CHAPTER 7

PROPOSED BRIDGES AND APPROACH ROADS

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7–1 Bridge and Approach Roads for Meghna

7–1–1 Design Methodology of Bridge

At the inception stage study in which the site conditions of the proposed bridge were identified, study was conducted mainly for the location of alternative bridge centre-lines, for the requirements for crossing the river, and for the selection of alternative span arrangements and alternative bridge types. For the study of the above alternative arrangements initial calculations were made to determine main structural elements.

This section describes how the bridge centre-line, bridge length and span were determined and gives the reasoning behind the engineering choice for all alternatives.

In general, there are many requirements to determine the final type of bridge but the determination of type may not be based on the economical span arrangement only. The general flow chart for determination of bridge type is shown in Fig. 7-1-1.

The most suitable type of bridge was decided through the comparative study as diagrammed on the flow chart and through evaluation of the requirements.

7–1–2 Determination of Bridge Centre-line

1) Present Conditions Around Meghna Ferry

The ferry across the Meghna River is located about 25 km eastwards from Dhaka. A road length of 2,500 metres on the Dhaka side and the one of 700 metre length on the Comilla side are on an approximately 4,000 metre long trangent including the 800 metre length of the width of the Meghna River.

On the road towards Dhaka two RC bridges, 154 metres long and 107 metres long, exist respectively at 1,250 metres and 1,600 metres from the west bank. Near the ferry on the Comilla side, there are about 50 shops located on the road side which sell snacks, cigarettes, etc. for people waiting for the ferry.

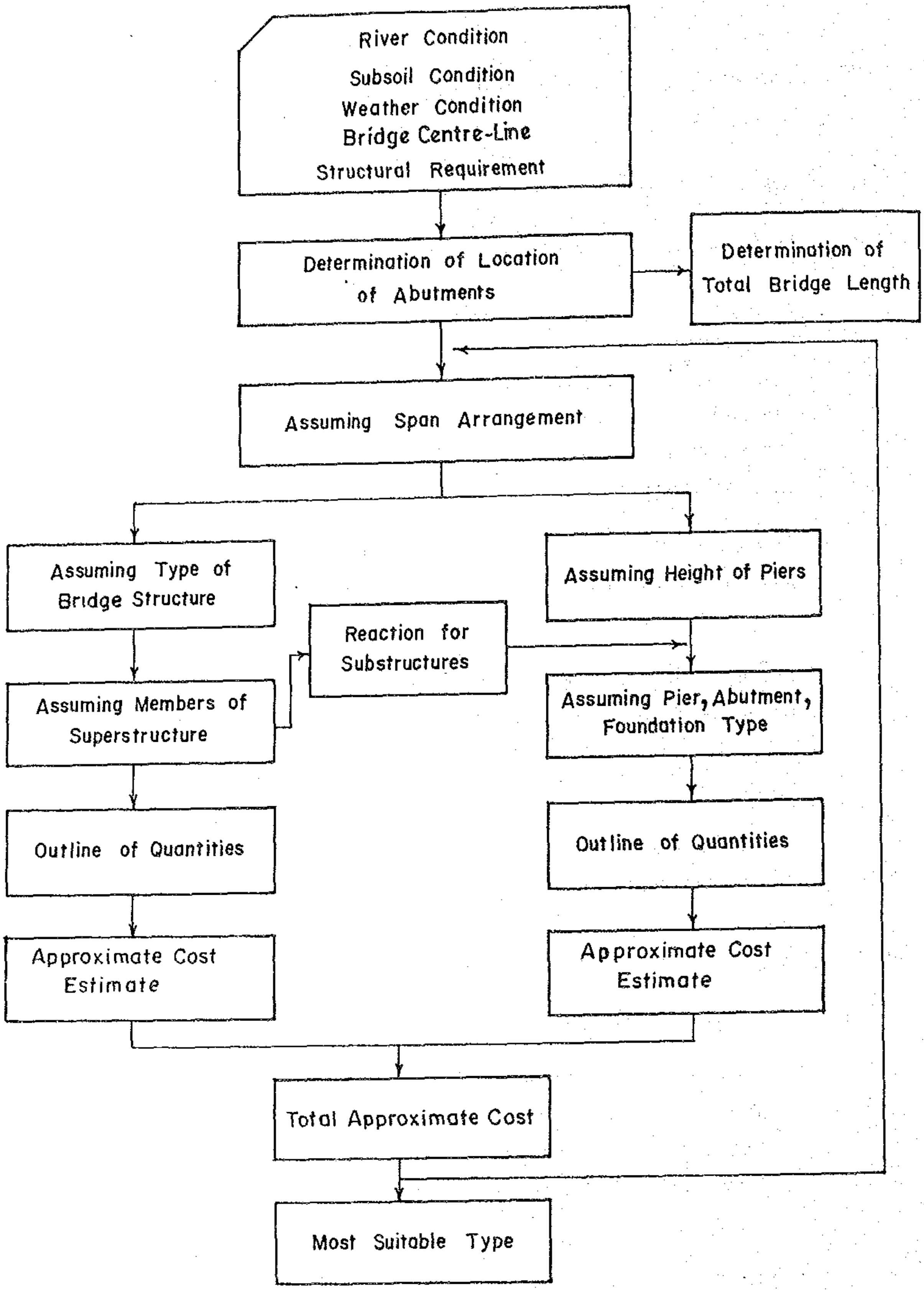

FIG. 7-1 -1 GENERAL FLOW CHART OF DETERMINATION OF BRIDGE TYPE

There exists a drainage structure of 6 metre width which has been silted up since April 1974. There is a small river which forms part of the river system, close to the southern side of the existing roadway at a distance of 1,400 metres from the left bank ghat towards Comilla.

About 2,000 metres upstream of the right bank ferry ghat a sand bar has been deposited and is developing each year. It now covers a space of more than one million sq. metres and its width has increased to more than 500 metres in the river. Thus the meander of the river has developed down to the vicinity of the existing ferry ghat. Downstream of the existing left bank ferry ghat a partial bank erosion can be noticed for a short stretch.

2) Selected Alternative Routes

In selecting the alternative routes, following points were kept in mind:

a) To utilise the existing Dhaka-Chittagong Highway as much as possible, the bridge site should be within a corridor of 500 metres either side of the present ferry route;

b) To avoid construction of a new long road structure, the diverging points for the new approach roads, if possible, should be selected within 1,300 metres or so from both ferry ghats.

c) To prevent the abutments of the proposed Meghna Bridge from bank erosion, the bridge site should be selected where the protections against erosion might be easily provided;

d) To make a smooth construction of the Meghna Bridge, consideration should be given to minimising the costs for traffic control during the construction period, the displacement of existing ferry ghats, and the compensation cost for the displacement of existing shops, if required;

e) To be in accord with future development plans in the project area, if any, the selection of the bridge site should be adjusted;

The following five alternative routes were selected the location of which are shown in Fig. 7–1–2. They were identified as follows:

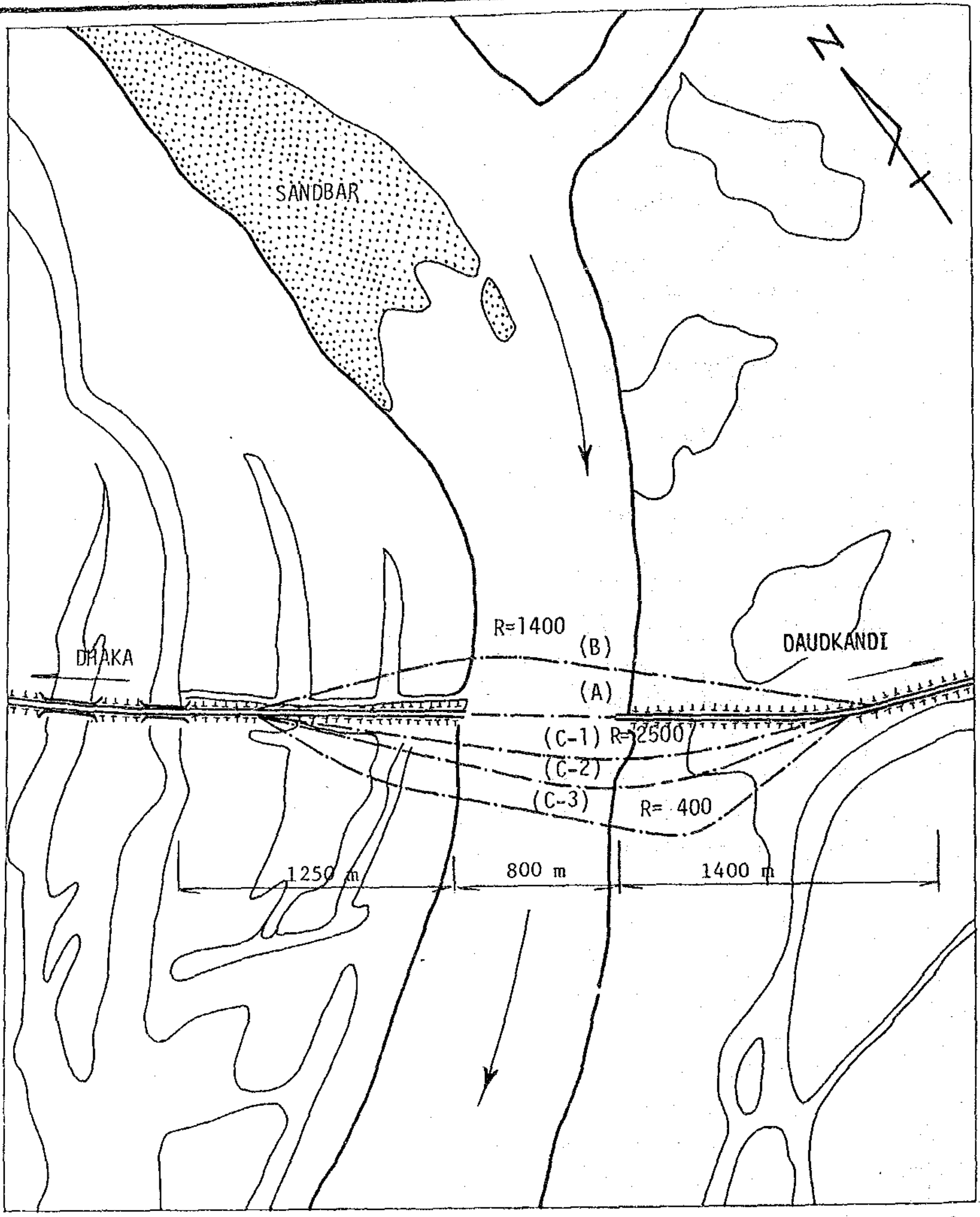

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FIG. 7-1-2 ALTERNATIVE ROUTES OF MEGHNA BRIDGE

Alternative A is the obvious route just alongisde the existing ferry line;

Alternative B is the plan for the route to pass upstream of the ferry line;

Alternative C-1 is the line that runs downstream of the existing ferry course: 100 metres away on the right bank and 200 metres away on the left bank;

Alternative C-2 is further downstream from the existing ferry course: 200 metres away on the right bank and 300 metres away on the left bank; and

Alternative C-3 is the furthest downstream line; 350 metres away on the right bank and 450 metres away on the left bank.

3) Slected Centre-line

The alternative routes were studied from technical view points listed in 2, a) through e) inclusive.

Alternative A has 3 excellent advantages: the best alignment, the lowest cost for the approach roads and the smallest land area for the project. However, protection against the left bank erosion is required, which is not easily provided. This is the main reason for rejection, and the displacement of existing ferry ghats and the compensation for shops to be replaced would add to cost.

Alternative B will also need the same protection against erosion, and besides it is inevitable that the control of navigable water depth for ships will be hampered by the development of the sand bar. Therefore this alternative was not selected.

The remaining Alternatives C-1, C-2 and C-3 could be provided with adequate protection against left bank erosion, that is, the triangular space between the existing road and a new approach road to the proposed bridge could be filled up with river sand to the same level as the height of the existing roadway. Because this embankment could be utilised as a protection bank to prevent the abutment of the proposed Meghna Bridge from erosion, with sheet piling works provided around the toe of the embankment near the water front.

However, Alternative C-1 has 3 disadvantages: a flat horizontal curve on the bridge, future trouble with navigable water depth control and the necessity to provide against partial erosion because this alternative alignment runs in the vicinity of the developing erosion just downstream of the left ghat. Therefore C-1 route was not recommended.

The most suitable centre-line from the remaining alternatives C-2 and C-3 was located with a minor adjustment: 250 m downstream of the right bank ferry ghat and 320 m downstream of the left bank ferry ghat.

The results of the above comparative study are tabulated in Ap. Table 7–1.

7–1–3 Foundation and Substructure

For the proposed bridge over the Meghna River, the following alternative foundation types were selected for consideration:

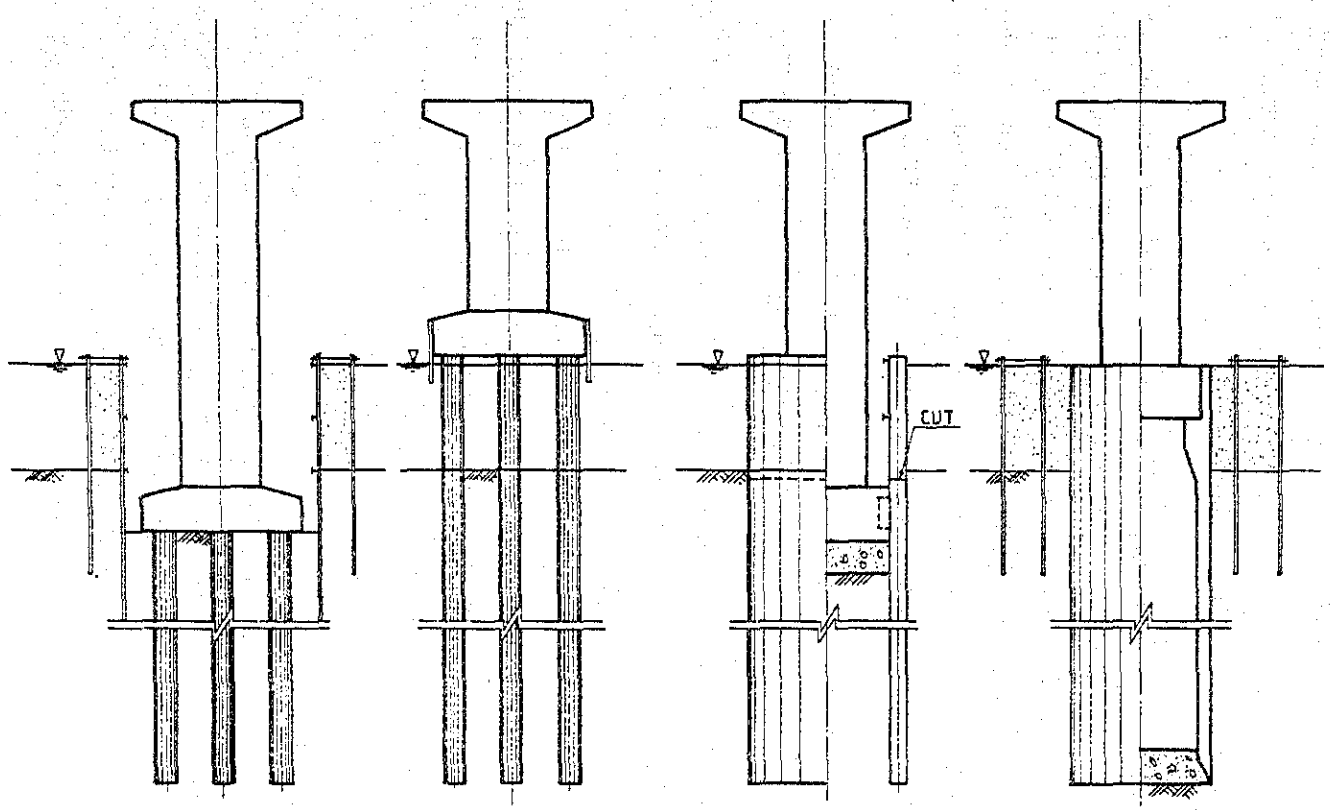
a) Reverse circulation drilled pile
b) Steel pipe pile;
c) Interlocked steel pile well; and
d) Open caisson

They are depicted in Fig. 7–1-3. A comparative study was made to select the most suitable foundation type amongst the four alternatives.

1) Selection of Applicable Type of Foundation

The depth of -55 metres (PWD) was determined as the effective foundation depth on the grounds that the middle layer which consists of alluvial fine sand and clayey silt will not be so reliable for bearing the load of the structures, and that the estimated 11 metre scouring would end in the same middle layer.

Pile foundation mentioned in a) and b) above is divided into projection type and non-projection type as shown in Fig. 7–1–3. Generally the merit of the projection type is to permit construction without a cofferdam. But in the case of the Meghna River this type will not be adopted. The scouring depth of the riverbed is so deep that the horizontal deflection of the top of the piers will be high due to the water forces or seismic load. Therefore it is considered that the projection type will not be preferred for the pile foundation.



(NON-PROJECTION TYPE) (PROJECTION TYPE) c) Interlocked Steel Pile Well d) Open Caisson

a) AND b): Pile Foundation

Source: The Study Team

FIG. 7-1-3 ALTERNATIVE TYPES OF FOUNDATION

The comparison of alternative foundation types is shown in Table 7–1–1. From the comparison it can be said as follows:

- The steel pipe pile type in b) above is suitable for a shorter construction period. And with this type it is possible to get a higher and more uniform quality because the pile is prefabricated in the factory. In spite of these merits, however, it has disadvantages: firstly the material of the pile is less durable against corrosion and secondly it is difficult to get a reliable bearing capacity because of the open bottom.

- The disadvantage of an open caisson type is that the construction period is too long. And in the case of such a deep well, the well can incline on its axis easily and it often happens that the well cannot be sunk to the proposed depth. The construction period of the caisson foundation could be shortened by providing bentonite injection devices. However the cost will be higher than the construction cost by reverse circulation drilled piles.

For these reasons both the steel pipe pile and the open caisson were excluded from the selection. Comparison of the remaining two types are as below:

- Interlocked steel pipe well is constructed by driving walled steel pipe piles in a closed arrangement, the rigidity of which is often comparable to that of concrete caisson. In the water construction, this method is very effective because the interlocked piles are also used for a cofferdam that can be cut and removed after construction. Contrary to these advantages, the construction cost is very high, about 1.6 times that of the reverse circulation drilled pile method. Therefore, the interlocked steel pipe well method was not recommended as the most applicable foundation.

- Compared with the above methods, the reverse circulation drilled pile method has no particular disadvantages for the foundation of the Meghna Bridge. By using a casing pipe there is no problem even in the underwater construction, and it can bore to over 100 metre depth. Furthermore, it is possible to get a large bearing capacity by adopting large diameter piles. As a result the number of piles and the construction cost can be reduced.

Through the above discussions the reverse circulation drilled piles were adopted as the most suitable foundation among the alternatives.

Table 7-1-1 Comparison of Alternative Foundation Types

ITEM / TYPE	R.C.D. Pile	Steel pipe pile	Interlocked steel pipe well	Open Caisson
Experiences in Bangladesh	Some	Few	None	Many
Construction period per one pier	Relatively short (5.5 months)	Short (5.0 months)	Short (4.5 months)	Long (11 months)
Construction cost per pier (x 10^3Tk)	15,638	17,437	25,116	14,084
Required temporary works	Cofferdam and temporary staging	Cofferdam and temporary staging	Temporary staging	Cofferdam/Artificial Island
Required Workability	Protection of the bored hole surface	High welding technique	Accurate driving operation and high welding technique	Many efforts are required : Easy to incline and difficult to sink to the proposed depth
Availability of material in domestic market	Easy	Not possible	Not possible	Easy
Ease of quality control	Relatively difficult	Easy	Easy	Relatively difficult
Confirmation of bearing stratum	Relatively easy	Relatively difficult	Relatively difficult	Relatively easy
Reliability of supporting	Reliable	Relatively unreliable because of open bottom	Relatively reliable	Reliable
Durability against corrosion	No problem	Less durable	Less durable	No problem
Security against ship collision	Safe with pier protection	Safe with pier protection	Safe with pier protection	Not so safe because of wide projection
Overall Evaluation	Recommendable due to the ease of construction and short construction period	Not recommendable due to unreliability of support	Not recommendable due to the highest construction cost	Not recommendable due to long construction period and difficulty of construction

Source: The Study Team

2) Dimensions of Substructure and Foundation

The dimensions of substructure and foundation were determined respectively as follows:

(1) Abutment

– Type: RC Buttress Type of Full Height Abutment

– Abutment Height: 15 m

– Nos. and Type of Piles: 49 Nos. of precast RC Piles (45 cm x 45 cm square, length = 20 m)

(2) Pier

– Type: Invert-T Type Pier

– Pier Height: 18.3 m to 34.3 m

– Nos. and Type of Pile: 9 Nos. of Reverse Circulation Drilled Pile (ϕ = 1.5 m, length = 44 m)

3) Protection of Piers Against Ship Collision

Protection of the piers against collision by ships was studied. The recommended plan by the Study Team is shown in Ap. Fig. 7–1.

7–1–4 Superstructure of Main and Side Span Bridges

1) Economic Span Length

Prior to the determination of span arrangements, for the river crossing bridge (main and side span bridges), the cost-span relations were studied for the eight types of superstructure listed in Table 7–1–2. In this study, use of reverse circulation drilled piles only was considered for pier foundations on the basis of the results obtained in the preceding Subsection 7–1–3.

Note: The method of pier protection was discussed between RDH and the Study Team and the above recommendation was accepted verbally by RHD at the end of July, 1984.

Table 7–1–2 Types of Superstructure and Span Length Studied

Type of Superstructure	Span Lengths (m)		
PC Box Girder (Cost-in-situ)	60,	90,	120
PC Box Girder(Segmental Box)	60,	90,	120
PC Box Girder* (Incremental Launching)	35,	45,	60
PC T-Beam Girder* (Precast beam)	25,	30,	45
Steel Truss Girder	60,	90,	120
Steel Lohse Girder	60,	90,	120
Steel Box Girder	45,	60,	90
Steel Composite Plate Girder*	25,	30,	45

Note: Types marked with * are used for side span bridge only.

The procedure to obtain the cost-span relationship is outlined in the flow chart shown in Fig. 7–1–1.

The costs for the above-mentioned comparative study were estimated on the following conditions:

a) The cost included direct costs for foundation and substructure and for superstructure, but excluded the costs for temporary stagings and false work, approach roads and other ancillary works.

b) The costs for the following common items, which do not affect the cost comparison, were excluded: pavement on bridge surface, handrails, kerbs, sidewalks and drain pipes.

c) The indirect costs such as overhead costs and profits of constructors and CDST for imported materials were also excluded.

d) Unit prices were broadly estimated based on the prevailing prices in Bangladesh as of June 1984.

The results of the cost-span relation study are shown in Fig. 7–1–4. From the view point of economy, the following types were selected:

a) For Main Span Bridge:

		Approximate Span Length (m)
– PC box girder (Cast-in-situ)	:	90*
– PC box girder (Segmental box)	:	90*
– Steel box girder	:	90*

b) For Side Span Bridge:

		Approximate Span Length (m)
– PC box girder (Cast-in-situ)	:	80
– PC box girder (Segmental box)	:	80
– PC T-beam Girder	:	45
– Steel composite girder	:	45

Note: The minimum span length of the main span bridge is determined from the view point of the navigation clearance.

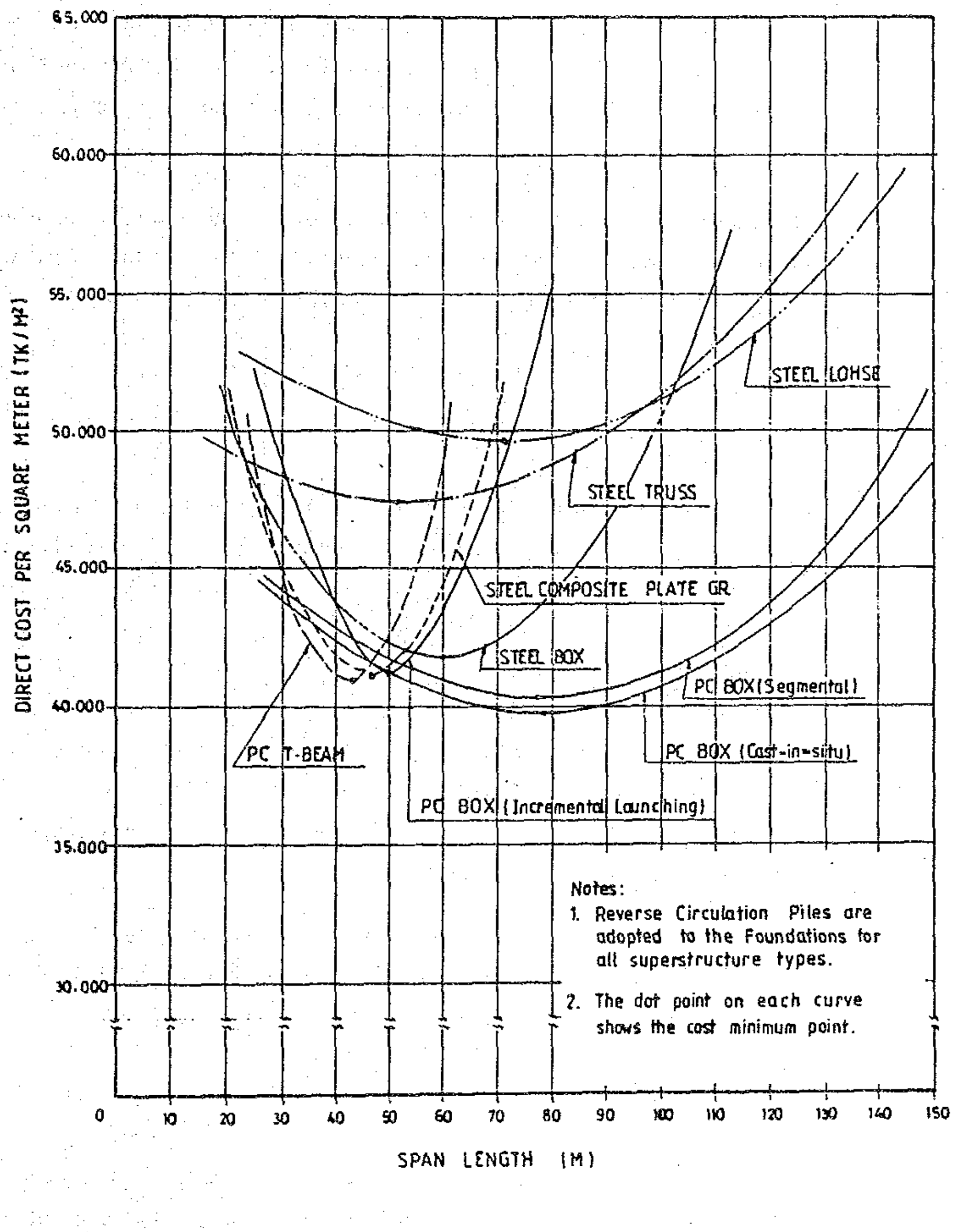
2) Span Arrangement

Determination of span arrangement which may directly affect the total economy is the most essential part of the bridge planning. In this study, the following were taken into consideration:

a) Results obtained from the study for structural requirements, construction requirements, economic factors and aesthetics which will all govern the span arrangements.

b) Economic span length discussed in the preceding paragraph.

c) River width in dry season which is one of the most dominant factors for determining the total bridge length as well as the span arrangements. As a result of the topographic survey, the measured river width is 825 metres.



Source: The Study Team

FIG. 7-1-4 DIRECT COST-SPAN RELATION FOR MEGHNA BRIDGE STUDY

d) Location of abutment and end pier of side span bridge:

The Meghna River is naturally erosion-prone. A distance of 30 metres from the edge of the river bank to the abutment on the Dhaka side and from the edge of the river bank to the end pier of the side span bridge on the Comilla side was considered enough to keep an allowance against future erosion.

In the initial stage, five alternatives (denoted by A to E) were selected, which are shown in Ap. Note 7–1. After elaboration two alternative span arrangements were recommended with some modifications to meet the special situations mentioned in b) through d) above, which are illustrated in Fig. 7–1–5.

The features of these selected alternatives are:

Alternative A

PC box girder by cantilever erection method is adopted for the 9 span superstructure. The standard span length is determined as 87.0 metres. The total bridge length is 930 metres.

Alternative D

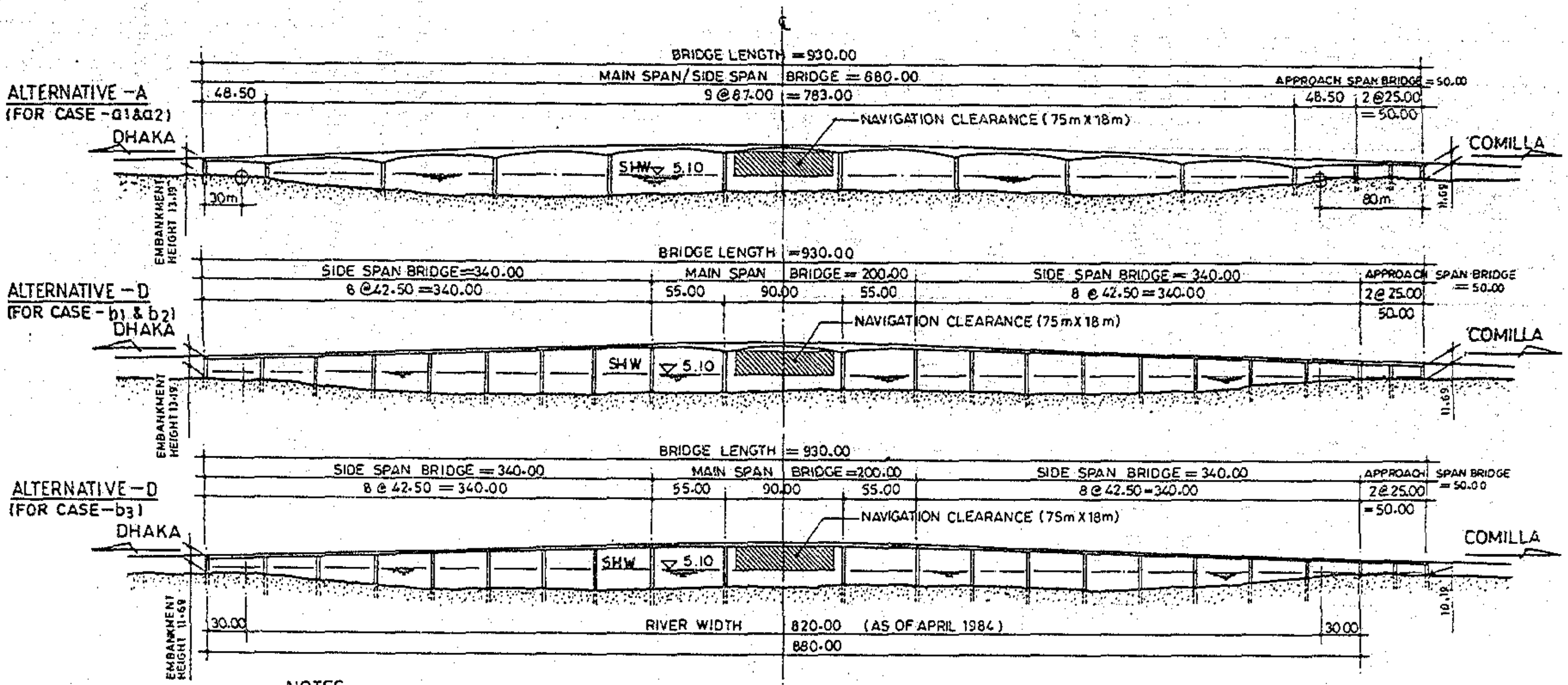
PC box girder by cantilever erection method is also adopted to only the navigation span of 90.0 metre length and its anchor span of 55 metre length. For the side pan bridge superstructures PC T-beams of 42.5 metre length are adopted. The total bridge length is 930 metres.

Types of superstructure were also recommended, mainly based on economy. The alternative span arrangements are tabulated in Table 7–1–3. The general view of these alternatives are shown in Ap. Figs. 7–2 through 7–4.

3) Comparison of Bridge Types

Five alternative span arrangements by bridge type (Cases a_1, a_2, b_1, b_2 and b_3) were examined and compared technically and economically, and the most suitable type of bridge was selected. Table 7–1–4 summarises the result of the study.

The figures of bridge construction cost in the same table were estimated based on the following works:



NOTES

1 THE DIMENSIONS ON THE DRAWINGS ARE SHOWN IN METERS.

2 THE LENGTH OF MAIN SPAN BRIDGE AND SIDE SPAN BRIDGE IS DETERMINED AS 880m TAKING INTO CONSIDERATION THE ACTUAL RIVER WIDTH OF 820m AND LAND CLEARANCE OF 30m EACH SIDES.

3 THE ALTERNATIVE NAME FOR SPAN ARRANGEMENT CORRESPONDS TO THE INTRODUCTION IN AP. NOTE 7-1

Source: The STudy Team

FIG. 7-1-5 SPAN ARRANGEMENTS FOR MEGHNA BRIDGE

Table 7-1-3 Alternative Span Arrangements by Bridge Type

		Case-a1	Case-a2	Case-b1	Case-b2	Case-b3
Span Arrangement*		Alternative A	Alternative A	Alternative D	Alternative D	Alternative D
Main Span Bridge	Type	PC Box (Cast-in-situ)	PC Box (Segmental)	PC Box (Cast-in-situ)	PC Box (Segmental)	Steel Box
	Total Length	880 m	880 m	200 m	200 m	200 m
Side Span Bridge	Type	-	-	PC T-Beam	PC T-Beam	Steel Composite
	Total Length	-	-	680 m	680 m	680 m
Approach Span Bridge	Type	PC T-Beam	PC T-Beam	PC T-Beam	PC-T Beam	Steel Composite
	Total Length	50 m	50 m	50 m	50 m	50 m

* Note: Details of span lengths are referred to in Fig. 7-1-5.
Source: The Study Team

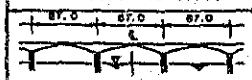
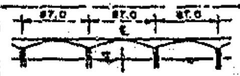
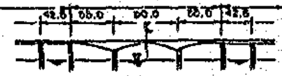
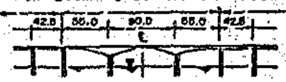
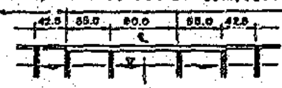
- Structural analysis, determination of required section of major members and quantity calculation;
- Construction method and period; and
- Unit price analysis and cost estimate.

As a result of the study, Alternative Case a_1 was found most suitable from construction cost, applicability of the technology to future projects and construction ease due to the possible repetition of one construction process, and was recommended as the final type of the Meghna Bridge.

4) Dimensions of Superstructure

The structural features of the recommended type of the bridge (Alternative Case a_1) are outlined hereunder. The general view of Case a_1 is shown in Ap. Fig. 7-2.

Table 7—1—4 Comparison on Bridge Alternatives over Meghna

Description \ Alternative		Case - a1	Case - a2	Case - b1	Case - b2	Case - b3
Span Arrangement		48.5m+9@87.0m+48.5m +2@25.0m = 930m	48.5m+9@87.0m+48.5m +2@25.0m = 930m	8@42.5m+55.0m+90.0m+55.0m +8@42.5m+2@25.0m = 930m	8@42.5m+55.0m+90.0m+55.0m +8@42.5m+2@25.0m = 930m	8@42.5m+55.0m+90.0m+55.0m +8@42.5m+2@25.0m = 930m
Side View Outline		PC Box(Cast-in-situ) 	PC Box(Segmental) 	PC T-Beam PC Box(C) PCT-Beam 	PCT-Beam PC Box(S) PCT-Beam 	Composit Gr. Steel Box Composit Gr. 
Principal Material of Superstructure		Prestressed Concrete	Prestressed Concrete	Prestressed Concrete	Prestressed Concrete	Structural Steel
Structural Features	Superstructure	Main/Side Span Bridge Cast-in-situ PC box with a central hinge Approach Span Bridge Precast PC T-beam	Main/Side Span Bridge Segmental PC box with a central hinge Approach Span Bridge Precast PC T-beam	Main Span Bridge Cast-in-situ PC box with a central hinge Side/Approach Span Bridge Precast PC T-beam	Main Span Bridge Segmental PC box with a central hinge Side/Approach Span Bridge Precast PC T-beam	Main Span Bridge 3-span contineous steel box girder Side/Approach Span Bridge Steel composit girder
	Foundation	Main/Side Span Bridge Cast-in-situ RC pile (Reverse Circulation Drill) Approach Span Bridge Precast RC pile	Main/Side Span Bridge Cast-in-situ RC pile (Reverse Circulation Drill) Approach Span Bridge Precast RC pile	Main/Side Span Bridge Cast-in-situ RC pile (Reverse Circulation Drill) Approach Span Bridge Precast RC pile	Main/Side Span Bridge Cast-in-situ RC pile (Reverse Circulation Drill) Approach Span Bridge Precast RC pile	Main/Side Span Bridge Cast-in-situ RC pile (Reverse Circulation Drill) Approach Span Bridge Precast RC pile
Construction Aspect	Main Span Br.	First experience in Bangladesh	First experience in Bangladesh	First experience in Bangladesh	First experience in Bangladesh	First experience in Bangladesh
	Side Span Br.	-	-	Already experienced	Already experienced	Already experienced
	Remark	To require one constru-ction process repetedly	To require one constru-ction process repetedly			
Availability of Materials from Domestic Market		Mostly available	Mostly available	Mostly available	Mostly available	Not available
Bridge Construction Period		38 months	31 months	38 months	34 months	32 months
Bridge Construction Cost*		Million Taka	Million Taka	Million Taka	Million Taka	Million Taka
	Superstructure	138	192	122	131	194
	Subst.& Fund	259	259	313	314	242
	Total	397	451	435	445	436
Maintenance Cost		Almost free	Almost free	Almost free	Almost free	Almost free**
Aesthetics		Good	Good	Fair	Fair	Fair
Travelling Quality on Bridge Surface		Good	Good	Fair	Fair	Fair
Overall Evaluation		Recommendable due to construction cost, applicability of te-chnology to future projects, and con-struction case				

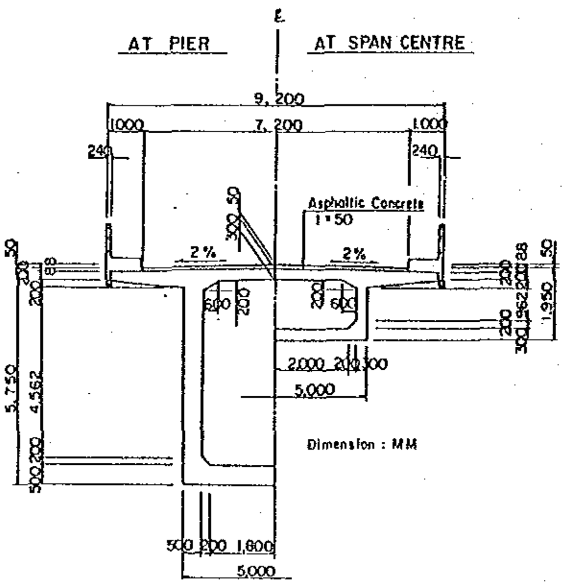
Notes : * The bridge construction cost excludes the cost of approach road, temporary work and ancillary work. The bridge construction cost is estimated by 1984 price, and includes direct and indirect costs except custom duty & sales tax (C.D., S.T.) in Bangladesh. Breakdown of these cases is shown in Ap. Table 7-2 through 7-6.

** For the purpose of maintenance-free, Hot-Dip-Galvanizing is adopted for the protective coat of steel corrosion.

Source: The Study Team

- Bridge Length (excluding the approach span bridge of 50 m in length) : 880 m
- Bridge Width : 9.2 m
- Carriageway Width : 7.2 m
- Sidewalk Width : 1.0 m on both sides
- Type : Cast-in-situ PC Box Girder (Cantilever Method)
- Span Length: : 87.0 m
- Depth of Girder : 5.75 m (at Pier) to 1.95 m (at Centre)

The cross section of the main girder is illustrated in Fig. 7–1–6.



Source: The Study Team

Fig. 7–1–6 Corss Section of Main Girder for Meghna Bridge

7–1–5 Approach Span Bridge

Taking into consideration the influence of erosion, the approach span bridge was located back from the river left bank a distance of 50 metres. The proposed elevation of the approach span bridge is not so high above the ground and the bearing stratum was judged to lie at a relatively shallow depth near the ground surface. Therefore, it is not necessary to adopt a large span as in the case of the main and side spans. The design criteria which are discussed in Subsection 7–1–4 were also applied to the approach spans.

1) Abutment

It is generally said that the scale of an abutment is mainly governed by the magnitude of earth pressure. That is to say, the dimensions and type of an abutment are determined by the structure height. The general relation between abutment height and structure type is shown in Ap. Table 7–7. The abutments of the Meghna Bridge were estimated at 13 to 15 metres high. From the same table, therefore, the buttress type was selected as the most suitable.

2) Superstructure

In the case of the approach span arrangement a larger span will not be economical. Therefore a 25-metre span was adopted as a suitable length judging from the total length, which makes the approaches consist of two spans.

For this scale of superstructure, the types generally available are as follows:

a) Composite plate girder;

b) Prestressed concrete T-beam; and

c) Prestressed concret hollow slab

Of the three types, the PC hollow slab in c) which is by the cast-in-situ method must be constructed on temporary staging. This method is inferior to the other two in terms of cost and construction period.

Therefore, the composite plate girder and prestressed concrete T-beam were selected as suitable. The overall bridge arrangement was studied by combining the above types with the main and side span bridges and their arrangements are shown by case below. As a result Case a_1 with PC box girder for both main span and side span bridges and PC T-beam girder for the approach bridge was adopted.

Case	Main	Side	Approach
a_1, a_2	PC Box Girder	PC Box Girder	PC T-beam Girder
b_1, b_2	PC Box Girder	PC T-beam Girder	PC T-beam Girder
b_3	Steel Box Girder	Steel Composite Girder	Steel Composite Girder

7–1–6 Construction Procedures for Main and Side Span Bridges

The construction schedule for the PC box girder cast-in-situ superstructure with reverse circulation drilled pile foundation was elaborated and it was estimated that 48 months would be required for the construction. The detailed schedule is shown in Fig. 7–1–7. At least three months will be spent for the importing of special materials and equipment by the contractor.

Since the project site is in an inundated area during the flood season (June to October) the contractor should prepare working yards on both river sides by land fill. This work will be commenced in the 2nd month by utilising the local facilities.

1) Temporary Quays

Part of the construction materials and equipment imported from abroad may be delivered by road from Chittagong Port, but heavy materials and equipment will be transported by inland water. In addition, sand and gravel, and cement are transported by boats. From the initial stage of the bridge construction, therefore, provision of temporary quays will be needed for unloading these water-borne materials and equipment at the river side of the working yard.

2) Temporary Stagings

Driving the sheet piles for the cofferdam and for the reverse circulation drilling is from barge mounted driving and drilling systems, which is considered the usual method. In adopting this system, however, at least four barges will be needed. They shall be installed with the pilling or reverse circulation drilling machinery, cranes and ancillary plants. In addition, tug-boats, earth disposal barges and other boats are required. The procurement and timely operation of these numerous boats might involve many unexpected difficulties.

In this project, however, the staging method was adopted; steel pile driving for cofferdams and reverse circulation pile driving can be provided at their exact locations, and that by the staging method, quick construction activities can be secured even on the windy days.

3) Steel Pile Driving for Cofferdam

For construction of the footing of the piers in the riverbed a cofferdam of steel sheet piles should be provided. In order to protect the cofferdam from collapse by water pressure and quick-sands, a double-skin sheet pile cofferdam system is adopted around the location of the footing. Partial re-use of these sheet piles may be possible.

4) Reverse Circulation Drilled Piles

For the foundation of the piers of the main and side span bridges one set of reverse circulation drilling equipment will be utilised. Small temporary stagings on which the drilling equipment can be operated will also be required.

5) Construction of Footings in the Riverbed

The following works will be conducted for the completion of footings:

– Underwater excavation inside the cofferdam;

– Placing the underwater concrete;

– Pumping up the water;

– Installation of the wales and struts; and

— Reinforced concrete work

These works will be scheduled during the low-water season only, to avoid accidents to the underwater works.

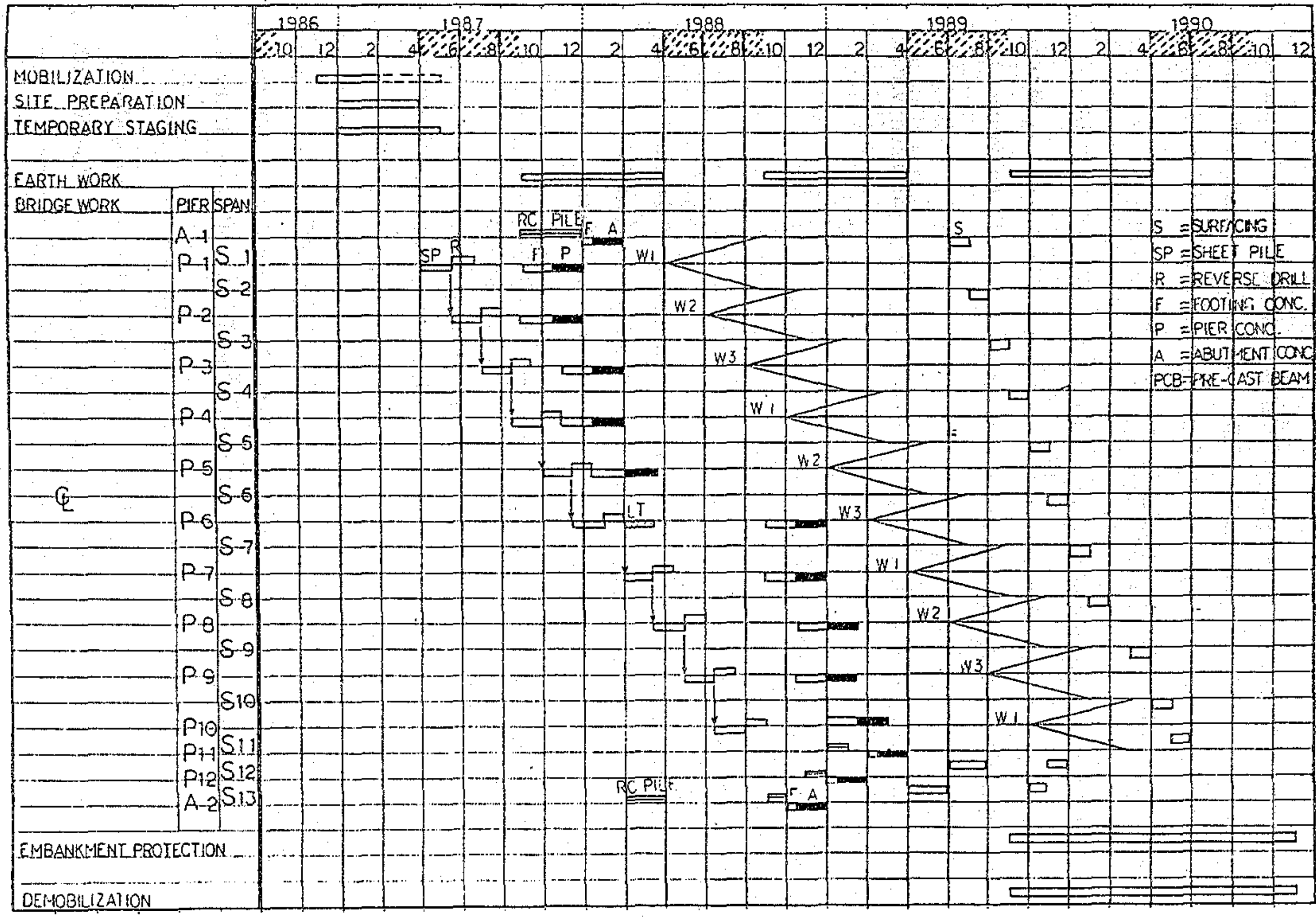
6) Construction of Superstructure

In the cast-in-situ PC box girder bridge construction, four sets of travelling forms will be used. Two sets of them will be utilised three times and the remaining two will be utilised twice.

The travelling forms are for forming the required shape of the concrete segments, holding the forms, false work, concrete and other materials in position, cantilevered from the previously constructed work.

7) Construction Schedule for Bridge

For the purposes of selection of bridge type and preliminary design, the construction schedules for bridge alternatives were studied. The one for Case aı is shown in Fig. 7–1–7.



Source: The Study Team

FIG. 7-1-7 BRIDGE CONSTRUCTION SCHEDULE (CASE-a1) FOR MEGHNA BRIDGE

7–1–7 Alignment and Design of Approach Roads

The alignments of the approach roads were studied on the topographic map at a scale of 1:3,000 which was prepared from the topographic survey during the initial stage of the Study. The preliminary design of the approach roads was made by taking into consideration the following basic requirements:

– To keep sufficient allowance in the designs of the horizontal and vertical

– To keep suffiicient allowance in the designs of the horizontal and vertical alignments so that minor probable deviations can be made during the final design;

– To maintain, in particular, the smooth operation of the existing ferryystem; and

– To minimise the removal of road side trees.

1) Horizontal Alignment

The location of the bridge centre-line was determined as discussed in Sub-section 7–1–2. To maintain safe driving and to provide an aesthetically pleasing alignment due consideration was given to the following factors:

– To set a right angle between the directions of the bridge centre-line and the river flow;

– To avoid small radius horizontal curves and short curve lengths between long tangent lengths; and

– To avoid sharp curves.

The minimum curve radius of the horizontal alignment was set at 400 metres. Spiral transition curves will be inserted into the horizontal curves during the final design stage.

The plans at a scale of 1:3,000 were used. The final alignment is shown in Drawings No. 3–1 through 3–3, together with edge lines of shoulders, 100-metre chainage stations, locations of the bridge and culverts required, etc.

2) Vertical Alignment

The vertical alignment along the centre-line is controlled by the requirements of the bridge and connecting roads especially in the case where the approach roads are short in length.

Both the navigation clearance and the design flood level are the important control points for the design of the vertical alignment. Other factors controlling the vertical alignment design which were taken into account are:

- Selection of vertical curve lengths which match with coincidental horizontal curves; and
- The elevation of the existing roads which intersect the proposed centre-line.

The vertical alignment which was prepared on the longitudinal profile sheets at 1:1,000 vertical scale and 1:3,000 horizontal scale, is shown in Drawings No. 3–1 through 3–3.

3) Description of Alignment

The proposed alignment diverges from the existing Dhaka-Chittagong Highway at a point 240 m after the existing RC bridge, which is 1,250 m from the ferry ghat on the Dhaka side. The alignment runs almost parallel to the existing road and ferry course and merges with the Dhaka-Chittagong Highway on the other side of the river. The total length of the alignment is 2,895 metres including the bridge. The major features of this alignment are:

- Between the point of divergence from the existing road and the west bank of of the Meghna River, the alignment passes through an area mainly of fields cultivated in the dry season, which are inundated in the flood season.
- On the left bank area (Gazaria side) the alingment intersects a narrow village road used by pedestrian and rickshaw traffic.
- Between the left bank and the village road mentioned above the alignment passes through an area of fields cultivated in the dry season, and between the village road and the end point of the alignment the route passes through rice fields. In this area jute is cultivated randomly in the flood season.

4) Pavement

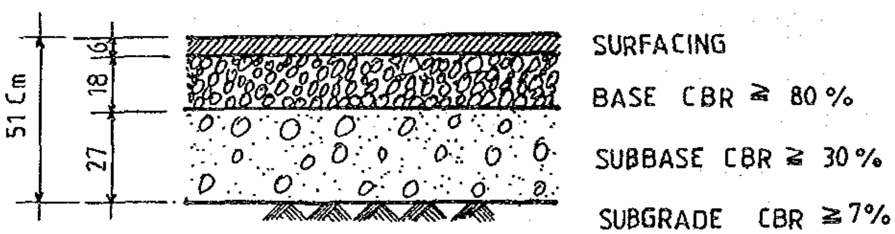
a) Design Method

The standard method to define the depth and strength of the various pavement layers used in the design of flexible pavement is based on the California Bearing Ratio, properties of the subgrade and the known and anticipated traffic loads over the intended life of the road.

The empirical formula and charts of the Transport and Road Research Laboratory of U.K. were adopted for the pavement design, the charts referred to being contained in Road Note 29 (a guide to the structural design of pavements for new roads) and Road Note 31 (a guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries). The pavement design is shown in Ap. Note 7–2.

b) Pavement Structure

The design result of pavement structure based on the estimated yearly equivalent standard axles (E.S.A.) is shown in Fig. 7–1–8.



SURFACING = ASPHALTIC CONCRETE SURFACE

BASE = WET MIX MACADAM ROAD BASE

SUB BASE = 50% LOCAL SAND AND 50% PEA GRAVEL

Fig. 7–1–8 Pavement Structure

5) Road Capacity and Number of Lanes

In Chapter 11 future traffic volumes are predicted, and in this chapter preliminary design of the bridges and approach roads are prepared. In this paragraph the capacity of the 2-lane, 2-way bridge/road is verified from the view points of the estimated traffic volumes and average running speeds.

There is no survey data for the conversion factor (K) from average daily to hourly traffic in Bangladesh. According to the result of the 24-hour traffic count survey in June 1984, the rate of the highest hourly traffic volume was between 5 and 6 percent of the daily total. In this study, taking into consideration the future traffic behaviour, 6% was used.

a) Traffic Volume Predicted

The traffic volumes for the year 2020 are:

Type	Vehicles/day	*PCE/day
Truck	5,153	15,459
Bus	2,388	7,164
Mini-bus	463	463
Car	3,455	3,455
Others	207	207
Total :	11,666	26,748

*Ref. Ap. Note 6–1
(Source: The Study Team)

From the PCE/day, the traffic of 1,600 PCE/hour is obtained for K = 6%.

The traffic for the year 2030 was estimated under low and high assumptions, and in the same way the hourly traffic volumes at K = 6% is respectively estimated as follows.

Assumptions	Vehicles/day	PCE/day	PCE/hour
Low	16,000	36,500	2,200
High	17,000	38,800	2,300

b) Service Volume on the Bridge/Road

The service volume of the bridge/road calculated in terms of PCE/hour from the capacity under ideal uninterrupted flow conditions (2,500 PCE/hour for a 2-lane, 2-way carriageway) with some adjustments resulting from: lane width, lateral clearance, site conditions, road gradient, etc.

In this study, the lane width is 3.25 metres which is wide enough; the bridge sites are rural areas where there are no intersections with traffic signals; and the road gradient is maximum 3%. But the lateral clearance on the bridge is 0.75 metre which is a little small, and inclusion of animal-drawn and or push cart traffic is foreseen. Therefore, an adjustment factor of 0.8 is applied:

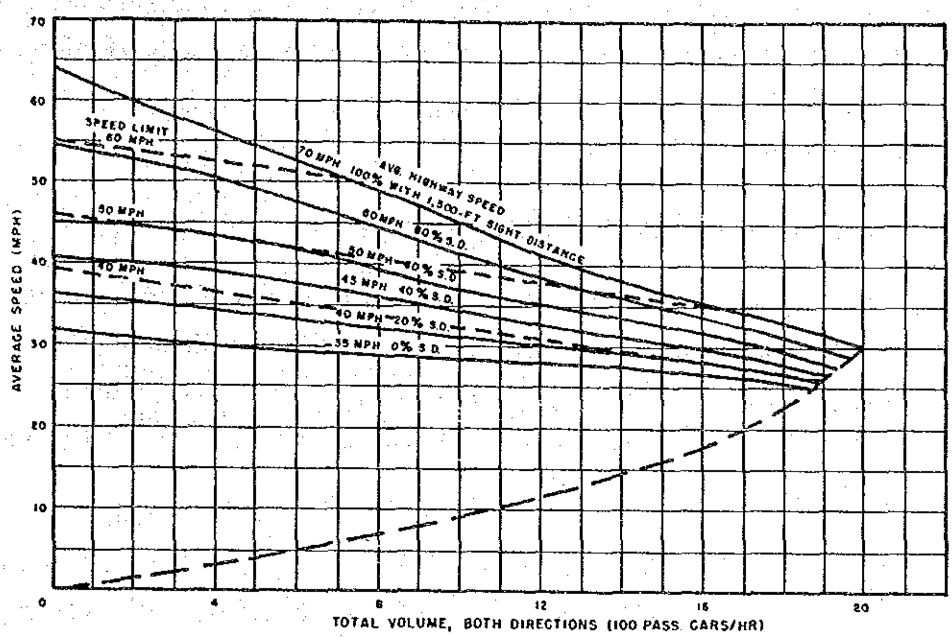
2,500 PCE/hour x 0.8 = 2,000 PCE/hour

Comparing this value (2,000 PCE/hour) with the predicted traffic (1,600 PCE/hour) in the preceding subparagraph a), it is found that the 2-lane, 2-way carriageway bridge/road proposed for this project be sufficient for the traffic in the design year 2020, that is, vehicles could maintain stable flow at certain speeds.

c) Check for Speed-Volume Relationship

As traffic volume increases, drivers are less able to choose their own speeds, the faster drivers being forced to decrease speeds more than the slow drivers, and the range of speeds is decreased. A check was made of the year when the peak hour traffic volume would arrive at or exceed the service volume per hour. A chart from "Highway Capacity Manual 1965" was referred to for this check.

The chart shows that the vehicles running at 50 mph (80 km/h) would be forced to reduce their speeds to less than 30 mph (48 km/h) as the traffic volume nears the service volume (2,000 PCE/hour). This is estimated to occur after the year 2025.



. *Typical relationships between total volume for both directions of travel and average speed under ideal uninterrupted flow conditions on two-lane rural highways.*
(Source: BPR, combined data from various studies)

Source: Highway Capacity Manual 1965

7–2 Bridge and Approach Roads for Meghna-Gumti

7–2–1 Design Methodology of Bridge

For the preliminary design of the Meghna-Gumti Bridge, the same methodology as that of the Meghna Bridge was applied. Reference is made to Subsection 7–1–1.

7–2–2 Determination of Bridge Centre-line

1) Present Conditions Around Meghna-Gumti Ferry

The ferry ghat is located about 40 kilometres east of Dhaka and to the south-west of Daudkandi. The Dhaka-Chittagong Highway which approaches from the Dhaka side to the ferry runs in the southeast direction and turns to the east with a 400 metre curve radius at a point 600 metres to the west of the ferry ghat.

The width of the Meghna-Gumiti River consists of the Branch Meghna River about 600 metres wide and the Gumti River about 300 metres wide, with sand bar about 450 metres wide in between. The BIWTA maintains the existing ferry course and other navigation courses by dredging the sand which develops in the sand bar every flood season. The sand bar is cultivated as paddy fields in the dry season but in the rainy season the fields are submerged.

On the Daudkandi side an access road with a length of about 2.5 kilometres runs to the east to connect the existing Daudkandi-Chittagong Road. Up-stream of the access road, some land has been raised by land fill.

On both sides of the Meghna-Gumti River in the vicinity of the proposed bridge site, there are buildings such as mosque, RHD rest house, Siddique Plant, Himalaya Ice Plant and Cold Storage, etc.

2) Selected Alternative Routes

In selecting alternative routes, the following points were kept in mind:

a) Short-time construction shall be managed, if possible, without any dis-placement of the existing approaches, ferry facilities, shops and other buildings around the nearby ferry terminals.

b) Bridge route shall be planned in a zone where there would be neither the existing ferry in operation nor pedestrians.

c) The shortest bridge crossing and the smallest land acquisition would be the critical factors.

The following five alternative routes were selected the locations of which are shonwn in Fig. 7–2–1. They were identified as follows:

Alternative A is the line to pass 100 metres upstream of both ferry ghats. This route will not hamper the ferry operations during the bridge construction.

Alternative B is a modification to A by which the approach road on the Dhaka side is shifted to the existing road. This route will hamper ferry operations during the bridge construction. Therefore the northernmost jetty on the Dhaka side must be re-sited downstream.

Alternative C is a straight connection between the existing ferry ghats. This route will require re-siting the existing ferry jetties and nearby terminal shops.

Alternative D is the shortest route to cross the river at an approximately right angle. This route will hamper ferry operations, thus requiring the displacement of the ferry ghats of the both sides.

Alternative E is a curved route passing downstream side of the existing ferry line to keep the ferry operations undisturbed.

3) Selected Centre-line

Alternative A has the longest bridge and approach roads in length. However this route will meet the points mentioned in a) and b) above. The reclaimed land palnned for the approach road on the Daudkandi side already belongs to the RHD.

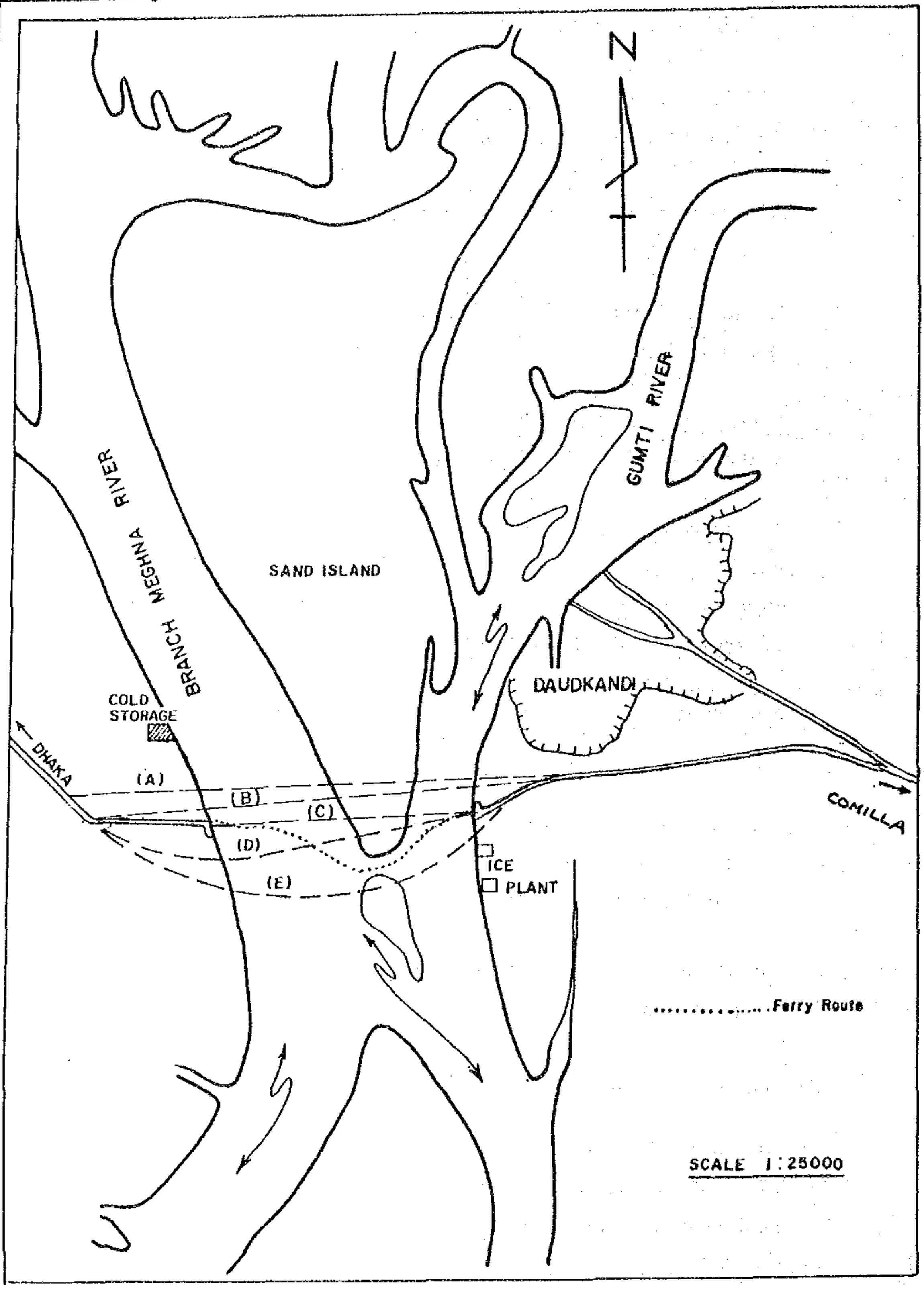


FIG. 7-2-1 ALTERNATIVE ROUTES, MEGHNA-GUMTI BRIDGE

Alternative B will require displacement of one (1) jetty which is the northern-most of the Dhaka side. However, land acquisition costs may be saved, because the approach road on the Dhaka side may pass partly within the existing RHD property. Similarly to Alternative A, the reclaimed land planned for the approach road on the Daudkandi side belongs to the RHD.

Alternative C will require provision of a temporary approach road on both Dhaka and Comilla sides because the alignment of the new roads will utilise that of the existing roads with raised profiles, and the displacement of minimum two (2) jetties on each side will be required.

Alternative D is a good line but it has the following demerits: safe construction may not be warranted due to the frequent crossing by ferry boats because the bridge location is very near to the existing ferry route. Three (3) jetties on Dhaka side and two (2) on the Comilla side must be re-sited, and shifting the ferry route would require temporary provision of a long approach road on the Dhaka side. This route was not selected.

Alternative E has a bridge on a curved alignment and a long approach road on the Dhaka side where land for the road must be acquired. This route was not recommended.

The most suitable route was located with a minor adjustment: 50 m upstream of the right bank ferry ghat and 120 m upstream of the left bank ferry ghat. The results of the comparative study are tabulated in Ap. Table 7–8.

7–2–3 Foundation and Substructure

1) Selection of Applicable Type of Foundation

Similarly, the foundation type of reverse circulation drilled piles was applied for the Meghna-Gumti Bridge because as a result of the surveys on the site conditions and the subsoil conditions it was found that this type would be most suitable. Reference is made to Subsection 7–1–3.

2) Dimensions of Substructure and Foundation

Dimensions of substructure and foundation were determined respectively as follows:

(1) Abutment

- Type: RC Buttress Type of Full Height Abutment
- Abutment Height : 10.0 m
- Nos and Type of Piles : 32 Nos. of precast piles (45 cm x 45 cm square, length = 32 m)

(2) Pier

- Type: Invert-T Type Pier
- Pier Height: 4.5 m to 19.5 m
- Nos. and Type of Pile:

  Foundation in the river:

  9 Nos. of Reverse Circulation Drilled Pile (ϕ 1.5 m, L = 50 m)

  Foundation on the sand bar:

  8 Nos. of Reverse Circulation Drilled Pile (ϕ 1.5 m, L = 65 m)

3) Protection of Piers Against Ship Collision

The same method as in the Meghna Bridge was applied for the protection of the piers against the collision by ships.

Reference is made to Subsection 7–1–3, 3) and the recommended plan applied for the Meghna Bridge in Ap. Fig. 7–1.

7–2–4 Superstructure

1) Economic Span Length

Similarly, the cost-span relationships were studied separately for the river crossing bridges and for the viaduct over the sand bar, taking into consideration the differences between them, such as dimensional difference of pier height and foundation depth and the difference of site conditions in the construction stage.

The procedure to obtain the cost-span relationship is outlined in the flow chart used for the Meghna Bridge. Reference is made to Subsection 7–1–4.

The cost used for the following study was estimated based on the same conditions as for the Meghna Bridge.

(1) River Crossing Bridge

From the results of the same study as on the Meghna Bridge, the five types of superstructure as listed in Table 7–2–1 were considered as possible alternative solutions. And use of reverse circulation drilled piles only was considered for pier foundations on the basis of the results obtained in Subsection 7–1–4.

Table 7–2–1 Types of Superstructure and Span Length Studied – River Crossing Bridge –

Type of Superstructure	Span	Lengths	(m)
PC Box Girder (Cast-in-situ, Cantilever)	60,	90,	120
Steel Truss Girder	60,	90,	120
Steel Box Girder	45,	60,	90
PC T-Beam Girder (Precast Beam)	25,	30,	45
Steel Composite Plate Girder	25,	30,	45

The results of the cost-span relation study are shown in Fig. 7–2–2. From the economic point of view, the following approximate span lengths were recommended for the succeeding study.

a) For Navigation Span Bridge

– PC box girder (Cast-in-situ, Cantilever) : 90 m

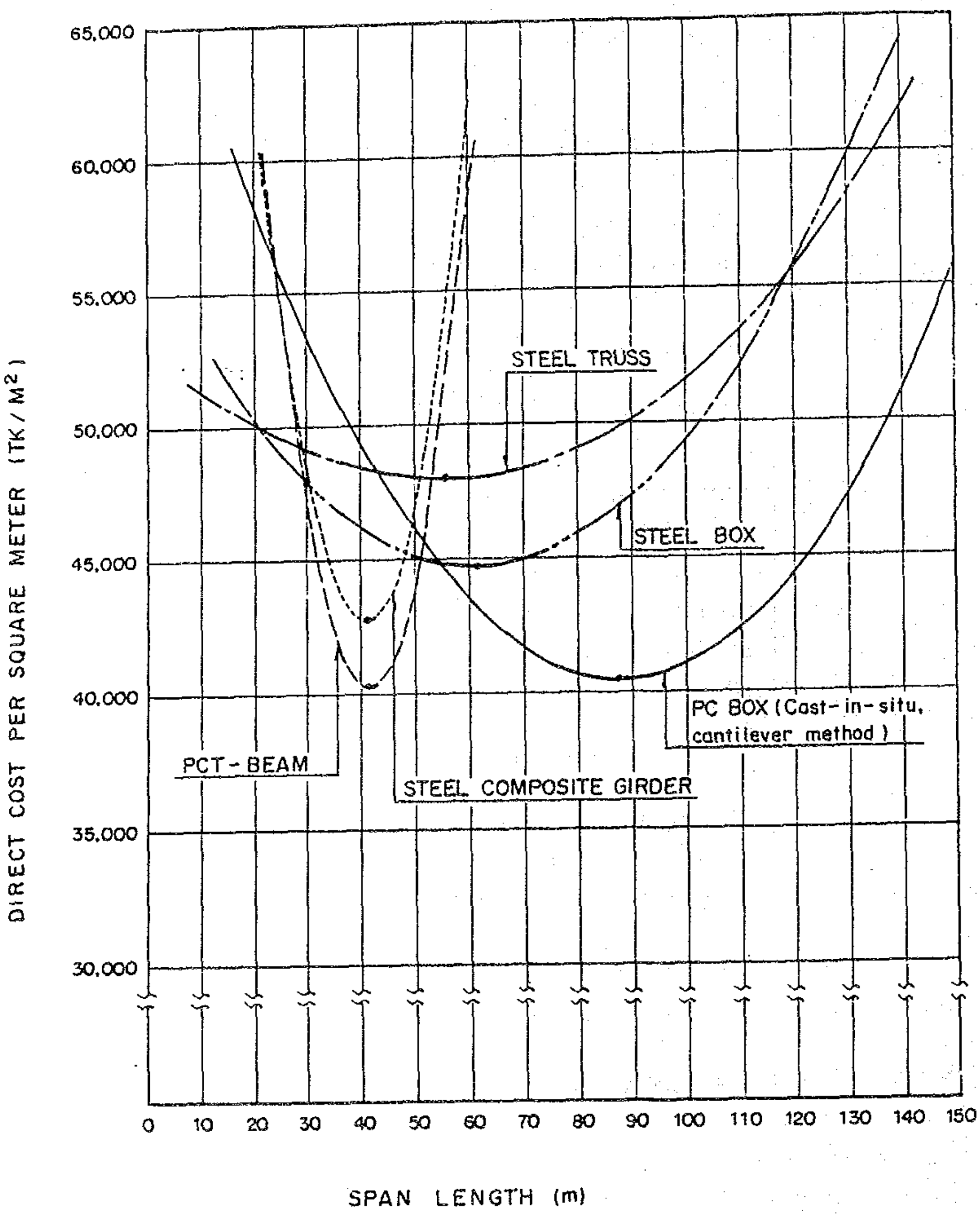
b) For Other Side Span Bridge:

– PC box girder (Cast-in-situ, Cantilever) : 87 m

– PC T-beam girder (Precast beam) : 42 m

(2) Viaduct over Sand Bar

The six types of superstructure listed in Table 7–2–2 were considered as possible alternative solutions, in which PC box girder type by full-



Source: The Study Team

FIG. 7-2-2 DIRECT COST-SPAN RELATION FOR MEGHNA-GUMTI BRIDGE STUDY scaffolding method as river crossing bridge, was added to the five types of superstructure for the Meghna Bridge taking into consideration the availability of the sand bar ground in the river. In this case, use of reverse circulation drilled piles was also considered for pier foundations.

Table 7–2–2 Types of Superstructure and Span Length Studied – Viaduct over Sand Bar –

Type of Superstructure	Span Lengths (m)		
PC Box Girder (Cast-in-situ, Cantilever)	60,	90,	120
PC Box Girder (Cast-in-situ, Full-scaffolding)	60,	90,	120
Steel Truss Girder	60,	90,	120
Steel Box Girder	45,	60,	90
PC T-Beam Girder (Precast Beam)	25,	30,	45
Steel Composite Plate Girder	25,	30,	45

The results of the cost-span relation study are shown in Fig. 7–2–3. From the economic point of view, the following span lengths were recommended for the viaduct over the sand bar:

- PC box girder (Cast-in-situ, Cantilever) : 85 m
- PC T-beam girder (Precast beam) : 42 m

2) Span Arrangement and Bridge Type

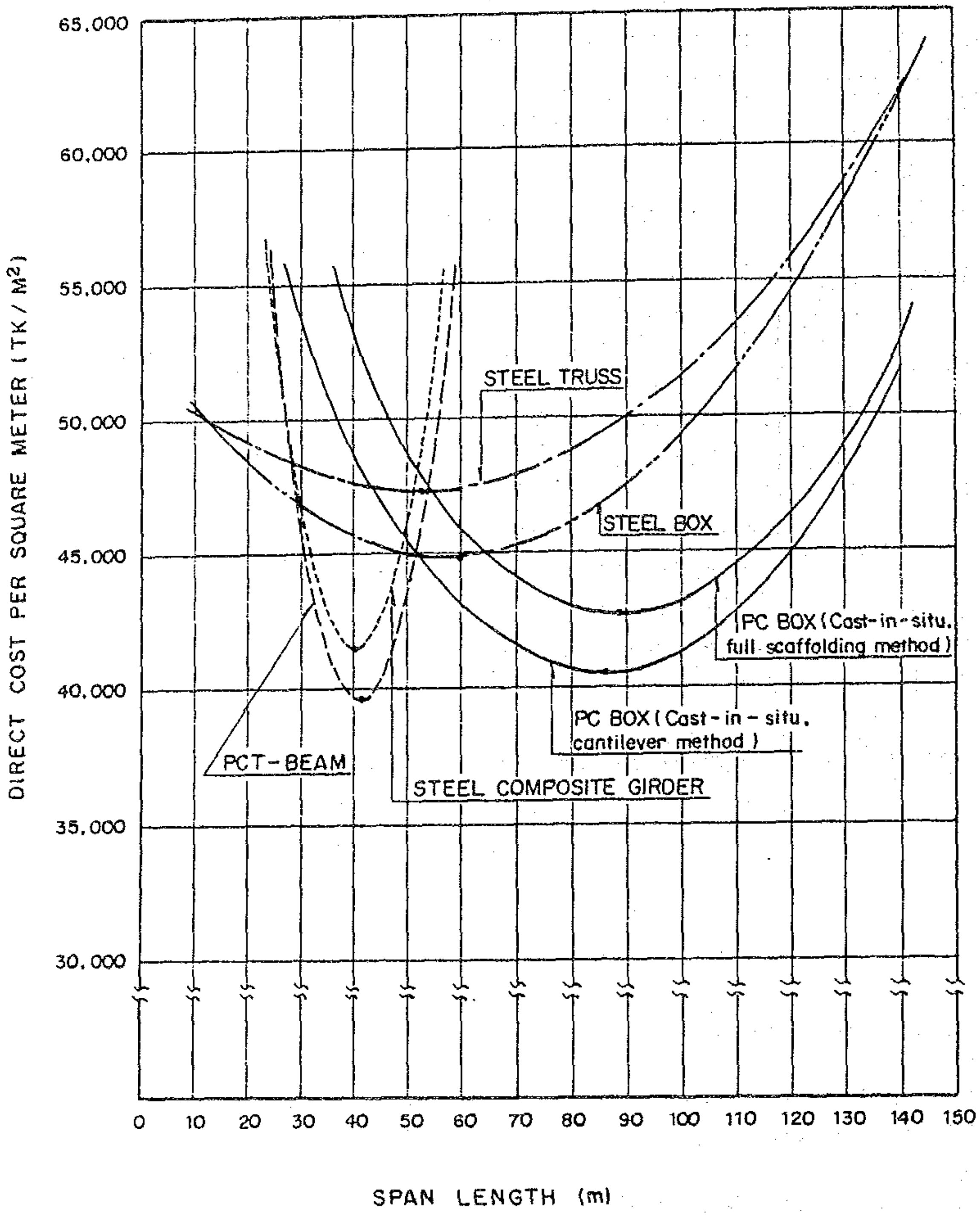
In determining the span arrangement, the following were taken into consideration:

a) Navigation Clearance

Refer to Subsection 6–2–1, Bridge Design Criteria.

b) Economic Span Length

Refer to the preceding Subsection 7–2–4.



Source: The Study Team

FIG. 7-2-3 DIRECT COST-SPAN RELATION FOR VIADUCT OVER SAND-BAR ACROSS MEGHNA-GUMTI

c) Distance between Two Navigation Centres

From the topograhic survey by using electronic distance metre, the distance between the navigation centre of the Branch Maghna and that of the Gumti River was measured at 860 metres. The numbers of spans between the navigation centres were determined by dividing the distance of 860 metres based on the approximate economic span length.

In the case of the Meghna Bridge, the comparison of bridge types including the steel box type was studied and as the result the steel structure type could not be recommended as the most suitable type, from the view point of economy and availability of material from the domestic market. For the Meghna-Gumti Bridge, the study of the alternative steel structure type was omitted because the comparison study result of the Meghna Bridge was used.

Accordingly, suitable solutions for the span arrangements are obtained as illustrated in Fig. 7–2–4.

The features of the respective alternatives are outlined hereunder:

Alternative A

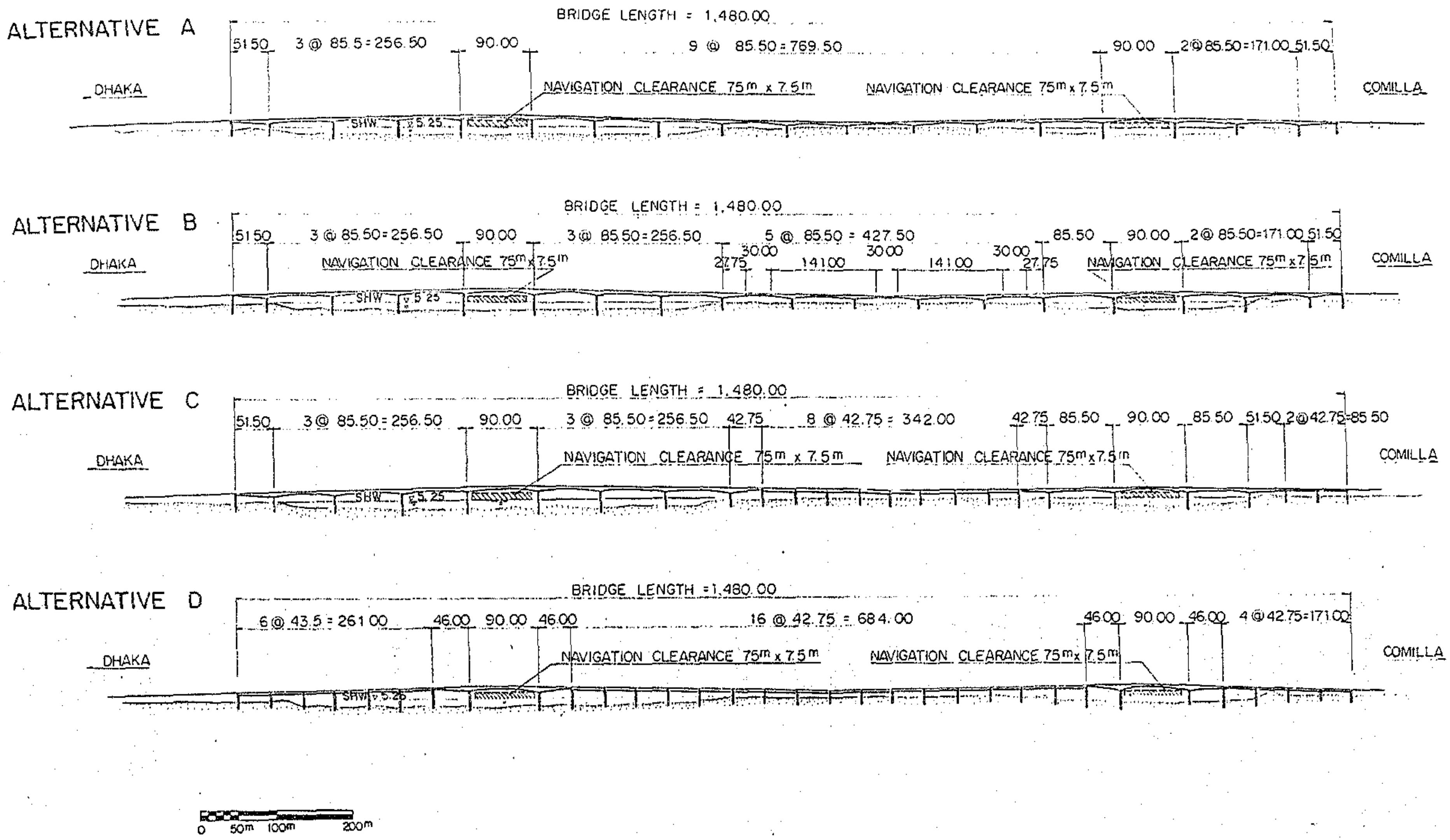
PC box girder by cantilever erection method is considered as the structural type of superstructure. The standard span length is determined at 85.5 metres except that the navigation span length is 90.0 metres. The total bridge length is 1,480 metres.

Alternative B

The portions of the two river crossings have the same span arrangements as Alternative a, and also the same structural type of supersturcture. Gelber type of superstructure is considered for the viaduct over the sand bar, where cantilever span of 27.75 m by PC box girder and suspended span of 30.0 m by PC T-beam are adopted. The total bridge length is 1,480 metres.

Alternative C

The river crossings have the same span arrangements as Alternative A, and also the same structural type of superstructure. PC T-beam is considered as the structural type of superstructure for the viaduct over the



Source: The Study Team

Fig. 7–2–4 SPAN ARRANGEMENTS FOR MEGHNA-GUMTI BRIDGE

sand bar. The span length of PC T-beam is 42.75 metres. The total bridge length is 1,480 metres.

Alternative D

PC box girder by the cantilever method is adopted only for the navigation span of 90 metres and anchor span of 46 metres. As for the river crossing of Branch Meghna, on the Dhaka side PC T-beams having a span length of 43.5 metres are adopted. And PC T-beam having the same span length as the viaduct of Alternative C is adopted for the portion between PC box girders provided for the navigation spans, and the river crossing of the Gumti on the Comilla side. The total bridge length is 1,480 metres.

The general view of these four alternatives are shown in Ap. Figs. 7–5 through 7–8.

3) Comparison of Bridge Types

Four alternatives, i.e. Case–A, B, C and D, were examined and compared technically and economically. The summary of this study is shown in Table 7–2–3. The figures of bridge construction cost in the same table were estimated using the same conditions of the Meghna Bridge.

As a result of the study, Alternative Case–A was found the most suitable from view points of construction cost and construction ease due to the repetition of one construction process, and was recommended as the final type of bridge.

4) Dimensions of Superstructure

The structural features of the recommended type of the bridge (Alternative Case–A) are outlined hereunder.

The general view of Case–A is shown in Ap. Fig. 7–5.

- Bridge Length : 1,480 m
- Bridge Width : 9.2 m
- Carriageway Width : 7.2 m
- Sidewalk Width : 1.0 m on both sides

Table 7–2–3 Comparison of Bridge Alternatives over Meghna-Gumti

Description \ Alternative		CASE - A	CASE - B	CASE - C	CASE - D
Span Arrangement		51.5m + 3@85.5m + 90.0m + 9@85.5m + 90.0m + 2@85.5m + 51.5m = 1,480 m	51.5m + 3@85.5m + 90.0m + 3@85.5m + 85.5m** + 85.5m + 85.5m** + 85.5m + 85.5m** + 85.5m + 90.0m + 2@85.5m + 51.5m ≒ 1,480 m	51.5m + 3@85.5m + 90.0m + 3@85.5m + 42.75m + 8@42.75m + 42.75m + 85.5m + 90.0m + 85.5m + 51.5m + 2@42.75m ≒ 1,480 m	6@43.5m + 46.0m + 90.0m + 46.0m + 16@42.75m + 46.0m + 90.0m + 46.0m + 4@42.75m = 1,480 m
Side View Outline	River Crossing Bridge	PC BOX 85.5 90 85.5	PC BOX 85.5 90 85.5	PC BOX 85.5 90 85.5	PC T-BEAM PC BOX PC T-BEAM @42.75 46 90 46 @42.75
	Viaduct over Sand-Bar	PC BOX 85.5 85.5 85.5	PC BOX GELBER PC BOX 85.5 85.5 85.5 27.75 30 27.75	PC T-BEAM @42.75	PC T-BEAM @42.75
Principal Material of Superstructure		Prestressed Concrete	Prestressed Concrete	Prestressed Concrete	Prestressed Concrete
Structural Features	Superstructure	River Crossing Bridge Cast-in-situ PC Box (Cantilever method) Viaduct over Sand-Bar Cast-in-situ PC Box (Cantilever method)	River Crossing Bridge Cast-in-situ PC Box (Cantilever method) Viaduct over Sand-Bar Gelber type consisting of PC Box and PC T-Beam	River Crossing Bridge Cast-in-situ PC Box (Cantilever method) Viaduct over Sand-Bar PC T-Beam (Precast)	River Crossing Bridge Cast-in-situ PC Box (Cantilever method) & PC T-Beam (Precast) Viaduct over Sand-Bar PC T-Beam (Precast)
	Foundation	River Crossing Bridge Cast-in-situ RC Pile (Reverse Circulation Drill) Viaduct over Sand-Bar Cast-in-situ RC Pile (Reverse Circulation Drill)	River Crossing Bridge Cast-in-situ RC Pile (Reverse Circulation Drill) Viaduct over Sand-Bar Cast-in-situ RC Pile (Reverse Circulation Drill)	River Crossing Bridge Cast-in-situ RC Pile (Reverse Circulation Drill) Viaduct over Sand-Bar Cast-in-situ RC Pile (Reverse Circulation Drill)	River Crossing Bridge Cast-in-situ RC Pile (Reverse Circulation Drill) Viaduct over Sand-Bar Cast-in-situ RC Pile (Reverse Circulation Drill)
Construction Aspect	River Crossing Bridge	Same method as Meghna Bridge	Same method as Meghna Bridge	Same method as Meghna Bridge	PC Box: Same method as Meghna Br. PC T-Beam: Already experienced in Bangladesh
	Viaduct over Sand-Bar	Same method as Meghna Bridge	Already experienced in Bangladesh	Already experienced in Bangladesh	Already experienced in Bangladesh
	Remark	To require one construction process repeatedly			
Availability of Materials from Domestic Market		Mostly available	Mostly available	Mostly available	Mostly available
Bridge Construction Period		About 4 Years	About 4 Years	About 4 Years	About 4 Years
Bridge Construction Cost*	Superstructure	210 Million Taka	216 Million Taka	191 Million Taka	172 Million Taka
	Substructure & Foundation	402	402	458	517
	Total	612	618	649	689
Maintenance Cost		Almost free	Almost free	Almost free	Almost free
Aethetics		Good	Good	Fair	Fair
Travelling Quality on Bridge Surface		Good	Good	Fair	Fair
Overall Evaluation		Recommendable due to construction cost and construction ease			

Notes : * The bridge construction cost excludes the cost of approach road, temporary work and ancillary work, and CDST also.
Breakdown of these cases is shown in Ap. Table 7-9 through 7-12.
** Gelber type of superstructure consists of cantilever span of 27.75m by PC box girder and suspended span of 30.0m by PC T-beam.
[redacted]

- Type of Superstructure : Cast-in-situ PC Box Girder (Cantilever Method)
- Span Length : 90.0 m (Navigation Span)
  85.5 m (Standard Span)
- Depth of Girder:

  For navigation span ....
  5.95 m (at Pier) to 1.95 m (at Centre)

  For standard span ....
  5.65 m (at Pier) to 1.95 m (at Centre)

The cross sections of the main girder are illustrated in Fig. 7–2–5.

7–2–5 Construction Procedures for Bridge

The construction method and schedule for Alternative A proposing the arrangement of PC box girder (cast-in-situ) with reverse circulation drilled pile foundation were elaborated. A period of 58 months was estimated for its construction. The detailed schedule is shown in Fig. 7–2–6. At least three months will be spent for the importation of special materials and equipment by the contractor.

Since the project site is in an inundated area during flood season (June to October) the contractor should prepare working yards on both river sides and one on the sand bar between the Branch Meghna and the Gumti Rivers by land fill.

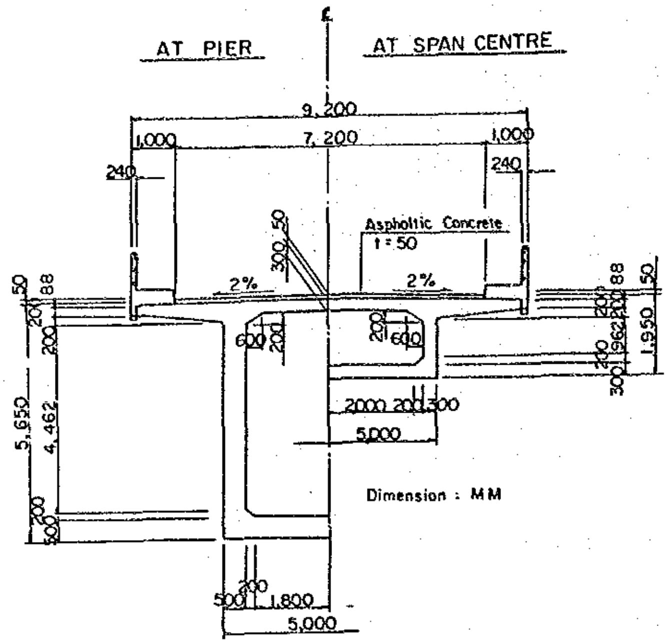
1) Temporary Quays

The same conditions as for the Meghna Bridge can be envisaged. Reference is made to Subsection 7–1–6, 1).

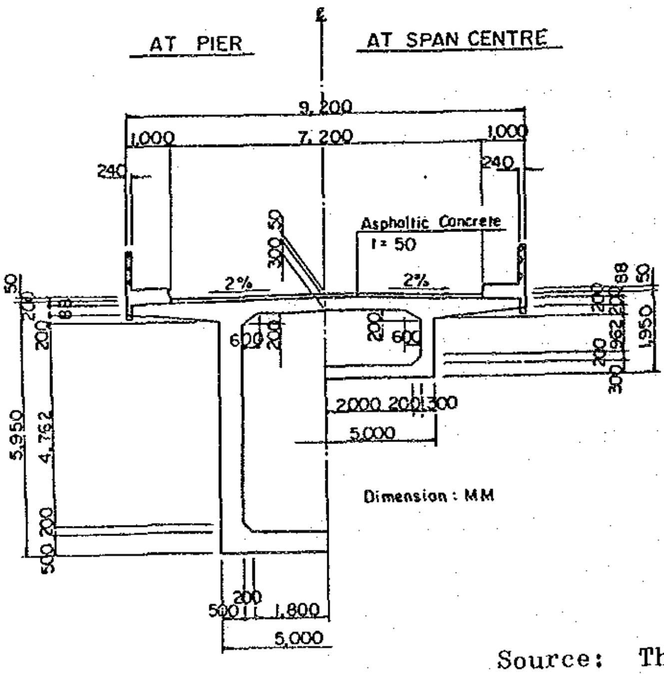
2) Temporary Stagings

As discussed in the construction procedure of the Meghna Bridge, (Ref. Subsection 7–1–6, 2)), the staging method was adopted for piling work, concrete placing work, etc. For the navigation of boats and ships during the construction period, the route around the main span bridge should always be kept open. Temporary steel stagings, having dimensions of 300 m long x 4 m wide for Dhaka side, 130 m long x 4 m wide for Comilla side, and 760 m long x 4 m wide for the sand bar, will be erected each extending towards the main navigation route.

FOR STANDARD SPAN



FOR NAVIGATION SPAN



Source: The Study Team

Fig. 7–2–5 Cross Sections of Main Girder by Span for Meghna-Gumti Bridge

3) Steel Pile Driving for Cofferdam

Similarly to the Meghna Bridge, double-skin sheet pile cofferdam system is adopted. Reference is made to Subsection 7–1–6, 3).

On the sand bar a cofferdam of steel sheet piles should also be provided. In this case, however, a single sheet pile cofferdam system may be adopted around the location of footing.

4) Reverse Circulation Drilled Piles

For the foundation of piers of the main and side span bridges two sets of reverse circulation drilling equipment will be utilised. Small temporary stagings on which the drilling equipment can be operated will also be required.

5) Construction of Footings in the Riverbed

The construction method of footing is discussed in Subsection 7–1–6, 5). This work in the river or on the sand bar will be scheduled during low water season only to avoid accidents to the underwater works.

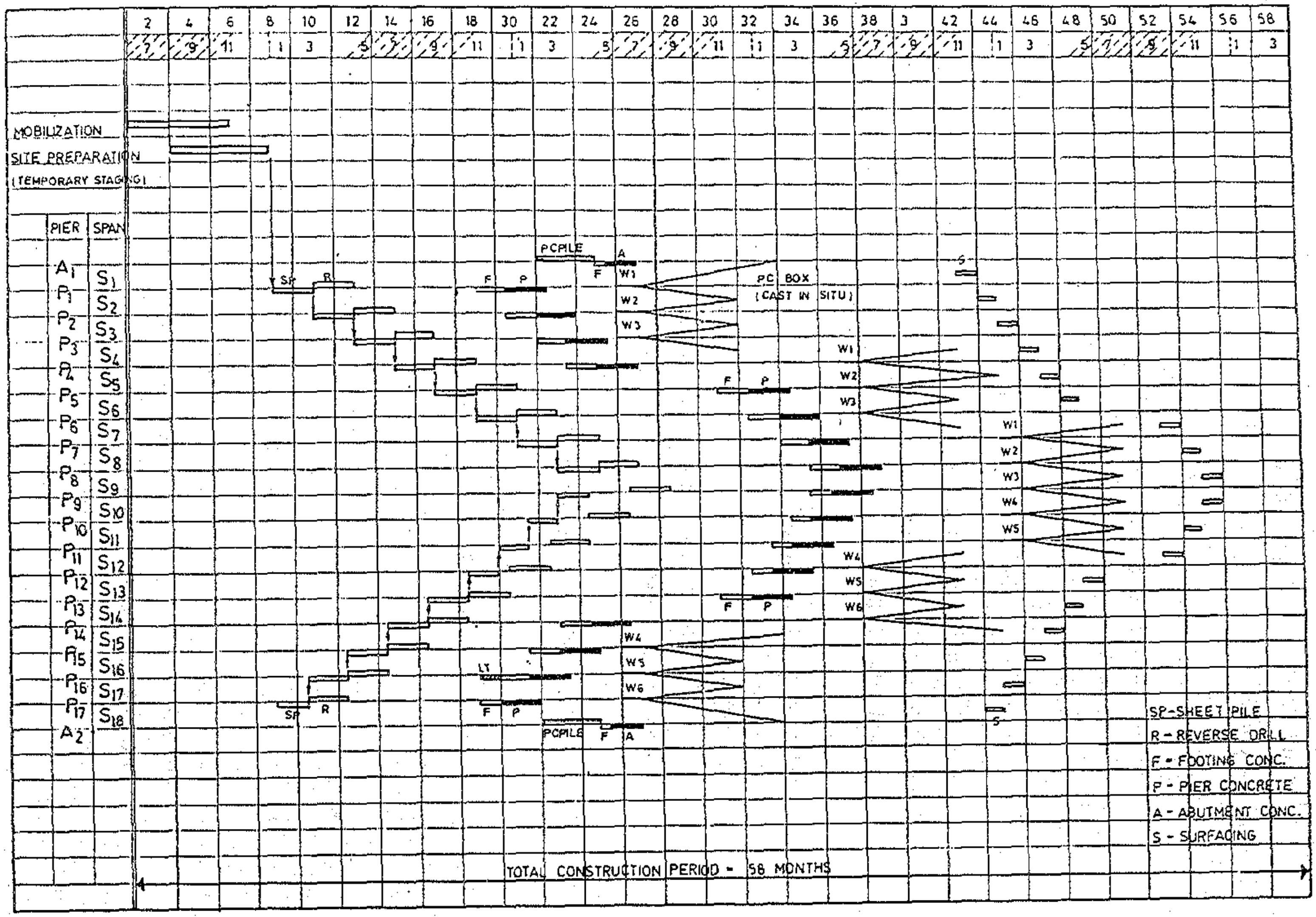
6) Construction of Superstructure

In the cast-in-situ PC box girder bridge construction, six sets of travelling forms will be used. Five sets will be utilised three times and the remaining one two times.

As for the travelling forms reference is made to Subsection 7–1–6, 6).

7) Construction Schedule for Bridge

For the purposes of selection of bridge type and preliminary design, the construction schedules for bridge alternatives were studied. The one for Alternative A is shown in Fig. 7–2–6.



Source: The Study Team

FIG. 7-2-6 BRIDGE CONSTRUCTION SCHEDULE (CASE-A) FOR MEGHNA-GUMTI BRIDGE

7–2–6 Alignment and Design of Approach Roads

The alignments of the approach roads were studied on the topographic map at a scale of 1:3,000 which was prepared from the topographic survey during the initial stage of the Study. The preliminary design of the approach roads was carried out taking into consideration the same basic requirements as the approach roads for the Meghna Bridge. Reference is made to Subsection 7–1–7.

1) Horizontal Alignment

The location of the bridge centre-line was determined as discussed in Sub-section 7–2–2. To maintain safe driving and to provide an aesthetically pleasing alignment, due consideration was given to the location of the centre-line. The predominant factors are:

- to avoid small radius horizontal curves, and
- to avoid sharp curves.

Similar to the Meghna Bridge, the minimum curve radius of the horizontal alignment was set at 400 metres. Spiral transition curves will be inserted into the horizontal curves in the final design stage.

2) Vertical Alignment

The vertical alignment along the centre-line was studied based on the same methodology as the Meghna Bridge. Reference is made to Subsection 7–1–7, 2).

For the Meghna-Gumti Bridge two different central navigation clearances must be kept; one for the Branch Meghna and the other for the Gumti. The vertical alignment was adjusted to meet their respective design requirements. Between the two rivers a sag section was inserted into the vertical alignment over the sand bar for economy in bridge construction and easier provision of a stairway by which the farmers could get down onto the sand bar.

The vertical alignment which was prepared on the longitudinal profile sheets at 1:1,000 vertical scale and 1:3,000 horizontal scale, is shown in Drawings No. 17–1 through 17–3.

3) Description of the Alignment

The proposed alignment diverges from the existing Dhaka-Chittagong Highway at a point 900 m from the ferry ghat on the Dhaka side. The alignment runs almost parallel to the existing road, crosses the Branch Meghna River, agricultural land on the sand bar and then the Gumti River, and merges with the Dhaka-Chittagong Highway on the Comilla side. The total length of the alignment is 2,820 m including the bridge. The major features of the alignment are:

- Between the point of divergence from the existing road and the west bank of the Branch Meghna River, the alignment passes through rice fields which are inundated in the flood season.
- The alignment passes through the sand bar which is utilised for rice fields through the year and is also inundated in the flood season.
- Between the left bank and the merging point the alignment passes through the right-of-way of the RHD which was filled with dredged materials from the nearby riverbed. At present the reclaimed area is utilised for stock piling stone and sand transported from Sylhet area.

4) Pavement

The method of the pavement design of the approach roads for the Meghna Bridge was applied to that of the approach roads for the Meghna-Gumti Bridge. Reference is made to Subsection 7–1–7, 4).

5) Road/Bridge Capacity

The estimation of the road/bridge capacity of the Meghna-Gumti Bridge is the same as that of the Meghna Bridge. Reference is made to Subsection 7–1–7, 5).

CHAPTER 8

STUDY ON EXISTING RHD FERRIES AND FUTURE FERRY REQUIREMENTS

CHAPTER 8 STUDY ON EXISTING RHD FERRIES AND FUTURE FERRY REQUIREMENTS

8–1 Introduction

Extensive investingations will be required if the ferry facilities are to carry all future traffic across the two rivers. A plan to continue the ferry facilities (with required investment for minimum expansion) for carrying the vehicles across the rivers was incorporated as an alternative proposal in the comparative economic study. A plan to continue the present ferry system is also necessary to provide a basis to estimate the extent of expansion required for proceeding with the Project, and the maintenance and transport costs associated with the system. In this chapter the existing conditions of the Meghna and Meghna-Gumti ferry facilities are examined and a plan for ferry expansion is established to meet this purpose.

8–2 Existing Ferry Conditions

Both the Meghna and the Meghna-Gumti ferries on the Dhaka-Chittagong Highway are operated by the Roads and Highways Department, and provide an essential service for transportation on the road. The ferry charges (by type of vehicle) are levied once for both ferries, as almost all the vehicles that make use of either ferry also cross the remaining river.

Type of Vehicle	Charge (Tk.)
Truck	200
Bus	75
Private car	10
Microbus	12
Autorickshaw	6

8–2–1 Existing Conditions of Meghna Ferry

At present 4 Utility ferry boats (Type I), one Utility ferry boat (Type II) and 3 Uniflote ferry boats are operated at Meghna ferry ghat. The loading capacity of the Utility (Type I) boat is 9 trucks, while that for both the Utility (Type II) and the Uniflote ferry is 4 trucks per trip. The ferry terminal facilities for both banks consist of 6 pontoons, 6 gangways, 6 jetties and 6 access roads.

The average unloading and loading time is 20 minutes. The saling time across the Meghna River averages 8 minutes per trip, and the waiting time for the vehicles varies on the peak and non-peak hours of the day and the type of vehicles waiting to cross. The normal daily operation hours of the ferry are from 6:00 a.m. to 10:00 p.m. and two large size ferry boats are operated between 10:00 p.m. and 6:00 a.m.

At present 103 personnel are employed on the Meghna ferry: 36 are ferry crew including masters, drivers, boatmen and greasers, and 67 are for terminal administration including manager, supervisors, toll collectors, gatemen, mechanics, electricians, generator drivers, and their helpers.

8–2–2 Existing Conditions of Meghna-Gumti Ferry

The number and type of ferry facilities for the Meghna-Gumti River crossing are the same as those for Meghna ferry. The loading capacities of the ferries, and the type and number of terminal facilities are also the same.

The average loading and unloading time of the ferries at the ghat is similar to that at the Meghna ferry crossing, whilst the average sailing time across the Meghna-Gumti River is 15 minutes per trip, and the waiting time for the vehicles also varies.

At present 110 personnel are employed on the Meghna-Gumti ferry: 32 are the ferry crew, and 78 are for terminal administration.

8–2–3 Vehicular Traffic Crossing the Rivers

In June 1984 a detailed traffic survey was conducted at the ferries. The survey revealed that the total traffic flow in one day was 1,468 vehicles, with a traffic composition of 55% trucks, 30% buses, 7% cars, 5.8% mini-buses and the remaining for other 4-wheel vehicles, tractor-trailors, autorickshaws and motor cycles. Truck traffic which ran during nighttime from 10:00 p.m. through 6:00 a.m. occupied about 50% of the daily total truck traffic whilst the bus traffic concentrated generally between 7:00 a.m. and 7:00 p.m. The number of cars was small, and concentrated between 8:00 a.m. and 12:00 noon for the eastbound traffic, and between 3:00 p.m. and 7:00 p.m. for the westbound flow. The total vehicle fleet was found to concentrate between 6:00 a.m. and 6:00 p.m., with about 60% of the daily total in each direction.

8–3 Capacity of Existing Ferry

8–3–1 General Assumptions

Based on the result of the crossing time survey of the vehicles conducted in June 1984, the capacity of the existing ferries was estimated by simulation on the queuing theory. The assumptions made were:

- Ferry shall be fully operated for 24 hours a day.
- One (1) of the eight (8) ferry boats provided shall be kept standby.
- Capacity of ferry boats in terms of HVEs (heavy vehicle equivalents) is:

  9 HVES : Type I Utility ferry boat
  4 HVEs : Type II Utility ferry boat
  4 HVEs : Uniflote ferry boat

  where HVE was estimated by vehicle type as follows:

  Truck and bus = 1.00
  Mini-bus = 0.67
  Car and others = 0.33

- Average capacity of one boat in operation is:

$$\frac{\text{4 boats x 9 HVE + 4 boats x 4 HVE}}{\text{8 boats}} = \text{6.5 HVEs/boat}$$

- Loading loss of 10% was considered for the average capacity of the boat with mixed traffic fleet:

  6.5 HVE x 0.9 = 5.85 HVEs/boat

- Headway between vehicles was taken at 6 seconds for loading and unloading each.
- Arrival time intervals of vehicles within the same time-band were assumed to be uniform.
- Within the same time-band the composition of vehicles carried with one boat was assumed to be the same as that of another ferry boat.

8–3–2 Capacity of Meghna Ferry

Usually the sailing time across the Meghna River is 8 minutes per trip and the average unloading and loading time is 20 minutes, which makes the average trip time 38 minutes for a ferry boat. One boat can make 25 round trips in one day and with 7 boats 175 round trips are available per day. Therefore, the capacity of the ferry boats in operation at this ghat is:

7 boats x 25 trips/one way x 5.85 VHEs
= 1,024 VHEs/one way/one day,

whereas the present eastward traffic is 673 HVEs. The figure 1,024 indicates one-way capacity that the ferry can handle in full operation in one day.

Under the present condition the total weighted average crossing time was calculated at 36 minutes with a maximum number of queuing vehicles equal to 0. The simulation showed that the present operation of the Meghna ferry was estimated to be 79% of capacity. It was estimated that the present capacity of the Meghna ferry could accommodate the traffic demand predicted up to the year 1993 (As for future traffic reference is made to Section 11–4).

8–3–3 Capacity of Meghna-Gumti Ferry

Usually the sailing time across the Meghna-Gumti River is 15 minutes per trip and similarly the average unloading and loading time is 20 minutes, which makes the average trip time 35 minutes. One boat can make 20 round trips and with 7 boats 140 round trips are available per day. Therefore, the capacity of the ferry boats at this ghat is:

7 boats x 20 trips/one way x 5.85 HVEs
= 819 HVEs/one way/one day,

whereas the present westward traffic is 678 HVEs. The figure 819 stands for the one-way capacity that the ferry can handle in one day.

Under the present condition the total weighted average crossing time was 69 minutes with a maximum number of queuing vehicles equal to 25 HVEs. The simulation showed that the present operation of the Meghna-Gumti ferry was estimated to be 87% of capacity. It was estimated that the present capacity of the Meghna-Gumti ferry could accommodate the traffic demand up to the year 1992.

8–4 Expansion of Ferry Facilities

8–4–1 Expansion Plan of Ferry Facilities

1) Future requirements of Ferry Facilities

The existing ferry facilities for both Meghna and Meghna-Gumti Rivers are well operated and have sufficient capacities to meet the present vehicular traffic demand as discussed in Section 8–3. The estimation by the Study Team has revealed that the existing facilities of Meghna ferry should start to expand in 1994 and that of Meghna-Gumti in1993.

To accommodate the traffic which would cross the rivers in future, the following ferry expansion plan (which is the case of "without-project") is proposed:

> One ferry boat shall be procured for an additional increase of about 177 and 141 HVEs/day for Meghna and Meghna-Gumti, respectively, one spare engine for each additional increase of two boats, and one set of terminal facilities including pontoons, gangways, jetties and access roads shall be provided for an additional increase of 2 to 3 ferry boats.

Ferry boats, engines and terminal facilities were allocated to correspond to the predicted traffic (HVEs) as shown in Tables 8–4–1 and 8–4–2 for the expansion plans of Meghna ferry and Meghna-Gumti ferry, respectively.

2) Proposed Sites of Ferry Points

The site survey for the ferry expansion was made taking into full account the hydrographical, topographical, land use and subsoil conditions.

Table 8-4-1 Expansion Plan of Meghna Ferry

Year	Traffic Volume in HVE	Ferry Boat		Spare Engine		Pontoon/Gangway & Approach	
		Needed units	New unit	Needed units	New unit	Needed sets	New set
1990	983	8	0	4	0	3	0
91	1044	8	0	4	0	3	0
92	1105	8	0	4	0	3	0
93	1167	8	0	4	0	3	0
94	1228	9	1	5	1	4	1
95	1289	9	0	5	0	4	0
96	1350	9	0	5	0	4	0
97	1411	9	0	5	0	4	0
98	1473	10	1	5	0	4	0
99	1534	10	0	5	0	4	0
2000	1595	11	1	6	1	5	1
01	1680	11	0	6	0	5	0
02	1765	12	1	6	0	5	0
03	1851	13	1	7	1	5	0
04	1936	13	0	7	0	5	0
05	2021	14	1	7	0	6	1
06	2105	14	0	7	0	6	0
07	2188	15	1	8	1	6	0
08	2272	15	0	8	0	6	0
09	2355	16	1	8	0	6	0
10	2439	17	1	9	1	7	1
11	2558	18	1	9	0	7	0
12	2677	19	1	10	1	7	0
13	2796	19	0	10	0	7	0
14	2915	20	1	10	0	8	1
15	3034	21	1	11	1	8	0
16	3152	21	0	11	0	8	0
17	3271	22	1	11	0	8	0
18	3389	23	1	12	1	9	1
19	3508	24	1	12	0	9	0
20	3626	25	1	13	1	10	1

Source: The Study Team

Table 8-4-2 Expansion Plan of Meghna-Gumti Ferry

Year	Traffic Volume in HVE	Ferry Boat		Spare Engine		Pontoon/Gangway & Approach	
		Needed units	New unit	Needed units	New unit	Needed set	New set
1990	991	8	0	4	0	3	0
91	1053	8	0	4	0	3	0
92	1115	8	0	4	0	3	0
93	1178	9	1	5	1	4	1
94	1240	9	0	5	0	4	0
95	1302	10	1	5	0	4	0
96	1364	10	0	5	0	4	0
97	1426	11	1	6	1	5	1
98	1488	11	0	6	0	5	0
99	1550	11	0	6	0	5	0
2000	1612	12	1	6	0	5	0
01	1698	12	0	6	0	5	0
02	1784	13	1	7	1	5	0
03	1869	14	1	7	0	6	1
04	1955	15	1	8	1	6	0
05	2041	15	0	8	0	6	0
06	2126	16	1	8	0	6	0
07	2212	16	0	8	0	6	0
08	2297	17	1	9	1	7	1
09	2383	18	1	9	0	7	0
10	2468	19	1	10	1	7	0
11	2589	19	0	10	0	7	0
12	2709	20	1	10	0	8	1
13	2830	21	1	11	1	8	0
14	2950	22	1	11	0	8	0
15	3071	23	1	12	1	9	1
16	3191	24	1	12	0	9	0
17	3311	25	1	13	1	10	1
18	3431	26	1	13	0	10	0
19	3551	27	1	14	1	10	0
2020	3671	28	1	14	0	11	1
21	3791	29	1	15	1	11	0
22	3911	30	1	15	0	11	0
23	4031	31	1	16	1	12	1
24	4151	32	1	16	0	12	0
25	4271	33	1	17	1	12	0

Source: The Study Team

a) Meghna Ferry

Similar to the location survey of the centre-line for Meghna Bridge, the location of the future ferry ghats should be downstream of the existing ferry ghats because of the existence of stable river banks and freedom from future river meanders, although a partial bank erosion can be noticed for a short stretch downstream of the existing left bank ferry ghat.

The locationof the proposed future ferry berths thus determined is shown in Ap. Figs. 8–1 and 8–2 for the right bank and the left bank of the Meghna River, respectively.

b) Meghna-Gumti Ferry

The existing Meghna-Gumti ferry is located where both the Branch Meghna River and the Gumti River merge, forming one single wide river in rainy seasons, whilst in dry seasons sand bars appear in between. Upstream of the ferry there exists a big sand bar called Donar Char and downstream a small one has developed. The ferry operates across the Meghna-Gumti River through the gap between these two sand bars. The survey by the Study Team has revealed that serious erosion would not be anticipated.

In order for the ferry boats to keep the shortest route, in general, the location of the future ferry berths should be in the downstream side of the existing ferry ghats. Downstream on the right bank the future ferry berths can be easily provided, whilst on the left bank only two ferry berths can be provided downstream because space is limited by the Siddique Ice Plant. Therefore, the reamining ferry berths must be provided upstream.

The location of the proposed future ferry berths thus determined is shown in Ap. Figs. 8–3 and 8–4 for the right bank and the left bank of the Meghna-Gumti River, respectively.

3) Additional Ferry Boats

For both the Meghna and the Meghna-Gumti ferry berths the existing ferry boats are of Type I Utility ferry boat, Type II Utility ferry boats and Uniflote ferry boats. The RHD Ferry Circle is thinking of the future use of Type I Utility ferry boats which can move prow and stern when berthing or sailing. In this study the use of Type I Utility ferry boat (capacity: 9 HVEs) was proposed as reinforcement, the outline of which is shown in Ap. Fig. 8–5.

4) Landing Facilities

a) Landing Method

The ferry boats are of roll-on and roll-off type. To make this operation easier, the direction of the landing approach should be provided at right angles to the stream line of the water. Ap. Fig. 8–6 shows a standard plan of the proposed ferry berths. Jiettiesare to be provided at about 50 metre intervals, taking into account the safe operations of the ferry boats. Landing will be adjusted by sliding the gangway over the jetty. Rollers are to be fixed underneath the ends of the gangway for adjustment to water level fluctuations. The method is illustrated in Ap. Fig. 8–7.

b) Jetty (Approach Ramp)

A general arrangement of the proposed ferry jetty is shown in Ap. Fig. 8–8. The slope of a jetty shall be one in 9 which is the safe maximum grade for the smooth loading and unloading of heavy vehicles. The width shall be 7.6 metres. The surface of the jetty is to be a concrete pavement 200 mm thick.

The river face of the jetty shall be steel sheet piling for earth retaining and scour protection. The heads of the steel sheet piles shall be restrained by tie-rods.

c) Pontton and Gangway

A pontoon having a size of 19.81 m x 7.92 m shall be used (Ref. Ap. Fig. 8–7). On its berthing face rubber fenders and one set of steel ramp plates handled by a winch are to be installed. The gangway shall be as light in weight as possible, being a structure of 13.5 m long and 4.0 m wide. Under the landward end, a roller shall be fixed at each side so as to roll on the steel guides provided on the jetty surface as the water level changes.

d) Protection

Slope protection is required for the portions of the bank where earth-filling is required for the construction of jetties to protect the fill during the rainy season. Reinforced concrete blocks shall be provided over the slope (Ref. Ap. Fig. 8–8).

5) Terminals

The road within the terminal shall have a minimum 6 metres (2 lanes) width and widened to 9 metres and 12 metres for parking lanes for waiting vehicles. The road surface shall be asphalt-paved.

8–4–2 Investment Cost for Ferry Expansion

The costs required for the expansion scheme of the existing facilities were examined. Costs of ferry boat, spare engine and pontoon/gangway which the Ferry Circle, RHD supplied are as follows:

Ferry boat, Type I	:	Tk.8,700,000/unit
Spare engine	:	Tk.2,962,000/unit
Pontoon/gangway	:	Tk.1,750,000/set

Breakdowns of these costs are respectively shown in Ap. Tables 13–2, 13–3 and 13–4. As for the construction of a jetty terminal including its access road, the cost for a jetty was estimated separately for river and for bank, because the construction of a jetty varies with the location. Ap. Tables 8–1 and 8–2 show the construction costs of jetties for Meghna and Meghna-Gumti Ferries, respectively. The costs summarised from the above tables are as follows:

Meghna Ferry:

One jetty on Dhaka side	: Tk.1,999,000
One jetty on Comilla side	: Tk.2,797,000

Meghna-Gumti Ferry:

One jetty on Dhaka side	: Tk.2,427,000
One jetty on Comilla side	: Tk.1,903,000

CHAPTER 9
PROJECT COST ESTIMATES

CHAPTER 9 PROJECT COST ESTIMATES

9–1 Basis of Cost Estimation

9–1–1 Construction Cost

Price source of the construction cost was as of June 1984, and the exchange ratios of foreign currencies were:

US$1.00 = Tk.25.0 = ¥235.

1) Materials and Equipment

By referring to the Import Policy Order (1983–1984) and Import Trade Control Order, it is found that in connection with this Project only the following main items could be imported due to lack of availability in Bangladesh:

– Construction machinery and plants except marine machinery such as dredgers, barges, tug boats, etc.;

– Deformed bar (SD30) specified in JIS G 3112;

– Rolled shaped steels for temporary staging in the river;

– High tensile steel bar and wire, and accessories; and

– Shoe, centre hing, expansion joint, etc.

Other items for the bridge projects are produced in sufficient quantities by the domestic industries in Bangladesh.

The unit prices of materials and fuel are listed in Ap. Table 9–1 being divided into foreign, local and tax components. The tariff of CDST (customs duty and sales taxes) and excise tax are shown in Ap. Table 9–2. The depreciation and maintenance costs of equipment were calculated as below based on "Depreciation Table 1984" issued by the Japan Construction Mechanisation Association.

$$\text{Average daily machine charge} = P \times \left(\frac{D+M}{Y} + C\right) \times \frac{1}{H} \times 6 \text{ hours}$$

where P = present machine price

D = depreciation cost ratio

M = maintenance cost ratio at site and head office

Y = life year of machine

C = control and managing cost ratio per year

H = average standard operation hours per year

The daily machine operation costs consist of average daily machine charge, fuel and lubricant charge of working hours per day and operator's daily wage. They are shown in Ap. Table 9–3.

CDSTs of machinery and plants are separately estimated by lump sum basis and included in sea-surface transportation costs.

The sea-surface transportation costs of imported items were estimated assuming that the origin is Yokohama Port, Japan, as shown in Ap. Table 9–4.

2) Manpower

The present working style of labourers in Bangladesh is specified as labour intensive as can be seen in:

– Rickshaw pullers in the cities;

– Excavation and hauling of earth by manpower; and

– Crushed aggregate production by hand.

On the other hand, Bangladesh has plenty of construction workers like machine operators who have become skilled through their experience of construction projects in the Middle East. Therefore all manpower for the project will be supplied in Bangladesh even for the advanced mechanised construction project like these bridges. These labour costs per day were surveyed through interviewing constructors in Dhaka and are listed in Ap. Table 9–5.

Income taxes were quoted by referring to the "Bangladesh Income Tax Manual, July 1977" and "Salient Features of Finance Ordinance 1983".

3) Proportion of Concrete

Concrete is the main item for the Project. The proportions of mixtures by class which may govern the project cost are tentatively designed only for the cost estimates shown in Ap. Table 9–6.

4) Working Conditions

Monthly workable days were calculated through the past 10 years' rainfall records of the Bangladesh Water Development Board (BWDB).

Average workable days through the year are 19 days per month, 14 days in the rainy season and 23 days in the dry season. The details are attached in Ap. Table 9–7.

Based on the daily water level and tidal survey recorded by BWDB at the Meghna ferry ghat and Daudkandi, the variation of the river water levels is diagrammed in Ap. Fig. 9–2 and can be summarised as follows:

a) The maximum variation from the highest to the lowest water level through the year is about 4.0 metres.

b) The highest water level was recorded in August and the lowest in February.

c) The maximum daily change of water level was about 80 cm which occurred in April, while the minimum change was about 8 cm in August.

From these, therefore, the carrying out of foundation works in the rivers during the rainy seasons is not recommended especially for works enclosed in sheet piles .

5) Tax Amount Estimated

Tax components are clarified by dividing into the following categories:

a) Direct Customs Duty and Sales Taxes (CDSTs)

(1) The full amount of CDST of the imported goods and materials to be used for the main body of bridge structures was considered.

(2) CDST of imported temporary materials such as steel products for platform, cofferdam and stagings in the river, which are to be removed after completion of the bridges, was estimated by their residual ratios.

(3) CDST of imported machines and plants for the construction, which would be added to CIF prices of them when the machines and plants are imported to Bangladesh, was estimated by their depreciation bases.

However, contractors who import these items will be required to pay the full amount of CDSTs at their customs clearance .

b) Other Taxes

(1) CDST of raw materials for local industrial products such as cement clinker, crude oil for fuel and asphalt and ingot and billet of steel products.

(2) Excise tax on local industrial products.

(3) Income tax of construction workers .

These taxes are already included in the prices of goods or wages when the constructors have paid for them.

CDSTs from the construction costs of the Meghna Bridge and the Meghna-Gumti Bridge were categorised and are shown in Ap. Tables 9–8 and 9–9, respectively. It can be seen from these tables that CDSTs from both bridge costs have a share of about 85% of the respective total tax amounts.

6) Overhead and Contingency

About 20% of the total direct cost was allocated to the overhead of the construction cost, and 7.5% of the total construction cost was prepared as the physical contingency of the construction cost.

7) Land Acquisition and Engineering Service Costs

The official prices for land acquisition by RHD are shown in Ap. Table 9–10.

The land acquisition costs were estimated based on the space required for approach roads, and the contractor's camp sites which shall be raised above 5.90 m, the high water level of the 5-year return period at both bridge sites. Engineering service costs were estimated for the detail design works and supervision works by a foreign consultant's team to prepare the contract documents and give certification of the works performed by the contractor(s). Additionally, the technology transfer to local consultants was considered in the staffing schedule.

9–1–2 Maintenance Cost

1) Road Maintenance

The past annual road expenditures which include the cost of upgrading and widening were about Tk.150,000 to Tk.235,000 per km for the Dhaka-Aricha Highway and about Tk.75,000 to Tk.140,000 per km for the Dhaka-Chittagong Highway. Based on these figures, the annual maintenance cost of the new approach roads to the proposed bridges were estimated at about Tk.45,000 to Tk.55,000 per km. Overlays were considered for future traffic volume of heavy vehicles.

2) Bridge Mainteannce

Data of the past bridge mainteance costs for repainting of steel railway bridges were obtained from the Bangladesh Railway Board. Their annual expenditures are about Tk.400,000 for Bhairab Bazar Bridge (56,130 sq.m. of painting) and about Tk.130,000 for Karnafuli Bridge (17,818 sq.m. of painting). However, the maintenance cost records of PC bridges were not available in Bangladesh. The environment of the proposed bridge sites is quite free from industrial exhausts and sea water as shown in Ap. Fig. 9–2. Besides, based on the soundness test pit sand in the site is judged almost free from sodium chloride. Accordingly, it can be said that the maintenance cost of PC bridges is negligible.

However, considering future traffic, increasing axle loads of trucks and traffic volumes around the year 2010 when the number of heavy vehicles is presumed to exceed 3,000 per one direction, the bridge mainteance costs were estimated using world-wide cost levels, reported at the Symposium on Bridge Repair, Maintenance and Rehabilitation, sponsored by the International Association for Bridge and Structural Engineering (IABSE), Washington in 1982.

– In Europe, the following cost magnitudes were recorded*:

Annual bridge inspection cost:

$2 \sim 7 \times 10^{-4}$ x (Construction Cost)

Annual repair and maintenance cost:

$0.3 \sim 1.5 \times 10^{-2}$ x (Construction Cost)

Therefore, if no maintenance system will be applied to the PC bridges, the functional life will be shorter. Considering the above concepts and the site conditions, maintenance costs of PC bridges were planned in the following cost ranges per year:

Inspection cost: $1.0 \sim 1.5 \times 10^{-4}$ x (Construction Cost)

Maintenance cost: $0.04 \sim 0.05 \times 10^{-2}$ x (Construction Cost) .

On the other hand, steel bridges are not free from maintenance even for corrosion resisting steel or zinc coated (hot dip galvanized steel) steel. The magnitude of maintenance costs is judged to be still larger than that of PC bridges due to the inevitable rust and corrosion in some limited parts which were observed on 70% of corrosion resisting steel bridges in U.S.A.**

* Theme reported – "Economic Aspect in Plannings of Bridge Rehabilitation and Repair" H.H. Gotfredsen (Denmark)
** Reported by the American Iron & Steel Institute in 1980.

9–2 Cost of Meghna Bridge

9–2–1 Capital Cost

The capital cost for the Meghna Bridge is summarised as shown in Table 9–2–1.

Table 9–2–1 Capital Cost for Meghna Bridge Construction

(Unit: 1,000 Taka, June 1984 prices)

Items	Foreign Currency	Local Currency	Total
A. Construction Cost			
1) Approach Roads	11,134	38,964	50,098
2) Main & 3) Approach Span Bridge	196,101	52,191	248,292
4) Temporary Works	45,673	14,748	60,421
5) Ancillary Works	8,130	46,846	54,976
6) Traffic Maintenance	7,461	3,508	10,969
7) Seasurface Transport	11,706	-	11,706
8) Inland Transport	329	3,157	3,486
9) Engineer's Office	2,505	4,856	7,361
Direct Cost Total	283,039	164,270	447,309
Overhead (20%)	50,947	89,545	140,492
Initial Const. Cost	333,986	253,815	587,801
Physical Contingency (7.5%)	25,049	19,036	44,085
Tax of A.	-	254,746	254,746
Subtotal	359,035 (40.5%)	527,597 (59.5%)	886,632 (100%)
B. Engineering Services			
1) Detail Design Cost	21,112	771	21,883
2) Supervision Cost	53,811	7,045	60,856
Subtotal	74,923	7,816	82,739
Tax of B.	-	3,392	3,392
C. Land Acquisition	-	11,561	11,561
Total Cost of A. + B. + C.	433,958	550,366	984,324

Source: The Study Team

The breakdown of the construction cost is shown by item in Ap. Table 9–11.

Disbursement schedule of the construction cost was planned in percentage as in Table 9–2–2.

Table 9–2–2 Disbursement Plan for Meghna Bridge

(Unit: %)

Items / Year	1986	1987	1988	1989	1990
1) Approach Roads	–	65	–	10	25
2) Main / 3) Approach } Bridge	–	20	45	25	10
4) Temporary Works	100	–	–	–	–
5) Ancillary Works	–	–	–	30	70
6) Traffic Maintenance	20	20	30	20	10
7) Sea-surface / 8) Inland } Transport	60	40	–	–	–
9) Engineer's Office	80	5	7.5	5	2.5

Source: The Study Team

9–2–2 Maintenance Cost

1) Maintenance Cost of Approach Roads

The annual maintenance costs of the approach roads of a total length of 1.97 km (Dhaka side: 0.94 km, Comilla side: 1.03 km) were estimated in Table 9–2–3.

Table 9–2–3 Maintenance Cost of Approach Roads for Meghna Bridge

(Unit: Taka, June 1984 prices)

Items of Maintenance	Foreign Currency	Local Currency	Total
A. Annual Maintenance per 1.97 km			
1) Daily Maintenance		13,368	13,368
2) Seasonal Maintenance After Flood	32,587	51,194	83,781
Overhead (10%)	2,933	5,983	8,916
Tax of A.	–	1,816	1,816
Subtotal (Tk. 54,800/km)	35,520	72,361	107,881
B. Overlay (5 cm) in 1998 Asphalt Concrete: 1,650 ton	848,364	1,349,815	2,198,179
Overhead (10%)	76,353	143,879	220,232
Tax of B.		273,307	273,307
Subtotal	924,717	1,767,001	2,691,718
C. Overlay (5 cm) after 2005 Asphalt Concrete: 1,650 ton	848,364	1,349,815	2,198,179
Overhead (10%)	76,353	143,879	220,232
Tax of C.	–	273,307	273,307
Subtotal	924,717	1,767,001	2,691,718

Source: The Study Team

2) Maintenance Cost of Meghna Bridge

Table 9–2–4 shows the mainteannce cost estimated for the Meghna Bridge.

Table 9–2–4 Maintenance Cost of Meghna Bridge

(Unit: Taka, June 1984 prices)

Item of Maintenance	Foreign Currency	Local Currency	Total
A. Annual Inspection			
1) Weekly Inspection	28,242	44,625	72,867
2) Seasonal Inspection After Flood	7,115	14,323	21,438
B. Annual Maintenance			
1) Daily Maintenance, Electricity Charge, etc.	97,192	58,790	155,982
Overhead (10%) for (A. + B.)	11,929	11,742	23,671
Tax of (A. + B.)	-	15,356	15,356
Subtotal	144,478	144,836	289,314
C. Periodical (every 5 years) Inspection	32,587	90,589	123,176
D. Periodical Maintenance			
1) Ordinary Repair of Shoe	27,563	2,611	30,174
Expansion Joint	52,847	2,038	54,885
Central Hinge	236,929	7,348	244,277
Handrail	7,037	10,160	17,197
Patching	2,070	3,294	5,364
Pier Protection	86,974	21,948	108,922
Others	65,175	20,107	85,282
2) Repair of Concrete Surface	32,779	81,597	114,376
Overhead (10%) for (C. + D.)	48,956	79,565	128,521
Tax of (C. + D.)	-	658,647	658,647
Subtotal (C. + D.)	592,917	977,904	1,570,821

Inspection Cost per year : 142,470 = 1.4×10^{-4} of the const. cost

Maintenance Cost per year: 461,009 = 0.05×10^{-2} of the const. cost

Source: The Study Team

9–3 Cost of Meghna-Gumti Bridge

9–3–1 Capital Cost

The capita cost for the Meghna-Gumti Bridge was estimated as shown in Table 9–3–1.

Table 9–3–1 Capital Cost for Meghna-Gumti Bridge Construction

(Unit: 1,000 Taka, June 1984 prices)

Items	Foreign Currency	Local Currency	Total
A. Construction Cost			
1) Approach Roads	5,045	15,071	20,116
2) & 3) Main Span Bridge	318,524	120,228	438,752
4) Temporary Staging	61,921	21,408	83,329
5) Ancillary Works	1,392	16,138	17,530
6) Traffic Maintenance	11,329	3,823	15,152
7) Seasurface Transport	6,821	–	6,821
8) Inland Transport	57	659	716
9) Engineer's Office	3,392	5,346	8,738
Direct Cost Total	408,481	182,673	591,154
Overhead (20%)	73,527	102,674	176,201
Initial Const. Cost	482,008	285,347	767,355
Physical Contingency (75%)	36,151	21,401	57,552
Tax of A.	–	363,077	363,077
Subtotal	518,159 (43.6%)	669,825 (56.4%)	1,187,984 (100%)
B. Engineering Service			
1) Detail Design Cost	15,541	1,125	16,666
2) Supervision Cost	41,721	8,142	49,863
Subtotal	57,262	9,267	66,529
Tax of B.	–	3,495	3,495
C. Land Acquisition Cost	–	5,833	5,833
Total Cost of A.+B.+C.	575,421	688,420	1,263,841

Source: The Study Team

The breakdown of construction cost is shown by item in Ap. Table 9–12. Disbursement schedule of the construction cost under Alternative Plan 1 was prepared in percentage as shown in Table 9–3–2. (As for alternative implementation plans reference is made to Sections 13–3 and 14–2.)

Table 9–3–2 Disbursement Plan for Meghna-Gumti Bridge
– Alternative Plan 1 –

(Unit: %)

Items Year	1991	1992	1993	1994	1995
1) Approach Roads	–	50	30	20	–
2) & 3) Main Span Bridge	–	15	25	40	20
4) Temporary Works	100	–	–	–	–
5) Ancillary Works	–	–	–	–	100
6) Traffic Maintenance	20	20	20	30	10
7) Sea-surface } Transport 8) Inland	100	–	–	–	–
9) Engineer's Office	80	5	7.5	7.5	2.5

Source: The Study Team

9–3–2 Maintenance Cost

1) Maintenance Cost of Approach Roads

The annual maintenance costs of the approach roads having a total length of 1.34 km were estimated as shown in Table 9–3–3. Overlay of the road improvement was planned assuming that the opening year is to be 1996.

Table 9–3–3 Maintenance Cost of Approach Roads for Meghna-Gumti Bridge

(Unit: Taka, June 1984 prices)

Items of Maintenance	Foreign Currency	Local Currency	Total
A. Annual Maintenance per 1.34 km			
1) Daily Maintenance		13,368	13,368
2) Seasonal Maintenance After Flood	21,725	20,902	42,627
Overhead (10%)	1,955	3,135	5,090
Tax of A.	-	1,122	1,122
Subtotal (Tk. 46,400/km)	23,680	38,527	62,207
B. Overlay (5 cm) in 2003 Asphalt Concrete: 1,000 ton	514,160	818,070	1,332,230
Overhead (10%)	46,274	87,199	133,472
Tax of B.		165,640	165,640
Subtotal	560,434	1,007,909	1,631,343
C. Overlay (5 cm) after 2010 Asphalt Concrete: 1,000 ton	514,160	818,070	1,332,230
Overhead (10%)	46,274	87,199	133,463
Tax of C.	-	165,640	165,640
Subtotal	560,434	1,007,909	1,631,343

Source: The Study Team

2) Mainteannce Cost of Meghna-Gumti Bridge

Following the concept of mainteannce cost of the Meghna Bridge, the maintenance cost of the Meghna-Gumti Bridge was calculated as shown in Table 9–3–4. Its cost magnitude was almost same with that of the Meghna Bridge.

Table 9-3-4 Maintenance Cost of Meghna-Gumti Bridge

(Unit: Taka, June 1984 prices)

Items of Maintenance	Foreign Currency	Local Currency	Total
A. Annual Inspection			
1) Weekly Inspection	25,674	40,569	66,243
2) Seasonal Inspection After Flood	11,653	20,881	32,534
B. Annual Maintenance			
1) Daily Maintenance, Electricity Charge, etc.	97,192	72,438	169,630
Overhead (10%) for (A.+B.)	12,107	13,174	25,281
Tax of (A. + B.)	-	15,296	15,296
Subtotal (A. + B.)	146,626	162,358	308,984
C. Periodical Inspection (every 5 years)	32,587	90,589	123,176
D. Periodical Maintenance			
1) Ordinary Repair of Shoe,	27,563	2,611	30,174
Expansion Joint	73,986	2,853	76,839
Centre Hinge	445,394	11,021	456,415
Handrail	10,790	15,579	26,369
Patching	3,016	4,800	7,816
Pier Protection	121,763	30,728	152,491
Others	81,468	25,134	106,602
2) Repair of Concrete Surface	49,169	123,297	172,466
Overhead (10%) for (C.+D.)	76,116	110,810	186,926
Tax of (C. + D.)	-	945,381	945,381
Subtotal (C. + D.)	921,852	1,362,803	2,284,655
Inspection Cost per Year	147,127 = 1.2×10^{-4} of the const. cost		
Maintenance Cost per Year	618,788 = 0.05×10^{-2} of the const. cost		

Source: The Study Team