PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

FEASIBILITY STUDY REPORT

VOLUME II

CONSTRUCTION PLAN AND ECONOMIC EVALUATION

AUGUST [illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

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VOLUME VIII

OVERALL CONSTRUCTION PLAN AND ECONOMIC EVALUATION

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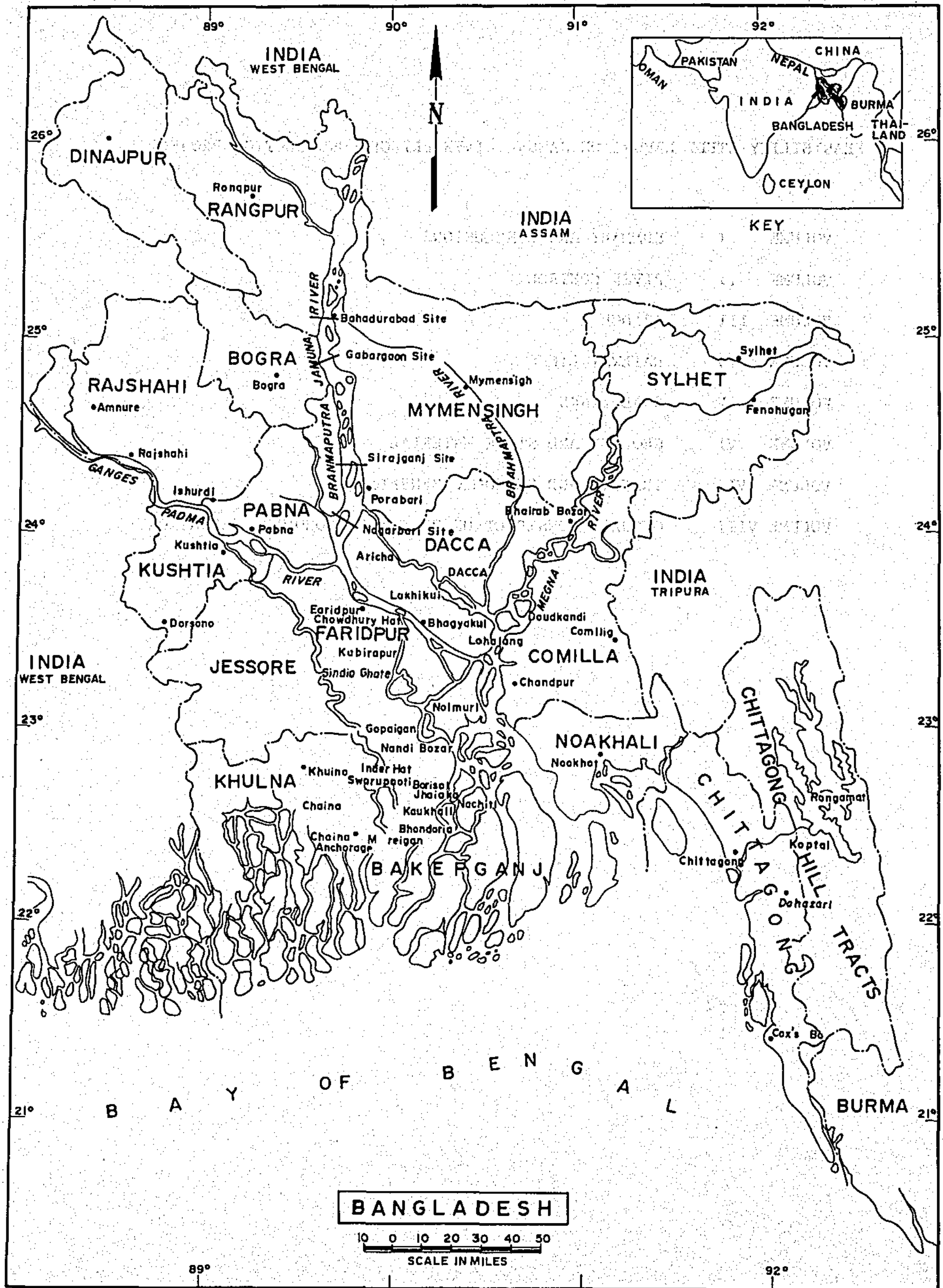

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DINAJPUR
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RANGPUR
JAMUNA RIVER
Bahadurabad Site
Gabargaon Site
BOGRA
Bogra
RAJSHAHI
Amnure
Rajshahi
GANGES
Ishurdi
PABNA
Pabna
PADMA
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RIVER
MYMENSINGH
Mymensingh
SYLHET
Sylhet
Fenchugan
BRAHMAPUTRA
Sirajganj Site
Porabari
Nagarbari Site
Aricha
DACCA
Bhairab Bazar
MEGNA
INDIA
TRIPURA
Lakhikul
Faridpur
Chowdhury Hat
FARIDPUR
Bhagyakul
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BAY OF BENGAL
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BANGLADESH
10 0 10 20 30 40 50
SCALE IN MILES
89°
90°
91°
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21°

THE JAMUNA RIVER
SIRAJGANJ SITE FOR BRIDGE CROSSING

ABBREVIATIONS, DEFINITIONS AND UNITS

Bangladesh	The People's Republic of Bangladesh.
MOC	Ministry of Communications.
R & H	Roads and Highways Directorate of the Ministry of Communications.
BWDB	Bangladesh Water Development Board.
SOB	Survey of Bangladesh.
JICA	Japan International Cooperation Agency, Government of Japan.
OTCA	Overseas Technical Cooperation Agency, Japan. Former name of the JICA.
Jamuna River	The Brahmaputra-Jamuna River.
Jamuna Bridge Project	Jamuna River Bridge Construction Project.
Jamuna Bridge	Tentative name of the bridge in the present project.
Preliminary Study Report	Preliminary Report on the Jamuna River Bridge Construction Project prepared by the Preliminary Study Team of the OTCA, Mar., 1973 (written in Japanese)
Inception Report	Inception Report on Feasibility Study of Jamuna River Bridge Construction Project submitted by the OTCA.
Interim Report	Interim Report on Feasibility Study of Jamuna River Bridge Construction Project submitted by the JICA.
Feasibility Report Volume I	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume I, Summary and Conclusions.
Feasibility Report Volume II	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume II, River Control.

Feasibility Report Volume III	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume III, Bridge.
Feasibility Report Volume IV	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume IV, Railway links.
Feasibility Report Volume V	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume V, Road links.
Feasibility Report Volume VI	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VI, Geology and stone material.
Feasibility Report Volume VII	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VII, Traffic and economic benefits.
Feasibility Report Volume VIII	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume VIII, Overall construction plan and economic evaluation.
Main construction works	Construction works comprizing Jamuna Bridge, river control, railway links and road links.
Bridge approach	Railway and/or road between an abutment of the bridge and a point at which it almost descends to the normal formation; 5,100 m respectively from the abutments.
Railway link	Railway between the end of the approach and a connection point on the existing railway.
Road link	Road between the end of the approach and a connection point on the existing road.
Guide bank	Bank built in the river to guide stream.
Cross dike	Dike built in the river to check river flow and support the function of the guide bank.

Cross dam	Embankment built across the river to close.
WL	Water level.
HWL	High water level.
LWL	Low water level.
DHWL	Design high water level.
PWD	Datum of Public Works Department.
GL	Ground level.
km	kilometer.
m	meter.
cm	centimeter.
mm	millimeter.
mi	mile.
yd	yard.
f, ft	foot.
in	inch.
cub.	cubic.
sq.	square.
ac	acre.
cfs	cubic foot per second.
t, ton	metric ton.
kg	kilogram.
lb	pound.
A	ampere.
V	volt.
W	watt.
KV	kilovolt.
KW	kilowatt.
KVA	kilovolt-ampere.
yr	year.
mon	month.
h, hr	hour.
s, sec	second.

1 mi = 5,280 ft = 1.6093 km.

1 yd = 0.9144 m.

1 ft = 0.3048 m.

1 in = 2.54 cm.

1 ac = 0.4046 ha = 0.004046 sq.km.

1 sq.ft = 0.0929 m .

1 cub.ft = 0.0283 cub.m.

1 cfs = 0.0283 cub.m/s.

1 in/mi = 1/63,360.

1 ft/mi = 1/5,280.

$ = U.S. Dollar.

Tk = Bangladesh Taka.

$1 = Tk 13.

C O N T E N T S

FIGURES

TABLES

CHAPTER I

INTRODUCTION

At the request of the Government of the People's Republic of Bangladesh, the Government of Japan decided to conduct a feasibility study for the construction of a bridge over the Brahmaputra-Jamuna River. This report gives the overall construction plan and economic evaluation of the project which were made based on the studies of river control, bridge, railway link, road link, geology and stone material, traffic and economic benefits.

Responding to the request of the Government of Bangladesh, a preliminary study team was dispatched by the Japan International Corporation Agency, formerly the Overseas Technical Cooperation Agency, in December 1972. The team recommended four candidate sites for bridge crossing; from upstream to downstream, downstream of Bahadurabad, near Gabargaon, about 10 km downstream of Sirajganj and about 20 km upstream of Aricha on the Jamuna River.

The Inception Report for the feasibility study was submitted by the Japan International Cooperation Agency to the Government of the People's Republic of Bangladesh in August 1973. All the studies were developed in accordance with the Inception Report. In October 1974, a preliminary design for the project was completed and based on this design, the Sirajganj site was chosen as the most suitable one for the bridge crossing at the meeting which was held in Dacca over the period from October 28, 1974 to November 6, 1974.

During the Study Team's stay in Dacca from November 29, 1974 to December 14, 1974, the Interim Report was submitted to the Ministry of Communications and the bridge axis was determined based on the aerial photographs newly taken by the Japanese Surveying Team in November 1974.

Following the above aerial survey, new topographic surveying including cross levellings over river widths were made in the Sirajganj area by the above-mentioned surveying team in the 1974/75 dry season. Based on these surveying results and using additional data on 1975-flood, studies were made to complete the plan of river crossing.

In this report, Volume VIII, the studies made in every Volume from II to VI are integrated together with the plan of construction bases, and further based on the cost study in the Volumes II to VI and the benefit study in Volume VII, economic analysis has been made.

Major staffs engaged in the study of Volume VIII are as follows.

Team leader	Seiichi Sato, Dr. Eng. NIKKEN Consultants, Inc.
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Planning of overall works	Shoji Kawabata NIKKEN Consultants, Inc.
Planning of overall works	Noboru Jitsuhiro NIKKEN Consultants, Inc.
Planning of bridge works	Tadao Kamide NIKKEN Consultants, Inc.
Planning of river works	Takayuki Nobe NIKKEN Consultants, Inc.
Economic analysis	Kinichi Ohno, Dr. Sc. NIKKEN Consultants, Inc.
Traffic and benefits	Yoshiwaka Yamakawa Pacific Consultants International

The Study Team wishes to extend its highest appreciation for the cooperation offered by the authorities concerned of the Government of the People's Republic of Bangladesh, especially its whole-hearted gratitude to the staffs of the counterpart team, and lastly, the Team wishes to express its gratitude to the Embassy of Japan in Dacca for its kind encouragement and suggestions.

BRIDGE CROSSING PLAN

CHAPTER II

DESIGN OF BRIDGE CROSSING

1. Bridge-Crossing Plan.

Based on the study at the first stage, the Sirajganj site was chosen as the most suitable site for bridge crossing from among the four candicate sites proposed by the Japanese Preliminary Study Team. Since the area called the Sirajganj site has an extension of tens of kilometers, an optimal location for bridge axis must be found within the area. For this purpose, new topographic surveying including cross levelings over river widths were made by the Japanese Surveying Team following the aerial survey in the 1974/75 dry season.

On the basis of the topographic map made by the above surveyings, the location of the bridge axis was chosen at a point about 12 km downstream of the town of Sirajganj taking account of the points that (1) the location must have a narrowest low-water channel, (2) stream line is as rectilineal as possible, (3) the location is as much protected as possible by the shelter of the natural narrow as well as the Sirajganj protection works and (4) construction works of river control are possible on the ground in narrowing the river width. The location of the bridge asix was thus determined as shown in Fig.2-1.

In order to keep the position of the bridge fixed, it was decided to take guide-bank system together with cross dikes which will form the bases of the bridge approaches. The left bridge approach must cross the Dhaleswari River. With a view to securing safety of the approach and promoting the function of the guide banks, it was decided to cross the river by a cross dam, which will form the base of the approach. In compensation for it, it was planned to excavate a new channel which connects the Dhaleswari River with a branch channel located about 6 km downstream of the bridge. These are outlined in Fig.2-1.

The bridge is connected with the Sirajganj-Ishurdi Railway Line at Salap Station by a new broad-gage single-track line and connected with Capital Dacca at a new station of Azampur by a new broad-gage single-track line. As for the road system, the bridge is connected with the allweather road of Sirajganj-Hatikumrul Route at Siakol and connected with of allweather road of Tangail-Madupur Route at a point about 500 m north of the crossing of Tangail-Madupur and Tangail-Gopalganj Routes. Outline of the railway links and the road links are shown in Fig.2-2.

2. Bridge.

2.1. Composition of width of the bridge and traffic system.

Composition of width of the bridge is an important factor which affects the future development of economy of Bangladesh and determines the magnitude of construction cost of the bridge. From this viewpoint, the width of the bridge should be a minimum which will meet the demand of the future traffic. Based on this conception, the composition of the width was studied and determined as follows.

If we take the year of 2020 as a target year of the future traffic, the road traffic will be 8,666 units per day in terms of passenger cars as was estimated in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS. For this traffic, if we take a two-lane carriageway of total width 24', traffic capacity of the road is estimated at 12,905 units per day in terms of passenger cars as was mentioned in VOLUME III BRIDGE. The two-lane carriageway is, therefore, sufficient for the future vehicle traffic.

Also in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS, railway traffic in the year of 2020 was estimated as 38 passenger trains and 21 cargo trains, 59 trains in total assuming broad-gage track of 5'6". If we assume the distance between the stations on both sides of the river to be 6 km in consideration of the total length of the bridge and the bridge approaches, a single broad-gage track of 5'6" will have a capacity for 74 trains per day. The single broad-gage track is, therefore, sufficient for the future railway traffic.

In the Tokyo meeting held in September 1974, it was decided by both the delegates from Bangladesh and Japan to take a railway-cum-road bridge as bridge-traffic system. Thus, the width composition was designed as shown in Fig.2-3.

2.2. Design criteria.

a. Loads.

All loads specified in Indian Road Congress Standard Vehicle Class A and Bangladesh Railways Schedule of Dimensions (5'6") were used with the following exceptions.

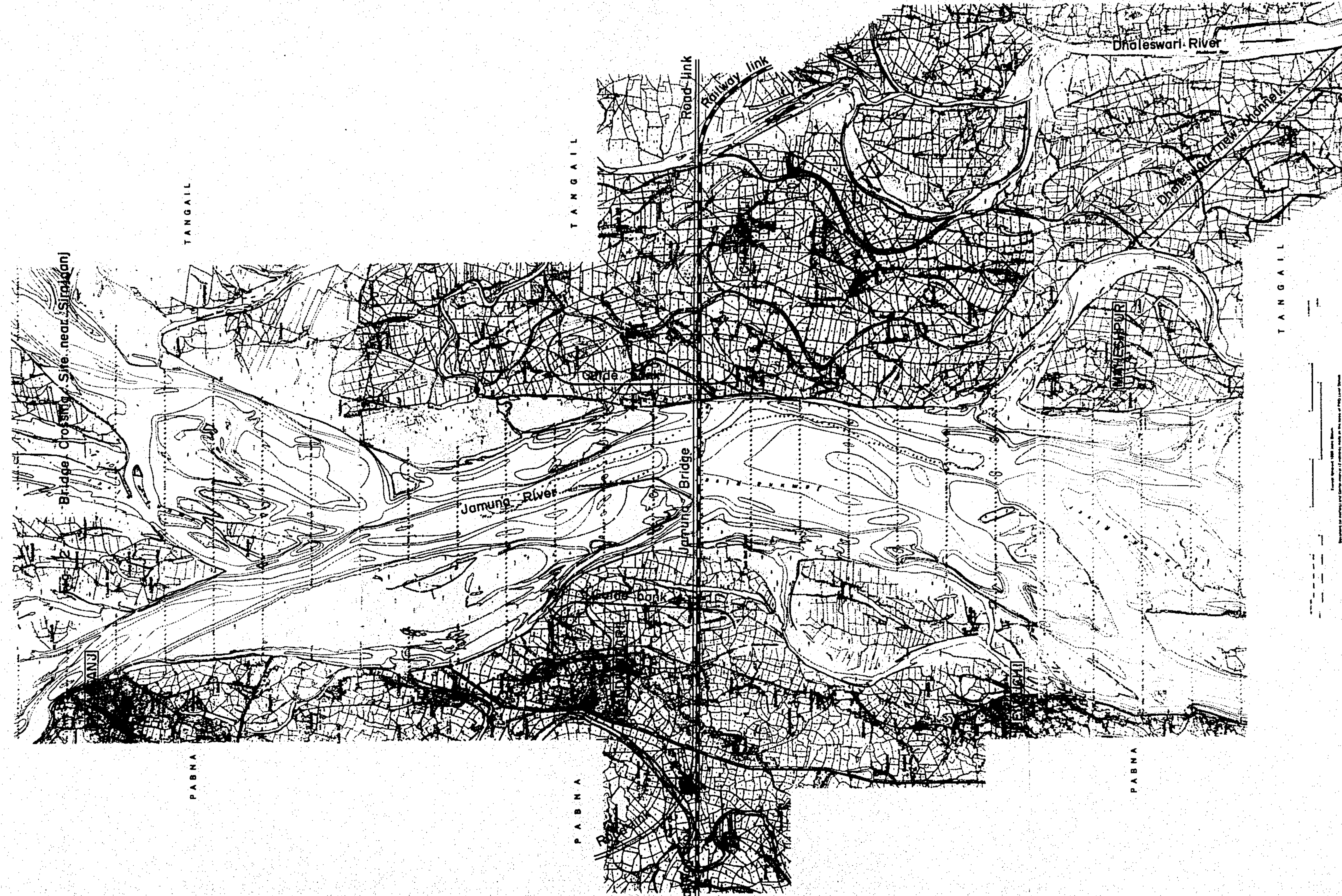
Standard wind velocity	:	35 m/s (115ft/s)
Range of temperature change	:	0°C - 60°C (32°F - 140°F)
Acceleration of earthquake		
Horizontal component	:	0.1 G
Vertical component	:	0

b. Construction gages.

Standard Specifications for Highway Bridge, AASHO were applied to the construction gage of the road portion, and Schedule of dimensions 5'6", Bangladesh Railways was applied to the construction gage of the railway portion.

c. Navigation clearance.

Minimum navigation clearance to be applied for the bridge was specified by the BIWTA as follows.



Bridge Crossing Site near Sirajganj

Fig. 2-2 Jamuna Bridge, Railway Links and Road Links

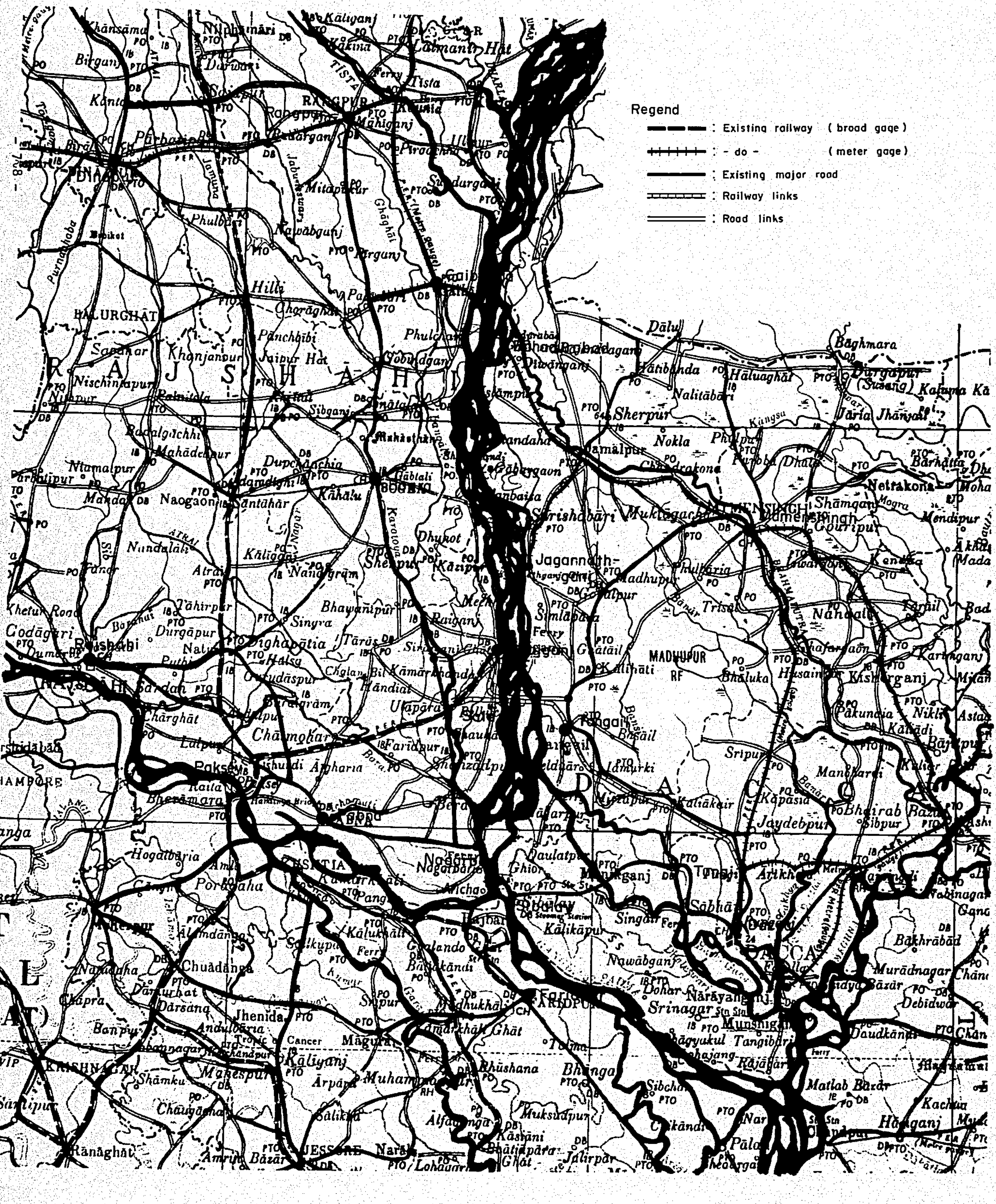
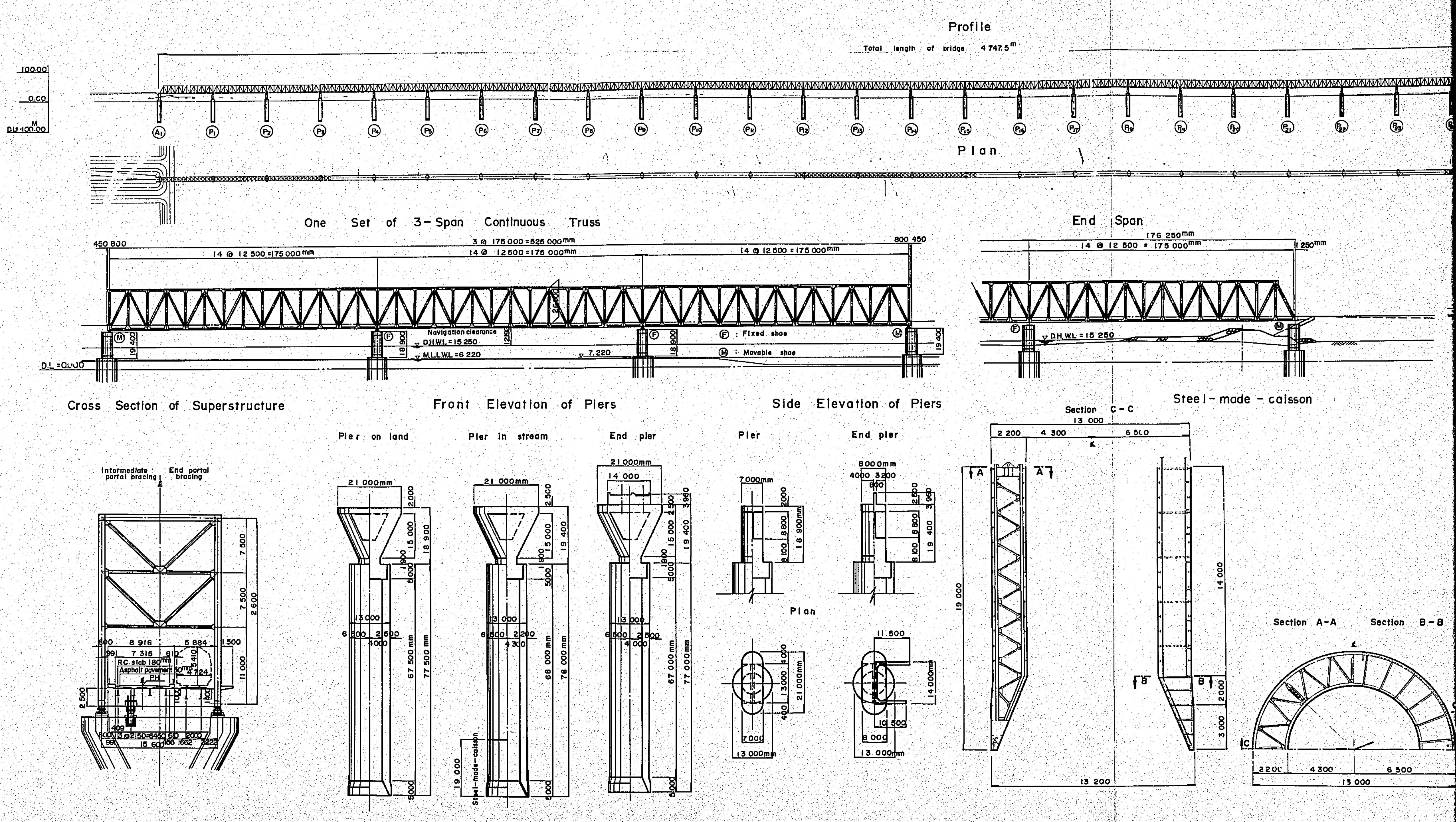
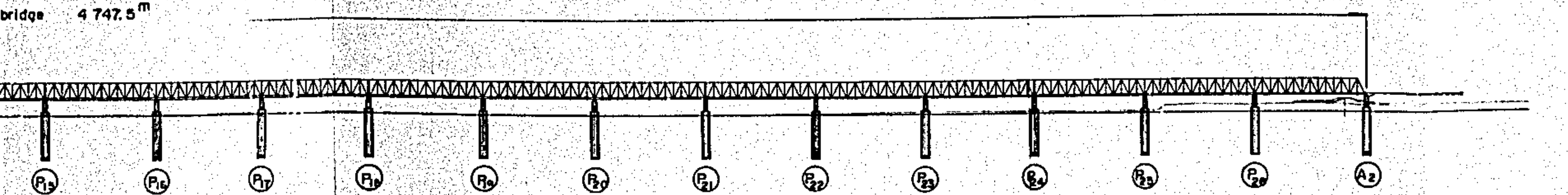


Fig. 2-3 General View of Jamuna Bridge

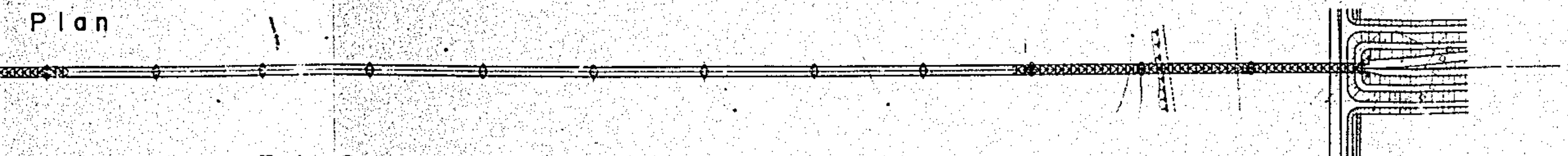


eneral View of Jamuna Bridge

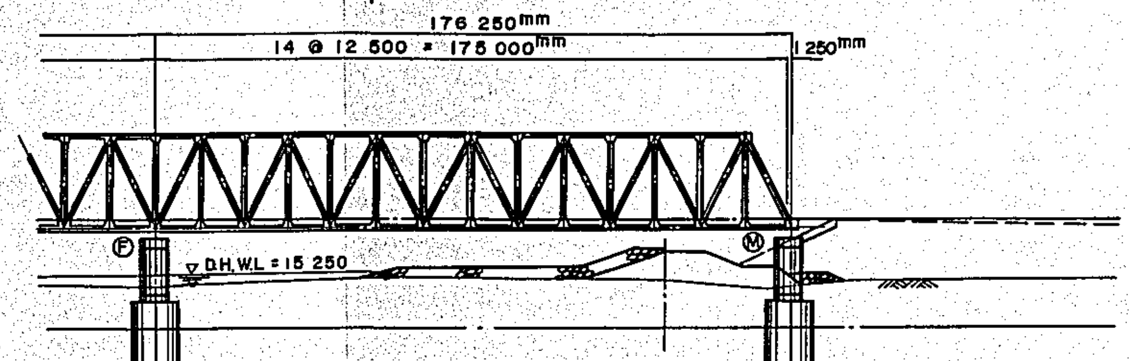
Profile



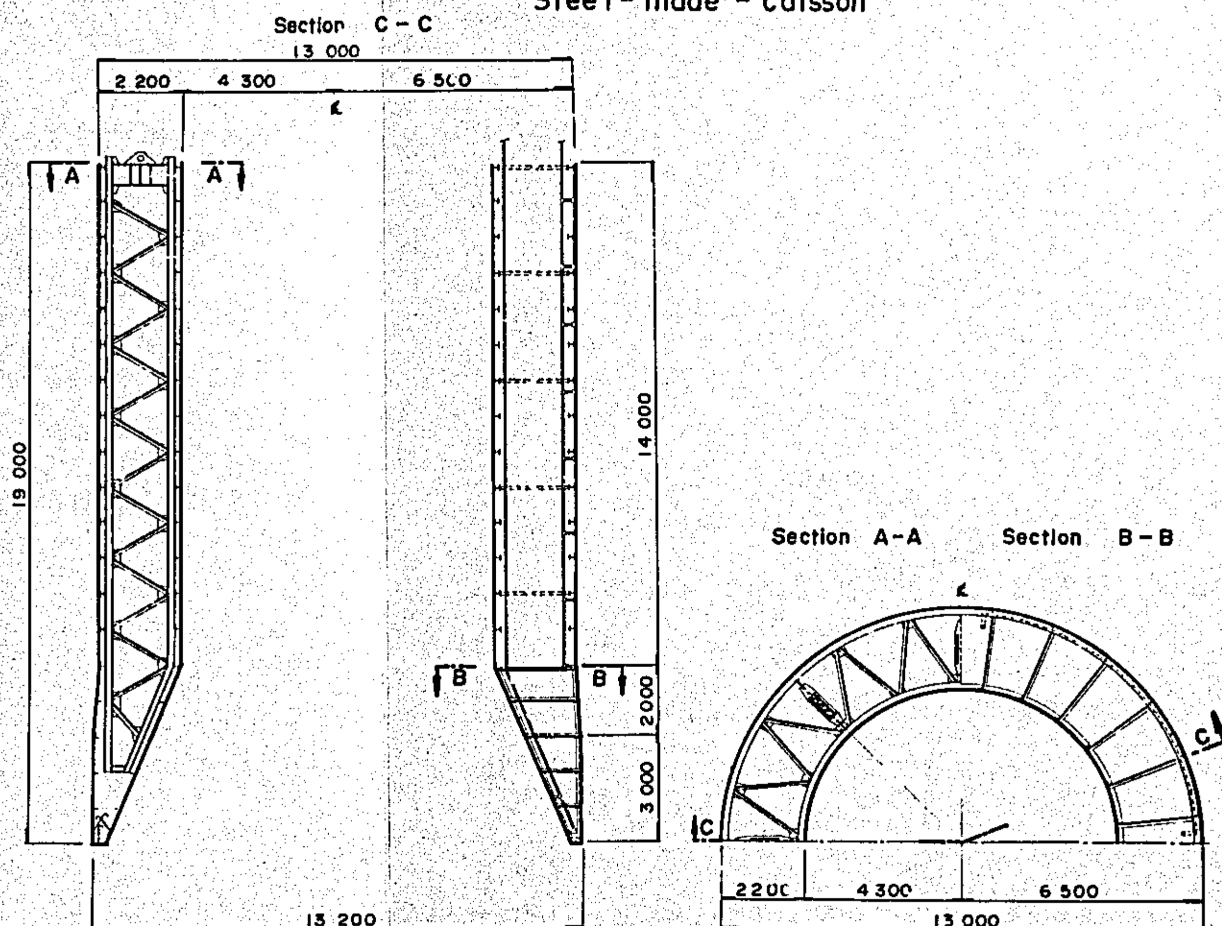
Plan



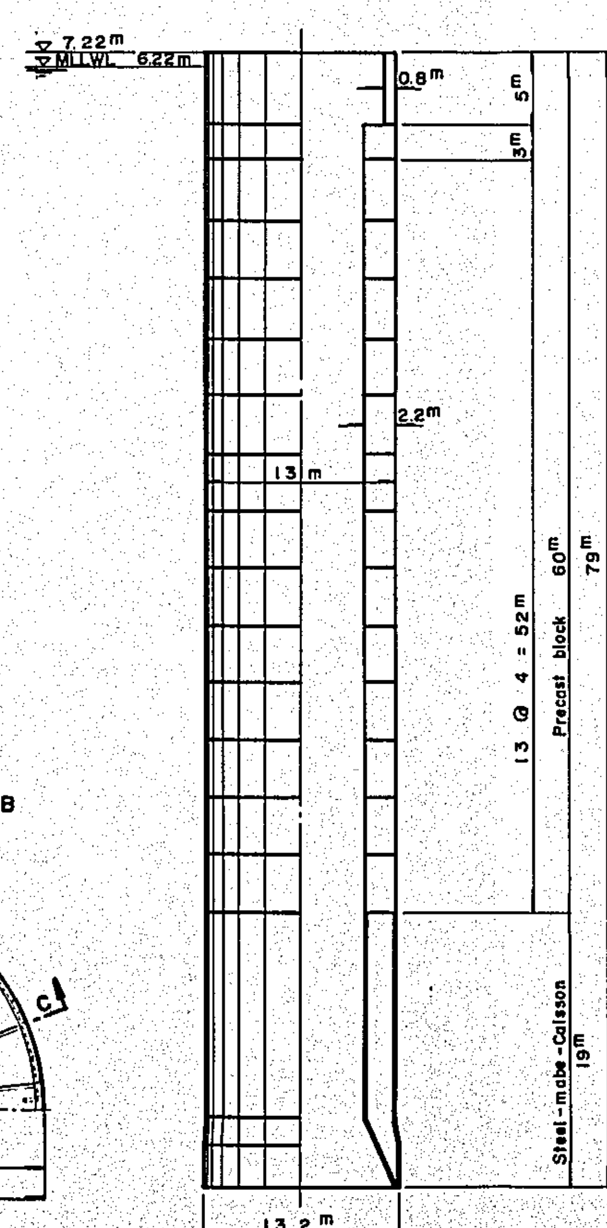
End Span



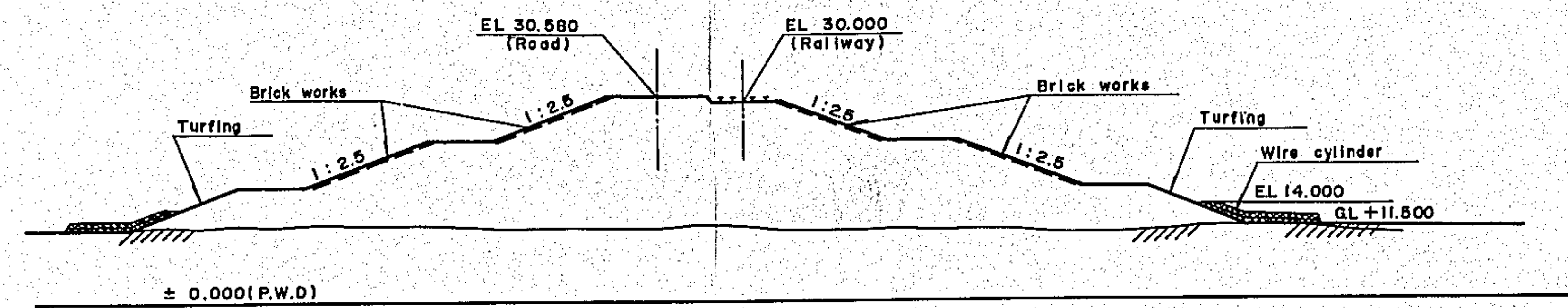
Steel-made-caisson



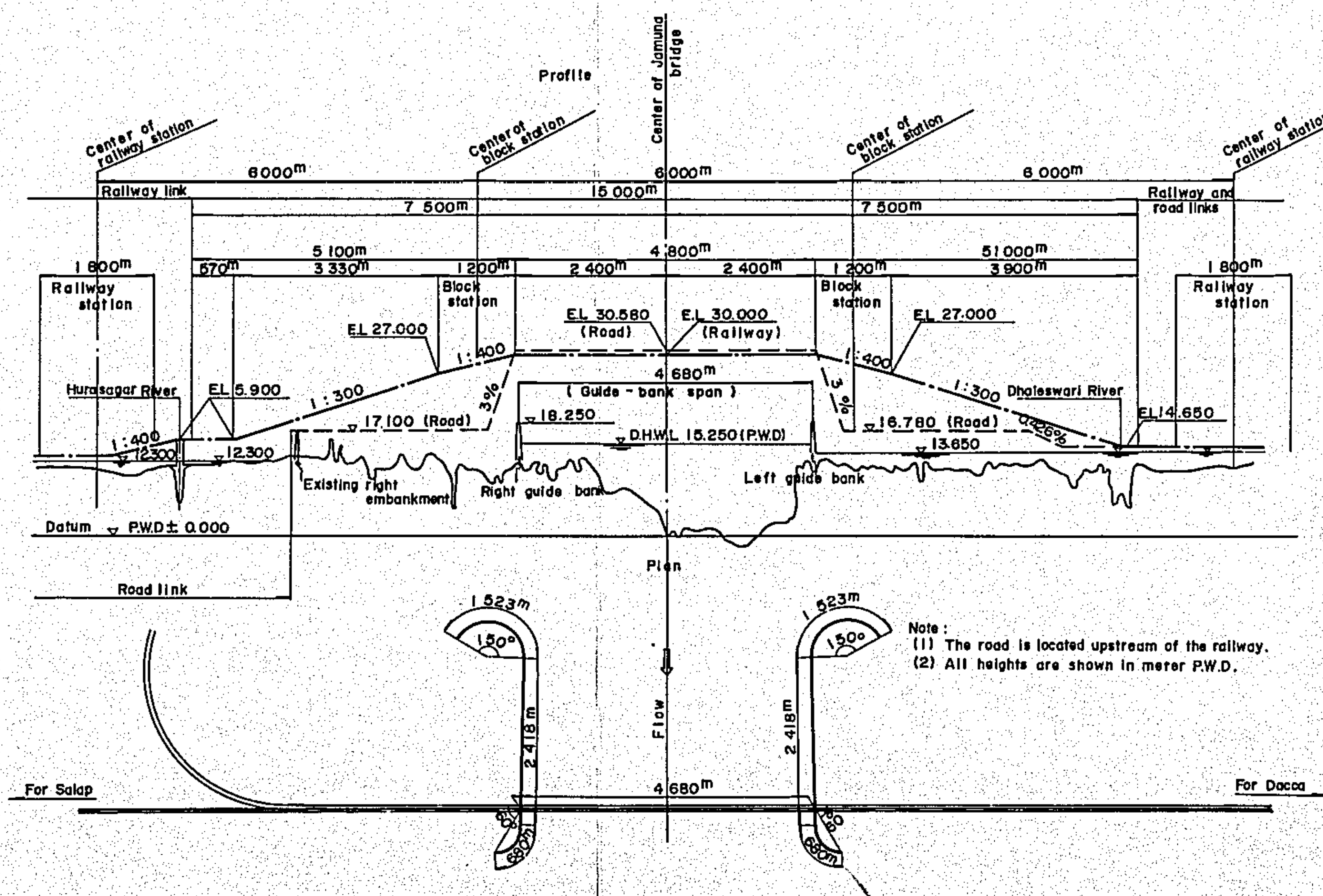
Composition of Rods of Well in Stream



Typical Cross Section of Bridge Approach



Sketch of Jamuna Bridge



Note :
(1) The road is located upstream of the railway.
(2) All heights are shown in meter P.W.D.

Minimum horizontal clearance : 250 ft (76 m)

Minimum vertical clearance above DHWL : 40 ft (12 m)

d. Steel structures.

All steel structures were designed pursuant to Standard Specifications for Highway Bridges established by the Japan Road Association except for railway floor system which was designed pursuant to Standard Specifications for Railway Bridge established by the Japan Society of Civil Engineers.

e. Concrete structures.

Concrete structures were all designed pursuant to Standard Specifications for Reinforced Concrete established by the Japan Society of Civil Engineers.

2.3. Types of superstructures and substructures.

Clear span of the bridge must be larger than 250' and vertical clearance must be larger than 40' pursuant to the above-mentioned specifications for the minimum navigation clearance, while the river control study mentioned in VOLUME II has concluded that the length of the bridge must exceed 42 km and the depths of the piers must be the same over the whole guide-bank span in view of changeability of thalweg. Further, it was judged from the geological survey mentioned in VOLUME VI-2 that the supporting layer of the bridge must be the gravel layer located about 80 m below the ground surface.

In view of the above-mentioned matters, it is easily considered that the construction cost of the bridge will reach a huge amount. In order to reduce the cost as much as possible, the superstructure should be of long span capable of bearing heavy load due to combination of both railway and road.

It is needless to say, therefore, the steel or prestressed concrete must be taken as structural material for the superstructure. However, in constructing such a long bridge, steel bridge is much lighter and more easily and quickly erected than concrete bridge, and further, inertia forces due to earthquake would be less in steel bridge than in concrete bridge. In consideration of these characteristics, it was decided to take steel as material of the superstructures.

As is known generally, continuous truss type or cantilever truss type is conformable to long span bridge. It was eventually concluded from the study of optimum span that continuous truss type has a decided advantage over cantilever truss type. In this case, equal span system was adopted considering unified appearance.

Since very long and large piers must be sunk steadily and quickly, well-foundation type and multipile type come to the objects of comparison in substructures.

Well-foundation type excels in stability because of its large body, while the execution will be of very large scale because of necessity of large depth of embedment although there is no basic difficulty in execution. In the case of multi-pile type, steel pipes of large diameter will be driven deeply until they reach the supporting layer and their heads will have to be connected rigidly with base slab on the water. This type is apt to bend because of its structure.

Scouring depth at piers is expected to be only 10 m in the case of multi-pile type whereas it will reach about 1.8 times of water depth in the case of well-foundation type. In this respect, the former has an advantage over the latter, but the former is inferior to the latter in the respects that construction cost will be increased because of insufficient rigidity and foreign currency portion of the cost will also be increased because of using steel material.

From these considerations, it was decided to adopt well-foundation type as substructures.

2.4. Determination of optimum span.

Total construction costs of both superstructures and substructures were estimated with respect to three-span continuous truss of equal span ranging from 100 m to 200 m and multi-span cantilever truss of equal span ranging from 200 m to 350 m assuming that every case has well-foundations. It was found from this study that the optimum span lies between 150 m and 200 m and that the most conformable type of superstructure having the optimum span is three-span continuous truss. In consideration of length and number of panels, it was decided to take 175 m as optimum span of the bridge.

2.5. Outline of the superstructures and the substructures.

Based on the above-mentioned studies, it was concluded that Jamuna Bridge should be composed of a series of steel three-span parallel-chord continuous Warren trusses of equal span 175 m having a traffic system for both railway and road and substructures of well foundations having a circular section of 13 m in diameter.

Height of the truss and interval between a pair of main trusses were set at 26 m and 15.6 m respectively. A span length of 175 m was, with verticals, divided into 14 panels of 12.5 m in each length by reason of composition of floor system and in order to reduce secondary stresses due to deformation of floor system and strengthen the rigidity of the bridge. As a result, the largest block of the superstructure members is about 22 ton in weight, 12.5 m in length and 110 cm × 80 cm in its size of cross-section. Two intermediate piers of a three-span continuous truss shall be provided with oil-damper shoes with a view of distributing horizontal forces due to earthquake in the direction of the bridge axis.

Length of well-foundations should be made as short as possible so that dynamic pressure due to river flow and inertia forces due to earthquake may be reduced as much as possible. In consideration of execution of construction works of the foundations and the piers to be built thereon, top height of the wells was set at EL + 7.22 m that is one meter higher than the Mean Lowest Low Water Level + 6.22 m. As a result, length of the well-foundations has come to reach as deep as 79 m at maximum because of the depth of the supporting layer.

Outer diameter of a well was set at 13 m in consideration of leaning which might occur during sinking, safety factor against bearing power of the supporting layer and cross-sectional area required at the bottom of the well. Thickness of the well was set at 2.5 m in those to be constructed on land and 2.2 m in those to be constructed in stream considering that it can be sunk without surcharge.

It was planned to execute construction works of the substructures in the dry seasons. In case of the execution in the low-water channel, steel caisson was adopted at the bottom portion of a well by reason that it is unreasonable to build islands in the stream and the period of construction maximum scour depth during execution. It was planned to construct a body of well by introducing prestresses after placing one concrete hollow cylinder block upon another by the aid of floating crane. The concrete blocks shall be precast in the block yards in size of 4 m in length, 2.2 m in wall thickness and 13 m in outer diameter.

Local scour around well-foundations has a possibility to reach a very large depth as was already studied in VOLUME II RIVER CONTROL. This depth has no problem in stability during ordinary time, but it may affect during earthquake since the embedment of the well must be stopped at the gravel layer. It is a prerequisite, therefore, to protect the wells with stone apron placed around them.

Shape of a pier to be built on a well-foundation will be an inverted triangle since the body of the pier, when constructed with reinforced concrete, has a circular section of 7 m in diameter at the bottom whereas the interval between a pair of shoes at a bearing of the bridge is 15.6 m. Hence the top face of pier will be an oblong shape of 7 m in minor axis and 21 m in major axis.

2.6. Determination of length of the bridge.

The study of river control mentioned in VOLUME II RIVER CONTROL has clarified that net width of the river must exceed 4,200 m. Since it was determined that the optimal span is 175 m and width of a well-foundation is 13 m, 26 piers are needed at least. Adding to this total span a length of 25 % of the total width of the wells as a lost width caused by stream and further considering arrangement of an abutment and a guide bank, it was decided to take a length of 4,747.5 m (15,575.6 ft) as the total span of the bridge. This means nine sets of three-span continuous truss of equal span 175 m with 26 piers and 2 abutments. These are shown in Fig. 2-3 together with typical sections of the approaches.

2.7 Bridge approaches.

The maximum height of the bridge approaches was set at EL + 30.0 m

PWD based on the dimensions of the superstructures and the vertical navigation clearance. Since the approaches form a hump extending over several kilometers, the gradient for them was moderated at 1/300 in consideration of performance of locomotives and others. On the other hand, on both sides of the river, block stations must be installed at an interval of 6 km to meet railway traffic which will cross the river at the Sirajganj site. The steepest gradient was set at 1/400 for the block station sections. Hence the lengths of the approach embankments were set at 5.1 km on each side of the river. While, the steepest gradient of road portion was set at 3 %. The alignments for the road and railway are as shown in "Sketch of Jamuna Bridge" of Fig.2-3.

Since the embankment is very high, a berm of 10 m in width was provided at every 7 m in height of the embankment for securing stability. Gradient of the slope of the embankment was set at 1 : 2.5 in consideration of loads due to trains and cars as well as the height of the embankment. This gradient was ascertained to be sufficiently safe by mechanical analysis.

Earth dredged in river bed or chars is used for the embankment besides surface soil in the area on the downstream side of the approaches. The toes on both sides of the embankments are protected by wire cylinders of brick against river flow.

3. River Control.

3.1. Necessity of guide banks.

The Jamuna River running through the alluvial plain is a comparatively new river that shifted from the Old Brahmaputra River about 150 years ago and a completely braided river which is still forming river channel. The ground that retains the river is covered by fine sand or silty sand and the banks are severely being scoured in a cliffy shape even at nodes of braiding as is seen at the bank of Sirajganj. No clayey bank as seen at Sara on the Ganges is found on the Jamuna River. In other words, no portion of the banks has resisting power to erosion.

Once flood has occured, river water spills over the areas on both sides of the river which produces huge river width. In building a bridge over such a river, it is terribly uneconomical and almost impossible at the present stage to revet the banks over the whole stretch, which indicates the necessity of fixing only a portion of river channel at which the bridge is contemplated to be spanned.

For this purpose, it is inevitably necessary to contrive the fixation of the river channel at the spanning site by means of passing river flow through a definite opening formed by both cross dikes that interrupt the widely stretched river flow and a pair of guide banks installed at the heads of the cross dikes to protect them and to guide the river flow to this opening by use of difference of water levels which would occur between the opening and the dead water area to be produced by both the guide banks and the cross dikes. The cross dikes which form the important components of the guide-bank system are utilized as the bases of the approaches of the bridge.

3.2. Design discharge.

Since there are no long-term records of flood discharges except at Bahadurabad, the design discharge at the Sirajganj site was derived from flood discharges measured at Bahadurabad in consideration of branching of the Old Brahmaputra River and the Dhaleswari River and joining of the Hurasagar River.

The design discharge should have a magnitude not less than 100-year return period in view of importance and scale of the projected bridge. Probalilistic discharge at Bahadurabad was estimated at 3,278,000 cfs or 92,770 m^3/s for 100-year return period and 3,358,000 cfs for 150-year return period. Since the influence due to the difference between the two discharges was found to be negligible, it was decided to adopt the 100-year discharge.

The 100-year discharge at the Sirajganj site was determined on the assumption that the discharge to be diverted to the Old Brahmaputra will be controled to 30,000 cfs by a barrage to be built on the river, joining of discharge of the Hurasagar will be stopped by the back-water of the Jamuna River and the discharge of the Jamuna will be confined within both levees which will be built in the future. Thus the design discharge at the spanning site was determined to be 3,420,000 cfs or 96,850 cub.m/s.

3.3. Distance between a pair of guide banks and the design high water Level.

Minimum river width was calculated at 4,900 ft (1,500 m) and 8,700 ft (2,700 m) respectively pursuant to the formulas put forward by G. Lacey and C. C. Inglis. These widths are unpractical from the viewpoint of maintenance of structures as well as construction works because the depth at thalweg between both guide banks will attain to a depth as large as 78 m below the ground level and the damming-up by the constriction due to the guide-banks will affect the extensive area upstream of the bridge. In the present planning, therefore, we determined the minimum river depth based on the study of the characteristics of the Jamuna River itself as mentioned in VOLUME II RIVER CONTROL. It was thus decided that the net river width must exceed 4,200 m.

Adding to this width the total width of the piers 13 m × 26 units = 338 m and hydraulic loss of 25 % of the total width of the piers, we got a length of 4,680 m as the interval of the guide banks. The constriction of this interval results in a damming-up of about 9 cm at a point closely upstream of the bridge taking into consideration the replacement of the inlet channel of the Dhaleswari River. But this 9 cm is an amount in case the design discharge is confined within the levees on both sides. It is needless to say, therefore, that the amount of damming-up will remain much less than the above until the left embankment is constructed. Further, the mean velocity is estimated at about 1.8 m/s even in case of big flood, which does not mean special difficulty in construction work. We thus decided to take the interval of 4,680 m (15,354.3 ft) for the guide-banks of this project.

3.4. Guide banks.

The guide banks and the cross dikes were disposed as seen in Fig.2-4 considering conformity with the present topography and direction of river flow and the alignment of the guide banks were set about 500 m apart from the edges of the river banks so as to avoid underwater works.

Horizontal alignment of the guide banks was determined pursuant to the proposal by R.R. Gales as shown in Fig.2-4. The length of a guide bank is 4,634 m (15,190 ft) and 9,268 m for both. Crown height of the guide banks was set at 18.25 m PWD (59.88 ft PWD) adding a freeboard of 3 m to the design high water level. In consideration of construction and maintenance after completion, crown width of the guide banks was set at 10 m of which 7 m shall be paved. Gradient of the river-side slope of the guide banks was set at 1 : 3 after the falling-apron system put forward by R.R. Gales, while gradient of the land-side slope was set at 1 : 3 as a whole including berms. In case we use natural stone for protection of the river-side slope, stone ranging from 60 kg to 100 kg is needed considering resistance to wave power presumed to act thereon. The land-side slope shall be protected by sodding with stone pitching at the toe.

We adopted the falling-apron system put forward by R. R. Gales for protecting the foot and the front of the guide bank. Length of the apron was determined pursuant to the Gales' proposal L = 1.5 D where D is the anticipated maximum depth in front of the apron from the ground level of the apron. The anticipated maximum depth from DHWL was estimated at 39.8 m based on the study mentioned in VOLUME II RIVER CONTROL. Thus the average lengths of the aprons were determined as follows according to the average ground height of the apron.

Left-side apron = 55.7 m ; right-side apron = 54.2 m.

In case we use natural stone as materials of aprons, stone ranging from 30 kg to 70 kg is needed judging from Gales' study and practice in the protection works for Hardinge Bridge as well as our study mentioned in VOLUME II RIVER CONTROL. Thickness of pitching stones for the aprons was set at 3 m referring to Gales' proposal and the practice in Hardinge Bridge.

3.5. Cross dikes.

It was already mentioned above that the cross dikes are utilized as the bases of the bridge approaches. The toes of them shall be revetted up to a height of 14.0 m PWD (46 ft PWD) for resisting to river flow and waves.

3.6. Stone material and alternative.

Concrete block is considered as a material to substitute for natural stone. Concrete block having sufficient strength and specific gravity would be an alternative for stone. Manufacturing such blocks is uneconomical because it needs a great quantity of cement besides almost the same amount of aggregate as in case of stone. Moreover,

Fig. 2-4 Guide Banks and Dhaleswari New Channel

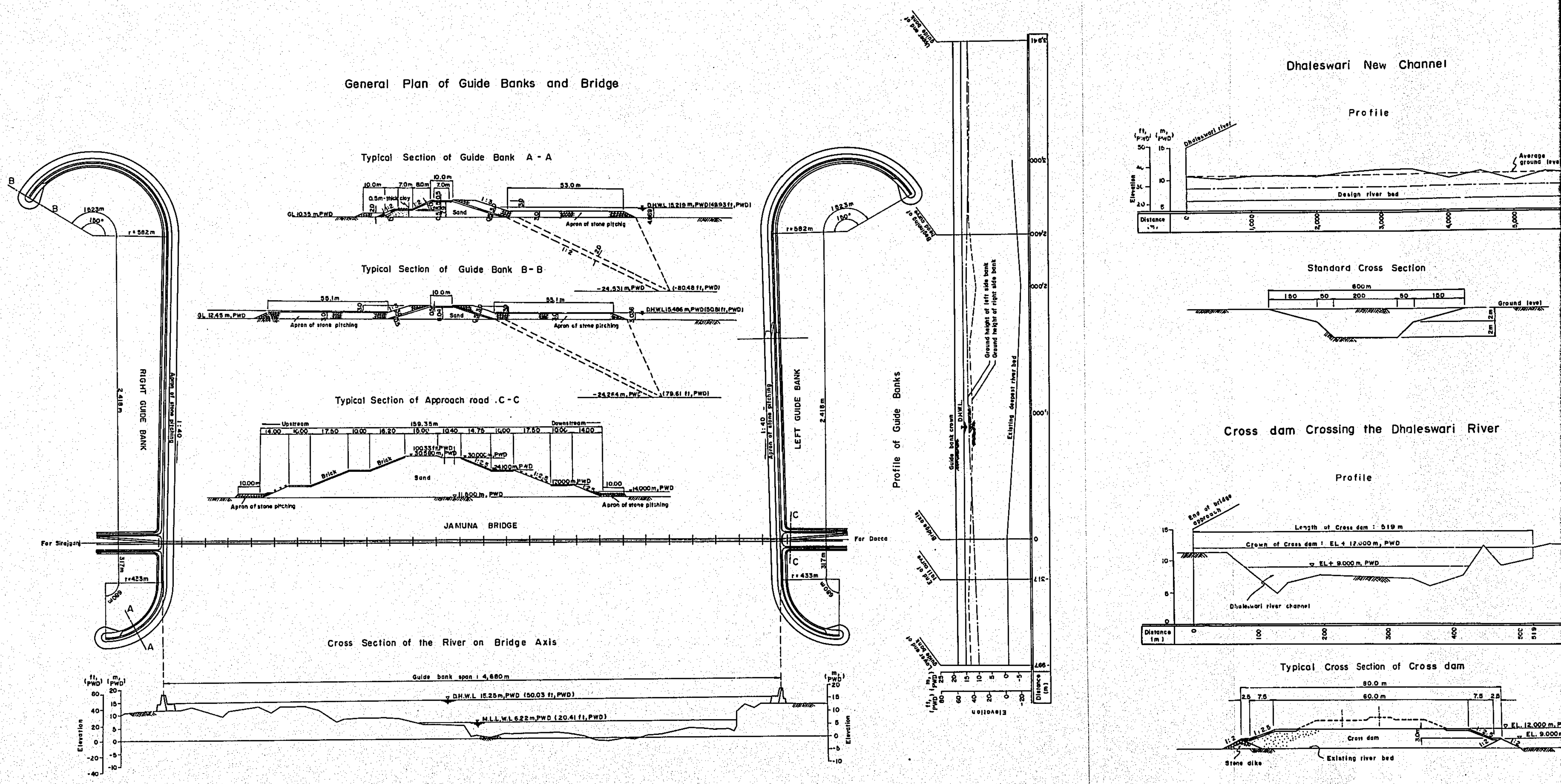
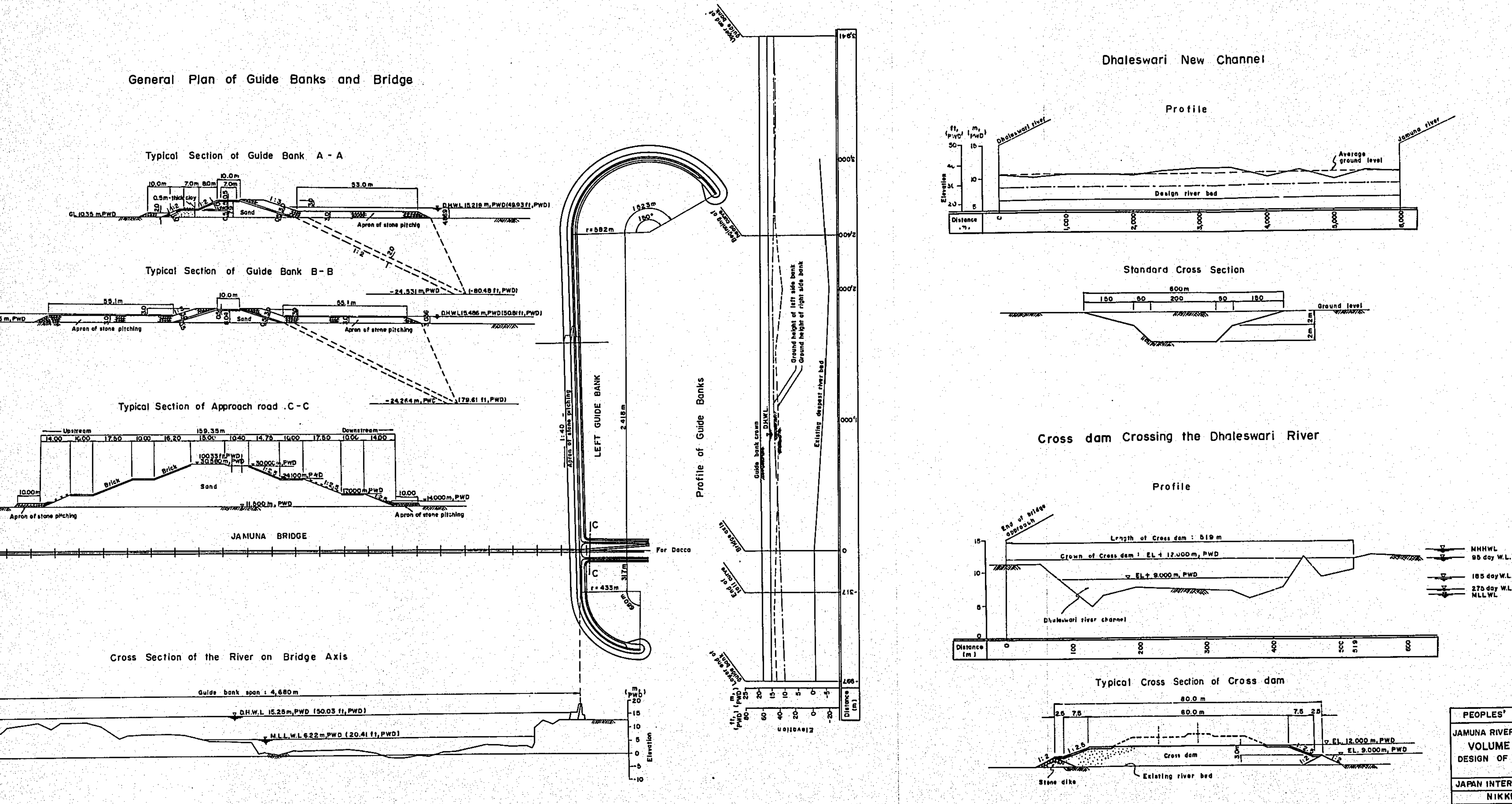


Fig. 2-4 Guide Banks and Dhaleswari New Channel



PEOPLES' REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME II RIVER CONTROL	
DESIGN OF GUIDE BANKS AND DHALESWARI NEW CHANNEL	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn	DRW. NO. II-1
Approved	

the great quantity of aggregate and cement must be imported from abroad because they must be used in a short term.

It is considerable to use soil at site instead of coarse aggregate but such blocks are unsuitable for pitching the aprons because they have no durability and necessitate gigantic size by reason of shortage of weight. To overcome these defects, it is necessary to take some counter measures such as steel jack system that is adopted in bank protection works at Sirajganj. As a result of study, it was found that this method is also uneconomical compared with natural stone.

After all, at the present stage, we can find no materials or methods that substitute economically and technically for natural stone. We therefore decided to take stone. It is strongly recommendable to exploit stone material in the Bangladesh Territory or develop other reliable methods not to necessitate stone material before entering implementation of the project.

3.7. Treatment of the Dhaleswari River.

The bridge approach on the left side of the river must cross the Dhaleswari River. If the approach will cross the river by a bridge, the opening on this approach may have a possibility of inducing flood flow thereto and causing serious damages to the approach and the bridge as well. In order to protect the approach from this menace, we will have to place another pair of guide banks around this opening, and that the pair of guide banks will have to be built nearly on the same scale as the main guide banks. Especially the right guide bank on the Dhaleswari may have to be connected with the left guide bank of the Jamuna. This system ought to need another huge cost and, in spite of this treatment, will not be able to escape from the menace of strong flood flow to run through the opening. Therefore we decided to cross the Dhaleswari by a cross dam and to connect the Dhaleswari with the Jamuna by excavating a new channel of about 6 km in length making use of a branch located about 6 km downstream of the bridge axis.

Considering that the new inlet channel of the Dhaleswari must secure the same water area as the present one, the width was set at 600 m and the water area under the average ground level was set at 1,400 sq.m. The left bridge approach shall be built on the cross dam. The projected Dhaleswari new channel and the cross dam are shown in Fig.2-4.

4. Railway Links and Road Links.

4.1. Railway links.

In order to fully expoit the potentialities of Jamuna Bridge, a railway system has been planned to connect the East and West from an existing railway to Capital Dacca via Jamuna Bridge and key areas on the left side of the Jamuna River.

From the viewpoint of transportation, operation and maintenance, the railway links should be regarded as an extention rather than independent of the existing railways. Naturally, the standards to be applied to the new construction must be the same as the existing railways. Not only these, but the opinions of Bangladesh railway experts as well as future railway plans such as reconstruction and improvement of the existing lines were prized for planning.

The Jamuna River divides the Bangladesh railway into two different systems. On her west is a mixed system of broad gage (5'6") and meter gage (1.00 m) and on her east is the meter gage only.

The connecting operation in the mixed system in the west is undertaken by transshipping yards at Santahar and Parbatipur. With the completion of Jamuna Bridge, the two railway networks in the east and west are to be integrated into a single one. Needless to say, the broad gage far excels the meter gage in transit capacity, speed, stability and in other various points, and has also advantages of international acceptance. Those stations and transshipping facilities which are designed for connecting the different systems should no longer be installed, but rather should the new plan presuppose the principle that the new railway from the west to Dacca can run on the same gage without interruption. The new line should be branched off from the Ishurdi-Sirajganj Line to provide a seamless line to the west. Based on this principle, the railway links were designed to assume the broad gage of 5'6".

The Economic and Traffic Survey Team estimated, in VOLUME VII, the required train services for the year 2020 at 59 trains for broad gage. Assuming that 59 trains are operated a day, the required average station interval was calculated at 8.2 km. If we take 6.0 km for 8.2 km, it will be able to answer the needs even in the far distant future as well as in the busy seasons. It was thus decided to employ the single-track system for all the sections including Jamuna Bridge.

The route diverges from Salap Station on the existing Ishurdi-Sirajganj Line (broad gage), runs eastward and reaches the Jamuna River at point 13 km after crossing the Hurasagar River. From there, it extends to the Dhaleswari River at point 23 km and runs down far to Tangail City at 42 km point where a new station will be built. The route crosses the Dhaleswari River on a cross dam.

The route runs further down, crosses the Lohajang and the Futjani, turns to the east, and then reaches Mirzapur at point 67 km. The route proceeds eastward, approaching the existing main highway in a comparatively arid area, reaches the Turag River at point 96 km by way of Kalikair. After striding over the Turag River, the route goes far down, crosses the Tungi River and terminates with Azampur Station which will be located on the existing railway line between Dacca and Tungi, to the north of the proposed airport complex. The total track length will be about 114 km (71 miles).

The Bangladesh government has another plan to construct a broad-gage line covering the extention between Azampur through to Dacca and a transshipment yard at New Dacca Station (Kamalpur). The stations from Salap through to Dacca numbers 24, of which exist four stations including Salap and Dacca.

Construction design criteria adopted here are as follows.

Gage	:	Broad (5'6")
Track	:	Single
Curvature	:	1,000 m in minimum radius, as standard
Gradient	:	5‰ (1/200) max. (for short section only)
Top of fill subgrade	:	over 3' above High Water Level
Design load	:	Axial load of 22.5 t in accordance with "Broad Gage Standard Loadings of 1926"
Train speed	:	Max., 96 km/hr (60 miles/hr) Average, 54 km/hr (34 miles/hr)
Track structure	:	Rail, 90 lbs/yr (45 kg/m) Sleeper, wooden Ballast base, crushed stone
Station	:	Center-to-center distance between tracks, 14'; pursuant to the Bangladesh Railway's Standards. Max. grade, 2.5‰ (1/400) Signal system, CTC in principle Effective line length, 700 m

4.2. Road links.

It was planned to connect the all-weather roads existing on both sides of the river through the projected Jamuna Bridge. The route diverges at Siakol located 4 km west of Sirajganj from Sirajganj-Hatikumrul Road which is scheduled to open in 1978 and reaches the right approach of the bridge at point 13,750 m. The route, further extending from the end of the right bridge approach which has crossed the Dhaleswari River, joins with Tangail-Madupur Road at point 37,350 m which is about 500 m north of the crossing point of Tangail-Madupur Road and Tangail-Bhuapur-Gopalganj Road. The length of the right link is 13,750 m and that of the left link is 10,580 m.

It was found that a road of 40' in width consisting of two 11-foot wide carriageways with flexible pavement and two 8-foot paved shoulders sufficiently meets the future traffic estimated in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS. The formation height was set higher than 3 m above the High Water Level. Geometric design was made pursuant to the Geometric Design Standards of Rural Roads in Bangladesh. Standard adopted here are as follows.

Width of roadway embankment	:	40' for primary roads
Hard crest width	:	22' for primary roads
Shoulder	:	8' paved
Design speeds	:	60 mph for rural areas 50 mph for urban areas
Radius of curvature	:	1,146' for 60 mph 754' for 50 mph

Grades	:	3.0 % max.
Passing sight distance	:	2,000' for 60 mph 1,700' for 50 mph
Stopping sight distance	:	475' for 60 mph 350' for 50 mph
Superelevation	:	8.0 % max.

5. Quantity of Construction Works.

Quantity of the works required for implementation of the project is shown in Table 2-1. Implementation schedule of the project is outlined in Fig.2-5. It will take more than three years for preliminary works which comprize topographic and geological survey, hydraulic model test, design, procurement of a part of equipment and materials, start of land acquisitions and construction of the right railway link. Next, it will take around seven years for construction of construction bases which comprize reclamation works for the bases on the right and left banks of the river, construction of temporary railway and roads on both banks, construction of cambers and canals on both banks, construction of job and dwelling settlements on both banks. Lastly, it will take around eight years for the main works which comprize construction works of bridge substructures, bridge superstructures, bridge approaches, guide banks, Dhaleswari new channel, railway link on the left side of the river and road links on both sides of the river. It will thus need thirteen years to complete project.

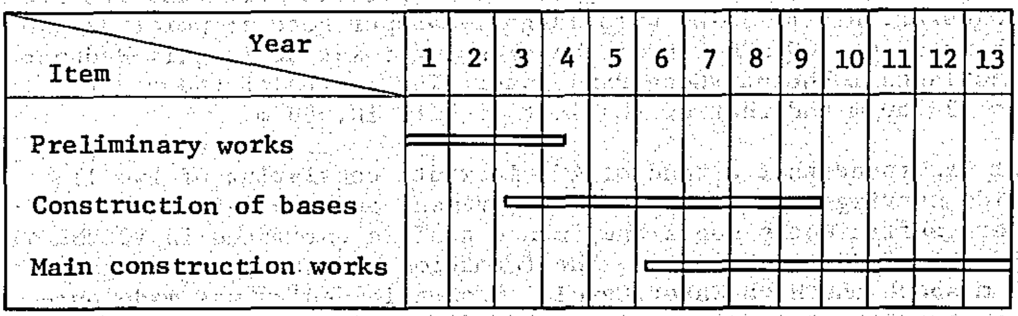


Table 2-1 Quantity of Works of the Project

Kind of works	Unit	Quantity of works			Remarks
		Right	Left	Total	
SUBSTRUCTURES		Total length of wells 2,177 m			
Well foundation (on land)		14 wells : 143.5 10 m in gross volume			
- do - (in stream)		14 wells : 145.3 10 m in gross volume			
Pier		28 piers : 34.8 10 m in net concrete volume			
Miscellaneous					
SUPERSTRUCTURES					* Three span-continuous truss 9 sets
Manufacturing & erection	10^3t	-	-	61.3	
Slab	10^3m^2	-	-	42.3	* Total bridge length: 4,747.5 m
Painting	"	-	-	937	
Permanent way	km	-	-	4.7	
Pavement	10^3m^2	-	-	35	
Miscellaneous					
BRIDGE APPROACHES					* Right : 5.1 km
Embankment	10^3m^3	4,111	4,784	8,895	* Left : 5.1 km
Stone pitching	10^3m^2	0	65	65	
Slope protection	10^3m^2	330	335	665	
Permanent way	km	10.2	5.1	5.1	
Pavement	10^3m^2	30	30	60	
Miscellaneous					
GUIDE BANKS					* Right : 4,938 m
Embankment	10^3m^3	831	874	1,705	* Left : 4,938 m
Stone pitching	"	1,400	1,406	2,806	
Sodding	10^3m^2	80	80	160	
Pavement	10^3m^2	35	35	70	
Miscellaneous					
DHALESWARI NEW CHANNEL					* Length : 6 km
Dredging	10^3m^3	-	6,600	6,600	
Miscellaneous					
RAILWAY LINKS					* Broad-gage single track
Formation	10^3m^3	563	7,184	7,747	* Length : 113.9 km
Bridge (A)	place	1	8	9	* Bridge (A): longer
Small bridge & spillway	km	0.26	294	320	than 100 m, Total
Permanent way (main line)	"	8.9	105.0	113.9	length: 1,352 m
Permanent way (sidings)	"	2.9	34.4	37.3	
Station & buildings	place	2	20	22	
Lighting telecommunication etc.	km	8.9	105.0	113.9	
Signalling	"	8.9	105.0	113.9	
Miscellaneous					
ROAD LINKS					* Two-lane carriageway
Embankment	10^3m^3	236	366	602	* Right : 13.75 km
Slope protection	10^3m^2	124	118	242	* Left : 10.75 km
Pavement	"	158	121	279	* Total length of bridge
Bridge (A)	place	1	1	2	(A) : 235
Small bridge & spillway	km	0.5	0.4	0.9	
Miscellaneous					

CHAPTER III

CONSTRUCTION BASES

1. Construction Bases.

1.1. General.

The construction of Jamuna Bridge is an epoch-making works which are composed of a huge quantity of subworks shown in Table 2-1 and require eight years for completion of the main works provided with a huge amount of construction materials and equipment. Therefore, good management of the works with good control of materials and equipment will evidently govern the accomplishment of the project.

The works also require a number of workers, who must be kept gathered near job sites since the sites are isolated from towns. Especially, numerous foreign workers will be engaged in the works since the major part of the works requires large-scale mechanized execution.

From these reasons, it was planned to construct the bases providing with the facilities necessary for management and operation. Since the area for the bases is unfortunately submerged by flood water almost every rainy season, settlements for jobs and dwelling must be built on all-weather lands, which shall be constructed artificially. Hence we have to begin with reclamation works for creating all-weather islands where the bases shall be constructed.

The construction works for the Jamuna Bridge project are composed of the following principal works.

a. Bridge construction works.

The works consist of substructure works, superstructure works and bridge-approach works including construction works of railway and road thereon. The works are concentrated on and around the bridge axis and both banks of the river.

b. River control works.

The works consist of guide-bank works on both banks of the river and excavation works for Dhaleswari new channel. The job sites are located on both banks and in the area about 10 km downstream of the bridge.

c. Road construction works.

This is the construction works of the roads to connect the bridge with the existing roads. Hence, the job sites stretch over more than ten km on each side of the river.

d. Railway construction works.

This is the construction works of the railways to connect the bridge with the existing railways and stretches over more than 10 km on the right side of the river and more than 100 km on the left side.

Among the above-mentioned works, those for construction of railways and roads can, in our judgement, be executed by the current system of construction control. In this project, therefore, we have only to plan a new exclusive system of construction control for the bridge and river control works. Construction bases were planned for this purpose and laid out on both sides of the river; the main is on the right bank and the branch is on the left bank.

The reason that the main construction base was laid out on the right bank is as follows.

a. Temporary railway and temporary roads are more easily constructed compared with the left side since the existing railway and road are located near the bridge on the right side.

b. The right side area is more advantageous in transportation of not only the materials and equipment from Khulna to the job site but also stone materials when it was planned to be imported from the western area of India.

c. Quantity of bridge works on land on the right bank exceeds that on the left bank.

d. Sirajganj, a big town which is a center of this area, is located upstream of the right-side job site.

Since the main construction base forms the center of all the construction works, it should be provided with sufficient facilities, whereas the branch base would be provided with least facilities in appropriate relation to the main.

The construction bases must be provided with the facilities required for comprehensive management of the whole jobs, the facilities required for management of carrying-in-and-out, storage and repair of the construction materials and equipment, the facilities required for work in the base areas and the facilities required for living of the workers. For construction of these facilities, the following works are necessary.

a. Construction works of land for the bases.

b. Construction works of temporary railway.

c. Construction works of temporary roads.

d. Construction works of cambers and canals.

e. Construction works of water supply.

f. Construction works of electricity facilities.

g. Construction works of settlements for job.

h. Construction works of settlements for dwelling.

i. Construction works of sewerage system.

j. Construction works of motor pools.

k. Transporation facilities in the base areas.

Fig.3-1 shows the layout of the work sites and the construction bases. The construction works of the bases are started four years before the commencement of the main works and shall be finished in seven years. The work schedule is shown in Fig.3-2.

The workers to dwell in the bases will be composed of domestic and foreign staffs for management of the works, domestic and foreign skilled laborers and domestic unskilled laborers. Table 1 in APPENDIX A shows daily maximum number of workers by year and by right and left of the river together with by with and without dependents. Based on this table, population for water supply was estimated at 8,200 on the right bank and 4,800 on the left bank taking bigger number between dwelling and daytime populations. Population for planning electric facilities and houses was estimated at 4,600 of workers without dependents on the right bank, 3,800 of those on the left bank and 5,100 of workers with dependents on the right bank in the ninth year. These are presumed to have sufficient reserves since the maximum number of population was taken in every case in the above-mentioned table.

1.2. Construction works of land for the bases.

Land must be created by reclamation on both sides of the river for construction bases comprizing job settlements and dwelling settlements. The reclamation must be made by dredging up to a height of 14.0 m PWD in consideration of the Mean Highest High Water Level, 13.14 m PWD. Quantity of the dredging works is as follows.

	Formation of reclamation (m, PWD)	Ground level (m, PWD)	Height of banking (m)	Area (m^2)	Rate of increase	Quantity of dredging (10^3m^3)
Right bank						
Job settlement	14.0	12.0	2.0	650,500	1.2	1,561
Dwl. settlement	14.0	12.0	2.0	560,000	1.2	1,344
Left bank						
Job settlement	14.0	12.5	1.5	211,900	1.2	381
Dwl. settlement	14.0	12.5	1.5	163,900	1.2	295

Dredging works are carried out by use of a 4,000-PS dredger to be employed for the river works and a 600-PS dredger to be employed

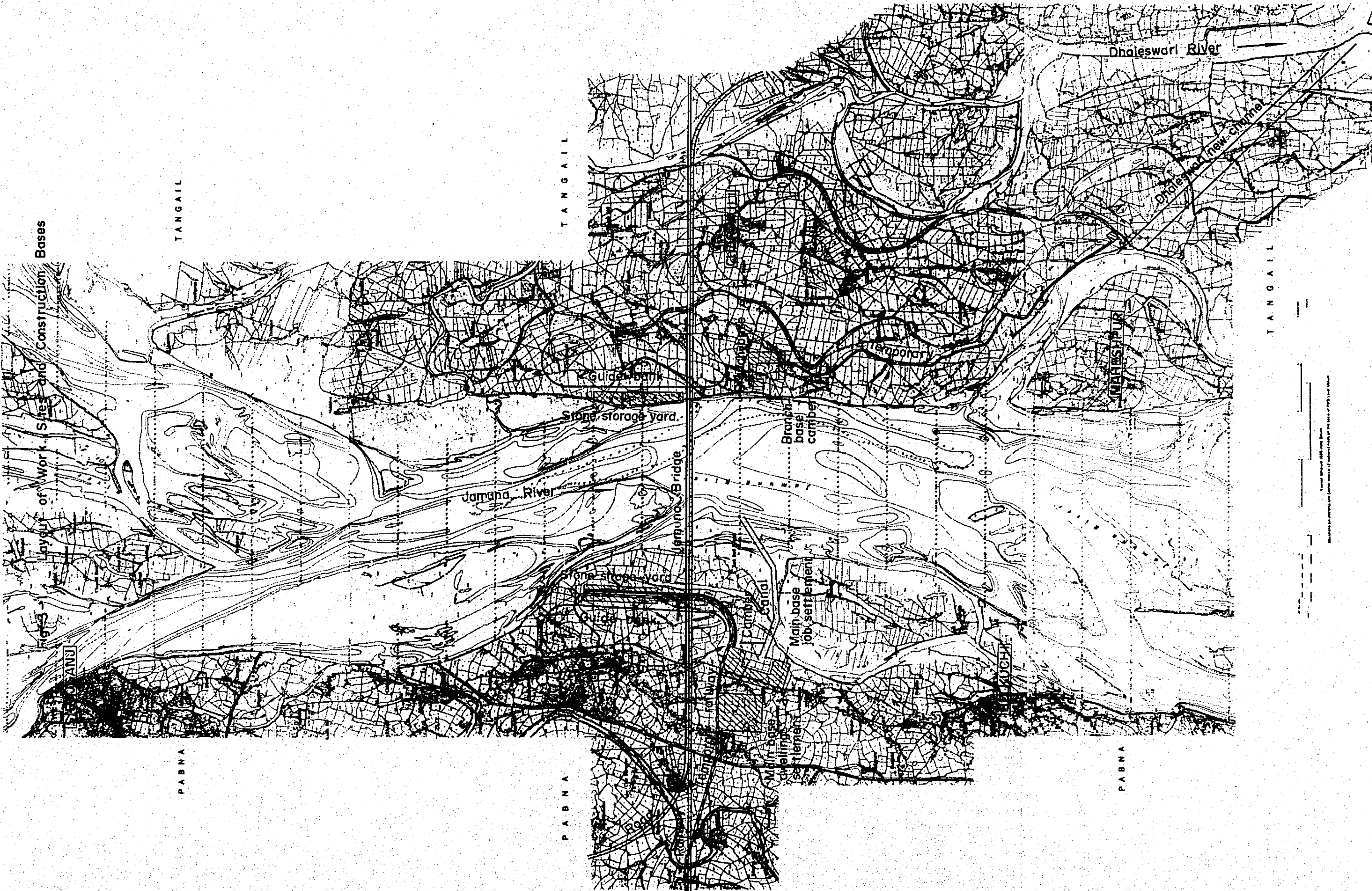
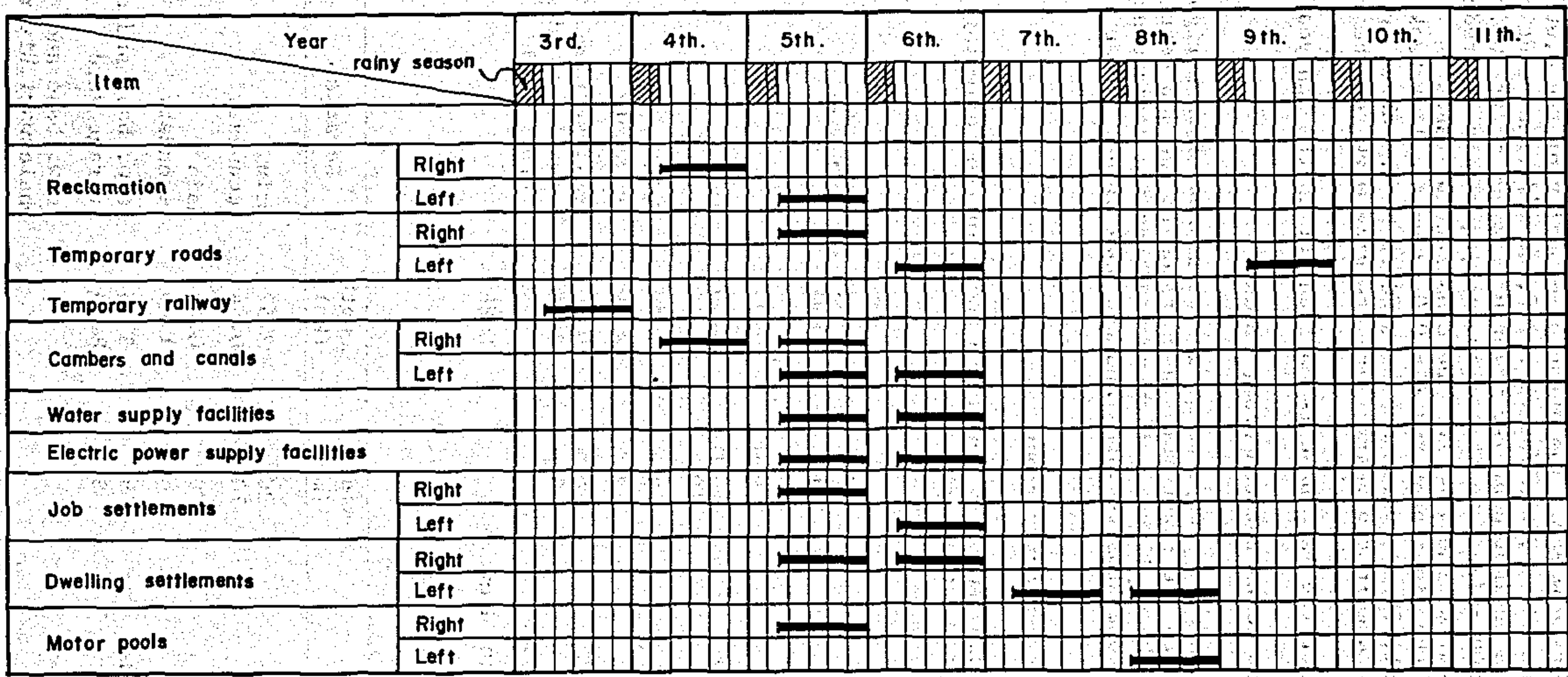


Fig.3 Layout of Work Sites and Construction Bases

Fig.3-2 Construction Schedule of Construction Bases



for such dredging works as maintenance of canals during the period of main construction works. The dredging capacity of the 4,000-PS dredger is estimated at 750 m^3/hr or 2,700,000 m^3/yr and that of the 600-PS dredger is estimated at 220 m^3/hr or 792,000 m^3/yr, which total to 3,492,000 m^3/yr. On the other hand, quantity of dredging required for creating the land for the construction bases is 2,905,000 m^3 on the right bank and 676,000 m^3 on the left bank, totaling to 3,581,000 m^3, which can be dredged by the above dredgers with sufficient ease in two years. The dredging work for the right base is carried out in the 4th year and the first half of the 5th year, and that for the left base is carried out in the 5th year.

1.3. Construction works for temporary roads.

Temporary roads are composed of an access road from a right all-weather road to the right main base, roads in the job settlements, roads in the dwelling settlements and service roads connecting the bases, the stone storage yards and the work sites. These are shown in Fig.3-1.

1.3.1. Lengths of temporary roads.

Lengths of the temporary roads are shown in the following table by the right bank and the left bank.

a. Right bank

Roads	Width (m)	Length (km)	Remarks
Access road	8 m	0.65	
Roads in job settlement	20 m	5.35	Main
	10 m	2.15	Secondary
Roads in dwl. settlement	9 m	1.30	Main
	6 m	5.50	Secondary
Service roads	8 m	0.10	Betw. settlements
	8 m	3.85	Betw. base and stone storage yard
Total on right bank		18.88	

b. Left bank

Roads	Width (m)	Length (km)	Remarks
Roads in job settlement	20	2.52	Main
	10	0.84	Secondary
Roads in dwl. settlement	9	0.40	Main
	6	1.60	Secondary
Service roads	8	3.15	Betw. base and stone storage yard
	5	8.10	Betw. base and Dhaleswari River
Total on left bank	-	16.61 km	

c. Total length of temporary roads on both sides of the river is 35.5 km.

1.3.2. Structure of temporary roads.

Banking is conducted with dredged earth or earth taken from the sides of the roads, the formation of which shall be + 14.0 m, PWD. Pavement is composed of subbase course of brick chips and surface course of asphalt concrete. The roads in the job settlements and the dwelling settlements are provid with gutters made of bricks for drainage of rain water. The thickness of the pavement is shown in the following table by subbase and surface courses.

Roads	Thickness of subbase course (cm)	Thickness of surface course (cm)
Access road	60	10
Roads in job settlement	60	10
Roads in dwl. settlement	35	7
Service roads	60	10

1.4. Construction works for temporary railway.

Construction equipment and materials including stone required for the works on the right bank are carried in by railway as well as by boat. For transportation by railway, temporary railway is built from the railway link to the settlements and the stone storage yard. The railway is shown in Fig.3-1.

1.4.1. Length of temporary railway.

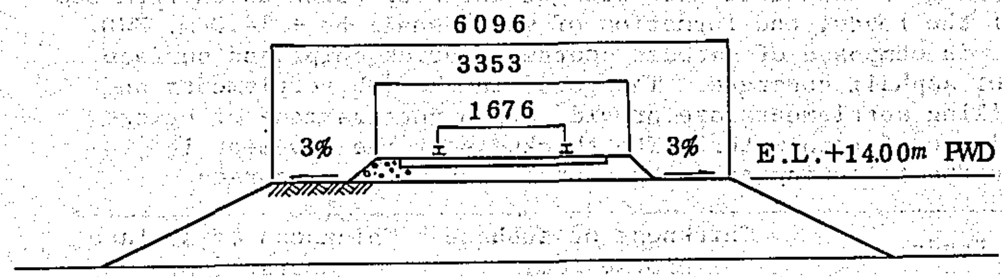
The length of the temporary railway is 8.35 km, a broad-gage single track from the right-side railway link to the stone stock yard through the settlements. The railway is provided with three refuge tracks of 300 m.

1.4.2. Structure of temporary railway.

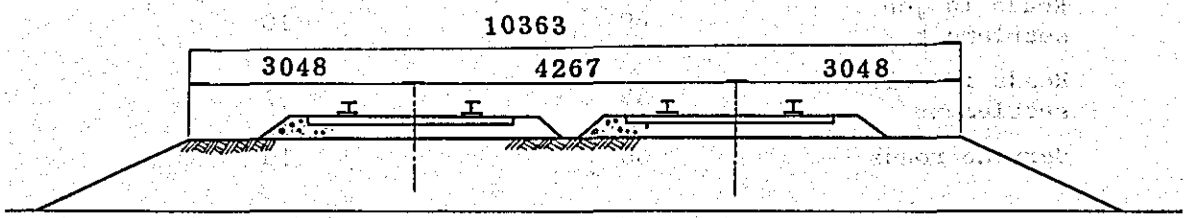
Banking is conducted with dredged earth or earth taken from the sides of the railway, the formation of which shall be + 14.0 m PWD. Cross-sections of the temporary railway are as follows.

Structure of Temporary Railway

Single track



Single track with refuge track



1.5. Construction works for cambers and canals.

Cambers and canals are construct. for carrying-in of the equipment and materials to be transported by boat into the bases, transportation of equipment and materials between the bases on both banks and carrying-out of materials and equipment required for erection of the bridge. Layout of the cambers and the canals on both banks are shown in Fig.3-1.

1.5.1. Structure and facilities.

The cambers and the canals should have sufficient water depth at the Mean Lowest Low Water Level +6.22 m, PWD.

Shape of the camber on the right bank was set at a rectangle of 300 m by 540 m having an area of 162,000 m^2. On the periphery of the camber are installed facilities for cargo handling, outline of which is shown below.

a. Pier for cargo handling: 120 m (length) by 16 m (width); capable of mooring of two 500-ton boats at the same time; steel-pile and rigid-frame structure.

b. Quaywall for carrying-out of caissons and precast concrete hollow cylinders: 300 m in length; capable of mooring of 1,000-ton floating crane; steel sheet pile structure.

c. Quaywall for bridge superstructures: 300 m in length; capable of mooring of 12,000-ton flat-barges; steel sheet pile structure.

Shape of the camber on the left bank was also set at a rectangle of 370 m by 430 m having an aera of 159,100 m^2. On the periphery of the camber are installed pier for cargo handling similar to the right camber.

The camber is provided with a depth of about 4 m by dredging up to a depth of +2.2 m, PWD considering the draft of tugboats. A portion of 100 m in front of the quaywall for bridge superstructure alone is provided with a depth of 3 m by dredging up to a depth of +3.2 m, PWD. This is based on the reason that the 3-m depth is sufficient for the barge for carrying bridge superstructures because the barge is moved or turned by using mooring cables in front of the quaywall and smaller depth is advantageous to the construction of the quaywall which must bear heavy loads. A gradient of 1 : 3 shall be set on excavated slopes in places other than the quaywalls.

Length of the canal on the right bank is 3,150 m and that on the left bank is 350 m. The both canals shall be provided with depth of 4 m, bottom width of 70 m and slopes of gradient 1 : 3.

Miscellaneous facilities such as mooring posts and navigation aids are installed.

1.5.2. Dredging works.

Quantity of dredging in the construction of the cambers and the canals is as follows.

a. Right bank.

Works	Average ground level (m, PWD)	Elevation of bottom (m, PWD)	Quantity of dredging ($10^3 m^3$)
Camber	12.0	2.2	1,224
Quaywall for superstructure	12.0	3.2	253
Canal	8.5	2.2	1,570
Total	—	—	3,047

b. Left bank.

Works	Average ground level (m, PWD)	Elevation of bottom (m, PWD)	Quantity of dredging ($10^3 m^3$)
Camber	12.5	2.2	1,605
Canal	12.5	2.2	399
Total	—	—	2,004

c. Total quantity of dredging on both sides of the river is 5,051,000 m^3.

1.1 was taken as the rate of increase of dredging works.

Dredging is executed by a 4,000-PS dredger and a 600-PS dredger. Since the dredging capacity of both dredgers is 3,492,000 m^3/yr as already mentioned, the above-mentioned quantity of earth can be dredged in two years of the fourth and the fifth. Also as mentioned previously, the quantity of the earth required for reclaiming lands for the right base is 2,905,000 m^3 and that for the left base is 676,000 m^3. Accordingly, the dredging of the cambers and the canals is favorable to the construction of the bases in the aspects of quantity and locality.

1.6. Facilities for water supply.

Water supply is divided into that for living and that for works. Water for living comprizes drinking water and others in the dwelling and job settlements and water for works comprizes water for plants such as concrete and other water for washing. Water sources can be sought in ground water and river water. River water is inferior to ground water in the aspects that it is very difficult to secure stable intake in all seasons of the year because of very large fluctuation of water level and, moreover, water quality, especially contents of sediment fluctuate in dry and rainy seasons. The geological survey indicates that thick gravel layer is located under fine sand layer about 80 m thick. It is expected, therefore, that water of good quality is reserved in abundance in the gravel layer. Water supply for living was planned on the use of ground water. On the other hand, water supply for works was planned on the use of river water and shallow wells.

1.6.1. Facilities for water supply in the right base.

Daily maximum water consumption in the right base was estimated at 2,460 ton per day assuming that population to be supplied is 8,200 and daily maximum water consumption per head is 0.3 t/day, and hourly maximum water consumption was estimated at 410 t/hr assuming that a half of daily water consumption is concentrated on the three hours in a day. In planning the facilities for water supply, it was assumed that the facilities would have capacity of reserve for one day.

a. Tube wells: If we assume that drawing capacity of a tube well is 0.5 t/min,

$$0.5 \text{ t/min} \times 60 \text{ min} \times 24 \text{ hr} \times 0.8 = 576 \text{ t/day}$$

hence required number of tube wells is

2,460 t/day ÷ 576 t/day = 4.3 wells or 6 wells including one well for construction works mentioned later.

b. Storage tank: Considering one-day's reserve

$$2,460 \text{ t/day} \times 2 \text{ days} = 4,920 \text{ t or } 5,000 \text{ t.}$$

c. Overhead distributing tank : Since the hourly maximum water-delivery is 410 t/hr,

$$410 \text{ t/hr} \times 10 \text{ min}/60 \text{ min} \times 0.5 = 34.2 \text{ or } 40 \text{ t}.$$

d. Purification facilities : If we assume working-capacity of 20 t/hr per unit, we need

$$2,460 \text{ t/day} \div (20 \text{ t/hr} \times 24 \text{ hr}) = 5.1 \text{ units or } 6 \text{ units}.$$

On the other hand, if we assume that daily maximum quantity of concrete to be placed is 600 m^3/day. The following quantity of water is required for concrete works.

$$600 \text{ m}^3 \times 0.16 \text{ t/m}^3 \times 1.2 = 115 \text{ t/day}.$$

In consideration of water for other works, water-supply facilities of 200 t/day were schemed. Unpurified water will in principle be used for the works, whereas a portion of purified water can be supplied to works at need since the facilities for living water have sufficient capacity.

1.6.2. Facilities for water supply in the left base.

Water supply for living in the left base is schemed on the same standard as the right base assuming that population to be supplied is 4,800 and daily maximum consumption per head is 0.3 t/day. The scheme is as follows.

a. Tube wells.

$$1,440 \text{ t/day} \div 576 \text{ t/day} = 2.5 \text{ wells or } 4 \text{ wells including one well for construction works.}$$

b. Storage tank.

$$1,440 \text{ t/day} \times 2 \text{ days} = 2,880 \text{ t or } 3,000 \text{ t}$$

c. Overhead distributing tank.

$$240 \text{ t/hr} \times 10 \text{ min}/60 \text{ min} \times 0.5 = 20 \text{ t}$$

d. Purification facilities.

$$1,440 \text{ t/day} \div (20 \text{ t/hr} \times 24 \text{ hr}) = 3 \text{ units or } 4 \text{ units adding one.}$$

1.7. Electric-power facilities.

All the electric power required for works and settlements must be generated in the bases. For this purpose, electric-power facilities must be set up in each of the bases.

1.7.1. Electric power.

Electric power required for the facilities in both bases is summarized as follows based on the estimation shown in Table 2 in APPENDIX A.

a. Right bank.

	Electric power demand(KW)
Dwelling settlement	8,980
Job settlement and main works	4,300
Total for right bank	13,280.

b. Left bank.

	Electric power demand(KW)
Dwelling settlement	4,020
Job settlement and main works	1,930
Total for left bank	5,950

c. Total electric demand on both sides of the river is 19,230 KW.

1.7.2. Facilities for electric power.

Power stations are installed in each construction base. Electricity shall be generated in heavy-oil plants, transmitted in 60 cycle and 3KV and transformed down to 100 V or 200 V according to use.

a. Electric-power facilities on the right bank.

Power generators: 2,000 KVA × 7 units = 14,000 KVA

Transformer substations for dwelling settlement: 14 units (100 V, 200 V)

Transformer substations for job settlement: 7 units (100 V, 200 V)

Transformer substation for main works: 1 unit

b. Electric-power facilities on the left bank.

Power generators: 2,000 KVA × 3 units = 6,000 KVA

Transformer substations for dwelling settlement: 6 units (100 V, 200 V)

Transformer substations for job settlement: 3 units (100 V, 200 V)

Transformer substation for main works: 1 unit

Power stations of 14,000 KW on the right bank and 6,000 KW on the left bank would have enough allowance because the power for the job settlements and the main works is consumed mainly in the daytime whereas the power for the dwelling settlements is consumed mainly in the nighttime.

1.8. Facilities in the job settlements and stone storage yards.

Job settlements are built on both sides of the river. In those settlements are set up such facilities required for control of the construction works as buildings, machines, materials storage yards, equipment yards and workshops. Fig.3-3 shows layout of the facilities in the main and branch bases. The following table gives area required for the lots for the job facilities, area required for roads and area required for cambers based on the estimates shown in Table 3 in APPENDIX A.

	Area (m^2)	
	Main base (right bank)	Branch base (left bank)
Lots for job facilities	522,200	145,700
Roads (20 m in width)	107,000	57,800
Roads (10 m in width)	21,300	8,400
Camber	162,000	159,100
Total	812,500	371,000

Stone storage yards are set on the existing grounds favorable to the guide-bank works. Stone materials are unloaded in the yards from trains or boats employed for carrying-in. Layout of the yards is shown Fig.3-1. Area of each yard is 510,000 m^2 which is necessary for storage of stone required for one-year works. If we assume that stone materials are imported from the eastern area of India and Assam State, they will be carried in to the right-bank storage yard by train and to the left-bank storage yard by boat from the producing sources or the right-bank sotrage yard.

1.9. Facilities in the dwelling settlements.

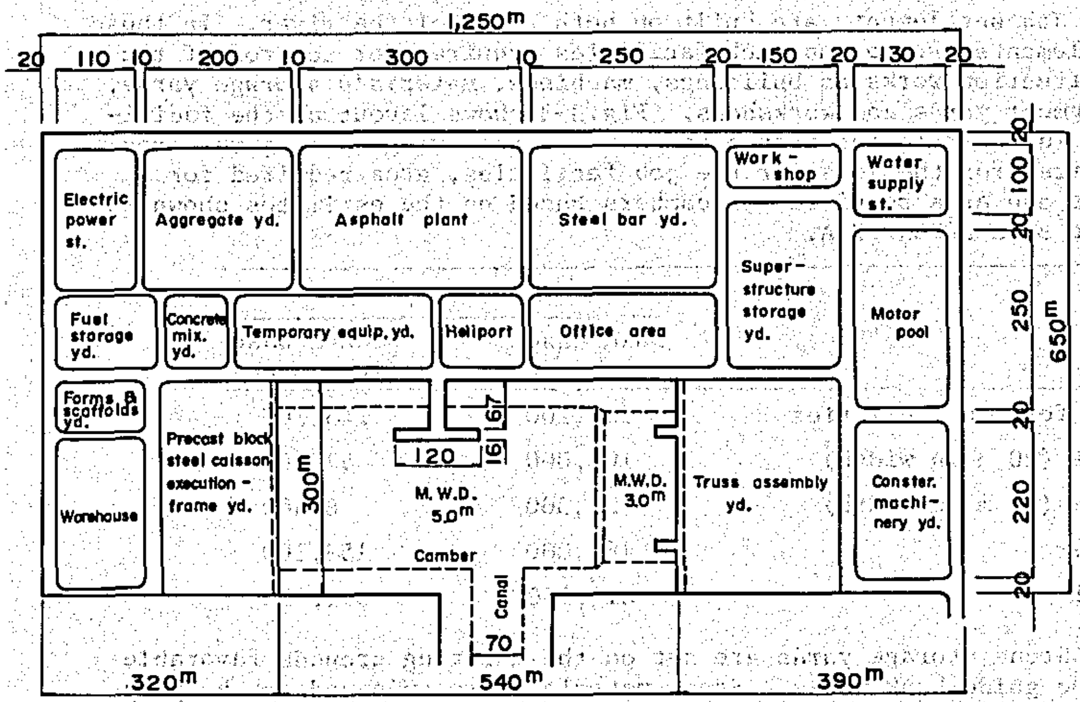
All the workers live in the dwelling settlements, where public facilities such as schools, distributing centers or markets, hospitals or clinics, police stations and facilities for recreation are prepared besides dwelling buildings. The dwelling settlements are prepared on each side of the river as shown in Fig.3-1 and 3-3. Area required for the dwelling settlements is estimated as follows based on the assumption given in Tables 4 and 5 in APPENDIX A.

	Floorage (m^2)	Plotage (m^2)
Right bank	173,800	560,000
Left bank	57,700	163,900

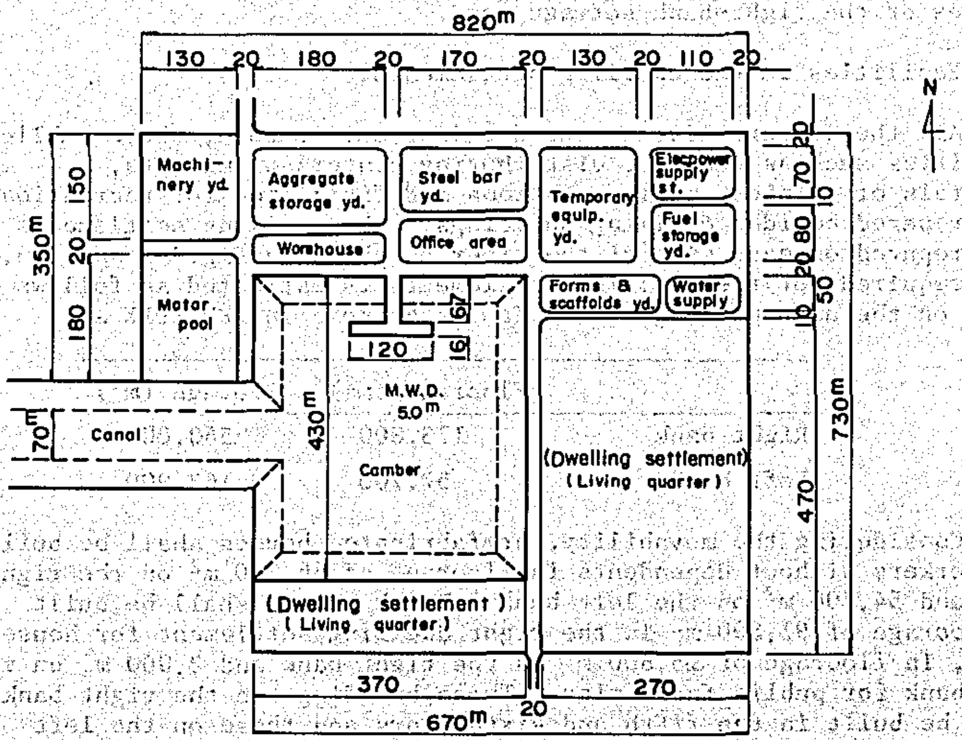
Considering the movability, prefabricated houses shall be built for workers without dependents in floorage of 66,200 m^2 on the right bank and 54,700 m^2 on the left bank. Brick houses shall be built in floorage of 91,800 m^2 in the right dwelling settlement for households, in floorage of 15,800 m on the right bank and 3,000 m on the left bank for public facilities. Those buildings on the right bank shall be built in the fifth and sixth years and those on the left

Fig. 3-3 Layout of Facilities in Construction Bases

Job Settlement in the Main Base (Right bank side)



Branch Construction Base (Left bank side)



Note : M.W.D = Minimum water depth

bank in the seventh and eighth years. In the seventh year, the main construction works on the left bank will just have started, hence the workers to be engaged in the works shall be sent from the right bank. Other facilities shall be built as mentioned in other articles.

1.10. Sewage treatment facilities.

Sewage treatment facilities shall be built on both sides of the river only for living waste water from the dwelling and job settlements and treated water shall be poured into the Jamuna River. The following facilities will be needed on each side of the river on the assumption that quantity of waste water on the right bank is 1,200 ton per day and 700 ton per day on the left bank. Waste water shall be lead by 500-mm-diameter vinyl pipes and treated water shall be poured into the river by open channels.

Facilities	Right bank	Left bank	Total
Storage tank (m^3)	1,200	700	1,900
Rotary aeration plant (unit)	12	7	19

1.11. Motor pools.

A motor pool having a plotage of 32,500 m^2 shall be set up in the main base and another motor pool having a plotage of 23,400 m^2 shall be set up in the branch base for periodical fixing and daily repairing.

Motor pools shall have buildings for offices, workshops, sheds, warehouses, laboratory and others. Floorage in the main base is estimated at 3,890 m^2 and that in the branch base 2,250 m^2. The buildings shall be provided with machines, tools and apparatuses. Besides these, the motor pools shall be provided with such mobile facilities as jeeps, machine-vehicles and trailers and further several facilities for water supply, oil supply and electric transformation.

1.12. Quantity of works for the construction bases.

Quantity of works for the construction bases is summarized in Table 3-1. The works on the right bank shall be finished in four years from the third through the sixth and the works on the left bank shall be finished in five years from the fifth through the ninth. Table 3-2 is the summary of quantity of major construction equipment, materials and number of laborers.

The above-mentioned quantity of materials and number of laborers include those required for maintenance and operation of the construction bases. Construction equipment whose life still remains after completion of the bases shall be applied not only to maintenance work of the bases but also to reserve for the main construction works.

Table 3-1 Quantity of Works for the Construction Bases

Items	Right base	Left base	Total
Reclamation of lands			
land area	1,210,500 m^2	375,800 m^2	1,586,300 m^2
dredging volume	2,905,000 m^3	676,000 m^3	3,581,000 m^3
Temporary roads			
road length	18.88 km	16.61 km	35.49 km
Temporary railway			
railway length	8.35 km	—	8.35 km
Cambers and canals			
area of cambers	162,000 m^2	159,100 m^2	321,100 m^2
canal length	3,150 m	350 m	3,500 m
dredging volume	3,047 m^3	2,004 m^3	5,051 m^3
Water supply facilities			
max water consumption per day	2,460 t/day	1,440 t/day	3,900 t/day
Electric power supply facilities			
electric power consumption	13,160 KW	5,960 KW	19,120 KW
Job settlements			
area	650,500 m^2	211,900 m^2	862,400 m^2
number of lots for facilities	16	11	27
Dwelling settlements			
area	560,000 m^2	163,900 m^2	723,900 m^2
Floorage for houses for workers without dependents	66,200 m^2	54,700 m^2	120,900 m^2
houses for households	1,700 houses	—	1,700 houses
Sewage-treatment facilities			
waste water per day	1,200 m^3	700 m^3	1,900 m^3
Motor pools			
area (inside of job settlements)	32,500 m^2	23,400 m^2	55,900 m^2

Table 3-2 Quantity of Major Construction Equipment, Materials and Number of Laborers

(Construction base)

Item	Unit	Year												Total
		2nd.	3rd.	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	
EQUIPMENT FOR CONSTRUCTION (FOREIGN)														
Bull dozer(2,8,13t)	nos		6	16	16	16	16	16	16	16	16	16	16	
Tractor shovel(1.2m³)	"		6	6	6	6	6	6	6	6	6	6	6	
Trailer(40t)	"		–	–	3	3	3	3	3	3	3	3	3	
Dump truck(4,8,12t)	"		5	5	33	33	33	33	33	33	33	33	33	
Truck(4,8,11t)	"		6	12	40	40	40	40	40	40	40	40	40	
Truck crane(10,20,30t)	"		2	4	17	17	17	17	17	17	17	17	17	
Crawler crane(8t,955)	"		–	–	10	10	10	10	10	10	10	10	10	
Concrete agitator car(4.5m³)	"		–	–	15	15	15	15	15	15	15	15	15	
Diesel hammer(2.2,4.0t)	"		–	–	6	6	6	6	–	–	–	–	–	
Vibro hammer(40,60,90KW)	"		–	–	6	6	6	6	–	–	–	–	–	
Generator(50,125,300KW)	"		5	5	38	38	38	38	38	38	38	38	38	
Under water pump(ϕ100,150)	"		–	–	20	20	20	20	20	20	20	20	20	
Winch(30PS)	"		–	–	10	10	10	10	10	10	10	10	10	
Pump dredger(600,4000PS)	"		–	2	2	1	1	1	1	1	1	1	1	
Anchor barge(5,15t)	"		–	6	6	5	5	5	5	5	5	5	5	
Tugboat(300,500,1500PS)	"		–	8	8	8	8	8	8	8	8	8	8	
Floating crane(1,000t)	"		–	2	2	2	2	2	2	2	2	2	2	
Communication boat(6.5PS)	"		2	4	4	4	4	4	4	4	4	4	4	
Survey boat(50PS)	"		–	1	1	1	1	1	1	1	1	1	1	
Other equipment	l.s.													
EQUIPMENT FOR FACILITIES (FOREIGN)														
Well equipment(0.5t/min)	units		–	–	7	10	10	10	10	10	10	10	10	
Purification plant(20t/hr)	"		–	–	6	10	10	10	10	10	10	10	10	
Diesel generator(2,000KVA)	"		–	–	7	10	10	10	10	10	10	10	10	
Transformer facilities	sets		–	–	1	2	2	2	2	2	2	2	2	
Unloader	"		–	–	2	4	4	4	4	4	4	4	4	
Goliath crane	"		–	–	3	5	5	5	5	5	5	5	5	
Stiff leg derick crane	"		–	–	2	2	2	2	2	2	2	2	2	
Sewage-treatment plant	units		–	–	12	12	19	19	19	19	19	19	19	
Machines for motor-pool(4kind)	sets		–	–	1	2	2	2	2	2	2	2	2	
Buildings(brick)	10^3m^2		–	–	108	111	111	111	111	111	111	111	111	
-do- (prefabricated)	"		–	–	81	143	143	143	143	143	143	143	143	
Bus(for 50men)	nos		–	–	–	–	15	15	15	15	15	15	15	
Jeep	"		–	–	–	–	100	100	100	100	100	100	100	
Ferry boat(for 300 men)	"		–	–	–	–	2	2	2	2	2	2	2	
Other equipment	l.s.													
MATERIALS(DOMESTIC)														
Brick	10^3Pc		–	–	2,469	1,002	34	34	–	–	–	–	–	3,539
Bat	10^3m^3		–	72.6	280.7	123.4	10.9	10.9	24.0	14.6	14.7	14.7	–	566.5
Crushed stone & gravel	"		–	–	21.7	10.1	0.3	0.3	2.7	1.6	1.6	1.6	–	39.9
Sand	"		–	–	12.8	6.0	0.2	0.2	1.5	0.9	0.9	0.9	–	23.4
Ballast	"		16.7	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	49.7
Other materials	l.s.													
MATERIALS(FOREIGN)														
Asphalt	m^3		–	–	1,640	800	–	–	200	100	100	100	–	2,940
Cement	t		–	–	1,214	556	94	84	–	–	–	–	–	1,948
Structural steel	"		–	–	9,518	2,940	10	100	–	–	–	–	–	12,568
Rail	"		835	–	234	–	–	–	–	–	–	–	–	1,069
Tie rod	nos		–	–	445	–	–	–	–	–	–	–	–	445
Steel bar	t		–	–	411	187	31	31	–	–	–	–	–	660
Service steel pipe	t		–	–	560	340	–	–	–	–	–	–	–	900
Oxygen gas	10^3m^3		–	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	–	–	67.2
Acetylene gas	10^3kg		–	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	–	–	48.0
Light oil	10^3kl		0.3	0.4	1.4	1.8	1.7	1.8	1.8	1.8	1.5	1.4	0.5	14.4
Heavy oil	"		–	5.4	5.9	8.2	9.5	8.7	10.7	9.3	7.7	7.7	7.7	80.8
Other materials	l.s.													
LABORER(DOMESTIC)														
Skilled laborer	10^3man. day		19.2	16.9	83.7	71.5	39.3	42.0	46.3	38.6	38.5	21.9	21.9	439.8
Unskilled laborer	"		18.0	39.8	385.2	281.7	84.4	101.3	103.0	59.7	59.7	59.6	59.6	1,252.0
LABORER(FOREIGN)														
Skilled laborer	10^3man. day		7.4	33.9	77.6	61.6	42.4	45.2	41.5	26.1	26.1	17.0	15.9	394.7

2. Operation and Maintenance of the Construction Bases.

The construction bases must be in good service for the main construction works over eight years from the sixth through the thirteenth, during which the facilities must be maintained so as to their functions.

2.1. Management.

Exclusive staffs, engineers and laborers shall be stationed and necessary materials shsll be provided for management of the temporary railway and such facilities in the bases as water supply facilities, electric-power facilities, sewage treatment facilities, motor pools, heliport and medical facilities.

For communication between the bases and the work sites as well as in the bases, further, for transportation of workers, equipment and materials among them, exclusive transport facilities shall be prepared and exclusive personnel and necessary equipment and materials shall be provided for them. Buses, jeeps, trucks and dump trucks employed for base construction works shall be provided for traffic on land; ferry boats, communication boats and barges employed for the base construction works shall be provided for water-borne traffic; and helicopters shall be prepared for air traffic. Table 3-2 also includes quantity of equipment and materials and number of workers necessary for the management.

2.2. Maintenance works.

Repair works will be necessary for maintenance of the roads and the railway since they may be damaged by heavy traffic. Also dredging works will be necessary for maintenance of depth of the cambers and the canals since they will be shallowed by sediment during every flood season. Some of the construction equipment shall be employed for the maintenance works for the railway and the roads. A600-PS dredger shall be employed for the dredging works for maintenance.

3. Procurement of Equipment and Materials Required for the Base Construction Works.

Equipment and materials required for the construction and the maintenance of the construction bases were already shown in Table 3-2. Procurement of them is mentioned in Chapter IV together with that for the main construction works.

CHAPTER IV

MAIN CONSTRUCTION WORKS

1. Construction Schedule.

It will take more than three years for preliminary works, around seven years for construction of construction bases and roughly eight years for the main construction works. These three will be executed overlapping each other; consequently the project will be completed in thirteen years. The detail of the schedule is shown in Fig.4-1.

The surveying will be commenced in the first year immediately after the rainy season has been over and one year and a half will be spent for it. Detailed designs will be commenced at the same time as the surveying and will be finished in three years. Procurement will be begun with equipment and materials required for hydraulic model test and other preliminary works. Procurement of equipment and materials required for the construction bases and the main construction works will be started in the second year and continued to the last year. Transportation of the procured equipment and materials will be commenced in the first year and continued to the last year. Land acquisition shall be started in the first year and finished in the eleventh year.

Construction of the construction bases shall be commenced in the third year to complete the main base on the right bank in the sixth year and the branch base on the left bank in the ninth year.

Execution of the main construction works shall be begun with the bridge approach works on the right bank in the sixth year. The bridge substructures shall be constructed in five years beginning in the seventh year, the superstructures shall be constructed in six years beginning in the eighth year. The guide banks shall be constructed in four years beginning in the seventh year, the bridge approaches in seven years and the Dhaleswari new channel in three years beginning in the tenth year.

The railway link on the right side of the river shall be constructed in the second year to be used for general communication and transportation of equipment and materials. The railway link to connect the bridge with the city of Dacca shall be constructed in three years beginning in the eleventh year. The road links on both sides of the river shall be constructed in three years beginning in the tenth year.

A 4,000-PS dredger shall be employed for nine years from the fourth year through the twelfth for the purpose of reclamation of the construction bases including construction of cambers and canals, obtaining of earth to be used for the guide banks and the approaches and excavation of the Dhaleswari new channel. The construction schedule was planned also in consideration of effective employment of the dredger. Thin lines in Fig.4-1 show the employment of the dredger.

2. Bridge Construction Works.

Bridge construction is composed of temporary works, substructure works, superstructure works, reinforced-concrete works, bridge-approach works, asphalt-pavement works and permanent-way works. Eight years beginning in the sixth year will be spent for carrying out these works. The construction schedule is shown in Fig.4-2.

The bridge construction shall be begun with dredging work for obtaining earth to be used for embankment of the right-bank approach in the sixth year. In the same year, temporary works shall be commenced and continued through the thirteenth year for preparation and execution of the bridge construction works.

Substructures shall be constructed in five years beginning in the seventh year, superstructure works shall be commenced one year later than the substructure works and finished in five years. Reinforced-concrete slabs of the bridge shall be built in four years beginning in the tenth year.

The bridge approach on the right side of the river shall be constructed in five years beginning in the sixth year and construction works of the left-bank approach shall be commenced two years later than the right-bank approach and finished in five years. In the last thirteenth year, the bridge construction works shall be finalized with asphalt-pavement works for road and permanent-way works for railway.

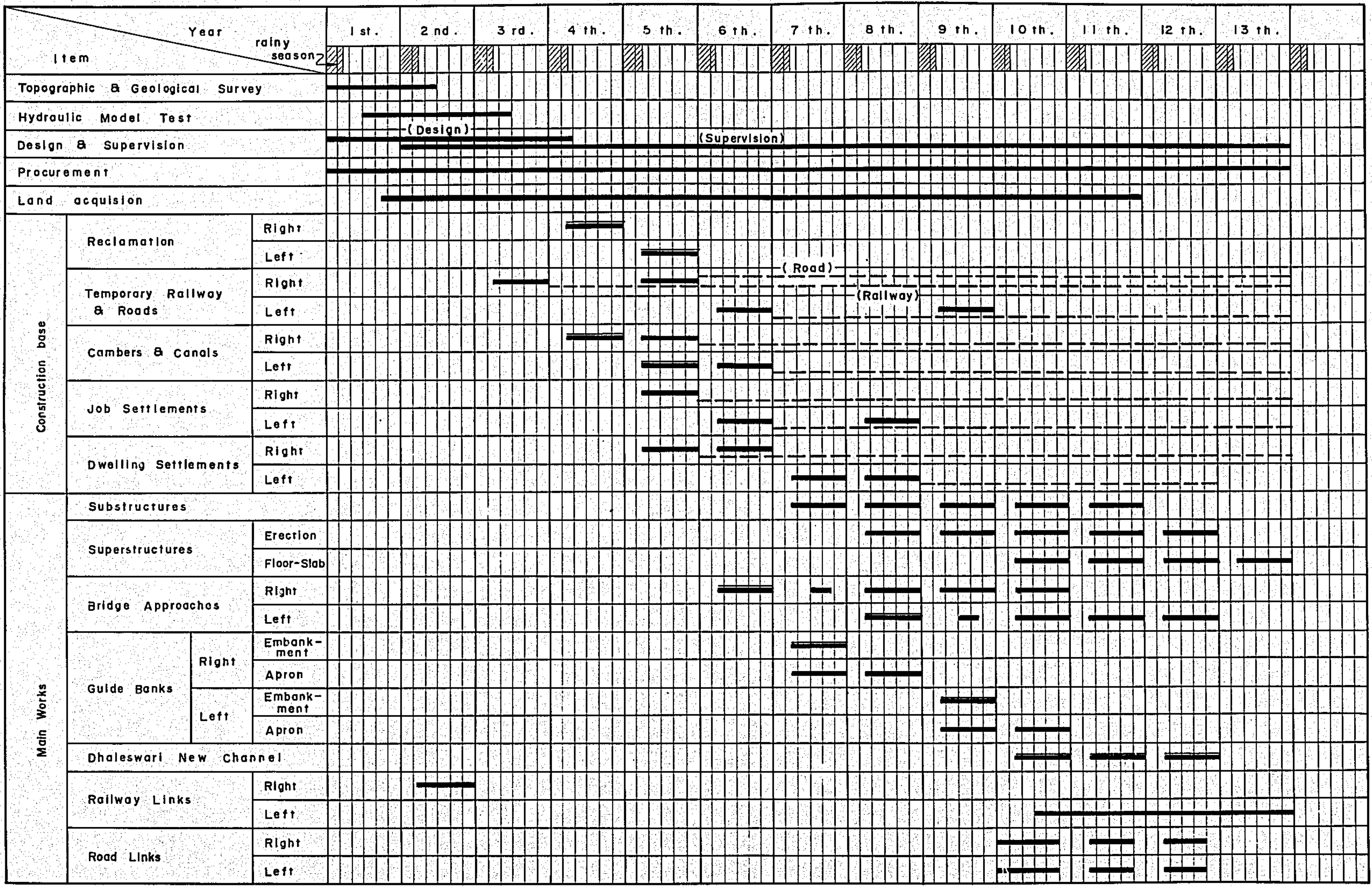
Substructure works shall be finished during dry seasons in consideration of severe scouring during flood seasons and employment efficiency of stagings for pier construction. Execution of the substructure works is classified into two parts. One is the works on land where chars will appear in the dry season and the other is the works in stream where water flow still exists even in the dry season. We have fourteen substructures respectively on land and in stream. Fig. 4-3 shows flow of well-sinking works on land and Fig.4-4 is flow chart of well-sinking works in stream.

In the well-sinking works on land, we adopted the ordinary method that the well is constructed after excavation of the ground until reaching the depth for setting the curb shoe. For construction of concrete well, slip-form system was adopted to shorten the term of the works.

The well-sinking works in stream shall be begun with setting-out of steel caisson and setting of execution frame to be used for holding of the caisson, excavation of earth and construction of concrete well. The execution frame is a truss structure composed of steel pipes and H-beams and weighs about 470 t. Execution of steel caisson works and well construction works by use of precast concrete blocks are shown in flow charts in Figs.4-5 and 4-6.

Two 2-m diameter boring machines provided with facilities for reverse circulation shall be employed for excavation of earth in wells on land as well as in stream. The two boring machines are set symmetrically and shifted so as to maintain uniform sinking without leaning.

Fig.4-1 Construction Schedule for the Jamuna Bridge Project



Note : Year begins in July and ends in June

Legend : ▬▬ : Works by pump dredger (4000 ps)
– – – – : Period of maintenance

Fig.4-2 Construction Schedule of Bridge

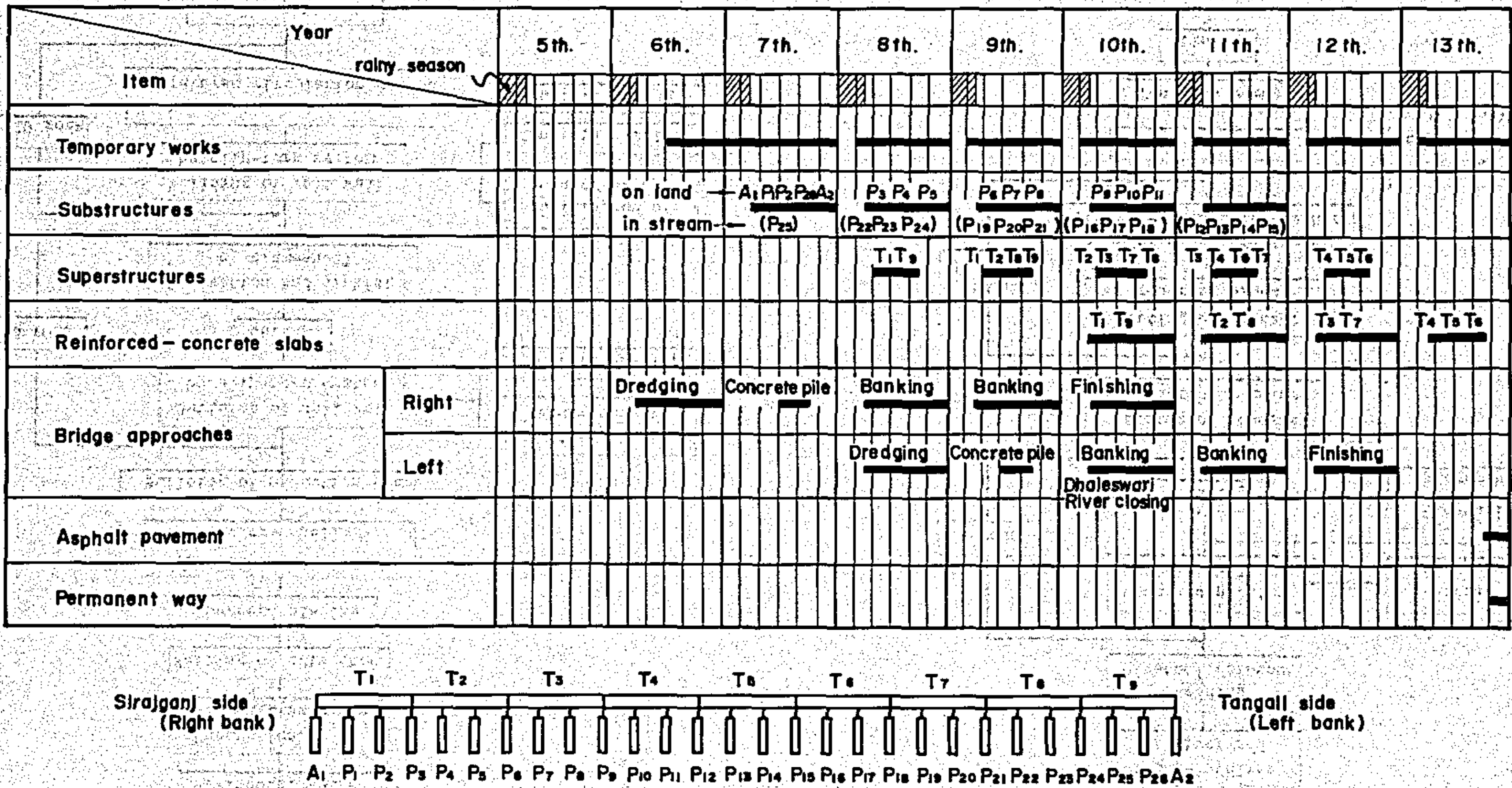


Fig.4-3 Flow Chart of Well-Sinking Work on Land

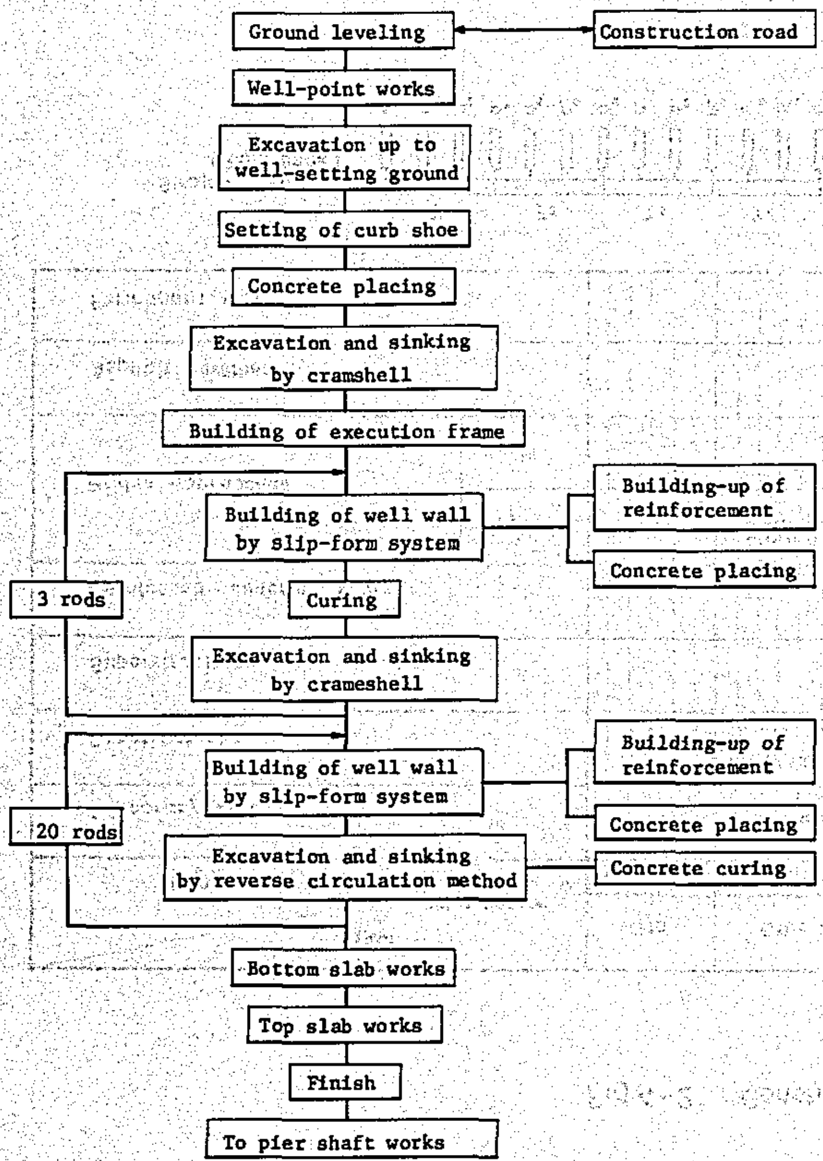


Fig.4-4 Flow Chart of Well-Sinking Work in Stream

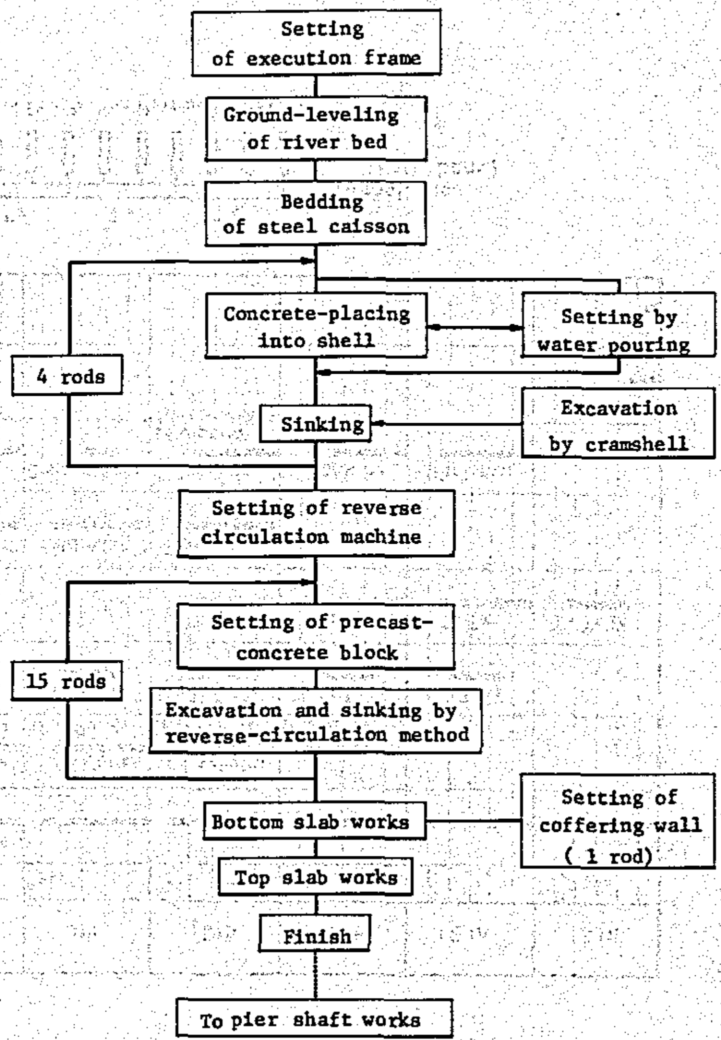


Fig.4-5 Flow Chart of Execution of Steel Caisson Work

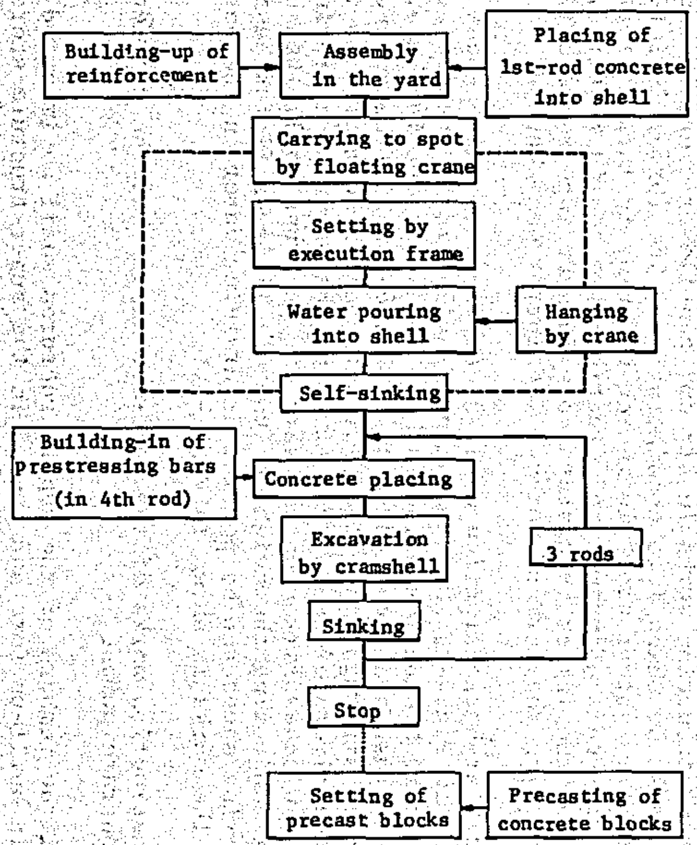
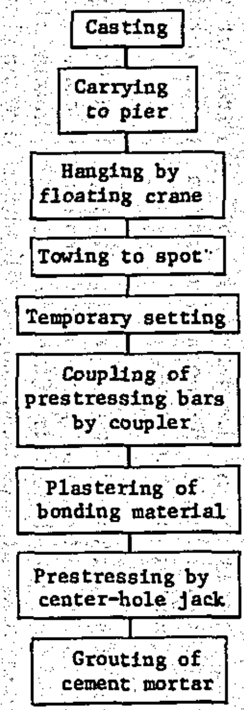


Fig.4-6 Flow Chart of Setting Work of Precast-Concrete Blocks



Air jetting shall be used for reducing friction in sinking. Bottom slab of the well shall be constructed in prepacked concrete and top slab of the well shall be constructed dividing 5-m thickness into two layers by concrete pump placed on a boat.

Pier shaft shall be constructed by concrete pump by using large steel forms so as to shorten the term of the works.

Twenty-eight substructures shall be completed in five years. Number of substructures to be finished in one year is six at maximum, three of which are those on land and the other three of which are those in stream. The works shall be commenced from the river banks and shifted to the center of the river.

Construction works of the superstructures consisting of 27 spans of trusses shall be started one year later than the construction works of the substructures and completed in five years. Six spans of trusses shall be erected in one year at maximum, three of which are on land and the other three are in stream. All the works shall be executed in the dry seasons.

For the construction works on land, erection by staging was adopted because of simplicity of works, less erection-stresses and economic advantage. Stagings shall be built every two panels (2 × 12.5 m) and pile foundation shall be applied. After setting shoes on piers, lower chords, lower lateral bracings and floor system shall be assembled on the stages and the first adjustment of camber shall then be conducted. Next, diagonals, verticals, upper chords, sway bracings and upper lateral-bracings shall be assembled and the erection will be finished by the second adjustment of camber. For connection of members, high-tension bolts shall be used. Staging erection shall be applied to 15 spans among 27. Flow of the works is shown in Fig.4-7.

For construction works in stream, cantilever erection and flat-barge erection must be taken into consideration. The former is inferior by reason that weight of steel is increased owing to larger erection-stresses and a large-scale adjustment of erection-stresses is required. On the other hand, the latter is advantageous in securing less erection-stresses and shortening the term of works. The latter was adopted.

The flat-barge erection shall be applied to twelve spans of P_{13} to P_{25} shown in Fig.4-2. One-span truss shall first be assembled in the assembly yard beside the camber of the main construction base. The assembled truss shall be loaded on a 12,000-ton flat barge and towed to the spot by six tugboats. The flat barge shall be moored to the achors set in the river beforehand and fixed at the position operating the tugboats and winches fitted on the barge. The truss shall then be set on the piers adjusting the height by use of oil jacks fitted beside the four bearing shoes and by pouring or draining water in the barge. The flow of the works is shown in Fig.4-8.

Construction works of the concrete slabs shall be carried out by using concrete pumps.

All the members of the superstructures shall be imported from abroad in built-up form and stored in the superstructure storage yard of the main construction base. Since it will take much time before erection

Fig.4-7 Erection of Superstructure by Staging

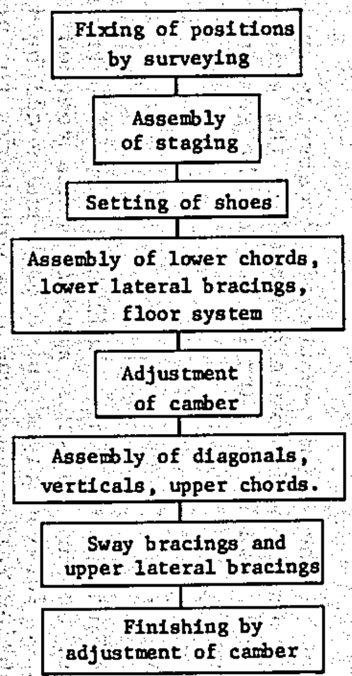
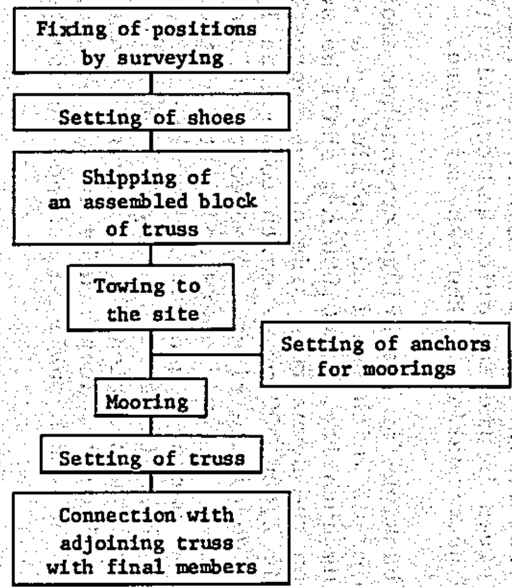


Fig.4-8 Erection of Superstructure by flat Barge



in the field after fabrication in factories abroad, the first undercoating alone shall be given in the factories and coated with paint after sand blasting and undercoating in the assembly yard.

Quantity of earth banking for the bridge approaches amounts to 8,900,000 m^3, 4,800,000 m^3 of which shall be supplied by a 4,000-PS dredger and the remaining quantity, 4,100,000 m^3, shall be supplied by excavation in the area on the downstream side of the approaches. The pump dredger shall supply 2,400,000 m^3 of earth to an area 1,500 m long and 600 m wide on each side of the river. Dredged earth shall be carried and banked by 32.4-m^3 motorscrapers and earth of the ground shall be excavated by 3-m^3 backhoes and carried by 32-ton dump-trucks to the spots. Dumped earth shall be leveled by 35-ton bulldozers together with motorgraders. Compaction shall be carried out by 12-ton tirerollers besides by bulldozers, dump trucks and motorscrapers to run during the banking. The works shall be stopped during the rainy months.

The works shall be begun with the banking of the right approach and, finishing in two years, shifted to the left approach. Slope protection works, drain works and subbase-course works shall be finished in one year following the banking works. Surface-course works and permanent-way works shall be carried out together with those on the bridge after the concrete-slab works have been finished.

On the left side of the river, the bridge approach crosses the Dhaleswari River by closing it by a cross dam, on which railway and road shall be built.

For closing the Dhaleswari River, stone dikes are first constructed up to a height of 9.00 m PWD on both sides of the approach axis or at both feet of the approach to be built, then the portion between the two stone dikes is reclaimed by earth and banked up to the height of 12.0 m PWD which is the average ground level. It will be comparatively easy to close the Dhaleswari River in the dry season because the river will almost dry up in that season.

Stones shall be pitched by man-power after carrying into the sites by 32-ton dump trucks which were employed in the guide-bank works. Banking of earth shall be carried out in the same way as the approach earth works.

3. River Control Works.

Construction of the guide banks shall be begun with the works on the right bank after storage of stone materials has reached a half of the quantity required for the right guide bank and shall be finished in four years. Banking works and stone pitching works for protection of the slope surfaces shall be carried out in one year and the stone pitching works for the apron shall be executed in the second year. After completion of the right guide bank, the work shall be shifted to the left guide bank, which shall be completed by the same procedures as the right.

The stone materials required for the guide-bank works shall be transported by train to the right-bank stone-storage yard and by boat to the left-bank stone-storage yard. The transportation work on every side of the river shall be begun one year and a half before commencement of the guide-bank works and finished in two years and a half.

The guide banks shall be banked with earth directly poured by a 4,000-PS dredger with the aid of enclosure wall of light sheet piles. 16-ton bulldozers shall be employed for banking-up and finishing. River-side slope is protected by stone pitching at the same time as banking, while land-side slope shall be protected by sodding. The crown of the banks shall be paved for protection and serving as maintenance roads.

In stone-pitching works for the aprons, stones will be loaded by tractorshovels in the stone storage yards, carried by dumptrucks and pitched by manpower by the aid of tiredozers. Stone chips will be placed on a layer of pitched stones for serving as construction road for the next layer, which shall form a part of the apron.

The construction schedule of the river control works is shown in Fig. 4-9 and the flow of the works is shown in Fig.4-10. Principal equipment to be employed for the works are as follows.

5-m^3 Tractorshovels

32-ton Dump trucks

19-ton Tiredozer

4,000-PS Diesel pump dredger

200-PS Anchor barges

15-KW Vibro pile driver/drawers

20-ton Crawler cranes

125-KVA Generators

16-ton Swamp-type bulldozers

10-ton Macadam roller

200-ℓ Asphalt sprayer

60-kg Tamper

Dhaleswari new channel shall be excavated by the dredger which was employed in the guide-bank works. In the first year of this work, the central channel 65 m in bottom width shall be excavated over the whole length of the channel and finished by widening-dredging in another two years. Dredged earth shall be pored into low-lying land or abondoned rivers adjacent to the channel. The area to be used for the spoil is estimated at 2,970,000 m^2. The dredging works and the spoil works shall be provided with swamp-type bulldozers as assisting machines. Principal machinery to be employed for the works are as follows.

4,000-PS Diesel pump dredger

200-PS Anchor barge

Fig.4-9 Construction Schedule of River Control Works

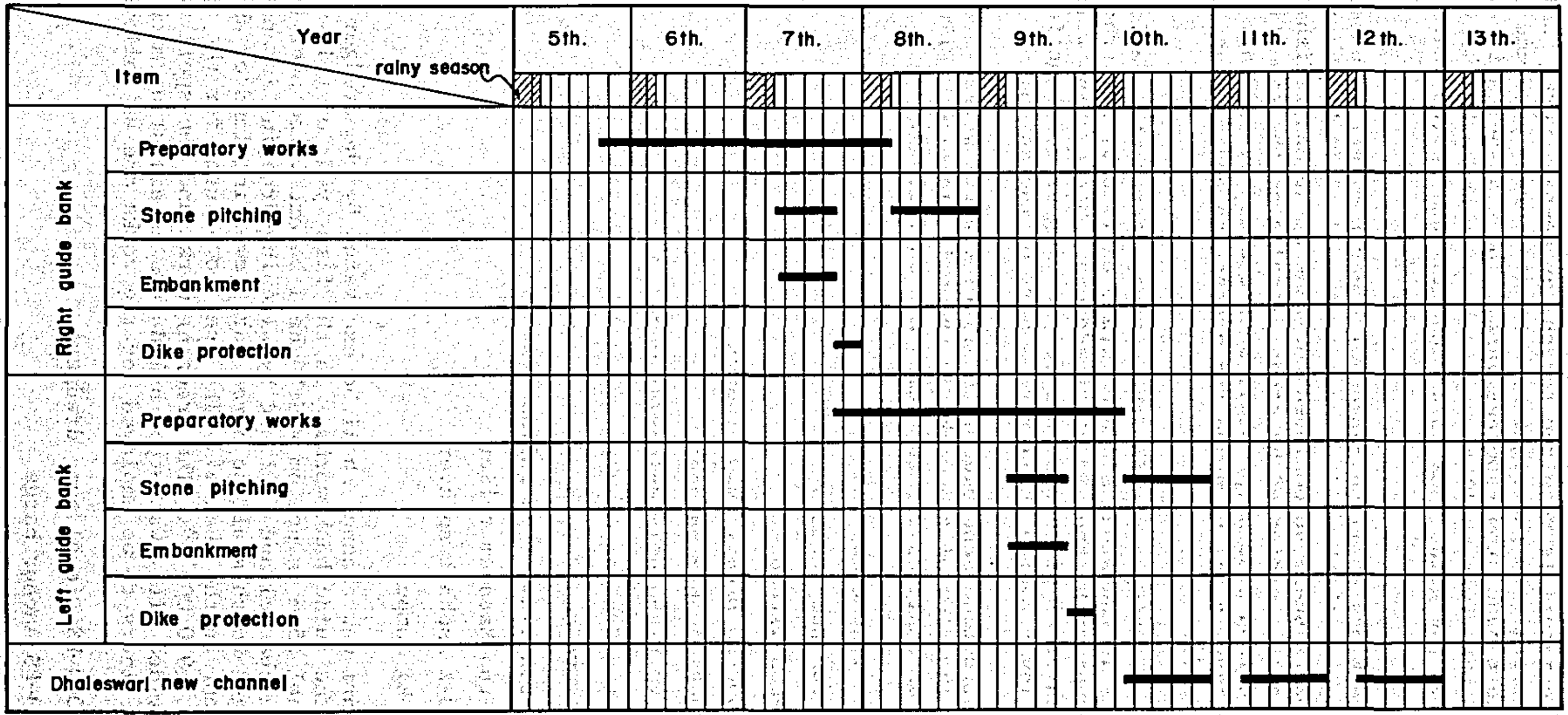
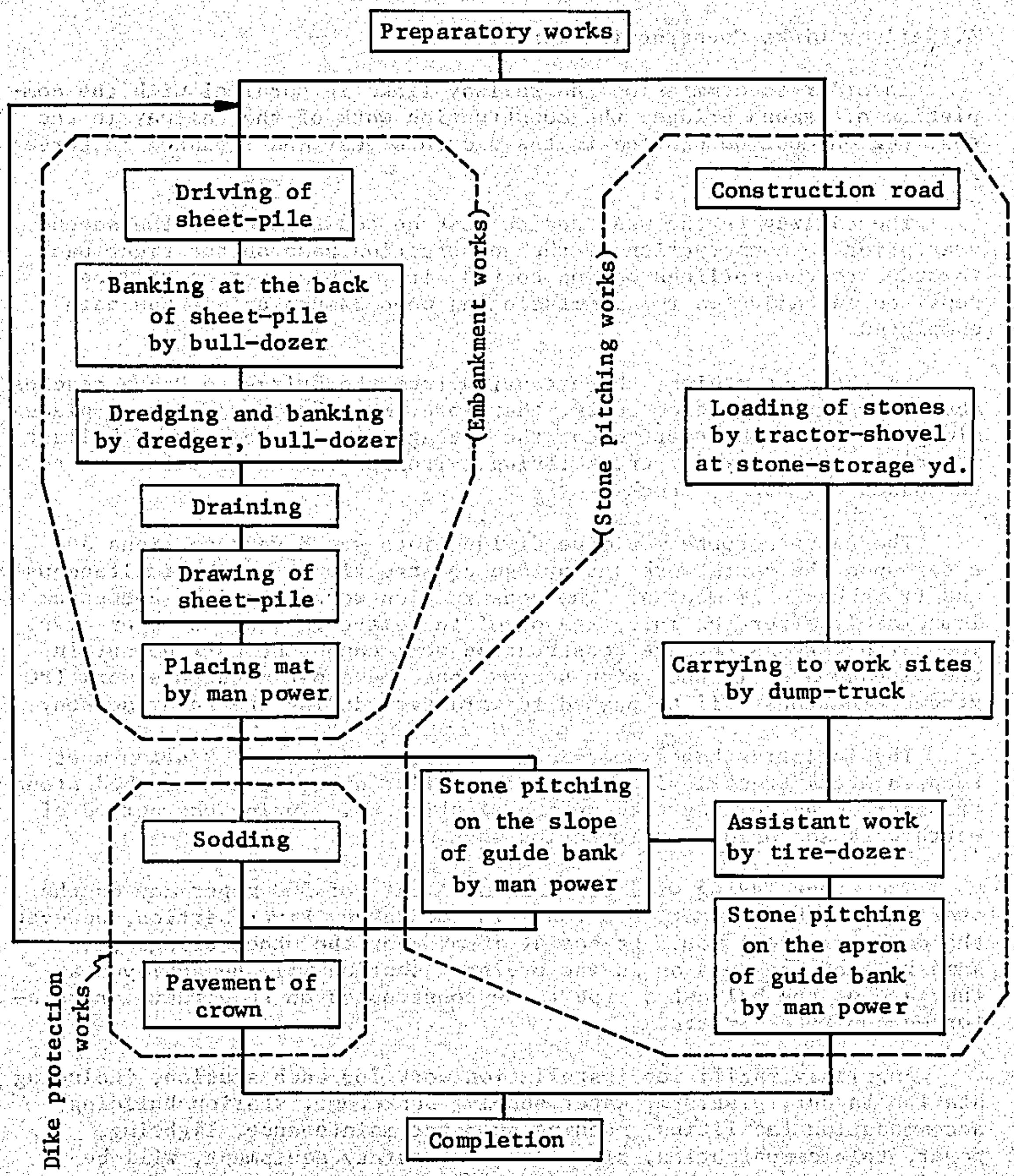


Fig.4-10 Flow of Construction Works of Guide Banks



15-KW Vibro pile driver/drawers

20-ton Crawler cranes

125-KVA Generators

16-ton Swamp-type bulldozers

32-ton Dump trucks

4. Railway Links Construction Works.

In order to commission the railway links in parallel with the completion of Jamuna Bridge, the construction work of the railway in the east region must be started in the eleventh year and finished in three years.

The railway in the west region must be constructed in the second year prior to construction of the construction base on the right bank in order to run rollingstock up to the site. This section will be repaired and adjusted for commissioning when Jamuna Bridge has been completed.

In the east region, the extension from the bridge to Dacca reaches about 100 km. Logistics bases, therefore, must be set at 3 to 4 places along the route in order to cut the haulage of huge volumes of ballast materials necessary for track laying. Transportation of materials to the bases will be by trucks.

The eastern route would be divided into say 8 work sections and enter upon the earth work and bridge construction of each simultaneously and finished in 28 months. The construction works shall be commenced immediately after the rainy season of the eleventh year has been over. The earth work and bridge construction work cannot be carried out in the flooded area in the rainy season, but the super structure work (PC girder erection) will be pushed forward even during the rainy season.

The logistics bases near Salap Station and Azampur Station must keep in stock track-laying materials, rails, sleepers and crushed stone transported by rollingstock by the existing rail during the period of earth work and bridge construction work.

The track laying will progress at a rate of 300 m per day on the average for the ordinary section. In the Jamuna River Section, however the daily progress would be set at 80 m. For the other bridges, the same rate of progress as in the ordinary section will be achieved as they are of the ballasted type to be constructed on PC girders or reinforced concrete girders.

Ancillary facilities installation work for each station, including station layout, platform, water supply, bunkerage, station building, accommodation facilities, machine shop for maintenance, lighting, power, telecommunication, signalling and safety equipment, will be carried out along with the principal track-laying work, and will be completed in time with the completion of the track. After the completion of the railway track, one or two months will be spared for track maintenance which is to be continued until the commissioning operation is started, as well as for the trial run. The construction schedule of the railway links is shown in Fig.4-11.

5. Road Links Construction Works.

The embankment work amounting to 602,000 m and box culverts construction works shall be commenced in the dry season of the tenths year and finished in three years. Two PC girder bridges, one on the right side (over the Hurasagar River) and the other on the left side, shall be constructed in two years of the 11th and 12th; the substructure works in the 11th year and the superstructure works in the 12th year. Pavement works, including 6" sand sub-base, 3" brick flat, 9" water bound macadam, 2.5" bitumious concrete, 0.5" surface, 4.5" brick on edge and 3" brick on end, together with shoulder protection work shall be carried out in three dry seasons from the 10th to 12th. The construction schedule is shown in Fig.4-12.

6. Procurement of Equipment and Materials.

In procuring equipment and materials, we must consider to take as much domestic products as possible. Under the present condition, however, most of construction equipment must be imported from abroad and further, procurement of construction materials also must rely on import in the majority as most of the required materials are not produced in the country and, even if we could procure some, they must smoothly be supplied in quantities and over a long period. It has been planned, therefore, to procure such domestic materials as sand, gravel, brick, bat and a part of timber. Even for these materials, production and supply system must be improved or strengthened as the capacity of production is insufficient in the present state.

Taking into consideration that we must import many and various equipment and materials in a considerably short period and moreover the present project is a great undertaking of national importance, unified importing by the Government is required for carrying forward the construction works smoothly. Construction equipment on land and on the water, vehicles and such equipment to be imported, and steel materials, steel manufactures, fuel, lubricant, paint, asphalt, cement and stone materials are enumerated as the major materials to be imported.

Among these, procurement of stone materials was studied in detail by the Geology and Stone Material Study Team. As mentioned in VOLUME VII GEOLOGY AND STONE MATERIAL, we can find promising sources of supply in the eastern area of India and Assam State provided that we assume to import stone materials. In this case, stone materials in the quarries in the eastern India shall be transported to the stone storage yard via the existing railways, the railway link to be built in the present project and the temporary railway, while the stone materials produced in Assam State shall be transported to the stone storage yard via the existing railways, the railway link to be built in the present project and the temporary railway, while the stone materials produced in Assam State shall be transported by boat running down the Brahmaputra-Jamuna River and directly carried in the stone storage yard.

Fuel and lubricant can be supplied by installing supply-facilities

Fig.4-11 Construction Schedule of Railway Links

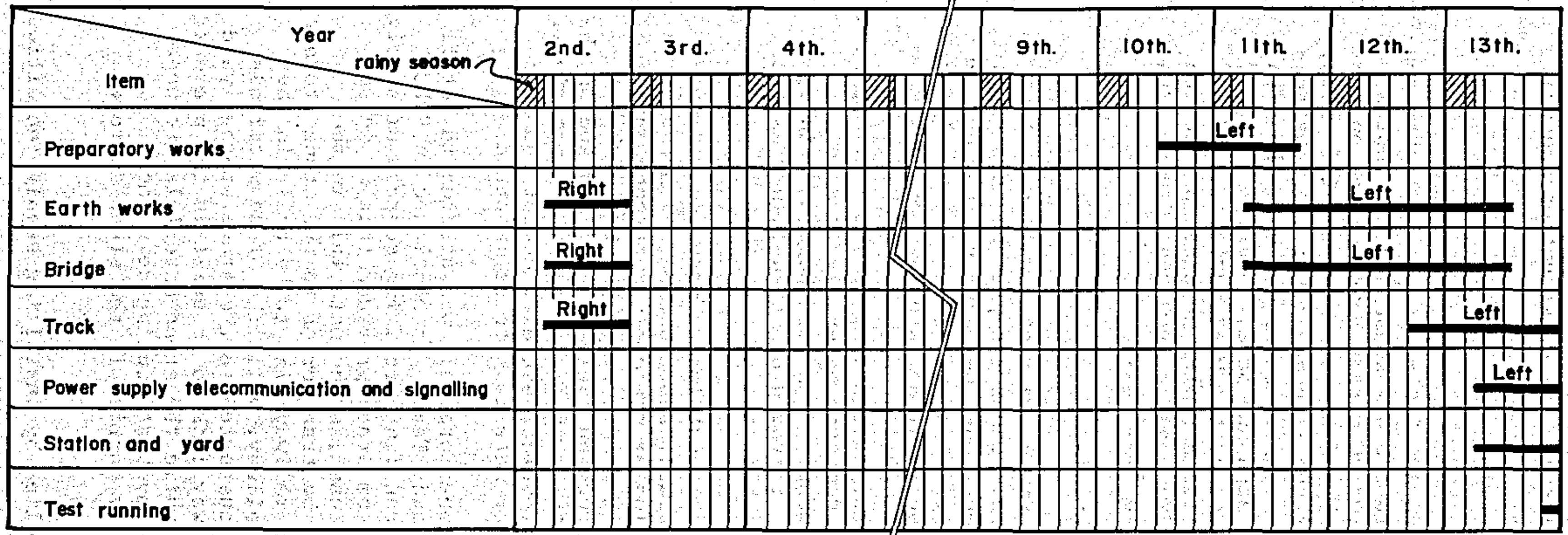
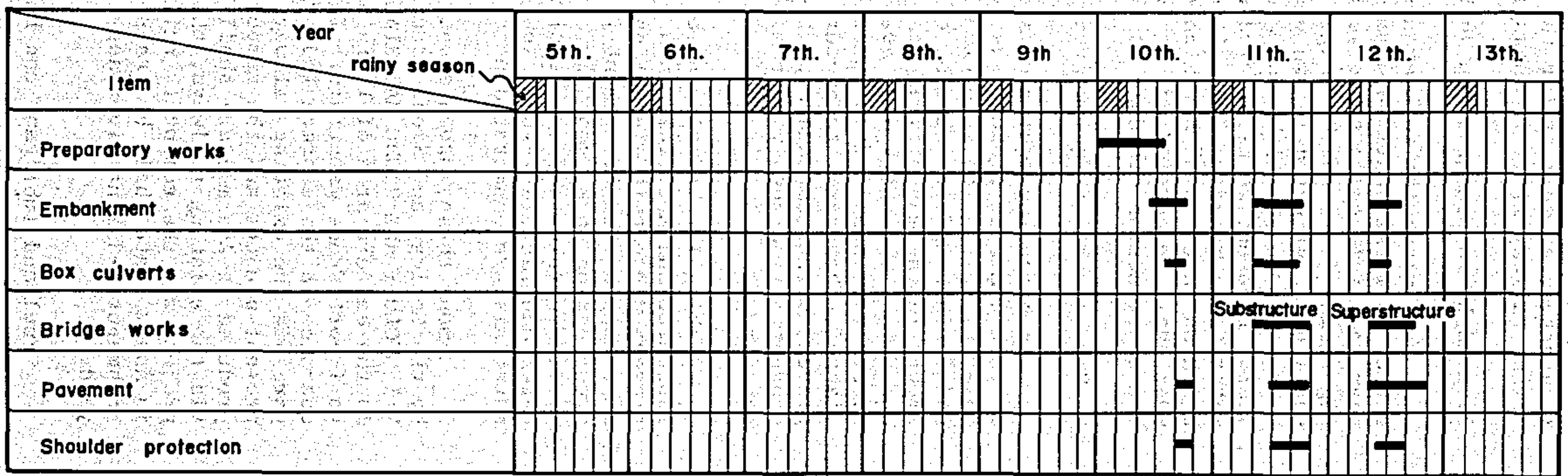


Fig. 4-12 Construction Schedule of Road Links



of the domestic oil-supply organization in the compound of the construction bases.

Other equipment and materials to be imported shall be transported by ship from shipping ports abroad to Chalna Port, and the following two routes can be taken for the transportation from Chalna Port to the job site.

a. Transportation on the water: From Chalna Port to the job site by boat.

b. Transportation by rail: From Chalna Port to Khulna Port by boat and to the job site by rail.

The present conditions of these routes are as follows.

a. The BIWTA guarantees a depth of 6 ft on all the channels from Chalna Port to the job site.

b. In our judgement of the present supply capacity of barges and tugboats, it is difficult to rely only upon the transportation on the water. Especially in the rainy season, transportation capacity may be much decreased as one tugboat may operate only one barge notwithstanding capable of two barges in the dry season.

c. Quaywalls and cargo-handling facilities in Khulna Port are on small scale and superannuated.

d. There is a distance more than 200 m between the quaywalls of Khulna Port and loading place of railway, and no facilities for cargo handling.

In our judgement of the above-mentioned conditions, it was decided to take both routes; transportation by rail for cargo that are easy to transship and transportation by boat for other heavy and large cargo.

For the transportation, the existing facilities must be improved by expansion or strengthening. The existing railway must be strengthened so as to meet the transportation of a large quantity of heavy cargo. For transportation on the water, it is necessary not only to maintain the navigation channels, but also to install such facilities as navigation aids so as to enable nighttime navigation. Also cargo-handling facilities must be supplemented or strengthened. Among others, we must pay attention to preparing temporary cargo-handling facilities for the equipment and materials piror to the completion of the facilities of the construction bases. We adopted a temporary cargo-handling system of two or three connected pontoons equipped with a 50-ton rotary crane in consideration of water-stage range as large as more than 6 m.

CHAPTER V

LAND ACQUISITION AND ADMINISTRATION

1. Land Acquisition.

Prior to execution of the construction works, land shall be acquired for construction bases, bridge approaches, guide banks, Dhaleswari new channel, railway links, road links and borrow-pits. Areas to be acquired are shown in Table 5-1 by construction works and by year. The areas to be acquired are 9,590,000 m^2 on the right side of the river and 11,563,000 m^2 on the left side, totaling 21,153,000 m^2.

Spoil of the dredging work shall be dumped into low-lying areas consisting of abandoned rivers. Those areas as well as the areas in the river channel are not included in the land acquisition.

2. Administration.

2.1. Engineering.

Prior to commencement of the construction works, detailed designs must be prepared based on several surveys, investigations and studies, principal things of which are topographic surveyings, geological surveys and hydraulic model tests.

2.1.1. Topographic surveyings.

A topographic map must be prepared by aerial photographic surveying over an area of about 600 km^2 covering a width of about 30 km and a length of about 20 km along the river course, and along with this, lateral and longitudinal profiles of the river must be prepared by conducting cross-levellings. These data shall be used for the last determination of alignment of bridge axis, guide banks and cross dikes, and arrangement of construction bases. Further, necessary cross-levellings must be conducted for preparing detailed designs and execution schemes of bridge approaches, guide banks and Dhaleswari new channel.

For railway links and road links, topographic maps must be prepared by aerial photographic surveying along their routes, and another cross-levellings must be conducted at those places where the routes will cross rivers by bridges.

2.1.2. Geological surveyings.

On the Jamuna bridge axis, boring tests with measurement of lateral K-values shall be conducted at about five places up to a depth of around 100 m. Samples taken by the borings shall be tested physically and mechanically.

For embankment works of bridge approaches and guide banks, boring tests of about 30 m in depth shall be conducted at large intervals

Table 5-1 Area of Land to be Acquired

		Area of land (10^3m^2)													Total
		1st.	2nd.	3rd.	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	
CONSTRUCTION BASES															
Job settlement	(R)	-	-	854	-	-	-	-	-	-	-	-	-	-	854
	(L)	-	-	-	390	-	-	-	-	-	-	-	-	-	390
Dwelling settlement	(R)	-	-	588	-	-	-	-	-	-	-	-	-	-	588
	(L)	-	-	-	172	-	-	-	-	-	-	-	-	-	172
Stone storage yard	(R)	-	-	-	-	510	-	-	-	-	-	-	-	-	510
	(L)	-	-	-	-	-	510	-	-	-	-	-	-	-	510
Temporary road	(R)	-	-	-	138	-	-	-	-	-	-	-	-	-	138
	(L)	-	-	-	-	95	-	-	162	-	-	-	-	-	257
Temporary railway	(R)	-	209	-	-	-	-	-	-	-	-	-	-	-	209
	(L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sub-total	(R)	-	209	1,442	138	510	-	-	-	-	-	-	-	-	2,299
	(L)	-	-	-	562	95	510	-	162	-	-	-	-	-	1,329
BRIDGE APPROACHES	(R)	-	-	-	-	1,956	-	-	-	-	-	-	-	-	1,956
	(L)	-	-	-	-	-	-	2,230	-	-	-	-	-	-	2,230
GUIDE BANKS	(R)	-	-	-	-	-	635	-	-	-	-	-	-	-	635
	(L)	-	-	-	-	-	-	-	611	-	-	-	-	-	611
DHALESWARI NEW CHANNEL	(R)	-	-	-	-	-	-	-	-	3,642	-	-	-	-	3,642
RAILWAY LINKS	(R)	574	-	-	-	-	-	-	-	-	-	-	-	-	574
	(L)	-	-	-	-	-	-	-	-	-	3,900	2,882	-	-	6,782
ROAD LINKS	(R)	-	-	-	-	-	-	-	-	484	-	-	-	-	484
	(L)	-	-	-	-	-	-	-	-	611	-	-	-	-	611
TOTAL	(R)	574	209	1,442	138	2,466	635	-	-	4,126	-	-	-	-	9,590
	(L)	-	-	-	562	95	510	2,230	773	611	3,900	2,882	-	-	11,563
	Total	574	209	1,442	700	2,561	1,145	2,230	773	4,737	3,900	2,882	0	0	21,153

(about 830 m in total), and the samples taken by the borings shall be tested physically and mechanically. In addition, cone penetration tests shall be conducted at small intervals.

For the railway links and road links, boring tests of about 20 m in depth shall be conducted at large intervals (about 690 m in total for the railway links and about 500 m in total for the road links) together with physical and mechanical tests of samples. Further, also at the places of bridge crossing, boring tests shall be conducted (about 2,400 m in total for railway and roads) together with physical tests of samples. Some mechanical tests of samples and lateral K-value tests shall be conducted according to the scale of bridges and the conditions of soil.

2.1.3. Hydraulic model tests.

Prior to entering detailed designs of the river control works, hydraulic model tests should be conducted for determining the alignment and length of the guide banks and the alignment of the Dhaleswari new channel. It was planned in the present study to conduct the model tests assistance of consulting engineers. As the tests will be on large-scale, main facilities for the tests must be imported from abroad.

2.2. Consultants and engineering guidance.

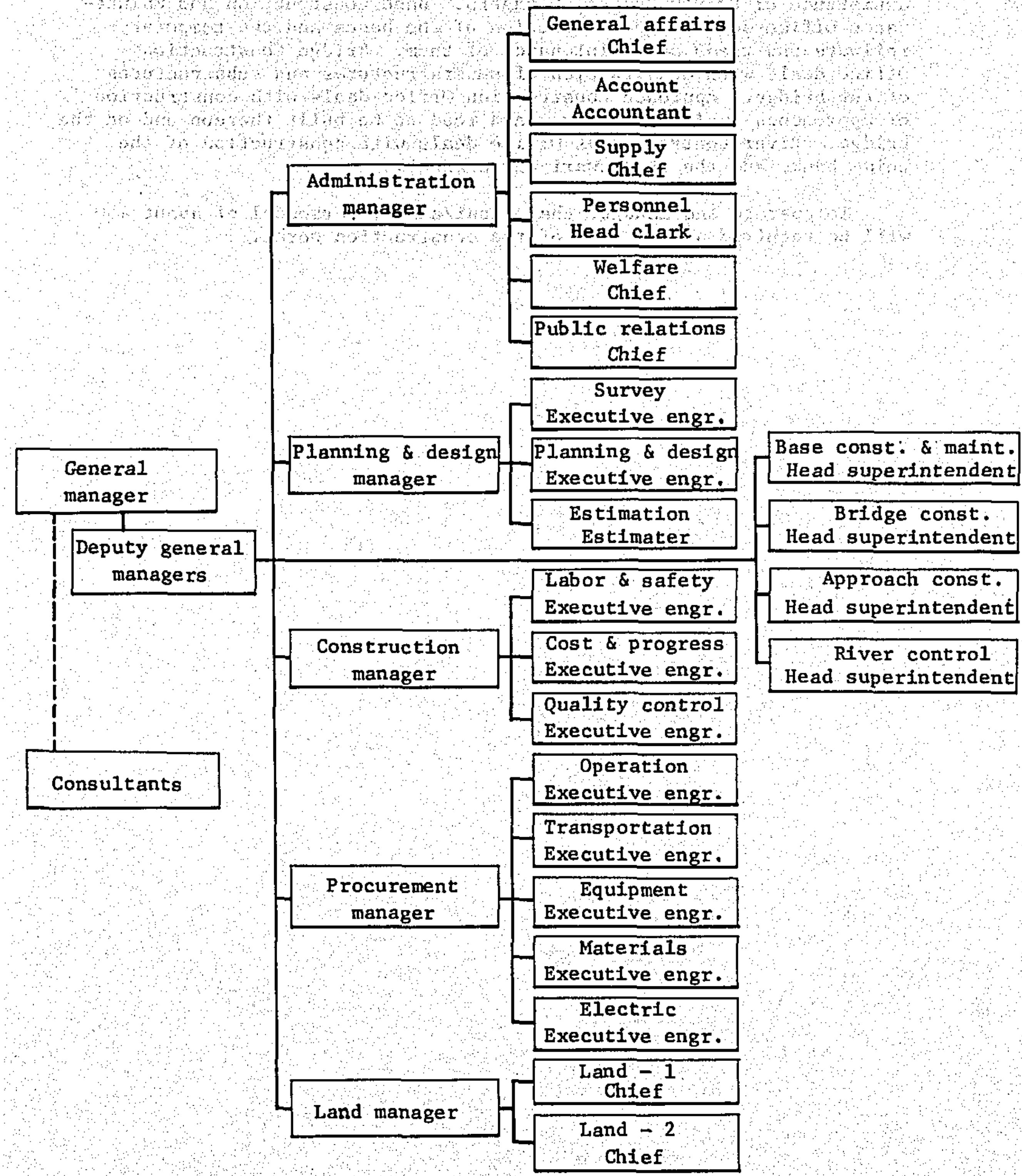
The investigations, the detailed designs and the supervision of construction works shall be made by the assistance of consulting engineers. In executing the construction works, technical guidance shall be made by skilled workers from abroad. As high-grade mechanical execution is needed in the present project except the construction works of railways and roads and stone-pitching works in the river control works, it was planned to employ a number of skilled workers from abroad, in consideration of training of local workers as well.

2.3. Organization for implementation of the project.

In the present study, the direct control system by the Government has been proposed for the implementation of the project. The proposed organization is shown in Fig.5-1.

The organization is controlled by General Manager and some Deputy General Managers under him. General Manager controls five Divisions, each of which has two to six Sections. Administration Division deals with general affairs, accounting, personnel affairs, contract, welfare, and public relations. Planning and Design Division deals with surveying, hydrology, planning, detailed and revised design and estimation of costs. Construction Division deals with planning of construction works, management of state of performance, labor management, safety management and quality management. Procurement Division deals with operation of vehicles and boats, transportation in and between the bases, operation of helicopters, transportation of equipment and ma materials to the works sites, fixation and arrangement of construction machinery, management of facilities in the bases, management of warehouses and procurement of equipment and materials. Land Division deals with land acquisition affairs.

Fig.5-1 Organization for Management of Construction Works



For implementing the construction works, four construction offices have been proposed, which are controled by General Manager with the assistance of Deputy General Managers. Base Construction and Maintenance Office deal with construction of the bases and the temporary railways and roads and maintenance of them. Bridge Construction Office deals with construction of superstructures and substructures of the bridge. Approach Construction Office deals with construction of approaches including railway and road to be built thereon and on the bridge. River Control Works Office deals with construction of the guide banks and the Dhaleswari new channel.

To operate and manager the organization, personnel of about 450 will be required at the peak of the construction works.

CHAPTER VI
MAINTENANCE

1. Maintenance Works.

Out of the facilities constructed in this project, the railway links and the road links including those on the bridge and the bridge approaches are to be maintained by the current agencies, but an exclusive organization must be established for the maintenance of the bridge, bodies of the approaches, guide banks and the Dhaleswari new channel. For this purpose, it was planned in this project to set up a maintenance office in the area employed as the main construction base. The maintenance works to be conducted by the office will be as follows.

1.1. Surveyings.

(1) Regular surveyings.

a. Crosslevellings of the river at intervals of 1.5 km in the extent of each 10 km upstream and downstream of the bridge.

b. Crosslevellings of the Dhaleswari new channel at intervals of 1 km.

c. Longitudinal levellings of the bridge approaches, the bridge and the guide banks with the view of measurement of settlement.

d. Measurements of water levels and discharges.

(2) Surveyings during floods.

a. Soundings around the piers.

b. Soundings around the riverside fronts of the guide banks for inspecting scouring.

(3) Other surveyings.

Surveyings required for repair works.

1.2. Patrol and inspection.

The staffs of the office must patrol the bridge, the guide banks, the bridge approaches and the Dhaleswari new channel for detecting unusualness. Especially during flood, servere inspection must be made by temporarily increasing the personnel with all-night system. In inspecting, attention must be paid to the following.

a. Condition of painting of steel, cast steel and cast iron portions.

b. Detecting of crack or break in concrete portions such as slabs and piers.

c. Condition of expansion joints.

d. Condition of drainage of bridge deck including storm drains and inlets.

e. Condition of handrails and newel pasts.

f. Condition of lighting facilities.

g. Condition of bearing shoes.

h. Behavior of vibration of the bridge.

i. Unusual settlement, poor drainage and other unusualness in bridge approaches, guide banks and Dhaleswari new channel.

j. Detecting and removal of deeds injurious to structures.

k. Scouring around piers and guide banks during flood season, and unusualness on the slope faces of bridge approaches and guide banks.

l. Special tests such as loading tests and vibration tests at need.

Inspecters must report on the above-mentioned items to the responsible person. Besides daily inspections, detailed inspections must be conducted in the presence of responsible engineers once a few months, and necessary inspections by use of testing apparatuses must be conducted once a year.

1.3. Repair works.

Informations obtained by inspections and surveyings must be analyzed at once to take necessary actions. Repair works considered in future are as follows.

1.3.1. Repair works of expansion joints and slabs.

Expansion joints must be renewed as they are to be worn out due to long use. In estimating maintenance costs, it was assumed that renewal works of road expansion joints will be made once every 20 years, while those of railway expansion joints will be conducted once every 10 years as they would be much more worn out than those of road.

We must endeavor to detect any damages in the slabs in their early stages in order to avoid increase in repair costs. In estimating the maintenance costs of the slabs, we assumed 1 % of the construction costs every 5 years.

1.3.2. Repainting works of superstructures of the bridge.

Repainting period of superstructures of the bridge was estimated at 6 years based on the study made by the Japan National Railway on the correlation among repainting period, life of bridge and cost with regard to railway steel bridges in Japan. In the present plan, the bridges to be built in a year are to be painted in the same year, and all the bridges are to be opened to traffic five years after completion of the first group. Therefore, the first repainting of the whole Jamuna Bridge will begin in the year of opening to traffic and end in six years thereafter.

Besides the above, short-period repainting is necessary for maintaining such portions in good condition as upper faces of lower flanges of cross-beams and stringers, lower periphery of heads of high strength bolts, expansion joints, handrails, lower periphery of heads of high strength bolts, expansion joints, handrails, lower periphery of shoes, fitting portion of drain pipes and other portions apt to rust.

In estimating maintenance costs, we assumed a yearly repainting of 190,000 m^2 adding local repainting of 11,000 m^2 to one-sixth of 1,075,356 m^2 of total surface areas of the superstructures.

1.3.3. Repairing works of wire cylinders at the feet of the approaches.

The wire cylinder works at the feet of the bridge approaches will have to be repaired in the course of time. In the present plan, we assumed that the uppermost layer of three-layers wire cylinders in an extent of 8 km on the upstream side of the approaches is replenished during every ten years.

1.3.4. Replenishment of stones to the guide banks and the piers.

Replenishment of stones to the guide banks depends on conditions of thalwegs after completion of the banks. As it is very difficult to foresee the conditions of thalwegs after completion of the banks, it is also very difficult to estimate the quantity of stones required for maintenance. In the present plan, we assumed that thalwegs flank the guide banks over an extent of 2 km, for which is required replenishment of stones of 4,000 m^3 per km per year.

Replenishment quantity of stones for protection of the piers was estimated based on the following considerations.

a. In designing the guide banks, the maximum scour depth at thalweg was estimated at -24.5 m PWD (-80.38 ft PWD), which was calculated based on a ratio $H_{max}/R = 3.4$ assuming, in Fig.5-5 of Chapter III of VOLUME V, that eccentricity of thalweg is 0.9. At this depth of river bed, local scour due to pier was estimated at -56.25 m PWD (-185.5 ft PWD).

On the other hand, 0.1 was taken as horizontal component of seismic coefficient in the design of piers. This gives a minimum depth -38.0 m PWD (-124.68 ft PWD) to secure necessary depth of embedment. Therefore, the pier will come to be dangerous if 100-year flood and earthquake of seismic coefficient 0.1 occured under the condition of eccentricity 0.9. However, the probability that those worst conditions occur at the same time must be very small.

b. Apron of guide bank is not mere foot-protection for structure, but we expect it to fall little by little according as scouring in front of the guide bank and come to form a revetment. It is, therefore, very natural from the viewpoint of the expected function of the guide bank apron to adopt such a severe design depth as those which correspond to the extreme value 0.9.

On the other hand, ripraps around piers are foot-protection works for the piers which are already deeply embeded. The guide bank will positively align the stream, consequently it will have a big possibility to flank a thalweg, while the piers will not have such characteristics. Therefore, it would not be necessary in designing scour depth for piers to take such severe value as 0.9 of eccentricity of thalweg.

In our judgement from the above-mentioned matters, it is enough to take the average value of the extreme eccentricity 0.9 and a value of 0.5 which indicates beginning of increase in the ratio H_{max}/R (see Fig.5-5, VOLUME V). By using eccentricity 0.7, we will obtain -14 m PWD (-45.93 ft PWD) as the scoured depth at thalweg under the design discharge. Accordingly, we obtain -37.5 m PWD (-123.0 ft PWD) as the local scour depth around pier. This depth can satisfy the condition of the minimum embedment depth. For the sake of safety, however, we planned to place ripraps of 15,000 m^3 around each of 14 piers which are built in stream in the dry season. In estimating the maintenance costs, we assumed ripraps of 2,000 m^3 per year against unexpected bed scouring which may occur between a guide bank and the adjacent pier and at other places.

Riprap works in maintenance will be usually conducted based on the surveying after flood. But in an emergency, protection works must be conducted even during flood. Therefore, system for the works must always be prepared in consideration of the emergency as well.

1.3.5. Repairing works of guide banks and bridge approaches.

Maintenance works will be necessary for repairing gullies on the slopes and damages to slope protection works of the guide banks and the bridge approaches, removal of sand and dust from the drainage system, and repairing depressions which are apt to occur at the connecting portions of the abutments and the approaches.

2. Organization for Maintenance and Management.

As already mentioned, maintenance and management of the railway links, the road links and the railway and road on Jamuna Bridge and the bridge approaches shall be left to the current system, and the maintenance office shall deal with the maintenance of Jamuna Bridge, the approaches, the guide banks and the Dhaleswari new channel. The scale of the office must be minimized in consideration of performing surveyings, patrols, inspections, tests, designing and ordering of necessary works, supervision for them and easy maintenance works. Organization, personnel and preparation of equipment and materials were planned based on this conception. Therefore, large maintenance works shall be carried out by employing temporary workers and hiring necessary equipment except for 600-PS dredger, which shall be kept permanently as it may be difficult to hire at need.

Fig.6-1 shows the plan for the organization and personnel together with necessary facilities and equipment for execution of the above-mentioned works.

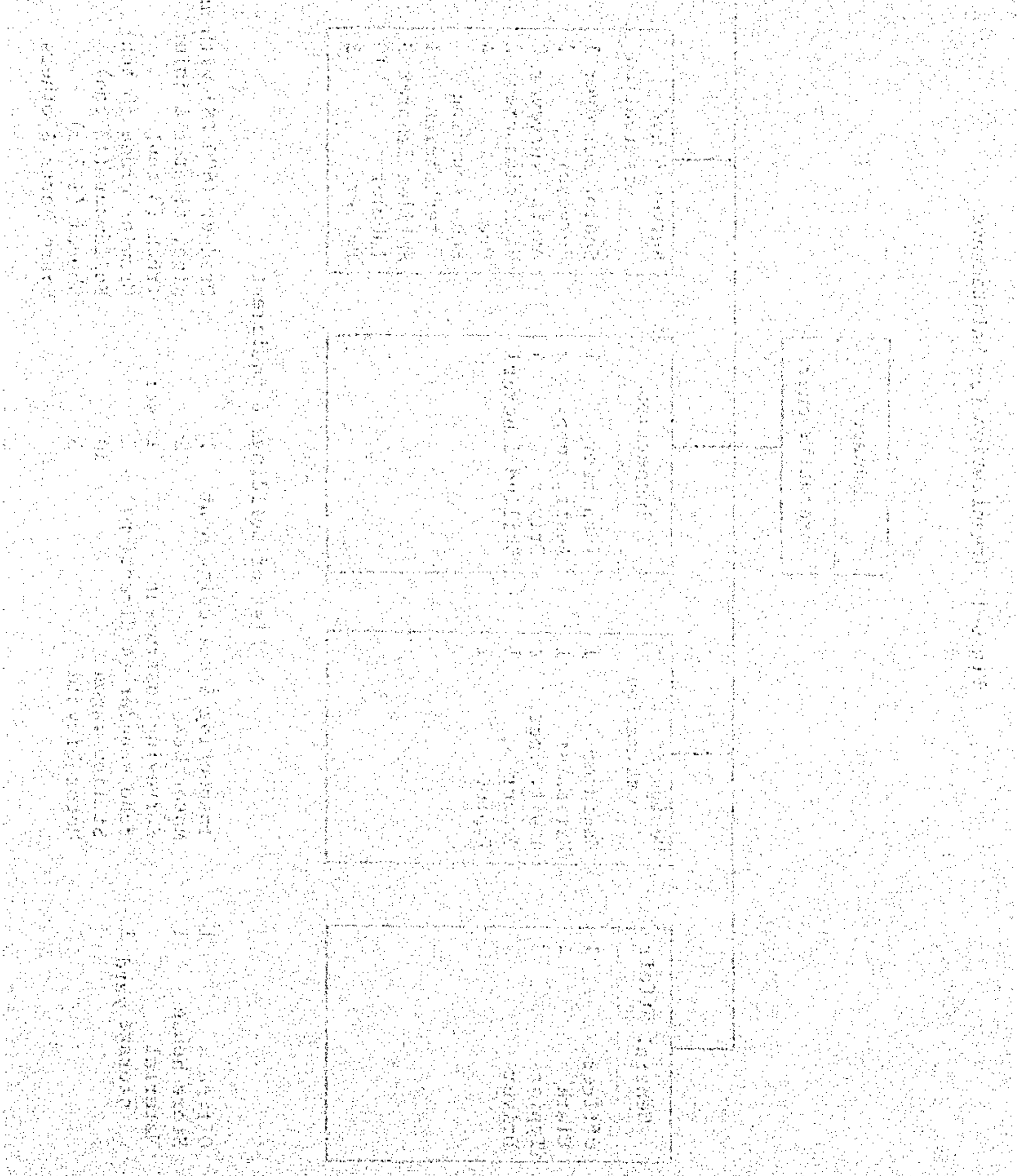
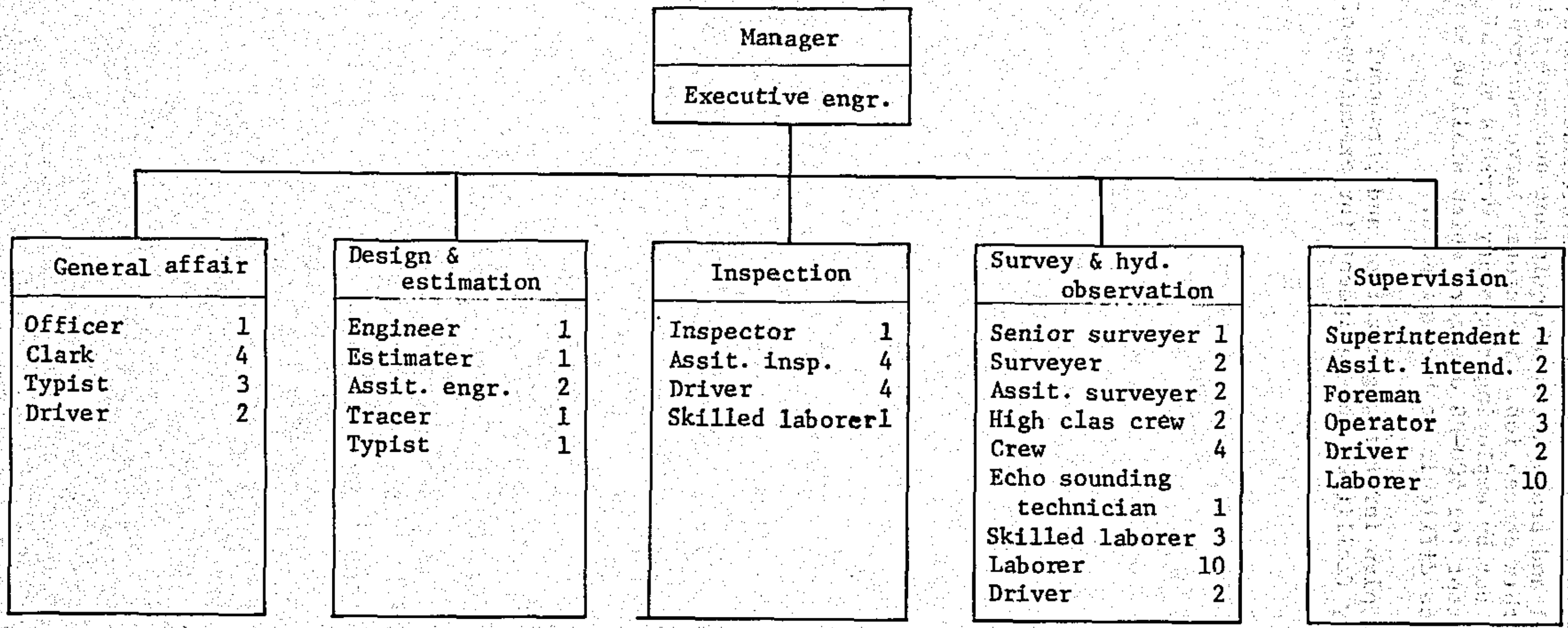


Fig 6-1 Organization for Maintenance



List of Buildings & Equipment

Office	1
Store house	1
Material storage yard	1

Inspecting & surveying boat	1
Motor boat	2
Surveying instrument	1 set
Echo sounder (4 direction)	2
Station wagon	10
Motor bicycle	3

Dredger (600 PS) with anchor barge, pipe, floater & joint	
Truck (8 ton)	12
Crawler crane (8 ton)	1
Bulldozer (13 ton)	1
Shovel (1.2 m)	1
Spare parts & others	30 % of the above

CHAPTER VII
CONSTRUCTION COSTS AND MAINTENANCE COSTS

1. Construction Costs.

1.1. Conditions for cost estimation.

The construction costs of the Jamuna Bridge Project were estimated under the following conditions.

a. Unit prices as of July, 1975 shall be applied.

b. Costs of domestic equipment and materials shall be estimated on the basis of market prices at job site. Costs of Bangladesh workers shall be estimated applying wages or salaries of domestic workers who are engaged in similar domestic works.

c. Unified importing by the Government shall be made for purchasing equipment and materials from abroad, and shall be taken a measure of exemption from duties and taxes within the country. Therefore, the costs of the equipment and materials to be imported are estimated on the basis of CIF prices adding inland transportation costs and other expenses at job sites to them. Costs of workers from abroad shall involve salaries, necessary travel expenses and overhead, but they shall be exempted from taxes in Bangladesh.

d. Expenses required for reinforcement of the existing facilities for transporting equipment and materials to the job site shall be included in their unit prices.

Classification of domestic and foreign currencies was made in accordance with the following conditions.

a. All the costs of domestic equipment, materials and workers shall be counted in domestic currency.

b. In costing of imported equipment and materials, the amount of CIF price shall be counted in foreign currency and such additional costs as inland transportation expenses shall be counted in domestic currency. Labor costs for workers from abroad shall be counted in foreign currency.

c. As it was planned that the construction works of the railway links and the road links are executed by the existing agencies, the costs of necessary equipment shall be estimated in hire and counted in domestic currency. Also in this case, equipment that the domestic agencies do not possess and those materials which are required in quantities and difficult to smoothly procure in Bangladesh shall be deal with as imports in the same way as mentioned above.

Allotment of the construction costs by year was made in accordance with the following conditions.

a. Labor costs for domestic and foreign workers shall be counted in the year that they are engaged in the works.

b. Costs of domestic equipment and materials shall be counted in the year that they are used in the works.

c. Costs of such imported materials as fuel, lubricant and stone materials shall be counted in the year that they are used in the works or they are stored for the works. Costs of other imported materials and equipment shall be counted in the year previous to the use considering the necessity of time for purchasing and transportation.

d. Costs for land acquisition shall be counted in the year previous to the use.

The unit prices of equipment, materials and workers to be applied to the cost estimation for the main construction works are shown in VOLUME II through VOLUME V, while those for construction bases are given in Table 1, APPENDIX B of this report.

1.2. Construction costs.

The construction costs were estimated by work based on the above-mentioned conditions, and are given in the reports, VOLUME II through VOLUME V. In this report, those construction costs were adjusted from the viewpoint of unification and have been arranged in accordance with the following items.

Cost of construction bases works.

Cost of main construction works.

Cost of bridge substructure construction works.

Cost of bridge superstructure construction works.

Cost of bridge approach construction works.

Cost of guide bank construction works.

Cost of Dhaleswari new channel construction works.

Cost of railway link construction works.

Cost or miscellaneous works.

Cost for land acquisition.

Cost for administration.

Contingency.

The total costs required for the Jamuna Bridge Project is summarized in Table 7-1. In this table, cost of miscellaneous works was estimated at 5 % of the cost of the main construction works except for it. The contingency was estimated at 15 % of the costs for the construction base works, the main construction works and the administration in view of the facts that the project requires as long a period as 13 years and importing of equipment, materials and workers' services on a large scale. It must be noticed that no escalation of prices during the construction is included in the contingency.

Table 7-1 Construction Costs for the Project

Item	Construction Costs		
	D.C. (10^3Tk)	F.C. (10^3\$)	Total (10^3\$)
Construction Bases	500,523	149,840	188,342
Main Works			
Substructures	156,990	107,609	
Superstructures	109,058	194,964	
Bridge Approaches	69,349	20,874	
Guide Banks	269,744	71,950	
Dhaleswari New Channel	3,900	5,142	
Railway Links	363,491	18,296	
Road Links	53,879	2,137	
Miscellaneous	51,321	21,049	
Sub-total	1,077,732	442,021	524,923
Land Acquisition	106,583	—	8,199
Administration	174,720	15,060	28,500
Contingency	278,934	91,038	112,494
Grand total	2,138,492	697,959	862,458

Notes: D.C. is domestic currency and F.C. is foreign currency.

Breakdown of the construction costs by year is shown in Table 7-2. The construction costs by work are shown in Table 7-3. The data which were used for estimation of costs are given in APPENDIX B of this report.

2. Maintenance Costs.

2.1. Conditions for cost estimation.

The maintenance costs were estimated based on the maintenance jobs mentioned in Chapter VI. The conditions for estimation are as follows.

a. The costs shall be estimated by year for 30 years after completion of the construction works, applying the unit prices as of July, 1975.

b. Costs of domestic materials and workers shall be estimated in the same way as in the estimation of the construction costs. But foreign workers shall not be engaged in the maintenance jobs.

c. Costs of equipment shall be counted in domestic currency on the basis of hire, except for those to be imported under the unification by the Government.

d. Costs of materials shall be counted in domestic currency on the basis of market prices (including taxes) at the bridge site, except for those to be imported under the unification by the Government.

e. Construction machinery and vehicles to be prepared for the maintenance office and such materials as stones, paint and wire nets for gabions which are difficult to smoothly procure in quantities in Bangladesh shall be imported under the unification by the Government. But in this case, exemption from duties and taxes shall not be made.

f. In classifying the costs of those equipment and materials into domestic and foreign currencies, the amount of CIF prices shall be counted in foreign currency and other costs such as import duty and inland transportation costs shall be counted in domestic currency.

g. In allotting the maintenance costs by year, the costs of construction machinery and vehicles to be imported shall be counted in the year previous to the use, and the costs of other equipment, materials and vehicles shall be counted in the year that they are used.

2.2. Maintenance costs.

The maintenance costs estimated based on the above-mentioned conditions are summarized in Table 7-4. Their details are shown in Table 7-5.

Table 7-2 Allotment of the Construction Costs by Year

Item / Year	Currency	1st.	2nd.	3rd.	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	Total
Construction Bases	D.C.	—	655	37,143	225,703	119,943	45,209	10,088	10,183	15,903	10,702	10,101	9,473	5,420	500,523
	F.C.	—	1,945	36,156	47,869	27,052	10,679	4,772	4,874	4,699	3,527	3,297	2,607	2,363	149,840
Main Works															
Substructures	D.C.	—	—	—	—	11,783	14,194	25,684	27,863	28,370	28,294	19,267	1,055	480	156,990
	F.C.	—	—	—	—	31,472	17,473	13,377	13,300	12,637	14,113	4,743	267	227	107,609
Superstructures	D.C.	—	—	—	—	1,182	16,440	12,053	14,725	14,949	16,436	15,007	7,736	10,530	109,058
	F.C.	—	—	—	—	8,997	2,341	38,191	33,309	33,895	33,493	30,144	11,223	3,371	194,964
Bridge Approaches	D.C.	—	—	—	—	—	943	2,815	2,386	10,622	14,255	9,321	10,207	18,800	69,349
	F.C.	—	—	—	—	—	2,002	7,633	3,441	2,746	2,340	1,201	322	1,181	20,874
Guide Banks	D.C.	—	—	—	—	—	55,804	70,160	63,210	71,220	8,550	—	—	—	269,744
	F.C.	—	—	—	—	—	21,871	21,012	5,800	21,123	1,063	—	—	—	71,950
Dhareswari New Channel	D.C.	—	—	—	—	—	—	—	—	—	1,250	1,320	1,330	—	3,900
	F.C.	—	—	—	—	—	—	—	—	—	1,770	1,559	1,813	—	5,142
Railway Links	D.C.	—	22,453	—	—	—	—	—	—	—	1,217	109,103	94,553	135,365	363,491
	F.C.	—	1,161	—	—	—	—	—	—	—	—	4,891	4,674	7,562	18,296
Road Links	D.C.	—	—	—	—	—	—	—	—	—	8,793	20,705	24,381	—	53,879
	F.C.	—	—	—	—	—	—	—	—	—	352	1,005	780	—	2,137
Miscellaneous (5% of the above)	D.C.	—	1,123	—	—	648	4,369	5,576	5,409	6,258	3,940	8,776	6,963	8,859	51,321
	F.C.	—	58	—	—	2,023	2,184	4,015	2,843	3,520	2,657	2,178	954	617	21,049
Sub-total	D.C.	—	23,576	—	—	13,613	91,750	117,088	113,593	131,419	82,735	184,299	146,225	173,434	1,077,732
	F.C.	—	1,227	—	—	42,492	45,871	84,309	59,693	73,921	55,788	45,729	20,033	12,958	442,021
Land Acquisition	D.C.	4,681	620	4,276	2,076	7,594	3,395	6,612	2,292	19,729	31,805	23,503	—	—	106,583
	F.C.	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Administration	D.C.	14,830	14,240	10,940	7,490	5,410	15,230	15,230	15,230	15,230	15,230	15,220	15,220	15,220	174,720
	F.C.	2,070	2,296	2,062	1,090	406	892	892	892	892	892	892	892	892	15,060
Contingency	D.C.	2,927	5,864	7,854	35,289	21,984	23,338	22,353	21,195	27,342	21,071	34,968	25,638	29,111	278,934
	F.C.	311	820	5,733	7,344	10,493	8,616	13,495	9,819	11,926	9,031	7,488	3,530	2,432	91,038
Grand total	D.C.	22,438	44,955	60,213	270,558	168,544	178,922	171,371	162,493	209,623	161,543	268,091	196,556	223,185	2,138,492
	F.C.	2,381	6,288	43,951	56,303	80,443	66,058	103,468	75,278	91,438	69,238	57,406	27,062	18,645	697,959
	Total(10^3\$)	4,107	9,746	48,583	77,115	93,408	79,821	116,650	87,777	107,563	81,664	78,028	42,182	35,813	862,457

D.C.: Domestic Currency (10^3Tk)
F.C.: Foreign Currency (10^3\$)

Table 7-3 Construction Costs for the Main Works

D.C.: domestic currency, F.C.: foreign currency.

	Quantity of works		Costs		
	Unit	Quantity	D.C. (10^3Tk)	F.C. (10^3\$)	Total (10^3\$)
SUBSTRUCTURES			(156,990)	(107,609)	(119,685)
Well foundation (on land)	10^3m^3	143.5	70,463	71,497	
- do - (in stream)	"	145.3	47,007	24,668	
Pier	nos	28	19,419	9,292	
Miscellaneous	l.s.		20,101	2,152	
SUPERSTRUCTURES			(109,058)	(194,964)	(203,353)
Manufacturing & erection	10^3t	61.3	76,682	169,583	
Slab	10^3m^2	42.3	9,251	7,869	
Painting	"	937	7,587	13,168	
Permanent way	km	4.7	4,306	407	
Pavement	10^3m^2	35	1,243	84	
Miscellaneous	l.s.		9,989	3,853	
BRIDGE APPROACHES			(69,349)	(20,874)	(26,209)
Embankment	10^3m^3	8,895	11,253	17,505	
Stone pitching	"	65	4,923	529	
Slope protection	10^3m^2	665	23,176	918	
Permanent way	km	5.1	13,122	1,096	
Pavement	10^3m^2	60	12,781	474	
Miscellaneous	l.s.		4,094	352	
GUIDE BANKS			(269,744)	(71,950)	(92,700)
Embankment	10^3m^3	1,705	10,801	38,305	
Stone pitching	"	2,806	238,270	29,331	
Dike protection	10^3m^2	Sodding: 160 Pavement: 70	7,919	944	
Miscellaneous	l.s.		12,754	3,370	
DHALESWARI NEW CHANNEL			(3,900)	(5,142)	(5,442)
Dredging	10^3m^3	6,600	3,714	4,897	
Miscellaneous	l.s.		186	245	
RAILWAY LINKS			(363,491)	(18,296)	(46,257)
Formation	10^3m^3	7,747	82,428	-	
Bridge (A)	place	9	33,012	2,666	
Small bridge & spillway str.	km	3.20	72,552	5,860	
Permanent way (main line)	"	113.9	44,421	4,118	
- do - (sidings)	"	37.3	15,107	1,328	
Stations & buildings	place	22	43,560	372	
Electric lighting, power & telecom	km	113.9	23,919	789	
Signalling	km	113.9	22,211	3,163	
Miscellaneous	l.s.		26,281	-	
ROAD LINKS			(53,879)	(2,137)	(6,282)
Embankment	10^3m^3	636	4,697	2	
Slope protection	10^3m^2	242	574	-	
Pavement	"	279	35,288	379	
Bridge (A)	place	2	6,661	376	
Small bridge & spillway str.	km	0.9	5,347	1,329	
Miscellaneous	l.s.		1,312	51	
MISCELLANEOUS			(51,321)	(21,049)	(24,996)
Total			1,077,732	442,021	524,923

Table 7-4 Maintenance Costs

D.C.: Domestic currency
F.C.: foreign currency

Item	D.C.(Tk)	F.C.($)
Bridge and River Control		
for 30 years	466,001,000	15,757,000
annual average	15,533,400	525,200
Railway Links		
for 30 years	300,720,000	7,800,000
annual average	10,024,000	260,000
Road Links		
for 30 years	95,187,000	—
annual average	3,172,900	—
Contingency (5%)		
for 30 years	43,095,000	1,178,000
annual average	1,436,500	39,300
Total		
for 30 years	905,003,000	24,735,000
annual average	30,166,800	824,500

Table 7-5 Maintenance Costs by Year

D.C.: domestic currency, F.C.: foreign currency.

Year	Bridge & river control		Railway links		Road links		Contingency		Total	
	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)	D.C. (10^3Tk)	F.C. (10^3\$)
0	20,549	2,606	-	-			1,027	130	21,576	2,736
1st.	15,834	223	10,024	260			1,293	24	27,151	507
2nd.	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
3rd.	13,598	223	10,024	260	-	-	1,181	24	24,803	507
4th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
5th	17,716	686	10,024	260	6,084	-	1,692	48	35,516	994
6th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
7th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
8th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
9th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
10th	23,615	2,510	10,024	260	18,585	-	2,612	140	54,836	2,910
11th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
12th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
13th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
14th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
15th	18,544	1,066	10,024	260	6,084	-	1,733	67	36,385	1,393
16th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
17th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
18th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
19th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
20th	24,429	2,569	10,024	260	18,585	-	2,653	142	55,691	2,971
21st.	13,598	223	10,024	260	-	-	1,181	24	24,803	507
22nd.	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
23rd.	13,598	223	10,024	260	-	-	1,181	24	24,803	507
24th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
25th	17,716	686	10,024	260	6,084	-	1,692	48	35,516	994
26th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
27th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
28th	13,598	223	10,024	260	1,765	-	1,269	24	26,656	507
29th	13,598	223	10,024	260	-	-	1,181	24	24,803	507
30th	14,844	282	10,024	260	18,585	-	2,174	27	45,627	569
Total	466,001	15,757	300,720	7,800	95,187	-	43,095	1,178	905,003	24,735
Mean annual cost	15,533	525	10,024	260	3,173	-	1,437	40	30,167	825

ECONOMIC EVALUATION

CHAPTER VIII

GENERAL DESCRIPTION OF ECONOMIC EVALUATION

The economic evaluation of the project will be made comparing; the construction costs of the Jamuna bridge, road links, railway links, guide banks of the river and a new channel of the Dhaleswari river, the maintenance costs of these facilities after completion of the construction with the benefits consisting of reduced transport costs, time-savings for passengers, reduced ferry facilities, and salvage values of equipment, materials and land after finishing of the construction.

The economic costs and benefits have to be applied for the purpose of assuring a proper economic evaluation of the project. They are net of taxes and with the shadow rates for the foreign exchange component and for the unskilled labour. The taxes consist of custom duties and sales taxes to be imposed on equipment and materials, and income taxes on the labour. In this study, the shadow rate of 1.75 times the official foreign exchange rate will be applied not only to the equipment, materials and services procured directly from abroad, but also to the foreign exchange component of those procured locally. Further, the shadow wage of 0.5 times the actual wage will be applied to the unskilled labour employed locally.

In calculating the economic costs and benefits of the project, it was also assumed that (1) the construction works will be started at the beginning of the fiscal year 1977 and completed by the end of 1989 taking 13 years, and that (2) the project will have an economic life of 30 years after completion of the construction and thereafter no allowance will be made for any salvage value.

The economic analysis will be made by three well-known methods, the net present value, the benefit-cost ratio and the internal rate of return making use of both the costs and benefits discounted at rates of some percent. Results of the analysis will be examined by sensitivity tests to such three major factors as (1) the future traffic volume to be affected by the population forecasted, (2) the shadow rate for the foreign exchange component, and (3) the project timing.

Finally, the conclusion will be drawn from the results of the above-mentioned analyses, taking into account the intangible benefits to be expected as well as the tangible benefits calculated in this study.