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CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

1–1 Background of the Project

The Dhaka-Chittagong Highway with a total length of about 257 km connects Dhaka City (about four million population), the capital of Bangladesh with Chittagong City (about 1.5 million population), the second largest city and an international port. With the recent completion of the Sitalakhya Bridge on the route between Dhaka and Chittagong, the construction of bridges over the remaining two rivers, the Meghna and Meghna-Gumti, will complete the 380 km long Aricha-Dhaka-Chittagong Highway, avoid the inconvenient, time-consuming ferry system, and boost economic activities.

The Meghna River (about 830 m wide) and the Meghna-Gumti River (about 1,360 m wide) cross the Dhaka-Chittagong Highway at 25 km and 40 km east of Dhaka, respectively, where the Roads and Highways Department (RHD) provides mechanised ferry services. The waiting time at each ferry will increase under the present ferry arrangement as the traffic demand on the Dhaka-Chittagong Highway continues its rising trend.

Proposals for construction of bridges over the Meghna and Meghna-Gumti have been included in the country's Five Year Plan (1980–1985), and the Ministry of Communication (MOC) has given top priority to the early construction of the bridges in the expectation that the movement of goods would be improved by smoother road transportation, and accordingly the economic activities of Bangladesh greatly enhanced.

Under the circumstances, the Government of the People's Republic of Bangladesh (hereinafter referred to as "the Government") requested the Government of Japan for a feasibility study leading to the construction of Meghna and Meghna-Gumti Bridges.

1–2 Study Objective

The objective of the Study is to carry out a feasibility study for the construction of Meghna Bridge and Meghna-Gumti Bridge including approach roads in order to facilitate transportation as well as removing traffic obstructions on the Dhaka-Chittagong Highway.

1–3 Study Approach and Implementation of Study

The work was carried out in accordance with the scope of work for the Study which is annexed to this Report. As a fundamental policy of this Study, the study for the Meghna Bridge preceded that of Meghna-Gumti Bridge. The efficient implementation of the Study required the work to be conducted in stages, and these were subdivided into logical functions as outlined in Figs. 1–1 and 1–2.

Between March 1984 and the end of May 1984, the Study Team conducted necessary engineering investigations to provide data to be used in alternative studies. The investigations included:

- Topographic survey of the existing ferry approaches and alternative locations of the proposed Meghna Bridge;
- Hydrological and hydrographical investigations at both bridge sites during the dry season;
- Soils investigations at the Meghna Bridge site including riverbed and bank borings;
- Review of existing design standards of roads and bridges and establishment of appropriate design criteria for this project;
- Review of unit prices of major construction items used in recent road and bridge construction projects;
- Broad comparative study for the Meghna Bridge; location, type, length, spans, foundations, approaches, etc.; and
- Determination of the recommended location of the Meghna Bridge and resulting centre-line.

The outcome of the work was presented in the Progress Report (I).

During the subsequent period from the beginning of June 1984 through the end of August 1984, the Study Team conducted the following work, the outcome of which was presented in the Progress Report (II).

- Outline design of the proposed Meghna Bridge;
- Topographic survey of existing ferry approaches and alternative locations of the proposed Meghna-Gumti Bridge;

- Hydrological and hydrographical investigations of both bridges during the rainy season;
- Soils investigations at the Meghna-Gumti Bridge site;
- Laboratory tests of soil samples taken from the Meghna and Meghna-Gumti Bridge sites;
- Determination of a recommended location of the Meghna-Gumti Bridge and resulting centre-line;
- Preliminary implementation programme for the Meghna Bridge;
- Conduct of the road traffic survey and analysis on the ferry crossing; and
- Preparation of data for the economic evaluation.

During the third period from the beginning of September 1984 through the end of November 1984, the Study Team conducted the following work, and prepared the Interim Report by incorporating all the results of the Study conducted during the period from March 1984 through November 1984.

- Refinement of the outline design of the proposed Meghna Bridge;
- Outline design of the proposed Meghna-Gumti Bridge;
- Forecast of future traffic demand;
- Study for improved ferry scheme (without-project case);
- Preliminary implementation programme for both bridges;
- Preliminary construction cost estimates for the two bridges; and
- Preliminary economic evaluation of the project.

During the fourth period from the beginning of December 1984 through February 1985, the Study Team carried out in Japan the following work and prepared the Draft Final Report to present the conclusion of the Study.

- Review of the comments of RHD on the contents of the Interim Report;
- Completion of the preliminary design of the two bridges;
- Design of ancillary facilities;
- Refinement of the construction cost estimates;
- Evaluation of the project; and
- Establishing a programme for construction.

The contents of the Draft Final Report were discussed on February 23, 1985 in Dhaka and accepted as recorded in the minutes of the meeting which are annexed to this Final Report.

1–4 Conduct of the Study

With full cooperation from the RHD counterpart staff, the Study was carried out by a Study Team composed of staff from Japanese consultants. JICA assigned members of Pacific Consultants International (PCI) and Nippon Koei Co., Ltd. (NK), to this Study.

The members of the Study Team dispatched by JICA stayed in Bangladesh from March 13, 1984 to November 30, 1984. Supporting main frame computers work was done in the head offices in Tokyo.

The Advisory Committee (representing the Japanese Government) held meetings in Tokyo as the need arose, monitoring the team's progress and providing necessary advice. The representatives of the Advisory Committee made five separate visits to Bangladesh during the period of the work to discuss technical and policy matters with the Study Team, and obtaining confirmation of essential points from the Government of Bangladesh.

1–5 Organisation of the Project Teams

JICA organised the Advisory Committee and the Study Team, while RHD organised its counterpart team. The complete staff who directly participated in the Study are listed below:

(1) Advisory Committee Members of the Japanese Government

Mr. Eigo HANAICHI (Chairman)	Ministry of Construction
Mr. Hideya ASANUMA	Ministry of Construction
Mr. Yoshiyuki YAMAMOTO	Ministry of Construction
Mr. Masaji ONO	Japan Highway Public Corporation
Mr. Taisuke AKIMOTO	Metropolitan Expressway Public Corporation

Mr. Hideki KOMATSU	Japan International Cooperation Agency

– Predecessors –

Mr. Tetsuo KOMATSUBARA	Japan International Cooperation Agency
Mr. Tetsuya MIWA	Japan International Cooperation Agency
Mr. Toshio MOROOKA	Japan International Cooperation Agency

(2) JICA Study Team

Dr. Tadayoshi OKUBO	Team Leader & Bridge Planning (PCI)
Mr. Kunio TESHIMA	Deputy Team Leader & Traffic/Highway Planning (PCI)
Mr. Tohru KAWAKAMI	Bridge Planning (Foundation) & Construction Cost Estimate (NK)
Mr. Hiroyuki ENDO	Bridge Planning (Superstructure) (PCI)
Mr. Katsumi NAITOH	Soils & Materials/Topographic Surveys (NK)
Mr. Seisho INAGAKI	Hydrology & Hydrography (NK)
Mr. Yuichi KITAMURA	Sounding/Topographic Survey (NK)
Mr. Katsufumi MATSUZAWA	Bridge Planning (Superstructure) (NK)
Mr. Masaaki SHIMIZU	Bridge Planning (Foundation) (NK)
Mr. Yaichi KOBAYASHI	Traffic Survey & System Analysis (PCI)
Mr. Takashi NOBEHARA	Economic Analysis (PCI)

(3) RHD Counterpart Staff

Mr. A. R. Chowdhury	Chief Engineer, RHD
Mr. Bazlur Rahman	Additional Chief Engineer, RHD, Foreign Aided Schemes
Mr. M. Eaqub Khan	Superintending Engineer, RHD, Special Project Circle, Dhaka
Mr. K. B. Luftful Karim	Superintending Engineer, RHD, Bridge Design Circle, Dhaka
Mr. M. Islam	Director, RHD, Road Research Laboratory, Dhaka
Mr. A. K. M. Harunar Rashid	Senior Economist, RHD, Dhaka
Mr. Md. A. Wadud	Executive Engineer, RHD, Special Project Division, Dhaka
Mr. Md. A. B. Siddique	Executive Engineer, RHD, Structural Design Division, Dhaka

Mr. A. K. M. Faizur Rahman	Executive Engineer, RHD, Hydraulic & Bridge Survey, Dhaka
Mr. M. A. Kabir Chowdhury	Executive Engineer, RHD, Foundation Division, Dhaka
Mr. A. Matin Chowdhury	Executive Engineer, Material & Research, B.R.R.L.
Mr. Md. Abdul Muqtadir	Assistant Engineer, RHD, Special Project Division, Dhaka
Mr. Farooq Ahmed	Assistant Engineer, RHD, Special Project Division, Dhaka
Mr. Mohiuddin Ahmad	Sub-divisional Engineer, Special Project Division, Dhaka

– Predecessors –

Mr. M. A. Bari	Superintending Engineer, RHD, IDA Aided Project
Mr. A. B. M. Abdul Kabir	Executive Engineer, L.P.D., Dhaka
Mr. Mayeen Uddin Ahmed	Executive Engineer, Bridge Survey & Hydrology Division, Dhaka
Mr. A. S. M. Manzoor	Executive Engineer, RHD
Mr. Abdus Salam	Assistant Engineer, RHD
Mr. M. H. Khan	Assistant Engineer, RHD
Mr. Ruhul Alam	Assistant Engineer, RHD

1–6 Report Procedures

This Final Report for the Feasibility Study on Meghna, Meghna-Gumti Bridges Construction Project consists of MAIN REPORT, APPENDICES and DRAWINGS.

At various stages during the Study, the following reports have been presented by JICA to RHD:

- Inception Report, March 1984 to discuss with RHD the study approaches and requirements, way of the implementation of works and undertakings of both Governments;
- Progress Report (I), May 1984 to present the outcome of the study works conducted from March 1984 through May 1984;
- Progress Report (II), August 1984 to present the outcome of the study works conducted from June 1984 through August 1984;

Fig. 1–1 Work Flow: March 1984 – May 1984

Order of Month	1	2	3
Month Year	March 1984	April 1984	May 1984

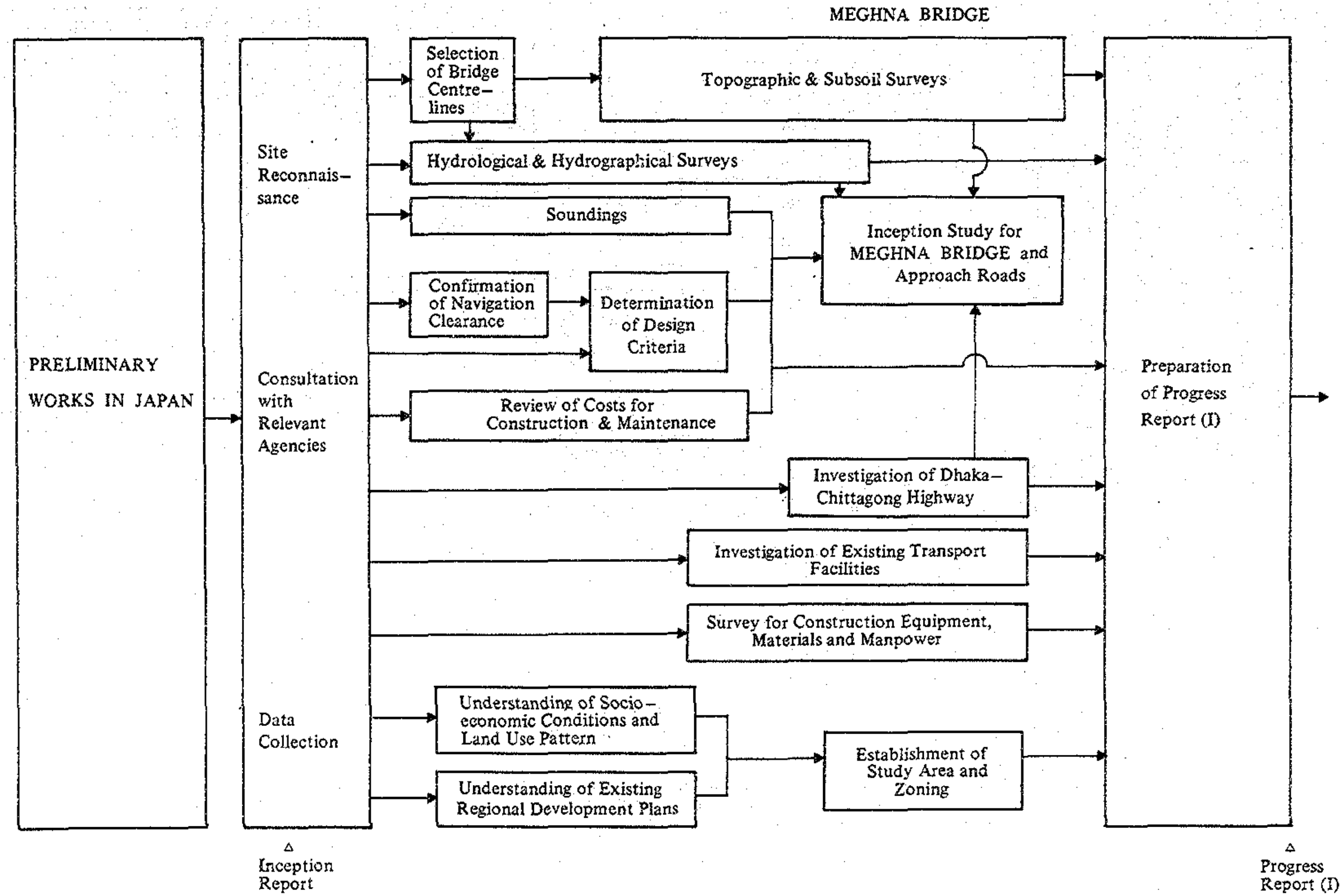
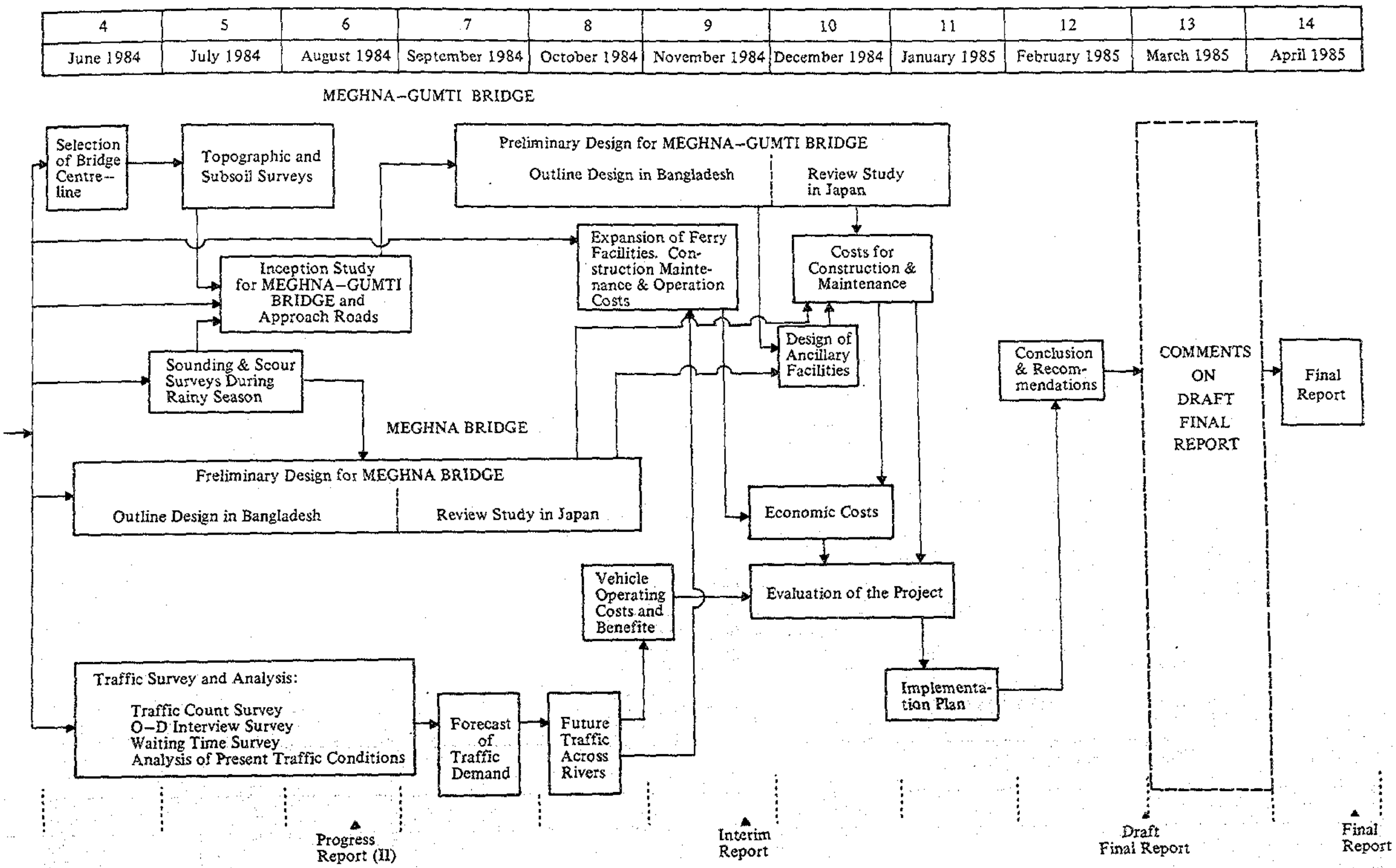


Fig. 1–2 Work Flow: June 1984 – April 1985



– Soil Investigation Report, September 1984 to present the results of subsoil investigation and laboratory tests;

– Interim Report, November 1984 to present all the results of the Study conducted from March 1984 through November 1984; and

– Draft Final Report, February 1985 to present all the study results to the Government for review and comments.

1–7 Abbreviations

The abbreviations used in this Report are as follows:

AASHTO	American Association of State Highway and Transportation Officials
AADT	average annual daily traffic
ADT	average daily traffic
Ap. Fig.	Appendix Figure
Ap. Table	Appendix Table
Ap. Note	Appendix Note
ASTM	American Society for Testing and Material
B.B.S.	Bangladesh Bureau of Statistics
BDSI	Bangladesh Standard Institution
BIWTA	Bangladesh Inland Water Transport Authority
B–C	benefit minus cost
B.R.R.L.	Bangladesh Road Research Laboratory
BWDB	Bangladesh Water Development Board
B/C	benefit cost ratio
BS	British Standards
°C	degree celsius
CBR	California Bearing Ratio
CC	cement concrete
cc	cubic centimetre(s)
CDST	customs duty and sales taxes

CIF	cost with insurance and freight
CKD	completely knocked down
cm	centimetre(s)
cm^2	square centimetre(s)
cub. metres	cubic metre(s)
DC	Deputy Commissioner
DIN	Deutsche Industrie Normen
D.L.	Datum Line
EIRR	economic internal rate of return
E.S.A.	equivalent standard axles
F/C	Foreign Currency
f.c.	factor cost
Fig., Figs.	Figure, Figures
GDP	gross domestic product
GNP	gross national product
GVW	gross vehicle weight
h, hr	hour(s)
H-Q diagram	water level-discharge diagram
HVE	heavy vehicle equivalent
H.W.L.	high water level
ha.	hectare(s)
IABSE	International Association for Bridge and Structural Engineering
I.D.A.	International Development Association
IOS	International Organisation for Standardisation
IRC	Indian Road Congress
IS	Indian Standards
JICA	Japan International Cooperation Agency
JIS	Japanese Industrial Standards
kg	kilogramme(s)

km	kilometre(s)
km^2	square kilometre(s)
kg/cm^2	kilogramme(s) per square centimetre
km/h	kilometres per hour
kg/m^2	kilogramme(s) per square metre
ℓ	litre(s)
L/C	local currency
LDC	least developed country
L.P.D.	Land Programming Division
L.W.L.	low water level
m	metre(s)
max.	maximum
min.	minutes, minimum
m.p.h.	mile(s) per hour
m/s	metre(s) per second
m^2	square metre(s)
m^3	cubic metre(s)
m^3/s	cubic metre(s) per second
mm	millimetre(s)
MOC	Ministry of Communication
M.S.L.	mean sea level
NK	Nippon Koei Co., Ltd.
NNP	net national product
O–D	origin and destination
PC	prestressed concrete
PCI	Pacific Consultants International
PR	ply rating
PWD	Public Work Department
PCE	passenger car equivalent
(p)	provisional

RC	reinforced concrete
R.C.D.	reverse circulation drill
RHD	Roads & Highways Department
R.O.W.	right-of-way
r.o.w.	rest of the world
s	second(s)
SCF	standard conversion factor
SDO	Sub-divisional Officer
SFYP	Second Five Year Plan (1980–1985)
S.H.W.	standard high water level
SPT	standard penetration test
sq.km	square kilometre(s)
t	ton(s)
TIP	Trading & Industrial Policy
Tk.	Taka
t/m^2, $tons/m^2$	ton(s) per square metre
t-m	ton-metre(s)
U.K.	United Kingdom
UNO	Upazila Nirbahi Officer
USA	United States of America
US$	US dollar(s)
VOC	vehicle operating cost
Yen	Japanese Yen

CHAPTER 2

CLIMATE, HYDROLOGY AND HYDOROGRAPHY

CHAPTER 2 CLIMATE, HYDROLOGY AND HYDROGRAPHY

2–1 Climate of the Study Area

The climate of the study area is characterised by a moderately high temperature, heavy rainfall, occasional excessive humidity and fairly marked seasonal variation.

The meteorological factors affecting design criteria for the bridges and ancillary structures, and the relevant meteorological variables relating to the stations nearest to the bridge sites have been examined.

2–1–1 Temperature

Temperature data for Dhaka and Comilla districts are given in Ap. Table 2–1. Generally the average maximum temperature prevails in April and May, recorded at 33.6° in Comilla and 36.2° in Dhaka. The average minimum temperature is in January, recorded at 12.1° in Comilla and 11.8° in Dhaka.

2–1–2 Rainfall

There are three main sources of rainfall in Bangladesh: (1) winter depressions, (2) the early summer thunderstorms known as the Nor'westers (North westerlies) and (3) the summer rains from the southwest known as the monsoons. The highest rainfall is concentrated during the main monsoon period (June to September). Only about one-fifth of the total annual precipitation occurs in the season of Nor'westers (March to May). The winter rain is negligible all over the country.

The monsoon period accounts for 80% of the total rainfall. The average annual rainfall varies from 1,270 mm to 5,080 mm. Maximum rainfall is recorded in the coastal areas of Chittagong and northern part of Sylhet district, while the minimum is observed in the western part of the country particularly Rajshahi area.

The average annual rainfall recorded at Dhaka and Comilla Stations is nearly 2,000 mm, the record of which is shown in Ap. Table 2-2. The monthly normal rainfall which was recorded at the above two stations fluctuates from 10 mm in January to 479 mm in June and is shown in Ap. Table 2-3. Generally the Comilla station records a higher rainfall in terms of monthly normal rainfall.

2–1–3 Relative Humidity

Monthly average relative humidity in the two districts is high. The highest humidity is 95% during October, November and December in Comilla and during June and July in Dhaka, and annually averages 93% in Comilla and 91% in Dhaka. The lowest is in March with 55% in both Comilla and Dhaka.

2–1–4 Wind Pattern

1) Intensity

The prevailing winds of Bangladesh are normally light, and as such, not an important factor in the weather of the country. Only a "Nor'wester" is accompanied by moderate to strong gales and intense rainfall, usually in March and April. It can attain hurricane intensity. Wind speeds in straight-line squalls (Nor'westers) generally vary between 30 and 80 knots. (Ref. Ap. Table 2–4 and 2–5).

2) Cyclone

Cyclones originating in the Bay of Bengal, often accompanied by rainfall of various intensities can affect the bridge sites. The impact of such cyclones on the bridge sites far from the origin is not significant as the wind speed withers away before it reaches the bridge sites. Records for cyclonic storms which affected only the vicinity of the Meghna esturary and bridge sites are shown in Ap. Table 2–6.

3) Wind Direction

During the winter and dry months, the prevailing wind is generally from the northern quadrants, i.e. northeast, north and northwest, while during the monsoons, the wind blows from the southeast. Maximum wind speed in knots-direction recorded at Dhaka and Comila Meteorological Stations is shown in Ap. Table 2–7, and Ap. Fig. 2–1.

2–2 Hydrological and Hydrographical Survey

2–2–1 General

The objectives of the survey are:

- To study proposed bridge sites;
- To determine design discharge and high water level;
- To find appropriate measures against river erosion; and
- To estimate scouring depth around piers.

The land of Bangladesh mainly consists of alluvial plain, which covers more than 50% of the national land area (at an altitude of 8 metres or less above mean sea level). Main rivers in Bangladesh are the Ganges and Brahmaputra Rivers, which originate in the Himalayas, and the Meghna River. The latter rises in Eastern India and flows southwards into the lowlands of Bangladesh, which are inundated every rainy season. 63% of the catchment area of the Meghna River lies outside Bangladesh. The Meghna River system is complicated, joining and diverting repeatedly, and is subject to meandering. The river system associated with the Meghna River is shown in Ap. Fig. 2–2.

Determination of design criteria for the bridge construction is extremely difficult in view of these features. Though the change in the river course due to meandering is very significant, it is nearly impossible to estimate without a thorough survey and basic investigation, i.e. hydraulic model tests.

As for protection against river erosion, the matter has not been adequately researched in Bangladesh.

2–2–2 Field Surveys for the Rivers

To provide the data necessary for the preliminary design of the proposed Meghna and Meghna-Gumti Bridges, the following field surveys were conducted in the dry and rainy seasons in 1984.

The velocity of the Meghna river flow was measured at the proposed bridge sites in order to obtain the data necessary for the study of scouring depth of riverbed materials after the construction of the bridge piers. The results are shown in Ap. Figs. 2–3 through 2–6.

At the site of the existing Bhairab Bazar railway bridge, which is the only structure across the Meghna River, the velocity of river flow and the scouring depth around the bridge piers were measured. The results are shown in Ap. Fig. 2–7.

2–2–3 River Conditions of Proposed Bridge Sites

The stability of the river course was also examined by referring to different maps which were obtained from Landsat photographs and topographic surveys, and suitable sites for the bridges were found in the vicinity of the existing ferry facilities.

1) Meghna Bridge

The site recommended for the Meghna Bridge is the one kilometre length downstream of the ferry ghat, after consideration of the following points.

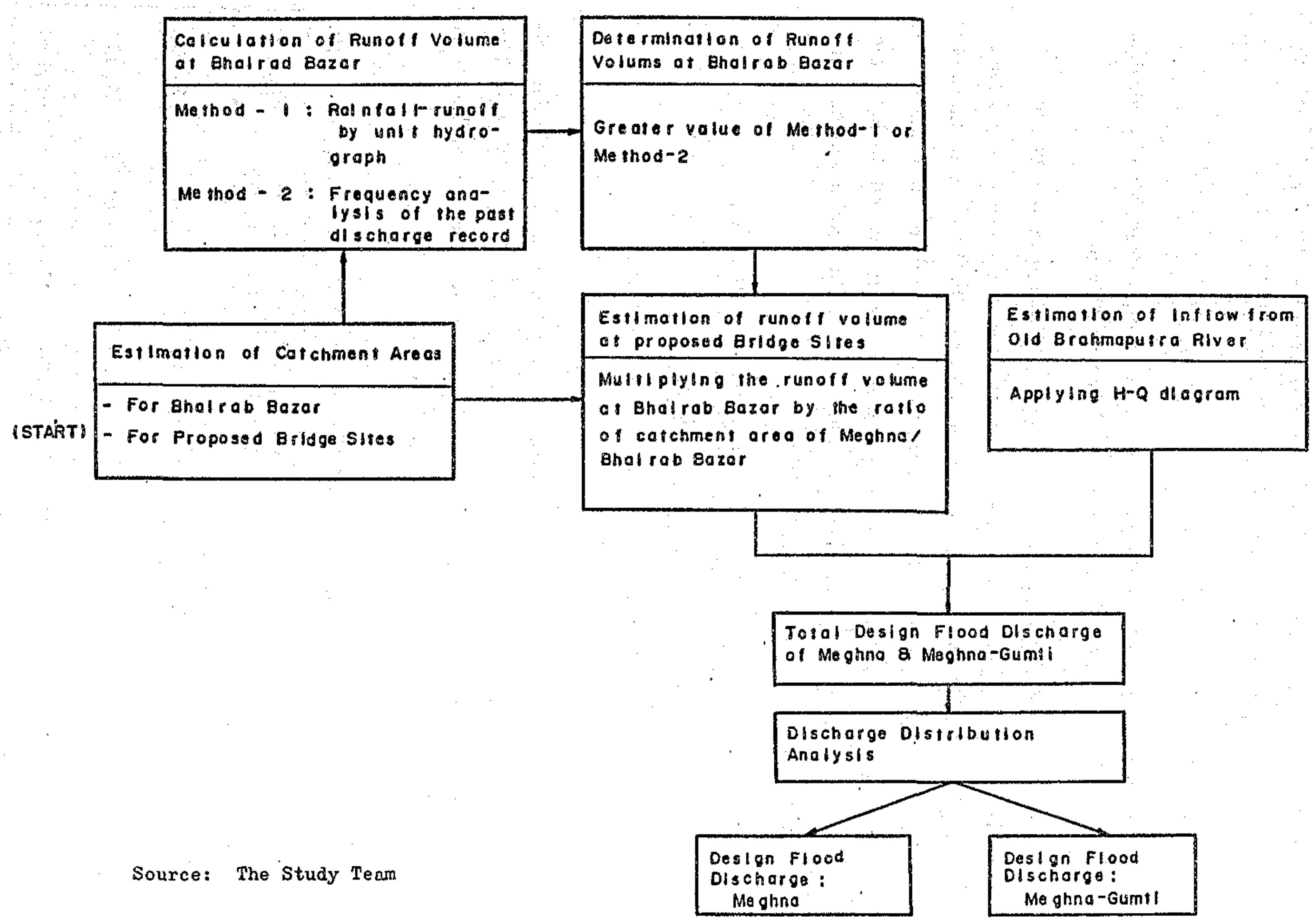
- According to the study of river course changes in the past 7 decades (Ref. Ap. Fig. 2–8) the river course has shifted largely at 2 places: one about 12 kilometres upstream and the other 3 kilometres downstream of the ferry ghat. This is still continuing. (Ref. Ap. Fig. 2–9.)

- At the downstream side of the Meghna ferry ghat, the thalweg, the deepest t riverbed portion, moves to the right bank and no erosion has been observed.

- As revealed by the survey based on the Landsat photographs during the period of 1973–1983, the most stable river bank for the bridge site is found to be in the one kilometre length immediately downstream of the ferry ghat. (Ref. Ap. Figs. 2–10 and 2–11.)

2) Meghna-Gumti Bridge

For the Meghna-Gumti River, no serious erosion of the river bank has been observed. The thalweg is stable upstream of the ferry. On the other hand, the sand bar at the confluence of the two rivers and the left bank of the Branch Meghna River downstream of the ferry ghats are expected subject to movement. (Ref. Ap. Fig. 2–12.) The suitable site recommended for the Meghna-Gumti Bridge located in the study area is upstream of the existing ferry ghats.



Source: The Study Team

FIG. 2-2-1 WORK FLOW FOR THE ESTIMATE OF FLOOD DISCHARGE

2–2–4 Design Flood Discharge

1) Methodology and Results

Design flood discharge for 100-year return period was determined based on the following two methods. The process is outlined in Fig. 2–2–1.

- Discharge due to runoff of rainfall in catchment areas in Bangladesh.
- Probability analysis of the past discharge records at Bhairab Bazar, located approximately 60 km upstream of the Meghana ferry ghat.

The runoff at Bhairab Bazar determined by the second method is 23,740 m^3/s, which is rather large. The total runoff at the proposed bridge sites was calculated by multiplying the runoff at Bhairab Bazar with the ratio of the catchment area of the proposed bridge sites to that of Bhairab Bazar taking into consideration the inflow from the Old Brahmaputra River, and discharge distribution analysis was conducted to estimate the design flood discharge at the respective bridge sites. The result was:

Meghna Bridge	: 15,200 m^3/s
Meghna-Gumti Bridge	: 12,400 m^3/s

2) Estimation of Catchment Area

Prior to calculating the runoff volume, the catchment areas of the Meghna River were measured from the topographic map (scale = 1:1,000,000). The locations of these catchment areas are shown in Ap. Fig. 2–13. The areas measured by location are shown in Table 2–2–1.

Table 2–2–1 Catchment Area of the Meghna River

(Unit: km^2)

	Outside of Bangladesh	Inside of Bangladesh	Total
Catchment Area at Bhairab Bazar Gauging Site	41,390	21,570	62,960
Others	2,760	4,170	6,930
Catchment Area at Proposed Bridge Sites	44,150	25,740	69,890

Source: The Study Team

3) Runoff Volume at Bhairab Bazar

The discharge due to runoff of rainfall was determined by adopting the greater value of discharge derived from the following two methods:

Method-1: Rainfall-runoff analysis by unit by hydrograph
Method-2: Frequency analysis of the past discharge record

(1) Runoff Volume by Method-1

a) Rainfall Intensity-Runoff Analysis

Based on the hydrographs for the same storm which were recorded for the past 13 years at 32 stations in the catchment area in Bangladesh, the total volume of rainfall was calculated using the Thiessen Polygons*.

The volume of rainfall from outside Bangladesh was calculated by summing up the volumes recorded at the stations near the border.

b) Unit Hydrograph Analysis

Different rainfall patterns were examined for the runoff analysis and grouped into two (2) cases; patterns in 1973 and 1974 as shown in Ap. Fig. 2–14. The rainfall pattern in 1974 was found applicable to the study. The calculation required was made every ten (10) days, and the results of runoff analysis are tabulated in Ap. Table 2–8.

The maximum discharge of 21,140 m^3/s, which is obtained from the table, was adjusted by the ratio between the maximum daily discharge and the average daily discharge for ten (10) days as shown in Ap. Table 2–9. Accordingly, the discharge for the return period of 100 years was obtained as follows:

$$Q = 21{,}900\ m^3/s \text{ (at Bhairab Bazar)}$$

* One of weighted average calculation methods.

(2) Runoff Volume by Method-2

The study was made by frequency analysis based on the maximum daily discharge recorded at Bhairab Bazar. Gumbel's method* was applied in deriving the frequency curve, and the results obtained are listed in Table 2–2–2 below.

Table 2–2–2 Discharge from Frequency Analysis (at Bhairab Bazar)

Return Period Year	Discharge (m^3/s)	Return Period Year	Discharge (m^3/s)
1.01	8,853	30.0	20,786
2.0	13,457	40.0	21,495
5.0	16,210	50.0	22,044
10.0	18,033	80.0	23,195
20.0	19,780	100.0	23,740

Source: The Study Team

Accordingly, the discharge for the return period of 100 years is:

$$Q = 23{,}740 \ m^3/s \text{ (at Bhairab Bazar)}$$

(3) Determination of Runoff Volume at Bhairab Bazar

Comparing the results from the above two methods, the discharge resulting from runoff of rainfall at Bhairab Bazar was determined at 23,740 m^3/s from Method-2, to make a safe allowance.

4) Design Flood Discharges for Meghna Bridge and Meghna-Gumti Bridge

(1) Runoff Volume at Proposed Bridge Sites

The runoff volume at the proposed bridge sites was calculated by multiplying the runoff volume at Bhairab Bazar by the ratio of the catchment area of the proposed bridge sites to that of Bhairab Bazar. Therefore, the runoff volume was calculated as below:

* One of probability analyses to obtain frequency curve.

$$Q = 23,740 \text{ m}^3/\text{s} \times \frac{69,890}{62,960} = 26,353 \text{ m}^3/\text{s}$$

(2) Inflow Volume from Old Brahmputra River

Based on the regular discharge records which were obtained at Bhairab Bazar over a relatively short period of four (4) years, H-Q diagrams (water level-discharge relation) were prepared in order to estimate the inflow volume from the Old Brahmaputra River.

The H-Q diagrams are given in Ap. Fig. 2–15 from which the inflow volume was estimated to be 1,200 m^3/s in the case with a water level of 7.5 m (PWD) at Bhairab Bazar.

(3) Determination of Design Flood Discharge

The total design discharge of the proposed sites of Meghna and Meghna-Gumti Bridges was obtained from Items (1) and (2) above:

$$\text{hence } Q_{total} = 26,353 + 1,200 = 27,553, \text{ Say } 27,600 \text{ m}^3/\text{s}$$

Discharge distribution analysis was conducted to estimate the design flood discharge at the respective bridge sites, and the result is summarised in Ap. Table 2–10. As a result, it was found that the percentages of the total design flood discharge were 55% and 45% for the proposed Meghna and Meghna-Gumti bridge sites, respectively. Accordingly, the design flood discharges for the respective bridge sites were determined as:

For Meghna : 15,200 m^3/s
For Meghna-Gumti : 12,400 m^3/s

2–2–5 Design High & Low Water Levels

High water level at the proposed Meghna Bridge site was determined to be 6.99 m (PWD) taking into consideration the results of probability analysis and the design flood discharge.

1) Probability Analysis by Method-1

Gumbel's method was applied in deriving the frequency curve, in which maximum values of the water level at the Meghna ferry ghat were extracted from the past annual records.

The plotting position was determined by using Thomas's method.* The records of the annual maximum water level from 1968 to 1976 are shown in Table 2–2–3 and the H.W.L. for various return periods are as listed in Table 2–2–4 and Fig. 2–2–2 (a).

Table 2–2–3 Annual Highest Records of Water Level at Meghna Ferry Ghat

Year	Water-level
1968	PWD 5.68 m
1969	5.63
1970	not used
1971	5.75
1972	5.11
1973	5.44
1974	6.19
1975	5.29
1976	5.32

Source: The Study Team

Table 2–2–4 H.W.L. Based on Probability Analysis

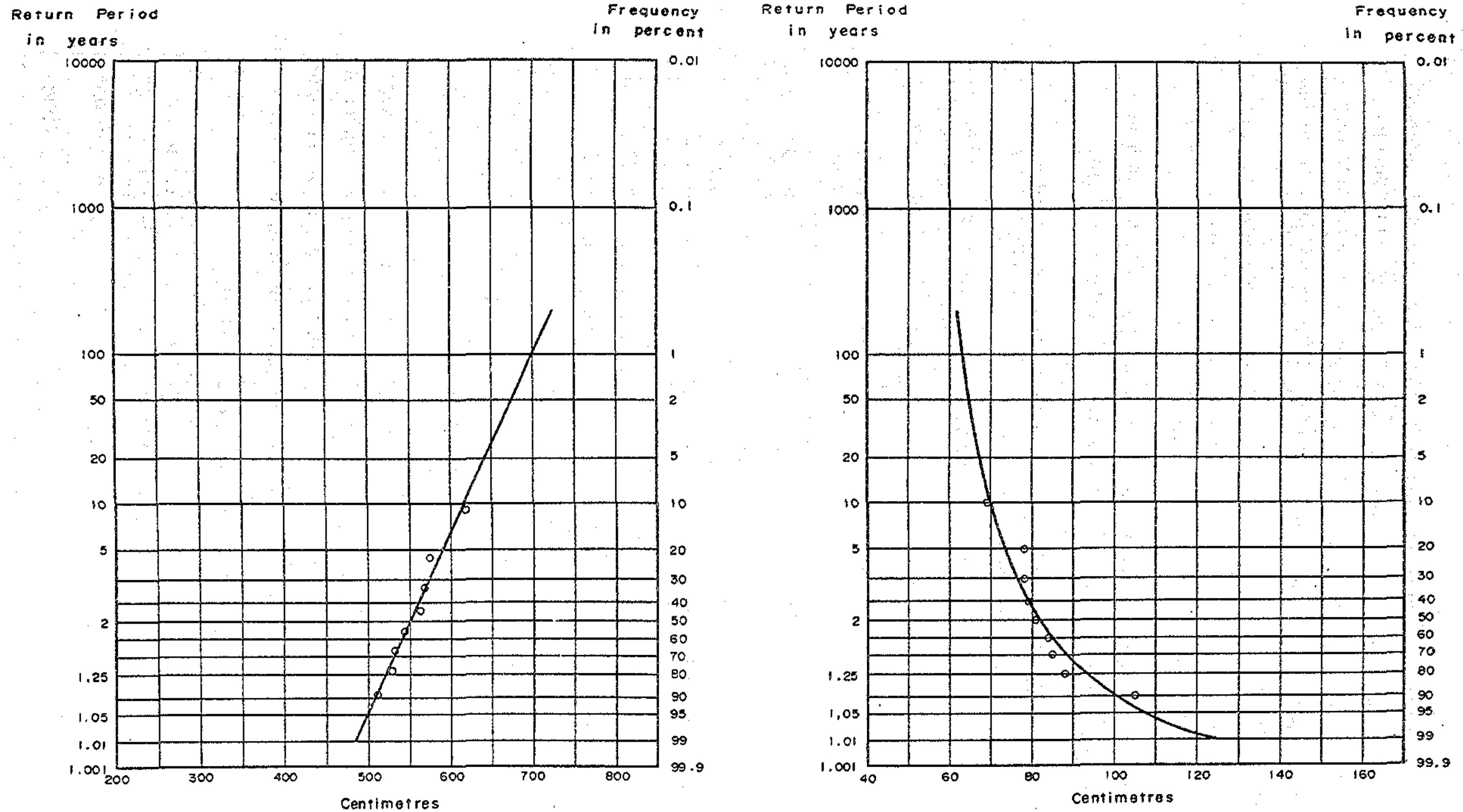
Return Period (Year)	Water-level (PWD ...m)
1.01	4.848
2.0	5.510
5.0	5.906
10	6.168
20	6.420
30	6.565
40	6.667
50	6.746
80	6.911
100	6.990

Source: The Study Team

2) Hydrographic Analysis by Method-2

Computation of discharge at the proposed bridge sites was conducted using the estimated water surface slope and 100-year probability discharge. Manning's formula was used in computing discharge. And the water surface slope was estimated from the difference of water surface for the 100-year probability water levels between Saitnal and Meghna Ferry Ghat. The results are shown in Ap. Table 2–10 which indicates that the design discharge of 15,200 m^3/s would be able to flow at a water level below H.W.L., while the river capacity of 18,435 m^3/s was estimated within the 825 metre river width at the same water level. This level was estimated to be 6.99 m as mentioned above.

* One of probability analyses to classify the data.



(a) ANNUAL HIGH WATER LEVEL (MEGHNA FERRY)

(b) ANNUAL LOW WATER LEVEL (MEGHNA FERRY)

Stream : MEGHNA RIVER

Station : MEGHNA FERRY GHAT

Kind of Record : WATER LEVEL (TIDAL) FOR 1968 ~ 1976

FIG. 2-2-2 FREQUENCY CURVE FOR HIGH AND LOW WATER LEVELS

The past water level recorded at Daudkandi which is located near the proposed Meghna-Gumti Bridge site, was almost the same as that at the Meghna ferry ghat. The H.W.L. at the proposed Meghna Bridge site is considered to be applicable also for the proposed Meghna-Gumti Bridge site in view of the safety allowance.

3) Low Water Level

Low water level was also determined at 0.628 metre by the same probability analysis and is shown in Tables 2–2–5 and 2–2–6 and Fig. 2–2–2 (b).

Table 2–2–5 Annual Lowest Records of Water Level at Meghna Ferry Ghat

Year	Water-level
1968	PWD 0.85m
1969	0.84
1970	0.69
1971	0.79
1972	0.78
1973	0.83
1974	1.05
1975	0.81
1976	0.78

Source: The Study Team

Table 2–2–6 L.W.L. Based on Probability Analysis

Return Period (Year)	Water-level (PWD ...m)
1.01	1.243
2.0	0.818
5.0	0.733
10	0.697
20	0.671
30	0.658
40	0.650
50	0.644
80	0.633
100	0.628

Source: The Study Team

2–2–6 Protective Measures Against River Erosion

1) Estimation of Undermining Depth in Flood

From the results of sounding surveys conducted both in dry and rainy seasons, the relation between hydraulic radius and maximum water depth was obtained. Undermining depths in flood at the proposed bridge sites are shown in Table 2–2–7, which were estimated based on the relation graph of Ap. Fig. 2–16.

Table 2–2–7 Undermining Depths Estimated

River	Mean Depth	Undermining Depth below Water Level	Altitude of Riverbed
Meghna	12.9 m	18.0 m	-11.0 m (PWD)
Meghna-Gumti	9.6 m	13.6 m	-6.6 m (PWD)

Source: The Study Team

2) Local Scouring Depth at Meghna Ferry Ghat

The scouring water depth (D_S) surveyed at the Meghna ferry ghat on Comilla side was 25 metres, and the mean water depth (h) of the river at the bridge site averaged at 9 metres. The relationship between D_S and h for the Meghna River was obtained through *$D_S/h = 2.78$. Based on this relationship, the scouring water depth during flood is estimated as follows:

$$
\begin{aligned}
D_S &= 2.78 \times h \\
&= 2.78 \times 12 \text{ m} \\
&= 33.26 \text{ m } (-28.36 \text{ m of PWD})
\end{aligned}
$$

where the mean water depth of the Meghna River in a general flood season is 12 metres. This scouring depth will be used as a depth based on which the existing ferry ghat on the Comilla side is reinforced.

3) Protection Methods Against River Erosion

(1) Meghna Bridge

The following four (4) methods were recommended to prevent embankment materials from erosion.

Method-1 : The bridge abutments should be set back as far as possible from the river banks, especially on the Comilla side.

Method-2 : The existing river banks should be strengthened by the provision of gabions .

Method-3 : The embankment slopes adjacent to the abutments should be protected by gabions or concrete blocks.

Method-4 : The river bank of the existing ferry ghat on the Comilla side is to be reinforced with steel sheet piles driven into riverbed at appropriate depth and with gabions laid in front of these sheet piles.

---

* This formula is a modification of Andru's formula.

(2) Meghna-Gumti Bridge

The proposed Meghna-Gumti Bridge would be sited at a node point in the shifting river system where no serious erosion is anticipated. For this reason, no specific countermeasures against erosion are recommended.

2-2-7 Scouring Around Bridge Piers

1) Scouring Levels

Three (3) formulas were applied to estimate the extent of scouring. These are Laursen's, Poona's, and Lacy's, which are well established methods in Bangladesh. The maximum scouring depths obtained from these three methods are listed in Table 2-2-8. These are to be considered in the bridge designs.

In addition, the Study Team has also calculated the scouring depths by other methods which are shown in Ap. Table 2-11, for the purpose of comparing the results obtained from these three methods. The maximum scouring depths for the Meghna and the Meghna-Gumti were obtained from Laursen's and Lacy's, respectively. The scouring levels determined by river are shown in Fig. 2-2-3.

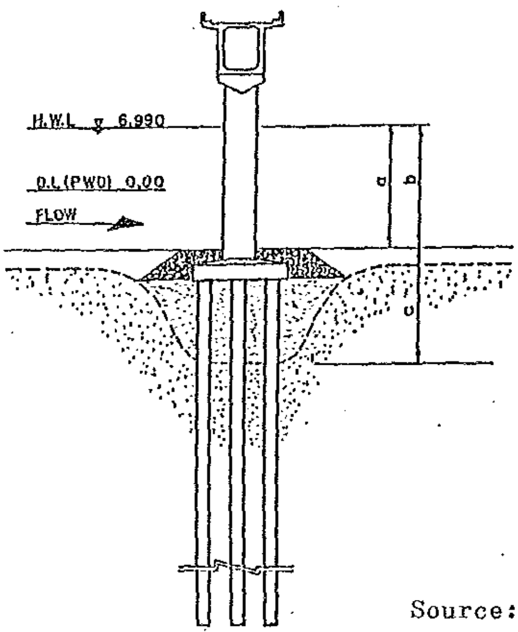


Fig. 2-2-3 Scouring Levels

Table 2-2-8 Scouring Depths

	Meghna Bridge	Meghna Gumti Bridge
H.W.L	EL.+6.990	EL.+6.990
Ordinary River Bed	EL.-9.000	EL.-6.000
Depth (a)	15.99	12.99
River Bed in Flood	EL. - 11.000	EL -6.610
Depth (b)	17.99	13.600
Scouring Depth (c)	11.00	12.30
Scouring Level	EL.-22.000	EL. -18.910

Source: The Study Team

2) Protection Method Against Scouring

Based on this analysis, the stability of the bridge foundation was confirmed under the condition of maximum scouring that would occur in the respective rivers, in which case the skin frictions of the piles above the scouring levels (–22.00 and –18.91 metres (PWD) for the Meghna and the Meghna-Gumti Bridges, respectively) were neglected as shown in Ap. Note 4–2. Besides, in order to increase the safety factor of the bridge structure, placing stones to protect the foundation is recommended.

CHAPTER 3

TOPOGRAPHIC AND SOUNDING SERVEYS

CHAPTER 3 TOPOGRAPHIC AND SOUNDING SURVEYS

3–1 General

Topographic surveys and soundings of the Meghna and Meghna-Gumti Rivers were conducted around the proposed bridge sites after careful site reconnaissance surveys by using available topographic maps, drawings and aerial photos. The extent of, and area covered by, these surveys are considered adequate to provide a basis for both the determination of the bridge centre-lines and the preliminary engineering design of the bridges and approach roads.

Bangladesh is a deltaic land located between 20°34' and 26°38' North Latitude and between 88°01' and 92°41' East Longitude. It covers an area of 143,998 square km, and is bounded by India in the west, north, northeast and east, Burma in the east and southeast and the Bay of Bengal to the south. As much as 90% of the country is flat, the remainder is hilly in the northeast and southeast, and some areas of high lands in the north and northwest.

The terrain in the vicinity of the proposed bridge sites is mainly of alluvial low plain forming agricultural land except those portions occupied by roads, waterways, marshes and swamps. In the rainy season, however, most of this plain is under water.

3–2 Topographic Surveys for Meghna Bridge

3–2–1 Topographic Survey

The geographical location of the site for the proposed Meghna Bridge is at 23°36'15" North Latitude and 90°37'04" East Longitude. The measured elevation of this low plain is less than 5.5 metres above M.S.L. The Dhaka-Chittagong Highway in the area of the topographic survey has road elevations varying from 6.42 to 6.87 metres (PWD) on the Dhaka side and 5.84 to 7.00 metres (PWD) on the Comilla side.

The topographic survey at the Meghna Bridge site included:

- Establishing ten (10) temporary bench marks constructed of brick in mortar and steel bars;

- Preparation of a topographic map by plane table survey (with scales of 1:500 and 1:3,000) for an area of 120 ha. including existing ferry facilities, structures, buildings, trees, etc. with contour lines at 500 mm intervals;

- 2 km long profile levelling survey at 50 metre intervals along the recommended centre-line, including the taking of additional levels at the top and bottom of abrupt changes in terrain;

- Cross section survey in a 100 metre wide band at 50 metre intervals along the recommended centre-line, including the taking of additional cross sections at abrupt changes in terrain; and

- Measurement of the river width by triangulation.

The topographic survey was entrusted to a local consultant, Development Design Consultants, Ltd. under the supervision of the topographic survey specialist of the JICA Study Team.

3–2–2 River Sounding in Dry and Rainy Seasons

Sounding of the Meghna River around the proposed bridge site was conducted on two occasions: the first in April 1984 for the dry season and the second in July 1984 for the rainy season. Prior to the sounding survey the necessary control points and markers were provided on the river banks to get the precise location of the sounding boat. Major equipment used for this survey are:

Eco-sounder	:	One unit
Boat	:	One unit
Theodolite	:	2 units
Transceivers (Walkie-talkie)	:	2 sets
Distance metre	:	One set
Accessories	:	One set

The sounding datum was established as the zero (0) datum of the water level gauge installed near the ferry terminal of the east bank of the Meghna. Because the Meghna has an unstable river system, soundings were taken over a wide area around the existing ferry route, the location of which is shown in Ap. Fig. 3–1. In addition to the sounding lines along the bridge centre-line, 20 other lines were sounded. These are in the hatched area of Ap. Fig. 3–1.

The surveys were conducted to determine the seasonal change in the riverbed. The bed cross sections in dry and rainy seasons as surveyed in 1984 are shown together in Ap. Fig. 3–3. The result was incorporated in the preparation of the topographic map of the Meghna Bridge site at a scale of 1:3,000.

3–3 Topographic Surgeys for Meghna-Gumti Bridge

3–3–1 Topographic Survey

The geographical location of the site for the proposed Meghna-Gumti Bridge is at 23°31′39″ North Latitude and 90°42′15″ East Longitude. The measured elevation of this low plain is less than 4.0 metres above M.S.L. The Dhaka-Chittagong Highway in the section of the topographic survey has average road elevations of 6.0 metres (PWD) on both sides of the river.

Work items and method of survey were almost the same as those for the Meghna Bridge. Reference is made to Subsection 3–2–1. The following points were different:

- Area surveyed for the preparation of topographic maps : 60 ha.
- Key points of the alignment such as the start and finish points, etc. were set up with provision of permanent markers at the site, because the construction of the Meghna-Gumti Bridge is presumed to start after the Meghna Bridge.

3–3–2 River Sounding in Dry and Rainy Seasons

The approach and method used for the soundings were the same as those for the Meghna Bridge. Reference is made to Subsection 3–2–2. The area sounded is shown in Ap. Fig. 3–2. New water level gauges were installed by the JICA Study Team on both banks.

The riverbed levels for the dry and rainy seasons as surveyed in 1984 are shown together in Ap. Fig. 3–4. Similarly the result was incorporated in the preparation of the topographic map of the Meghna-Gumti Bridge site at a scale of 1:3,000.

3–4 Results of Survey

The topogrpahic and sounding surveys necessary for the engineering works of the project were conducted as described, and the results are presented in the form of survey plans as follows:

– Topographic Plan (The result of sounding is incorporated.)	:	1:3,000
– Centre-line Plan	:	1:3,000
– Longitudinal Plan	:	Horizontal = 1:3,000 Vertical = 1:500
– Cross sections	:	1:500

CHAPTER 4

SOILS INVESTIGATIONS AND GEOTECHNICAL CONSIDERATIONS

CHAPTER 4 SOILS INVESTIGATIONS AND GEOTECHNICAL CONSIDERATIONS

4–1 Introduction

Subsurface investigations were conducted along the proposed centre-lines of the Meghna and Meghna-Gumti Bridges to clarify the geotechnical problems and to provide data for substructure design. The results of the investigations and tests are presented in the following sections for field investigations, laboratory tests, soil profiles, physio-mechanical properties of soils, geotechnical considerations to the bridge foundation, and recommendations. Detailed information is separately compiled in the "Soil Investigation Report" which was submitted to the Government in September 1984. The works of the soil boring and laboratory testing were entrusted to a local firm, SOILTECH INTERNATIONAL LTD. under the supervision of the soil survey specialist of the JICA Study Team.

4–2 Geotechnical Features Around Bridge Sites

4–2–1 Geomorphology

The area of the Meghna and Meghna-Gumti Bridge sites, is situated in the middle Meghna floodplain. The overall characteristics differ among different parts of the floodplain. It is due to the size of the channels and the bed load they transport, the stability of the channels themselves and the nature of the soil formation that exists.

The floodplain has been formed by the River Meghna along with its tributaries which carry a large bed load when in flood. The load eventually builds deposits to a height such that the river ultimately finds a new course through the lower adjoining land which becomes the new course of the river.

The subsidiary channels follow meandering courses which erode the char (sand bar) formation and the adjoining parts of the older floodplain which is eventually deposited over the former basin deposits, constantly eroding the outside bank of bends, laying new deposits on the inside of bends and often cutting through adjoining loops of meanders.

The meanders of the River Meghna move downstream, and require about 15 to 20 years to move down the position of its predecessor. The river swings within the belt of an active plain which lies between the older floodplain areas on either side. The width of this active plain is about 8 to 12 kilometres.

The coarser materials tend to settle near the river bank and the finer materials further away from the bank. This can be attributed to the fact that the velocity in the middle is higher than that near the banks of the river, where the velocity becomes insufficient to carry the heavier particles or keep them in suspension.

4–2–2 Geology

The floodplains of Bangladesh were affected by earth movements in the past. The primary reason is due to settlement of the deposits by consolidation and secondly by geotectonic movement which occurred beneath the lower Meghna floodplain. In the past there were major changes in the river alignment primarily due to earth movements. The exact age of the floodplain has not yet been confirmed, and these changes have taken place gradually over the years.

The salient feature of the soil is that it contains a high silt content. The subsoil is predominantly sand with clayey or silty layers in the sand layers. The minerological composition of Meghna floodplain consists predominantly of amphiboles and epidote and lower contents of moscovite and biotite. The clay minerals that are found in that area are kaolinite, illite and chlorite.

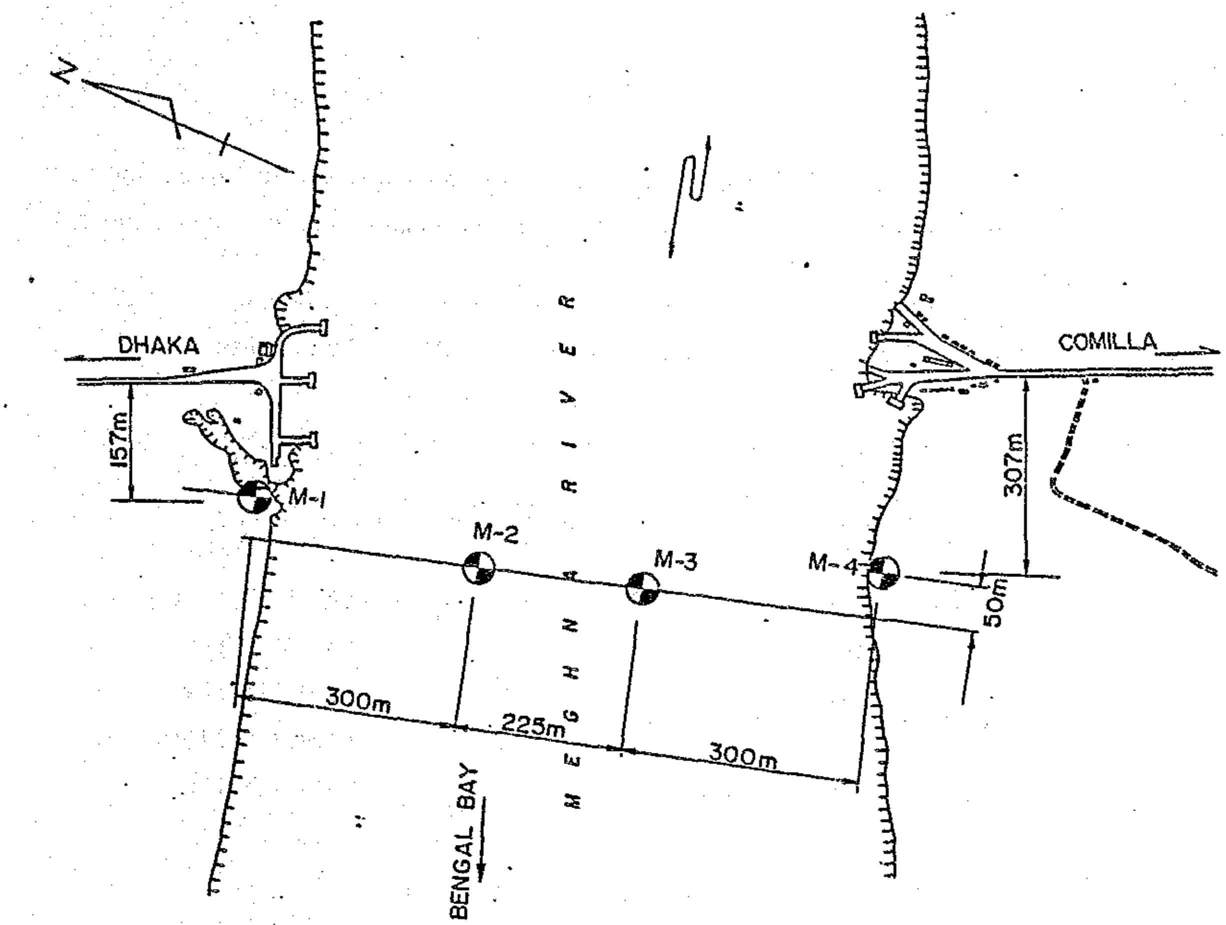
An outline of geology and soils of Bangladesh is presented in Ap. Note 4–1.

4–3 Soil Investigation for Meghna Bridge

4–3–1 Field Investigations

Four 15 cm diametre bore holes were made by the Percussion Method to the following depths below the existing ground level. Locations are shwon in Fig. 4–3–1.

Bore Hole No.	Depth of Bore Holes below Ground Level in metres
M-1	60.00
M-2	60.00
M-3	60.00
M-4	50.00



Source: The Study Team

Fig. 4-3-1 Location of Bore Holes for Meghna Bridge

Undisturbed soil samples were taken to determine the shear strength and settlement characteristics of the soils. The undisturbed samples were collected in thin walled Sheiby Tubes of 7.62 cm in diametre and 45.72 cm long. The position of all undisturbed samples extracted from the cohesive soil layers are shown in the form of boring logs in Ap. Fig. 4-3.

The Standard Penetration Test (SPT) was made to determine the parametres of the soil in-situ. All SPT values obtained from the tests were plotted as N-counts under the respective bore charts. The corrected SPT values as found are given in Ap. Table 4–1.

4–3–2 Laboratory Tests

Different types of laboratory tests were performed on both disturbed and undisturbed soil samples taken from bore holes and borrow pits to evaluate the soil properties for foundation designs.

The tests which were performed in the laboratory are as follows:

Test Item	Nos. of Samples Tested	Method
Natural Moisture Content	95	ASTM D2216
Specific Gravity	95	AASHTO T100
Atterberg's Limits	18	AASHTO T89 & T90
Grain Size Analysis	60	AASHTO T88
Wet & Dry Density	5	AASHTO T180
Unconfined Compression Test	5	AASHTO T208
Consolidation Test	5	ASTM D2435
Triaxial Compression Test	5	ASTM D2850
CBR Test	6	AASHTO T193
Fineness Modulus of Sand Test	44	AASHTO T104

4–3–3 Soil Profile

The soil profile prepared for the Meghna Bridge is shown in Drawing No. 7. It is found that the subsoils consist mainly of non-cohesive soil with fine sand, silty sound and silt, etc. The reliable bearing strata are found to exist around a depth of 52 to 55 metres below the datum zero (0) of PWD. Therefore the foundations of the river bridge spans shall be designed to a depth of -55m, where the N-values are more than 75.

On the other hand, the reliable bearing strata below the river banks are found to exist at a depth of 22 to 25 metres, the conditions of which are suitable for the provision of precast RC piles for the foundations of the proposed approach bridge spans. The N-values of the Standard Penetration Test in the strata are over 30, and the ultimate bearing capacity of over 300 ton/m^2 could be expected at the tip of the piles.

4-3-4 Tests for Materials

1) Test Sampling

Two kinds of construction materials were tested in order to confirm the availability of sand materials for the construction of the proposed Meghna Bridge: one was obtained from the stock piles at Daudkandi to which the sand materials are transported from Sylhet by inland water, and the other from the sand bar in the river 2 kilometres upstream of the existing Meghna ferry ghat.

The samples were taken in expectation of the following use:

- Sand from Sylhet .... for cement and asphaltic concrete
- Sand from the sand bar ..... for cement and asphaltic concrete, embankment and subbase and base courses

2) Laboratory Tests

Test items and testing standards applied are as follows:

a) Sand from Sylhet

- Sieve analysis test .... AASHTO T27

b) Sand from Sand Bar

- Sieve analysis test .... AASHTO T27
- CBR test .... AASHTO T193
- Soundness test* .... ASSHTO T104

* Soundness test is to clarify the salt content (sodium chloride content) by use of sodium sulfate or magnesium sulfate. The test was made at the Central Laboratory of the Industrial Ministry on July 15, 1984.

The details of the test result were compiled in a separate report: "Soil Investigation Report" and its summary is shown in Drawings No. 8 through 15 for Meghna and Drawings No. 22 through 29 for Meghna-Gumti.

The major findings were:

a) Sand from Sylhet is classified as "coarse sand" with a fineness modulus of 2.4 and 1.87 for two samples.

b) CBR test of the sand from the sand bar showed around 10 at 95% compaction and the fineness modulus is 0.24 and 0.18 for two samples.

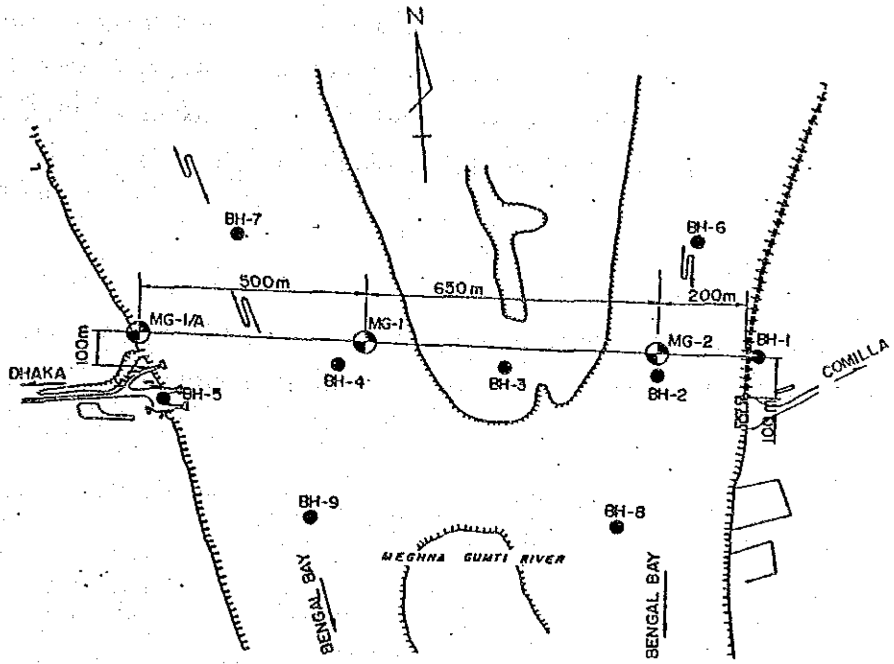
c) The result of the soundness test showed a range of 0.004 to 0.005% which is well below the maximum allowable value of 0.10%.

From this, it is concluded that sand material from the sand bar is good for embankment but for concreting it should be mixed with sand from other sources because of its low fineness modulus. The soldium chloride content in the sand material, which may have a bad effect on the durability of reinforced concrete, is found to be negligible even if pit sand from the site is employed.

4–4 Soil Investigation for Meghna-Gumti Bridge

4–4–1 Field Investigations

Since RHD had conducted the subsoil and geotechnical investigation for the Meghna-Gumti Bridge construction project, with nine (9) bore holes, three (3) holes were bored to supplement this investigation. Their location is shown in Fig. 4–4–1.



NOTE (1) 9HOLES BH-1~BH-9 WERE BORED BY THE RHD IN DEC 1980.
(2) SUPPLEMENTAL HOLES MG-1, MG-1/A, and MG-2 WERE BORED BY JICA SURVEY TEAM IN JULY 1984.

Source: The Study Team and "Report on Subsoil & Geotechnical Investigation" Dec. 1980 METRO SOIL ENGINEER

Fig. 4–4–1 Location of Bore Holes for Meghna-Gumti Bridge Project

The RHD bore holes were up to 50 metres deep, while the depth of the three supplemental bore holes are:

Bore Hole No.	Depth of Bore Holes below Ground Level in metres
MG-1	24.85 *
MG-1/A	69.85
MG-2	69.85

The bore holes, MG-1/A and MG-2 have clarified the conditions of soil layers of more than 50 m depth. The boring logs based on the soil classification at site are shown in Ap. Fig. 4–4.

* The boring, MG-1 had been suspended at 24.85 metre depth due to a sudden strong storm which damaged the staging boats. It made the resumption of the boring at the same spot impossible.

Disturbed samples were collected to determine the properties of soils. The Standard Penetration Test (SPT) was made to determine the parametres of the soil in-situ. All SPT values obtained were plotted as N-counts under the respective bore charts. The corrected SPT values are given in Ap. Table 4–1.

4–4–2 Laboratory Tests

Different laboratory tests were performed on the disturbed soil samples taken from the bore holes and borrow pits to evaluate the soil properties for foundation designs.

The tests which were performed in the laboratory were:

Test Item	Nos. of Samples Tested	Method
Natural Moisture Content	83	ASTM D2216
Specific Gravity	46	AASHTO T100
Atterberg's Limits	31	AASHTO T89 & T90
Grain Size Analysis	44	AASHTO T88
CBR Test	6	AASHTO T193
Fineness Modulus of Sand Test	20	AASHTO T104

4–4–3 Soil Profile

The soil profile prepared is shown in Drawing No. 21. It is found that the subsoils consist mainly of non-cohesive soils with fine sand, sandy silt and silt down to the depth of -30 metres PWD and below that level sandy silt exists. It is estimated that the bearing strata for a bridge pier foundation would exist at the depth varying from -60 m on the right bank to -70 m on the left bank below the datum zero (0) of PWD in the river.

On the other hand, a reliable bearing strata for the abutment structures on both banks are presumed to exist at the depths of -25 to -30 metres below the datum of PWD. Similarly as the Meghna Bridge, an ultimate bearing capacity of about 300 ton/m^2 would be expected at the tip of driven piles.

4–4–4 Tests for Materials

Sand from Sylhet was tested in order to confirm the availability of sand materials for the construction of the proposed Meghna-Gumti Bridge. Reference is made to Subsection 4–3–4.

4–5 Geotechnical Considerations to Foundation

4–5–1 Bearing Capacity of Bridge Foundation

A reverse circulation drilled pile foundation is recommended for both the Meghna and Meghna-Gumti Bridges. The determination of this type of foundation is discussed in detal in Chapter 7.

The allowable bearing capacity of a pile can be determined from both the strength of the bearing stratum and the friction between the pile and the surrounding subsoil. Assuming the bearing stratum consists of dense sand layers, the ultimate supporting strength can be estimated at over 300 ton/m^2, while the skin friction (f) can be estimated from N-values using the "Specification for Highway Bridges" prepared by the Japan Road Association as follows:

For sandy layer : $fc = 0.5\ N\ (t/m^2),\ fc \leq 20\ (t/m^2)$

For clayey layer : $fc = N\ (t/m^2),\ fc \leq 15\ (t/m^2)$

As discussed in Subsections 4–3–3 and 4–4–3, an estimate was made of the bearing strata for the foundation of piers at a depth -55 m (PWD) for the Meghna site and -60 m to -70 m (PWD) for the Meghna-Gumti site. The bearing capacities of piles for the foundation design were obtained as shown in Table 4–5–1, the details of which are shown in Ap. Note 4–2.

Table 4–5–1 Bearing Capacities of R.C.D. Pile (ϕ 1,500 mm)

Unit: Tons/Pile

Capacity \ Site		Meghna	Meghna-Gumti
Ultimate		2,200	2,900
Allowable	Normal	700	900
	Seismic	1,100	1,400

Source: The Study Team

4–5–2 Foundation for Approach Roads

1) General

It is clear in general that as the height of road embankment is increased the factor of safety for embankment is reduced. In this project it is necessary to construct the embankment to a sufficient height above the flood levels during rainy season.

The average elevation of the existing road embankment near the project site is 6.5 metres above PWD datum, and the approximate embankment height above the ground level is from 5.5 to 7.5 metres. Based on the reconnaissance study, it is known that the elevation of the existing road is high enough to prevent the road surface from being submerged by the flood of the 30-year return period.

2) Settlement

According to the soil profiles identified at the project sites, the soil layer of the right bank of the Meghna site consists of sand to about 12 metres depth below the ground surface. On the left bank, however, the top layer of approximately 1.8 metres depth consists of clayey silt which is subject to settlement.

For the design of a high embankment for the approach road sections, attention should be paid to settlement due to consolidation. In the preparation of the construction schedule sufficient period for preloading of the embankment should be considered. For preliminary design purposes the construction of sub-grade is assumed to commence after one year's pre-loading.

3) Embankment Stability

To assess the embankment stability the total stress slip circle analysis was made. The factor of safety was calculated by computer using the following co-efficients:

Cohesion	:	$C = 3.0\ t/m^2$
Internal friction	:	$K = 15°$
Unit weight	:	$W = 1.7\ t/m^3$
Earthquake intensity	:	$E = 0.05$

A plot of factors of safety against embankment height is shown in Ap. Figs. 4–5 and 4–6 for embankments with a standard cross section and with a toe berm type, respectively.

It can be seen from the two figures that the height of embankment with a standard cross section must be less than 11 metres to have a factor of safety of more than 1.5, while that of embankment with toe berm type can be extended up to 13 metres for the same safety factor.

When earthquake effects are considered, the factor of safety will be reduced from 1.5 to 1.2.

CHAPTER 5
MATERIAL INVESTIGATIONS

CHAPTER 5 MATERIAL INVESTIGATIONS

5–1 Construction Materials for Bridges

5–1–1 Materials Required

Based upon the results of the preliminary design for the construction of the two bridges, the construction quantities by major item were estimated. These quantities were then broken down to find the required quantities of materials as shown in Ap. Tables 5–1 and 5–2 for Meghna Bridge and Meghna-Gumti Bridge, respectively. The itemisation was made to conform to the RHD construction specifications, and the required materials thus identified are summarised in Table 5–1–1 for each bridge.

5–1–2 Materials Surveyed

Construction materials were surveyed by conducting interviews at Government offices and laboratory, local contractors and others. The annual average production of cement, stone and steel were confirmed through on-the-spot surveys at factories, quarry sites, stock piles, etc. The information gained is as follows:

1) Cement

Cement in Bangladesh is produced at two factories, Chhatak Cement Co., Ltd. located in Sylhet district and Chittagong Cement Clinker Grinding Co., Ltd. located in Chittagong. Present average annual production of cement is 100,000 tons (maximum 110,000 tons) at the former, and 300,000 tons (maximum 350,000 tons) at the latter.

Cement produced in this country is of the portland type and supplied generally with either the brand name Assam Bengal Cement or Clinker Cement. Cement is packed into 50 kg bags and transported by country boats and trucks to the users.

Standard specification for the quality is in accordance with British Standard Specification. A test result of cement is shown in Table 5–1–2.

Table 5-1-1 Materials Required for the Bridges

Materials Required	Quantity for Meghna Bridge	Quantity for Meghna-Gumti Br.	Source Supplied
Cement	7,700 ton	16,540 ton	Chittagong
Sand	4,560 m^3	9,660 m^3	Sylhet
Shingle	7,750 m^3	15,740 m^3	-do-
Pit sand	4,560 m^3	9,660 m^3	Sand bar
Crushed stone	7,750 m^3	15,740 m^3	Stones from Sylhet
*Plasticiser	20.4 ton	42.7 ton	Imported
TORESTEEL	2,040 ton	3,680 ton	Chittagong
*Deformed bar	840 ton	1,480 ton	Imported
*High tensile bar & accessories	420 ton	760 ton	Imported
*High tensile wire & accessories	9 ton	-	Imported
*Fabricated steel & cast iron	106 ton	100 ton	Imported
Shaped steels	6,910 ton	10,810 ton	Imported

* Imported material

Source: The Study Team

Table 5-1-2 Test Result of Cement

Source	Mortar Cubes	Compressive Strength	Remarks
Chittagong	3 days	208.1 kg/cm^2	30 °C
	7 days	257.0 kg/cm^2	30 °C
Chhatak	7 days	328.4 kg/cm^2	27 °C
	28 days	426.4 kg/cm^2	27 °C

Source: Chhatak Cement Co., Ltd.

2) Fine and Coarse Aggregates

Near the project site fine and coarse aggregates are exploited and processed in Sylhet, Kapasia and Tok Chandpur which are located in the upper reaches of the Lakhya River.

The typical fineness modulus of aggregates produced in Sylhet district is 2.5 to 2.8 and the original rock is igneous including hard granite. Annual production volume averages 34,000 cubic metres with 40,000 cubic metres maximum. Besides, the sizes of coarse aggregate vary from 6 to 38 mm diametre as Shingle and from 76 to 23 mm diametre as stone.

Transport is available by self-propelled cargo vessels of 300 to 350 ton capacity or by dump barges of 200 to 250 ton capacity from the sources to the proposed project site.

Pit sand is available near or at the project site and is a suitable material if mixed with sand from Sylhet. The Study Team confirmed the salt content of the pit sand was in the range of 0.004 to 0.005% which is well below the allowable value of 0.10% for concrete work.

Stone sources in Sylhet district are recommended for the project due to the short transportation route by barge. Daudkandi, which is situated on the east bank of the Meghna-Gumti River, is one of stock yard sites to deliver stone to the users.

In Sylhet district, quarry sites are located at Bholaganj, Piyanganj, etc. Stone size as quarried is almost 8 to 23 cm in diametre. Annual production volume of boulders is approximately 11,000 cubic metres (maximum 13,000 cubic metres). Test results of quality of the typical crushed stone is shown in Table 5–1–3.

Table 5–1–3 Test Result of Quality of Crushed Stone

Compression strength	833 kg/cm^2	2" x 2" x 2" size
Unit weight	1.71 t/m^3	
Specific gravity	2.74	
Abrasion value	2.6%	

Source: The Engineers Ltd.

The transport of these boulders will be by self-propelled cargo vessels with 300 to 350 ton capacity and dump barges with 200 to 250 ton capacity.

Stone is normally produced manually using stone hammers and the boulders will be broken at the project site to any required size (10 to 100 mm size).

3) Reinforcing Steel Bar

The factories of this material in this country are Bengal Steel Works, Ltd., Chittagong; Chittagong Steel Mills, Chittagong; Dhaka Steel Works, Ltd., Tongi, Dhaka; Prince Iron Steels, Mirpur, Dhaka; and Northern Steel Mills, Ltd., Tongi, Dhaka.

Chittagong Streel Mills is the largest factory in this country, with an annual production of 36,000 tons (maximum 37,200 tons), while the whole annual production volume including other companies is approximately 69,600 tons.

Generally, plain round Mild Steel bars are available for all sizes ϕ 6 mm to ϕ 28 mm.

A high strength cold-twisted deformed bar brand named "TORSTEEL" is produced by Bengal Steel Works, Ltd. since 1983. It is produced from steel billet, and the annual production capacity is said to be 15,000 tons and the maximum 1,300 tons per month.

The permissible stress of TORSTEEL is shown in Table 5–1–4.

Table 5–1–4 Permissible Stress of TORSTEEL

Test	Permissible Stress
Tension, D ϕ20 mm and below	2,300 kg/cm^2
Over D ϕ20 mm	2,100 kg/cm^2
Shear	1,750 kg/cm^2
Compression	1,750 kg/cm^2
Bond	40% more than plain bar

Source: Booklet of TORSTEEL

TORSTEEL conforms to the following standards: British Standard BS 1144 and BS 4461, British Code of Practice CP 114, French Standard B.A. 1968, German Standards DIN 1045 and DIN 488.

Standard sizes available are: ϕ8, 10, 12, 16, 20, 22, 25 and 28 mm diametres.

4) Iron or Steel Articles

In this country available are some types of shaped steels such as mild steel angles of different sizes, mild steel flat bar and mild steel sheet of 8 thicknesses: 2.38, 3.20, 4.76, 6.35, 9.52, 12.7, 19.04 and 25.4 mm.

Annual production of steel sections is approximately 6,000 tons (maximum 6,200 tons). Mild steel plates are produced in Chittagong Steel Mills, Ltd. in accordance with the various domestic or international standards such as BS, ASTM, DIN, JIS, IS, ISO, BDSI. The plates are of hot rolled weldable quality structural steel and may be used for the fabrication of structural works.

However rolled steel sections, fabricated cast iron goods like shoes, high tensile bar or wire for PC bridge and their accessories for prestressing works are not available in the Bangladesh market.

5–2 Construction Materials for Approach Roads

5–2–1 Materials Required

The materials required for the construction of the approach roads were obtained from the results of the preliminary design of approach roads. The major materials for the approach roads of the two bridges are shown in Table 5–2–1.

Table 5-2-1 Materials Required for the Approach Roads

Materials Required	Quantity for Meghna's	Quantity for Meghna-Gumti's	Source Supplied
Sandy soil (m^3)	460,000	480,000	Sand bars or River beds
Sand (m^3)	4,110	3,340	Sylhet
Pea gravel (m^3)	5,050	3,990	Sylhet
Shingle (m^3)	1,610	1,100	Sylhet
Pit sand (m^3)	1,250	1,080	Sand bars or River beds
Asphalt (ton)	340	370	Chittagong
Filler cement (ton)	140	150	Chittagong
Turf grass (m^2)	81,000	44,600	Near Site

Source: The Study Team

5-2-2 Materials Surveyed

1) Sandy Soil

A large quantity of sandy soil is required for the approach roads and for the reclamation of the contractor's camp site. The borrow pit for the Meghna Bridge construction was selected to be the sand bar which has been deposited 2 km upstream of the ghat on the Dhaka side. Use of the sand bar is found to be more expensive, but the use of about 460,000 m^3 of material from the sand bar will be effective not only for controlling the meander of the Meghna River but will also minimise the use of soil from the nearby farm land which is usually considered as a material source by the conventional "side borrow filling system". The CBR value of the sandy soils from the sand bar was proved to be about 10.

In the Meghna-Gumti Bridge construction, the use of the borrow pit from the riverbed around the Meghna-Gumti Bridge site was considered, as the result of a suggestion by a staff member of BIWTA. In order to make effective use of total resources available in Bangladesh, the construction of highways would be economic by using material dredged from the riverbeds. Average CBR value of the material from the riverbed is 9 from the six (6) numbers of test results.

2) Asphalt

Asphalt for domestic demand is mainly supplied by the Eastern Refinery's Bituminous Plant located in Chittagong and the annual production of the factory is about 70,000 tons.

Asphalt is produced to conform to BS or ASTM specifications; the penetration at 25°C is Min. 80 and Max. 100.

3) Turf Grass

Turves for the embankment slopes are available in the areas near the site.

5–3 Construction Materials for Ferry Facilities

In the case of "Without Project", additional ferry facilities are required to be constructed. Materials for the civil works are shown in Table 5–3–1.

Table 5–3–1 Average Quantity per Set for Ferry Facilities

Work Items	Meghna Ferry per one set	Meghna-Gumti Ferry per one set
Sand filling for access	6,600 m^3	6,030 m^3
Pavement of access	1,330 m^2	1,250 m^2
Concrete blocks in slope	5,420 m^2	5,670 m^2
Wooden pile ϕ 100 mm	2,000 m	1,920 m
Concrete pavement for jetty	540 m^2	645 m^2
Steel sheet pile	2,400 m	1,800 m
Anchor block	4 sets	4 sets

Source: The Study Team

In the pavement of the access road, bricks will be laid in the form of flat soling and herring bone bond as the base course of asphalt-paved road.

Bricks are widely used, having great demand for building and road construction. They are indeed a very important construction materials.

Two types of bricks are generally used by RHD: Picked Jhama (P.J) bricks and First Class Bricks. Test results for the P.J. Bricks and First Class Bricks are shown in Table 5–3–2.

Table 5–3–2 Test Result for Typical Bricks

Bricks	Unit Weight	Crushing Strength	Water Absorption
P.J. Brick	1,311 kg/m^3	245.0 kg/cm^2	12.79%
1st Class Brick	1,148 kg/m^3	181.0 kg/cm^2	14.00%

Source: Road Research Laboratory, Dhaka, RHD.

The anchor block for the ferry pontoon will be secured with wooden piles. Wood logs are to be used to strengthen slope edges. This kind of wood material is available in Bangladesh.

However steel sheet piles for the ghat must be imported. The depth of sheet piling at the left bank ferry of Meghna will be up to 20 metres but that of other banks 12 metres. The sheet pile is of the same type as that used for the temporary quay.

CHAPTER 6

DESIGN STANDARDS AND GEOMETRIC CRITERIA

CHAPTER 6 DESIGN STANDARDS AND GEOMETRIC CRITERIA FOR ROADS AND BRIDGES

6–1 Existing Standards

The Roads and Highways Department (RHD) has recently revised its design standards for roads and bridges. The following is a review of these standards concerning design standards and geometric criteria for roads and bridges.

6–1–1 Classification of Roads

The level of traffic flow which is used in developed countries cannot be used in Bangladesh because the traffic composition and site conditions of the roads (such as they are mostly multi-purpose roads with liberal accessibility to pedestrians and animals.) are completely different from those of developed countries. In this study a reduced level of traffic flow was adopted as the basis of the road classification.

Bangladesh has its own coefficients of PCE (Passenger Car Equivalent) conversion which are shown in Ap. Note 6–1.

For the systematic development of a road network, the roads/highways of Bangladesh have been classified into four (4) types namely, national highways, regional highways, upazila roads and rural roads. This classification of roads/highways together with corresponding standards and specifications has been recommended on the basis of economic, strategic importance, regional consideration, traffic volume, etc. The national highways and regional highways are categorised into two classes, A and B, and the rural roads are also subclassified into two classes, union roads and village roads. These classifications are given in Table 6–1–1 together with corresponding design elements such as crest width, pavement width, shoulder width and basic volume of traffic in PCEs.

6–1–2 Geometric Design Standards for Roads

RHD has adopted geometric design standards in building and improving roads. Table 6–1–2 shows the minimum geometric design shape, by each class of road, specifying the radius of horizontal and vertical curves, grades, superelevation rates,

Table 6–1–1 Definition and Cross–Sectional Widths by Type of Roads

Type of Roads with Traffic Capacity (in PCE*)		Definition	Crest Width (m)	Pavement Width (m)	Shoulder Width on Each Side (m)
National Highways		Connecting the national capital with the divisional and important district headquarters, port, cities, places of economic, commercial and strategic importance, important international highways			
Category – A	More than 500 PCE		12.20	6.70	2.75
Category – B	200–500		12.20	5.50	3.35
Regional Highways		Connecting different region with each other and with national highways and district headquarters not connected by national highways			
Category – A	200–500		11.00	5.50	2.75
Category – B	50–200		9.15	3.65	2.75
Upazila Roads	Less than 50	Connecting the upazila headquarters and other growth centres with arterial road system	7.35	3.65	1.85
Rural Roads	Less than 50	(a) Union Roads: Connecting Union headquarter and other growth with upazila headquarter and intra and inter union headquarters	5.50	3.65	0.93
		(b) Village Roads: Connecting villages with union headquarters and inter and intra villages	3.65		

Source: Roads & Highways Department

* PCE : Passenger Car Equivalent. See Ap. Note 6-1.

Table 6–1–2 Geometric Design Standards by Road Classification

Road Classification			National Highway	Regional Highway	Upazila Road	Rural Road
Design Speed (km/hr.)	Plain Terrain	Ruling design speed	80	65	50	30
		Minimum design speed	65	50	40	25
	Rolling Terrain	Ruling design speed	65	50	40	25
		Minimum design speed	50	40	35	20
Minimum Horizontal Curve Radii (m)	Plain Terrain	Ruling minimum	230	55	90	40
		Absolute minimum	155	90	60	30
	Rolling Terrain	Ruling minimum	155	90	60	30
		Absolute minimum	90	60	45	25
Vertical Curves	Min. grade change (%) not requiring a vertical curve		0.6	0.8	1.0	2.0
	Minimum length of vertical curve (m)		50	40	30	10
Superelevation Rate. Min. (%)			6	6	6	4
Cross Fall of Carriageway (%)			2.0	2.5	3.0	4.0
Passing Sight Distance, Min. (m)			470	340	235	120
Stopping Sight Distance, Min. (m)			120	90	60	30

Source: Roads & Highways Department

sight distance, etc. consistent with a particular design speed for safe and comfortable driving. However the maximum longitudinal gradient is not specified in the same table.

6–1–3 Pavement Structure

RHD has specified the pavement structures to be followed in RHD road projects for up-grading, new construction and widening of national and regional highways, as in the following four cases:

Case 1 : Up-grading/widening,
where the cement concret (CC) is in good condition and no crack has developed in CC.

Case 2 : Up-grading/widening,
where CC is in damaged condition.

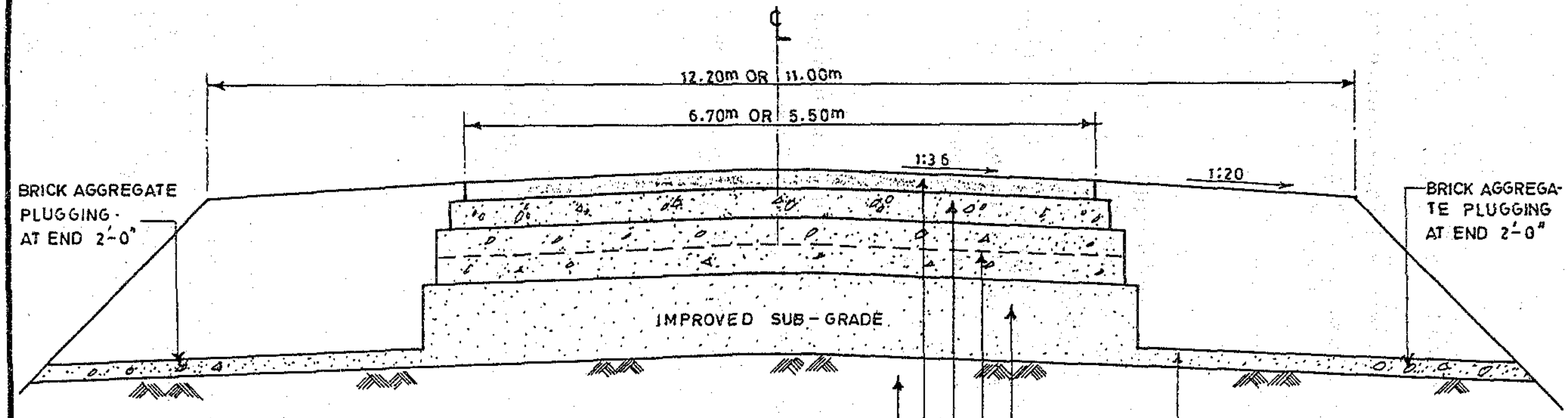
Case 3 : Up-grading/widening,
where the pavement is of a felexible nature and with no CC pavement underneath.

Case 4 : New construction

For the Study on the Meghna, Meghna-Gumti Bridges Construction Project the last case will be applied for the approach roads. The cross section of pavement to be followed in the construction of new roads that the Planning Unit of RHD has specified is shown in Fig. 6–1–1.

6–1–4 Design Standards for Bridges

RHD has adopted the AASHTO bridge design standards in principle, and the confirmation of each loading was made from time to time by the Indian Road Congress (IRC) Standards. Class "A" of the live load of IRC is used for confirmation.



NOTE: -1 THE IMPROVED SUB-GRADE CBR SHOULD BE BROUGHT TO 8% AND IN CASE IT CAN NOT BE ACHIEVED 8% BY COMPACTION THEN THE THICKNESS OF SAND LAYER MAY BE INCREASED IN CONSULTATION WITH R.R. LAB IN ALL CASES.

2 CHECKS TO BE MADE IN GRADATION, COMPACTION, DENSITY AND C.B.R. IN CONSULTATION WITH R.R. LAB.

3 INITIALLY SEAL COAT FINISH WILL BE GIVEN ON SEMI-GROUTING MACADAM. 2" CARPETTING / CONCRETING WORK WILL BE TAKEN UP AFTER KEEPING THE ROAD OPEN TO TRAFFIC FOR 2-3 YEARS TILL THE TIME TRAFFIC BUILDS UP.

4 ROAD NOTE 31 HAS BEEN FOLLOWED WITH SOME MODIFICATION TO SUIT LOCAL CONDITION

Source: ADD. CHIEF ENGINEER
PLANNING UNIT (RHD)
APPROVED ON 6.11.80

FIG.6-1 -1 PAVEMENT SECTION TO BE FOLLOWED IN THE CONSTRUCTION OF NEW ROADS : CASE IV (NOT TO SCALE)

6–2 Adopted Standards and Geometric Criteria for the Project

In this section the basic concept for design standards and geometric criteria of the bridges and roads is discussed to establish the design criteria for the Study.

6–2–1 Bridge Design Criteria

1) Loads

The AASHTO Standard (Standard Specifications for Highway Bridges) is generally followed for this study, but some modifications are made based on the Indian Road Congress (IRC) to meet local requirements arising from natural conditions such as wind, earthquake and temperature. The comparison of loading specifications for Highway Bridges of AASHTO, IRC, Japan Road Association and adopted design criteria is summarised in Ap. Table 6–1.

a) Dead Load

The dead load shall consist of the weight of the structure complete, including the carriageway, sidewalks, handrail and other public utility services.

For the computation of the dead load the unit weights of materials shall be as specified in Article 1.2.2 of AASHTO Standard.

b) Live Load

The live load shall consist of the weight of the applied moving load of vehicles, cars and pedestrians. The load shall meet the AASHTO HS 20-44 (MS 18) Standard.

c) Impact Friction

$$I = \frac{15.24}{L + 28}$$

where I = impact fraction (maximum 30%)
K = span length in metres

d) Sidewalk Loading

As specified in Article 1.2.11 (A) of AASHTO Standard.

e) Kerb Loading

As specified in Article 1.2.11 (B) of AASHTO Standard

f) Wind Load

Design wind velocity = 140 m.p.h (225.3 km/h)
Base wind velocity = 100 m.p.h (160.9 km/h).

The wind load intensity specified in Article 1.12.14 of AASHTO Standard shall be increased by the ratio of the square of the design wind velocity to that of the base wind velocity. The moving uniformly distributed wind load of the following intensities shall be accordingly applied horizontally.

For truss and arches . . . . 718 kg/m^2
For girders and beams . . . . 479 kg/m^2
For substructure . . . . 383 kg/m^2

g) Earthquake Load

An equivalent horizontal force of 0.05 W (which is considered as a dead load) was proposed as an earthquake load based on the analysis which is shown in Ap. Note 6–2.

h) Thermal Effects

A range of 26°C ± 17°C shall be considered; the average temperature during the years 1931 – 1960 at Dhaka and Comilla is computed to 26°C.

The range of temperature shall follow the IRC Standard.

i) Stream Current Force

The effect of flowing water on piers shall be calculated by the following IRC formula:

$P = 52 KV^2$

where P = intensity of pressure in kg/m²

V = velocity of water in m/s: 2.6 m/s for substructure design and 1.5 m/s for temporary structure design

K = a constant spedified in Article 213 of IRC Standard.

j) Earth Pressure

As given by the Coulomb's formula.

2) Materials

a) Structural Steel

Allowable tensile stress: $f_s \geq 2{,}100\ kg/cm^2$

The structural steel shall conform to ASTM A633 (C, D or E), or JIS* G3106 (SM50A, SM50Y or SM53).

*JIS: Japanese Industrial Standards

b) Concrete

Compressive strength of concrete shall be as follows:

– Prestressed concrete :	$f_c' \geq 350\ kg/cm^2$
– RC slab for steel bridge:	$f_c' \geq 270\ kg/cm^2$
– Cast-in-situ RC pile:	$f_c' \geq 300\ kg/cm^2$
– Substructure:	$f_c' \geq 210\ kg/cm^2$

where $f'c$ = compressive strength of a cylinder at age of 28 days

c) Reinforcing Steel Bar

Allowable tensile stress (f_s) of reinforcing steel bar is as follows:

– TORSTEEL (local products): $f_s \geq 2{,}100$ kg/cm² (by TORSTEEL)

– Deformed bar (imported materials): $f_s \geq 1{,}800$ kg/cm²

The TORSTEEL shall conform to BS 1144, while the deformed bar to JIS G3112 (SD30).

3) Prestressing Tendon

The allowable stresses shall be calculated as specified in Article 1.6.6 of AASHTO Standard.

3) Navigation Clearances

In Bangladesh the confirmation for the construction of a crossing structure over the navigable rivers has to be obtained from the Bangladesh Inland Water Transport Authority (BIWTA). The Study Team discussed with the Chief Engineer of the Civil Engineering Department, BIWTA the requirements for the construction of bridges including minimum clearances, number of navigation channels, and location of navigation centre. The following requirements shall be met:

	Min. Vertical Clearance	Min. Horizontal Clearance	Standard High Water Level (PWD)
Meghna River	18.00 m (60′)	75.00 m (250′)	5.10 m (17′-0″)
Branch Meghna River	7.50 m (25′)	75.00 m (250′)	5.25 m (17′-6″)
Gumti River	7.50 m (25′)	75.00 m (250′)	5.25 m (17′-6″)

The given figures of the standard high water level at the bridge sites correspond to around the 2-year return period. This frequency will not affect the usual navigation after the completion of the bridges.

The locations of the respective navigation centres are shown in Ap. Figs. 6–3 and 6–4 for Meghna and Meghna-Gumti Rivers, respectively.

6–2–2 Roadway Design Criteria.

1) Design Speed

The design speed of 80 km/hour specified by RHD for the area of flat terrain for national highways is adopted for this project, as the Dhaka-Chittagong Highway is a Category-A national highway.

2) Widths of Road Pavement and Bridge Carriageway

The lane width depends on the desirable lateral allowance, the size of the large vehicles which will use the road and the design speed, and is determined by the operational experience of the country. In the case of the design speed of 80 km/hour the pavement width of 6.70 m for a 2-lane road which is specified by RHD is adequate considering the design vehicle width (2.50 m) and economy in construction costs.

On the bridge, a side lateral allowance should be provided, between the carriageway and the footpath. Generally the minimum allowance of 0.25 m is adopted. The bridge carriageway width of 7.20 m which RHD specifies is adopted.

3) Shoulder Width

The shoulder width is related to the parking space for disabled vehicles, the side clearance of running vehicles, and the use by the pedestrians and other non-mechanised slow-moving traffic. Therefore, the width of 2.75 m on each side will be used.

4) Cross Fall for Normal Crown

A satisfactory drainage of the road surface is extremely important for safe speed driving during heavy rains. However, for road sections with a high volume of slow-moving traffic such as animal-drawn carts, bicycles, cycle rickshaws require no cross fall. Therefore the use of 2.0% cross fall on the normal crown that RHD specifies is used.

5) Maximum Gradient

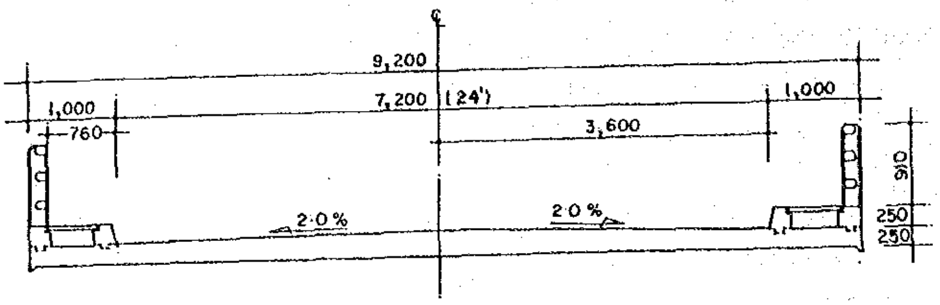
Bangladesh is a flat-land country. Rivers of important navigational routes must be bridged with the specified vertical clearance above the water level. The total bridge length is longer with flatter grades, which is not economical in construction cost. In such locations a steeper gradient that would not hamper slow-moving traffic could be provided with a lower design speed.

The approach roads of the Sitalakhya Bridge, on the Dhaka-Chittagong Highway about 13 km east of Dhaka, have a gradient of 6% which is very steep. This bridge site has such limitations as a high navigational vertical clearance but only a short distance for the provision of the approach road to connect with the existing road to sylhet. A four-lane carriageway is provided both on the bridge and approach roads so that the slow-moving traffic can utilise the outer lanes. Traffic flow on such a steep gradient does not appear to be hampered.

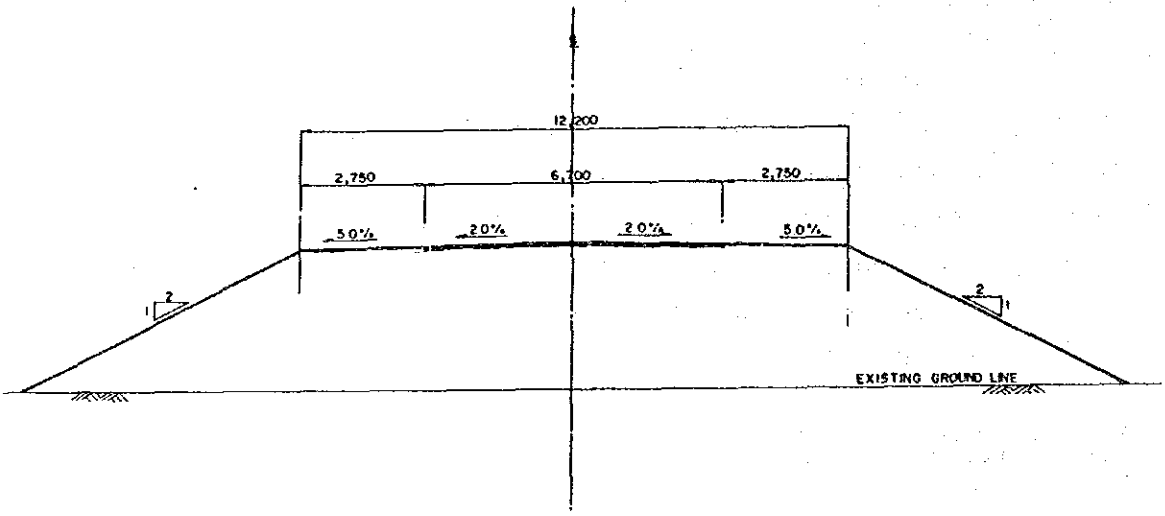
In the case of the proposed Meghna and Meghna-Gumti Bridges, which will have a 7.20 m wide carriageway, traffic flow will be hampered by vehicles having a low slope-climbing capability, if such a steep gradient is adopted for the approaches. Therefore a maximum gradient of 3% is adopted with which light vehicles can run at the ruling design speed of 80 km/hour and loaded trucks at 65 km/hour, the minimum design speed, for the approximate length of 550 m of the incline.

6–2–3 Standard Cross Sections

Based on this discussion the standard cross sections for the bridge deck and approach road are proposed as in Fig. 6–2–1.



BRIDGE DECK



APPROACH ROAD

NOTE: Dimensions are in millimetres.

Fig. 6–2–1 Typical Cross Sections