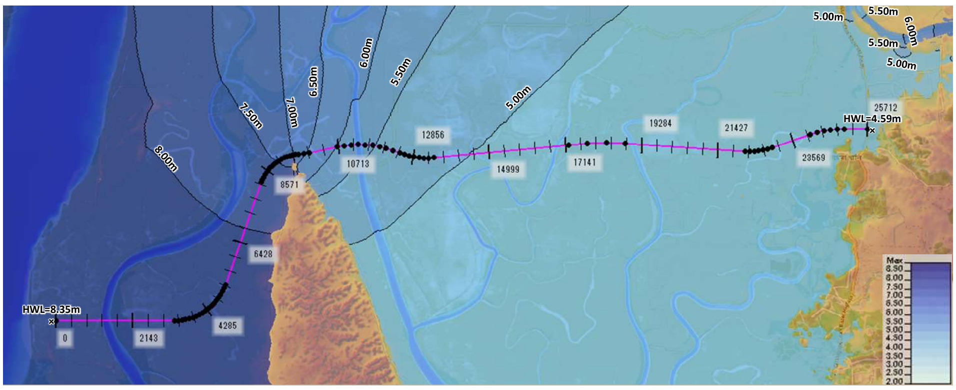
Terrain Elevation



20-year Flood



20-year Flood + 50-year Storm Surge



20-year Flood + 100-year Storm Surge

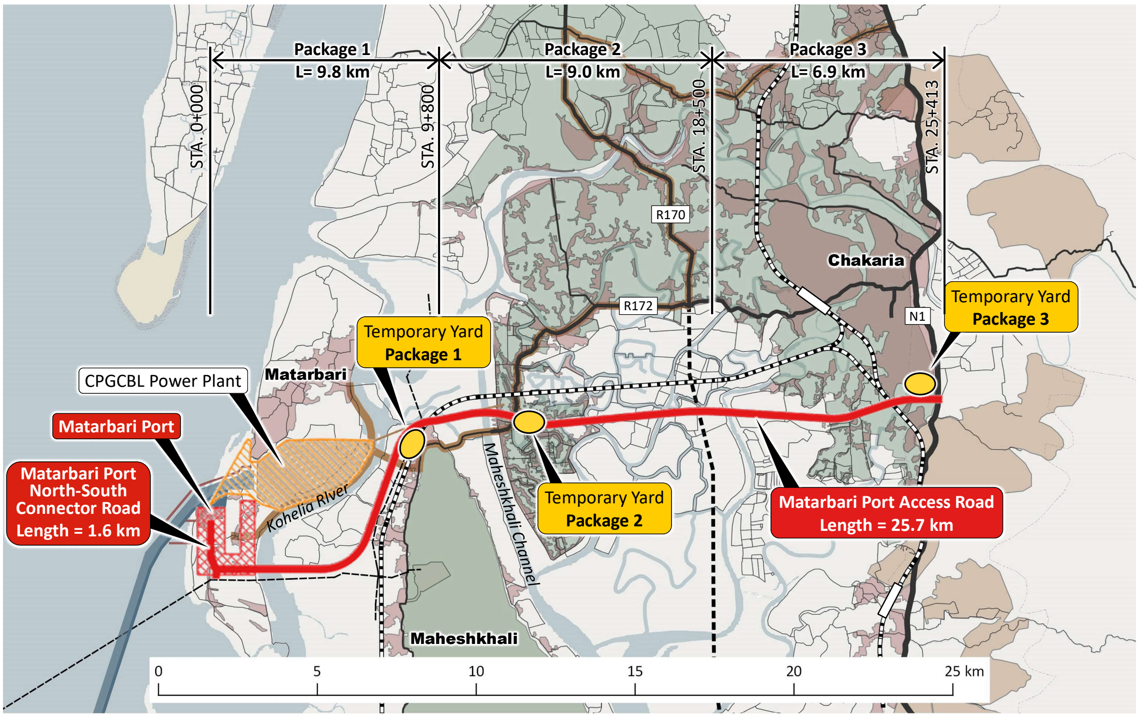
Source: JICA Survey Team

Figure 3.6-5 Water Surface Elevations at Different Flooding Situations (m)

Construction Contract Packages

The estimated construction cost of BDT 50.5 billion (excluding VAT and other taxes) would be too high to expect many bidders to participate in the project. In order to avoid bid failure, the contract should be divided into several packages. Considering the volume of the construction works and the estimated construction cost, three (3) packages would be recommended and the following sections would be reasonable in view of accessibility to the construction site through national/regional highways and major rivers.

- Package 1: From 0+000 to 9+800 (9.8 km)
- Package 2: From 9+800 to 18+500 (9.0 km, with station equation of 300 m)
- Package 3: From 18+500 to 24+413 (6.9 km)



Source: JICA Survey Team

Figure 3.6-6 Construction Contract Packages

The following locations are considered as accessible points for the respective packages:

- Package 1: CPGCBL Power Plant Access Road, R172, Kohelia River, Maheshkhali Channel
- Package 2: R172, Maheshkhali Channel, Mathamufuli River
- Package 3: N1, Mathamufuli River

Table 3.6-3 shows the construction cost of each package. The boundaries of the packages should be re-examined during the detailed design stage.

3.6.3 Justification for the Project Scope

During the presentation of the Draft Final Report of the project to RHD as well as the stakeholders' meetings conducted at the project site, several observations/comments were raised. The following tables summarize the contents of the comments from RHD and local stakeholders, and the responses from JICA Survey Team.

Table 3.6-4 RHD's Observations/ Comments on the Draft Final Report

Observations/ Comments	Study Team's Response
1. The justification for using the steel narrow box girder bridge in the project, which is located in a coastal area susceptible to airborne salinity that may result in corrosion of steel.	• Steel members of the steel narrow box girder bridge will be protected by heavy-duty anti-corrosion coating, which has been widely used in Japan including in coastal areas since 1980. The heavy-duty anti-corrosion coating consists of five layers, namely primer, first undercoating, second undercoating, intermediate coating and top coating and it will keep the durability of steel members for at least 30 years. • In Japan, there are many steel bridges constructed in coastal areas such as Tokyo Bay Aqua-Line (with 4.4 km-long steel box girder bridge section), Honshu-Shikoku Bridges (most of the major bridges in totaling 56.6 km of bridge length are steel bridges), and Tokyo Gate Bridge (with 760 m-long steel truss and steel box girder bridge section). Since the completion of their construction, these bridges have been in good condition with advanced anti-corrosion technologies and appropriate maintenance work. • The Okinawa Islands as well as coastal areas of the Sea of Japan are the most prone to airborne salinity. Following several studies undertaken in Japan, it was decided that consideration of salinity damage under bridge design is limited to bridges within 1 km from the coastal line even for the above prone areas. In the Matarbari Port Access Road Project, all the proposed bridges are located beyond 1 km from the coastal line of Bay of Bengal. Therefore, the effect of airborne salinity to the steel bridges under the project is not expected to be so high. • Furthermore, the steel narrow box girder bridge is a rationally invented type of steel box girder bridge in Japan and the area of steel members is less (-29%) than that of the ordinary steel box girder bridge so it has an added advantage against airborne salinity. • For more details, see **Justification 2: Bridge Types**
2. Advantage of steel narrow box girder in comparison to PC-I girder or PC box girder bridges in terms of cost and construction time.	• Kohelia River and Maheshkhali Channel, which are designated as BIWTA's Class II waterways, require 76.22 m width of horizontal clearance. As shown in Table 3.6-7, the only reasonably applicable bridge types for such a clearance would be the PC box girder bridge or steel box girder bridge. • Based on the comparative analysis (see Table 3.4-28), it was concluded that a steel narrow box girder bridge has more advantages over a PC box girder bridge in terms of structural stability (less by 45% in girder weight), construction cost (less than 4%) and construction time (less by 4.5 months). • For more details, see **Justification 2: Bridge Types**
3. If more length of the alignment could be built with viaducts to avoid 80 to 90 m Right of Way (ROW) and reduce requirement of land acquisition.	• Viaducts require higher construction costs and more time, and thus embankment construction would be more reasonable for the following; a) Matarbari and Maheshkhali areas will be developed in future with high embankment of land reclamation for power plants and economic zones. Embankment is better for ensuring good accessibility to such development areas in Matarbari and Maheshkhali. b) About half of the sections in Chakaria area are owned by the government for agricultural and fishing project purposes.The fishing project in these areas has not been a success so far. Therefore, it is expected that land acquisition will not be difficult. • However, if the Government of Bangladesh prefers viaducts for the section through paddy fields especially in Chakaria such as Badharkhali or Fashiakhali, this option can be adopted in a bid to minimize the affected area. • For more details, see **Justification 3: Road Structural Types (Embankment vs Bridge)**

Observations/ Comments	Study Team's Response
4. The Project Affected Person (PAP's) should be determined as accurately as possible to avoid any increase of these numbers during Detailed Design.	• See Chapter 4
5. Land acquisition area should tabulated with the information of plot no., Mouza name, area in acres, as per standard land acquisition proposal of the Land Acquisition Manual 2017.	• See Chapter 4
6. Justify the cost of the project for various components (embankment, soft soil treatment, steel narrow box girder bridge / other bridges and other items).	• The estimated construction cost of the project road is relatively high due to the following reasons: a) Availability of construction materials around the project site is low and many of them need to be transported/imported from far away, and thus additional cost for transportation is required; b) Accessibility to the construction site is low and construction of temporary access roads is required for road and bridge works even across rivers and thus there is need for additional costs. c) The project site is prone to flooding during rainy seasons and construction of cofferdams is necessary for ensuring safe and stable construction for the bridge piers, and thus additional cost is required; d) Due to the estimated high water level expected from storm surges, both embankment and bridges need to be high. As the estimated construction cost for embankment and slope protection works account for 44% of the total road construction cost consequently this results into high construction cost. • For more details, see **Justification 4: Construction Cost**

Source: JICA Survey Team

Table 3.6-5 Request from Local Stakeholders

Comments	Study Team's Response
1. There are many academic institutions, market areas, and religious buildings in Badarkhali and the proposed road alignment passes through such areas. There is a preference for the alignment from the Port Access Road to avoid such locations.	• The original road alignment proposed in the Draft Final Report passed through the Badarkhali Degree College property but resettlement of buildings belonging to academic institutions was not expected. • As a result of series of discussions with RHD, it was agreed to modify the alignment of the Port Access Road by diverting away from such densely populated areas in order to accommodate the local stakeholders request. • For more details, see **Justification 1: Route Selection**
2. Utternalvila Baruapara Village under Kalamarchara Union of Maheshkhali is a densely populated village. The inhabitants of the village strongly requested that the Port Access Road alignment be shifted to the north and avoid the village.	• The original road alignment proposed in the Draft Final Report passed through Utternalvila Baruapara Village in order to ensure the good compatibility with the proposed railway project. • In order not to cause any delay in project implementation, the alignment was revised so as to avoid the Utternalvila Baruapara Village. • For more details, see **Justification 1: Route Selection**

Source: JICA Survey Team

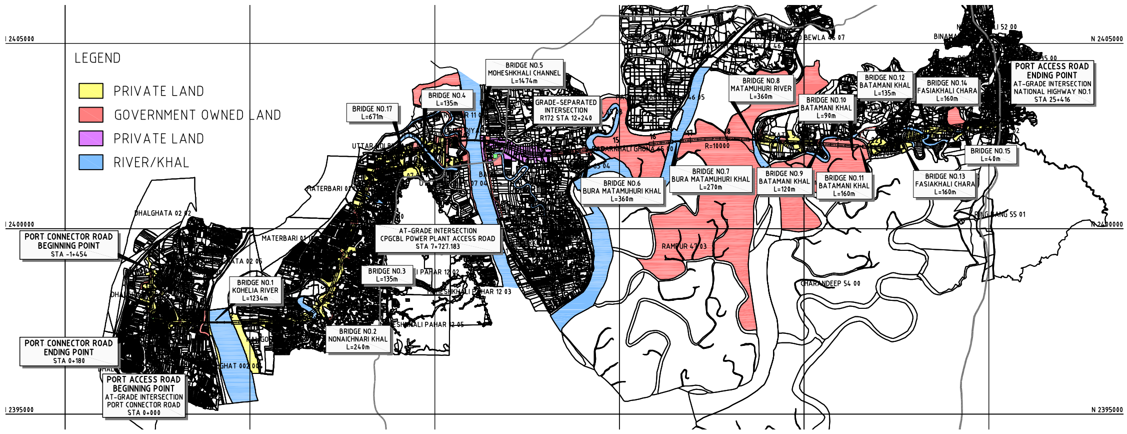
(1) Justification 1: Route Selection

The project route was selected in consideration of the following;

- The shortest route to N1 avoids the Maheshkhali Hill, which is environmentally protected;
- Less social environmental impacts because most of the road section passes through agricultural lands such as salt farms and rice fields;
- Good accessibility to both Matarbari Port and CPGCBL's power plant from the north such as Dhaka and Chittagong.

After selecting the optimal route, Mouza Map and certified latest Khatians (land titles) along the route were collected and digitized. Figure 3.6-7 shows the Mouza Map and types of land ownership. Yellow color lots show private lands, pink color lots show government lands, purple color lots show the lands leased from government and blue color lots show rivers or khals. The required ROW along the alignment consists of private land (57%), government land (26%), privately used land but leased from government (7%) and rivers/ khals and roads (10%).

As it can be seen in Figure 3.6-7, most of the land in Matarbari and Maheshkhali is privately owned however, the land in Chakaria excluding the area near N1 is owned by government. Therefore, the selected route for the project road is reasonable in view of land acquisition.

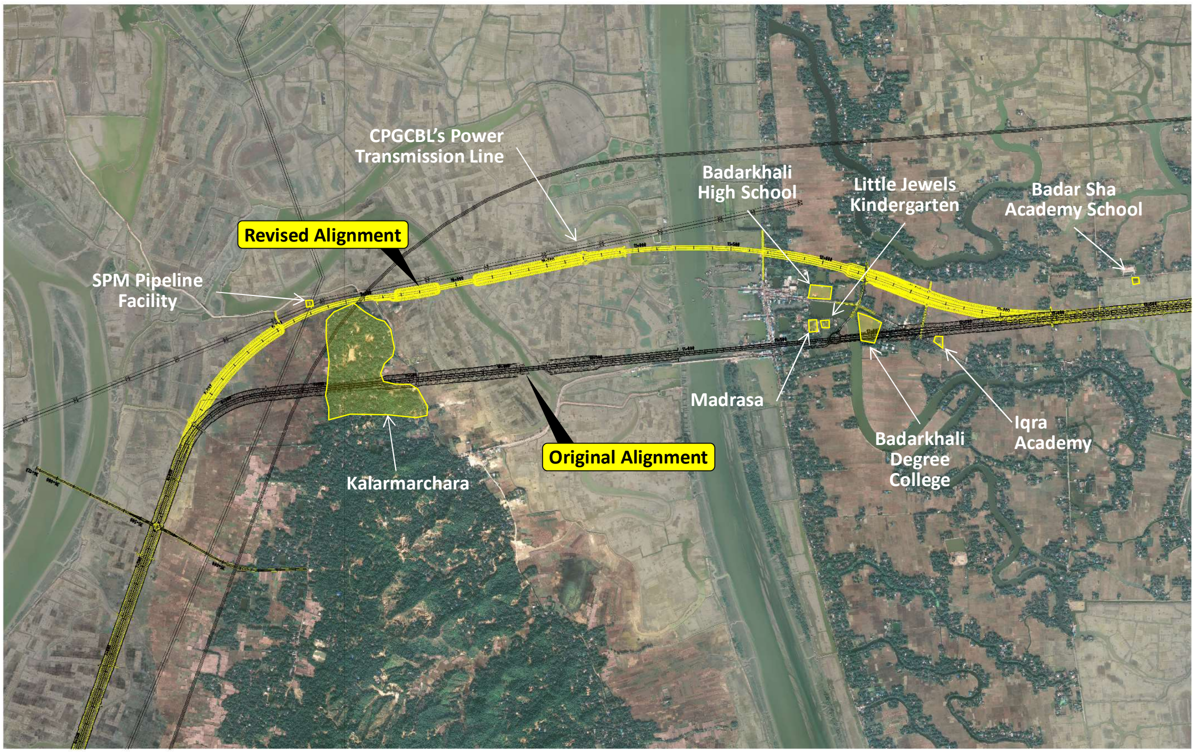


Source: JICA Survey Team

Figure 3.6-7 Mouza Map at Project Site

However, some critical issues were raised during the stakeholders' meeting held at the project site. Some residents in Kalarmarchara requested the JICA Survey Team to avoid the village at the north edge of Maheshkhali Hill, namely Utternalvila Baruapara Village. Also, existence of some academic institutions at Badarkhali was identified. Therefore, the alignment of the project road needed to be revised to avoid such critical areas as shown in Figure 3.6-8.

The design controls for the revised alignment are the LNG pipeline facility, the newly installed CPGCBL's 132 kV power line at Maheshkhali side and Badarkhali market area. According to the Consultant for CPGCBL's Matarbari Ultra Super Critical Coal Fired Power Plant Project, Electricity Grid Code (Bangladesh Energy Regulatory Commission, 2012) states that 32 m width of the space along the 132 kV power line is designated only for power line facilities and no any other structures are allowed to be constructed. Therefore, the alignment was designed not to interfere with the power line reserved area (see Figure 3.6-10).



Source: JICA Survey Team

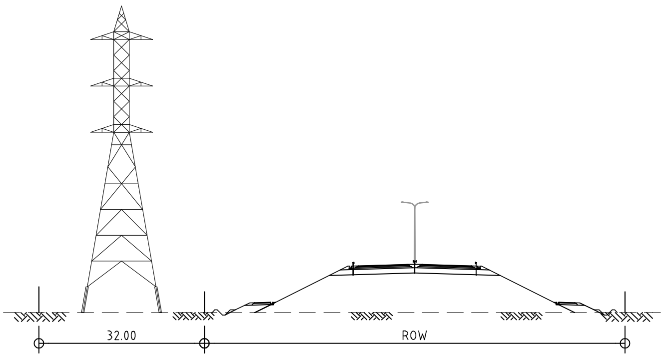
Figure 3.6-8 Revised Alignment of the Project Road

LNG Pipeline Facility

CPGCBL's Power Line (132 kV)

Source: JICA Survey Team

Figure 3.6-9 Photos of Design Controls



Source: JICA Survey Team

Figure 3.6-10 Design Control against CPGCBL's Power Line

(2) Justification 2: Bridge Types

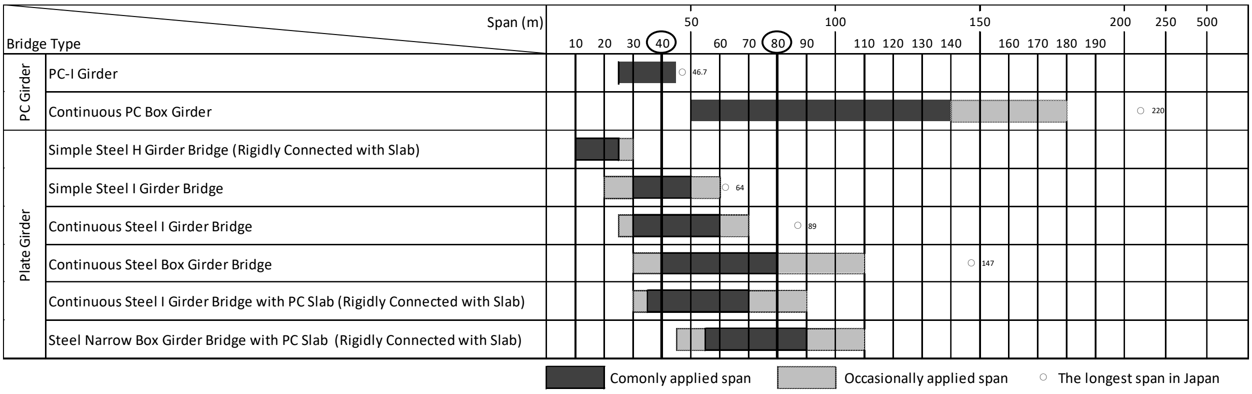
Table 3.6-6 summarizes the designed bridge types under the project. Steel narrow box girder type bridge with steel and concrete composite slab and steel pipe sheet pile foundation was selected for long-span bridges. Prestressed concrete (PC) I girder type bridge with reinforced concrete (RC) slab and bored pile foundation was selected for short-span bridges. For Bridge No. 16, a steel I girder type bridge was selected in order to shorten its construction period given its long span.

Table 3.6-6 Designed Bridge Types

		Long-Span Bridges	Short-Span Bridges	
Superstructure	Girder Type	Steel Narrow Box Girder	Prestressed Concrete (PC) I Girder	Steel I Girder
	Slab Type	Steel and Concrete Composite Slab	Reinforced Concrete (RC) Slab	Steel and Concrete Composite Slab
	Span (m)	70, 87	40, 45	45, 50, 60
Substructure	Foundation Type	Steel Pipe Sheet Pile (SPSP)	Bored Pile	Bored Pile

Source: JICA Survey Team

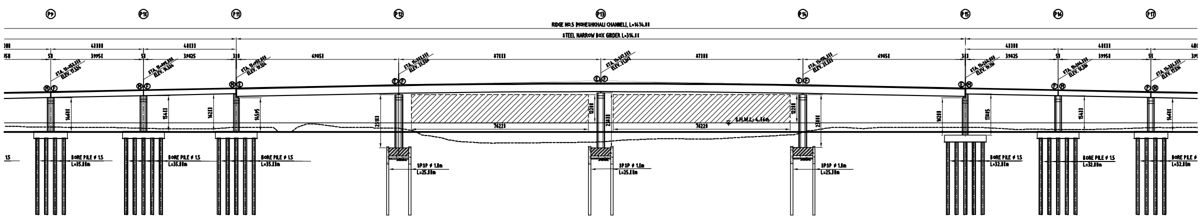
Table 3.6-7 Applicable Bridge Span for Bridge Types



Source: JICA Survey Team

Long-Span Bridges

The Steel narrow box girder type bridge was selected for long-span bridges across BIWTA's Class II waterways, namely Kohelia River and Maheshkhali Channel. The widths of these rivers are about 300 m and the space for waterway can be allocated at the middle of the rivers. Therefore, two (2) spans of the bridges were decided to be 87 m, which is equivalent to the double span of the existing bridge (43.5 m) at Badarkhali and 70 m span was decided for the remaining section within the river because of the optimal combination for balancing bending moments for the bridge.

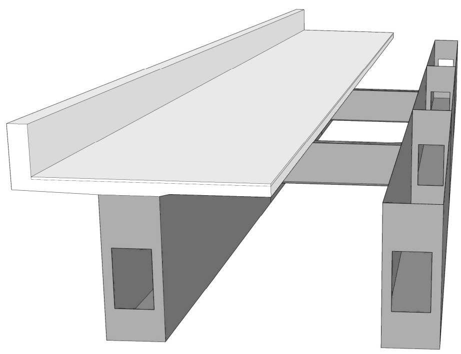


Source: JICA Survey Team

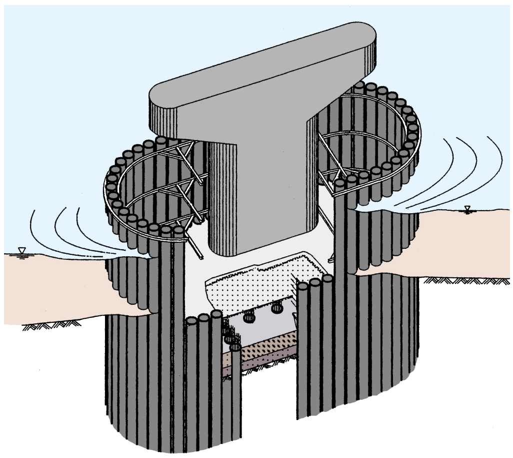
Figure 3.6-11 Long-Span Bridge

The Steel pipe sheet pile wall foundation was selected as the optimal foundation type for the long-span bridges inside the rivers because of the following reasons:

- The steel pipe sheet pile can be used for both permanent foundation and cofferdam work and it is not necessary to construct cofferdam and foundations separately unlike the bored pile option;
- More economical than the bored pile option (including the cost for cofferdam work);
- The construction period is shorter than that of the bored pile option; and
- The size of steel pipe sheet pile option is smaller than that of the bored pile option, and the impact on rivers such as scouring would be minimized.



Steel Narrow Box Girder Bridge



Steel Pipe Sheet Pile Wall Foundation

Source: JICA Survey Team

Figure 3.6-12 Long-Span Bridge

As described in the section 3.4.2, the steel narrow box girder type bridge has more advantages than other bridge types for the following reasons;

- The steel narrow box girder is lighter than that of other bridge types (55% of the weight of PC box girder) which makes it preferable in soft ground conditions;
- The steel/concrete composite deck is more durable than conventional reinforced concrete slab; and
- Formwork and scaffolding for the deck slab works are not required. This coupled with the reduced number of parts leads to a reduction in the overall construction. Generally, construction cost for PC box girder type bridge is almost equal to that of steel box girder type bridge.

However, the PC box girder type bridge would not be suitable for the project site of Matarbari Port Access Road due to the following reasons:

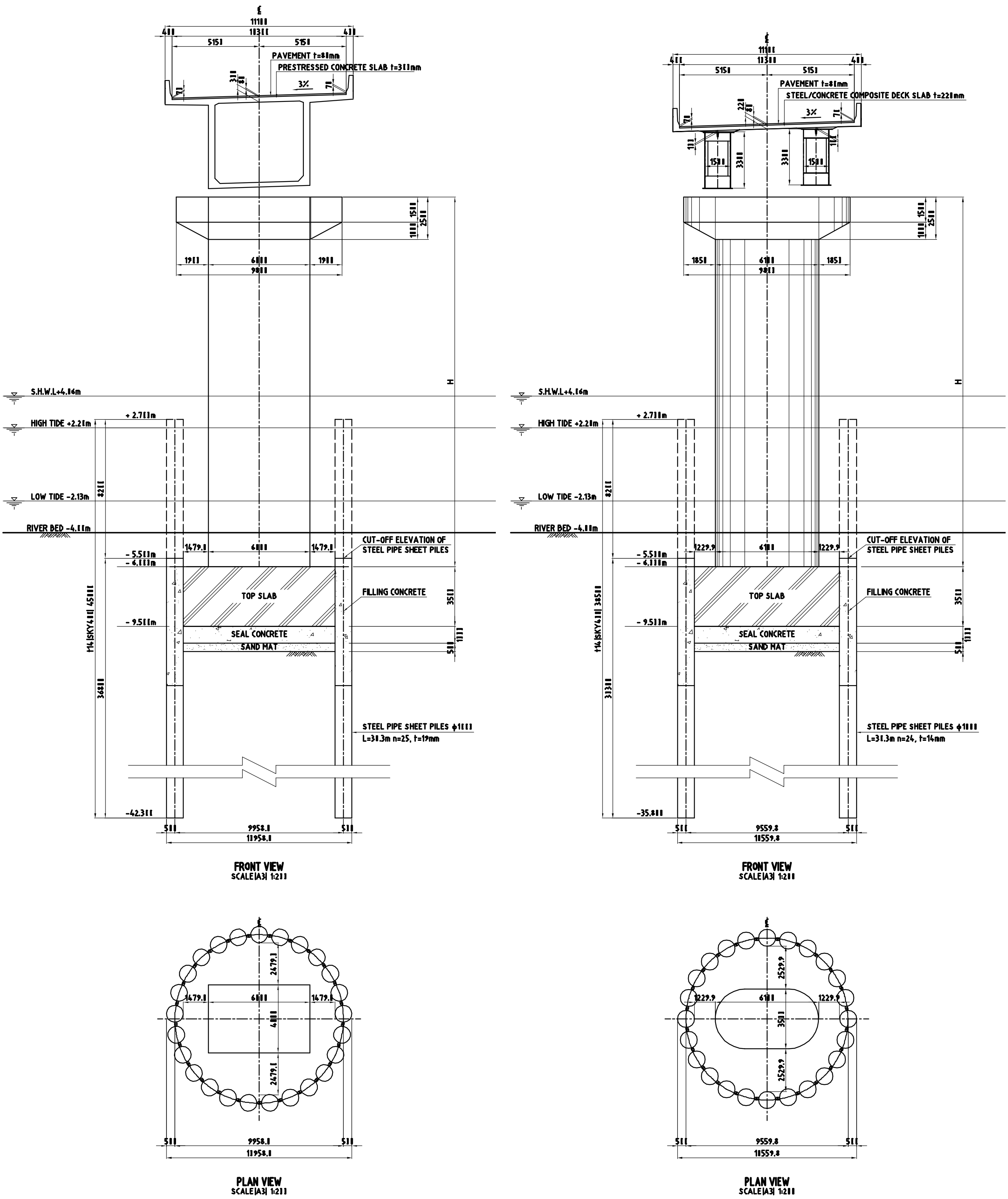
- The PC box girder is heavier than steel box girder and it requires bigger substructure and foundations. The required size of steel pipe sheet pile foundation become bigger than the width of 2-lane bridge and thus the spacing of two (2) bridges, namely 2-lane bridges in Phases 1 and 2, becomes bigger;
- Longer construction period (additional 4.5 months) would be required for PC box girder bridge construction because of the construction method (cantilever method).

Figure 3.6-13 shows the summary of comparison of bridge construction cost over BIWTA's Class II waterways (bridge length: 70m+2@87m+70m=314 m). As mentioned above, the construction cost of the three (3) alternative options are estimated and found to be almost similar. Figure 3.6-14 and Table 3.6-8 show the details of the comparison of bridge structural types and Table 3.6-9 shows the details of the comparison of bridge construction schedule.

	Bridge Construction Cost over BIWTA's Waterway (BDT million)					
	PC Box		**Steel Box**		**Steel Narrow Box**	
1. Temporary Work						
2. Piling Work						
3. Substructure Work						
4. Superstructure Work						
5. Road work						
Total						
Ratio						

Source: JICA Survey Team

Figure 3.6-13 Comparison of Bridge Construction Costs over BIWTA's Class II Waterway



PC Box Girder Bridge **Steel Narrow Box Girder Bridge**

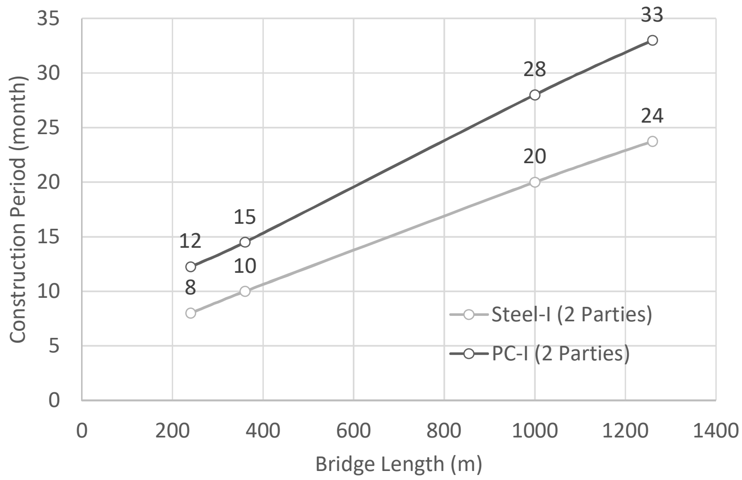
Source: JICA Survey Team

Figure 3.6-14 Comparison of PC Box Girder Bridge and Steel Narrow Box Girder Bridge

Short-Span Bridges

As a short span bridge, it is generally recognized that the PC-I girder type is the optimal and economical bridge type at most field conditions and many RHD's bridge projects in Bangladesh applied the same bridge type. Therefore, the PC-I girder type bridge was adopted as a short-span bridge without special comparison.

However, applicability of steel-I girder type bridge was studied in order to shorten the construction period. Figure 3.6-15 shows the estimated construction periods for PC-I girder and steel-I girder for different bridge lengths. As it can be seen, steel-I girder has an advantage if the bridge length is longer than 200 m. Due to the longer spans, the quantity of substructure works can be reduced. On the other hand, if the bridge length is shorter than 200m, the quantity of substructure works cannot be reduced and the extent of time saving is limited.



Source: JICA Survey Team

Figure 3.6-15 Comparison of Construction Period

The construction cost for a steel bridge is high (148% of the cost for PC-I girder bridge) and application of steel bridge should be limited to the bridges which are critical for construction planning. Although, the above bridges are expected to be constructed as PC-I girder bridges under this study in view of construction costs, further study should be undertaken during the detailed design stage depending on the necessity and availability of funds.

Table 3.6-10 Possible Bridges to be Steel I Girder Type

Bridge Name	Bridge Length	Construction Cost (BDT million)		
		PC-I	Steel-I	Difference
Bridge No. 2				
Bridge No. 4				
Bridge No. 6				
Bridge No. 7				
Bridge No. 8				
Total				

Source: JICA Survey Team

Salt Damage

The proposed Matarbari Port Access Road will be located near the coastal area and construction of three (3) steel bridges is proposed. In order to verify the applicability of applying steel bridges, the project site was examined.

Firstly, there are many steel bridges constructed in coastal areas in Japan because of the following reasons:

- Long span length is required for navigational clearances or geographic/ topographic conditions;
- Quality control is easy and the quality is stable because steel members are produced in factory;
- Site work over the water can be shortened and thus safe;
- Maintenance is easy since corrosion and damage can be observed from outside;
- Partial repair can be done easily; and
- Extension of bridges' life time is possible by conducting appropriate maintenance work.

Tokyo Bay Aqua-Line
- Location: Kanagawa-Chiba
- Bridge Length: 4.4 km (Steel Box Girder)
- Open: 1997

Honshu-Shikoku Bridges
- Location: Hyogo-Tokushima, Okayama-Kagawa, Hiroshima-Kagawa
- Bridge Length: Total 56.6 km in 3 routes
- Open: 1998, 1988, 1999

Tokyo Gate Bridge
- Location: Tokyo
- Bridge Length: 2.6 km (main: 760 m steel truss and steel box girder, approach: steel box girder)
- Open: 2012

Irabu Bridge
- Location: Okinawa
- Bridge Length: 3.5 km (main: steel box girder, approach: PC box girder)
- Open: 2015

Source: JICA Survey Team

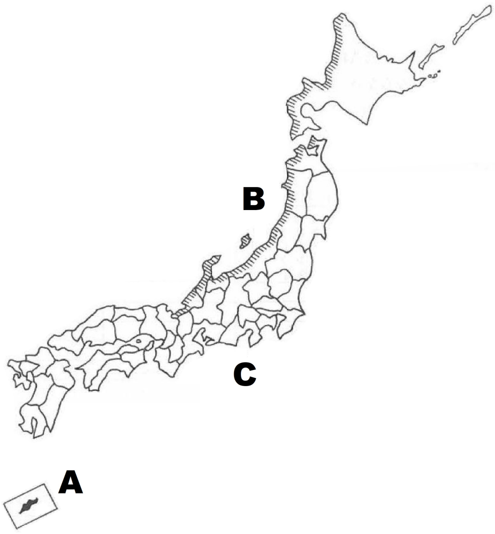
Figure 3.6-16 Example of Steel Bridges in Coastal Areas of Japan

Secondly, durability against salt damage is considered for bridge construction in Japan. For example, cover thickness of concrete structure is always increased as shown in Table 3.6-11 and Figure 3.6-17 in order to protect the steel reinforcement bars from airborne salinity that results into corrosion. For the bridges constructed in areas that are severely affected by airborne salinity, coated reinforcement bars or concrete surface coating is done in addition to increased cover thickness.

Table 3.6-11 Minimum Required Cover Thickness against Salt Damage (mm)

Extent of Salt Damage	Category of Countermeasure	Prestressed Concrete Structures fabricated in Factory	Other Prestressed Concrete Structures	Reinforced Concrete Structures
Severely affected	S	70*		
Affected	I	50	70	
	II	35	50	70
	III			50
Not affected				

Note: *: Coated reinforcement bars or concrete surface coating is required.
Source: Specifications for Highway Bridges (Japan)



Area		Distance from Coastal Line	Category of Counter-measure	Extent of Salt Damage
A	Okinawa	On sea and within 100 m from coastal line	S	Severely affected
		100-300 m	I	Affected
		Over 300 m	II	
B	Coastal areas of Sea of Japan	On sea and within 100 m from coastal line	S	Severely affected
		100-300 m	I	Affected
		300-500 m	II	
		500-700 m	III	
C	Other areas	On sea and within 20 m from coastal line	S	Severely affected
		20-50 m	I	Affected
		50-100 m	II	
		100-200 m	III	

Source: Specifications for Highway Bridges (Japan)

Figure 3.6-17 Extent of Salt Damage in Japan

Steel members deteriorate irreversibly under natural conditions, and thus protection against rusting/ corrosion is necessary to keep the bridge structures in good condition and fit for purpose. The typical protection measures against rusting/ corrosion are summarized in Table 3.6-12.

In Japan, corrosion of steel members have been observed depending on the extent of airborne salinity. Anti-corrosion coating is the most popular protection method and is applicable even in the most severely affected airborne salinity conditions. The type of anti-corrosion coating is selected based on the extent of airborne salinity at the bridge location. The extent of airborne salinity is typically evaluated by the distance from the coastal line as a macro perspective. Nevertheless the actual condition of airborne salinity would vary depending on the geographic/ topographic conditions and the wind path as well as seasonal variations. Therefore, necessity for heavy-duty anti-corrosion coating can be justified by airborne salinity tests at the proposed bridge locations.

Table 3.6-12 Typical Protection Measures against Rusting/ Corrosion

	Fundamental Function	Condition of Deterioration	Repairing Method	Applicable Airborne Salinity Condition Low ← → High
Anti-Corrosion Coating	Blocking of exposure to atmospheric environment by coated film	Deterioration of coating	Repainting	Normal Coating Heavy-Duty Coating
Weathering Steel	Inhibition of corrosion speed by forming delicate rusting layer	Occurrence of delamination rust and decrease of thickness	Painting	
Hot Dip Galvanizing	Formation of protective membrane by zinc oxide or sacrificial protection by zinc	Decrease of zinc layer	Painting	
Thermal Spraying	Formation of protective membrane and sacrificial protection by thermal spraying	Decrease of thermal spraying layer	Thermal spraying or painting	Sealing Treatment Heavy-Duty Coating

Source: Edited by JICA Survey Team based on Specifications for Highway Bridges (Japan) and Manual for Steel Road Bridge Corrosion Protection

Considering the above and the site conditions of the project area, use of steel bridges would be reasonable for the following reasons:

- The designed steel narrow box girder bridges will have heavy-duty anti-corrosion coating, which can protect steel members against airborne salinity even at severely affected areas. The heavy-duty anti-corrosion coating will keep its function for at least 30 years according to the several studies and tests undertaken in Japan;
- The proposed steel bridges are located a distance beyond 1 km from the coastal line, meaning they are outside the salt damage affected area considered in Japan.

However, airborne salinity tests should be conducted during the detailed design stage for the project in order to confirm the extent of airborne salinity at the project site and justify the applicability of heavy-duty anti-corrosion coating in reference to the experience in Japan.

(3) Justification 3: Road Structural Type (Embankment vs Bridge)

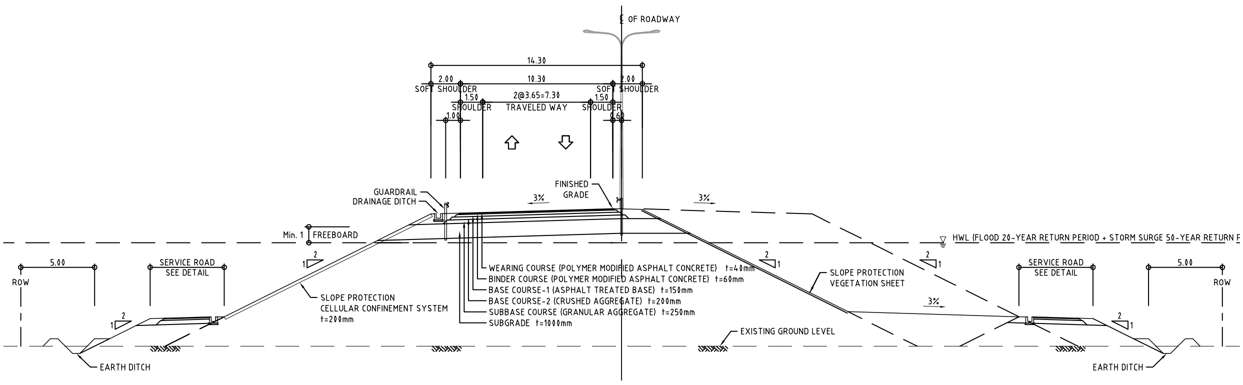
Embankment is a common structural type for roadway and is basically more economical than bridge structure. Thus, embankment type was applied as the basic road structure under the preliminary design for the Matarbari Port Access Road excluding the sections at river crossings or special ground conditions such as the existence of alternate layers of sand and clay. However, due to the design controls such as high flood/ storm surge levels as well as the provision of grade separation with local road crossings, embankment height of the access road became high and thus the required width for ROW became very big. Therefore, there was need to justify the reasonableness for applying embankment type rather than bridge/viaduct type. Justifications for road structural type can be evaluated from the following two (2) aspects.

- Technical evaluation for construction of the road
- Road structural type based on the land use condition for the project site

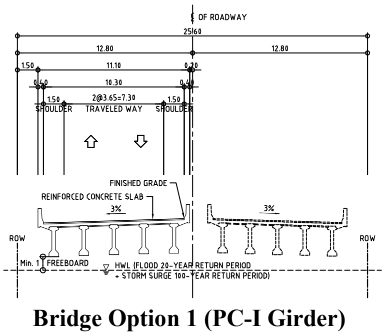
For this project, it was concluded that the embankment option would still be reasonable as the basic road structural type for the Matarbari Port Access Road.

<u>Technical evaluation for construction of roadway</u>

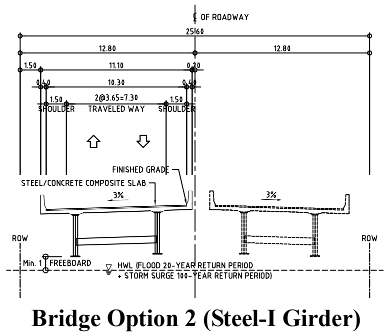
As shown in Figure 3.6-18 and Table 3.6-13, the required area of ROW for embankment option is much larger than the bridge option, but the embankment option is more advantageous than the bridge option in view of construction period and cost. Also, considering that the project road is expected to be expanded to 4-lanes in future, embankment option is more economical than bridge option because the remaining construction works for expansion to a 4-lane embankment is very limited in comparison with bridge construction cost which will be double. Therefore, the considerable justifications for construction of the road embankment with a wide ROW would be i) the easiness of land acquisition and resettlement of houses and ii) availability of embankment materials (see Justification 4).



Embankment Option



Bridge Option 1 (PC-I Girder)



Bridge Option 2 (Steel-I Girder)

Source: JICA Survey Team

Figure 3.6-18 Road Structural Types

Table 3.6-13 Comparison of Road Structural Types

		Embankment Option	Viaduct Option 1 (PC-I Girder)	Viaduct Option 2 (Steel-I Girder)
Design Conditions		• Slope gradient: 1:2.0 • Width of roadway: 14.3 m • Service road: 5.0-7.5 m • ROW width: 80-90 m	• PC-I girder • Bored pile foundation • Width of bridge: 10.3 m • ROW width: min. 25.6 m	• Steel-I girder • Bored pile foundation • Width of bridge: 10.3 m • ROW width: min. 25.6 m
Advantage		• Widening to 4-lane in future is easy with low additional cost	• ROW width is minimal	• ROW width is minimal
Disadvantage		• ROW width is very wide	• Additional cost for widening to 4-lane in Phase-2 will be same as that in Phase-1.	• Additional cost for widening to 4-lane in Phase-2 will be same as that in Phase-1.
Construction Period (by 2 parties)		**13** month/km	**28** month/km	**20** month/km
Construction Cost (A)	Phase 1			
	Phase 2			
Area of Land Acquisition for 4-lane		8-9 ha/km	2.6 ha/km	2.6 ha/km
Land Acquisition and Resettlement Cost (B)				
Total Cost (A)+(B)	Phase 1			
	Phase 2			
	Total			
Evaluation		**Recommended**		

Source: JICA Survey Team

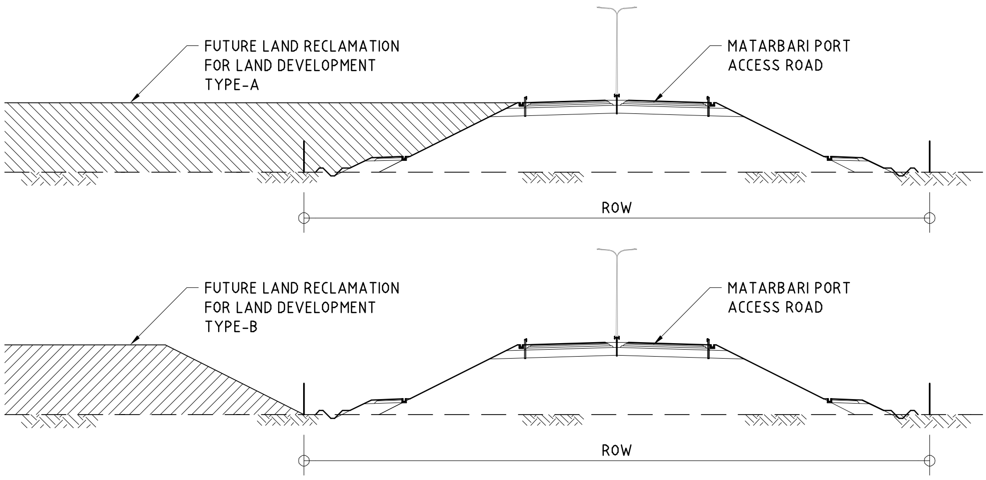
Figure 3.6-19 Cost Comparison of Road Structural Types (BDT billion/km)

<u>Road structural type based on land use condition at the project site</u>

In addition to the technical comparison of road structural types, the relationship between road structural type and future land use condition was also considered. As there are several land development plans in Matarbari and Maheshkhali areas such as the proposed CPGCBL's Power Plant, the proposed Matarbari Port which are all to be constructed on high embankments following land reclamation. In both cases the expected flooding/ storm surge levels are high which justifies the need for high embankments.

Also, the Matarbari Port Access Road will be extended to the south of Maheshkhali according to the area development plan (see Figure 3.2-3) but the intersecting point with the southern access road cannot be decided until the land use master plan of Maheshkhali is confirmed.

In this regard, the embankment type of road structure in Matarbari and Maheshkhali areas should also be embankment in order to fit with the conditions of the surrounding area and ensure the possibility of extension to the south.

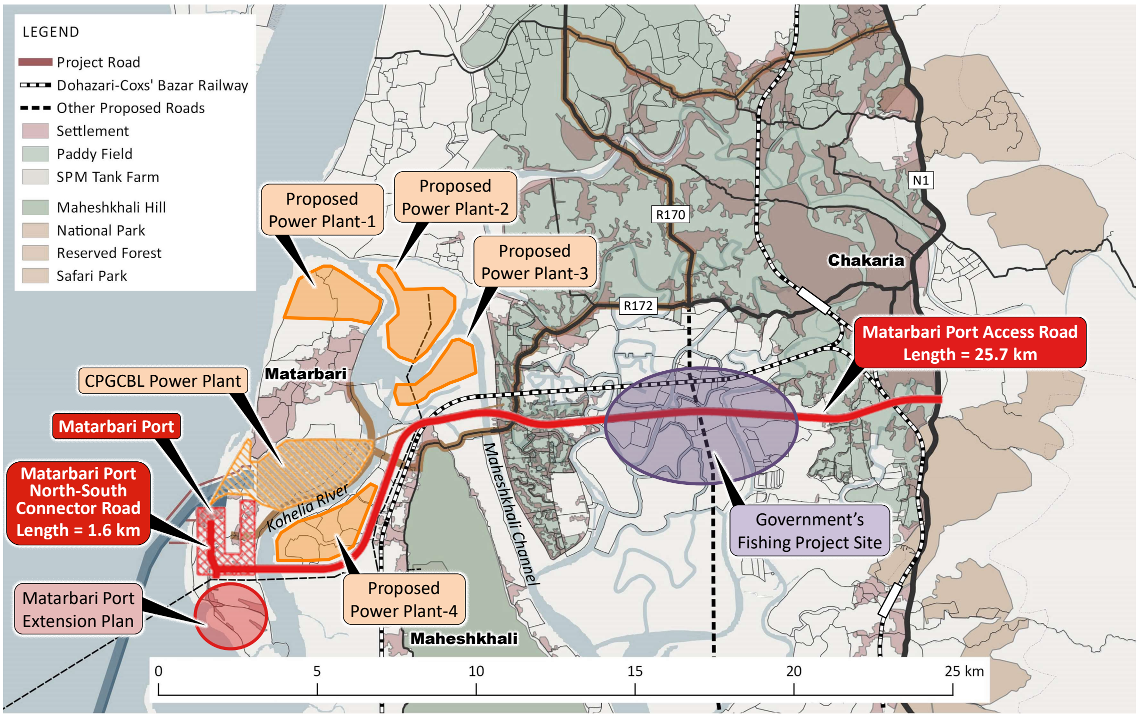


Source: JICA Survey Team

Figure 3.6-20 Image of Land Reclamation in Matarbari and Maheshkhali

On the other hand, there is no such large scale land development plans in Chakaria area, and thus future land use would be different from that of the Matarbari or Maheshkhali areas. However, most of the land in Chakaria area is owned by government for agricultural purpose or fishing projects, which have not been successful in the past (see Figure 3.6-7). Therefore, it is expected that the land acquisition in Chakaria area would not be difficult except for the areas in Badarkhali Market and the area near N1.

Most land in Badarkhali area is privately used for agricultural purposes but it is leased from the government. Several academic institutions and residential houses are located within the area. Furthermore, most of the land in Fashiakhali is privately owned and mainly used for agricultural purposes (rice production). Therefore land acquisition in this area is expected to be difficult.



Source: JICA Survey Team

Figure 3.6-21 Current and Future Land Use at the Project Site

As has been pointed out before, if the Government of Bangladesh prefers the viaduct option to the embankment option in view of minimizing the area of land acquisition, the sections shown in Table 3.6-14 would be considerable for the construction of viaducts at additional construction cost because these sections are primarily privately owned. The viability of the road structural types at these sections should be re-examined during the detailed design stage and should be modified depending on necessity and availability of funds.

Table 3.6-14 Possible Section for Viaduct

Section	Length	Type of Land	Construction Cost including Land Acquisition Cost (BDT billion)		
			Embankment	Viaduct	Difference
12+800 – 13+440 13+140 – 14+000	1.5 km	Agricultural land leased by Government			
19+000 – 20+400	1.4 km	Agricultural land owned by private			
22+050 – 23+550	1.5 km	Agricultural land owned by private			
Total	4.4 km				

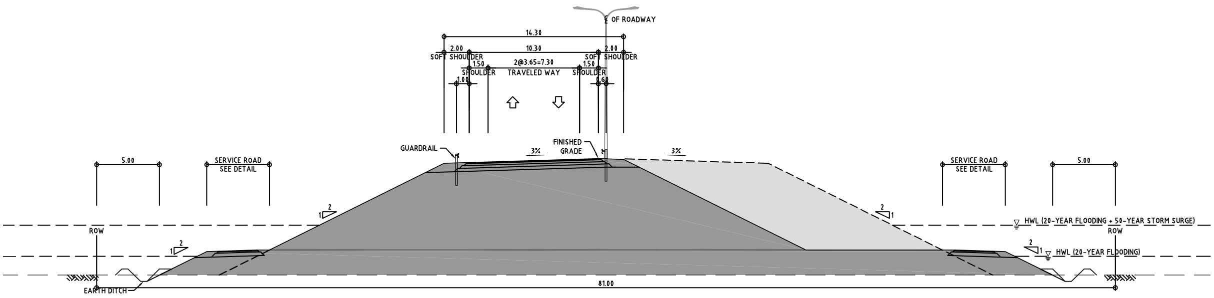
Source: JICA Survey Team

(5) Justification 5: Embankment Design

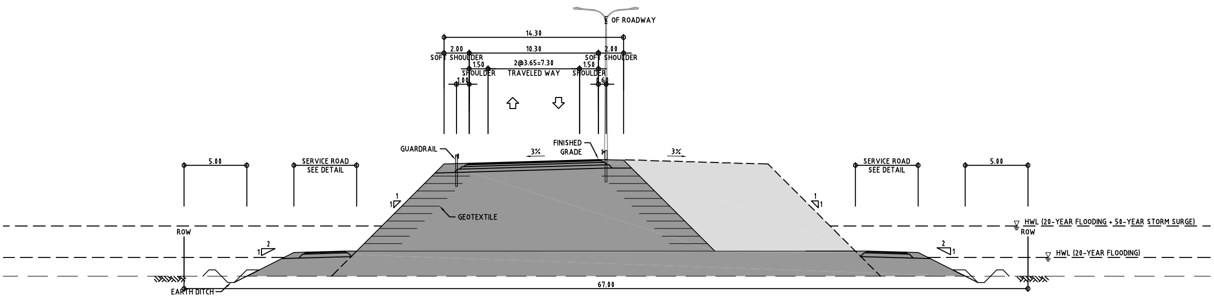
Slope Gradient

Slope gradient is a key element governing the width of the Right of Way (ROW) and construction cost especially for high embankment. This study applied embankment slope of 1:2.0 in accordance with the RHD standard but the average 8.0 m height of embankment with service roads on both sides of embankment requires about 80 m width of ROW, which is relatively wider than the ordinary ROW width for National Highways. Therefore, the following alternative options were examined in order to justify the reasonableness of the slope gradient and to evaluate the possibility to make the embankment slope steeper:

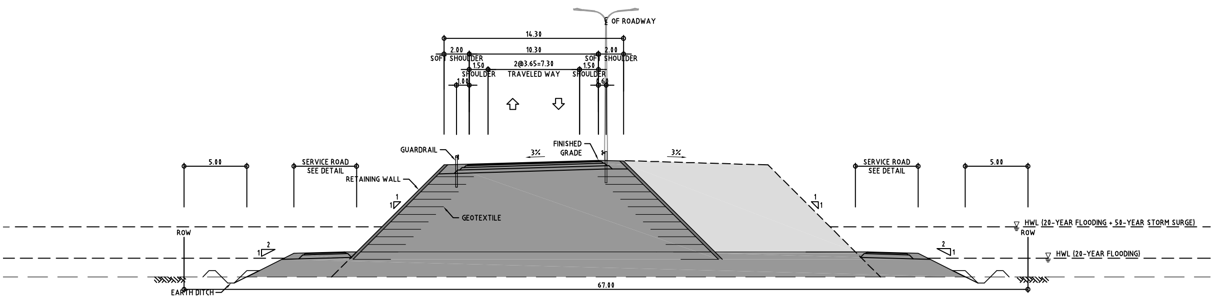
- Option 1: Slope gradient 1:2.0 (RHD standard)
- Option 2: Slope gradient 1:1.0 (Geotexitile-reinforced embankment)
- Option 3: Slope gradient 1:1.0 (Geotexitile-reinforced embankment with retaining wall)



Option 1: Slope gradient 1:2.0 (RHD standard)



Option 2: Slope gradient 1:1.0 (Geotexitile-reinforced embankment)



Option 3: Slope gradient 1:1.0 (Geotexitile-reinforced embankment with retaining wall)

Source: JICA Survey Team

Figure 3.6-28 Slope Gradient Options

As a result of analysis, Option 1 (slope gradient 1:2.0, RHD standard) was evaluated as the optimal slope gradient for the project site condition because of the ease of construction and economic viability.

Table 3.6-19 Comparison of Slope Gradient

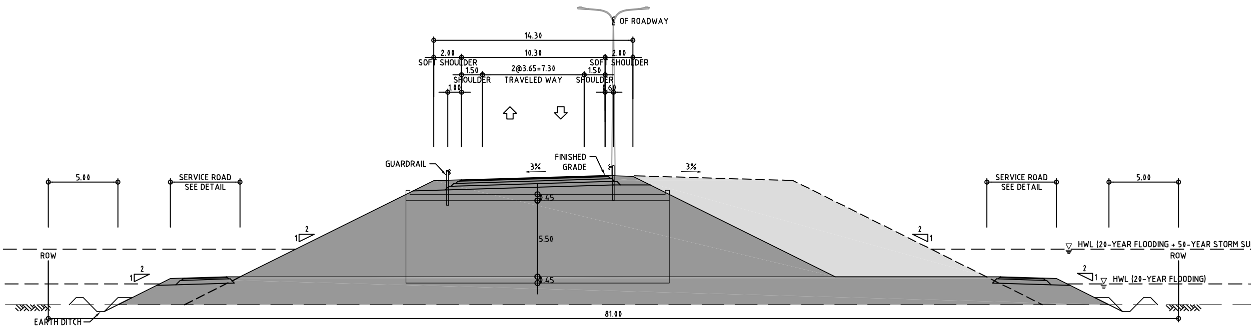
	Option 1 (RHD Standard)	**Option 2 (Geotexitile-Reinforced Embankment)**	**Option 3 (Geotexitile-Reinforced Embankment with Retaining Wall)**
Slope gradient	1 : 2.0	1 : 1.0	1: 1.0
Volume of embankment material	**5.50** million m^3	**4.16** million m^3	**4.16** million m^3
Embankment stability during construction stage	**Good** • Soft ground improvement can be undertaken in parallel with the embankment filling	**Fair** • Soft ground improvement would be required before filling embankment	**Fair** • Soft ground improvement would be required before filling embankment
Constructability	**Good** • Easy to construct for filling and compacting	**Fair** • Additional human-powered works are necessary for installing several layers of geotextile and edge treatment	**Fair** • Additional human-powered works are necessary for installing several layers of geotextile and edge treatment • It would be difficult to apply this method for 18 km-long embankment work
Durability against water force	**Fair** • Slope with vegetation is week against scouring	**Fair** • Slope with vegetation and geotextile-reinforced embankment is week against scouring	**Good** • Composite structure of retaining wall and geotextile -reinforced embankment has high resistance against scouring
Evaluation	**Recommended**		

Source: JICA Survey Team

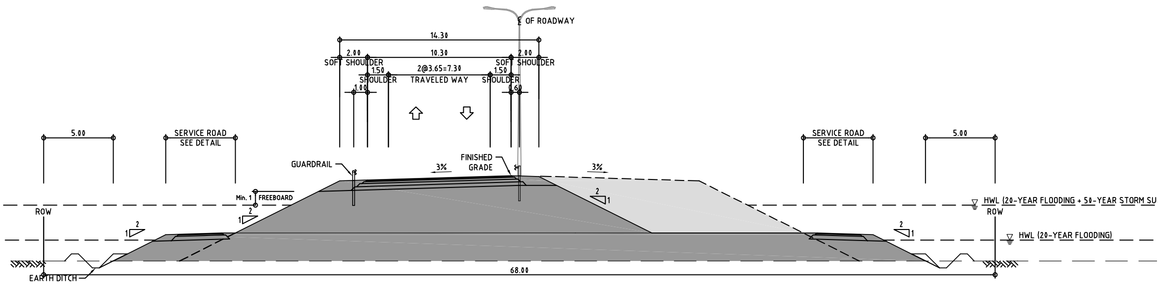
<u>Embankment Construction Concept under Phased Construction</u>

As mentioned above, the required volume of embankment material was estimated as 5.26 million m^3 and procurement of such large volumes of embankment material is one of the biggest challenges for the project. In order to justify the feasibility of the design and come up with alternative measures to reduce the volume of embankment material, the following three (3) options were examined:

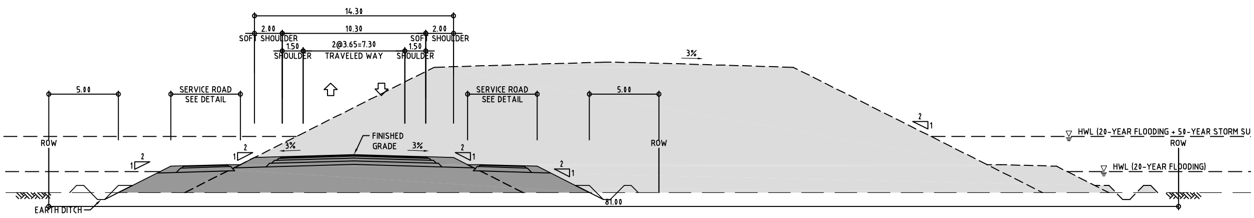
- Option 1: Access control for providing smooth flow of long-distance freight traffic by physically separating it from short-distance local traffic. The controlling aspects of the vertical alignment are; the underpass box culverts and the high water level.
- Option 2: Non-access control in order to minimize embankment volume. All road crossings including R172 are intersected at-grade. The design control for vertical alignment in this instance is high water level only.
- Option 3: Temporary construction based on the design concept of the Option 1. Embankment height is lower than high water level and is almost at the same elevation as the existing roads.



Option 1: Access Control



Option 2: Non-Access Control



Option 3: Temporal Construction

■: To be constructed under this project, □: To be constructed in future

Source: JICA Survey Team

Figure 3.6-29 Embankment Construction Concepts

As a result of comparative analysis, it was determined that Option 1 (original design) would be the most feasible option, despite of the large volume of embankment material and the required area of the ROW for the following reasons:

- Interference by short-distance local traffic such as NMT or SMVT is one of the biggest issues affecting National Highway operation in Bangladesh. The project road will cater mainly for long-distance freight traffic (cargo trucks) so access control should be provided to ensure smooth traffic flow;
- Option 2 (non-access control) has a reduced requirement for embankment material but drastically affects the intended function of the road.
- Option 3 (temporary operation) has a risk of closure of the road during flooding or storm surge. This is not suitable from the planning point of view for inland freight transport.

Table 3.6-20 Embankment Construction Concepts

	Option 1	Option 2	Option 3
Design Concept	Access control (R172 and CPGCBL Power Plant Access Road are the only accessible roads between N1 and Matarbari Port)	Non-Access Control (Not only R172 and CPGCBL Power Plant Access Road, other Zila Roads, Village Roads intersect with the project road at grade)	Temporary construction with minimum volume of embankment material (excluding the following sections where bridges are closely located) • 0+000 – 1+000 • 10+000 – 12+300 • 20+500 – 25+413
Design Control for Vertical Alignment	Bridge: 100-year storm surge Embankment: 50-year storm surge and underpass	Bridge: 100-year storm surge Embankment: 50-year storm surge	Bridge: 100-year storm surge Embankment: Service road + 50cm
Average Height of Embankment	7.90 m	7.19 m	5.88 m
Embankment Volume	5.50 million m^3	4.65 million m^3	3.32 million m^3
Construction Cost for Embankment			
Road Crossings	At-grade: 1 Grade Separated: 1 Underpass: Many	At-grade: Many Grade Separated: 1	At-grade: Many Grade Separated: 1
Traffic Smoothness	• The accessible points for the project road are limited only at two (2) locations and the distance between the accessible points is over 10 km. short-distance local traffic will not use the project road and smooth traffic flow for freight traffic can be ensured.	• All roads which are accessible by vehicles will intersect with the project road. Short -distance local traffic will use the project road which would be an obstacle for smooth traffic flow of freight traffic due to encroachments.	• Same as Option 2 during temporary operation. • Expandability to Option 1 is secured. • But the construction cost for the future expansion is high.
Constructability	• Procurement of embankment materials and height of embankment fill on soft ground presents challenges.	• Relatively lower risk than Option 1.	• Embankment volume and risk are the lowest.
Prospect of Bidders' Participation	• Probable candidates for the dredging works need to be confirmed at the detailed design stage. • The risk can be resolved if the above is confirmed.	• Lower risk than Option 1	• Embankment volume and risk are the lowest.
Possibility of Damage by Flooding or Storm Surge	• The finished grade for the project road would be higher than a 50-year storm surge and all weather traffic can be provided.	• Same as Option 1	• The finished grade of the project road is lower than a 50-year storm surge and the project road would be closed in the event that a storm surge occurred.
Easiness of Land Acquisition	• An average of about 80m width of ROW would be required.	• An average of about 70m width of ROW would be required.	• It is better to acquire the same area of ROW as Option 1 but an average of 45 m width of ROW can accommodate the temporary construction.
Evaluation	Recommended		

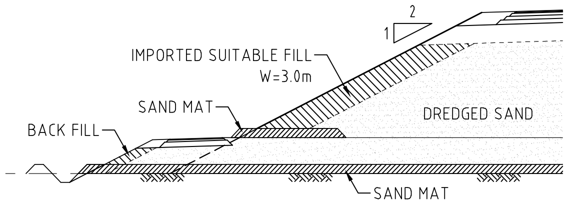
Embankment Material

This study assumed that there is no available material source on land near the project site and dredged sand from the nearest location of the channel of Matarbari Port would be the most economical and realistic source of embankment material. But the dredged sand would be easily eroded by rainfall or flooding, and should be limited to use inside the embankment, and imported suitable sand/clay should be filled at embankment slope for the purpose of slope protection against erosion by rainfall. However, the suitable embankment material necessary to be imported is too expensive. In order to verify the design assumptions, the following three (3) alternative options were examined.

- Option 1: Soil Blanket (3.0 m width)
- Option 2: Soil Blanket (1.5 m width) w/ Vegetation Sheet
- Option 3: Cellular confinement System w/ Geotextile and Excavated Clay Materials

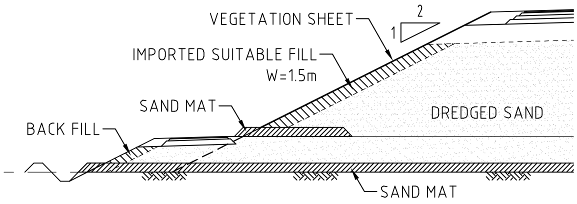
The original design (Option 1) was considered to provide a soil blanket with enough width for mechanical compaction of the suitable fill materials however, this width is considered unnecessary. Therefore, Option 2 is considered as an alternative to reduce the volume of the suitable fill material to half (1.5 m width). It would be possible to manage compacting the 1.5 m width suitable fill by mechanically although a vegetation sheet should be provided in order to protect the slope from erosion.

Option 3 is another alternative to use high-strength geo-cell (cellular confinement system) instead of using the suitable fill material. Generally, there is limited availability of suitable fill materials. This is a similar case in Japan as well and this method has been applied on some projects. The cellular confinement system is expanded on-site to form a honeycomb-like structure, which can be filled with excavated site materials, and is applied for soil stabilization, retaining walls, slope erosion control, load platforms and tree root protection.

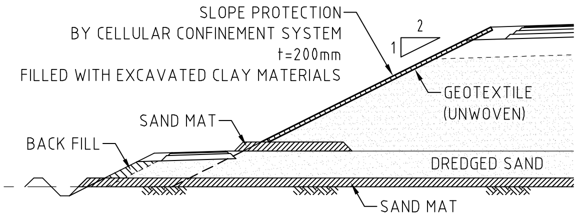


Option 1: Soil Blanket (3.0 m width)

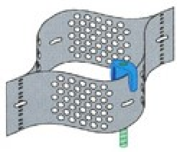
Vegetation Sheet



Option 2: Soil Blanket (1.5 m width) w/ Vegetation Sheet



Option 3: Cellular Confinement System w/ Geotextile and Excavated Clay Materials

Cellular Confinement System

Source: JICA Survey Team

Figure 3.6-30 Embankment Slope Options

Table 3.6-21 summarizes the results of comparative analysis for embankment slope structures. As described in the table below, it was concluded that Option 3 (Cellular Confinement System w/ Geotextile) is the most economical and preferable option for ensuring slope stability at a reasonable construction cost.

Table 3.6-21 Comparison of Embankment Slope

	Option 1 **Soil Blanket (3.0 m width)**	**Option 2** **Soil Blanket (1.5 m width) w/ Vegetation Sheet**	**Option 3** **Cellular Confinement System w/ Geotextile and Excavated Clay Materials**
Design Concept	• In order to ensure slope stability against erosion, 3.0 m width of soil blanket by suitable fill material is provided. • Even if the soil blanket receives minor erosion, the entire width would not be eroded.	• In order to reduce the volume of expensive suitable fill material, half of the soil blanket width is reduced. • In order to ensure slope stability against erosion, vegetation sheets are provided to promote vegetation growth.	• Instead of using expensive suitable fill materials, high-strength geo-cell is applied. • In order not to spill the fill material, a geotextile is provided under the geocell and the excavated clay materials are filled in the geocell.
Embankment Material – Imported Suitable Sand	0.53 million m^3	0.27 million m^3	0 m^3
Embankment Material – Dredged Sand	4.96 million m^3	5.23 million m^3	5.50 million m^3
Construction Cost for Embankment			
Constructability	**Excellent** • 3 m width of suitable fill layer can be easily compacted by machine.	**Good** • 1.5 m width of suitable fill layer can be compacted by machine but more caution is necessary than Option 1. • Extra work to lay vegetation sheet is needed.	**Good** • Erosion of slope may occur during the period of surcharge and pre-loading. • Extra work to lay cellular confinement system is needed.
Easiness of Procurement of Materials	**Poor** • Large volume of suitable material need to be imported.	**Fair** • Large volume of suitable material need to be imported.	**Excellent** • The geo-cell can be transported compactly.
Easiness of Expansion in Future (Phase 2)	**Good** • Natural vegetation slope can be easily excavated for preparation of embankment fill.	**Good** • The installed vegetation sheet can be easily removed for preparation of embankment fill.	**Fair** • The installed geocell is too strong and should be removed for preparation of embankment fill but it may increase work volume.
Easiness of Maintenance	**Fair** • Repair work may be necessary until the slope is filled with vegetation.	**Good** • Vegetation sheet will protect the slope against erosion and maintenance work for repairing slope is not necessary.	**Good** • Geo-cell will protect the slope against erosion and maintenance work for repairing slope is not necessary.
Evaluation			**Recommended**

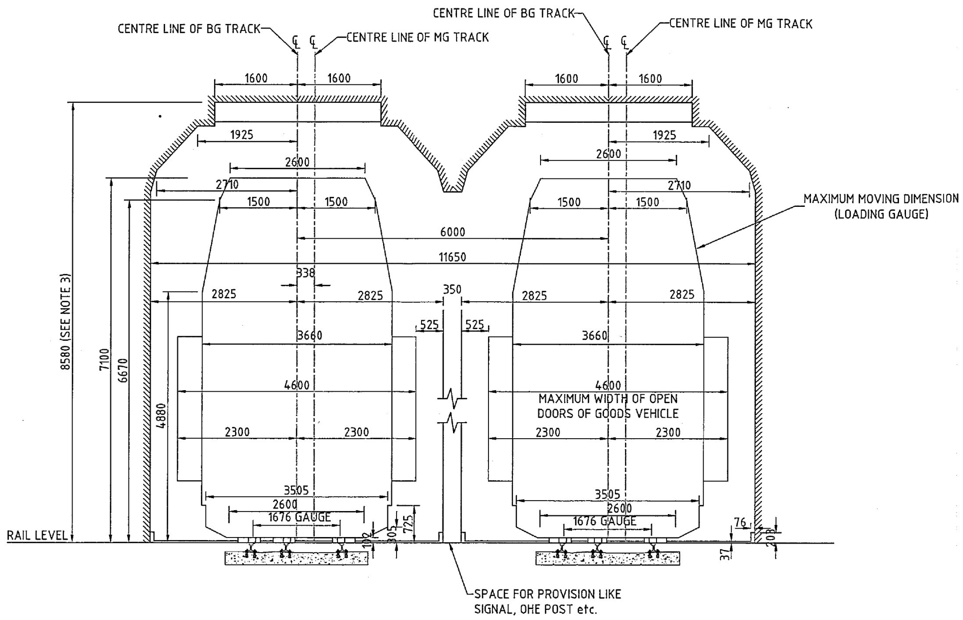
Source: JICA Survey Team

(6) Justification 6: Rail Crossings

The proposed Matarbari Port Access Road will have the following two (2) railway crossings:

- Dohazari-Cox's Bazar Railway between Chakaria Station and Dulahazara Station; and
- Rail Spur Line to Matarbari Port

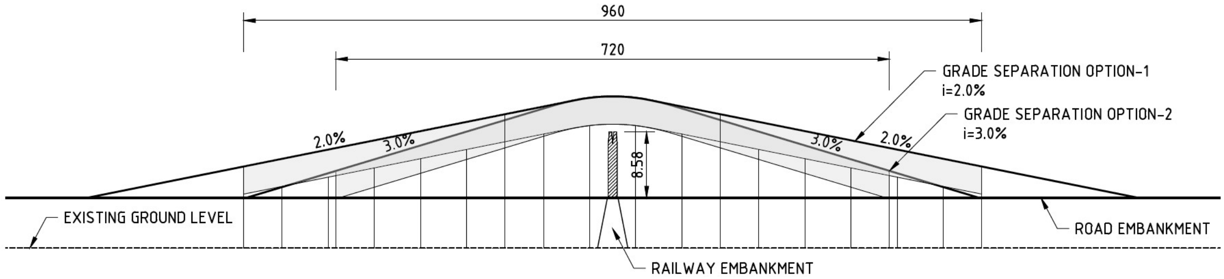
According to Bangladesh Railway, the above railways are planned to accommodate double decker container trains and require at least 8.58 m vertical clearance above rail level. Considering that the railways are also planned to be constructed with high embankment (8.8 m above MSL), the vertical clearance would be equivalent to 17.38 m above MSL (approximately 15.0 m above existing ground level).



Source: ADB Consultant for Study for Dhaka-Chittagong-Cox's Bazar Railway Project Preparatory Facility

Figure 3.6-31 Clearance for Railway

In general, there are two (2) types of rail crossings, namely i) at-grade crossing and ii) grade separation. At-grade crossing is more economical than grade separation but vehicular traffic on the road needs to stop before crossing. Grade separation is more efficient than at-grade crossing but the above-mentioned horizontal clearance requires approximately 700 m to 1000 m long viaduct with 3% to 2% of vertical grade respectively.



Source: JICA Survey Team

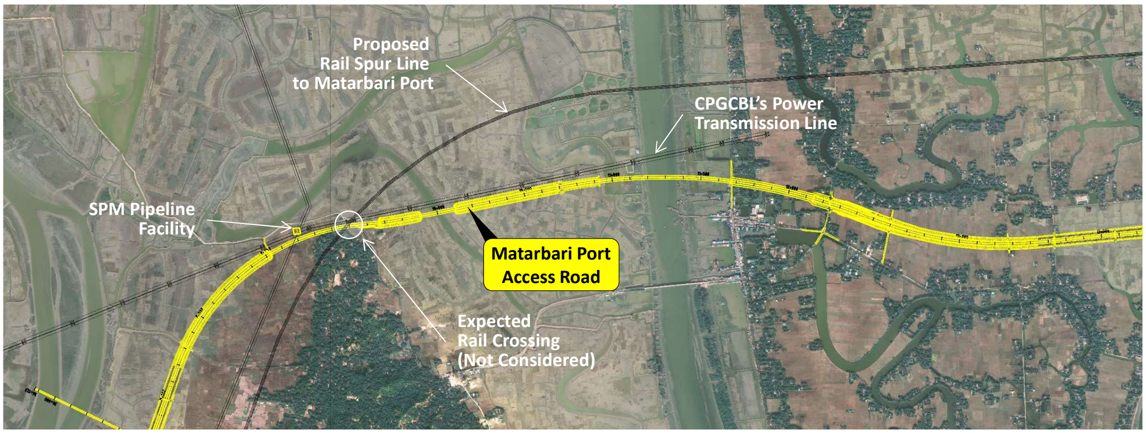
Figure 3.6-32 Comparison of Rail Crossing Types

Considering the following, at-grade crossing was selected for the rail crossing at Dohazari-Cox's Bazar Railway:

- Grade separation will need an additional cost of approximately BDT 1.6 to 2.3 billion;
- Frequency of usage of the trains may not be so high;
- Matarbari Port Access Road will be constructed under phased construction and construction of a viaduct would be possible in future as and when the frequency of the trains becomes high.

However, the rail crossing with the rail spur line to Matarbari Port has not been considered under this study for the following reasons:

- The structural type of the project road at the expected rail crossing point is a bridge. At-grade crossing would be difficult if the CPGCBL's power transmission line and the densely populated residential areas of Maheshkhali Hill, are to be avoided;
- The alignment of the project road at the location is designed as a horizontal curve with a radius of 1,200 m, which requires a 2% reverse curve and thus at-grade crossing is not preferable;
- At this stage, the alignment of the railway has not yet been confirmed which makes it difficult to ascertain the exact position of rail crossing for designing of a grade separated viaduct. ;
- The proposed alignment of the rail spur line to Matarbari Port requires relocation of the CPGCBL's power transmission line which is difficult to confirm at this stage. If the grade separated viaduct is constructed and the proposed railway is not, the investment for the grade separated viaduct would be wasted.



Source: JICA Survey Team

Figure 3.6-33 Rail Crossing with the Proposed Rail Spur Line to Matarbari Port

Therefore, the following are recommended to be undertaken at the time of construction of the rail spur line to Matarbari Port:

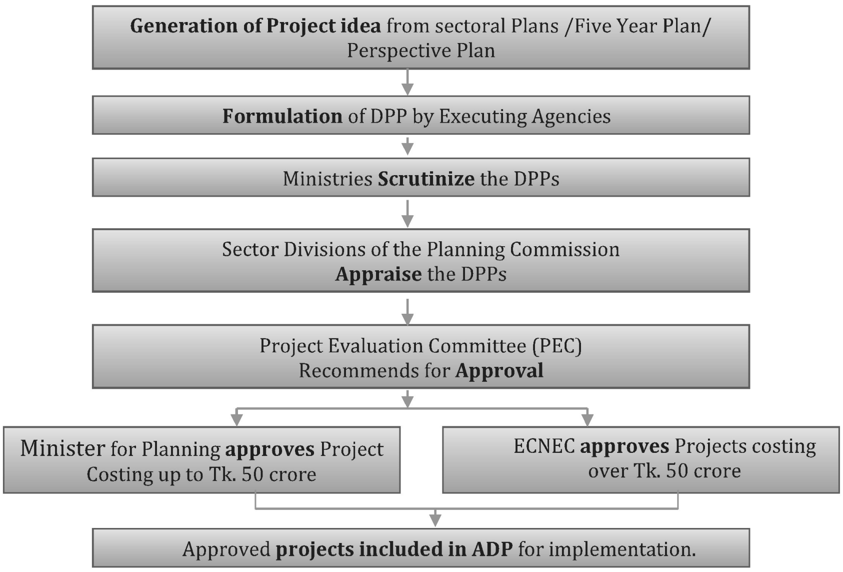
- The required elevation of the railway should be determined basing on its operational plan and a decision taken on either adopting at-grade crossing or grade separation ;
- To reconstruct Matarbari Port Access Road provision for either a grade separated viaduct or an embankment to accommodate at-grade crossing should considered;
- Securing of the required clearance necessary to relocate CPGCBL's power transmission line from both Matarbari Port Access Road and the railway should be considered; and
- All the resulting costs should be borne by the railway project.

3.6.4 Implementation Schedule

3.6.5 Implementation Structure

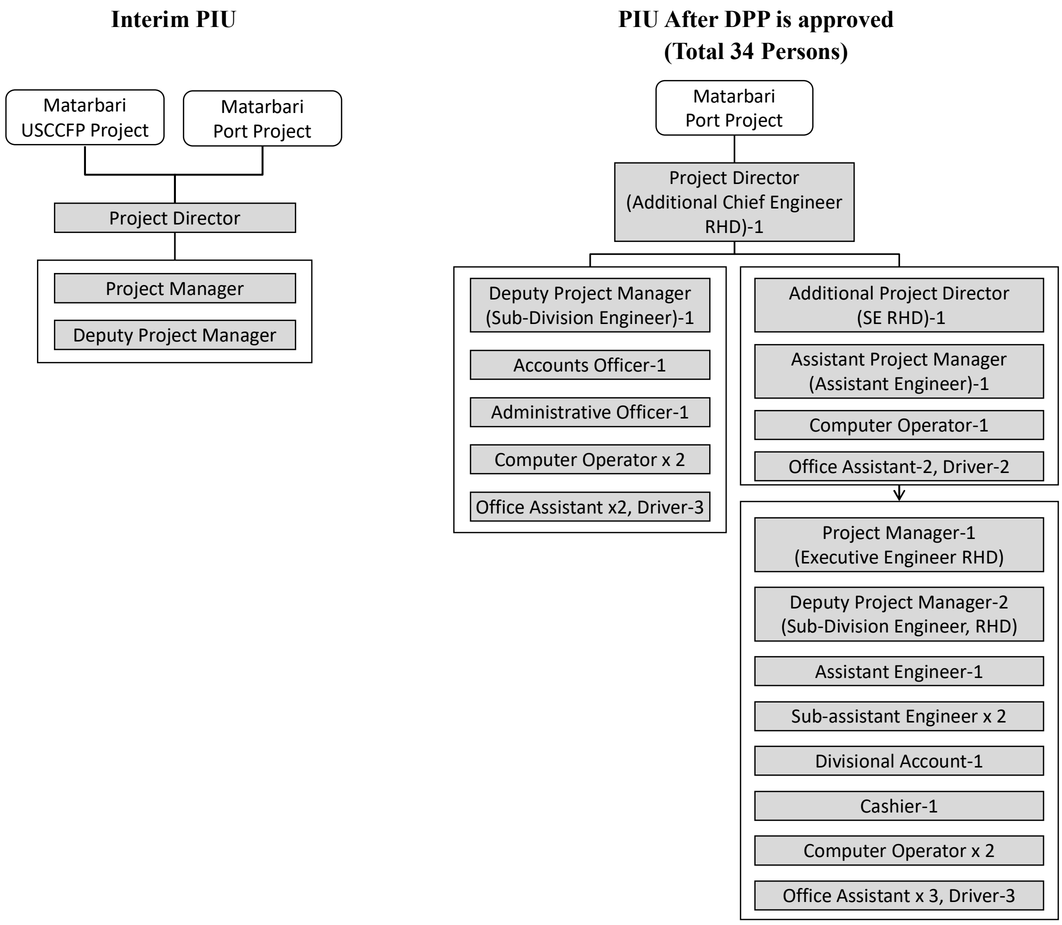
RHD will be the executing agency of the access road component of the project. After approval of the Development Project Proposal (DPP), a Project Implementation Unit (PIU) will be organized under RHD. Before approval of DPP, an Interim PIU has been organized under the same umbrella of the CPGCBL's Power Plant Access Road Project. The required personnel of PIU are estimated to be 34 persons.

Processing of development projects (both GOB financed and aided) for approval involves several steps. After preparation of Development Project Proposals (DPPs) by executing agencies, concerned ministries evaluate the DPPs and then Sector Divisions of the Planning Commission appraise the DPPs. This is followed by recommendations for approval by the Project Evaluation Committee (PEC). Then the Minister for Planning or the Executive Committee of the National Economic Council (ECNEC) approves the project depending on its size, after which the approved projects are included in the Annual Development Program for implementation. An Interim Project Implementation Unit (PIU) was formed as shown in the figure below.



Source: Development Project Proforma/Proposal (DPP) Manual, General Economic Division

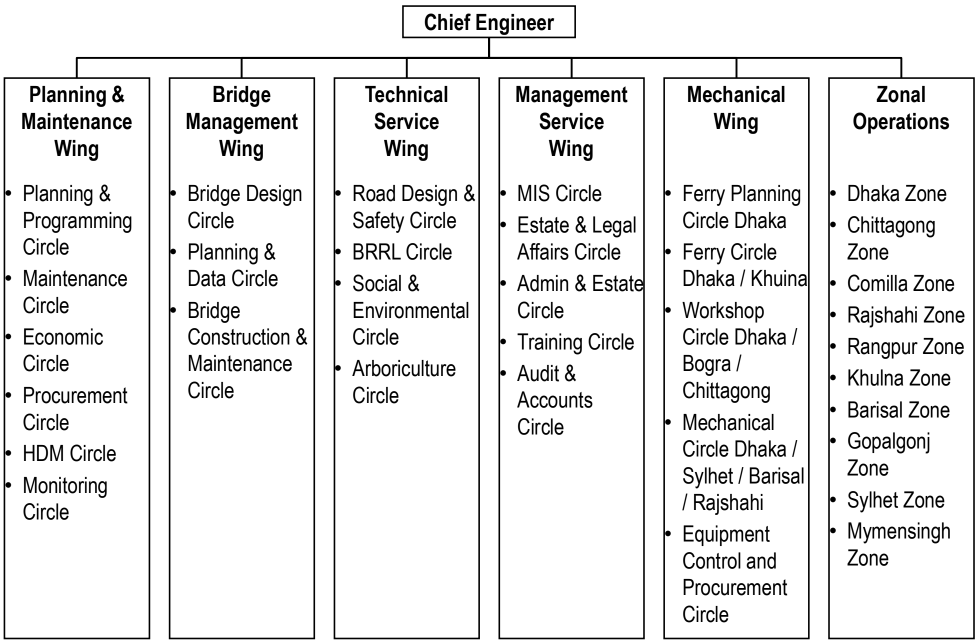
Figure 3.6-34 Steps Involved in Approval Process of Investment Projects



Source: RHD

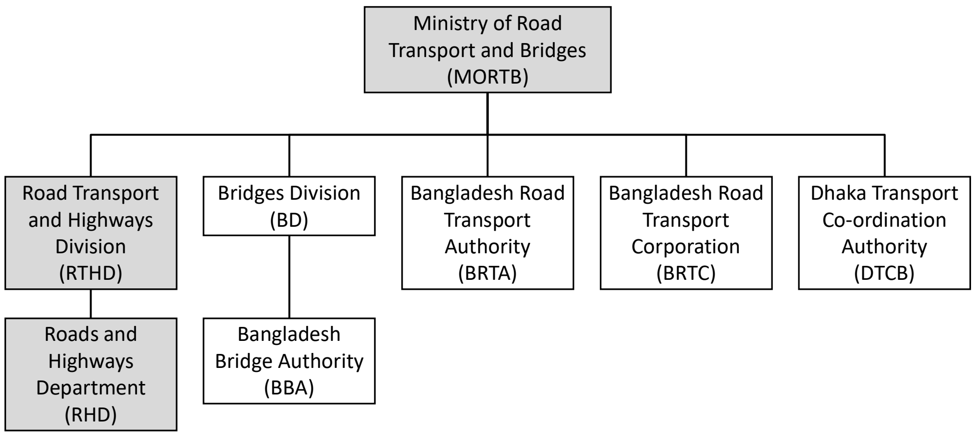
Figure 3.6-35 Implementation Structure (RHD)

RHD is an executing agency under the Ministry of Road Transport and Bridges (MORTB), and is responsible for the construction and maintenance of the major road network in Bangladesh. The department is headed by one Chief Engineer (CE) who is supported by fifteen (15) Additional Chief Engineers (ACEs). The recent organization structure of RHD consists of five (5) headquarter wings and ten (10) zonal operation offices, each headed by an Additional Chief Engineer who reports directly to the Chief Engineer. Furthermore, eight (8) Additional Chief Engineers are appointed to manage donor funded projects.



Source: JICA Survey Team

Figure 3.6-36 Organizational Structure of RHD



Source: JICA Survey Team

Figure 3.6-37 Organization Structure of MORTB

3.6.7 Operation and Maintenance Plan

Road maintenance and operations covers various activities related to inspections, maintenance and repairs, which require a quick response and appropriate treatment to preserve functionality of the road. RHD should be responsible for the following activities of road maintenance and operations:

- Inspections by maintenance patrol unit
- Road cleaning of road surface, etc.
- Vegetation control
- Repairs of traffic safety and management facilities
- Maintenance and repairs of pavement
- Maintenance and repairs of bridges
- Maintenance and repairs of other structures
- Disaster prevention and restoration
- Others

The budget for RHD's routine maintenance is allocated from the Ministry of Finance (MoF) through the Ministry of Road Transport and Bridges (MoRTB) every year. The RHD's Road Master Plan pointed out the insufficiency of the budget for routine maintenance of roads and bridges and that the maintenance activities have not been carried out properly. The Master Plan estimated that BDT 230 billion and BDT 6.8 billion would be required for the full costs of periodic maintenance for roads and bridges respectively over the Master Plan period (20 years).

Road maintenance and operations programs should be made on annual, monthly and weekly basis, considering priority of the work, available resources, past work records, road inventories, road structure inventories, traffic volumes, meteorological data, etc.

(1) Maintenance of Pavement

The objectives of pavement maintenance and repair are as follows:

- To sustain pavement durability and integrity
- To sustain driver's comfort and maintain traffic safety
- To avoid environmental deterioration

Inspection and maintenance activities are often conducted while open to public traffic. Therefore the following aspects should be considered while inspections and maintenance are undertaken:

- Identify surface condition changes in the early stages of deterioration
- Damages which need emergency repairs shall be repaired temporarily
- Surface conditions shall be monitored to predict future surface changes
- Maintenance schedules shall have long term plans
- Make effective use of surface condition information and construction records
- Enforcement of automobile laws and traffic safety education

Investigation for the pavement surface involves measurement and evaluation of the existing deficiencies of the pavement surface. It is the fundamental process for rational and systematic repair/maintenance of the pavement surface. The methods of attesting the pavement surface conditions are broken down into inspections and investigations. The major inspection items for pavement are rutting, cracking, skid resistance, faulting and local deformation and the major repair methods for asphalt pavement are overlay, patching or replacement of pavement.

(2) Maintenance of Bridges

Experience shows that the need for maintenance and repairs to bridges is due to the following reasons:

- Deterioration commences immediately after completion of most civil works
- Live loads of vehicles and loading frequency will increase with time
- Structures may be constructed with unexpected defects which create inefficiencies and eventually affect the safety of the structure

In addition to the above, the reliability of technical products decreases with time. It is necessary to emphasize that a bridge is a technical product. The purpose of maintenance and repairs can be classified in two categories:

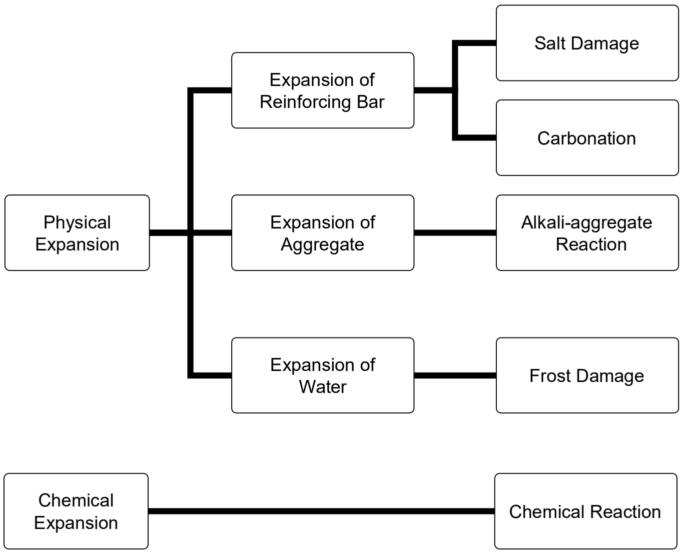
- To retain load bearing capacity and to sustain bridge durability
- To prevent failure of the bridge structure and to maintain traffic safety

It is necessary to keep design data, in particular the detailed engineering specifications, design calculations and drawings of bridges and viaducts since these are essential reference materials for planning and engineering maintenance.

Maintenance and repairs of bridges is closely related to inspection of bridges. In order to maintain bridges in good condition, the deck surface, superstructure and substructure of bridges should be inspected by routine, periodic and special inspections. When deficiencies are detected, maintenance and repairs must be carried out.

The major types of concrete deterioration are cracking, delamination, pop-outs, scaling, abrasion, spalling, efflorescence, honeycombs, or corner failure. Concrete structures are used frequently because their cost-effectiveness, strength and durability. In roadway bridges, concrete is used in many superstructures and substructures. However a concrete structure has disadvantages that offsets its high versatility as mentioned above. Deterioration of a concrete structure starts at the time of construction. Causes of concrete deterioration are listed below;

- Exposure: Carbonation caused by CO_2 in the air and salt damage caused by airborne salinity from the sea.
- Internal structure: Alkali aggregate reaction, salt damage caused by insufficient desalinization and resulting from shoddy workmanship
- Loading: Overloading and fatigue of the reinforced concrete slab
- Good knowledge of these deteriorations, suitable inspection at appropriate timing and suitable maintenance & repair will ensure that concrete structures keep their performance for a long period.

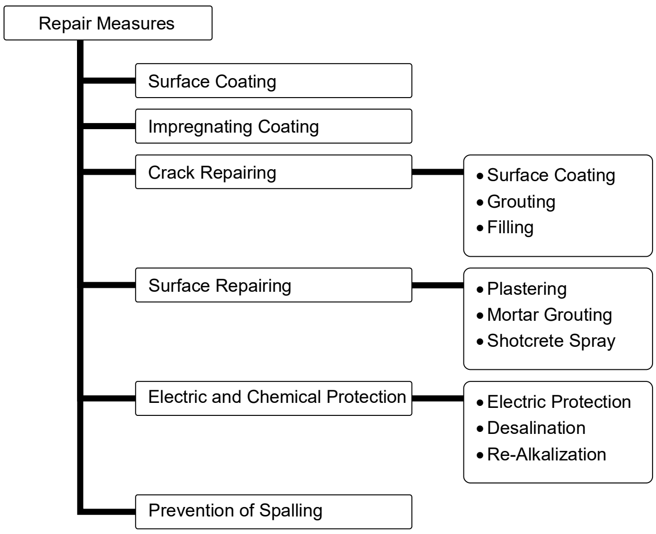


Source: JICA Survey Team

Figure 3.6-38 Classification of deterioration Mechanism

Objectives of concrete bridge repair are as follows:

- Restoration of deteriorating sections such as cracking or scaling, and prevention of reinforcing bar corrosion or deterioration around the cracks.
- Removing concrete that has suffered an attack of chloride ions (Cl-) or carbonation.
- Surface coating to prevent organic substance penetration.
- Rehabilitation for re-alkalization



Source: JICA Survey Team

Figure 3.6-39 Major Repairing Measures

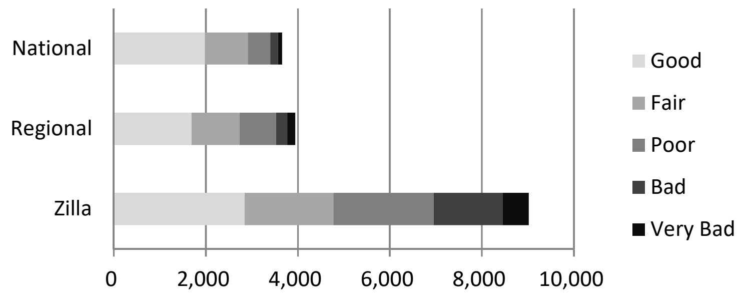
(3) Institutional Capability of RHD for Roads and Bridges Maintenance

RHD has been using the Highway Development and Management Model (HDM-4) as a financial tool since FY 1999-2000. All roads have been analyzed to assess the overall long-term maintenance needs of the RHD road network. Ongoing projects have been excluded from the HDM analysis to project the immediate maintenance requirements. However, few segments either completed or ongoing may appear in the HDM outputs because they were not reported by the field officers before the HDM analysis.

The outputs from HDM-4 are based on the Road Maintenance and Management System (RMMS) database of RHD. Using the RMMS database, RHD has identified the total maintenance need of the RHD road network and has selected and prioritized the maintenance works based on NPV over financial cost ratio.

Since FY 2005-2006, RHD has introduced a new procedure of maintenance program called Road and Bridge Asset Management System (RAMS), which brings together all RHD's databases and analytical procedures. The final output of RAMS is a GIS-based map for each Division which combines all relevant information and shows decision makers where they can most effectively allocate funds for maintenance and rehabilitation.

However, the biggest challenge for roads and bridges maintenance under RHD road network is lack of sufficient funds. Even though the maintenance system has been formulated, the physical maintenance activities have not been conducted properly.



Source: RHD, Need Report 2016-2017

Figure 3.6-40 Road Condition of RHD Road Network

The RHD's maintenance report "Needs Report 2016-2017" presented the required maintenance cost as follows:

Table 3.6-24 Overall Maintenance Needs for RHD Road Network

Work Type	Overall Maintenance Needs (Million BDT)					
	2016-17	2017-18	2018-19	2019-20	2020-21	Grand Total
Routine Maintenance	3,848.70	6,770.62	6,911.18	7,203.86	7,810.91	32,545.28
Periodic Maintenance	50,895.03	17,226.79	13,812.55	10,543.56	3,895.54	96,373.47
Partial Reconstruction	39,681.48	4,907.70	4,332.47	1,696.86	983.47	51,601.98
Full Reconstruction	30,327.93	543.82	89.92	0.00	0.00	30,961.67
Grand Total	124,753.14	29,448.94	25,146.11	19,444.28	12,689.92	211,482.40

Source: RHD, Needs Report 2016-2017

(4) Maintenance Plan for the Project Road

In order to maintain the project road in good condition, the following maintenance activities should be carried out during the operation and maintenance stage:

- Inspection of the road weekly
- Partial resurfacing of pavement (in total 2 km section) every year
- Full resurfacing of pavement every 10 years
- Full resurfacing of bridge pavement every 15 years
- Replacement of bridge expansion joints every 15 years
- Replacement of waterproofing layer on bridge decks every 30 years
- Repainting of steel bridge coating every 30 years

The following table summarizes the estimated maintenance cost for the project road during 30 years.

Table 3.6-25 Estimated Maintenance Cost for the Project Road (30 Years)

	Frequency	Unit Cost (Million BDT)	No. of Times	Cost (Million BDT)
Routine Maintenance				
Inspection	Every week	0.00625	1,440	10.5
Partial Resurfacing of Pavement	Every year	17	30	510.0
Sub-total				**520.5**
Periodic Maintenance				
Full Resurfacing of Pavement	Every 10 years	682	3	2,046.0
Bridge pavement resurfacing	Every 15 years	80	2	160.0
Replacement of Expansion Joint	Every 15 years	182	2	364.0
Replacement of Waterproofing Layer of Bridge	Every 30 years	265	1	265.0
Repainting of Steel bridge coating	Every 30 years	270	1	270.0
Sub-total				**3,105.0**
Total Cost per 30 Years				**3,625.5**