

PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

FEASIBILITY STUDY REPORT

VOLUME II

BRIDGE

AUGUST 1976

JAPAN INTERNATIONAL COOPERATION AGENCY

PEOPLE'S REPUBLIC OF BANGLADESH
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FEASIBILITY STUDY REPORT

VOLUME III

BRIDGE

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FEASIBILITY STUDY REPORT ON JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

VOLUME I	SUMMARY AND CONCLUSIONS
VOLUME II	RIVER CONTROL
VOLUME III	BRIDGE
VOLUME IV	RAILWAY LINKS
VOLUME V	ROAD LINKS
VOLUME VI	GEOLOGY AND STONE MATERIAL
VOLUME VII	TRAFFIC AND ECONOMIC BENEFITS
VOLUME VIII	OVERALL CONSTRUCTION PLAN AND ECONOMIC EVALUATION

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.
WAPDA	Water and Power Development Authority.
BIWTA	Bangladesh Inland Water Transport Authority
IWTA	Inland Water Transport Authority.
SOB	Survey of Bangladesh.
JICA	Japan International Cooperation Agency, Government of Japan.
OTCA	Former name of 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, Road links.
Feasibility Report Volume V	Feasibility Study Report on Jamuna River Bridge Construction Project, Volume V, Railway 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 con- struction plan and economic evaluation.
Project	Main works including railway links and road links.
Main works	Jamuna Bridge construction works comprizing Jamuna Bridge, approaches, river control and treatment of the Dhaleswari River.
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 con- nection point on the existing road.
Guide bank	Dike built to guide river flow.
Cross dike	Dike built crosswise 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.

MLLWL	Mean Lowest Low Water Level
LLWL	Lowest Low Water Level
GL	Ground Level
DRB	Design River Bed
RB	River Bed
DH	Design Height
B	Width
H	Height, Water depth
L,l	Length
I	Slope
Q	Discharge
V	Velocity or Volume
N	N-value, given by Standard Penetration Test
B,D	Diameter of foundation pile
C	Cohesion of soil
ϕ	Internal friction angle of soil
E	Modulus of Elasticity, Modulus of Deformation
K	Coefficient of soil reaction
vpd	Vehicles per day
vph	Vehicles per hour
JIS	Japanese Industrial Standard
ASTM	American Society for Testing Materials
BS	British Standard
HTB	High Tension Bolt
km	kilometer
m	meter
cm	centimeter
mm	millimeter
mi	mile
yd	yard
f, ft, (')	foot
in, (')	inch
t, ton	ton (metric)
kg	kilogram
g, gr.	gram
lb	pound
I.G.	Imperial Gallon

yr	year
mon	month
hr	hour
s, sec	second
cu.	cubic
sq.	square
ac	acre
m ³ /s	cubic meter per second
cfs	cubic foot per second
kt.	knot
max.	maximum
min.	minimum
G	Gravity

The conversion table of unit

1. Length

(a)

m	cm	yd	ft	in
1	100	1.09361	3.28084	39.370
0.01	1	0.010936	0.032803	0.39370
0.91440	91.4400	1	3	36
0.30480	30.480	0.33333	1	12
0.02540	2.54000	0.02778	0.08333	1

(b)

km	yd	mile
1	1093.61	0.62137
0.000914	1	-
1.60934	1760	1

2. Area

(a)

m ²	ft ²
1	10.764
0.09290	1

$$1 \text{ ft}^2 = 144 \text{ in}^2 \quad 1 \text{ in}^2 = 0.006946 \text{ ft}^2$$

(b)

ha	km ²	acre	mile ²
1	0.0100	2.471	0.00386
100	1	247.10	0.3861
0.4047	0.004047	1	0.001563
259	2.590	640	1

3. Volume and capacity

ℓ	m ³	ft ³	yd ³	I.G
1	0.001	0.03531	0.001308	0.2200
1,000	1	35.31	1.308	219.99
28.317	0.02832	1	0.03704	6.229
764.6	0.7646	27.00	1	168.21
4.5456	0.004546	0.1605	0.00595	1

4. Weight

kg	t	oz avdp	lb	t(tn)
1	0.001	35.27	2.2046	0.00110
1,000	1	3.527x10 ⁴	2,204.6	1.1023
0.02835	2.835x10 ⁻⁵	1	0.06250	3.125x10 ⁻⁵
0.4536	4.536x10 ⁻³	16	1	0.0005
907.2	0.9072	32.000	2.000	1

5. Velocity

m/sec	km/h	ft/sec	mile/h	knot
1	3.600	3.2808	2.237	1.9438
0.2778	1	0.9113	0.6214	0.5400
0.3048	1.0973	1	0.6818	0.5925
0.4470	1.6093	1.4667	1	0.8690
0.5144	1.8520	1.6878	1.1508	1

6. Temperature (from °C to °F)

°C	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
-200	-328	-346	-364	-382	-400	-418	-436	-454		
-100	-148	-166	-184	-202	-220	-238	-256	-274	-292	-310
0	32	14	-4	-22	-40	-58	-76	-94	-112	-130
°C	0	10	20	30	40	50	60	70	80	90
0	32	50	68	86	104	122	140	158	176	194
100	212	290	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	986	1022	1040	1058	1076	1094
600	1112	1130	1148	1166	1184	1202	1220	1238	1256	1274
700	1292	1310	1328	1346	1364	1382	1400	1418	1436	1454
800	1472	1490	1508	1526	1544	1562	1580	1598	1616	1634
900	1652	1670	1688	1706	1724	1742	1760	1778	1796	1814

Inter- polation	°C	1	2	3	4	5	6	7	8	9
	°F	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2

$$5(t^{\circ}\text{F}-50)=9(t^{\circ}\text{C}-10)$$

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SUMMARY

1. Objective and Progress of the Study.

There are two objectives of the present study. Firstly, it is to determine the priority order among the four candidate sites on the Jamuna River for the bridge construction from the technical and economical points of view. The four candidate sites are Bahadurabad, Gabargaon, Sirajganj and Nagarbari from the upstream to the downstream of the Jamuna River. For the purpose of above, we studied the most suitable type and span of super- and substructures and discussed for bridge approaches. Secondly, it is to carry out the design, the construction plan and the cost estimate of the superstructure, substructure and the bridge approaches for the most suitable site selected from the four proposed sites.

The Japanese Preliminary Study Team for the Jamuna River Bridge Construction Project dispatched in December 1972 by JICA (former OTCA) proposed the four candidate sites for the bridge construction, namely, downstream of Bahadurabad, near Gabargaon, 10 km downstream from Sirajganj and about 20 km upstream from Aricha.

The Bridge Study team consisted of five members headed by Kaoru Tezuka, NIKKEN Consultants, Inc., was sent to Bangladesh for the inspection of the Jamuna River and collecting data required for the study of basic criteria related to design and execution of the Jamuna Bridge Construction Project from 7th to 27th January 1974.

The Bridge Study Team has established a basic plan for bridge construction in Japan based on the data collected by the Bridge Study Team in both Bangladesh and Japan. Further, the preliminary design and cost estimation of the bridge were carried out by the combination of suitable width system, span and type of super- and substructures of the bridge.

The preliminary design and cost estimation of bridge approaches and some other bridges which included in the railway and road links were also carried out.

In these cases, the design provisions were decided after consultation with the Government of Bangladesh authorities concerned.

In progress of the first stage study, a Tokyo Meeting was jointly held by the Japanese delegates and the Bangladesh delegates from August 31 to September 13, 1974 to discuss the selection of the most suitable site for crossing the Jamuna River and several problems posed by each study team. This discussion was further continued to the Dacca Meeting which was held from October 28 to November 6, 1974. The Sirajganj site was finally selected as the most suitable site among the four candidate sites by above-mentioned two meetings.

The Interim Report was submitted to Bangladesh during the Japanese Team's stay in Dacca from November 29 to December 14, 1974 and the bridge axis at Sirajganj site was, in December 1974, determined based on the aerial photographs newly taken by the Japanese Surveying Team in November 1974. Following the above aerial surveying, the Surveying Team carried out a new topographic surveying including cross-levellings over river width at the Sirajganj site in the 1974/75 dry season. Also, cross levellings

of large rivers acrossing the railway and road links were conducted by the above team. At the same time, the Geological Survey Team completed geological surveys along the bridge axis. Based on these new data, the plan of river control and the treatment of the Dhaleswari River for bridge crossing, the plan of bridge construction and approach execution were completed. The results of the study are mentioned below in short.

2. Width and Traffic System of the Bridge.

Decision of the width system of the Jamuna Bridge is one of the most important items for this project, because of it will not only affect the future nationwide transportation of Bangladesh but also control the total construction costs of the Jamuna Bridge. Hence, the bridge width is required to be a minimum in the range that will fully meet the traffic flow in the future.

If the year of 2020 was taken as a target year of forecasting the future traffic, the road traffic will be 8,666 vehicles per day in passenger car equivalent as was estimated in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS. For this traffic, since the design traffic capacity of two-lane carriageway of width 24' is 12,900 vehicles per day in passenger car equivalent as mentioned in APPENDIX-6 of this report, the two-lane carriageway is amply sufficient for the future vehicle traffic of the bridge.

Also in VOLUME VII, railway traffic in the year 2020 was estimated at 38 passenger trains and 21 freight trains, 59 trains in total assuming broad gage track of 5'6". If we assume the average distance between the stations to be 6 km in consideration of the total length of the bridge and its approaches, a single broad-gage track of 5'6" will have a capacity for 74 trains per day. Therefore, the single broad-gage track is entirely sufficient for the future railway traffic.

As for a result, the width system of the Jamuna Bridge will fully answer the purpose with single broad-gage track and two-lane carriageway.

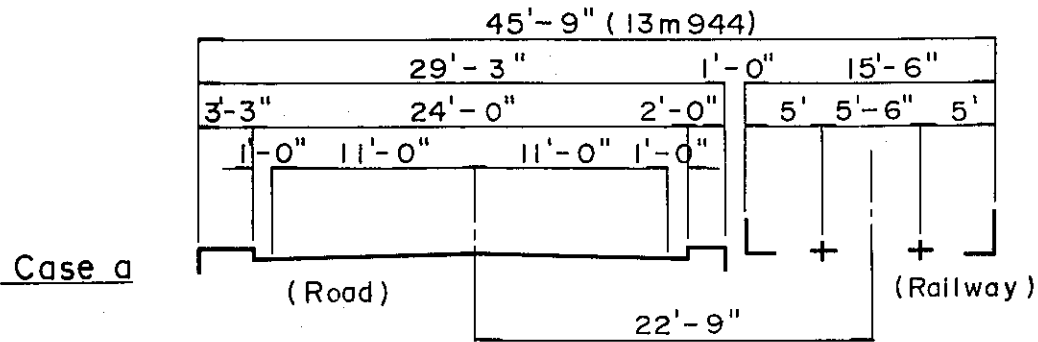
As the traffic system of the bridge that will cope with the future traffic as mentioned above, two ways may be taken into consideration. Namely, a method to construct a railway bridge and a road bridge by use and another way to built a railway-cum-road bridge. The former will, as a matter of course, cost higher than the latter. Since the bridge system of latter has, as stated previously, no objections lodged, we judged it is the best to built a railway-cum-road bridge.

When the preliminary design was made, it was concluded that the bridge should be planned in its width with the irreducible minimum of a demand for the bridge in due consideration of the following factors. (1) Future increases in the traffic. (2) Strict regard of the future traffic of crossing the bridge and the economic development of Bangladesh. Based on these two points of view, the bridge system was studied with the following two cases in mind. (See Fig. S-1)

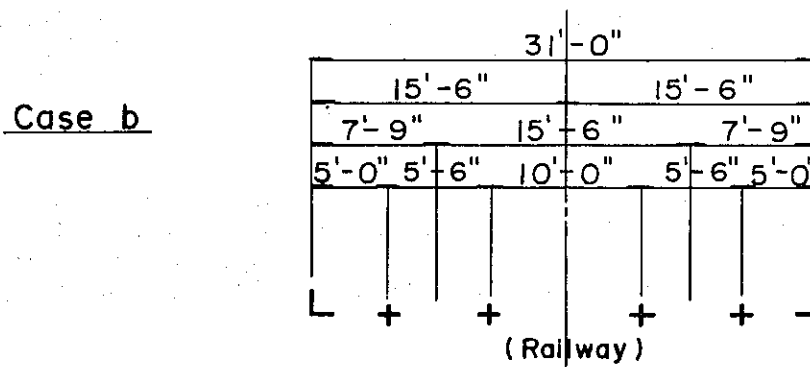
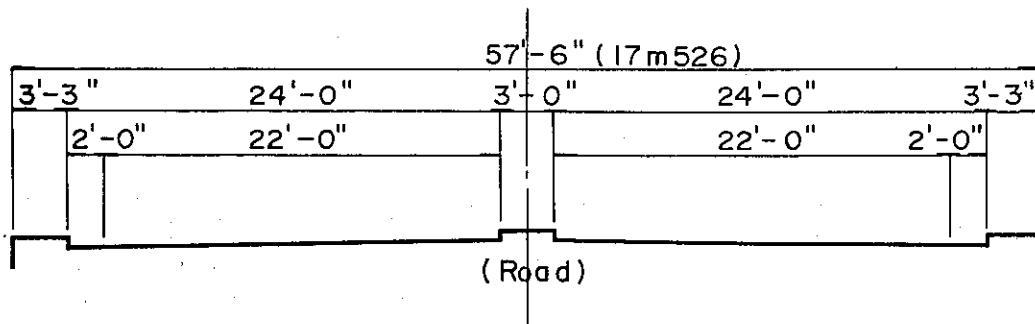
Case a	Railway portion: Single broad-gage track (5'6")
	Roadway portion: Two-lane carriageway (24')

Fig S-1. Width System of Bridge

a) In case of two lane , single track.



b) In case of four-lane , double tracks
(for double decks)



Case b Railway portion: Double broad-gage track (2@5'6")
 Roadway portion: Four-lane carriageway (48')

3. Design Criteria.

3.1. Loads.

All loads specified in the Indian Road Congress (Vehicle Class A) and the Indian Railway Standard (Steel Bridge Code) 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

3.2. Construction gages.

Standard Specifications for Highway Bridge established by AASHTO 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.

3.3. Navigation clearance.

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

Minimum horizontal clearance	: 250 ft (76 m)
Minimum vertical clearance above DHWL	: 40 ft (12 m)

3.4. 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 Bridges established by the Japan Society of Civil Engineers.

3.5. Concrete structures.

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

4. Type of Superstructure and Substructure.

The navigation width to be adopted in the design of the Jamuna Bridge should accord as stipulated in the BIWTA to have a minimum horizontal clearance of 250' and a minimum vertical clearance of 40', and the minimum space of piers and the clearance under the soffit of bridge are controlled by the above stipulation.

Meanwhile, in due consideration of design discharge, design high water level, water depth and local scouring, it is obvious that the Jamuna Bridge will exceed 4 km in its total length. Hence, since the Jamuna is a braided river, even though guide banks are used for fixing the channel, the thalweg of the flow shifts to and fro in its range. Accordingly, it should be required to lay the foundation for piers in uniform depths. Further, based on the results of geologic surveys, the bearing layer reliable as the foundation for piers is a sand layer lying approx. 70 m beneath the ground surface and, hence, each of the piers is required to have an exceedingly deep foundation. For these reasons, the substructure works are anticipated to expand to works of extra-ordinary scale together with enormous costs of construction.

Hence, for reducing the overall construction costs of superstructure and substructure as much as possible, the superstructure is required to be of a long span bridge.

For the reason as stated above, as materials for the superstructure, steel or prestressed concrete is doubtlessly made the object. When these two materials are compared, since a steel bridge is lighter in the bridge weight than the prestressed concrete one, it affects the substructure less by earthquake and is economical to that degree, the steel bridge in longer span bridges brings about superior workability to that of the prestressed concrete bridge and accordingly a shorter term of execution. Through these studies, a conclusion has been reached that the steel bridge is eminently practical for the Jamuna Bridge's superstructure.

As to the structural type of the superstructure, in case a long span of 100 m ~ 350 m is made the object, it is well known that a continuous truss type or a cantilever type is proper. In the case of b, in due consideration of the member composition of the superstructure, its rigidity and economics, the location of the railway and the roadway in the width system was determined to adopt a double deck type, in which the roadway is the upper deck and the railway is the lower part.

In the case of a, a single deck type will no doubt be adopted for its width system. Further, the span proportion is in view of the unified external appearance, an equal span system is adopted in either case of a or b. As a result of comparison between the continuous truss type and the cantilever type, due to the deciding process of the optimum span as will be stated later, it was concluded to adopt the continuous truss type for the superstructure of the Jamuna Bridge.

As the type of substructure, the well and multipile foundation were made the comparable objects in consideration of following condition.

- (1) It must support in safety the large loads from the long span bridge,
- (2) the depth of foundation is, as mentioned above, extremely long,
- (3) it must be suitable for the geology and river conditions of bridge site and (4) it has to be executed easily.

The well foundation is superior in its stability as the well itself has large dimensions. Even though there are no fundamental difficulties, this type of foundation becomes enormously large in scale in the case of the Jamuna Bridge which requires a longer depth of embedment of foundation. On the other hand, the multi-pile foundation is erected

by driving large-diameter steel pipes up to the supporting layer of the ground and then the pile heads are rigidly connected by base slab over the water surface. However, it will easily get deflected structurally. Moreover, seen from a viewpoint of local scouring around piers a local scouring of 1.8 times of water depth is forecasted, while in the case of the outer diameter of a pile is between 2.0 m ~ 3.0 m, the local scouring of 10 m is forecasted in the case of multi-pile foundation. Consequently, in the case of multi-pile foundation, influence by local scouring is comparatively small when compared with the case of well foundation. As a result of comparing these two types of foundation, we have concluded that the well foundation is the optimum as the foundation of the substructure of the Jamuna Bridge.

In order to reduce the current pressure that will affect the well, and the inertial force during earthquake, it is desirable to lower a crown height of well, as low as possible. Moreover, from a viewpoint of external appearance in a dry season, it is most adequate to support the superstructure by pier shaft constructed on the top slab of well.

For a pier shaft, two types of structure, namely reinforced concrete structure and steel structure, were studied.

In this case, the well requests larger length of 9 m than the case of reinforced concrete pier shaft, consequently, larger current pressure and inertial force by earthquake will be anticipated. Moreover, it requires approx. 220 tons structural steel and the construction cost was estimated twice as high as that of reinforced concrete pier.

Therefore, it was determined that the reinforced concrete pier is more preferable than the steel frame from the economical point of view.

5. Type of Bridge Approach.

Bridge approaches are indispensable for connecting railway links and roadway links with the bridge.

It is most economical to utilize approaches as embankment, provided that the ground of the approaches is capable of supporting the weight of embankment. The embankment is built in a right angle direction with the guide bank and serves as a cross dike which forms an important part of the guide-bank system. Hence, the embankment is constructed to form a straight line. The length of embankment is determined by the longitudinal slope of railway and at the stage of preliminary design, due to a longitudinal slope of railway which was set at 1/200, the embankment became approx. 3.5 km in length.

It was previously stated that the bridge of case b in width system was determined to adopt a double deck type, in which a roadway is laid on the upper deck and a railway on the lower deck. Consequently, for connecting the approach embankment with the roadway, it is required to shift the axial line of road from the center line of railway. The road surface of the bridge is comparatively high and, since the roadway is lapping over the railway, an elevated bridge becomes necessary in this portion. For the type of this elevated bridge, a steel continuous box girder bridge is most suitable.

As to the stability of the embankment, since the properties of banking materials were not made clear at the stage of preliminary design, calculation was tentatively made based on the circular arc method and it was assumed that a unit bulk density is 1.9 t/m^3 , angle of internal friction 20° , cohesion 0, and the slope gradient 1:2.5. As a result, it was proved that the banking was completely safe.

6. Preliminary Design and Selection of the Most Suitable Site for Bridge Construction.

According to the Inception Report, three factors in selecting the most suitable site out of the 4 candidate sites were suggested by our study team. In another words, (a) stability of the river channel, (b) the bridge construction cost, and (c) the traffic flow. The bridge construction cost will increase in proportion to the increase of guide bank span while the cost of river training works does not always increase with the increase of the guide span. Hence, it is necessary to seek a minimum value of the bridge work cost (total costs of river training works and bridge construction works) by various guide bank spans.

As river control measures of the Jamuna, 3 types of guide bank for four proposed sites were discussed by the River Control Team to fix the water channel at the bridge construction site area.

In the case of the type A, as the interval of guide banks at the bridge construction site, a main channel width of approx. 2 km was taken while in the case of type B, 4.2 km was adopted as the river width. For type C, the following river widths were adopted at each of the four proposed sites.

Bahadurabad site	5.6 km
Gabargaon site	5.2 km
Sirajganj site	5.6 km
Nagarbari site	5.2 km

As previously stated, the width system of bridge taken as the object of preliminary design consists of 2 types, namely (1) Case a: Single broad-gage track (5'6"), 2-lane carriageway (24'), and (2) Case b: Double broad-gage tracks (2@5'6"), 4-lane carriageway (48'). As the composition of spans for superstructure, a span length between 100 m ~ 350 m will be adopted as the object, in due consideration of a minimum horizontal clearance of navigation and the construction cost of the substructure.

Accordingly, for the span of the superstructure to determine the optimum span, the following 7 types were selected.

3-span continuous truss bridge (R.C. floor slab)

Spans: 100 m, 150 m, and 200 m

3-span continuous truss bridge (steel plate floor)

Spans: 200 m

Multi-span continuous cantilever truss bridge (steel plate floor)

Spans: 200 m, 250 m, and 350 m

As to the substructure, as previously stated, the well foundation and the multi-pile foundation were taken as the object for the preliminary design. For the multi-pile foundations, investigation was made on large scale steel pipe piles of the two types, namely piles of 2.0 m and of 3.0 m in diameter. As a result, it was judged that it is more economical to use piles of 3.0 m in diameter than to use piles of 2.0 m in diameter. However, in the case of the multi-pile foundation using piles of 3.0 m in diameter, due to higher construction cost than the well foundation, it was determined to adopt the well as the foundation of the Jamuna Bridge.

Though the well foundation reaches the depth of approx. 70 m, it is imperative on the foundation to complete excavating and sinking works in course of a dry season. For achieving this process, conventional methods of using tripod derricks and clamshell buckets are not effective. Hence, as the earth moving system it was decided to adopt excavators of large caliber, having a function of an earth moving system (reverse circulation system) by reverse circulation. It is also important for the multi-pile foundation to drive large diameter steel pipes and to place concrete for base slabs, of which pile-heads are rigidly connected. In order to drive piles at predetermined positions keeping predetermined intervals, temporary steel frames are prepared and by combining with the steel plates which will serve as the bottom surface forms of the base slab, the frames are made to serve as the guide during driving piles. This step is effective in execution.

For the erection method of the superstructure, the staging method by means of crawler cranes shall be adopted on land but in stream, the collective erection method by a flat barge or the cantilever erection method shall be adopted.

From a viewpoint of finding a span which will reduce the construction cost to the minimum by combining the width system, types of superstructure works, spans, types and shapes of substructure, and intervals of guide banks at each of the 4 candidate sites, various investigations and examinations were conducted. In another words, in order to determine the optimum span, in due consideration of the harmonization and simplicity of the superstructure and the substructure, comparison of the total construction costs, including both superstructure and substructure, was made by variations of span.

As a result, it was made clear that, throughout the 4 candidate sites, spans near 150 m long showed the utmost economics. In this case, the type of the superstructure of a 3-span continuous truss and the type of the substructure of the well foundation were adopted. Hence, it was decided to adopt a span of approx. 150 m long as the optimum for selecting the bridge construction proposed sites. As to Type A of the guide bank at intervals of 2 km, through the examination by the River Control Team, it was concluded that the intervals must be 4.0 km and more, and, hence, Type A was excluded from the object of the preliminary design.

The total construction costs of the superstructure, substructure and bridge approaches were calculated and shown in Table S-1. The estimation of the construction costs was based on the standards shown in 5, Chapter III. The construction costs mentioned here do not include those of

constructing general equipment and facilities such as housing quarters, motor pools, fuel storage installations, goods warehouses, and cargo loading and unloading facilities, and power supply facilities and water supply and drainage systems, etc.

As shown above, based on the 3 factors, (a) stability of river channel, (b) construction costs, and (3) traffic flow, selection of the optimum bridge construction site was made. Seen from an aspect of the stabilization of the river channel, Sirajganj and Gabargaon surpass the other two proposed sites and these are little difference to chose between them. In respect of construction costs, the overall construction costs including the costs of bridge works and river control works, were compared between these sites, then the case of 4.2 km distance between guide banks was most economical. Also as to the traffic flow, movements of men and transportation of materials, forecasting and estimation were made. These things are stated in the Interim Report on Feasibility Study of Jamuna Bridge Construction Project. Seen from a viewpoint based on the above standards, it has been determined to select Sirajganj as the most suitable as the bridge construction site.

After the most suitable site for bridge construction was selected, in due consideration of the panel length of 12.5 m and for attaining more accuracy on the decision of the optimum span, examination was given on the span length of 175 m and as a result, it was concluded that the construction costs of the superstructure and substructure will make no difference in both cases of 150 m span and 175 m span. Consequently, the 2 cases were further discussed and it was decided that in case of interval of guide banks is 4.2 km, the total number of well foundation was reduced 4 wells less in the case of 175 m spans than those in the case of 150 m

Table S-1 Total Costs of Bridge Construction Estimated at Preliminary Design

	Proposed site	Distance btw. guide banks	Total costs (100 million yen)
Case a Two lanes Single track	Bahadurabad	4.2 km	805
		5.6 km	1,009
	Gabargaon	4.2 km	819
		5.2 km	959
	Sirajganj	4.2 km	802
		5.6 km	1,006
Case b Four lanes Double tracks	Nagarbari	4.2 km	878
		5.6 km	1,024
	Bahadurabad	4.2 km	1,419
		5.6 km	1,767
	Gabargaon	4.2 km	1,437
		5.2 km	1,673
	Sirajganj	4.2 km	1,420
		5.6 km	1,765
	Nagarbari	4.2 km	1,508
		5.2 km	1,787

spans. This is more favorable in securing the water running section and at the time of execution of the foundation, it will minimize chances for accidents to take place. Moreover, in order to prevent the guide banks from scouring, it is more advantageous to adopt longer spans as far as possible.

7. Bridge Construction Works at Sirajganj Site.

Based on the aerial surveying data newly taken by the Surveying Team, the bridge axis at the Sirajganj site was determined in December 1974. The bridge axis is located about 12 km downstream of Sirajganj town. This site lies under the protection of the narrow as well as the Sirajganj bank protection works and has only one main stream with chars on both sides. The topographic plan indicated the bridge axis is shown in Fig. S-2.

The geological study team performed 5 drillings along the bridge axis attaching importance to the confirmation of continuity of each stratum and the position of supporting layer. The soil mechanical tests were also performed using bore holes. The summary of the locations and results of survey were shown in Fig. S-3.

The river control team added the new data of flood which took place in 1974 and based on these data, the fundamental items of the river control, for example the design discharge etc., were revised. The revised items were shown in Fig. S-4 with the standard cross section of the guide bank.

As the type of the Jamuna Bridge, superstructure has been decided, as previously stated, to adopt a railway-cum-roadway bridge of a 3-span steel continuous Warren truss of span length 175 m, and substructure has been decided, as will be mentioned later, to adopt a circular well foundation of 13 m in outside diameter. In due consideration of the navigation clearance and structural dimension of the superstructure, the formation level of the railway was fixed at EL=+30.0 m PWD. Moreover, since the navigation clearance between guide banks is required to be secured throughout the bridge, the longitudinal slope of the bridge was made horizontal. In the arrangement of the railway and the roadway, the railway was set on the downstream side and the roadway on the upstream side.

As to the horizontal alignment of the railway and the roadway, first of all, the railway is laid in a straight line along the bridge axis but the roadway on the right side of the Jamuna will go in parallel to the railway from the bridge to the existing embankment. After passing this embankment, the roadway will turn considerably to the upstream. As the roadway at left side of the Jamuna crosses the Dhaleswari River which shall be closed, the roadway will go straight along the bridge axis as well as the railway.

As for the longitudinal alignment, the railway on the right bank side, via the longitudinal slope of 1/400 of the block station from the railway formation level EL=+30.0 m of the bridge, goes down the approaches as 1/300 and is fitted on the formation level EL=15.9 m of the bridge which crosses the Hurasagar River. The longitudinal slope of the railway

on the left bank side is as same as the right bank side, but as the Dhaleswari River as previously stated is not required to be crossed by a bridge, it is kept the free board of one meter above the inland-flood water-level. As to the road, the right approach goes down from the surface height EL=30.58 m at the foot of the bridge to the height EL=17.1 m using the longitudinal slope of 3% and is fitted to the existing embankment directly (height of top of existing embankment is EL=17.1 m), and then it is connected with the road link. As there is no embankment at the left bank side such embankment as at the right bank side of the Jamuna, it is fitted at a slope of 3% gradient to the height keeping the free board of one meter above the inland-flood water-level.

Above-mentioned alignment relations were shown in Fig. S-5 graphically.

The proposed discharge of the Jamuna River was decided to be 96,850 cu.m/s and 4,200 m is sought for a minimum net width of the waterway corresponding to the proposed discharge. It was decided that the most economical span of bridge is 175 m and the outside diameter of well required for each pier is 13 m. This will necessitate 26 units of piers between both right side and left side guide banks. The total width of pier is added with 25% regarded as loss for the total width and when the interval between the guide bank and the abutment due to the span length of 175 m is considered, 4,680 m is obtained as the guide bank span. By this estimation, the effective river width becomes 4,257.5 m, and exceeds the minimum net width between the guide banks.

Since the bridge length was decided as 4,747.5 m corresponding to the above 4,680 m of the guide bank span, 9 sets of 3-span continuous truss of 175 m span were arranged. Accordingly, the number of units of the substructure totals to 28 units. The general view of the Jamuna Bridge was shown in Fig. S-6.

As to the superstructure, the height of the main truss is 26 m and the distance between both main trusses is 15.6 m and the panel length of the Warren truss was decided as 25 m which was obtained by dividing the 175 m long span into 7 equal parts. Further, for the necessity of sectional composition of the floor system, reduction of secondary stresses due to the deformation of the floor system, and also for increasing of rigidity of the bridge body, a subvertical member was installed on the panel of 25-m length to make the effective span of the floor system to be 12.5 m. The maximum weight of the largest member of the superstructure is approx. 22 tons and the maximum length of the largest member is 12.5 m and the maximum sectional form of the largest member is 110 cm x 80 cm. Furthermore, as to the bearing shoe, in order to stabilize the piers, all of the bearing shoes are made movable shoes and by installing dumpers at 2 intermediate supporting points of the 3-span continuous truss. This step was taken to disperse the horizontal force of the superstructure for the bridge axial direction during earthquake.

Above all, as to the pier shaft of substructure, as the length of top surface of pier becomes 21.0 m due to the erection of bearing shoes, longer than 15.6 m which is the distance of bearing shoes on the pier, and since the bottom end of the pier requires a circular section of 7.0 m in diameter, the pier shaft takes a inverted triangular shape.

In the second place, as to the well foundation, as previously stated, it takes a maximum length of 79 m. Hence, its execution, structure and stability were taken into consideration and also in due regard of the required sectional form of the pier-shaft bottom, eccentricity during sinking of well, it was decided to make the well foundation 13.0 m in outside diameter. In order to sink the well by its dead weight, the wall thickness of the well was made 2.5 m on land, and was made 2.2 m in stream.

In the stream area, execution of the substructure should be concentrated in a dry season and from a viewpoint of easier workability and reduction of the term of execution, the lower part of the well foundation was made of steel caisson. The steel caisson was 19 m long considering the local scouring during execution. At the same time, for the same reason, the foundation well of upper portion above the steel-made-caisson in stream was made of precast concrete blocks of circular ring shape made at factory (4 m height, 2.2 m in wall thickness, 13 m in outside diameter and 750 tons in weight). These blocks will be lifted by a floating crane ship and will be executed accumulating blocks one by one, by means of prestressing method. Further, the crown height of the well foundation is, from a viewpoint of execution, made EL=+7.22 m which is higher by 1 m than MLLWL +6.22 m.

In the well foundation, there is every possibility that local scouring around piers will attain a range of 1.8 times of the water depth from the water surface. The local scouring possesses no problems at normal state, but during earthquake, if local scouring is left as it is, the well foundation can not keep its stability. Hence, it is requested to provide the foot protection works around pier in order to keep the necessary embedment of well foundation against scouring.

For the protection of the foundation well against local scouring around the well which is deeper than the design riverbed, constant inspection must be continued against scourings and utmost care should always be paid for the maintenance and administration of the design riverbed.

Fig. S-2 Topographical Map of Bridge Site
and Bridge Axis
(Sirajganj Site)

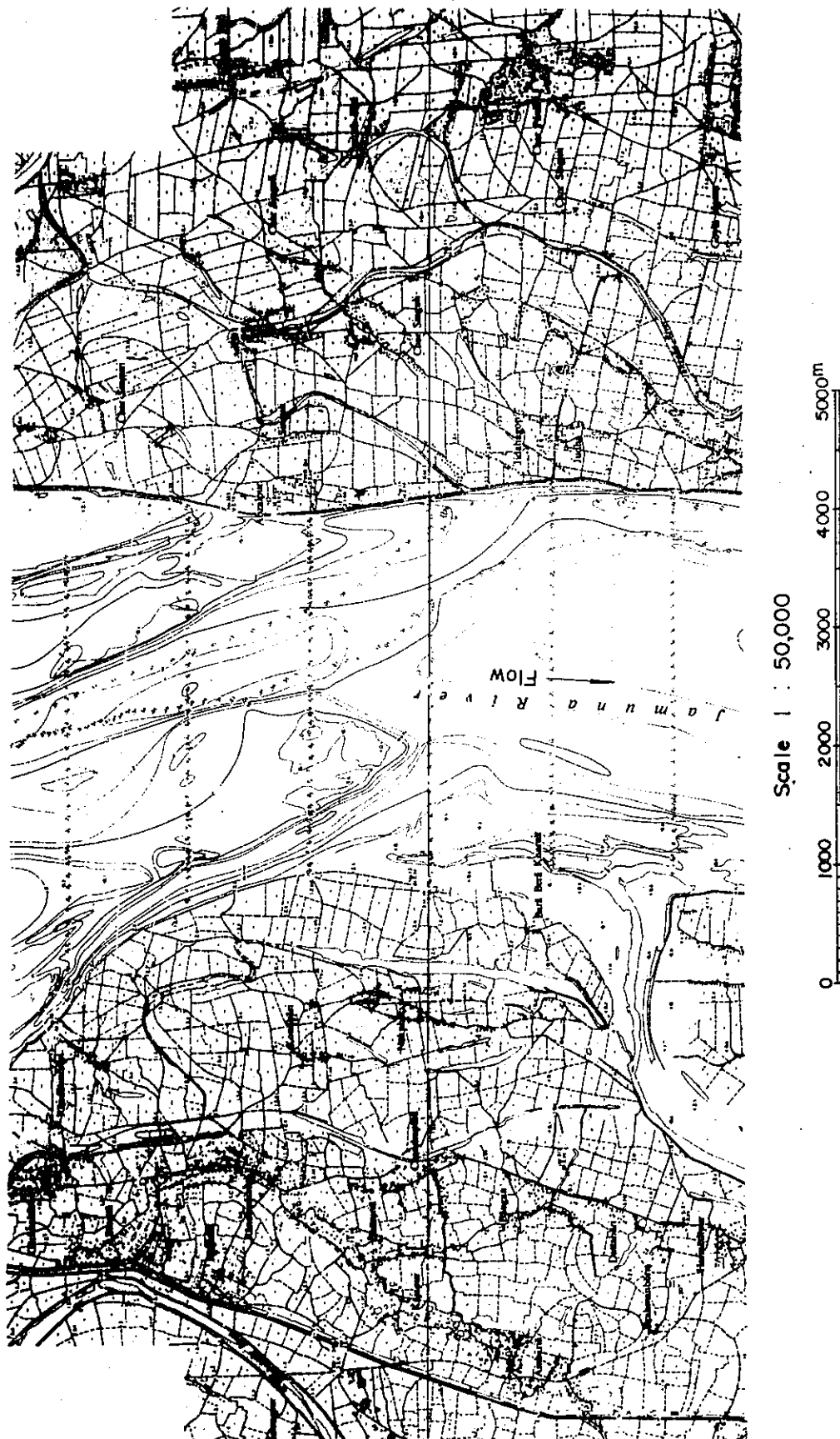
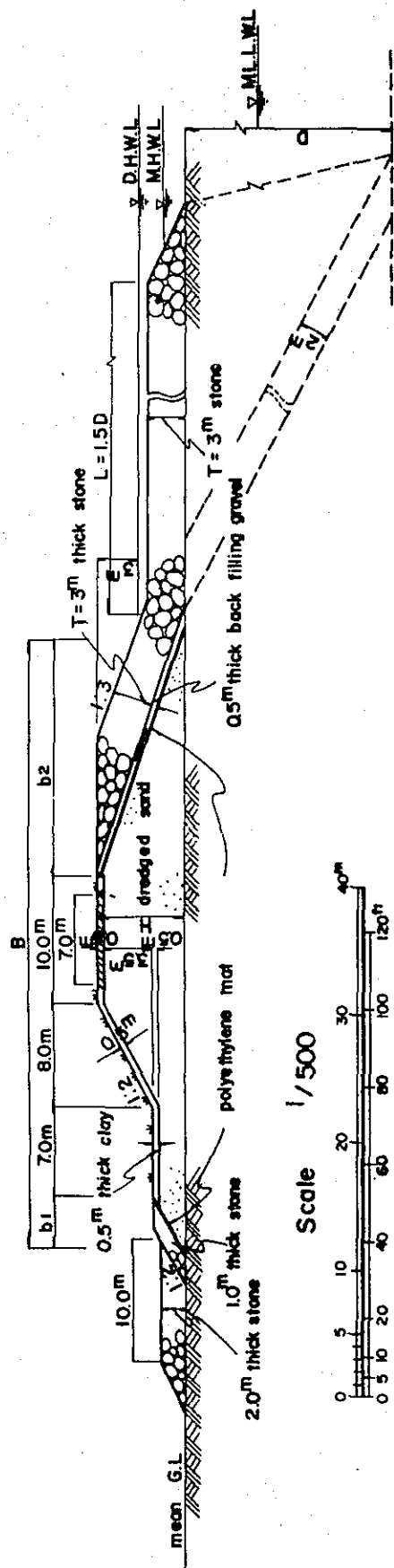


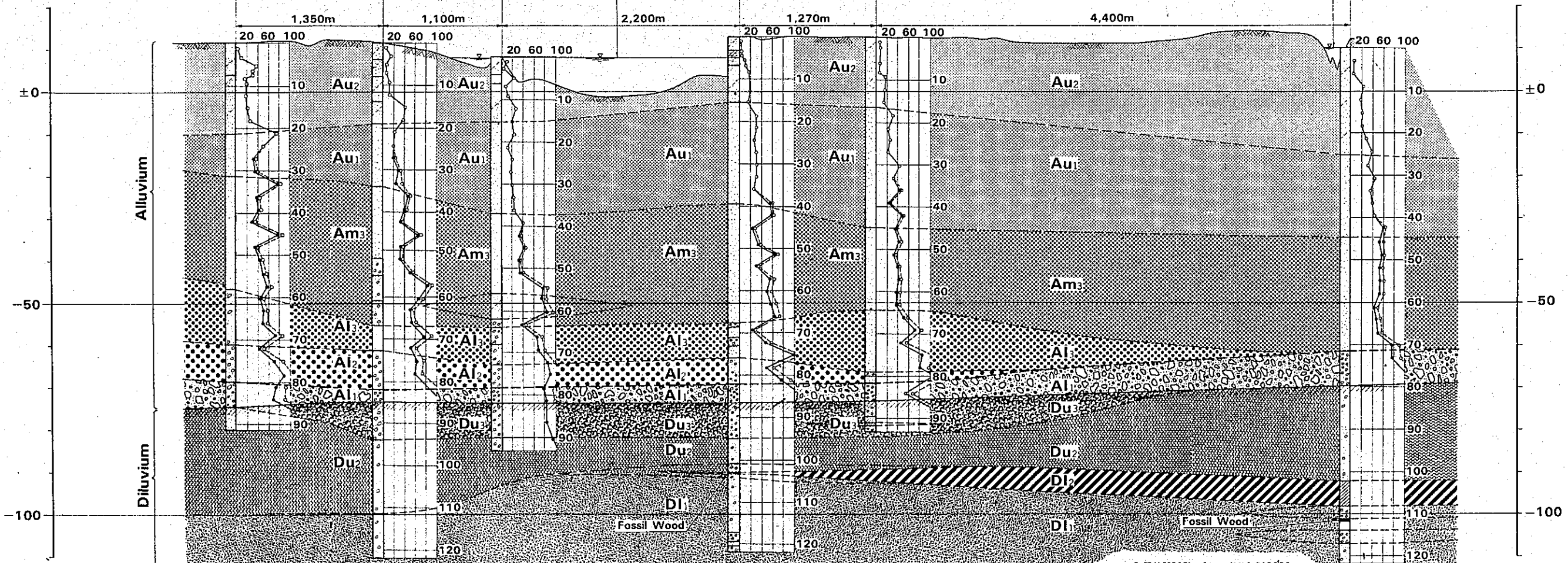
Fig. S-4 Standard Cross Section of Guide Banks



Design high water level	DHWL	+ 15.25 m
Mean river bed	MRB	+ 3.57 m
Lowest low river bed	LLRB	- 24.5 m
Mean lowest low water level	MLLWL	+ 6.22 m

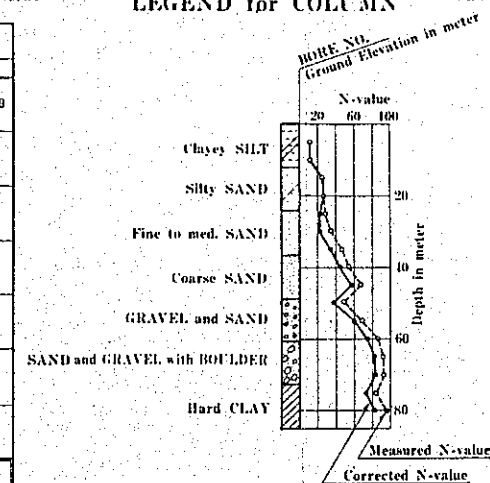
Fig. S-3 Geological Profile and Explanation Table on Bridge Site

ELEVATION IN METER

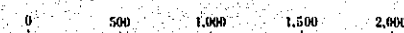


GEOLOGICAL AGE	STRATIGRAPHY		STRATA	DESCRIPTION			TYPICAL GRAIN SIZE DISTRIBUTION						UNIFIED SOIL CLASSIFICATION	CORRECTED N-VALUE		DEFORMATION MODULUS (E-VALUE) (kg/cm ²)			ESTIMATED SOIL MECHANICAL VALUE						
				CHARACTER	COLOR	FACES	20	40	60	80	%	D ₁₀		D ₆₀	C _u	by U.T.C. FORMULA	by INSITU DATA	E ₁	E ₂	E ₃	C	φ	γ _t		
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	UPPER	Au2	SILT and Fine SAND	GRAY	Fluvial to deltaic	AM						0.035	0.15	4.3	S-M	8	10	56	28	77	0	0.1	1.8~1.9	
			Au1	Fine to Med. SAND	-do-	-do-								0.06	0.3	5	S-M	30	36	210	101	89	0	34	2.06
			Am3	Fine to Med. SAND	-do-	Terrace to Fluvial								0.015	0.3	6.7	S-M	38	40	266	112	111	0	36	2.17
	OLD ALLUVIAL DEPOSITS	LOWER	Al3	GRAVEL and coarse SAND	-do-	Basal of Alluvium							0.065	0.55	8.5	S-Mg	78	60	516	168	114	0	40<	2.21	
			Al2	GRAVEL and coarse SAND	-do-	-do-								0.05	0.7	14	S-Mg	78	60	516	168	114	0	40<	2.21
			Al1	SAND and GRAVEL with BOULDERS	-do-	-do-								0.2	3.6	18	G-M	80<				230	0	40<	2.26
PLEISTOCENE	YOUNG DILUVIAL DEPOSITS	UPPER	Du3	Coarse SAND with small gravels	-do-	Upper of Diluvium							0.043	0.73	17.4	S-Mg						0	40<	2.26	
			Du2	Coarse SAND scattered small gravels	-do-	-do-								0.04	0.35	8.8	S-Mg								
	OLD DILUVIAL DEPOSITS	LOWER	Dl2	Hard CLAY	greenish GRAY	Lower of Diluvium							0.009	0.07	7.8	M-H									
			Dl1	Gravel and SAND, dense	GRAY	-do-								0.028	0.35	12.5	S-M								

LEGEND for COLUMN

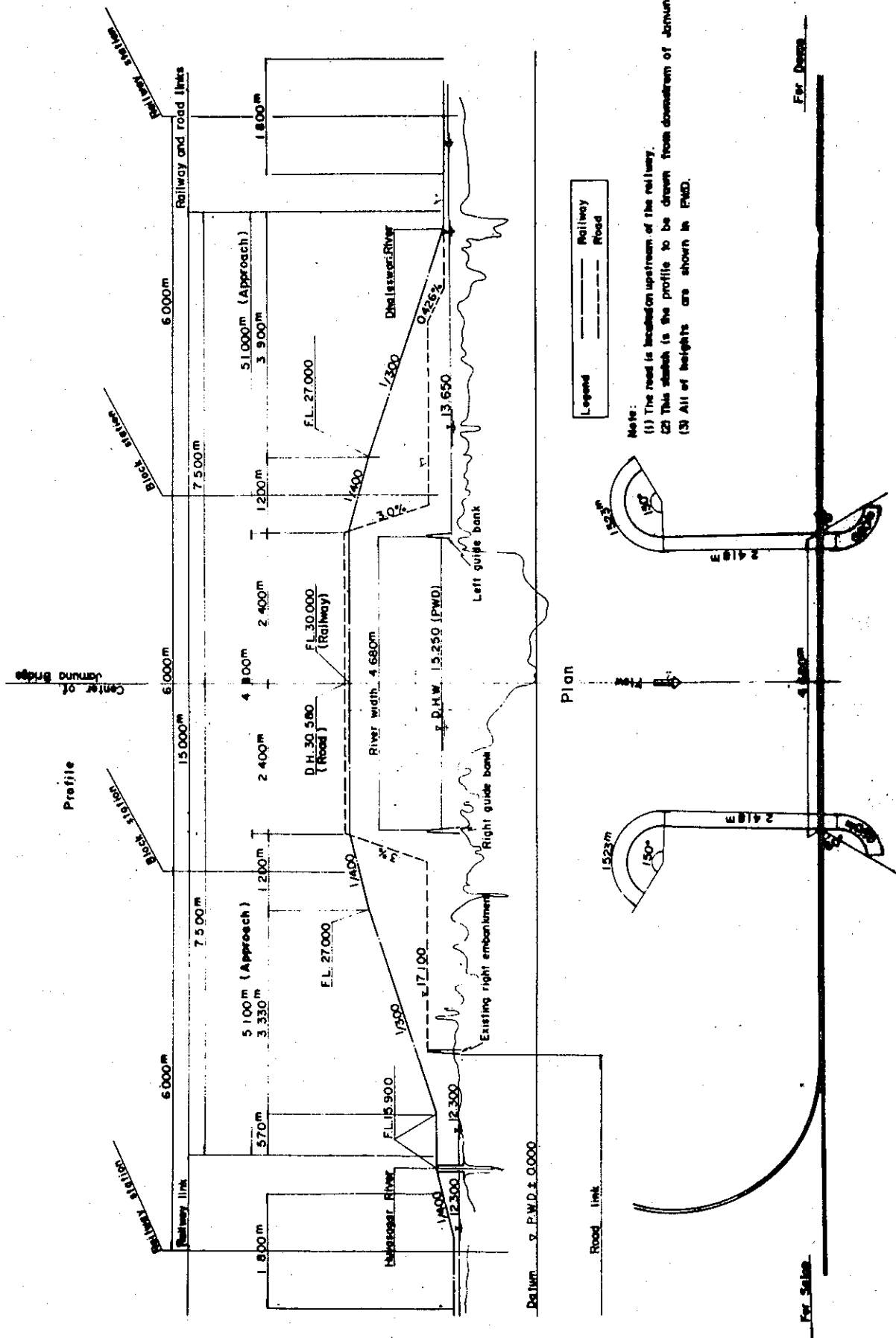


SCALE for distance in meter



JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLES' REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
GEOLOGICAL PROFILE AND EXPLANATION	
TABLE ON BRIDGE SITE	
DRAWN <i>H. Chandra</i>	DATE 14-Nov.'75
APPROVED <i>S. Islam</i>	DATE 15-Nov.'75
NIPPON KOEI CO. LTD.	

Fig. 5-5 Diagrammatic Sketch of Jamuna Bridge



- xxxxi -

The extension of banking of the bridge approaches is affected by a longitudinal slope of the railway. The steepest gradient of the railway was made at 1/300 in due regard of an extremely long slope and the traction capacity of locomotives. As previously stated, due to a distance of about 6 km between railway stations, it is required to build block stations in both sides of bridge. For these block stations, the steepest gradient was taken at 1/400. The highest level of the embankment depends on the design of the bridge. When the navigation clearance and the structural dimensions of the superstructure are considered, the formation level of permanent way was decided to be EL=30.0 m PWD. Accordingly, because the above longitudinal slope for the railway was used, the extension of the approach embankment fitted to the railway link will reach about 5.1 km.

In the cross section of the approach embankment, in due consideration of actual conditions of the existing high embankment and for the stability of embankment, berms shall be built for each when the banking height surpasses 7.0 m. The embankment was determined by changing the width of berms and the gradient of slope, and its stability was checked by the circular arc method applied on the portion of the highest embankment. As a result, it was confirmed that the embankment was stabilized with berms of 10 m in width and the slope gradient of 1:2.5. The mechanical properties of the earth used for this stability analysis were obtained as the test results by the Geological Survey Team and are shown as follows.

Dry density	1.6 t/cu.m
Water contents	26 %
Cohesion	1.5 t/sq.m
Internal friction angle	17.5°
Bulk density	2.0 t/cu.m

The approach embankment on the left bank of the Jamuna is required to cross the Dhaleswari River. Hence, the approach embankment in the Dhaleswari River, stone dikes are first constructed up to a height of 9.0 m PWD on both sides of the approach to be built, and then the portion between the both stone dikes is reclaimed by earth and banked up to 12.0 m PWD which is the mean ground height.

For the protection of the side slope of approach embankment, wire cylinders filled with bricks were set up to 14.0 m PWD so as to resist the flow and waves, and the slope surface is sodded up to the height of the road surface of the roadway (2-lane carriageway) which passes the upstream side of the embankment. Meanwhile, the upper area above the sodded slope was protected by one-layer brick masonry.

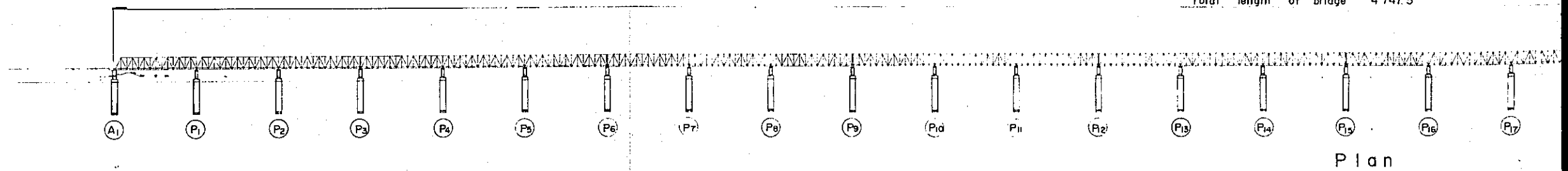
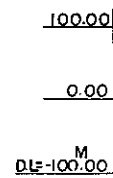
Quantities required for the superstructure, substructure and bridge approaches were shown in Tables S-2, 3, 4. The substructure works were divided into the land area and the stream area. Further the railway extension of the main bridge part and both side the approaches reaches 15 km and the materials required for this district are shown in Table S-5.

As to the working rate of the construction works, the working rate

S-6 General View of

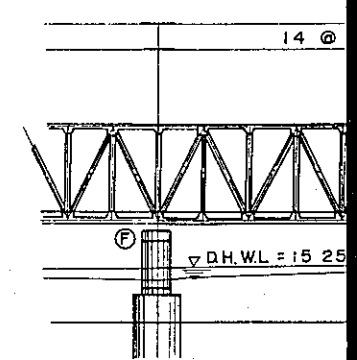
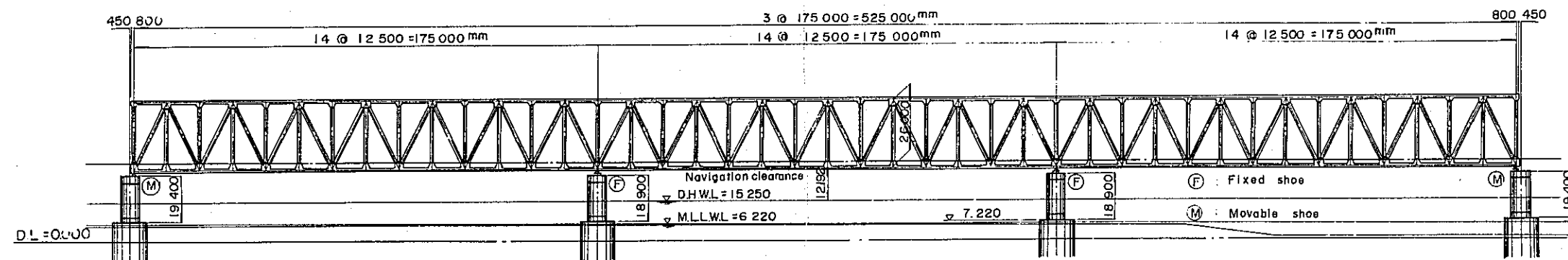
Profile

Total length of bridge 4 747.5 m



One Set of 3-Span Continuous Truss

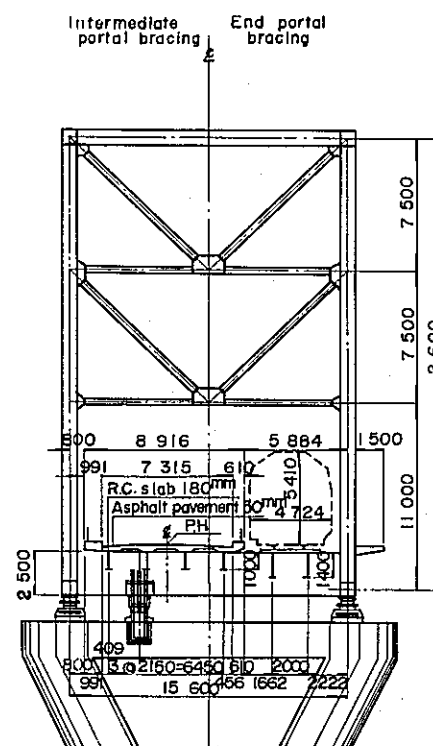
End



Cross Section of Superstructure

Front Elevation of Piers

Side Elevation of Piers



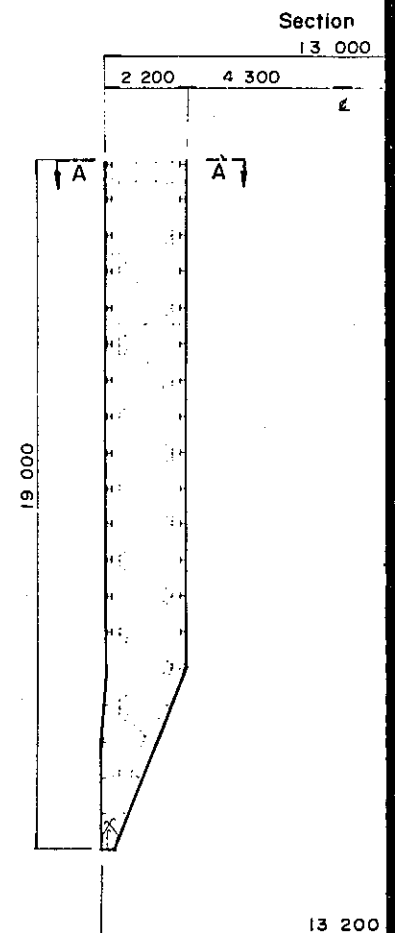
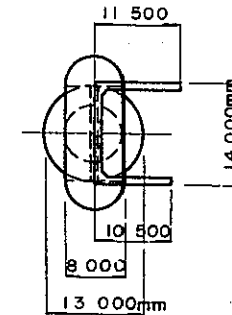
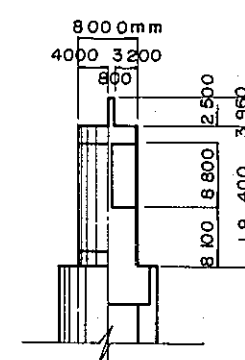
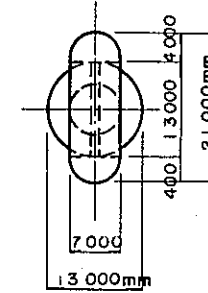
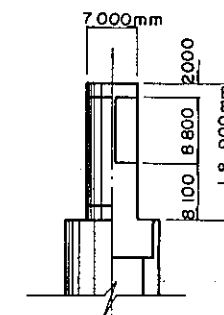
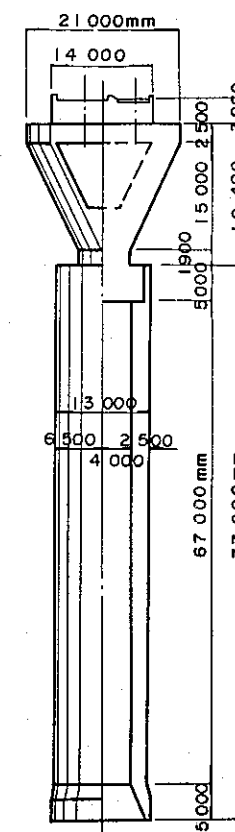
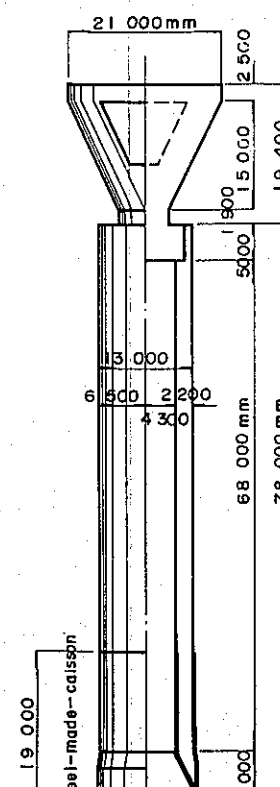
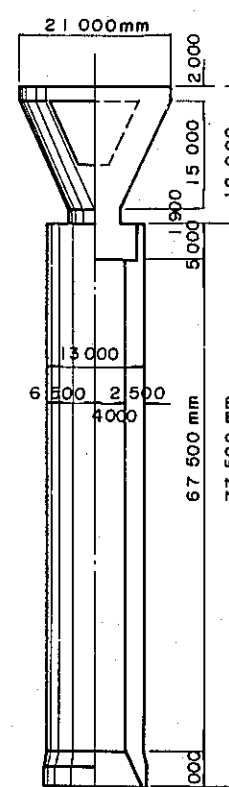
Pier on land

Pier in stream

End pier

Pier

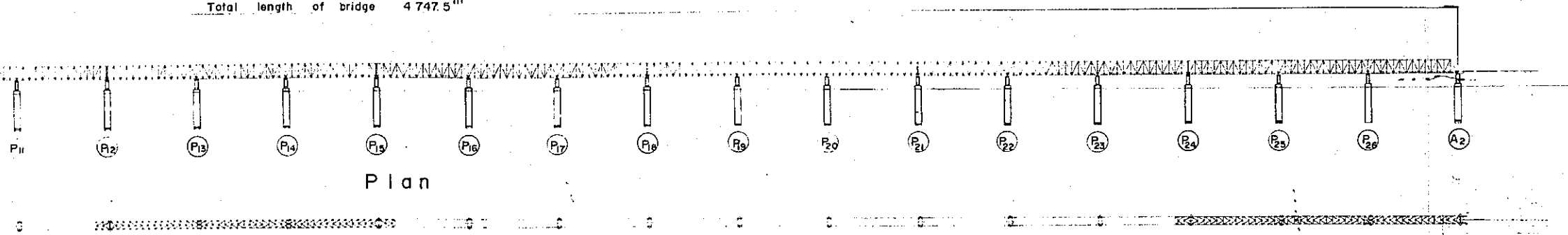
End pier



S-6 General View of Jamuna Bridge

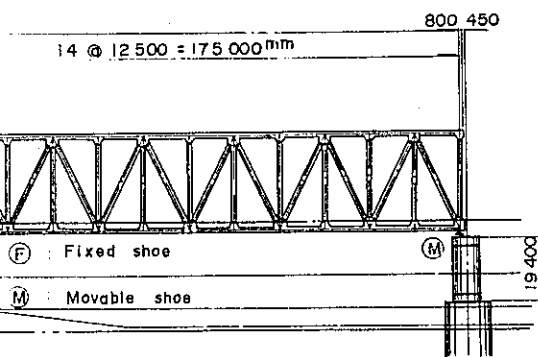
Profile

Total length of bridge 4 747.5 m

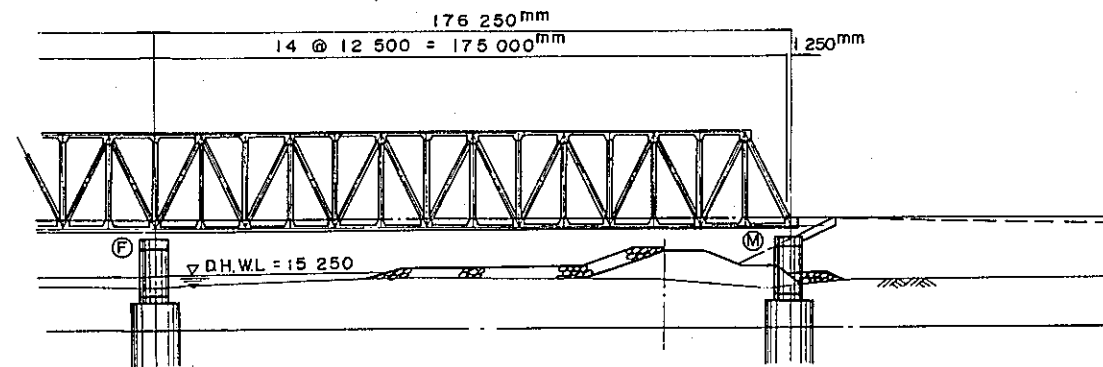


Plan

End Span

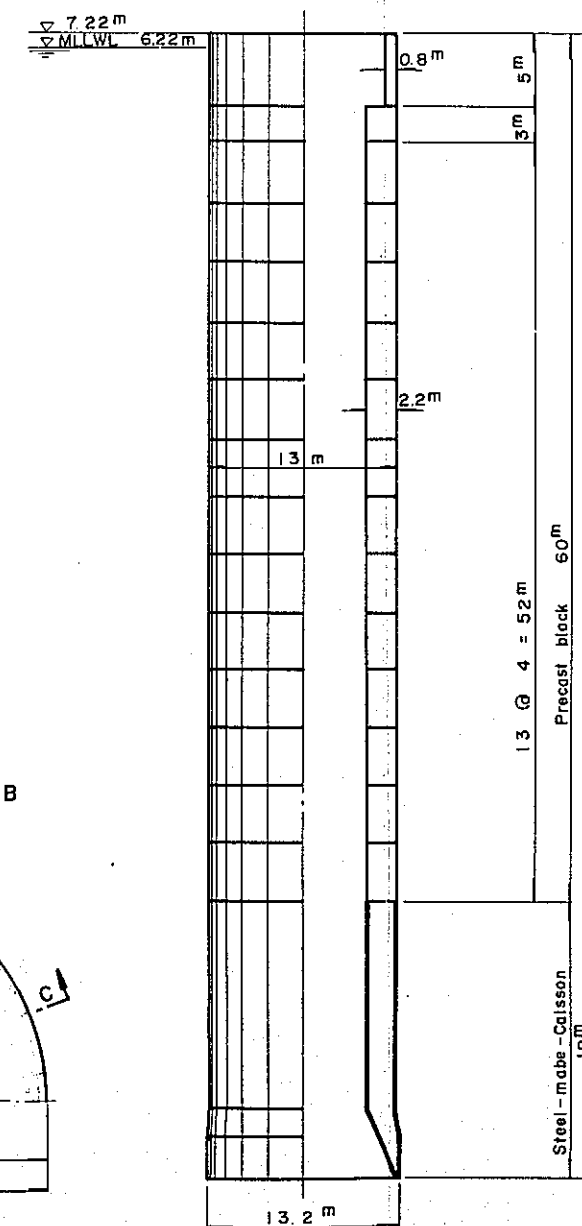


Side Elevation of Piers

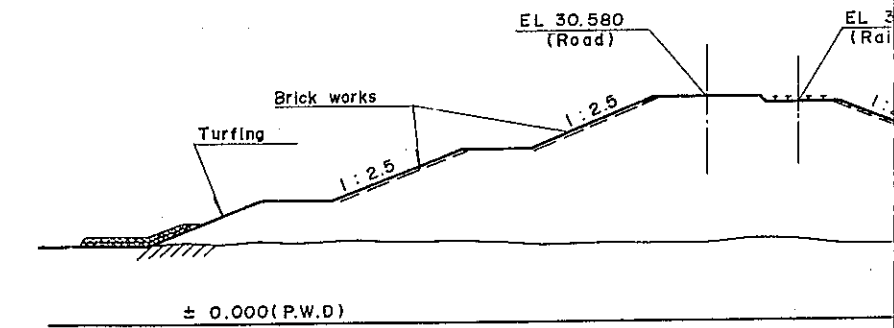


Steel-made - caisson

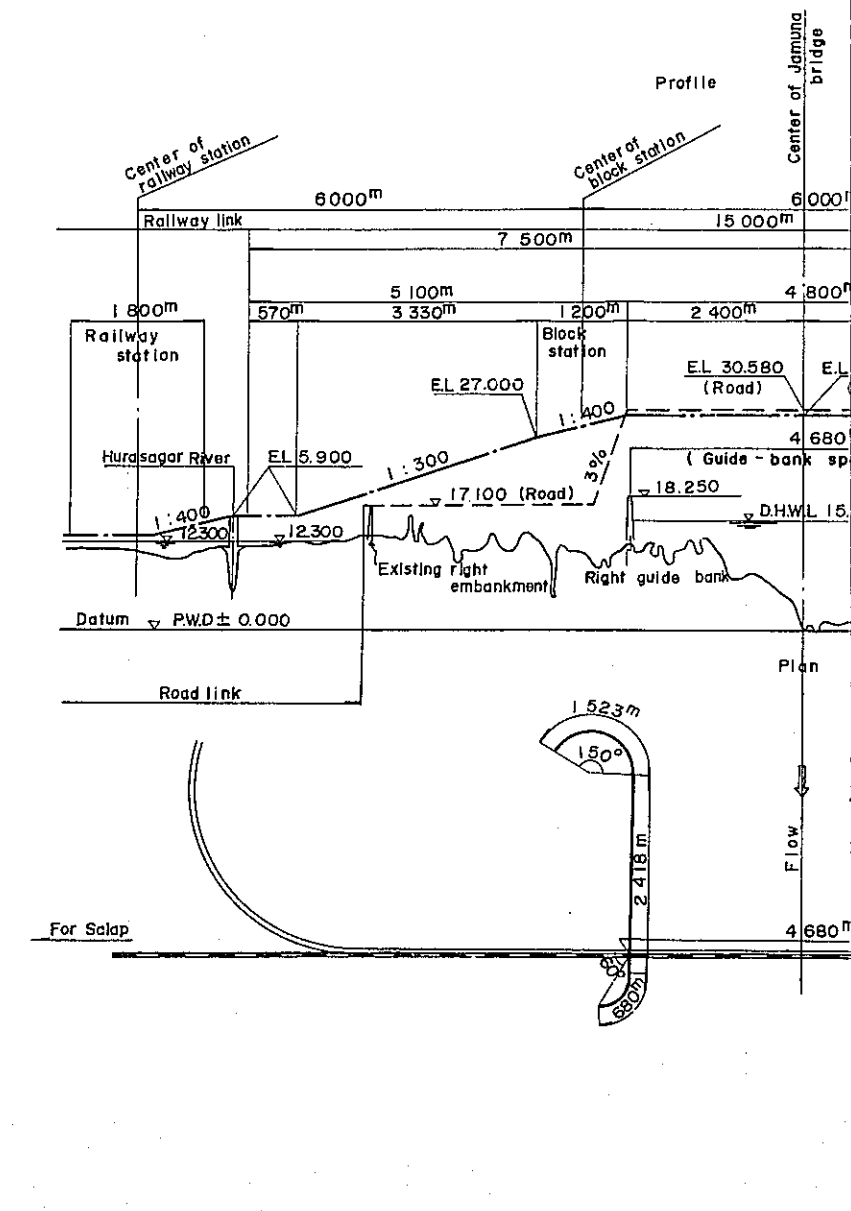
Composition of Rods of Well in Stream



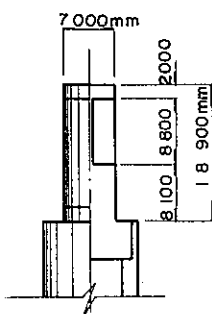
Typical Cross Section of Bridge



Sketch of Jamuna

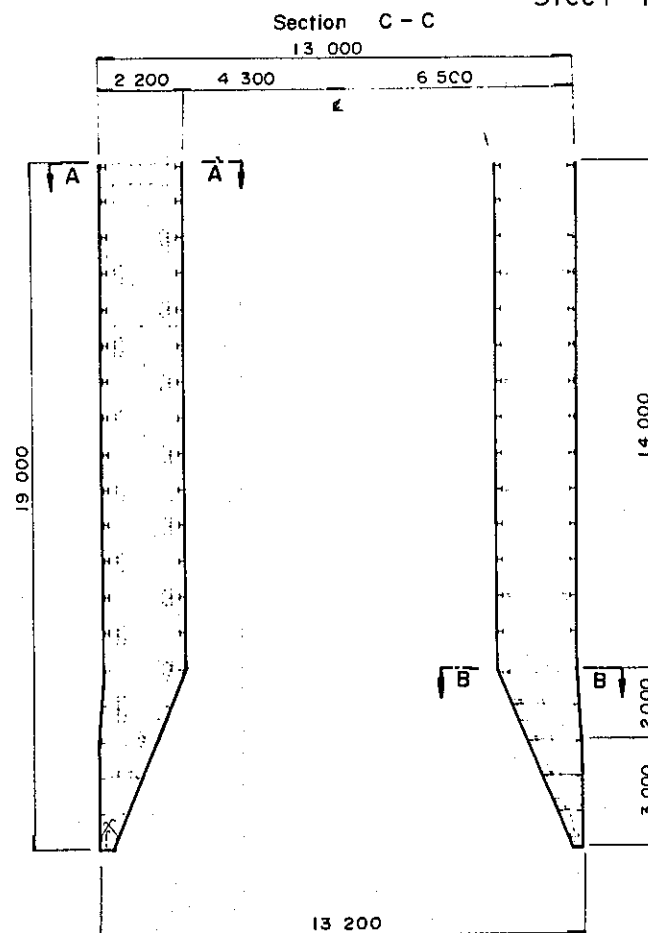
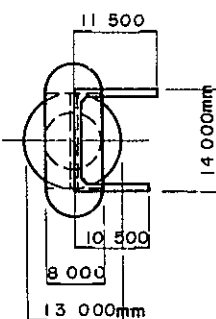
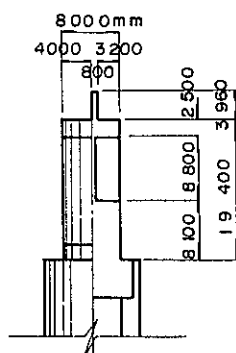


Pier

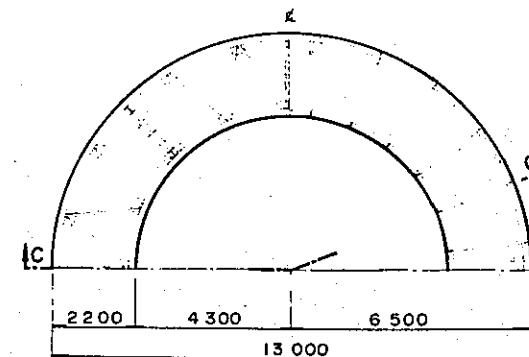


Plan

End pier



Section A-A Section B-B



Composition of Rods of Weir
in Stream

Section B - B

6 500

3 000

13.2 m

13 m

0.8 m

5 m

3 m

2.2 m

13 @ 4 = 52 m

Precast block 60 m

Steel-mat-calcium 19 m

7.22 m

MLWL 6.22 m

P23, P24, P25, P26, A2

EL 30.580 (Road)

EL 30.000 (Railway)

Brick works

Turfling

1:2.5

1:2.5

1:2.5

1:2.5

Wire cylinder

EL 14.000

GL +11.500

± 0.000 (P.W.D.)

The drawing consists of two main parts: a **Profile** view at the top and a **Plan** view at the bottom.

Profile View:

- Horizontal Dimensions:** The bridge is divided into several sections with lengths of 8000m, 7500m, 15000m, 7500m, and 6000m.
- Vertical Dimensions:** Key elevations include EL 27.000, EL 30.580 (Road), EL 30.000 (Railway), EL 27.000, and EL 14.650.
- Structural Features:** Labels include "Railway link", "Center of railway station", "Center of block station", "Hurasagar River", "Dhaleswari River", "Existing right embankment", "Right guide bank", "Left guide bank", and "Datum ∇ P.W.D. $\pm$ 0.000".
- Gradients:** Slopes are indicated as 1:400, 1:300, and 0.426%.

Plan View:

- Dimensions:** Shows a total width of 4680m and individual guide bank widths of 1523m and 2418m.
- Angles:** Curved guide banks are shown with angles of 150° and 90°.
- Flow Direction:** An arrow labeled "Flow" points towards the "For Dacca" end.
- Labels:** "For Salap" and "For Dacca" are at the ends of the bridge.

Note:

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

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

Table S-2 Total Materials Used for Superstructure

Unit : Ton

Main bridge work									
Items	Main truss	Floor system			Lateral bracing			Sway bracing	Sub total
		Stringer	Cross beam	Sub total	Upper	Lower	Sub total		
SM 53 & SM 50Y	18,144		3,024	3,024					21,168
SS 41 & SM 41	20,439	6,354	1,170	7,524	1,377	2,025	3,402	4,536	35,901
Cast steel									
H.T. Weight	918	270	126	396	18	54	72	90	1,476
bolt Number	1050210	456660	206910	663570	36270	86670	122940	151380	1988100
Total	39,501	6,624	4,230	10,944	1,395	2,079	3,474	4,626	58,545

Incidental bridge work									
Items	Expan-sion joint	Drainage	Hand rail	Bridge side-walk	Shoe	Sub total	Total		
SM 53 & SM 50Y									21,168
SS 41 & SM 41			711	945	99	1,755			37,656
Cast steel	117	45			801	963			963
H.T. Weight									1,476
bolt Number									1,988,100
Total	117	45	711	945	900	2,718			61,263

Slab work			
Concrete			11 169m ³
Form area			44 433m ²
Reinforcing bar			2 682t
Asphalt pavement			34 668m ¹
Painting area			
Shop			1,075,356m ²
Field			1,075,356m ²

Table S-3 List of Materials for Substructure

Items		On land	In stream	Total
Total length of wells	m	1,081.5	1,095.0	2,176.5
Excavation				
General	cu.m	63,300	---	63,300
Well	"	144,300	138,800	283,100
Total	"	207,600	138,800	346,400
Concrete				
Pier	cu.m	17,750	17,010	34,760
Top slab	"	---	10,500	10,500
Well	"	90,530	---	90,530
Total	"	108,280	27,510	135,790
In water	"	---	14,700	14,700
Precast	"	---	58,760	58,760
Prepacked	"	6,020	6,300	12,320
Form area	sq.m	86,050	84,760	170,810
Reinforcement				
D32 - D29	ton	3,188	680	3,868
D25 - D16	"	1,783	1,375	3,158
D13	"	16	182	198
Total	"	4,987	2,237	7,224
Structural steel	ton	560	2,100	2,660
Prestressing bar	"	---	2,408	2,408
Coffering wall				
Concrete	cu.m	---	1,400	1,400
Form area	sq.m	---	5,880	5,880
Reinforcement	ton	---	70	70

Table S-4 Materials Used for Bridge Approaches

Description	Unit	Right bank	Left bank	Total
Volume of earth	cu.m	2,894,200	3,367,500	6,261,700
Slope protection works				
Slope dressing	sq.m	329,730	334,950	664,680
Sodding	"	150,730	124,050	274,780
Brick work	"	130,910	134,710	265,620
Wire cylinder (Filled with bricks)	"	50,310	58,450	108,760
Drainage works				
Side ditch 200x200	m	21,500	28,800	50,300
" 250x250	"	5,600	5,700	11,300
Conduit ϕ 350	"	2,600	3,600	6,200
Inlet 500x500x700	nos.	450	580	1,030
Pavement works				
Subbase coarse t=450 mm	sq.m	22,920	37,450	60,370
Surface coarse t= 50 mm	"	22,920	37,450	60,370
Asphalt mixture	t	4,370	7,140	11,510
Stone	cu.m	---	65,000	65,000

Table S-5 Material List of Permanent Way of Railroad

Description	Unit	Quantity	Remarks
Length of permanent way	m	15,000	
Length of permanent way on bridge	"	4,747.5	
Length of permanent way on embankment	"	10,252.5	
Length of siding	"	1,900	
Rail (90 lbs./yd.)	ton	1,537	
Guard rail (90 lbs./yd.)	"	424	Second-hand rail
Fish plate	pcs.	6,760	
"	"	1,899	Second-hand fish plate
Bolt and washer	"	17,318	
Sleeper (wooden)	"	25,378	9' x 5" x 10"
Tie plate	"	46,234	
Rail-spike	"	236,411	
Hook bolt	"	18,040	
Anticreeper	"	2,051	
Guard timber	m	9,495	0.1 x 0.1 x 1.0
Scaffold board	"	4,748	0.03 x 0.4 x 1.0
Ballast	cu.m	19,064	
Switch and crossing #16	set	2	
" #12	"	2	
" # 8	"	2	
Various marks	ls.	1	

of the substructure works throughout the stream area and the land area, was estimated as 0.85 during the term of execution, the superstructure works 0.90 and 0.87 in the bridge approach works, respectively.

The temporary equipment and facilities are divided into preparatory works and temporary works. The preparatory works are handled collectively together with other works in VOLUME VIII OVERALL CONSTRUCTION PLAN AND ECONOMIC ANALYSIS. The temporary works includes facilities which are directly related to the bridge construction works such as a stock yard, a paint shop, a concrete plant, a barge mounted concrete plant, a prepacked concrete plant, an asphalt plant, temporary roads, a power generation system for construction use, a precast concrete block fabrication, an assembling yard of steel caissons, well execution frames and well points etc. The plant capacities for the above structures and

facilities are: Concrete plant - $80 \text{ m}^3/\text{hr}$; barge mounted concrete plant - $70 \text{ m}^3/\text{h}$; prepacked concrete plant - $20 \text{ m}^3/\text{hr}$; asphalt plant - 45 t/hr .

Main contents of the bridge works include well construction, pier shaft works, erection works of superstructure, slab works and approach banking works.

The execution of the substructure works is divided into the land area and the stream area. In the land area 14 units are constructed while in the stream area the same number of 14 units are erected. The flow charts of well sinking works in both land area and stream area are shown in Fig. S-7, 8, respectively. The excavation of the interior of well is executed by 2 boring machines of 2.0 m in diameter, which are provided with reverse circulating functions. These two machines are employed to operate at the same time. In order to promote the sinking of wells, the air jet method which will reduce the peripheral friction of the well is adopted. The upper part of well in the stream area is constructed by accumulating precast concrete blocks but the well in the land area is constructed by the slip-form method. The bottom slab of the well shall be executed by the prepacked concrete method and since the top slab of the well is 5 m thick, the concrete is placed in 2 layers by means of the barge mounted concrete plant. For the pier shaft works, large scale forms are used and the barge mounted concrete plant equipped with concrete pump having a capacity of $60 \text{ m}^3/\text{hr}$, is employed for the work. At any time of the day, aggregates, cement and water are supplied to the barge mounted concrete plant by a supply ship which is a 1,000-tonner.

It has been planned to complete the substructure works of 28 units within a 5-year period. The maximum number of construction of units per year is 3 on land and also 3 units in stream. The work schedule of the substructure works per unit on land and in stream are shown in Fig. S-9. The construction will first start at the river banks and then gradually works at the river's central part are caused to start.

Next, as to the construction of the superstructure works, the staging method is employed on land and the flat barge method is adopted in stream. Works at both areas are to be executed during a dry season. Due to large reaction of the superstructure under construction, stagings are erected at every 2 panels and the pile foundation is adopted for the foundation of the stagings. In the first stage, lower chord members, floor system, stringers are erected, and after the works was completed, verticals, diagonals, upper chords, upper lateral bracings and sway bracings are fitted, in sequence. The adjustment of cambers is made twice, firstly at the same time of lower chords fitting and, secondly when upper chords are fitted. Connecting of members are made by high tensile bolts. The staging method is used for the erection of 15 spans.

The flat barge method is adopted for 12-span between $P_{12} \sim P_{25}$. First, at the assembly yard equipped with a jetty in the main construction base, one-span trusses are dimensionally assembled, one span after another. The assembled truss is transported aboard a deck barge, a 12,000-tonner, which is towed by 6 tugboats. By using mooring wires on the prearranged sinkers and anchors, the position of barge is adjusted by winches loaded on board of the barge and by the tugboats. Then the assembled truss is erected at a stroke.

It has been planned to start the superstructure works of 27 spans within one year later than the substructure works, and to complete within a 5-year period. The maximum number of spans erected per year is 6 spans. On land, 3 spans shall be completed but 3 spans in stream. The work schedule of the superstructure works was shown in Fig. S-10.

In the slab works, concrete for the floor slab of the superstructure located in stream is transported by a barge mounted concrete plant which was previously set at the work site and arranged to place 500 cu.m concrete per day and to pump out concrete from the fixed location.

Since a quantity of banking earth for the bridge approaches amounts to 8,900,000 cu.m, 4,800,000 cu.m shall be supplied on the both banks by a 4,000-PS dredger from the Jamuna River. The remaining 4,100,000 cu.m shall be supplied by excavation from the borrow-pit at the down-stream of the approaches. The works shall be carried out in 3.5 m high at the initial stage of works along the whole of approaches and its formation is +14.0 m PWD.

The works shall be begun with the banking of the right approach and finished in two years, then, shifted to the left approach. Slope protection works, drain works and subbase course works shall be finished in one year following the banking works. Pavement works and permanent way works shall be executed together with those on the bridge.

Based on the work schedule and estimated planned progress of various works, and various material lists of various works, various materials required for each period of execution have been sought and classified by types and items, and by summarizing these, planned material lists have been prepared. These lists are shown in Table 7-7 and -8.

The number of labourers necessary for each construction work was decided taking the work conditions and used equipment for respective work into consideration. List of labourers was shown in Table 7-9.

The number of equipment and machines requested for each construction work was decided based on the working capacity of each equipment and scheduled construction period of the respective work. Necessary construction equipment and facilities were summarized and shown in Table 7-19.

When overall quantities of main materials used for the temporary equipment and the main construction works are summarized, they are as shown in the following.

<u>Item</u>	<u>Unit</u>	<u>Quantity</u>
Cement	ton	85,000
Sand	m ³	192,000
Gravel	"	200,000
Reinforcing bar	ton	12,300
Steel material	"	106,000
Cast iron	"	1,100
PC steel	"	2,700
Brick	piece	39,500,000
Crushed brick	m ³	158,000
Stone	"	281,500

<u>Item</u>	<u>Unit</u>	<u>Quantity</u>
Crushed stone	m ³	8,100
Heavy oil	K	24,100
Light oil	"	55,800
Gasoline	"	2,300
Lubricant	"	4,500
Paint	ton	1,700

The total number of laborers is added up as follows:

<u>Classification</u>	<u>Foreigner</u>	<u>Local laborer</u>
Skilled laborer	840,000 man-day	1,140,000 man-day
Unskilled laborer		1,710,000 man-day

As the aggregate for concrete, gravels produced in Boraganj are used. The annual aggregate output in Bholaganj totals approx. 57,800 m³/yr. As the quantities required for this Project are approx. 47,000 m³/yr., the quantities of aggregate given above can tentatively be secured.

The bridge construction works means, as previously stated, a combination of the main bridge and approaches. Hence, in due consideration of preparatory works which starts first, temporary works, superstructure works, substructure works, slab works, approach works, pavement works, and permanent way works and their correlationship between them, the overall work schedule was prepared and Fig. S-11 indicates the work schedule of the bridge construction.

As to the wages for laborers engaged in the bridge construction works and unit costs of construction equipment and materials locally procured or imported from abroad, decision was reached based on the survey results by the Price Study Team organized in July 1975. Consequently, the construction costs of this report were calculated based on the unit costs as of July 1975.

The exchange rate of currencies adopted for calculation was fixed at a rate of \$1.00 = Tk13.00.

The construction costs of the bridge are as shown in Table S-6. The construction costs of approach works include those costs of and cross dam required for closing the Dhaleswari River. However, costs of the preparatory works are excluded from the above costs.

As the maintenance costs of the bridge and bridge approaches, research expenses of the local scouring depth around the well foundations, deformation of the approach embankment and accident of the superstructure, expenses required for river bed protection to cope with local scouring, painting expenses of the superstructure, maintenance and repair expenses of railway, roadway, and maintenance and repair expenses of the embankment of the approaches and office administration expenses can be considered. Since an organization for the maintenance of the Jamuna Bridge should be considered together with the maintenance for organization of the river control, such maintenance costs were dealt with in VOLUME VIII OVERALL CONSTRUCTION PLAN AND ECONOMIC EVALUATION.

Fig. S-7 Flow Chart of Well-Sinking Works in Stream

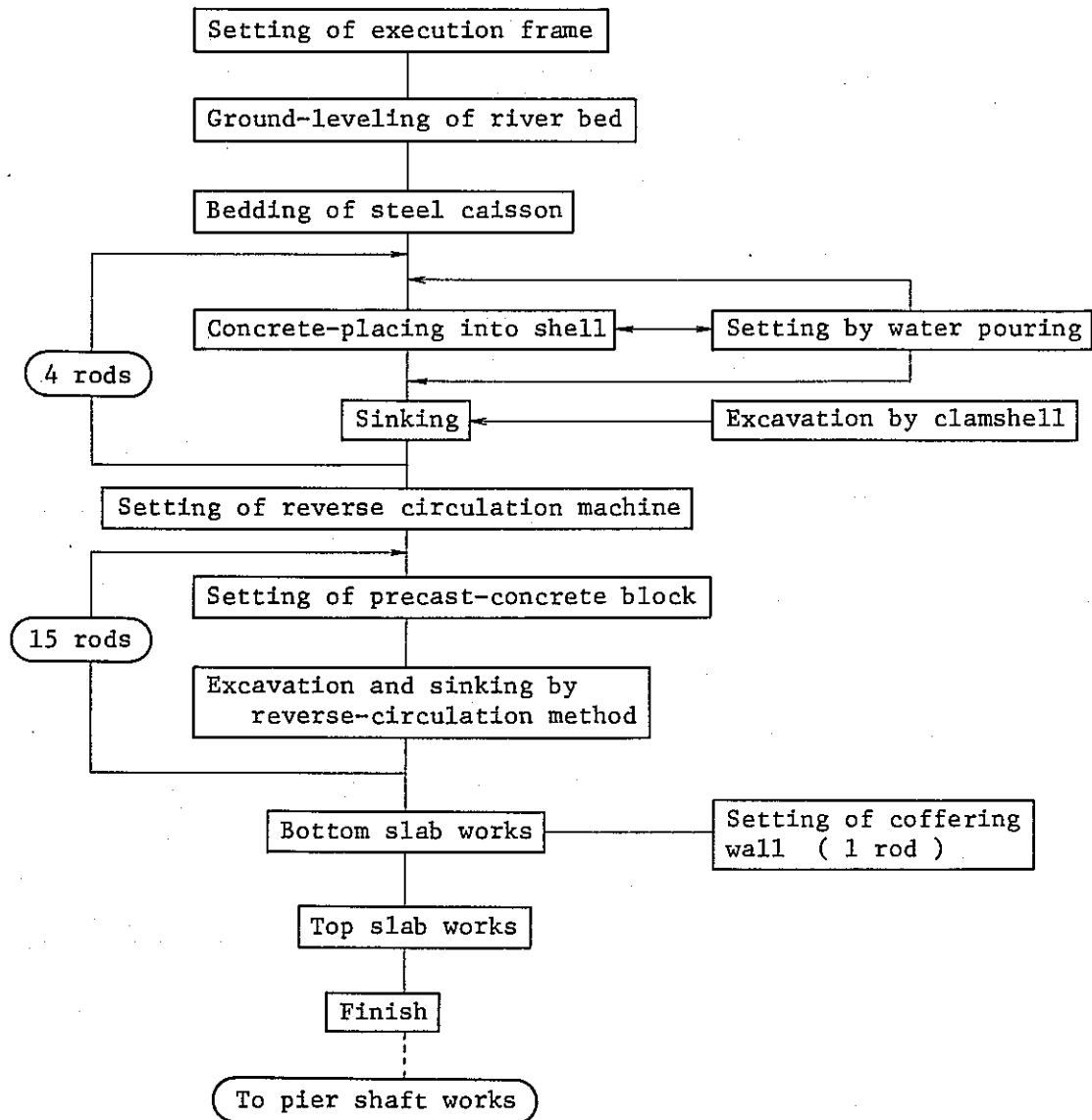


Fig. S-8 Flow Chart of Well-Sinking Works on Land

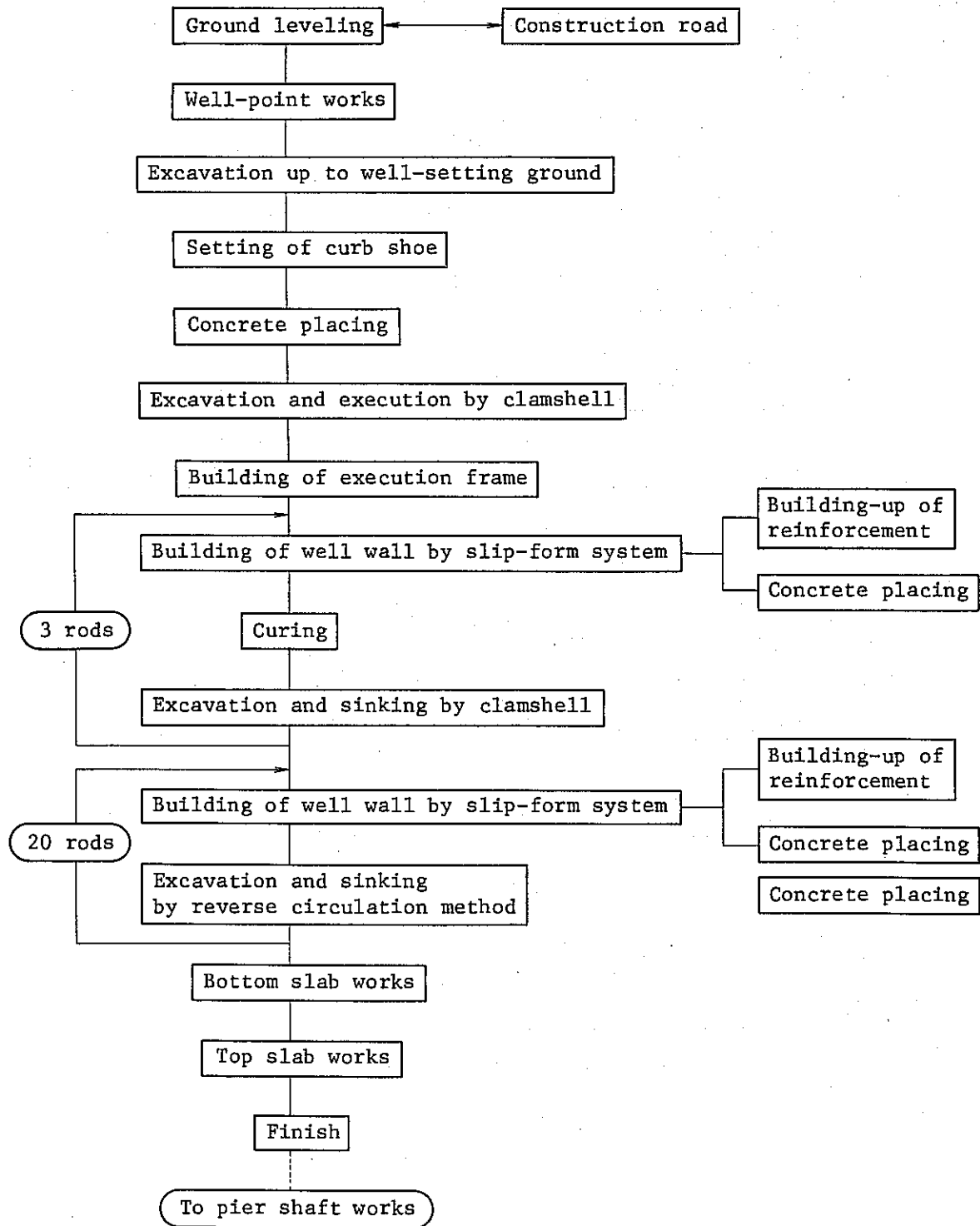


Fig. S-9 Time Schedule of Pier Works (One Pier)

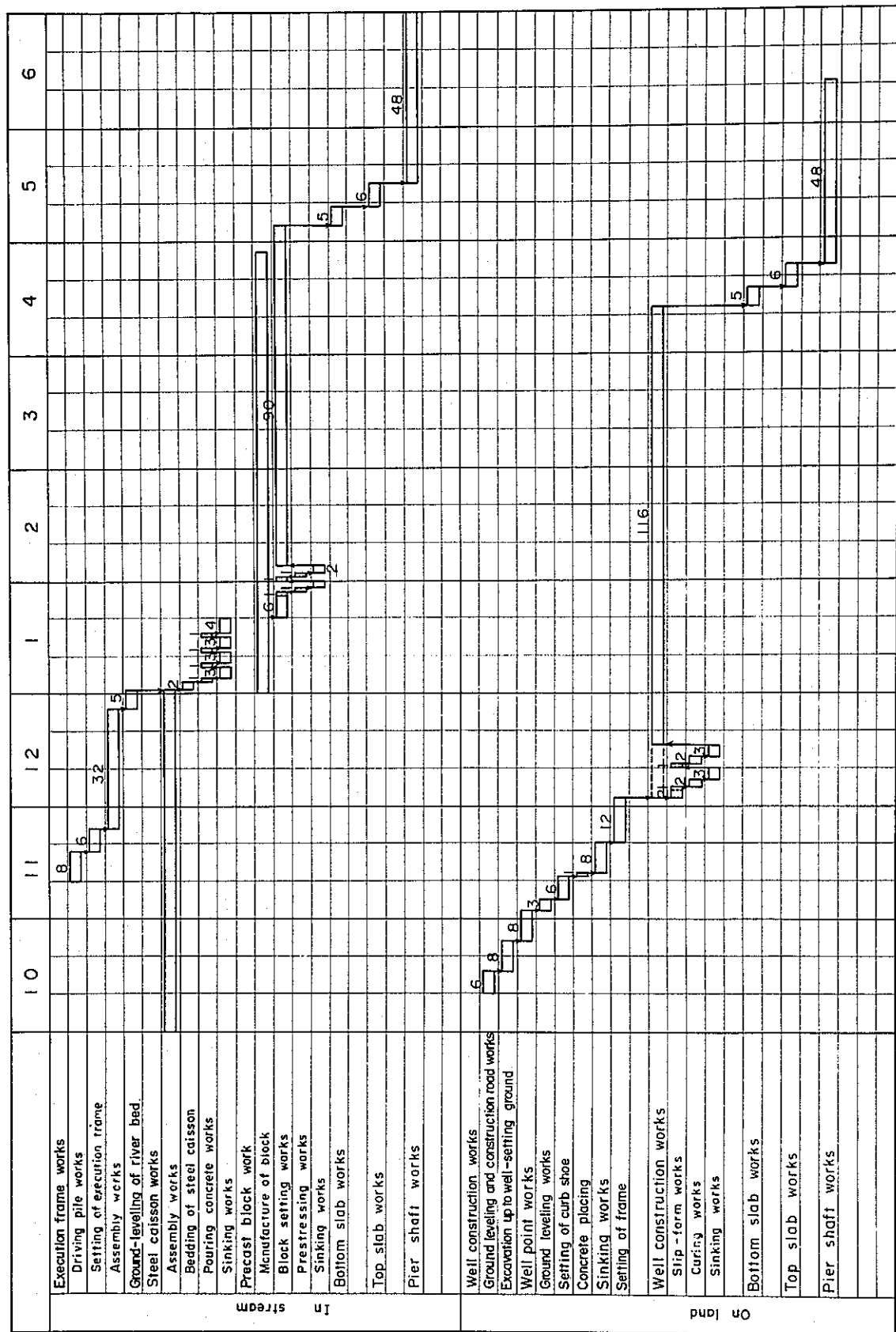
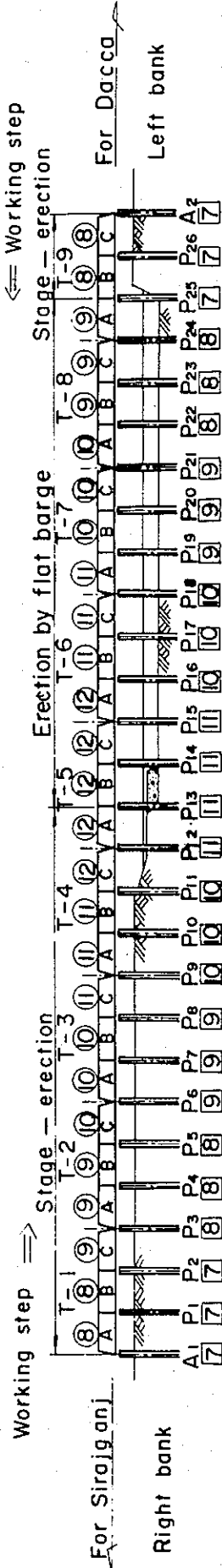


Fig. S-10 Time Schedule of Erection for Superstructure

Works	Year Month	6th.	7th	8th.	9th.	10th	11th.	12th.	13th
Preparation		A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J
Erection of T - 1									
Erection of T - 2									
Erection of T - 3									
Erection of T - 4									
Erection of T - 5									
Erection of T - 6									
Erection of T - 7									
Erection of T - 8									
Erection of T - 9									

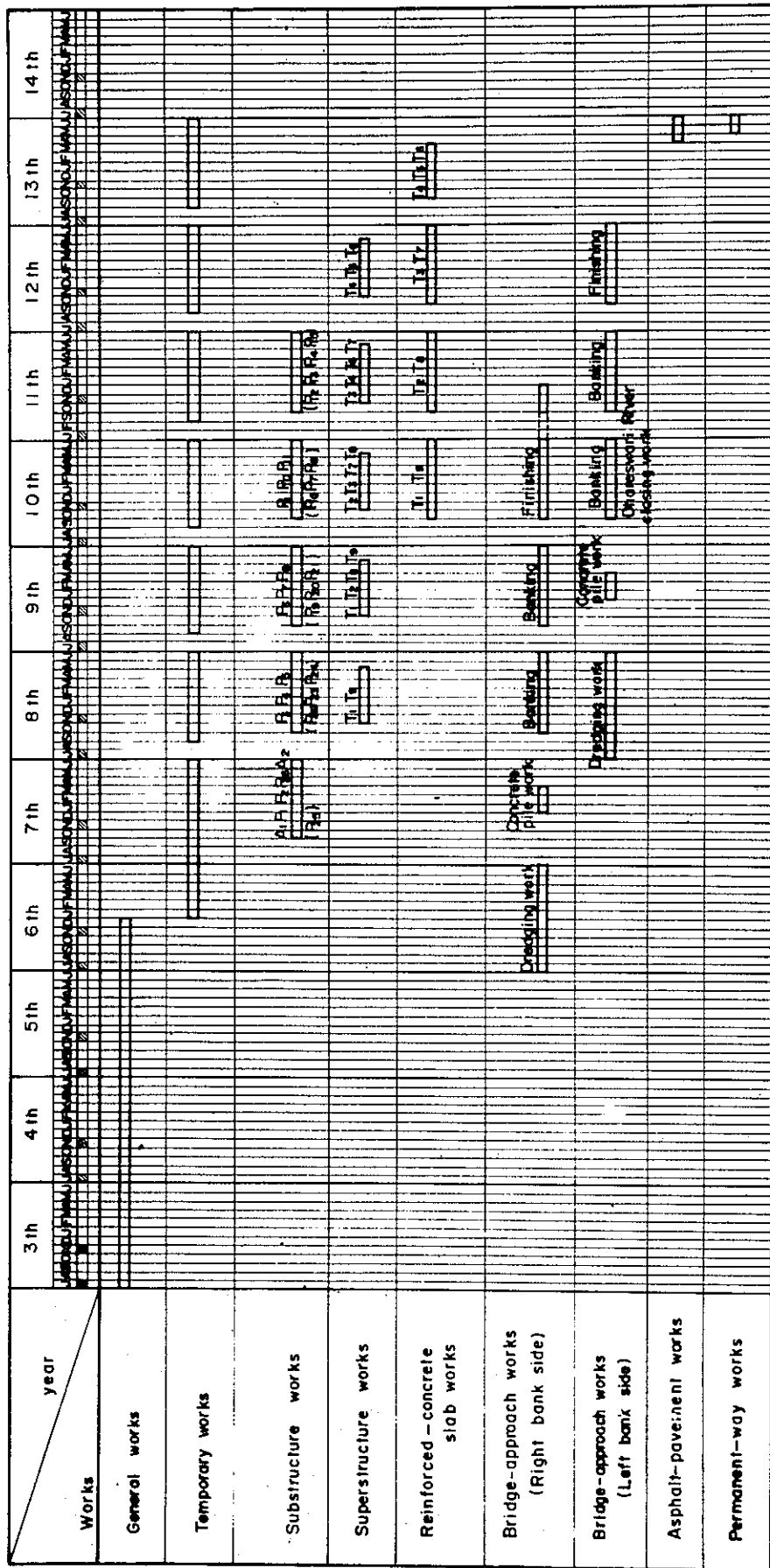
Notes:

- Number in circle shows erection year of superstructure, and number in a square shows execution year of substructure.
- Stage erection shall be executed in the dry season.
- In the case of erection by flat barge, truss shall be erected at yard during dry season and erected truss shall be set up on piers in dry season.
- Number in bracket shows necessary months for erection.
- Dry season is about six months from early in November to mid-May and rainy season is from late in May to late in October



Legend : C/C : Stage erection by crawler crane
S/E : Stage erection at yard.
S : Removing of scaffold.
J : Continued to the erection scaffolding by flat barge

Fig. S-11 Construction Schedule of Bridge



- xxxxxx -

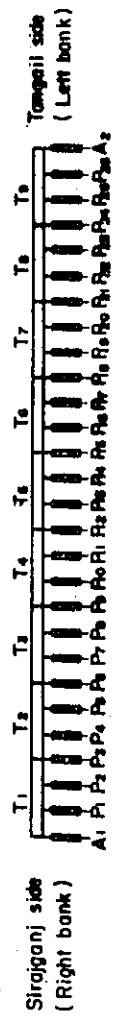
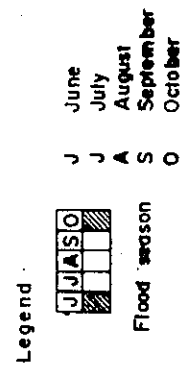


Table S-6 Total Costs of Bridge Construction

Description	Foreign currency (Dollars)	Domestic currency (Taka)	Total (Taka)
Substructure works	107,609,000	156,990,000	1,555,910,000
Superstructure works	194,557,000	104,760,000	2,634,000,000
Bridge approach works	19,834,000	56,490,000	314,330,000
Permanent way works	1,447,000	17,160,000	35,970,000
Land acquisition	---	12,410,000	12,410,000
Total	323,447,000	347,810,000	4,552,620,000

CHAPTER I

INTRODUCTION

1. Objective of the Present Study.

As described in the Inception Report (Inception Report on Feasibility Study for Jamuna River Bridge Construction Project), the study was divided into following two stages.

At the first stage of the study, the objective of the study is to provide the necessary data concerning to the bridge construction in order to discuss and decide the order of priority of the following four candidate sites on the stretch of the Jamuna River.

Downstream of Bahadurabad,
near Gabargaon,
about 10 km downstream of Sirajganj, and
about 20 km upstream of Aricha.

To furnish the above-mentioned data, the following works are to be requested from the technical and economical points of view.

- *Determination of the suitable structural types of bridge by use.
- *Determination of the suitable structural types of bridge super- and substructure from the technical view points.
- *Determination of the most suitable composition of spans of bridge superstructure.
- *Determination of the effective width of the bridge.
- *The planning of the approach embankment. This embankment serves as the cross dyke of the river training system.
- *The rough estimation of construction cost of bridge works.

Above-mentioned works should be carried out for every candidate site respectively.

At the second stage of the study, after the determination of the most suitable bridge site, the following works are to be needed for the study concerning to the most suitable bridge site.

- *To carry out the rough design of super- and substructures of the bridge and the approach embankments.
- *To estimate the approximate quantities of the construction materials to be needed for the bridge construction.
- *To estimate the construction equipments to be required for the bridge construction.
- *To discuss the method of transportation of construction materials and equipment to the working fields.
- *To estimate the approximate construction costs of bridge works.
- *To make the work schedule for the bridge works.

Of course, some alternatives should be discussed to decide the above-mentioned items.

This report was prepared by the Bridge Study Team according to the results of the studies which were performed by the team from July 1973 to March 1976.

2. Progress of the Study.

Prior to making the feasibility study for this project, the JICA organized a preliminary survey team headed by Mr. Ishio Kawasaki. The team visited Bangladesh and stayed there from Nov. 30 to Dec. 27, 1972 and carried out the survey of this project. The team proposed the four suitable bridge sites along the stretch of the Jamuna River. These four candidate sites were described in 1. of this chapter.

In order to collect the necessary data for bridge planning and to inspect the field conditions of the four proposed sites, the bridge planning team visited and stayed there from Jan. 7 to Jan. 27, 1974. The bridge study team was organized by the following members.

Team leader	Kaoru Tezuka NIKKEN Consultants, Inc.
Member	Takeo Sakurai Japan Engineering Consultants Co. Ltd.
Member	Toshio Tanaka NIKKEN Consultants, Inc.
Member	Yoshihiko Wakabayashi Japan Bridge & Structure Institute, Inc.
Member	Tadao Kamide NIKKEN Consultants, Inc.

Using the data collected both in Bangladesh and in Japan, the bridge study team made a basic plan for bridge construction and performed the preliminary design and rough estimate of construction costs of the bridge according to the design provisions. In this case, some alternatives were discussed with regard to the effective width, bridge types and composition of span. The team also carried out the rough design and cost estimate about various bridges which are included in the approach portion and in the railway and road links.

3. Acknowledgment.

The team wishes to express his highest gratitude for the cooperation of the Government of Bangladesh authority concerned, and also for the staffs of the counterpart team.

CHAPTER II

PLANNING OF THE BRIDGE

As present, there are no bridges across the Jamuna River and the ferry is the only means to cross the Jamuna. But the Jamuna River is a famous braided river and it change its course frequently by the natural conditions and this cannot be forecast. The regular operation of ferries could not be expected especially in rainy season. This made up the bottleneck of over-land transport in Bangladesh.

Therefore, The construction of the Jamuna Bridge will be sure not only to promote the growth of communication between east and west of the Jamuna River but also to be useful for the economic development of Bangladesh.

There are two ways to be considered to cross the Jamuna except by ferry. One is to cross the Jamuna by bridge and the other is by tunnel. But it is clarified by the preceding study for tunnel crossing that the execution of tunnel work is expected to be more dangerous and difficult than the bridge work and also the costs of construction of the tunnel work are more expensive than the bridge work.

Therefore, in the present study, the tunnel crossing as an alternative for the bridge crossing, was excluded and bridge crossing was solely taken into consideration from the technical and economical points of view.

1. Field Reconnaissance.

The bridge team carried out the field reconnaissance at candidate sites, and collection of data necessary for planning and design of bridge during their stay in Bangladesh. The team also discussed with the Government authority concerned with respect to the design provisions. The work schedule of the bridge study team during their stay in Bangladesh and summary of the collected data are shown in APPENDIX-1 and APPENDIX-2.

The design specifications of railway and highway bridges were decided by the meetings which were held between the delegates of the Japanese Feasibility Study Team and the Bangladesh Government Authority concerned. The results of discussions are as follows.

Design Provisions

a. Live Load

Live load to be used for design of railway bridge shall be specified by the Indian Railway Standard (Steel Bridge Code) and the Bridge Rules as shown in Fig. 2-1.

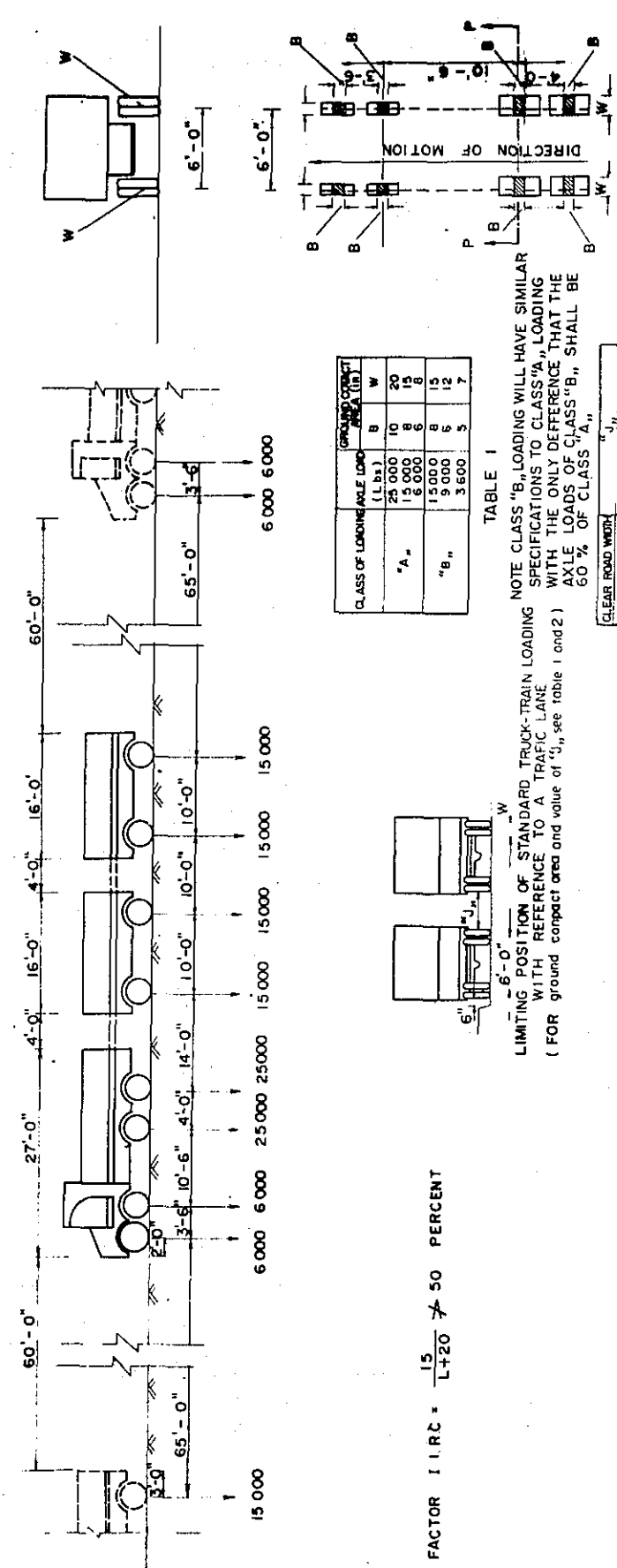
Live load to be used for design of highway bridge shall be specified by the I.R.C. (Indian Road Congress) Standard Vehicle Class 'A' as shown in Fig. 2-2.

Fig.2-1 BROAD GAUGE STANDARD LOADINGS OF 1926
AXLE LOAD OF 22.5 TONS

Axle load in tons wheel dia.											Train load of 23 tons Per lin foot
	11 3'-0"	22½ 5'-1½"	22½ 5'-1½"	22½ 5'-1½"	22½ 5'-1½"	19 3'-7"	19¼ 3'-7"	19¼ 3'-7"	19¼ 3'-7"	19 3'-7"	
Axle	5-0	6-0½	5-7¼	5-7¼	5-7¼	10'-11"	6'-0"	8'-6"	6'-0"	10'-11"	6'-0"
Spacing	9-2	6-0½	5-7¼	5-7¼	5-7¼	10'-11"	6'-0"	8'-6"	6'-0"	10'-11"	6'-0"
78'-3" Over buffers						78'-3" Over buffers					

Fig.2-2 IRC STANDARD VEHICLE

IRC STANDARD VEHICLE CLASS 'A'



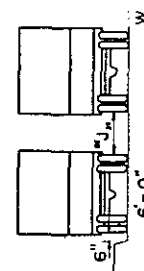
IMPACT FACTOR $1 + \frac{15}{L+20} \leq 50$ PERCENT

CLASS OF LOADING	AXLE LOAD (Lbs)	B	W
"A"	25,000	10	20
"A"	15,000	6	12
"B"	15,000	8	12
"B"	9,000	5	7

TABLE 1

NOTE CLASS "B" LOADING WILL HAVE SIMILAR SPECIFICATIONS TO CLASS "A" LOADING WITH THE ONLY DIFFERENCE THAT THE AXLE LOADS OF CLASS "B" SHALL BE 60 % OF CLASS "A"

LIMITING POSITION OF STANDARD TRUCK-TRAIN LOADING WITH REFERENCE TO A TRAFFIC LANE (FOR ground contact area and value of 'j', see table 1 and 2)



CLEAR ROAD WIDTH	J
16'-0" or Less	0
16'-0" to 18'-0"	Increasing uniformly from 0 to 1
18'-0" to 24'-0"	ditto 1 to 4
Above 24'-0"	4

TABLE 2

LOADING CLASS "A" FOR HIGHWAY BRIDGES

b. Railway Track Gauge

The railway track gauge to be used for design shall be 5' 6".
(broad gauge)

c. Navigation Clearance

The minimum navigation clearance to be used for design is specified by BIWTA which is as follows.

Minimum horizontal clearance	250 ft
Minimum vertical clearance (above DHWL)	40 ft

2. Proposed Sites of Bridge.

The Preliminary Survey Team has proposed the following four suitable bridge sites on the stretch of the Jamuna River.

Site-1	downstream of Bahadurabad,
Site-2	near Gabargaon,
Site-3	about 10km downstream of Sirajganj,
Site-4	about 20km upstream of Aricha.

3. Choice of Bridge Types by Use.

The following types can be considered from the aspect of transportation system.

- a. Highway bridge
- b. Railway bridge
- c. Railway-cum-highway bridge

The transport network in Bangladesh consists of railway transport, highway transport, inland water transport and air route transport, among which railway and inland water transport are predominant.

Above all, railway transport occupies a greater part of overland transportation in Bangladesh. It can be said that railway transport plays the most important role in the overland transportation socially and economically.

Therefore, when bridge across the Jamuna River will be planned, it is clear that railway bridge held a more dominant position than highway bridge at present. But according to the recent study for land transport in Bangladesh, highway transport is increasing gradually by the strengthening of capacity of road ferry. Such transport tendency can not be disregarded.

There are two ways to be considered in order to meet such transport demand. One is to construct railway bridge and highway bridge separately and the other way is to construct railway-cum-highway bridge. The former will be expected larger benefit than the latter but higher construction cost will be needed.

After the comparison of above-mentioned each case and considering the present status of the overland transport in Bangladesh, here we proposed that it is the most suitable way to construct railway cum highway bridge across the Jamuna taking the future transport network and the economic development in Bangladesh into consideration.

This proposal was completely accepted by the Bangladesh delegates at Tokyo Meeting.

By the report of the Jamuna River Bridge performed by Freeman, Fox & Partners, it is reported that the estimated benefit-cost ratio of railway-cum-highway bridge will be about double of that of highway bridge.

4. Effective Width of Bridge.

The decision of the effective width of the Jamuna Bridge is one of the most important matters for this project, because it depends largely upon not only future overland transport in Bangladesh but also total cost of construction.

There are two ways of thinking in order to determine the effective width of the Jamuna Bridge. One way is to determine the effective width of bridge so as to minimize total cost of construction of the bridge. This will be done by giving the least necessary width to the bridge considering future increase traffic volume across the bridge.

The other way is to determine the effective width of bridge taking the future increase of traffic volume through the bridge and also future economical development of Bangladesh into consideration. In this case, higher cost of construction will be needed than the previous case but is desirable for the future economical development of Bangladesh.

Taking above-mentioned two ways of thinking into consideration, we carried out the study of following two cases for the railway cum highway bridge.

Case a.

Railway portion:	Single broad gauge track (5' 6")
Highway portion:	Two-lane carriageway of total width 24 ft.

Case b.

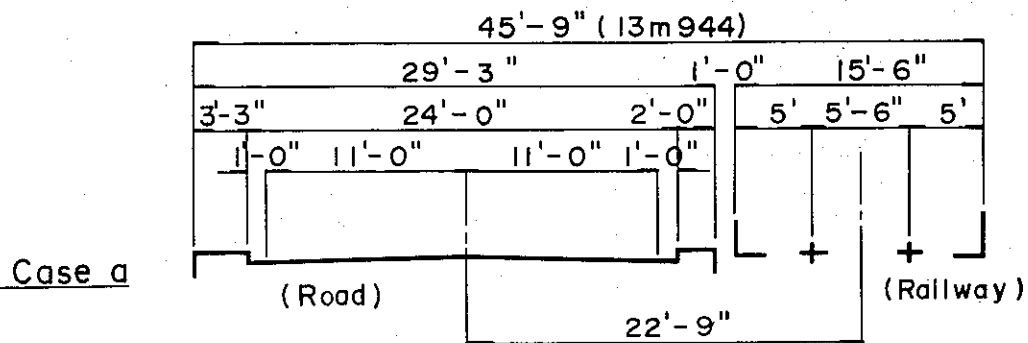
Railway portion:	Double broad gauge tracks (2@ 5' 6")
Highway portion:	Four-lane carriageway of total width 48 ft.

In case b, so far as the traffic conditions permit, it is possible to introduce a method of stage construction, namely, at first construct a bridge with least necessary width and afterwards, residual width will be added in accordance with an increase of traffic volume through the bridge.

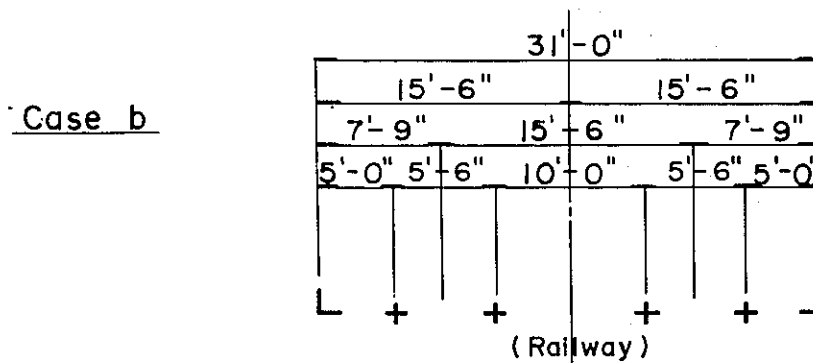
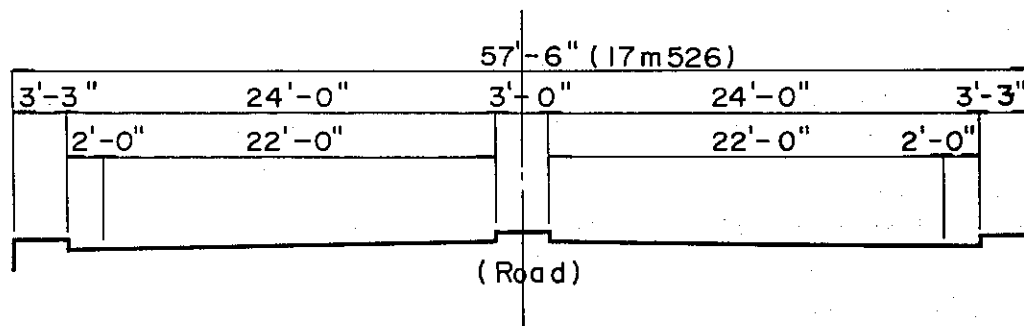
The standard cross section of above-mentioned two cases were shown in Fig. 2-3.

Fig.2-3 Width System of Bridge

a) In case of two lane , single track.



b) In case of four-lane , double tracks
(for double decks)



5. Scope of Works.

The bridge study team performed the next three kinds of study works.

- a. Study for the main bridge over the Jamuna River,
- b. Study for the approach embankments,
- c. Study for the various bridges which are included in the railway links and highway links.

The classifications and descriptions of the study works were shown in Fig. 2-4.

6. Preliminary Selection of Structural Types of Bridge.

6.1. Main bridge over the Jamuna River.

Choice of the structural types of bridge was performed considering the following three aspects.

- a. Selection of construction materials,
- b. Selection of structural type of bridge superstructure,
- c. Selection of structural type of bridge substructure.

6.1.1. Materials for bridge superstructure.

It is clear that the total length of bridge is determined by the necessary width of waterway between left and right guide banks.

The each clear span of the bridge will be determined considering the width of horizontal navigation clearance which is specified by the BIWTA, that is 250 ft.

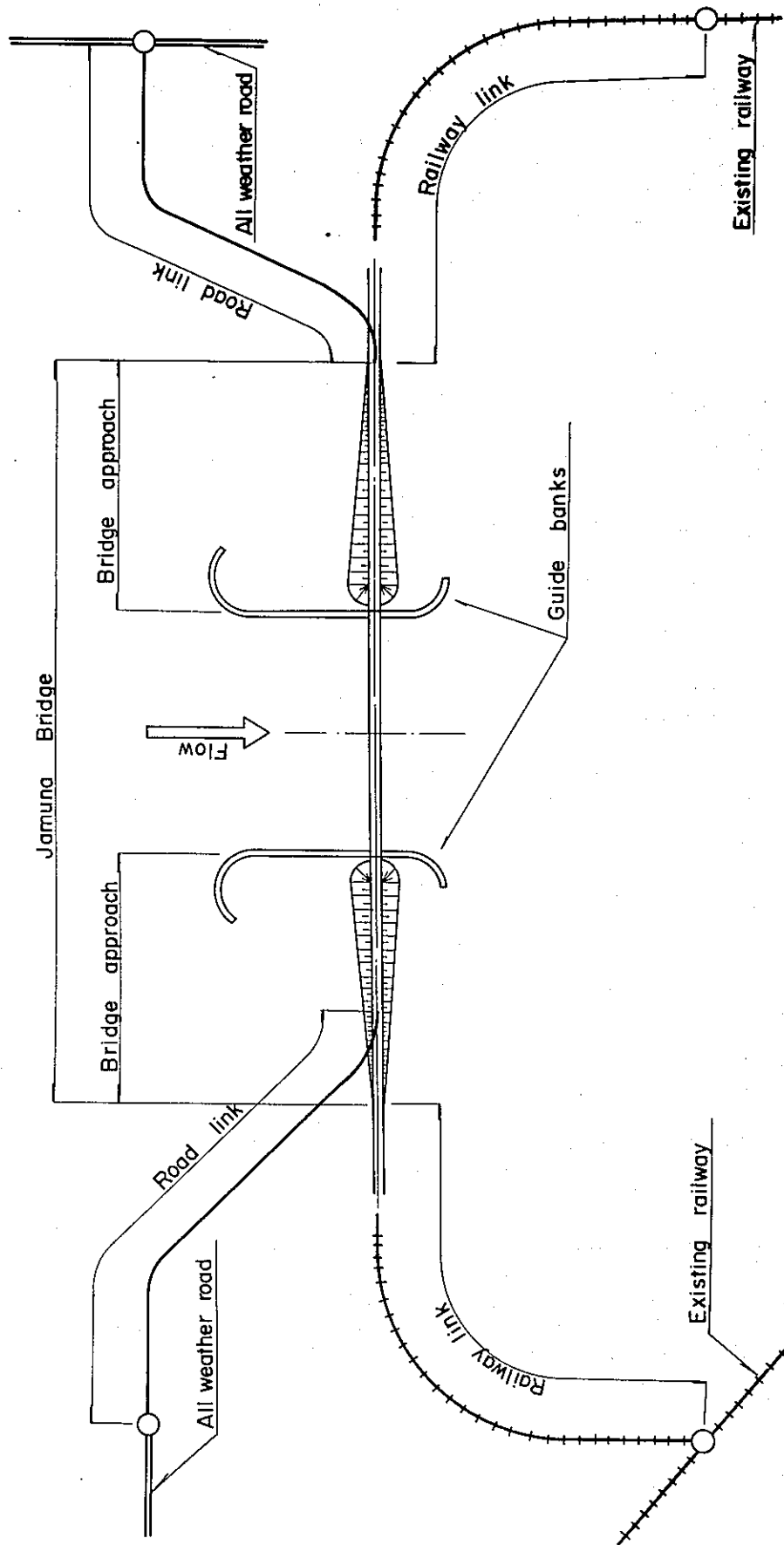
Here we suggest that the steel and concrete (prestressed concrete) are suitable materials for bridge taking the above conditions into consideration.

The merits of steel bridge as compared with prestressed concrete bridge are as follows.

a. The weight of steel bridge is smaller than that of prestressed concrete bridge providing the length of bridge is same. Therefore, the inertial force of steel bridge induced by earthquake which acts to the substructure of bridge is smaller than that of prestressed concrete bridge. Hence the cost saving of substructure will be expected in the case of steel bridge.

b. The application of steel bridge for long span such as the Jamuna Bridge is more practicable than the prestressed concrete bridge. The steel spans are more easily and quickly erected than the prestressed concrete spans. This is the noticeable fact for the Jamuna Bridge Project, because it is expected that the time for erection will be restricted by the natural conditions of the river.

Fig.2 -4 Diagrammatic Sketches of Each Part of the Study



c. When the multi-pile system will be applied for the foundation of the substructures, such system will be deflected horizontally by lateral forces such as current pressure or seismic force. But the effect of horizontal displacement of bridge shoe due to such forces can be easily treated in the case of steel bridge.

The demerits of steel bridge are as follows.

- a. Higher maintenance cost will be needed. (cost of repainting, etc.)
- b. Possibility of application of domestic material will be restricted.

Considering above-mentioned merits and demerits of both materials, we concluded that the steel bridge is more practicable than the prestressed concrete bridge in the case of the Jamuna Bridge.

6.1.2. Superstructure.

In order to minimize the total cost of construction of bridge works, it is requested that the structural type of bridge should be selected among the various types of bridge applicable to long span.

As is generally known, cantilever truss type and/or continuous truss type is suitable for the long span bridge. Therefore, above-mentioned both types were taken into consideration in the present study.

6.1.3. Substructure.

The Jamuna is a braided river, so even if the guide bank system is applied to the river training to fix the river channel, the deepest part of river channel will fluctuate to and fro in the river channel. Therefore, it is requested that the foundation of all piers should have equal depth.

According to the results of our test drillings, it was clarified that the reliable layer of thickness over 10 meters exists at several ten meters below the ground level at each of the proposed sites. It seems that such gravel layer is suitable for the supporting layer of bridge foundation. This means that very deep foundation will be needed for every pier of the bridge.

To cope with such conditions, the reinforced concrete well is recommended as a suitable structural type of foundations and also the multi-pile system is taken into consideration as an alternative of well foundation.

In general, bridge piers should be sunk enough to stand by themselves without any protection around them. In our case, if the well foundation will be applied, the scouring depth is estimated to be about 1.8 times as the water depth and if the multi-pile type of foundation will be applied, the scouring depth at piers is assumed about 10 m. The special considerations were given to the above-mentioned conditions for the design of bridge piers. The use of brick work is not preferable to such a deep foundations. The brick work will be available for a shallower well.

6.1.4. Bridge approaches.

The embankment is the most economical way to connect a bridge with railway links provided that the bearing power of ground under such an embankment is enough to resist the weight of embankment.

If these conditions should not be satisfied, to arrange a short span bridge continuously instead of high embankment is recommended as a suitable method for bridge approaches.

The embankment crosses the guide banks at right angle and the necessary length of embankment will be about 2.6 miles provided that the allowable maximum longitudinal slope of railway is 1/200. This embankment serves as the cross dyke of the river training system.

For case b, the double deck system will be applied and in this case, the upper deck will be provided for highway vehicles and lower deck for railway trains. In this case, the center line of highway approach must be shifted from the center line of railway approach in order to keep the construction gauge of railway. The curved bridge will be needed for the highway approach and the steel bridges are recommended in view of execution.

6.2. Bridges in the railway and road links.

There are many bridges included in the railway and highway links. Among these, total length of over 100 m were tabulated in the Table 2-1 and Table 2-2. In Table 2-2, names of river to be crossed by bridge, required total length of bridge and minimum navigation clearance were tabulated.

Necessary navigation clearance is shown in the map of the BIWTA by river. But the following navigation clearance are requested for the Bangali River, Karatoya River (upstream of Bogra) and the Chatal River.

Minimum horizontal clearance	100 ft
Minimum vertical clearance above HWL	12 ft

In order to utilize the local materials and to mobilize the local contractors, the reinforced concrete or prestressed concrete were applied for these bridges as a general rule.

Table 2-1 Data of Bridges (Longer than 330 ft.) in the Part of Railway Links

Sites	Right Side of River - Bank					Left Side of River - Bank					Number of Bridges
	Location (mile)	Name of the River	Total Length of Bridge	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	Location (mile)	Name of the River	Total Length of Bridge	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	
1. BAHADURABAD	4.8	Bangali	980	100	12	—	—	—	—	—	2
	7.8	"	660	100	12	—	—	—	—	—	
2. GABARGAON	0.6	Karatoya	330	100	12	30.2	Chatal	1 310	180	25	7
	5.5	Hurasagar	330	100	12	30.7		490	60	6	
	11.6	Bangari	490	100	12	31.5		490	60	6	
	13.2		330	100	12	—	—	—	—	—	
3. SIRAJGANJ	—	—	—	—	—	27.8	Lohatang	330	60	6	6
	—	—	—	—	—	34.2	Futjani	660	60	6	
	—	—	—	—	—	42.5	Bansi	330	60	6	
	—	—	—	—	—	49.1		660	100	12	
	—	—	—	—	—	60.0	Turag	980	100	12	
	—	—	—	—	—	68.5	Tungi	980	100	12	
4. NAGARBARI	9.2	Chikunai	330	60	6	35.9	Old Dhaleswari	660	60	6	9
	9.6	Rukunai	660	60	6	42.9	Dhaleswari	3 770	180	25	
	19.2	Baral	1 970	60	6	48.3		330	60	6	
	20.4	Hurasagar	980	180	25	62.1	Bansi	820	150	20	
	—	—	—	—	—	70.6	Turag	490	150	20	

Table.2-2 Data of Bridges (Longer than 330 ft.) in the Part of Road Links

Sites	Right Side of River Bank					Left Side of River Bank					Number of Bridges
	Location (km)	Name of the River	Total Length of Bridge	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance (ft.)	Location (km)	Name of the River	Total Length of Bridge	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance (ft.)	
1. BAHADURABAD		Bangali	980	100	12		—	330	100	12	3
		Bangali	660	100	12		—	—	—	—	
		Karatoya	330	100	12		—	330	60	6	
2. GABARGAON		Bangali	980	100	12		Chatal	1310	180	25	5
		—	—	—	—		—	330	60	6	
		—	—	—	—		—	—	—	—	
3. SIRAJGANJ		—	—	—	—		—	—	—	—	
		—	—	—	—		—	—	—	—	
		—	—	—	—		—	—	—	—	
4. NAGARBARI		Hurasagar	1970	180	25		Old Dhaleswari	660	60	6	4
		—	980	60	6		—	330	60	6	
		—	—	—	—		—	—	—	—	

CHAPTER III

PRELIMINARY DESIGN

1. Design Provisions.

1.1. River.

The armored guide banks and cross dykes were introduced into the river training system and the following three types of guide bank system were considered at each of the four proposed sites (see Fig. 3-1).

The design high water level (DHWL), height of river bed after the completion of guide banks (DRB) and ground height (GH) at each of the proposed sites were shown in Table 3-1. The heights were measured from the benchmark of PWD, and the height of river bed means the height of the deepest part of river bed.

The design discharge Q (m^3/sec), the mean velocity V_m (m/sec) and the mean velocity at the deepest part of river channel V (m/sec) were shown in Table 3-2 by site.

1.2. Local scouring around piers.

As was mentioned previously, if the well foundation system will be adopted, the scouring depth around piers is estimated to be about 1.8 times as the water depth provided that the diameter of well is about 10-13m. If the multi-pile foundation system will be adopted, the scouring depth at piers is assumed at about 10m, provided that the diameter of each pile is 2-3m and intervals of each pile is three times of diameter of pile.

The estimated depths of local scouring around piers for each type of guide banks at the four proposed sites were shown in Figs. 3-2 ~ Fig. 3-5 respectively.

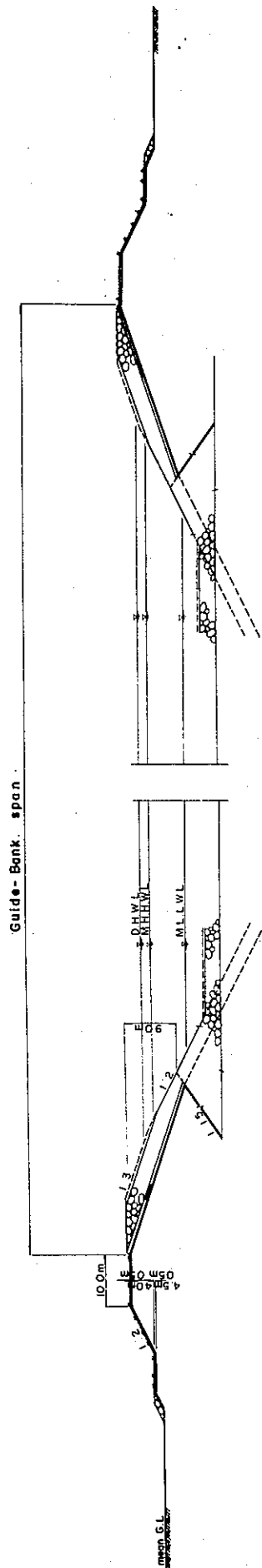
1.3. Soil texture.

According to the test drillings of our team, it is clarified that the upper layer is composed of silty and fine sand (Au_2) and the lower layer is composed of medium sand and dense fine to medium sand (Au_3 , Am_3 and Am_2).

By the results of our experiments, it is clarified that the layers below Am_3 have N-value (standard penetration) of over 60, and these layers were considered to be suitable for supporting layers of bridge foundation.

At Nagarbari and Sirajganj sites, gravel and boulder layer (Al_1) of about 7m-9m in thickness was found out about 90m and 70m below the ground level respectively.

Fig. 3 - I Distance between Guide Banks



SITE	TYPE	Unit KM (MILE)		
		A	B	C
1. BAHADURABAD		2.0 (1.2)	4.2 (2.6)	5.6 (3.5)
2. GABARGAON		2.0 (1.2)	4.2 (2.6)	5.2 (3.2)
3. SIRAJGANJ		2.0 (1.2)	4.2 (2.6)	5.6 (3.5)
4. NAGRARI		2.0 (1.2)	4.2 (2.6)	5.2 (3.2)

Table. 3 -1 D.H.W.L., D.R.B and G.H (m) PWD

Site \ Item	D.H.W.L.	D.R.B			G.H
		A	B	C	
1. Bahadurabad	20.86	- 29.68	- 16.82	- 10.37	17.95
2. Gabargaon	19.44	- 35.45	- 21.60	- 16.11	15.73
3. Sirojganj	15.24	- 38.60	- 25.50	- 18.20	11.38
4. Nagarbari	14.01	- 42.13	- 28.37	- 22.82	9.45

Table. 3 -2 Q, Vm and V

Site	Item	Q (m ³ /s)	Vm (m/s)	V (m/s)
	Type			
1. Bahadurabad	A	89 600	2.40	4.66
	B	"	1.93	4.35
	C	"	1.74	3.94
2. Gabargaon	A	89 600	2.21	4.29
	B	"	1.77	4.00
	C	"	1.65	3.73
3. Sirojganj	A	89 600	2.25	4.36
	B	"	1.78	4.03
	C	"	1.63	3.68
4. Nagarbari	A	82 700	1.99	3.87
	B	"	1.58	3.57
	C	"	1.47	3.32

Note; 1km = 0.621 mile 1m = 3.28 feet 1m³ = 35.3 cu. feet

V : Mean velocity at thalweg

D.R.B: Hight of river bed at thalweg

Fig. 3-2 Design River Bed Height and Soil Map.

Site-1 BAHADURABAD

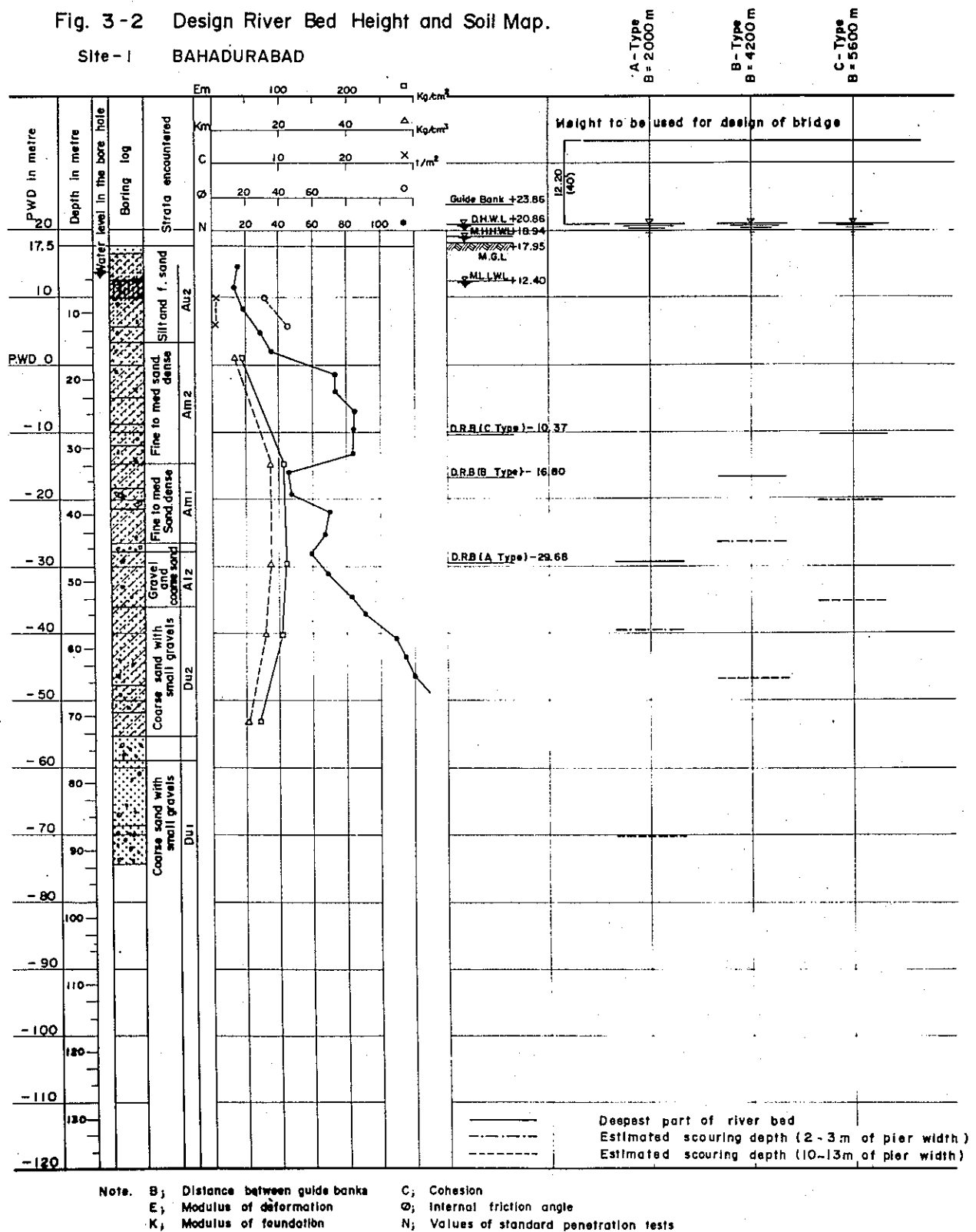
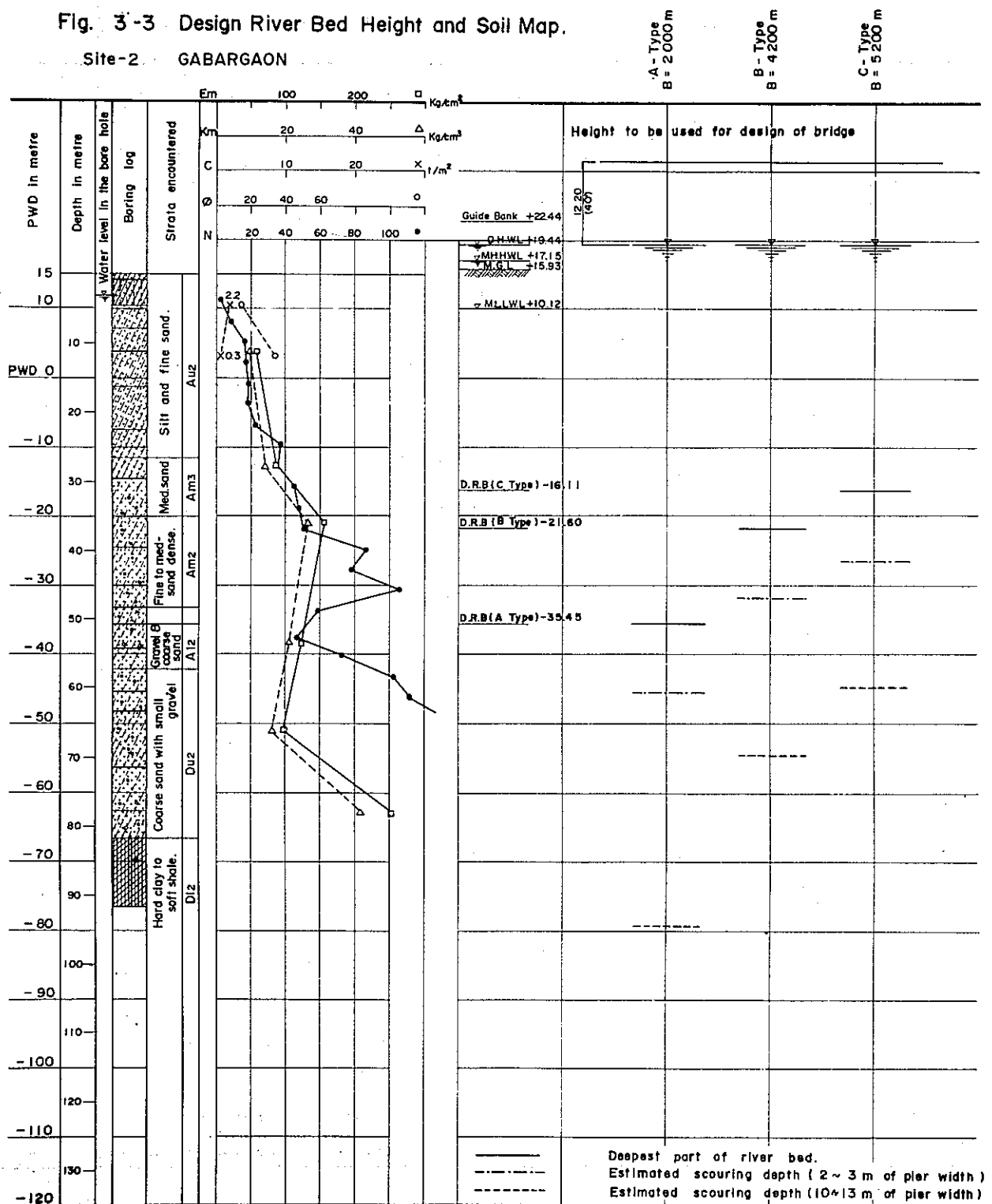


Fig. 3-3 Design River Bed Height and Soil Map.

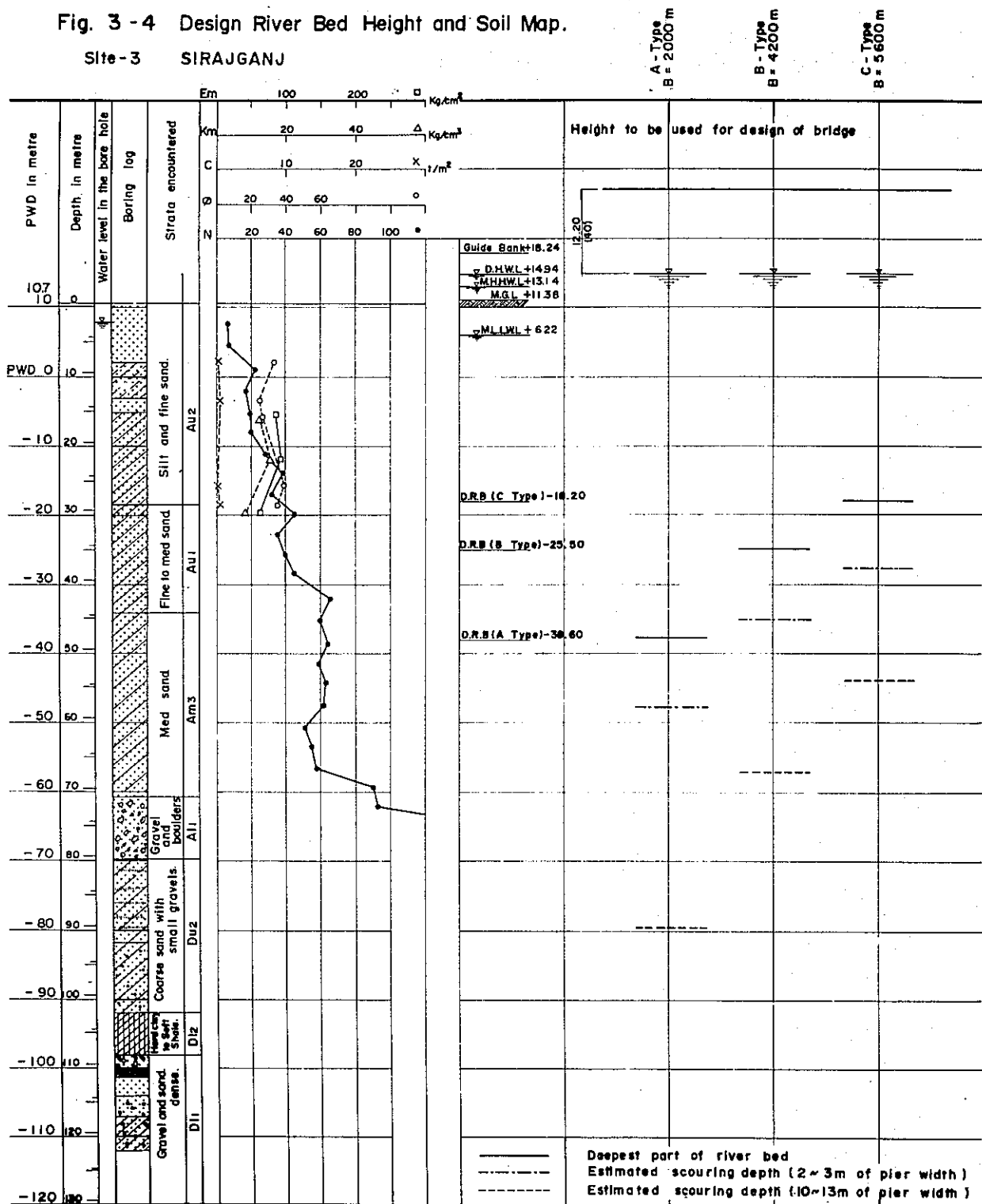
Site-2 GABARGAON



Note. B; Distance between guide banks
E; Modulus of deformation
K; Modulus of foundation
C; Cohesion
Ø; Internal friction angle
N; Values of standard penetration tests

Fig. 3 - 4 Design River Bed Height and Soil Map.

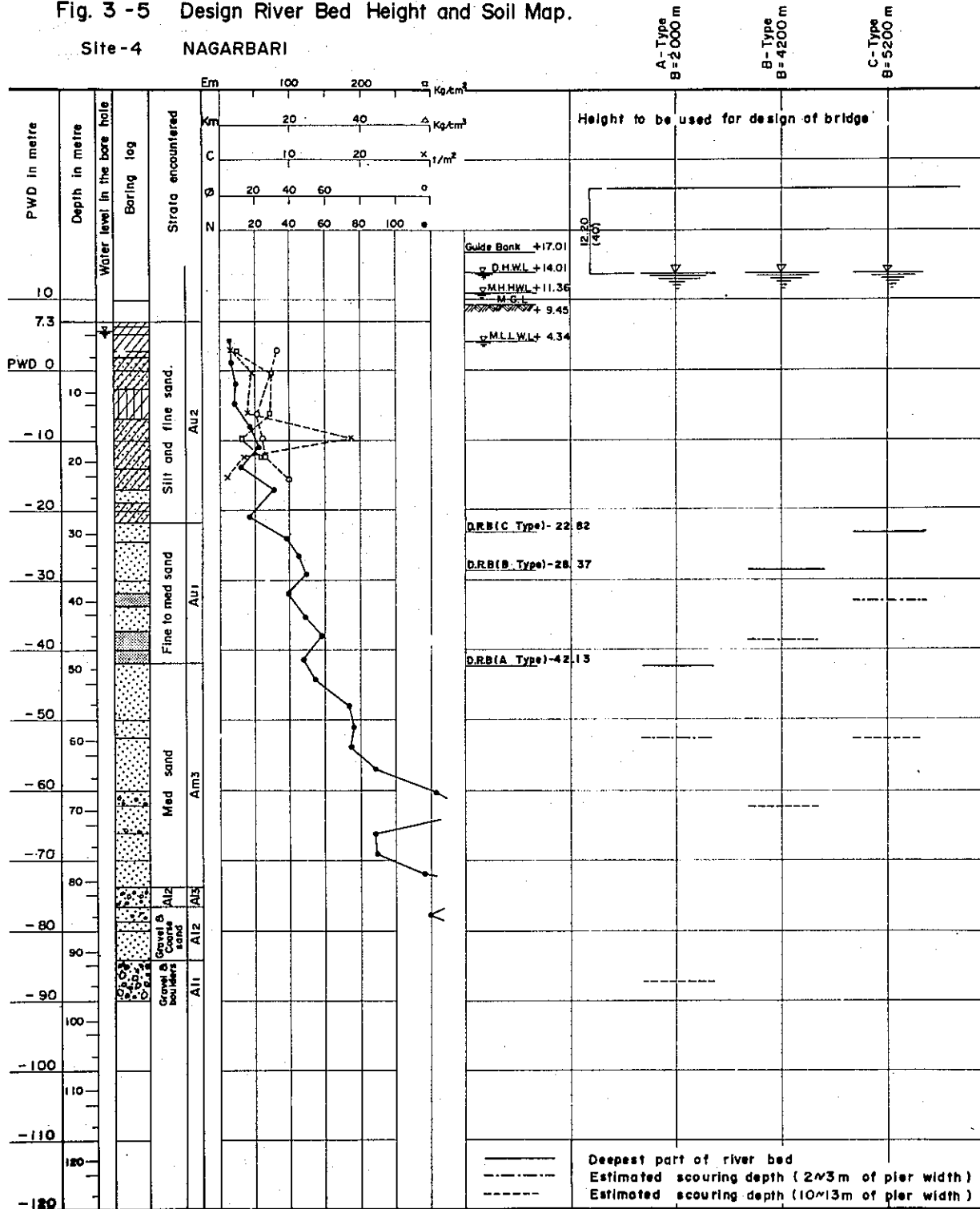
Site - 3 SIRAJGANJ



Note. B; Distance between guide banks
 E; Modulus of deformation
 K; Modulus of foundation
 C; Cohesion
 ϕ ; Internal friction angle
 N; Values of standard penetration tests

Fig. 3 -5 Design River Bed Height and Soil Map.

Site-4 NAGARBARI



Note. B; Distance between guide banks C; Cohesion
E; Modulus of deformation ϕ ; Internal friction angle
K; Modulus of foundation N; Values of standard penetration tests

The soil textures at each of the four proposed sites which were obtained by our test drillings were shown in Figs. 3-2 ~ Fig. 3-5. The height of design river bed, design high water and low water levels and mean ground height were also shown in these figures by site and by type of guide banks. All heights were measured from the benchmark of PWD.

1.4. Substructure.

1.4.1. Railway bridge.

a. Loads (APPENDIX-3)

All loads to be used for design of bridge shall be specified by Main Line Loading of Bridge Rule for Indian Railways. (Fig. 2-1)

b. Construction gauge (APPENDIX-3)

The construction gauge to be used for design shall be specified by the Pakistan Railways, Schedule of dimensions (5 ft 6 in gauge) considering the future electrification.

c. Track gauge (APPENDIX-4)

The track gauge to be used for design shall be 5 ft 6 in (Broad gauge).

d. Structures

The floor system of railway portion shall be designed by the Standard Specifications for the Railway Bridges adopted by the Japan Society of Civil Engineers authorized by Ministry of Construction, Japan, and deflections shall be checked by the above specifications.

But the wind velocity, range of temperature change and acceleration of earthquake to be used for design should be determined taking the natural conditions in Bangladesh into consideration.

Referring to the meteorological data of Bangladesh, we assumed these items as follows.

Standard wind velocity	30 m/sec
Range of temperature change	0°C to 40°C
Acceleration of earthquake	
Horizontal component	0.1 G
Vertical component	0

e. Construction materials (APPENDIX-4)

All materials to be used for design shall be specified by the Japanese Industrial Standard (JIS).

1.4.2. Highway bridge.

(1) Loads

Live loads to be used for design shall be specified by I.R.C. (Indian Road Congress) Standard Vehicle Class A (Fig. 2-2).

(2) Construction gauge

The construction gauge (highway portion) to be used for design shall be specified by I.R.C. and AASHO.

(3) Structures

All structures shall be designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association authorized by Ministry of Construction, Japan, with the exemption of following items.

Standard wind velocity
 Range of temperature change
 Acceleration of earthquake

These items are just same as railway bridge.

(4) Construction materials
 Just same as above.

1.5. Substructures (Reinforced concrete structures).

All reinforced concrete structures shall be designed by the Standard Specifications for Reinforced concrete adopted by the Japan Society of Civil Engineers (authorized by Ministry of Construction, Japan), (APPENDIX-4).

1.6. Minimum navigation clearance (APPENDIX-5).

The minimum navigation clearances to be used for design are specified by the BIWTA as following.

Minimum horizontal clearance	250 ft.
Minimum vertical clearance	40 ft. above DHWL.

2. Properties of Materials.

2.1. Structural steel.

Structural steels to be adopted for the design of bridge were shown in Table 3-3.

2.2. Allowable stresses of structural steel.

Allowable stresses to be used for design were shown in Table 3-4.

Table 3-3 Description of Symbols used for Standard Steel Materials

Standard	Description	Symbols used for steel materials
JIS G 3101	Rolled steel for general structure	SS 41
JIS G 3106	Rolled steel for welded structure	SM41, SM 50Y, SM53, SM 58

Table 3-4 Allowable Axial Tensile Stresses for Steel Materials

Steel materials	Allowable axial tensile stress (kg/cm ²)
SS 41, SM41	1,400
SM 50Y, SM 53	2,100
SM 58	2,600

2.3. Allowable stresses of concrete and reinforcement.

Allowable stresses of concrete and reinforcement to be used for design of superstructures were shown in Table 3-5.

Allowable stresses of concrete and reinforcement to be used for design of substructures were shown in Table 3-6.

2.4. Allowable stresses for prestressed concrete.

As described previously, the prestressed concrete bridges were applied to such a bridge as was included in the railway links and highway links. In such a case, the allowable stresses to be used for design were shown in Table 3-7.

Table 3-5 Allowable Stresses of Reinforced Concrete for Superstructure

Concrete; Design strength σ_{28}	240 Kg/sq.cm
Allowable bending compressive stress for bending	80 "
Allowable compressive stress for normal force	72 "
Allowable shearing stress: concrete	9 "
" : concrete with web reinforcement	20 "
Allowable bond stress	16 "
Allowable bearing stress	72 "
Reinforcing bar:	
Tensile stress (SD 30)	1,800 Kg/sq.cm
Yielding point	3,000 "

Table 3-6 Allowable Stresses of Reinforced Concrete for Substructure

Concrete; Design strength σ_{28}	210 Kg/sq.cm
Allowable bending compressive stress for bending	70 "
Allowable compressive stress for normal force	63 "
Allowable shearing stress: concrete	8.5 "
" : concrete with web reinforcement	18.5 "
Allowable bond stress	15 "
Allowable bearing stress	63 "
Reinforcing bar;	
Tensile stress (SD 30): usually	1,800 Kg/sq.cm
" : under water	1,600 "
Yielding point	3,000 "

Table 3-7 Prestressed Concrete for Superstructure

Concrete; Design strength σ_{28}	350 Kg/sq.cm
Allowable compressive stress (for design load)	115 "
Allowable tensile stress (")	13.5 "
Required minimum compressive strength under prestressing	300 "
Maximum size of coarse aggregate	25 mm
Prestressing wire; $\phi 7$ mm	
Ultimate strength	155 Kg/sq.cm
Yielding stress	135 "
Allowable tensile stress (for design load)	93 "
" (at prestressing)	122 "

3. Preliminary Design.

3.1. Outline.

As for the river control, the armored guide bank and cross dyke system was adopted and the following three types of guide bank system were considered at each of the proposed sites.

Unit: Km (Mile)

Proposed Sites	Distance between a pair of guide banks		
	A-type	B-type	C-type
Bahadurabad	2.0(1.24)	4.2(2.6)	5.6(3.5)
Gabargaon	2.0(1.24)	4.2(2.6)	5.2(3.2)
Sirajganj	2.0(1.24)	4.2(2.6)	5.6(3.5)
Nagarbari	2.0(1.24)	4.2(2.6)	5.2(3.2)

The total length of bridge is determined by the width between a pair of guide banks. Therefore, the above-mentioned widths between a pair of guide banks are to be considered as the total length of bridge in the present stage.

Considering the results of the economic and traffic study of our team and referring to the report of the Bangladesh Transport Survey, the following two cases were investigated for the railway-cum-highway bridge.

Case a:

Railway portion; Single broad gauge track (5' 6")
 Highway portion; Two-lane carriageway of total width 24'.

Case b:

Railway portion; Double broad gauge tracks (2@5' 6")
 Highway portion; Four-lane carriageway of total width 48'.

For the superstructure of bridge, steel truss was adopted and four kinds of span length of 100m, 150m, 250m and 350m were investigated in order to decide the most suitable composition of span from the technical and economical points of view.

For the substructure of bridge, the well type foundation and multi-pile foundation system were considered. The multi-pile system was investigated as an alternative procedure of well foundation.

3.2. Superstructures.

3.2.1. Types of superstructure.

As was mentioned above, the span lengths to be investigated were ranged from 100m to 350m. Generally, structural types of bridge to cope with such span length are shown in Fig. 3-6.

Fig. 3-6 Structural Types of Bridge Adequate for Long Span

Span Length Bridge Types					
	100	200	300	400	(m)
Suspension Bridge					
Cantilever Truss					
Continuous Truss					
Cable-stayed Bridge					

There are various types of bridge to cope with such a range, for example, suspension bridge, cantilever truss bridge, continuous truss and cable-stayed bridge will be enumerated.

As was generally known, above-mentioned each structural type of bridge has respective specific characteristics and such characteristics of each type were discussed from the technical and economical points of view. The Jamuna Bridge is designed as a railway-cum-highway bridge, therefore, it must have a high rigidity to resist a heavy and dynamic railway loads and in case b (double broad gauge tracks and four-lane carriageway), the double deck system will be needed. Considering above conditions, we judged that the steel truss type is most suitable for the Jamuna Bridge.

Moreover, in general the members of truss bridge will be lighter than those of other types, therefore, the cost of marine transportation of truss members will be cheaper than the other.

The three span continuous truss type was applied to the span length of 100m and 150m and multi-equal span cantilever truss type was applied to the span length of 250m and 350m from the economical point of view.

In case of multi-equal span cantilever truss, the curved chord truss is more reasonable than the parallel chord truss, therefore, the frame of truss is decided as shown in Fig. 3-7.

3.2.2. Outline of the structures.

Box section was applied to the members of truss and I-section was applied to the stringers and floor beams of the bridge.

The electric arc welding shall be used to build up each members at shop and high tension bolt method shall be applied for the connection and splice of members at field.

For the floor of the highway portion of the bridge, the reinforced concrete slab and orthotropic steel plate were investigated and from the results of investigation, it is decided that the reinforced concrete slab shall be applied for the continuous truss bridge of span length of 100m and 150m and the orthotropic steel plate shall be applied for the cantilever truss bridge of span length of 250m and 350m to decrease the weight of floor. The open floor system was adopted for the railway portion of the bridge.

The standard cross section of bridge by span length were shown in Figs. 3-8 and -9.

3.2.3. Results of calculations.

Attentions were paid for the effective span to be required for the calculation of impact coefficient and for the fatigue phenomena to be required for the calculation of railway floor system. The margin of the cross section of each members of bridge were reserved for the secondary stresses of the truss which will be induced by the eccentricity of truss members, rigidity of panel point, deflection of cross beam, deformation of floor system by elastic deformation of chord members, deformation of members of truss by dead load, etc.

The stringers were set on the upper flange of cross beam for convenience of erection.

The upper and lower lateral bracings, sway and portal bracings were provided for to resist lateral forces.

As an example, the results of calculations of the bridge of span length of 150m were shown in Tables 3-8 and -9.

3.3. Substructures.

3.3.1. Structural types.

In Bangladesh, wells were used for the foundation of bridge usually. The well was adopted for the foundation of Hardinge Bridge and King George IV Bridge in Bangladesh and recently, well foundation were also adopted for some long bridges included in the all weather road from Dacca to Aricha.

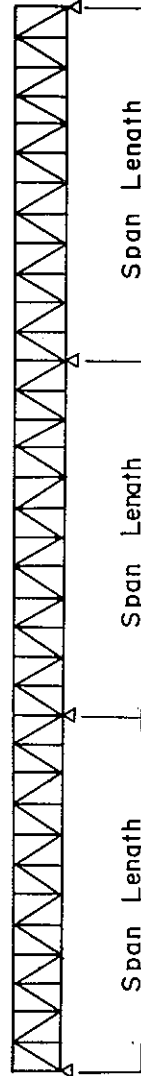
The multi-pile foundation systems were recently developed and these systems were also taken into consideration as an alternative of well foundation.

Although a scouring depth of this system is less than that of well, the non-deformable base slab should be settled on the top of piles in order to distribute the vertical forces to the each column uniformly and the head of each column must be rigidly connected with base slab. As the weight of this slab is heavy and its mass is large, such system made up a top heavy structure.

In the case of the Jamuna Bridge, piles with long free standing length will be necessary for the foundation of some piers in the river channel. In such a case, the multi-pile foundation systems are more unstable than the foundation systems and the former is easy to deflect by the horizontal forces. This is the undesirable demerits of the multi-pile foundation systems.

Fig. 3 - 7 Truss Frame

3 Span continuous truss frame for span of 100 m or 150 m



Multi - Span cantilever truss frame for span of 250 m or 350 m

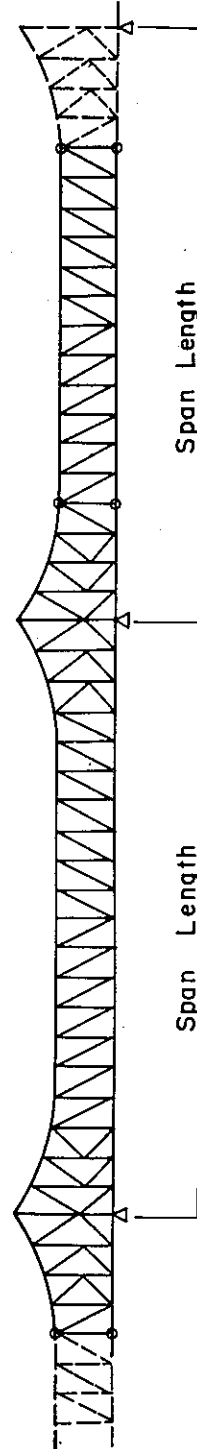
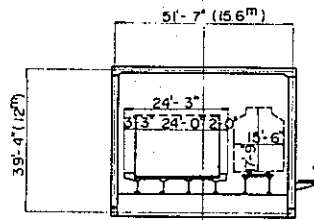
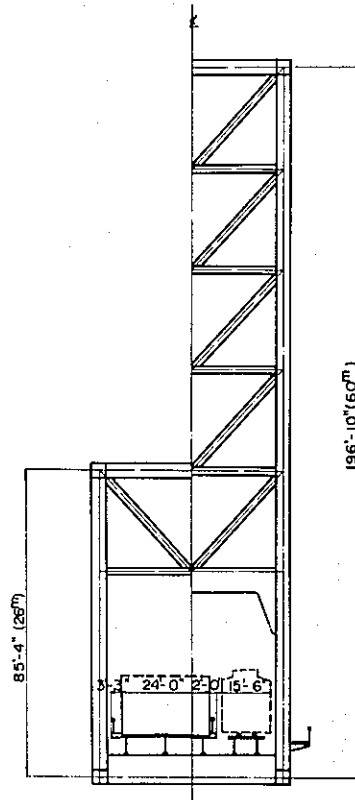


Fig.3 - 8 Typical Cross Section of Superstructure in Case a

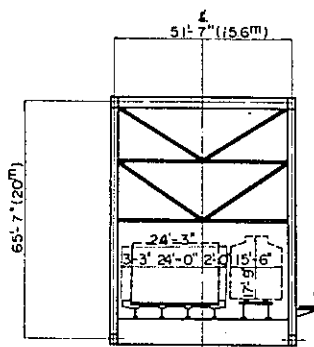
Span length $L=100\text{m}$



Span length $L=350\text{m}$



Span length $L=150\text{m}$



Span length $L=250\text{m}$

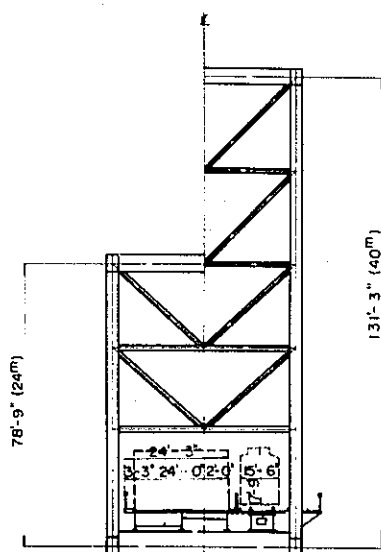
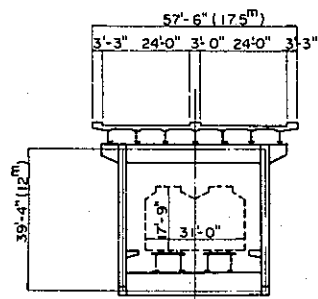
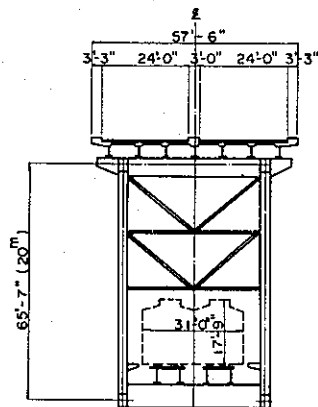


Fig. 3 - 9 Typical Cross Section of Superstructure in Case b

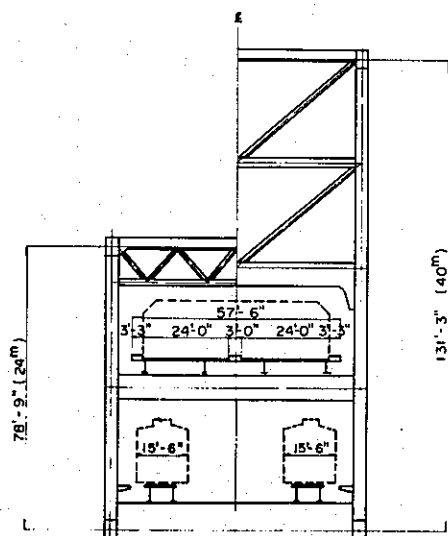
Span length $L = 100^m$



Span length $L = 150^m$



Span length $L = 250^m$



Span length $L = 350^m$

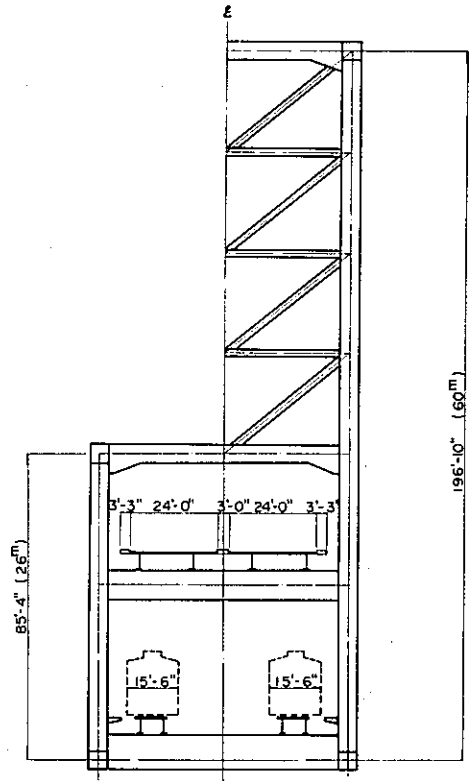
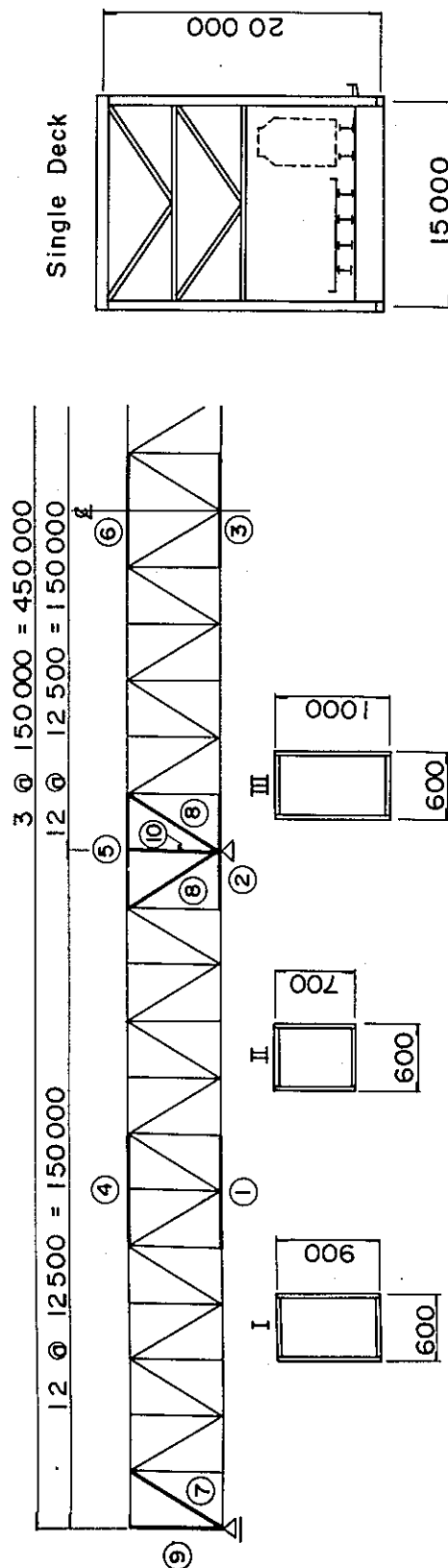


Table. 3-8 Result of Preliminary Design of 3-equal-span Continuous Truss (Span Length 150m)

(Case a)

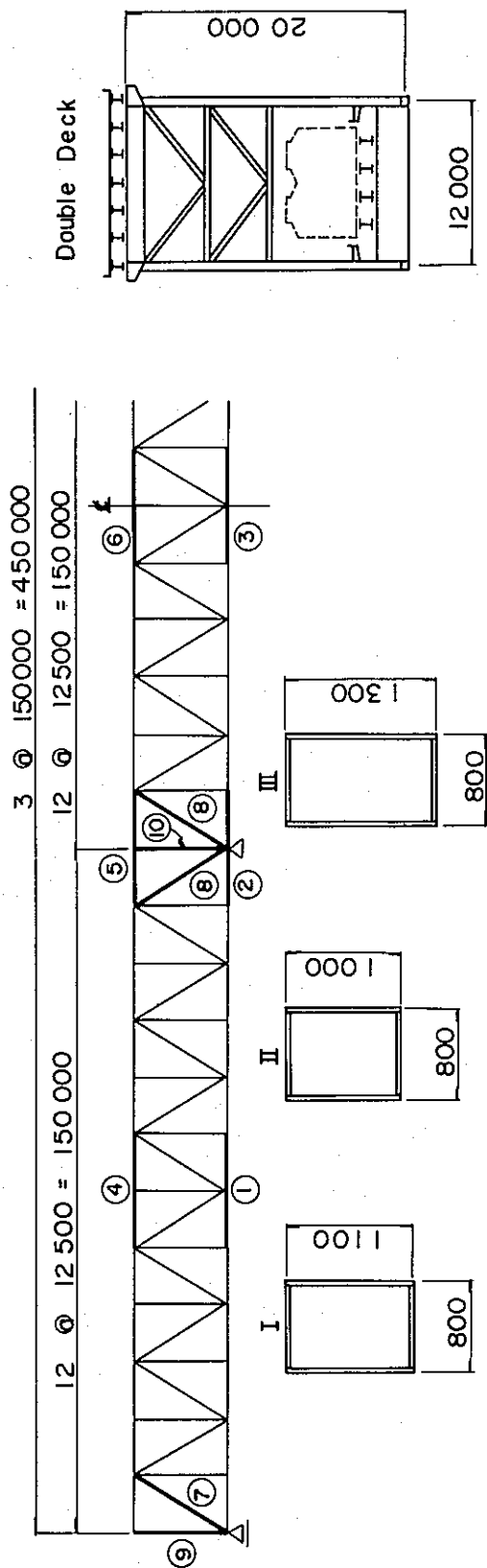


Member	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Axial Force	1 573	- 2 422	743	- 1 573	1 659	- 806	- 1 257	- 1 678	- 1 085	- 2 775
Type of Section	I	I	I	I	I	I	III	III	II	III
Material	SM53	SM 58	SM53	SM58	SM58	SM53	SM58	SM58	SM58	SM 58
Allowable Stress	2 100	2 106	2 100	2 127	2 600	1 782	896	885	1 496	1 812
Stress	1 851	1 858	1 838	1 876	2 328	1 523	566	701	1 224	1 585
Plate Thickness	30	50	17	32	25	22	60	65	40	50

Maximum Deflection (mm)	
Railway (Single Truck)	163
Railway + Road	191

Road		Railway	
Stringer	2-Pls	300 x 22	2-Pls 400 x 25
	1-Pl.	950 x 9	1-Pl. 1400 x 13
Floor Beam	2-Pls	600 x 32	
	1-Pl.	2200 x 12	

Table. 3-9 Result of Preliminary Design of 3equal-span Continuous Truss (Span Length 150m)
(Case b)



Member	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Axial Force	† 2 473	-3 547	1 105	-2 473	2 364	-1 204	-1 893	-2 615	-1 753	4 458
Type of Section	I	I	I	I	I	I	III	III	II	III
Material	SM 58	SM 58	SM 53	SM 58	SM 58	SM 53	SM 58	SM 58	SM 58	SM 58
Allowable Stress	kg/cm ² 2 600	2 263	2 100	2 276	2 600	1 868	1 376	1 336	1 969	2 062
Stress	kg/cm ² 2 415	2 070	1 879	2 038	2 411	1 645	1 190	1 119	1 783	1 850
Plate Thickness	mm 30	50	17	36	27	20	40	60	37	50

Maximum Deflection (Live-load)	(mm)
Railway (Singl Truck)	94
Railway + Road	137

	Stringer	Floor Beam
Road	2-Pls 270 x 22	2-Pls 400 x 28
	1-Pl. 1100 x 9	1-Pl. 1600 x 9
Railway	2-Pls 400 x 25	2-Pls 600 x 30
	1-Pl. 1400 x 13	1-Pl. 2000 x 10

3.3.2. Outline of structures.

(1) Well foundation

The execution of well sinking work is one of the most difficult problems in this project. In order to reduce a current pressure and a seismic force which acts on the body of well and to keep a good appearance of well, height of the top of well should be decided as low as possible. If we decide the height of top of well as 1 meter above MLLWL, well sinking work must be finished during the dry season in view of execution. To cope with above condition, here we suggest that the reverse circulation method is one of the most suitable way for sinking of well considering the soil properties of each bridge site. In this case, some devices will be needed to reduce the frictional resistance between the body of well and surrounding earth.

As the sinking velocity of well depends largely upon the weight of well itself, the thickness of wall of well shall be designed as thick as possible in order to accelerate the sinking velocity of well. In this case, we decided the thickness of wall as 2.5m - 3.5m.

As the definite depth of embedment of well should be necessary to keep stability against lateral forces, the foot protection work around piers should be requested and also its regular inspection and maintenance will be needed in future.

The Jamuna is a braided river. It has a tendency to change a flow direction in the river channel. If we adopt a circular section for the cross section of well, it is expected that the scouring condition around piers does not change even if the flow direction may be changed in the river channel.

By the above reason, circular section was adopted for the cross section of well. But in the case of cantilever truss with span length of 250m and 350m, the oblong section was adopted from the economical point of view.

Chief dimensions of foundation well by span and by site were shown in Fig. 3-10.

(2) Multi-pile foundation systems

In the multi-pile foundation systems, steel pipe piles were to be used for the foundation piles. In the present case, steel pipe piles of diameter of 2m and of 3m were considered. The head of each pile should be rigidly connected with the thick base slab.

As the base slab of this system should be constructed above the DHWL, the shaft of piers could be executed in the open air (not in the water).

The shaft of piers consists of two trapezoidal reinforced concrete walls and both walls are connected each other by the thin reinforced concrete partition wall. The end bearings of bridge were settled on the top of this wall respectively. The bottom of these walls are connected with the base slab rigidly. The outline of this system was shown in Fig. 3-11.

Although the estimated scouring depth at piers of this system is smaller than that of well, foot protection work must be provided for to secure the necessary depth of embedment of piles.

3.3.3. Results of calculations.

(1) Well foundation

The estimation of local scouring depth around piers is one of the most important problems in the present study. As was mentioned previously, if the well foundation will be adopted, the local scouring depth around piers is estimated to be about 1.8 times as of the water depth.

By the results of our test drillings, it was clarified that the very firm strata appropriate for the foundation of the heavy structure in the aspect of bearing strength exist about 80m - 90m below the ground. This layer seems to be desirable for the supporting layers of this bridge.

But in this case, if we leave the wells as they are, safety against lateral loads can not be secured for some wells standing in the river channel. Such piers must be protected by the foot protection works to secure a necessary depth of embedment.

The primary requirement of the calculation of stability of well is to determine the necessary depth of embedment of well at the worst condition.

After the pursuance of trial calculations of the stability of well for several cases assuming the depth of scouring at wells and taking the geological conditions into consideration, the necessary depth of embedment of wells at each of the proposed sites were determined.

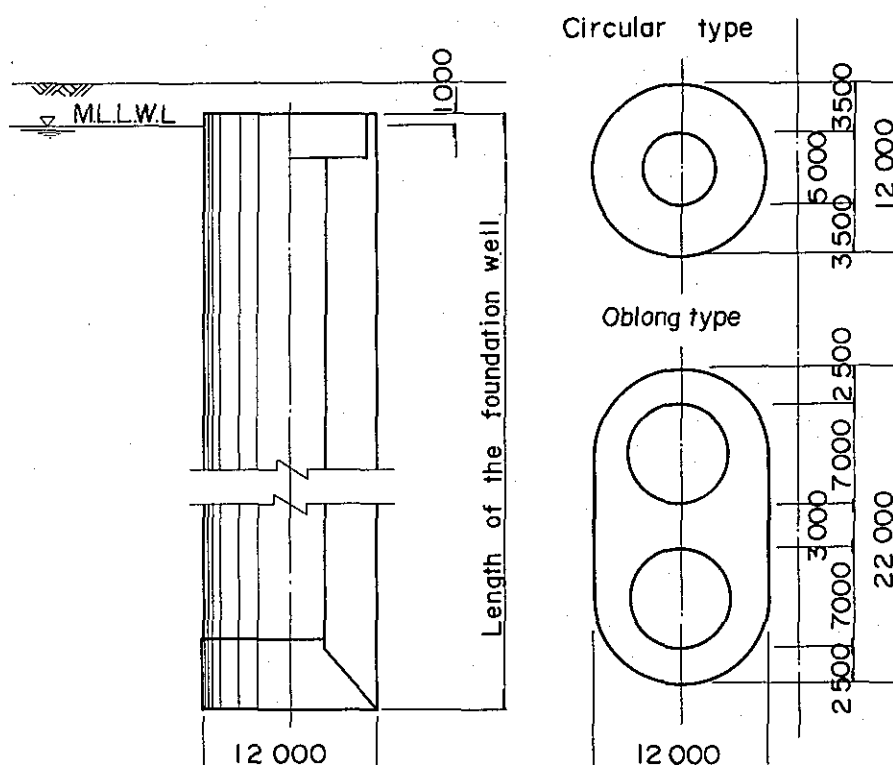
Now we showed the results of above calculations at Sirajganj site as an example (See Figs. 3-12-1 and -12-2).

It was clarified by the above Figs. that the larger the span length is, the deeper the depth of embedment will be needed.

(2) Multi-pile foundation systems

As was described previously, the local scouring depth is assumed at about 10m below the river bed. So long as the local scouring depth, the multi-pile systems seem to be more desirable than the well foundation systems.

Fig.3-10 Structural Dimensions of Foundation Well



Proposed sites	Length of the well foundation
Bahadurabad	70.0 m
Gabargaon	72.0 m
Sirajganj	68.0 m
Nagarbari	78.0 m

Fig.3-11 Structural Dimensions of Multi-pile Foundation

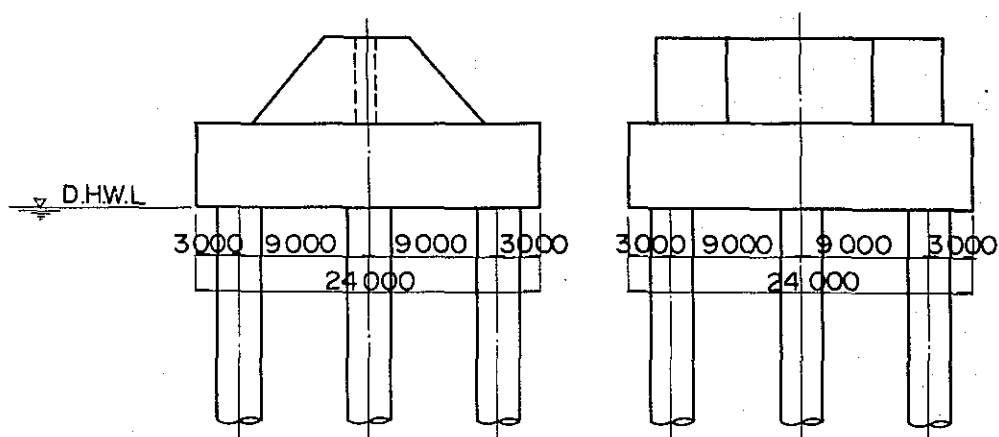
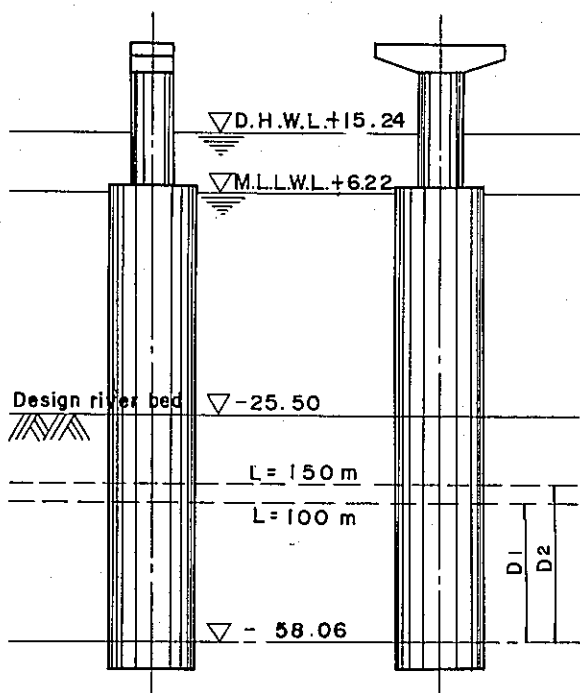
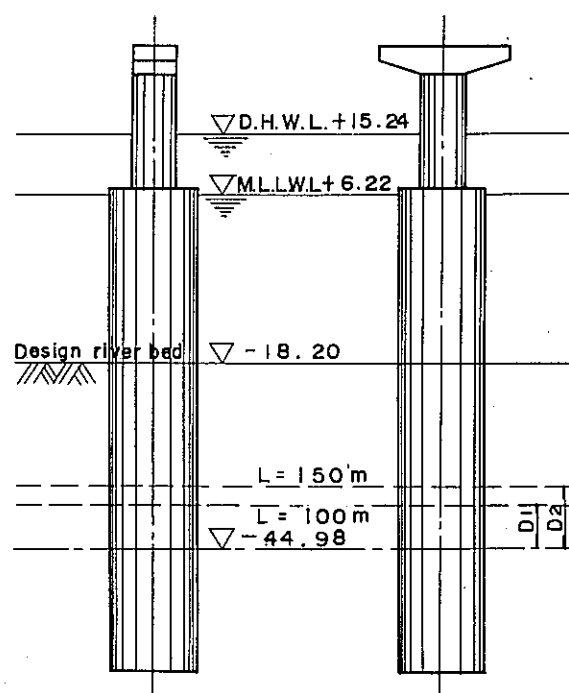


Fig. 3-12-1 Necessary Depth of Embedment Required for Stability of Well
(Case -a) at Sirajganj Site.

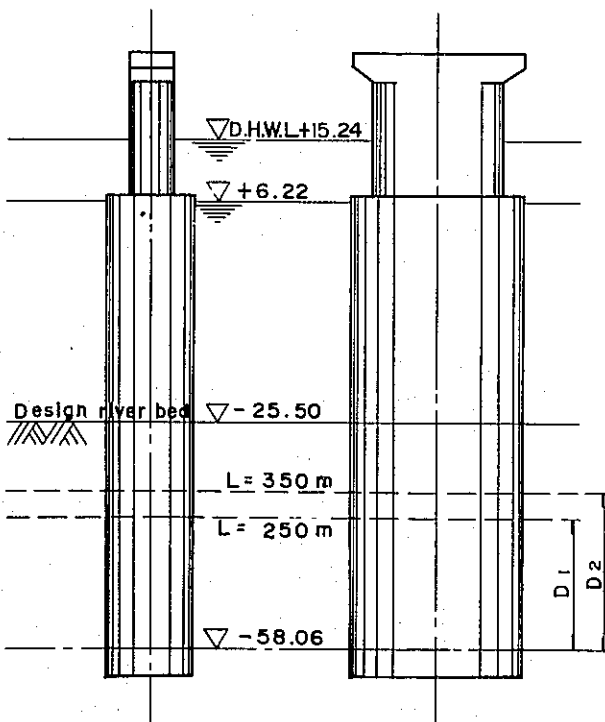
(a) $B = 4.2 \text{ km}$
 $L = 100 \text{ m} \text{ \& } 150 \text{ m}$



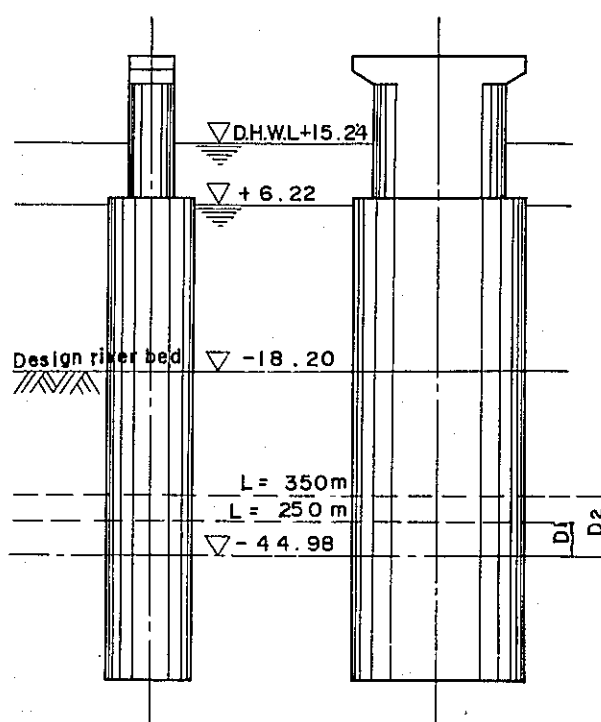
(c) $B = 5.6 \text{ km}$
 $L = 100 \text{ m} \text{ \& } 150 \text{ m}$



(b) $B = 4.2 \text{ km}$
 $L = 250 \text{ m} \text{ \& } 350 \text{ m}$



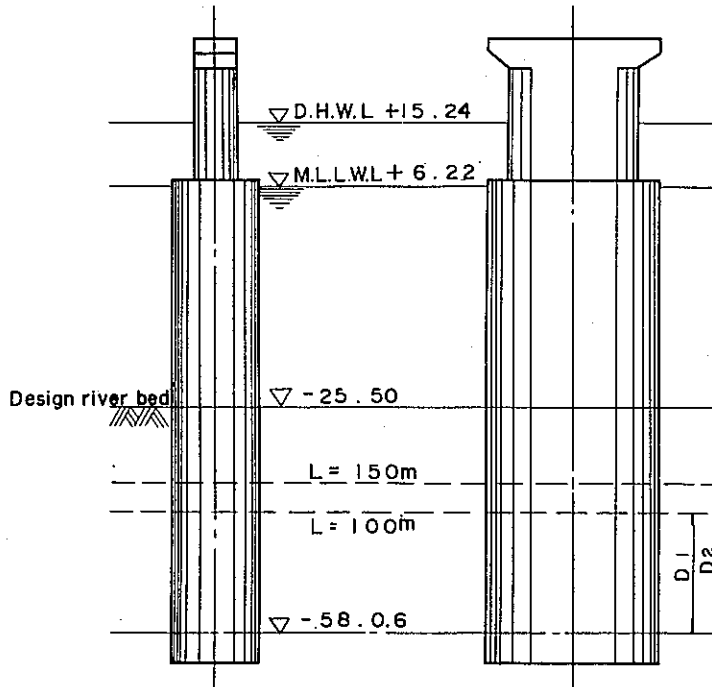
(d) $B = 5.6 \text{ km}$
 $L = 250 \text{ m} \text{ \& } 350 \text{ m}$



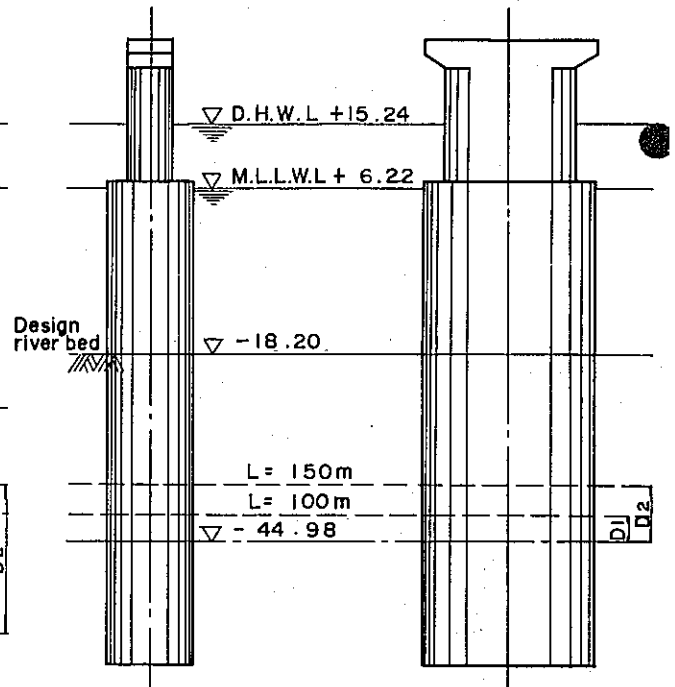
--- : Estimated Height of River Bed
 --- : Height of River Bed required for Stability of Well.
 B : Distance between Guide Banks.
 L : Span Length of Bridge.
 D1, D2 : Necessary Depth of Embedment Required for Stability of Well

Fig. 3-12-2 Necessary Depth of Embedment Required for Stability of Well
(Case - b) at Sirajganj site.

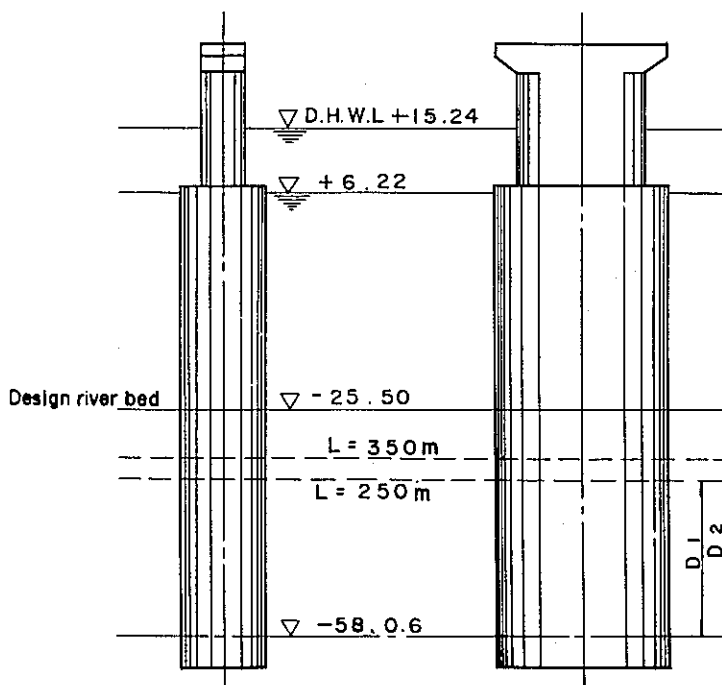
(a) $B = 4.2 \text{ km}$
 $L = 100 \text{ m} \text{ \& } 150 \text{ m}$



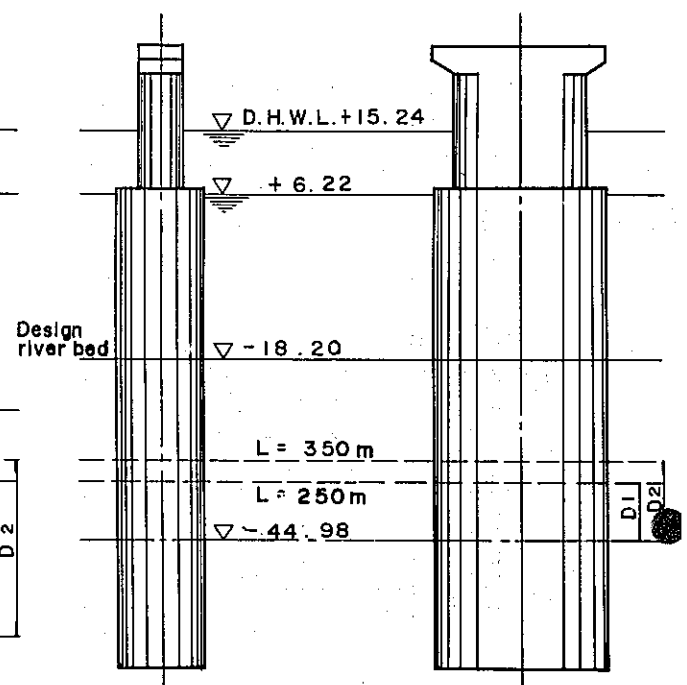
(c) $B = 5.6 \text{ km}$
 $L = 100 \text{ m} \text{ \& } 150 \text{ m}$



(b) $B = 4.2 \text{ km}$
 $L = 250 \text{ m} \text{ \& } 350 \text{ m}$



(d) $B = 5.6 \text{ km}$
 $L = 250 \text{ m} \text{ \& } 350 \text{ m}$



----- : Estimated Height of River Bed
----- : Height of River Bed required for Stability of Well.
 B : Distance between Guide Banks.
 L : Span Length of Bridge.
 D_1, D_2 : Necessary Depth of Embedment Require for Stability of Well

But in this case, it is expected that the free standing length of each pile will become very long. The expected free standing lengths of piles without any foot protection works were estimated as shown in Fig. 3-13 and Table 3-10 by site.

As shown in this Table, in the case of guide bank system of type A, the free standing lengths of piles were counted over 60m at each of the sites. This implies that the each pile must confront with the worst buckling condition and also the fixed end of each pile (lower end) will be attacked by the large bending moment due to lateral forces.

Such conditions are not desirable for the design of foundation piles, therefore, type A was disregarded from our study and type B and type C were taken into consideration.

Concerning the strength of pile, 14 cases were studied by the reasonable combination of diameter of pile, span length and bearing conditions at the top of piers (fixed or movable). As an example, the results of calculation of the following case were shown in Fig. 3-14.

Type; Three equal span continuous truss
Span length; 150m
Diameter of pile; 3m

3.4. Bridge approaches.

3.4.1. Embankment.

The approach embankments are to be needed to connect the bridge with both railway and road links.

The length of approach embankment is affected by the longitudinal slope of railway.

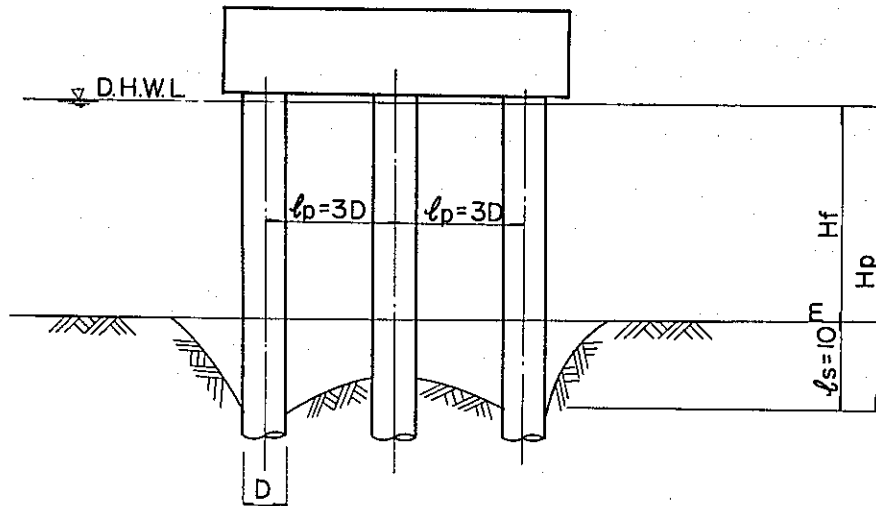
Because of the design height of formation level of railway at the foot of the bridge is about 27.5m (90') above the DHWL, length of embankment of about 3.5km was needed provided that the longitudinal slope of railway is 1/200. These embankments serve as the cross dyke of the river training system. All surfaces of slope of embankment below DHWL should be protected against scouring by the brick wire cylinder (wire cylinder filled with brick).

As the high embankment is needed, its stability must be checked. The stability of the embankment was checked by the circular arc method and it was confirmed by the results of calculation that the design slope of 1:2.5 is suitable for the slope of approach embankment.

The physical indices which were used for the stability calculation are as follows.

Bulk density	1.9 t/cu.m (119 lbs/cft)
Angle of internal friction	20°
Cohesion of soils	0

Fig. 3 - 13 Diagrammatic Sketch of Multi-pile - foundation



- (Legend)
- l_p : Pile interval
 - D : Diameter of pile
 - l_s : Scored depth
 - H_f : Depth of water
 - H_p : Free-standing length

Table 3-10 Free-standing Length of Pile at Each Site

Proposed sites	Mark	Type of guide bank		
		Type A	Type B	Type C
Bahadurabad	Hf	50.5 m	37.7 m	31.2 m
	Hp	60.5	47.7	41.2
Gabargaon	Hf	54.9	41.0	35.6
	Hp	64.9	51.0	45.6
Sirajganj	Hf	52.5	39.9	32.6
	Hp	62.5	49.9	42.6
Nagarbari	Hf	56.1	42.4	36.8
	Hp	66.1	52.4	46.8

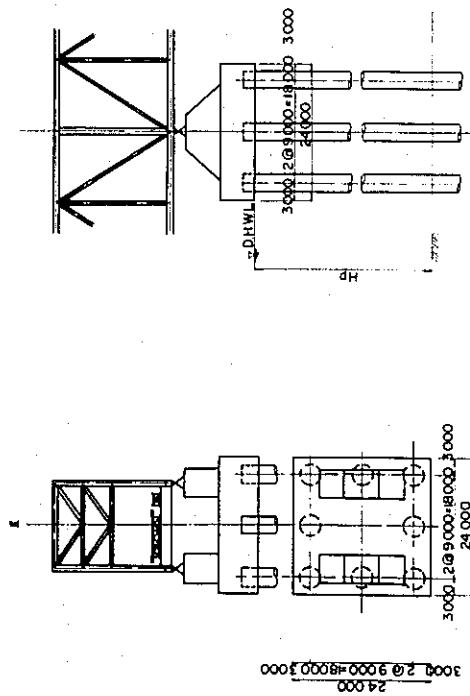
Fig. 3-14 General View of Multi-pile - foundation in Case a

Span length $L = 150.0\text{m}$

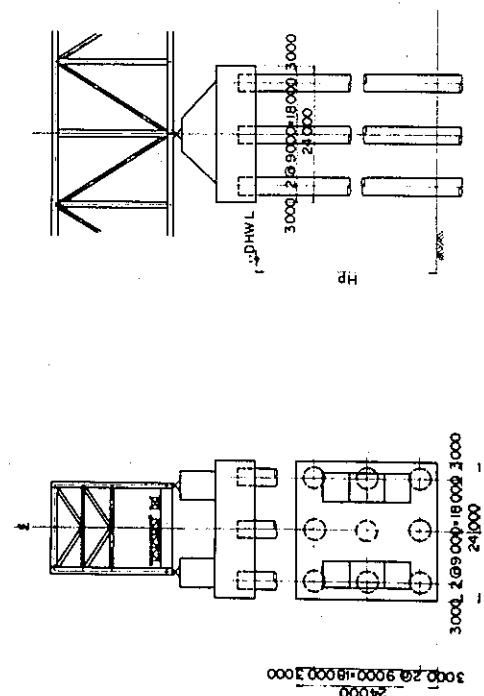
Diameter of pile $D = 30\text{m}$

a) Pier with fixed end

i) Distance between guide banks $B = 42\text{ km}$

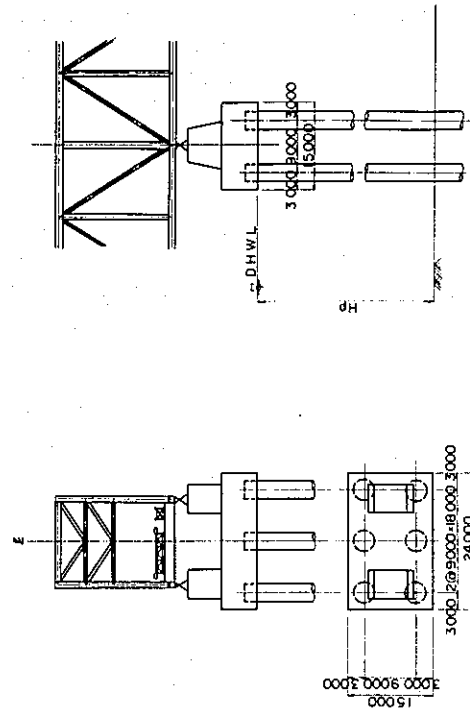


ii) Distance between guide banks $B = 5.2 \text{ or } 56\text{ km}$

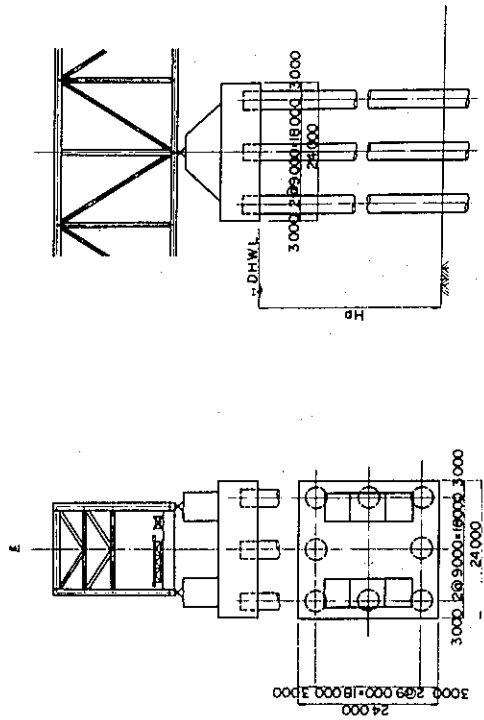


b) Pier with movable end

i) Distance between guide banks $B = 42\text{ km}$



ii) Distance between guide banks $B = 5.2 \text{ or } 56\text{ km}$



Elevated structures were considered as an alternative of embankment, but the results of study showed that the embankment is more economical than the elevated structures. Therefore, we adopted the embankment in the present study.

3.4.2. Elevated structures.

When the width system of bridge consists of double broad gauge tracks and four-lane carriageway, the double-deck system was adopted for the bridge floor. In this case, the upper deck is utilized for highway traffic. In this case, the viaduct should be needed to connect the highway deck with road links.

Concerning about the structural type of viaduct, three equal span continuous steel girder with box section was adopted considering the alignment of viaduct. In this case, applied span length is 60m.

In portion where the both decks overlap each other, the steel portal frame was adopted for the piers.

3.5. Foot protection works around piers.

As the guide-tank system was adopted in this study, the estimated river bed at each proposed site becomes very deep in water as shown in Fig. 3-15.

In general, bridge piers should be sunk enough to stand by themselves without any protection around them. In order to achieve this purpose, the definite depth of embedment of well must be needed to maintain a stability against lateral forces even if the conditions were worst. But in the present study, it is clarified by the results of calculation that the wells over 100m long must be needed for some parts where the river is deep providing that there are no foot protection works.

Such a work is difficult to execute and also uneconomical. Therefore, it is necessary to prevent the well from local scouring by foot protection works in order to secure the necessary depth of embedment.

According to the above-mentioned consideration, the studies were performed and the results were shown as follows.

3.5.1. Range for protection.

(1) Gales' proposal

R.R. Gales proposed a protection range to be taken around piers in consideration of oblique attack of flow scattering of stones in falling, which is shown in Fig. 3-16.

(2) K. Ishizaki and K. Homma's study

K. Ishizaki and K. Homma obtained the results shown in Figs. 3-17 and -18 on the basis of extensive experiments. In these figures,

H ; normal water depth without scour,
 q ; unit discharge in the normal water depth,
 v ; mean velocity in the normal water depth,
 x ; distance from the pier wall,
 r ; radius of pier,
 d_s ; depth of scour at the pier wall or at $x=0$,
 H' ; the scoured depth measured from the water surface,
 q' ; unit discharge at the pier wall,
 v' ; mean velocity at the pier wall,
 y ; a value of q'/q at the pier wall, or at $x=0$.

Fig. 3-17 shows the correlation between q'/q and x/r and Fig. 3-18 shows the correlation between d_s/H and y .

As seen in Fig. 3-17, the ratio q'/q is larger than unity in the range $x/r < 2$ or in the distance smaller than D from the pier wall. Therefore, it may be sufficient, if we take the range for protection as $2D$ from the pier wall in consideration of scattering of stones, where D is diameter of pier.

(3) Present stage at Hardinge Bridge

According to the results of pricking around piers of Hardinge Bridge, it is reported that stones have been scattered around the piers approximately within the range of about $2D$ from the the pier wall.

3.5.2. Method of protection.

The protection around piers is carried out using pitching stones with preferable weight.

The theoretical diameter or weight of stones to be used for the protection around piers is large. The required values of this stones by site were shown in the VOLUME II of this report. The values given in the above-mentioned volume mean the sizes of stones which will not be moved without the supply of sediment. But if we consider the continuous supply of sediment to the scoured hole and maintenance supplement of stones, stones smaller than these will be available for the protection works.

Even in dry season, if the stability of well will be endangered by the local scouring during the period of execution of well, protection works by pitching stone should be executed as soon as possible. Therefore, adequate volume of pitching stone should be reserved at the working field for emergency.

As the river bed will be subsided by the scouring action of flood and stones will be scattered by the scouring of river bed, regular inspection of protection work and constant supply of pitching stones will be needed.

In order to perform above-mentioned jobs and to treat the unforeseen scouring occurred by the shift of thalweg, some managing organization and stock of pitching stones for emergency will be requested.

Fig. 3 -15 Geological Profile and Height of River Bed

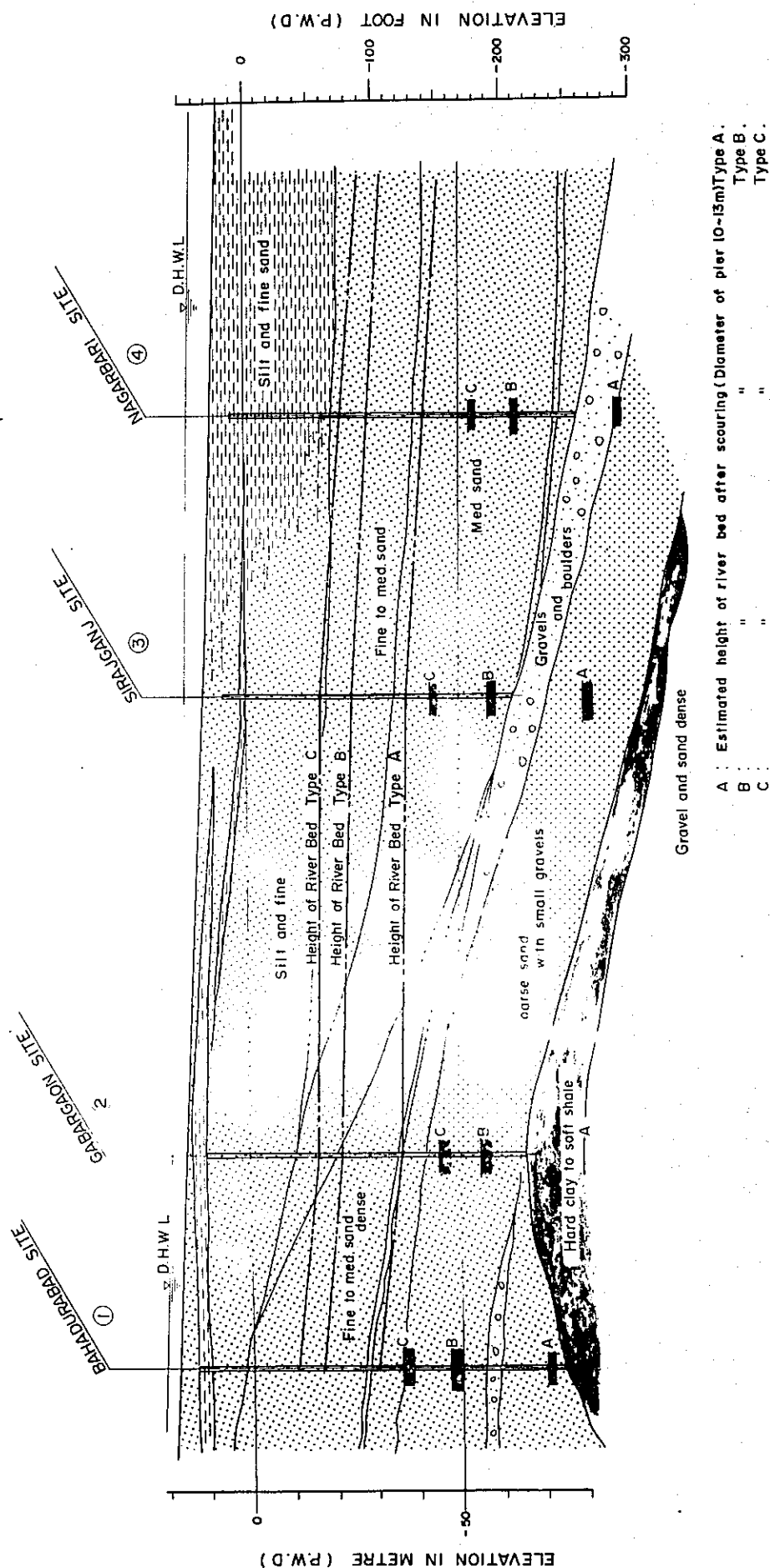


Fig. 3-16 Diagram of Pier - apron

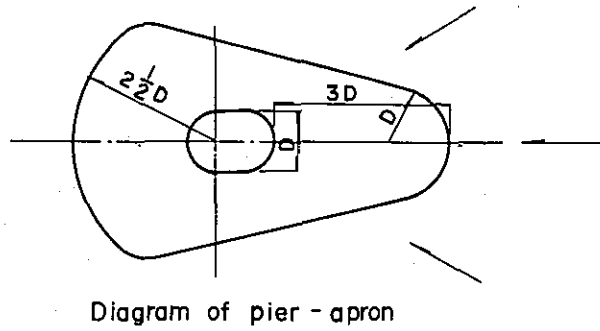


Fig. 3-17 The Relation between q'/q and x/r

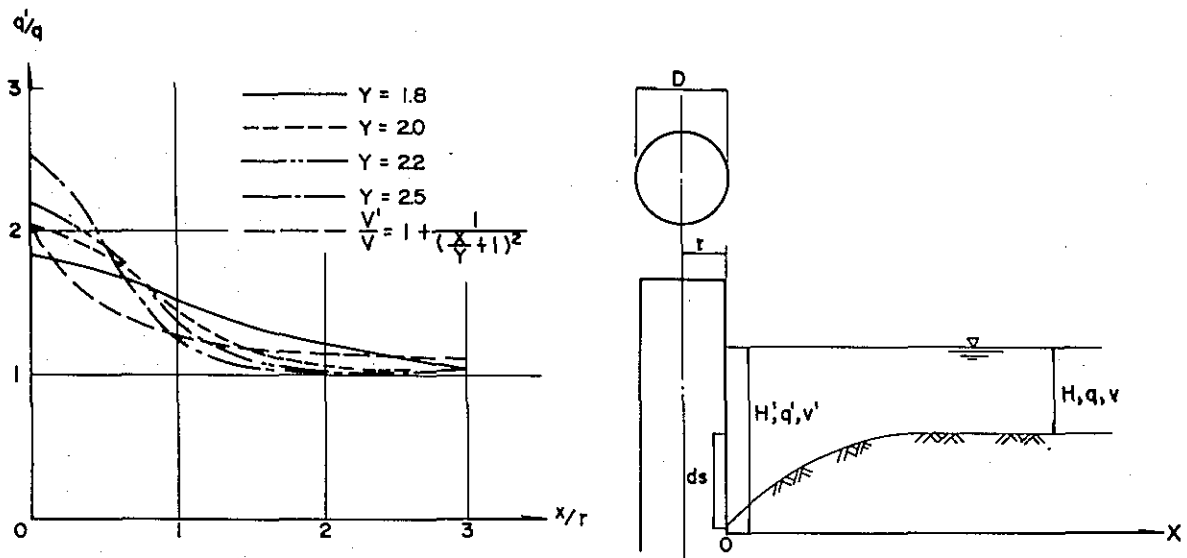
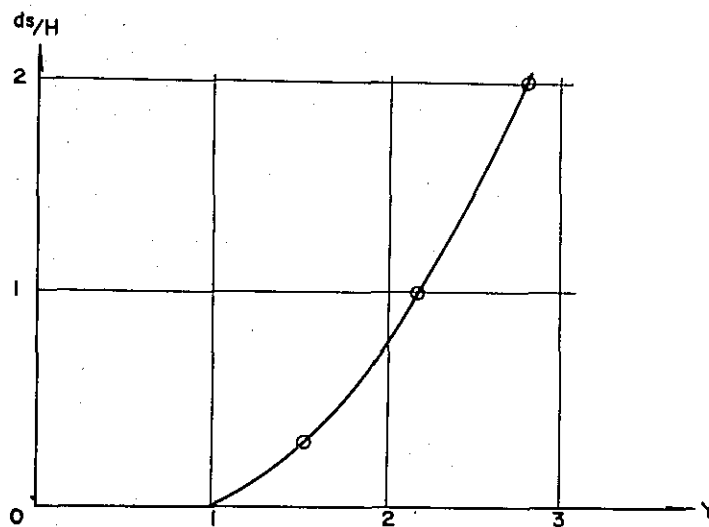


Fig. 3-18 The Relation between ds/H and Y



4. Bridge Construction Works.

4.1. Natural conditions of the proposed bridge sites.

4.1.1. Meteorological conditions.

Data of meteorological conditions of the bridge sites or their vicinities necessary for the study were collected and rearranged by the River Study Team. Such data sources are those which were kept at Bogra, Sirajganj and Faridpur meteorological observation stations.

The Bridge Study Team referred to the following data arranged by the River Study Team.

- Data for temperature
- Data for wind speed
- Data for rainfall

These data were shown in the VOLUME II of this report.

4.1.2. Water level at the proposed bridge sites.

The River Study Team investigated the monthly mean water level of the river at the proposed bridge sites based on the data kept at Bahadurabad, Sirajganj and Jagannathganj water level observation stations. From these data, the annual variation of monthly mean water level of the river at the proposed bridge sites were estimated.

Fig. 3-19 shows the annual variation of monthly mean water level of the river, ground height and mean height of the river bed at the proposed bridge sites.

As was clarified by this figure, in general, the water level of the river attains its highest value in July or August and it shows the lowest value in February or in March.

Variation of the monthly mean water level of the river during the above period is counted about 6.5m - 7.0m. (21' - 23')

4.1.3. Criterion of the workday.

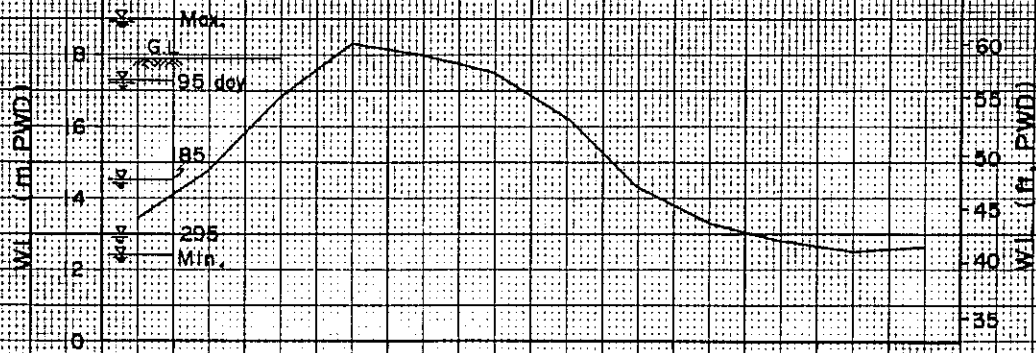
Workday means the day possible to perform the field construction work. In order to contemplate the work schedule of the bridge construction, number of workdays should be estimated. As the workday is affected by the weather conditions, data for weather conditions at the bridge sites should be needed. Fig. 3-20 shows the water level of the river, wind speed and number of rainy days in past few years at Sirajganj site. Referring such meteorological data at Sirajganj site, we decided that the workdays are to be estimated by the following criteria.

(1) Water level of the river

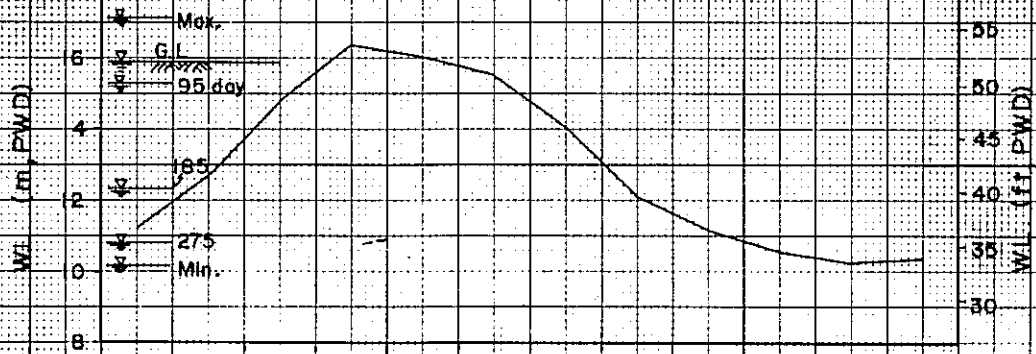
(i) Substructure

Fig. 3-19 Monthly Mean Water Level at Each Site

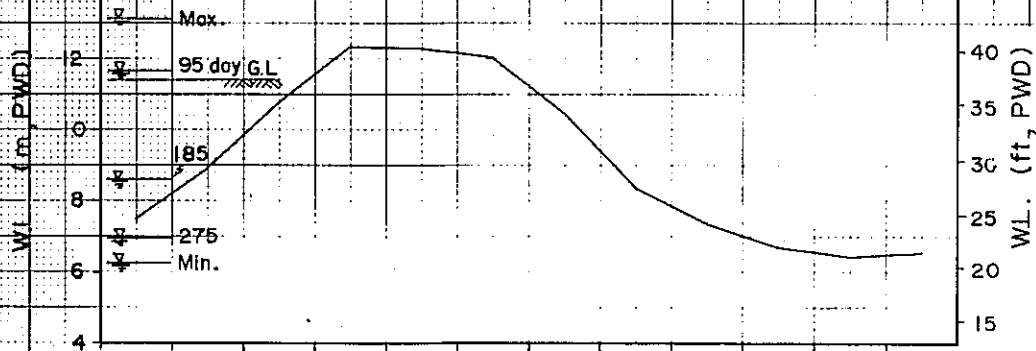
Bahadurabad Site (DHWL = 20.86 m, PWD)



Gabargadon Site (DHWL = 19.44 m, PWD)



Sirajganj Site (DHWL = 14.94 m, PWD)



Nagarbari Site (DHWL = 14.01 m, PWD)

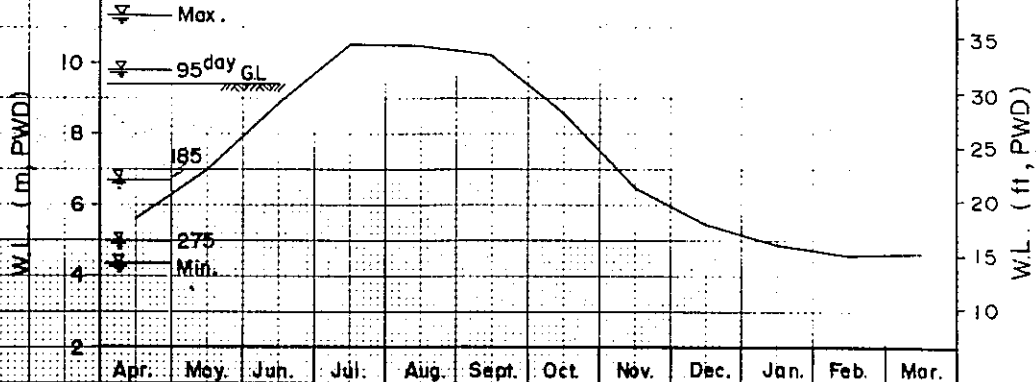


Fig. 3 - 20 Natural Condition at Sirajganj Site

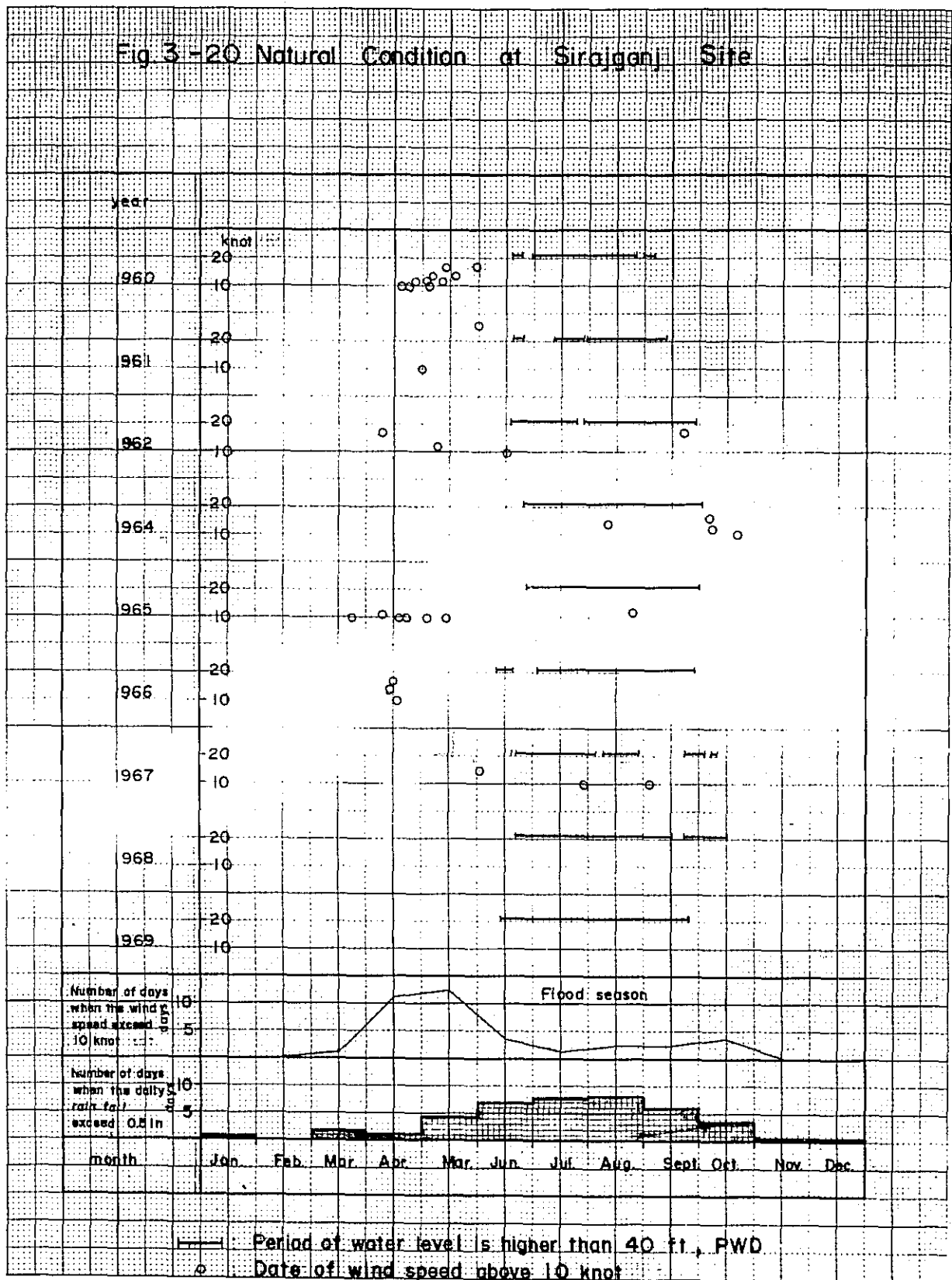


Table. 3 - 11 Workdays

	Month	Days in month	Non Workdays				Total Workdays	30 days		
			by High Water	by Rainy >0.5 in/day	by Holiday	Subtotal		30	20	10
Substructure	Jul.	31	31	7.6	2	31.0	0			
	Aug.	31	31	8.0	2	31.0	0			
	Sep.	30	30	5.8	2	30.0	0			
	Oct.	31	0	3.4	2	5.4	26			
	Nov.	30	0	0.2	2	2.2	28			
	Dec.	31	0	0.2	2	2.2	29			
	Jan.	31	0	0.2	2	2.2	29			
	Feb.	28	0	0	2	2.0	26			
	Mar.	31	0	1.4	2	3.4	28			
	Apr.	30	0	1.0	2	3.0	27			
	May	31	0	4.2	2	6.2	25			
	Jun	30	0	6.8	2	8.8	21			
	Total	365	92	38.8	24	127.4	239			

In the case of well foundation, as the design height of the top of well is 1 meter higher than the MLLW, the construction works will be possible till the end of June judging from the weather conditions. But in this case, the temporary cofferdam should be provided in accordance with necessity. And we judged that the execution of the field construction works will be impossible from the beginning of July to the end of September. In this period, the Jamuna will be flooded and the regular operation of various barges will be impossible. Therefore, this period should be excluded from the workdays. Same considerations will be available for the case of multi-pile foundations.

(ii) Superstructure

The construction works of superstructure are not affected by the condition of water level of the river, if the erection equipment can be carried through the bridge already erected. But in some cases, the equipment should be lifted from the barge. In such a case, the works will be affected by the river conditions. Therefore, the interrupted period of works is assumed from the beginning of July to the end of September.

(2) Rainfall

We assumed that the field works can not be performed if the daily amount of rain-fall will exceed 0.5 inches.

(3) Non workdays

We assumed that the non workdays are two days month by month during the period of execution of the bridge construction works.

(4) Wind speed

If we assumed that the execution works will be possible when the wind speed does not exceed 10 knots, the execution works will not be interrupted by wind through the year. But the possibility of formation of gust was disregarded in the present case.

(5) Workdays

According to the above criteria, the workdays by month were counted and the results were shown in Table 3-11.

As shown in the Table, workdays are 239 days through the year.

Above results were obtained by the meteorological conditions at Sirajganj site, but we assumed that these data can be available for the other three proposed sites.

4.2. Quantity of works.

4.2.1. Superstructures.

As for the superstructure we recommend the 3-span-continuous truss for span length of 100m and 150m and cantilever truss for span length of 250m and 350m.

Considering the span and width for Case a and Case b, the weight of structural steel per meter is compiled in Table 3-12. Fig. 3-21 shows the relations between steel weight per unit length and span length of bridges. The total steel weights which were roughly estimated, were shown in Table 3-13.

4.2.2. Substructures.

(1) Well foundation

The quantity of works for well foundation, that is, concrete volume for substructure and gross volume of foundation wells at each proposed site for every span length of superstructure and each guide-bank span was estimated for cases a and b as shown in Tables 3-14-1 and -2.

(2) Multi-pile foundation

The quantity of works for multi-pile foundation at each site for every span length of superstructure and each guide-bank span was estimated for cases a and b as shown in Table 3-15.

As the multi-pile foundation, it is clear that the making use of 3.0m-pile in diameter is better than 2.0m-pile in diameter with regard to total weight of piles from the Table 3-15. Therefore, we selected multi-pile foundation of 3.0m in diameter as the object to compare with the well foundation in costs. Accordingly, we adopted hereafter the multi-pile foundation of 3.0m as the alternative plan for the well foundation.

4.2.3. Bridge approaches.

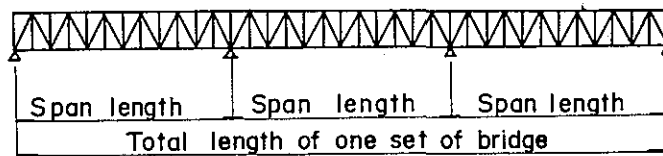
The quantity of materials required for the embankment of approaches including selected earth, dredged sand, pitching stone and sodding is shown in Table 3-16.

In case b, the viaduct was planned. The quantity of materials for the viaduct is shown in Table 3-17.

**Table 3 - 12 Comparison of Steel Weight
per Unit Length of Bridge**

Case	Type	Span length (m)	Total length of one set of bridge	Steel weight B (t)	unit weight B/A (t/m)
a	3 span continuous truss	100	300	2 430	8.10
		150	450	4 833	10.7
	Cantilever truss	250	500	9 783	19.6
		350	700	20 634	26.6
b	3 span continuous truss	100	300	3 249	10.8
		150	450	6 482	14.4
	Cantilever truss	250	500	15 413	30.8
		350	700	28 328	40.5

Marking diagram for span of 100^m or 150^m



Marking diagram for span of 250^m or 350^m

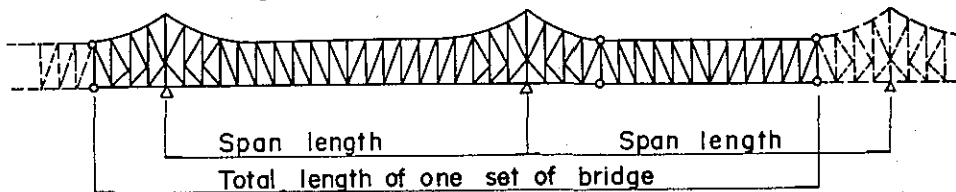


**Fig. 3 - 21 Relation between Span Length
and Steel Weight**

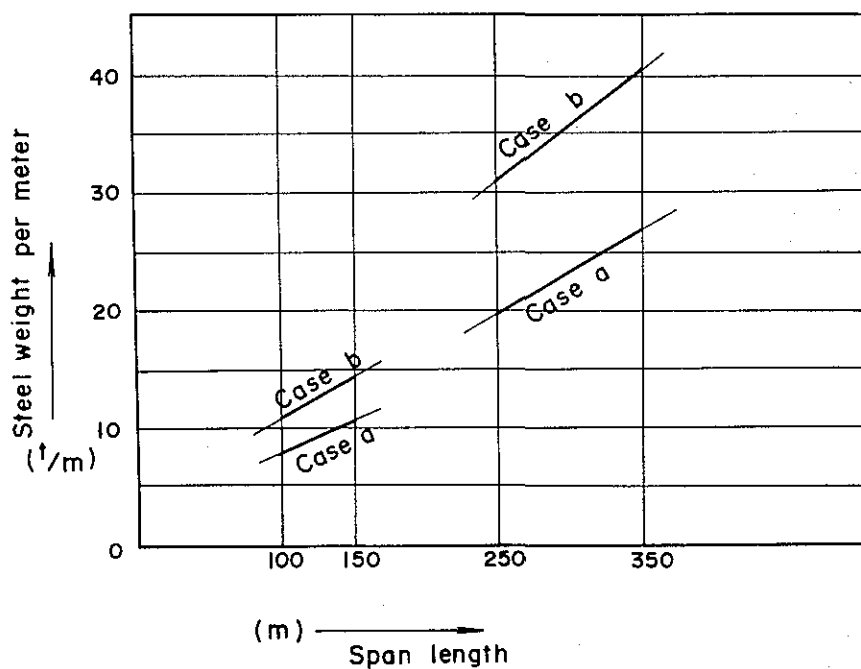


Table 3-13 Total Weight of Steel of Superstructure

Unit: Ton

Case	Span (m)	Distance between guide banks			
		2.0 km	4.2 km	5.2 km	5.6 km
a	100	16,230	34,054	42,018	45,412
	150	22,823	47,251	57,023	61,908
	250	43,050	91,281	110,881	110,881
	350	68,469	130,438	171,750	171,750
b	100	21,705	45,403	56,394	60,793
	150	30,311	62,734	75,704	82,188
	250	67,880	143,901	174,791	174,791
	350	94,125	179,233	235,971	235,971

Table 3-14-1 Total List of Construction Materials of Well Foundations
in Case a

Span (m)	Dist. Btw. G.B (Km)	Items	Proposed site			
			Bahadurabad	Gabargaon	Sirajganj	Nagarbari
L= 100	4.2	R.C	329,970	337,640	322,310	360,640
		G.V	345,670	356,170	334,600	380,730
	5.2	R.C	----	419,990	----	448,600
		R.V	----	443,040	----	473,590
	5.6	R.C	442,650	----	432,370	----
		G.V	463,710	----	448,860	----
L= 150	4.2	R.C	225,350	230,580	220,110	246,290
		G.V	236,070	243,240	228,510	260,010
	5.2	R.C	----	280,000	----	299,070
		G.V	----	295,360	----	315,720
	5.6	R.C	297,770	----	290,860	----
		R.V	311,950	----	301,960	----
L= 250	4.2	R.C	238,950	244,570	233,340	261,430
		G.V	312,790	322,270	302,760	344,500
	5.2	R.C	----	298,910	----	319,530
		G.V	----	393,890	----	421,060
	5.6	R.C	292,050	----	285,180	----
		G.V	382,290	----	370,040	----
L= 350	4.2	R.C	159,300	163,040	155,550	174,290
		G.V	208,520	214,850	201,840	229,670
	5.2	R.C	----	217,390	----	232,380
		G.V	----	286,460	----	306,220
	5.6	R.C	212,390	----	207,400	----
		G.V	278,030	----	269,120	----

(Note) R.C. : Reinforced Concrete
G.V. : Gross Volume of Wells

Table 3-14-2 Total List of Construction Materials of Well Foundations
in Case b

Span (m)	Dist. Btw. G.B (Km)	Items	Proposed site			
			Bahadurabad	Gabargaon	Sirajganj	Nagarbari
L= 100	4.2	R.C	560,060	572,850	547,270	611,270
		G.V	712,460	734,060	689,620	784,700
	5.2	R.C	----	712,570	----	760,360
		G.V	----	913,100	----	976,090
	5.6	R.C	751,360	----	734,150	----
		G.V	955,740	----	925,100	----
L= 150	4.2	R.C	382,480	391,220	373,750	417,450
		G.V	486,560	501,310	470,960	535,890
	5.2	R.C	----	375,050	----	506,910
		G.V	----	608,740	----	650,730
	5.6	R.C	505,410	----	493,870	----
		G.V	642,950	----	622,340	----
L= 250	4.2	R.C	235,880	251,500	240,270	268,360
		G.V	312,790	322,270	302,760	344,500
	5.2	R.C	----	307,380	----	328,000
		G.V	----	393,890	----	421,060
	5.6	R.C	300,520	----	293,650	----
		G.V	382,290	----	370,040	----
L= 350	4.2	R.C	163,920	167,660	160,170	178,910
		G.V	208,520	214,850	201,840	229,670
	5.2	R.C	----	223,550	----	238,540
		G.V	----	286,460	----	306,220
	5.6	R.C	218,550	----	213,560	----
		G.V	278,030	----	269,120	----

Table 3-15 Rough Estimation of Weight of Steel Pipe Piles
for Multi-pile Foundation

1. Diameter of pile $D=2.0$ m, thickness $t=40$ mm.

a) Width system of bridge.....Case a

Unit : Thousand tons

Distance btw. guide banks	(m)	Proposed sites			
		Bahadulabad	Gabargaon	Sirajganj	Nagarbari
4.2 km	100	---	---	---	---
	150	162	207	203	209
	250	108	177	174	180
	350	159	203	200	205
5.2 km or 5.6 km	100	112	---	114	---
	150	119	192	121	195
	250	88	141	90	130
	350	122	207	124	209

b) Width system of bridge.....Case b

4.2 km	100	---	---	---	---
	150	229	276	271	279
	250	170	248	244	251
	350	181	237	232	239
5.2 km or 5.6 km	100	166	---	169	---
	150	194	272	198	275
	250	142	203	144	205
	350	181	236	184	239

2. Diameter of pile $D=3.0$ m thickness $t=60$ mm

a) Width system of bridge.....Case a

4.2 km	100	72	99	98	101
	150	65	80	79	82
	250	63	87	86	89
	350	65	82	81	85
5.2 km or 5.6 km	100	79	87	79	89
	150	76	77	76	78
	250	64	75	64	76
	350	74	83	74	85

b) Width system of bridge.....Case b

4.2 km	100	82	99	98	101
	150	97	136	134	140
	250	90	113	111	116
	350	95	99	98	101
5.2 km or 5.6 km	100	90	99	90	101
	150	106	114	107	116
	250	88	106	88	108
	350	117	123	118	125

Table 3-16 List of Materials Required for Bridge Approach Embankment

Unit : Thousand m³

Items		Case a				Case b			
		Selected earth	Dredged sand	Pitching stone	Sodding	Selected earth	Dredged sand	Pitching stone	Sodding
	2.0 ^{Km}	1,740	1,250	212	247	2,561	1,750	212	247
Bahadurabad	4.2 "	1,740	1,699	314	359	2,561	2,379	314	359
	5.6 "	1,740	2,357	385	459	2,561	3,300	385	459
	2.0 "	1,740	1,069	224	253	2,561	1,497	224	253
Gabargaon	4.2 "	1,740	1,930	338	388	2,561	2,702	338	388
	5.2 "	1,740	2,585	393	484	2,561	3,619	293	484
	2.0 "	1,740	1,555	208	249	2,561	2,177	208	249
Sirajganj	4.2 "	1,740	2,246	375	412	2,561	3,144	375	412
	5.6 "	1,740	3,137	453	521	2,561	4,392	453	521
	2.0 "	1,740	2,051	278	313	2,561	2,871	278	313
Nagarbari	4.2 "	1,740	2,920	400	442	2,561	4,088	400	442
	5.2 "	1,740	3,713	457	521	2,561	5,198	457	521

Table. 3-17 List of Materials used for Viaduct of Bridge Approach in Case b

	Items	Unit	Quantities	Remarks
Superstructure	Structural steel	ton	7,404	SM53, SS41
	Cast steel	"	276	Shoe
	Reinforced concrete	m ³	9,260	Slab
	Asphalt pavement	m ²	27,504	
Substructure	Structural steel	ton	2,504	SM53, SS41
	Reinforced concrete	m ³	26,000	
	Steel pipe pile	ton	5,600	ø 600

4.3. Term of construction works.

The term of construction works for Jamuna Bridge Project was estimated at about nine years including two years for preparation and seven years for main construction works. For the execution of the works, best efforts must be concentrated in the direction of speed-up of the execution and reduction in erection schedules of the works on a gigantic scale, in which massive materials, equipment and machinery are used. Moreover, the work is under a strict restraint of weather--rainy seasons.

For the main bridge works, priority is given to the foundation wells works which starts, first of all, and the substructure, including foundation wells and piers must be completed, one after another, within the course of one single dry season, meanwhile, the superstructure works were planned to start in succession 1 year later, over the substructure, and to finish the works after six years.

4.4. Construction method and equipment.

4.4.1. Transportation.

Khulna port is expected to be available for the unloading materials and equipment from abroad while Chittagong port may be used for unloading a part of them.

Transportation by railway does not answer the purpose because of increase of freight trains and an improvement of rail gage are needed to supplement the shortage of waggons and to avoid loading and unloading arise from difference of rail gages.

Transportation by road does not answer also the purpose because there are few roads available for rainy seasons and having enough bearing strength for the heavy load, in addition, due to limitation of weight and ferry capacity.

To smoothen the transportation by barge, it is requested to construct a wharf which can be available throughout a year and to construct a new road connecting the wharf with the bridge site.

4.4.2. Substructure.

Ordinary method of excavation by tripod derrick cranes and clam-shell grabbing cranes are not available in this case because the well length to be excavated is over 70m and the excavation must be done as quickly as possible. Therefore, the excavation methods by the excavator of a large diameter and the reverse circulation equipment were adopted.

For execution of works of multi-pile foundation, driving of steel pipes of a large diameter and placing of top slab concrete are essential. For the works on the river, a large piling barge should be used and it is advisable to set steel frames in the water and connect them with the steel plates which serve as bottom form for the top slab and utilize them as a guide for driving for securing the correct position of piles.

4.4.3. Superstructure.

Erection of superstructure was planned to be executed by bent erection method on land and river where the water is shallow and its speed is slow.

The cantilever erection method was adopted to other places.

4.5. Problems on construction works.

4.5.1. Points at issue on preparatory works.

(a) Massive materials and equipment to be imported from abroad are transported to Chalna Port by ocean-going steamer and transshipped to the barge and transported to Khulna Port. Then they are divided by use and transported to the bridge site by railway or inland water. Hence, unloading facilities and yard are needed at the bridge site.

(b) Concrete mixing plants should be prepared and located at the most convenient places for the works requiring the materials of concrete.

(c) As a great quantity of fuel is consumed for the construction equipment and generators, fueling stations of a large capacity are required at both sides of the river.

(d) For the purpose of making inspection of and repairs on all kinds of the construction equipment, motorpools on a large scale are required at both sides of the river.

(e) Other facilities than those mentioned above, accommodations for the laborers, and the facilities for water supply, drainage, electric power supply, heliport, etc. must be prepared as the construction base. The base should be constructed so that it may not be submerged during the flood season.

4.5.2. Points at issue on temporary works.

(a) The temporary road for construction works must be provided to connect between the site and the base. However, as the roads will be submerged and broken by floods during a rainy season, they must be repaired each year.

(b) Temporary piers for barges must be constructed at a spot in the construction site where water floods each year.

These temporary piers should be assembled by prefabricated members so that they can be withdrawn from the spot to prevent any loss or breakage of the piers when a flood occurred.

4.5.3. Points at issue on main construction works.

(a) The construction works must be executed at a rapid speed and the construction equipment with high efficiency should be used. Simplifying the structure and mechanizing the works, reduction of the construction term must be achieved.

(b) Since almost all works are executed at once in parallel during a dry season and the quantity of the works is very large, the job sites might be congested with laborers and equipment. Therefore, the management of these laborers and equipment shall not be ignored.

(c) Due consideration in utilizing man-powers as much as possible.

5. Construction Costs.

5.1. Estimating bases of construction costs.

In estimating construction costs, costs of general facilities such as living quarters, motor pool, fuel storage, material storage, cargo-handling facilities at the sites and electric power supply system, water and drainage equipment for these, are excluded.

The estimation was in due regard of the following special circumstances.

(a) General unit prices were studied based on the result of price researches as of the end of March 1974.

(b) According to the investigation of the first stage by the Quarry Study Team, the unit prices at stock yards of the four sites are as follows.

Bahadurabad	6 TK/ft ³
Gabargaon	6.3 "
Sirajganj	7 "
Nagarbari	7.4 "

(c) Unit prices of basic materials for construction are as follows.

Structural steel	2,200 TK/t	79,000 yen/t (in foreign country)
Deformed bar	2,080 "	75,000 " (")
Steel sheet pile	1,610 "	58,000 " (")
Light sheet pile	1,720 "	62,000 " (")
Cement	321 "	11,500 " (")
Sand	448 TK/100ft	5,700 yen/m ³ (at site)
Gravel	700 "	8,500 " (")

5.2. Rough estimate of construction costs.

5.2.1. Superstructures.

The construction costs of each span length of superstructure classified by cases of a and b about the guide-bank spans of 2.0km, 4.2km, 5.2km and 5.6km, were roughly estimated.

These costs were estimated by itemizing into structural steel of each class and prices of shoe, fabrication costs, costs of erection, pavement costs and costs of slab concrete, respectively.

Breakdown costs are shown below.

SS 41 structural steel	60,000 yen/t
SM 50 " "	83,000 "
SM 58 " "	98,000 "
Cast steel	500,000 "
Fabrication	150,000 "
Erection: cantilever method	360,000 "
" bent method	260,000 "
Pavement	2,000 yen/m ²
Slab concrete	70,000 "

Table 3-18 indicates total costs of superstructures collectively and construction costs per unit weight of steel.

The costs of superstructures are shown by guide bank types and totaled by application of the corresponding costs for each type of guide banks for each proposed site.

5.2.2. Substructures.

Total costs of substructures are affected by conditions of the proposed sites and totaled by the corresponding types of guide bank and each span length of superstructure at each site. The total costs of well foundation were shown in Table 3-19, and the total costs of multi-pile foundation in Table 3-20.

However, it was concluded in the investigations made by the River Control Team as following, "In general, in selecting river for the bridge, it is most desirable to take a river width larger than the present state, or it is undesirable to narrow the present one in view of future possible increase of discharge which will generally take place as river improvement works go forward and considering future river plans as well as future possible change in river bed and other regime. Even though the river is inevitably narrowed, a minimum width should be about 4,000m and more." Hence, case of guide-bank span of 2,000m was excluded from the construction costs tabulation.

5.2.3. Bridge approaches.

The costs of each candidate site and distance between guide banks were totalized about the case a and b, and these results are shown in Table 3-21.

6. Selection of the Most Suitable Type of Structure and Span Length.

As mentioned above on the optimum type of superstructure, 3-span steel continuous truss bridges of 100m and 150m span and steel cantilever truss bridge of 250m and 350m span were selected for the suitable type of superstructure.

As for substructure, merits of well and multi-pile-foundation were studied by comparison and the best type of substructure was determined.

In the second place, we obtained the optimum span length by comparison of total costs of superstructures and substructures based on each type of guide banks and span length at each proposed site.

6.1. Selection of the type of substructures.

The costs of well foundation shown in Table 3-20 were compared with the costs of multi-pile-foundation shown in Table 3-21.

As the results of these comparison, in the case a, it is evident that well foundations are more economical than multi-pile-foundation in any proposed site and span length.

In the case of b, since the same dimension for well section was used even in different span of bridge, costs of well foundation decreased in proportion to the number of wells by decreasing number of well in a long span.

In multi-pile foundation, there was not much difference among the costs for various span length to compare with well foundation, and total costs was not always in proportion to the difference in span length.

As in the case b, well foundations are more economical than multi-pile foundations in most cases but on the contrary, in guide-bank span of 5.2km or 5.6km, multi-pile foundations are more economical than well foundations in the case of 100m in span length.

Through above studies on foundation types, the result proved that well foundations would be proper in the case a and be superior in the most cases of case b.

Table 3-18 List of Rough Estimated Construction Costs
of Superstructure

	Case	Span (m)	Distance between guide banks (km)		
			4.2	5.2	5.6
Total costs of construction (100 million yen)	a	100	194.0	234.6	251.0
		150	268.7	318.5	342.8
		250	506.1	603.5	603.5
		350	726.0	938.8	938.8
	b	100	265.7	324.5	346.9
		150	366.0	434.2	467.2
		250	798.0	951.6	951.6
		350	997.9	1,290.0	1,290.0
Costs per unit weight (10 thousand yen)	a	100	57	56	55
		150	57	56	55
		250	55	54	54
		350	56	55	55
	b	100	59	58	57
		150	58	57	57
		250	55	54	54
		350	56	55	55

Table 3-19 Rough Estimate of Construction Costs of Well Foundation

		Unit : 100 million yen				
Dist. btw. G.B (km)	Span(m)	Proposed site				
		Bahadurabad	Gabargaon	Sirajganj	Nagarbari	
Case a	4.2	100	459.4	472.3	445.9	504.8
		150	313.7	322.5	304.5	344.7
		250	390.7	401.8	379.0	429.5
		350	260.4	267.9	252.6	286.3
	5.2 or 5.6	100	616.2	587.5	598.1	627.9
		150	414.6	391.7	402.4	418.6
		250	477.5	491.0	463.2	524.9
		350	347.2	357.1	336.8	381.8
Case b	4.2	100	896.4	921.8	869.9	984.9
		150	612.1	629.5	594.1	672.6
		250	389.4	404.7	381.9	432.4
		350	262.3	269.8	254.6	288.2
	5.2 or 5.6	100	1,202.5	1,146.7	1,166.8	1,225.2
		150	809.0	722.4	784.9	816.9
		250	481.0	494.6	466.7	528.5
		350	349.8	359.7	339.4	384.4

Table 3-20 Rough Estimate of Construction Costs of Multi-pile Foundation

		Unit : 100 million yen				
Dist. btw. G.B (km)	Span(m)	Proposed site				
		Bahadurabad	Gabargaon	Sirajganj	Nagarbari	
Case a	4.2	100	565.0	708.0	711.3	721.9
		150	479.0	596.2	559.0	607.2
		250	465.7	648.9	592.1	660.8
		350	487.6	597.9	583.2	609.2
	5.2 or 5.6	100	578.4	700.7	581.6	710.6
		150	570.7	566.0	573.8	574.6
		250	490.9	553.1	493.3	561.4
		350	561.0	631.1	564.0	640.5
Case b	4.2	100	881.5	995.8	1,006.8	974.5
		150	708.1	994.8	922.9	1,014.0
		250	669.0	818.0	792.3	833.7
		350	694.3	714.9	708.0	728.7
	5.2 or 5.6	100	986.9	1,076.0	991.8	1,091.5
		150	806.8	836.7	810.9	849.4
		250	668.9	750.0	672.3	762.0
		350	870.3	902.4	874.9	916.2

Table 3-21 Rough Estimate of Construction Costs for Bridge Approaches

Unit : 100 million yen

Case	Proposed site	Distance between guide banks	Earth work by dredging	Earth work for embankment	Viaduct	Total
a	Bahadurabad	4.2 Km	49	90	-	139
		5.6 "	53	90	-	143
	Gabargaon	4.2 "	53	90	-	143
		5.2 "	57	90	-	147
	Sirajganj	4.2 "	53	90	-	147
		5.6 "	69	90	-	159
	Nagarbari	4.2 "	89	90	-	179
		5.2 "	53	90	-	183
b	Bahadurabad	4.2 Km	51	133	94	278
		5.6 "	56	133	94	283
	Gabargaon	4.2 "	56	133	94	283
		5.2 "	60	133	94	287
	Sirajganj	4.2 "	66	133	94	293
		5.6 "	72	133	94	299
	Nagarbari	4.2 "	93	133	94	320
		5.2 "	98	133	94	325

6.2. Decisions of the optimum span length and total construction costs.

Generally speaking, as indicated graphically, costs of superstructure in ordinate and span length in abscissa, costs of superstructure increase extremely curving sharply upward in accordance with an increase in its span length.

As for substructure, an individual scale of foundation will be enlarged in accordance with the increment of span length, but the increasing rate of the total costs of substructure is less than that of superstructure. Now, considering a multi-span bridge having the constant bridge length, total costs of superstructure increase in accordance with the increment of span length of bridge but the total costs of substructure decrease in a slow curve gradually because the number of piers decreases due to increment of span length.

When both costs are added, this curve tends to be convex downward generally. This means that the span length corresponding to the bottom point of the curve is the economical minimum. Therefore, we can call this the optimum span length.

We have studied on bridges having four types of spans, and results were obtained as shown in Figs. 3-22-1 ~ 4 in the Case a and in Figs. 3-23-1 ~ 4 in the Case b.

Apparently as shown in above graphs, about 150m span length was concluded as the most economical in the case a and b and at each proposed bridge site.

In these cases, a type of superstructure is a 3-span continuous truss and a type of substructure is a well foundation. Consequently, at the first stage of the study, 3-span continuous truss of span length of 150m was adopted as the basis of the selection of sites for the optimum span length. According to the classification of Fig. 2-4, the total costs of construction in a scope of the Jamuna River Bridge are shown in Table 3-22, and in this table the total costs contain costs of superstructure and substructure, bridge approaches and transportation about each case, each site and each guide-bank type, respectively. In this case, the superstructure of the main bridge is a 3-span continuous steel truss of span length of 150m and the substructure is well foundations.

7. Priority of Evaluation of Proposed Sites.

The total costs of construction according to the most suitable type of structure and span length at each proposed site were shown in Table 3-22. The priority order of evaluation for proposed sites to be obtained from this table, is as shown in Table 3-23.

Fig. 3-22-1 The Relation between Construction Costs and Span Length of Bridge in Case a (Well Foundation)

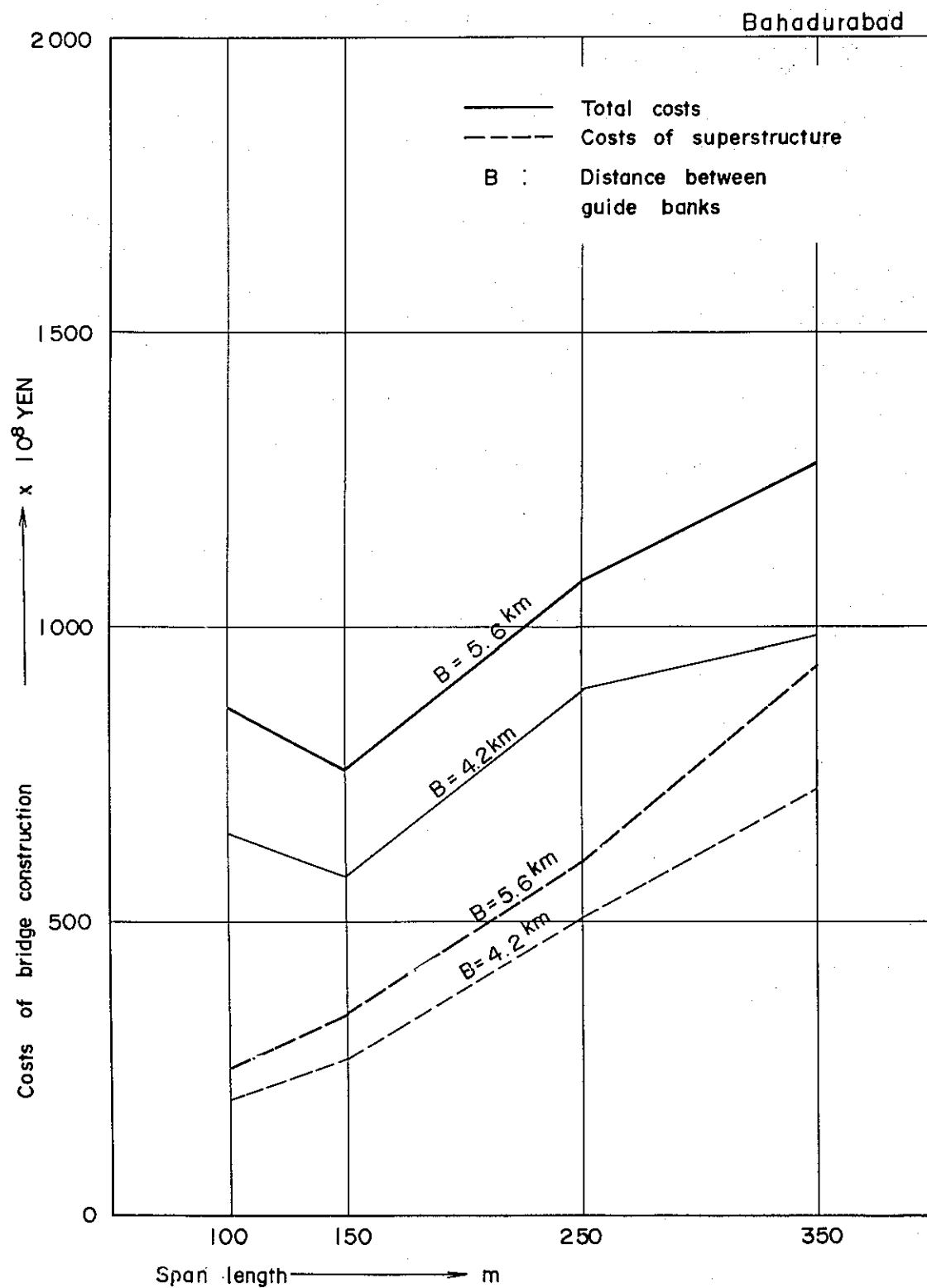


Fig. 3 - 22-2 The Relation between Construction Costs and Span Length of Bridge in Case a (Well Foundation)

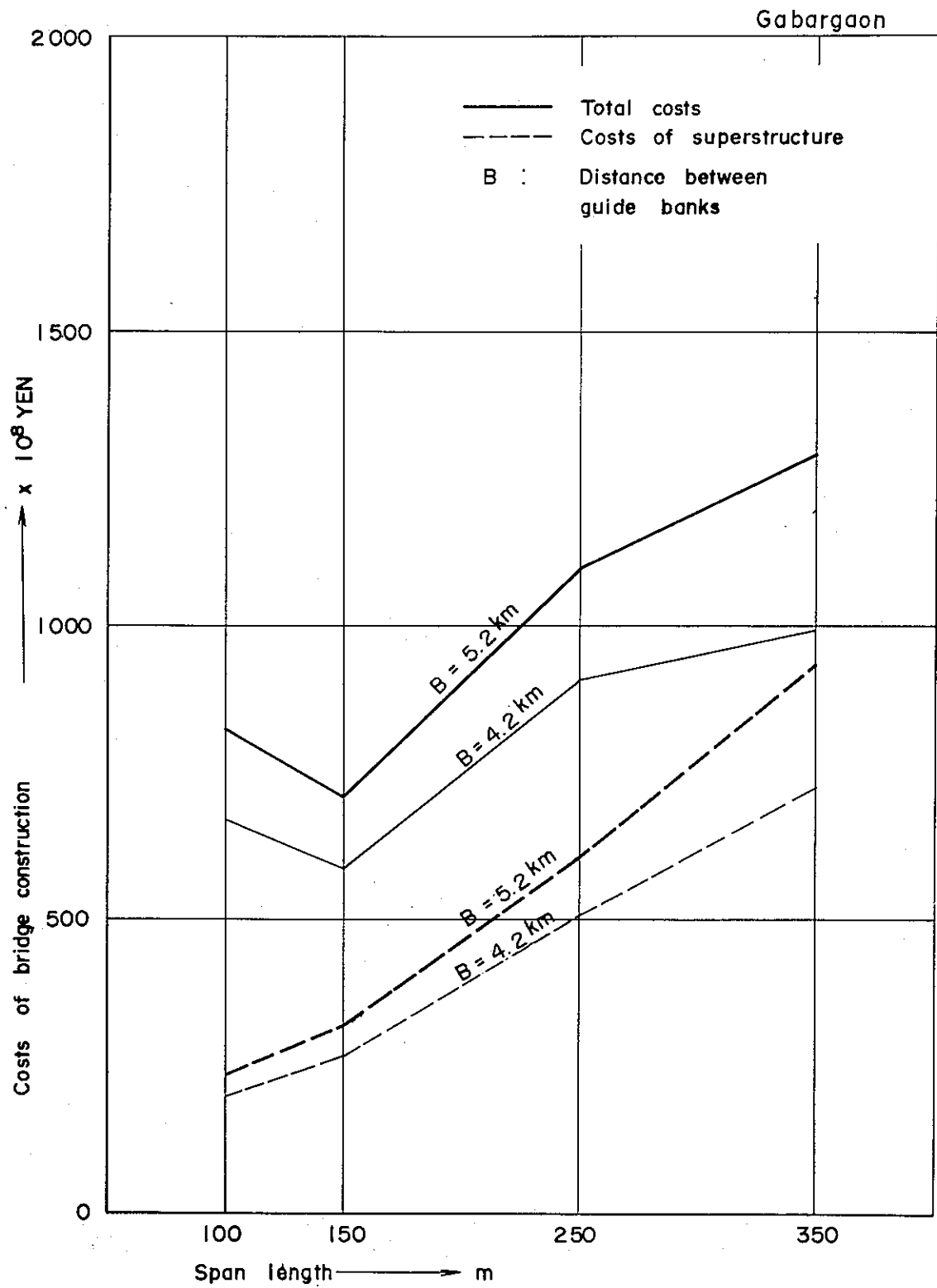


Fig. 3 - 22 - 3 The Relation between Construction Costs and Span Length of Bridge in Case a
(Well Foundation)

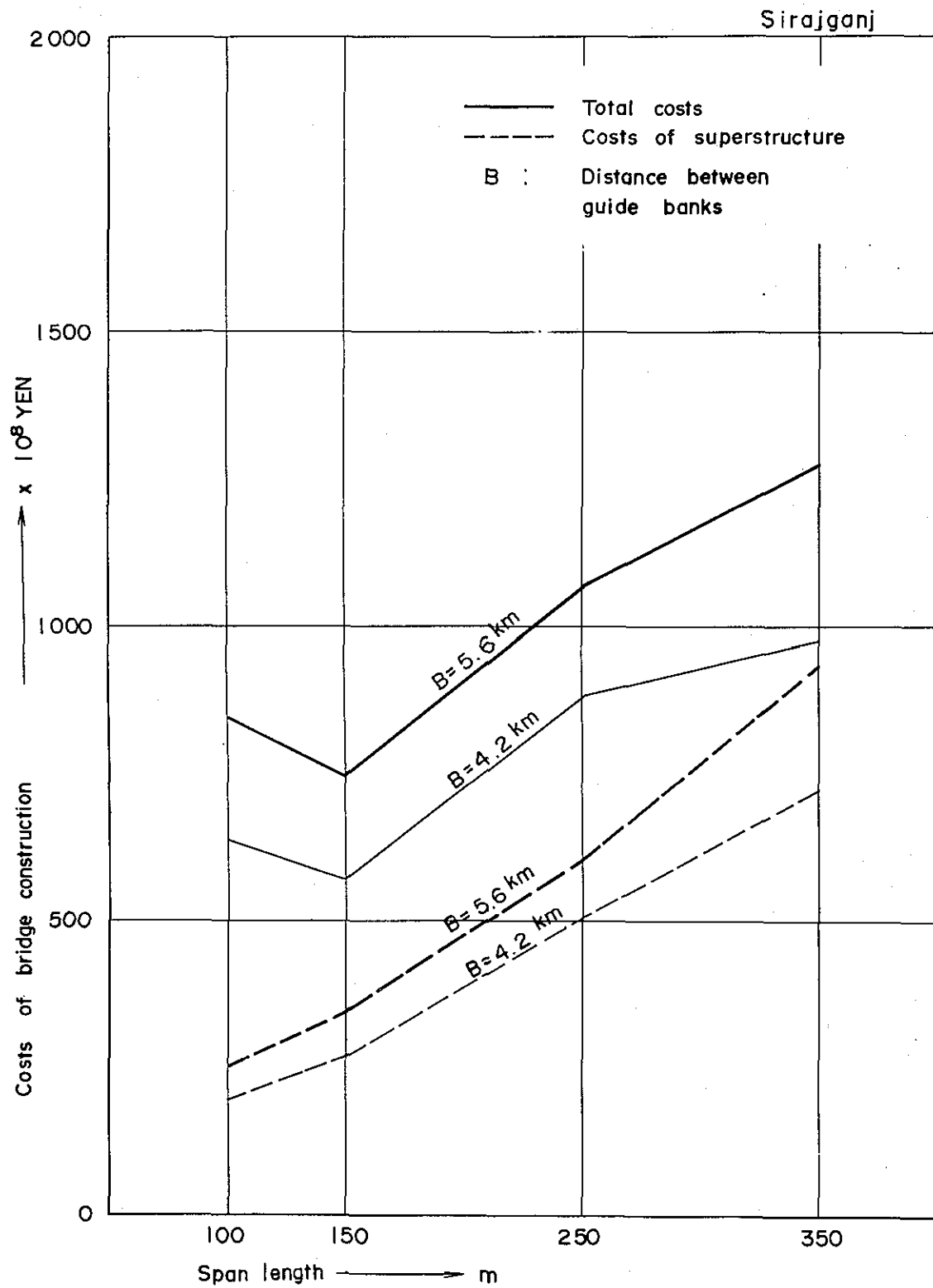


Fig. 3 - 22- 4 The Relation between Construction Costs and Span Length of Bridge in Case a.
(Well Foundation)

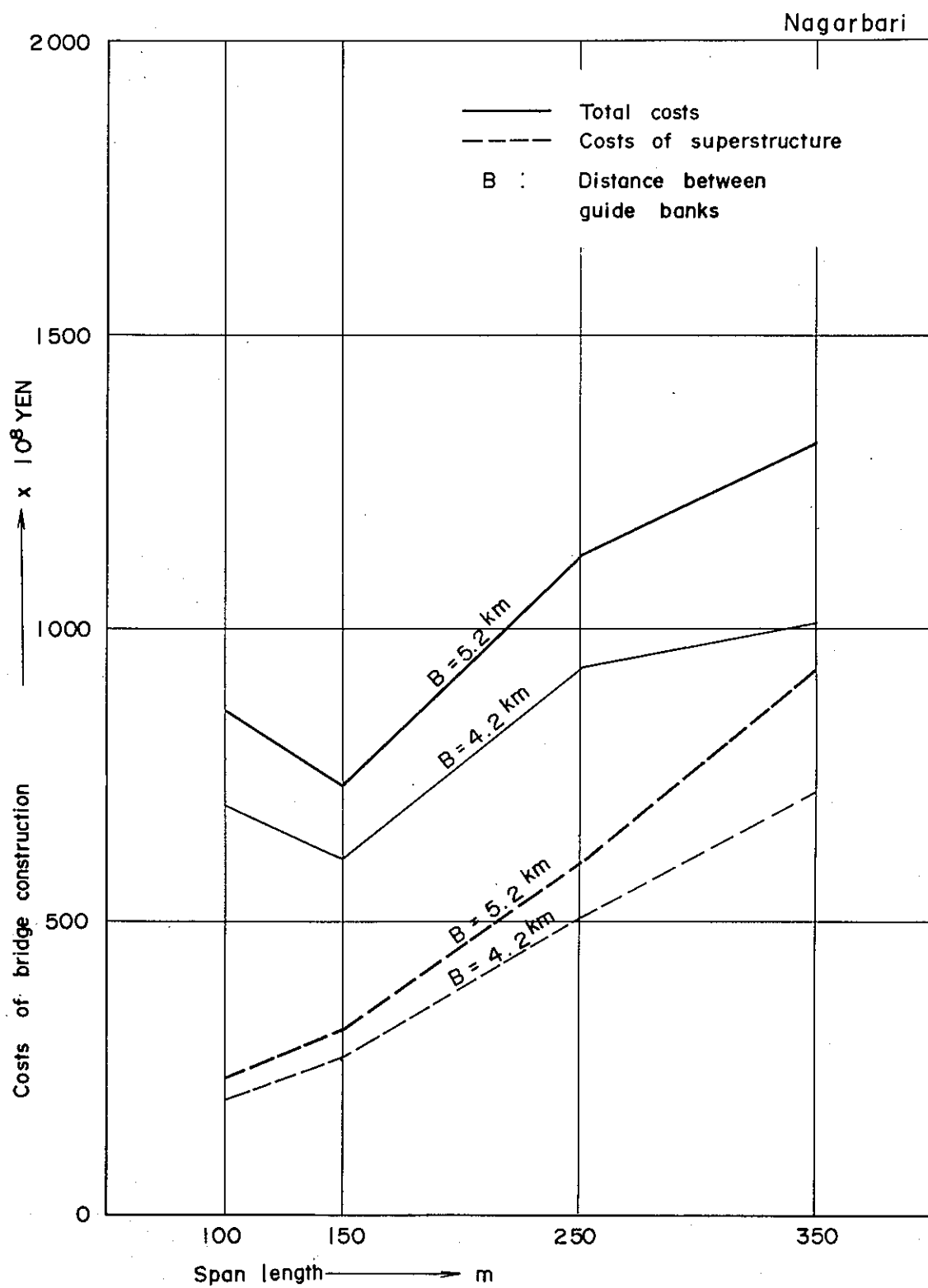


Fig. 3-23-1 The Relation between Construction Costs
and Span Length of Bridge in Case b
(Well Foundation)

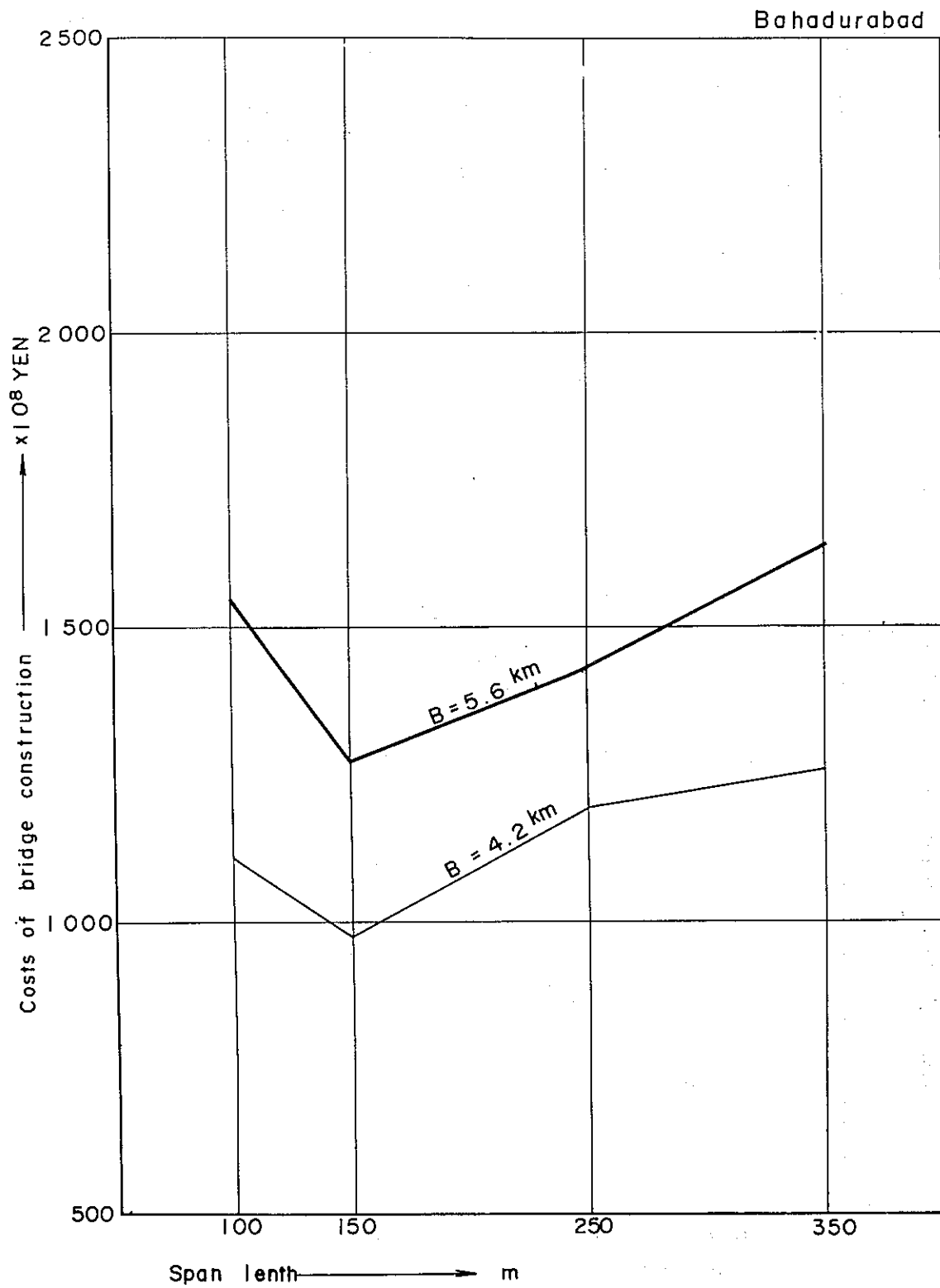


Fig. 3-23-2 The Relation between Construction Costs
and Span Length of Bridge in Case b
(Well Foundation)

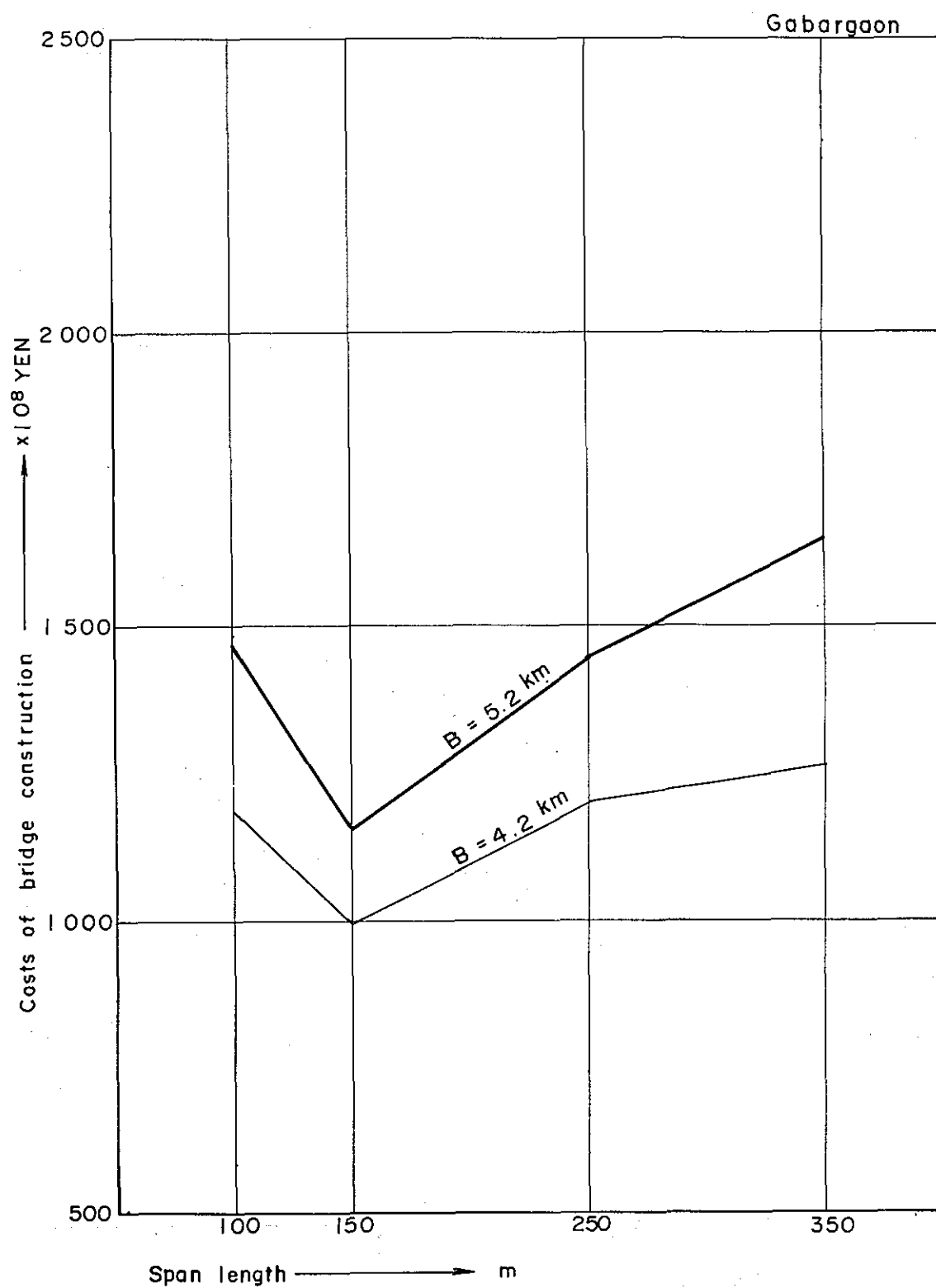


Fig. 3-23-3 The Relation between Construction Costs
and Span Length of Bridge In Case b
(Well Foundation)

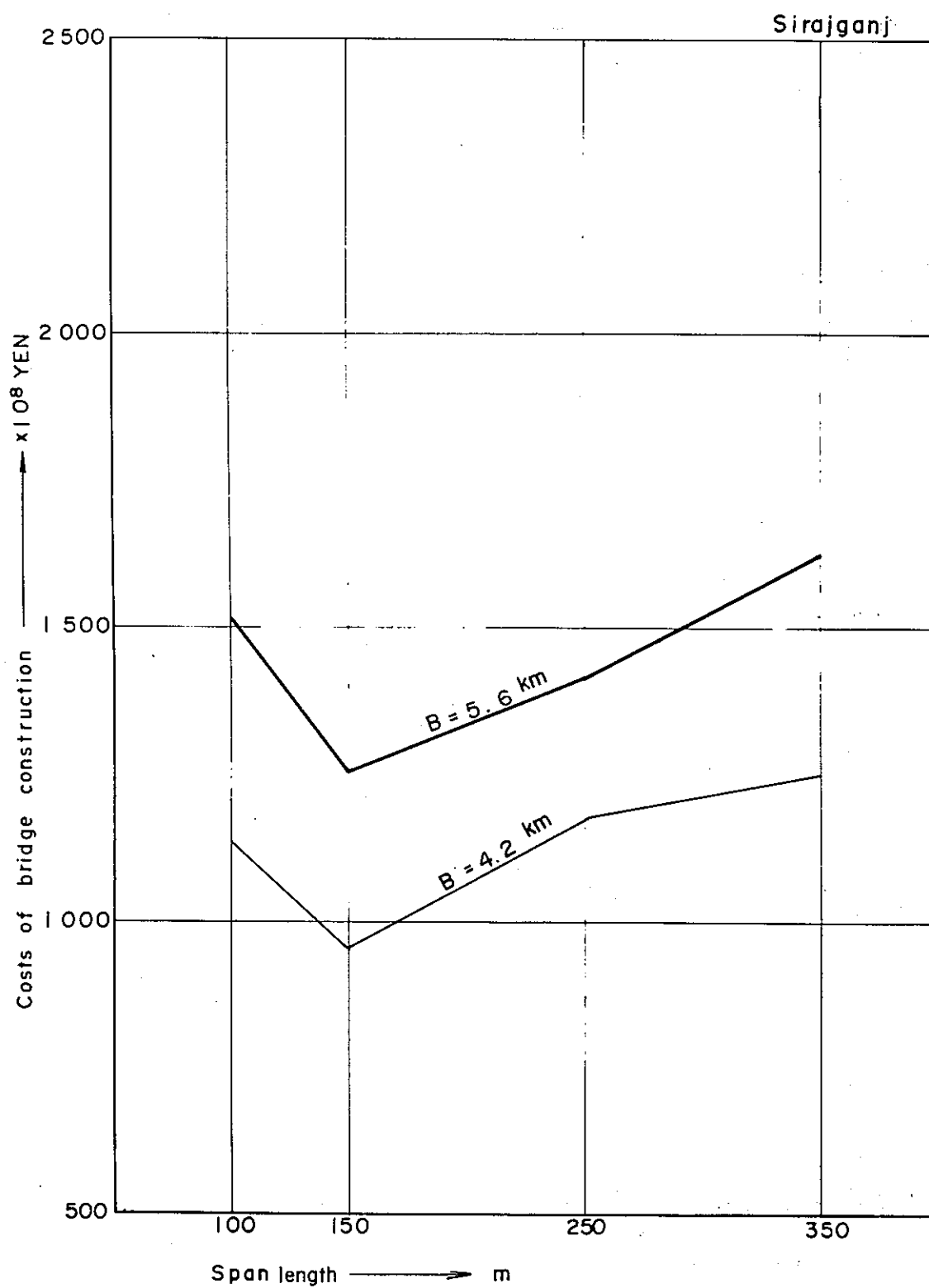


Fig. 3-23-4 The Relation between Construction Costs
and Span Length of Bridge in Case b
(Well Foundation)

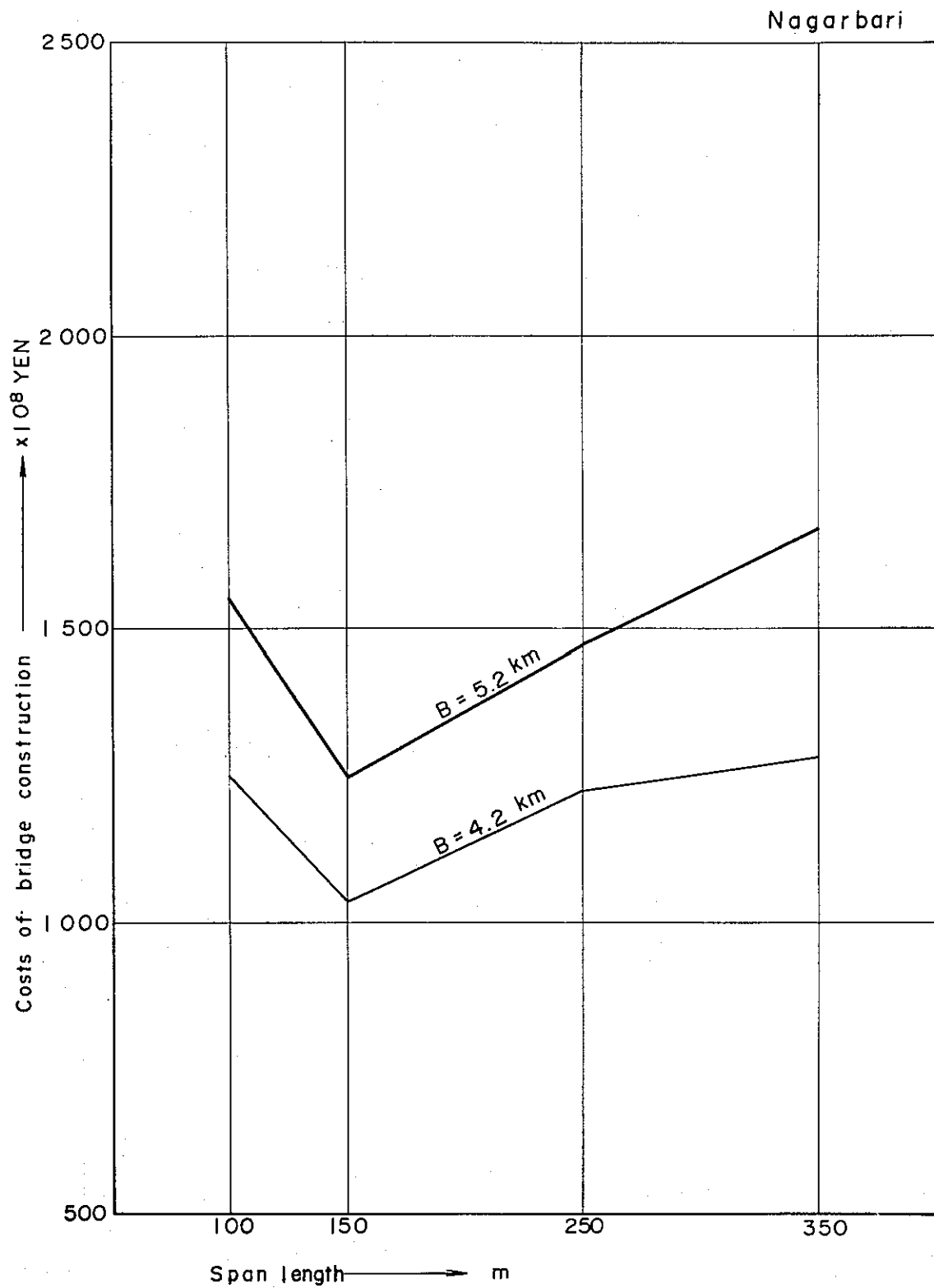


Table 3-22 Rough Estimate of Bridge Construction Costs

Unit : 100 million yen

Case	Proposed site	Distance btw. guide banks	Super- structure	Sub- structure	Bridge approach	Subtotal	Transportation costs	Total
a	Bahadurabad	4.2 km	269	314	139	722	83	805
		5.6 km	343	415	143	901	108	1,009
	Gabargaon	4.2 km	269	323	143	735	84	819
		5.2 km	319	392	147	858	101	959
	Sirajganj	4.2 km	269	305	147	721	81	802
		5.6 km	343	402	159	904	102	1,006
	Nagarbari	4.2 km	269	345	179	793	85	878
		5.2 km	319	419	183	921	103	1,024
b	Bahadurabad	4.2 km	366	612	278	1,256	163	1,419
		5.6 km	467	809	283	1,559	208	1,767
	Gabargaon	4.2 km	366	630	283	1,279	158	1,437
		5.2 km	434	722	287	1,443	230	1,673
	Sirajganj	4.2 km	366	594	293	1,253	167	1,420
		5.6 km	467	785	299	1,551	214	1,765
	Nagarbari	4.2 km	366	673	320	1,359	149	1,508
		5.2 km	434	817	325	1,576	211	1,787

Table 3-23 Priority Order of Proposed Sites with Regard to Bridge Construction Costs.

Site	Case Distance btw. guide banks	a		b	
		4.2 km	5.2 km or 5.6 km	4.2 km	5.2 km or 5.6 km
Bahadurabad		2	3	2	3
Gabargaon		3	1	3	1
Sirajganj		1	2	1	2
Nagarbari		4	4	4	4

8. Bridges in the Part of Access Links.

Bridges over 300ft in span included in the part of railway and highway links were shown in Table 2-1, Table 2-2 and as for the type of superstructure of these bridges, we adopted the prestressed concrete bridges. Composition of span was decided by the next two factors. These factors are navigation clearance of river to be crossed and minimization of total construction costs of bridge. In the latter factor, composition of span is affected by the well or pile foundation. As stated above, the well foundation was adopted for the place where local scours are anticipated and for this reason the pile foundation was adopted for other sites.

Types and composition of span of bridge included in railway links are shown in Table 3-24 and those in road links are in Table 3-25.

The rough estimate of construction costs for these types and composition of span of bridges are shown in Table 3-26 for railway links and Table 3-27 for road links, respectively.

9. Study of Bridge Construction Plan without Guide-bank System.

9.1. Bridge construction plan without guide-bank system.

It is concluded in the investigations made by the River Control Study Team that, in case of bridge construction on the Jamuna River, unless a bridge is spanned across the river in its total width, it is an imperative necessity to build the guide banks having cross dikes. By means of adopting this guide-bank system with cross dikes, the channel of flood flow is fixed between the both guide banks by dead water basins to be due to cross dikes and by the training function of the guide banks. Further, these cross dikes are utilized as the bridge approaches and should be designed as they are not broken by any displacement of thalweg and can resist for erosion of river banks due to flood flow.

However, in opposition to the plan to build a bridge by narrowing the river width by means of a guide-bank system having the above functions,

Table. 3-24 Miscellaneous Data for Bridges ($\geq 100\text{m}$) in the Part of Railway Links

Name of Site	Name of Bridge	Side of River Bank	Total Length of Bridge	Span Length (m)	Type of Superstructure	Type of Sub-Structure
1 BAHADURABAD	1 - A	Right	300	9 @ 33	P.C. Simple - G	R.C. Pile
	1 - B		200	6 @ 33	"	"
2 GABARGAON	2 - A	Right	100	3 @ 33	"	"
	2 - B		100	3 @ 33	"	"
	2 - C		150	5 @ 30	"	"
	2 - D		100	3 @ 33	"	"
	2 - E	Left	400	7 @ 57	P.C. 3-Cont. Box - G	Open Caisson
	2 - F		150	7 @ 21	P.C. Simple - G	R.C. Pile
	2 - G		150	7 @ 21	"	"
3 SIRAJGANJ	3 - A	Left	100	5 @ 20	"	"
	3 - B		200	10 @ 20	"	"
	3 - C		100	5 @ 20	"	"
	3 - D		200	6 @ 33	"	"
	3 - E		300	9 @ 33	"	"
	3 - F		300	9 @ 33	"	"
4 NAGARBARI	4 - A	Right	100	5 @ 20	"	"
	4 - B		200	10 @ 20	"	"
	4 - C		600	30 @ 20	"	"
	4 - D		300	5 @ 60	P.C. 3-Cont. Box - G	Open Caisson
	4 - E	Left	200	10 @ 20	P.C. Simple - G	R.C. Pile
	4 - F		150	20 @ 57.5	P.C. 3-Cont. Box - G	Open Caisson
	4 - G		100	5 @ 20	P.C. Simple - G	R.C. Pile
	4 - H		250	5 @ 50	P.C. 3-Cont. Box - G	Open Caisson
	4 - I		150	3 @ 50	"	"

(note) P.C. : Prestressed Concrete 3-Cont. : 3-Span Continuous
R.C. : Reinforced Concrete G : Girder

Table. 3-25 Miscellaneous Data for Bridges ($\geq 100\text{m}$) in the Part of Road Links

Name of Site	Name of Bridge	Side of River Bank	Total Length of Bridge	Span Length (m)	Type of Superstructure	Type of Sub-structure
1 BAHADURABAD	1 - 1	Right	300	9 @ 33	P.C. Simple - G	R.C. Pile
	1 - 2	"	200	6 @ 33	"	"
	1 - 3	Left	100	5 @ 20	R.C. Simple - G	"
2 GABARGAON	2 - 1	Right	100	3 @ 33	P.C. Simple - G	"
	2 - 2	"	300	9 @ 33	"	"
	2 - 3	Left	100	5 @ 20	R.C. Simple - G	"
	2 - 4	"	400	7 @ 57	P.C. 7-Cont. Box - G	Open Caisson
	2 - 5	"	100	5 @ 20	R.C. Simple - G	R.C. Pile
3 SIRAJGANJ	3 - 1	"	150	7 @ 21	R.C. Simple - G	R.C. Pile
4 NAGARBARI	4 - 1	Right	600	10 @ 60	P.C. 3-Cont. Box - G	Open Caisson
	4 - 2	"	300	15 @ 20	R.C. Simple - G	R.C. Pile
	4 - 3	Left	200	10 @ 20	"	"
	4 - 4	"	100	5 @ 20	"	"

(note) P.C. : Prestressed Concrete
R.C. : Reinforced Concrete
3-Cont. : 3 Span Continuous
G. : Girder

Table 3-26 Rough Estimated Costs of Bridge Constructions
in the Part of Railway Links

Proposed Site	Name of Bridge	Name of the River	Total Length of Bridge (m)	Cost (x Million yen)		Total	Unit Price (yen/m)
				Super Structure	Sub-Structure		
Bahadurabad	1-A	Bangali	300	240	150	390	1,320,000
	1-B	Bangali	200	160	110	270	
Gabargaon	2-A	Hurasagar	100	80	60	140	1,390,000
	2-B	Karatoya	100	80	60	140	
	2-C	Bangali	150	120	80	200	
	2-D	Bangali	100	80	60	140	
	2-E	Chatal	400	330	350	680	
	2-F		150	90	60	150	
	2-G		150	90	60	150	
Sirajganj	3-A	Lohatang	100	60	40	100	1,210,000
	3-B	Futjani	200	120	80	200	
	3-C	Bansi	100	60	40	100	
	3-D		200	160	110	270	
	3-E	Turag	300	240	150	390	
	3-F	Tungi	300	240	150	390	
Nagarbari	4-A	Chikunai	100	60	40	100	2,010,000
	4-B	Rukunai	200	120	80	200	
	4-C	Baral	600	350	230	580	
	4-D	Hurasagari	300	540	360	900	
	4-E	Old-Dhaleswari	200	120	80	200	
	4-F	Dhaleswari	1,150	2,100	1,400	3,500	
	4-G		100	60	40	100	
	4-H	Bansi	250	210	140	350	
	4-I	Turag	150	120	90	210	

Table 3-27 Rough Estimated Costs of Bridge Constructions
in the Part of Road Links

Proposed Site	Name of Bridge	Name of the River	Total Length of Bridge(m)	Cost (x Million yen)		Unit Price (yen/m)
				Super Structure	Sub-Structure	
Bahadurabad	1-1	Bangali	300	180	100	280
	1-2	Bangali	200	120	70	190
	1-3		100	53	52	110
Gabargaon	2-1	Karatoya	100	59	50	110
	2-2	Bangali	300	180	120	300
	2-3		100	53	52	110
	2-4	Chatal	400	450	450	900
	2-5		100	53	52	110
Sirajganj	3-1		150	89	56	150
Nagarbari	4-1	Hurasagar	600	680	650	1,330
	4-2		300	160	140	300
	4-3	Old-Dhaleswari	200	110	90	200
	4-4	Old-Dhaleswari	100	53	52	110
						1,000,000
						1,620,000

another plan to build a bridge over the whole width of a river will become an object of study. We call the latter plan "bridge construction plan without guide-bank system".

9.2. Decision of width for flood flow and bridge length.

From a geomorphological viewpoint, the Jamuna River can be divided into the upper reaches and the lower reaches. By the upper reaches are meant from the border between India and Bangladesh to Sirajganj and by the lower reaches from Sirajganj to the junction of the Ganges and the Jamuna. In the upper reaches, width of river is wide and composed of a network of smaller streams. The upper reaches of the river are characteristic of those in the alluvial fan but the features of the lower reaches are characteristic of those in a natural levee region.

Changes in banklines of the Jamuna can be observed by comparing data on banklines of the Jamuna collected by BIWTA for a period between 1830 to 1963 and aerophotographs taken by SOB during the dry seasons of 1952, 1953 and 1970/71 covering almost the whole stretch of the Jamuna River course. From these data it is evident that (1) the Jamuna is a typically braded river, (2) the river is almost stable at the proposed four sites compared with the other reaches, and (3) the width of main stream in the dry season is roughly 2 km.

In the Jamuna River, the brading produces cliffy banks almost on the whole of the river at least within the land of Bangladesh. The space between the both cliffy banks is regarded as an effective width for flood flow.

Notwithstanding the both banks form cliffs, such clayey banks as are seen at Sara on the Ganges River is not found on the Jamuna. In other words, it can be said that any portion of the bank has no resisting power to erosion. It means that any portion of the bank cannot be fixed without any artificial protection and this holds at nodes of brading as well as at loops.

Meanwhile, in every flood season, flood water habitually overflows over the both banks so that a low land located between the two Barinds is always inundated irrespective of river channel or land. This phenomenon not only facilitates spilling to tributaries but also produces incessant erosion at banks. In this sense, we can call this river a bankless river.

Since the Jamuna is characteristic as mentioned above, it is very difficult to decide the total length of a bridge by estimating the whole width of the river flow. However, based on the investigations made on the data so far obtained, the total bridge length on the four candidate sites was determined in consideration of the following items. (1) A long span bridge shall be constructed over a space between both cliffy banks which is regarded as an effective width for flood flow, (2) in view of conspicuously inundating places and natural levees, elevated bridges shall be erected, and (3) the bridge thus built shall have to be led to the existing ground level by approaches. We selected the appropriate location in the each candidate site as the bridge construction plan without guide-bank system, and decided the total bridge length as shown in Fig. 3-24.

9.3. Construction costs at the preliminary design.

The costs of the bridge construction without guide banks at each site were roughly estimated based on the construction costs of the preliminary design. These results are shown in Table 3-28-1 and the bridge construction costs with guide banks when the river was controlled are shown in Table 3-28-2. From comparison of the both cases, it is obvious that the former case is always found to be more expensive than the latter case. Therefore, the plan without guide banks is excepted from the scope of the Jamuna-River Bridge-Construction plan.

Table 3-28-1 Rough Estimate of Bridge Construction Costs
(without Guide Banks)

Unit : 100 million yen

Site	Substructure	Superstructure	Bridge-approach	Viaduct	Total(A)
Bahadurabad	900	972	50	132	2,054
Gabargaon	770	810	78	107	1,765
Sirajganj	657	729	85	81	1,552
Nagarbari	984	972	39	177	2,172

Note: Superstructure: 3-span continuous truss (3@150 m).
Substructure : Well foundation.

Table 3-28-2 Rough Estimate of Bridge Construction Costs
(with Guide Banks)

Unit : 100 million yen

Site	Bridge Construction	River Training	Total(B)	$\frac{A-B}{B} \times 100$ (%)
Bahadurabad	805	299	1,104	86
Gabargaon	819	346	1,165	52
Sirajganj	802	335	1,137	36
Nagarbari	878	409	1,285	69

Note: Superstructure: 3-span continuous truss (3@150 m).
Substructure : Well foundation.
Guide-bank span: 4.2 km.

9.4. Bridge-construction costs after determination of the most optimum span

The most optimum span was decided at 175.0 m in length by comparative design after determination of Sirajganj site as the most suitable site of bridge construction. The bridge-construction costs without guide banks

were estimated in the span length of 175 m in accordance with the cost estimating as same as the bridge-construction costs with guide banks at the Sirajganj site. The cost estimation in this case was limited at only the site of Sirajganj and the bridge length and the approach extension are shown in Fig. 3-25. The suitable site for the plan without guide banks was planned through the southern area of the big town of Sirajganj.

Table 3-29 shows the roughly estimated construction costs of the bridge without guide banks and the construction costs of the bridge with guide banks, as stated later, which control the river flow. In this table the construction costs of railway and road links were excluded but the railway links became longer and the road links shorter than the plan with guide banks in the plan without guide banks. As the results, only the increment and/or the decrement of the construction costs of railway and road links were summed up and maintenance costs were also estimated in this table.

From this comparison, it is clear that the bridge-construction plan without guide banks is not appropriate for the Jamuna River crossing as same as the result of the preliminary design. Therefore, the plan without guide banks cannot be an object of the Jamuna River crossing plan.

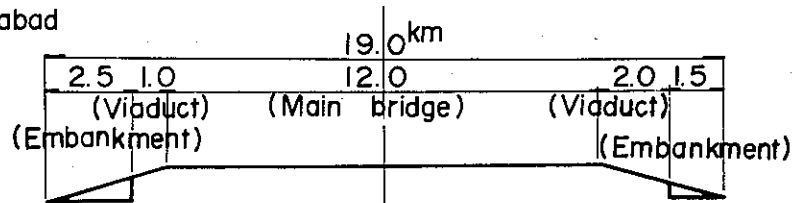
Table 3-29 Bridge Construction Costs of the Plan with-and-without Guide Banks

Description	Unit : 100 million yen	
	Without Guide Banks	With Guide Banks
Substructure	667	359
Superstructure	1,148	610
Bridge Approaches	64	79
Viaduct	70	---
Railway Links	28	---
Road Links	-12	---
Guide Banks	---	278
Dhaleswari New Channel	---	16
Subtotal	1,965	1,342
Maintenance Costs	132	154
Total	2,097	1,496

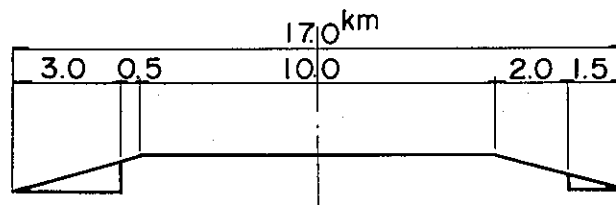
Note: Guide-bank span is 4,680 m in the plan with guide banks.
 Superstructure: 3-span continuous truss (3@175 m).
 Substructure : Well foundation, 13 m in diameter.

Fig. 3-24 Length of Bridge-crossing without Guide Bank at Each Site

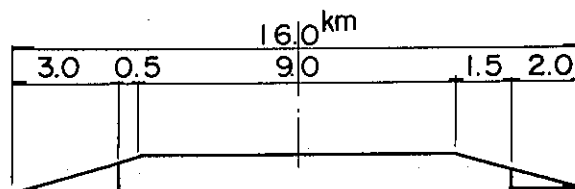
1 Bahadurabad



2 Gabarugaon



3 Sirajganj



4 Nagarbari

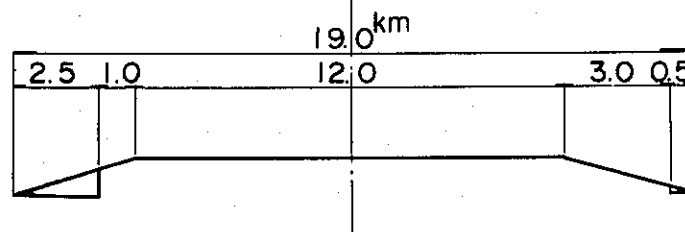
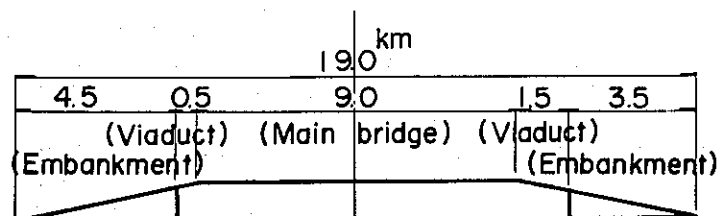


Fig. 3-25 Length of Bridge-crossing without Guide Bank at Sirajganj Site



CHAPTER IV

SELECTION OF THE MOST SUITABLE SITE FOR BRIDGE CROSSING

In the Inception Report, it is mentioned that selection of the most suitable site for bridge crossing must be based on the following factors; (a) stability of river channel, (b) construction costs and (c) traffic volume.

The selecting procedures for the most suitable bridge site based on the above mentioned criteria considering the result of the other study team, are as follows.

As mentioned above, all the four sites which have been proposed as bridge crossing points are certainly located at nodes of braiding flow, which suggests that any of them is favorable for spanning a bridge across the river.

From a topographical point of view, Sirajganj narrow is most stable among the four, the Gabargaon site comes closely next, Bahadurabad site compares unfavorably with the former two and Nagarbari falls behind any of the others.

From a river-morphological point of view, Nagarbari site is the worst one while the other three sites are almost equal judging from the fact that the variation of the displacement of banklines is almost constant since nearly 1860, but Gabargaon site is best and Bahadurabad and Sirajganj sites are almost equal from the aspect of the size of width between the banks.

Therefore from both the topographical and river-morphological points of view, there is nothing to choose between the two sites, Sirajganj and Gabargaon.

At Sirajganj, bridge axis was chosen a little downstream of the Sirajganj narrow. This site lies under the protection of the narrow as well as the Sirajganj bank protection works and has only one main stream with chars on both sides. This means that the site is very favorable for spanning a bridge. However, this site have two branch channels to the Dhaleswari River, one of which must be crossed by a causeway. Fortunately, the proposed bridge axis lies between entrances of the two branch channels. Therefore, it is the best way to close the upper inlet channel and improve the lower inlet channel as the main to the Dhaleswari River.

The overall costs consisting of those of the river control works and the bridge building works were compared on the three type of A, B and C in the Interim Report on this study. From these study, total construction costs are most economical in the case of the guide-bank span of 4.2 km.

As to the traffic volume, person trips and movements of goods were forecasted and estimated along the routes of four proposed sites of bridge construction respectively. In the Interim Report on this study, it was decided to take the Sirajganj site as the most suitable one for bridge crossing from the view point of the above-mentioned criteria. Besides this, from the future estimation it was judged that the width of bridge should have the capacity to held the single track of railway and two-lane carriageway of highway.

CHAPTER V

BRIDGE PLAN OF SIRAJGANJ SITE

1. Determination of the Most Suitable Span Length.

1.1. Outline of preliminary design.

Two alternative cases were studied during the preliminary design stage, namely, (1) single broad gage track of railway and two-lane carriageway of road (case a), and (case a), and (2) double broad gage tracks of railway and four-lane carriageway of road (case b), in the next four kinds of span lengths. Then we proposed the single-deck type of bridge in case a and recommended the double-deck type in case b.

- (a) Span length of 100m 3-span continuous truss bridge with reinforced concrete slabs
- (b) Span length of 150m " " "
- (c) Span length of 250m cantilever truss bridge with steel deck plates
- (d) Span length of 350m " " "

For the substructure and foundations, multi-pile-foundation of 2m and/or 3m in outer diameter of steel piles were employed in several cases, and well foundation of circular shape of 12m-diameter and oblong shape of 12m in short diameter by 22m in long diameter were investigated.

The proposed four sites investigated and studied, were Bahadurabad, Gabargaon, Sirajganj and Nagarbari. The guide-bank spans included in the studies for each proposed site are B = 2.0km, 4.2km and 5.2km or 5.6km.

From the above studies and investigations, the following results were obtained. Furthermore, other research data made by other teams connecting with the bridge study were appended.

(a) As a results of comparative studies, a 150m long three-span continuous truss-bridge structure on well foundation was determined as the most economical.

(b) Needless to say, construction costs of case b as compared with case a are high cost by far.

Furthermore, from a viewpoint of a future traffic, the composition of bridge 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 volume will be 8,666 vehicles per day (vpd) in passenger car equivalent (P.C.E.) as was estimated in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS. For this traffic, if we take a two-lane carriageway of total width 24', design traffic capacity of the road on bridge was estimated at 12,900 vpd in P.C.E. as was mentioned in APPENDIX-6 of this VOLUME. Therefore, the two-lane carriageway is sufficient for the future traffic volume on road.

Also in VOLUME VII TRAFFIC AND ECONOMIC BENEFITS, railway traffic in the year of 2020 was estimated at 38 passenger trains and 21 freight trains in total assuming broad-gage track of 5'6". If we assume the distance between 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. Therefore, the single broad-gage track is sufficient for the future railway traffic.

Accordingly, we adopted the case-a as the width composition of the bridge.

(c) It has been determined that the most economical guide-bank span is 4.2km considering the economics of each guide-bank span from the costs of bridge construction works and guide-bank works.

1.2. Terms of agreement.

The following conditions concerning the bridge study were agreed upon between the Bangladesh side and the Jamuna River Bridge Construction Project Team, on the contents of the Interim Report.

(a) Traffic capacity of the bridge

Railway track shall be a single broad-gage track of 5'6" and width of road shall be a two-lane carriageway of 24' and the traffic capacity of the bridge should be determined to meet the future traffic to take a target year of 2020.

(b) Effective width of bridge

A single broad-gage track (5'6") for railway and the two-lane carriageway (24") for road are required. Parking space for emergency purposes will be determined in the detailed design.

(c) Selection of the most suitable site for bridge construction

Sirajganj site was selected seen from the technical, engineering, traffic and economical points of view.

1.3. Preliminary design of the bridge with a span length of 200m.

1.3.1. General.

As mentioned above, four kinds of span lengths (100 m, 150 m, 250 m, 350 m) were taken into consideration in order to determine the most suitable span length. But the internal of span length to be adopted is not sufficient to determine the most suitable span length satisfactorily. Therefore span length of 200 m was added to raise up the accuracy of determination of the most suitable span length. Following were performed for the span length of 200 m.

Studies of types made about span length of 200 m are as follows:

(a) Three-equal-span continuous truss (with reinforced slabs)

- (b) Three-equal-span continuous truss (with steel deck plate)
- (c) Multi-equal-span cantilever truss (with steel deck plate)
- (d) Well foundation for the above (a ~ c) superstructures.

As these were studied, the span length of 175m was also studied for comparative designs to determine the most economical and suitable span by rough estimate of costs.

1.3.2. Rough estimate of costs.

Table 5-1 indicates the additional studies of guide-bank span to facilitate the completion of Table 3-22 for guide-bank spans of 4.2km and 5.6km. In this table, the costs of span length of 175m for the guide-bank span 4.2km are added. From this table, Fig. 5-1 was plotted with span length and construction costs. Construction costs for the bridge approaches are excluded in this graph.

It was found from comparative designs that superstructure in a 200m-multi-span cantilever-type in guide-bank span of 4.2km is higher in cost than the other two alternatives (a) and (b) of 1.3.1. However, since the seismic forces are distributed, the substructures were determined to be low costs, and total construction costs were found to be lower than the other bridges with same span length but are higher in cost by about 7,200 mil. yen than the bridge of span length of 150 m. The results of investigation show that the foundation well for three-span continuous truss of span length of 200 m at the fixed end pier is oblong in shape. And for cantilever truss, the circular shape dimension is sufficient in all piers. By interpolating the span length of 200 m, stricter accuracy was obtained in determining the most suitable span.

As the span length between the span lengths of 150m and 200m, a bridge of span length of 175m was studied considering pannel-interval length of 12.5m, and for its pier foundation on the fixed end was sufficient a circular shape well. Then 175m-span bridge was determined to be comparatively low-cost. Results of comparative analysis show that construction costs for spans of 150m and 175m are almost the same.

1.4. Determination of the most suitable span.

Based on results of comparative analysis, it was determined that the most economical span as compared with other alternative is either 150m or 175m. Selection of spans to be employed, will depend on the optimum construction method.

(a) Well foundation requires a comparatively difficult construction method. Therefore if the number of foundation wells is reduced, it eliminates the construction difficulty and dangers or chances of accidents. For span length of 175m, well foundations are reduced by four when compared with span length of 150 m in case the guide-bank span is 4.2 km.

(b) Reduction of four wells reduces the obstruction of the flow of water, and hence, the effective width of the river channel can be reduced about 60 m.

Table 5-1 Rough Estimate of Bridge Construction Costs

Unit : 100 million yen

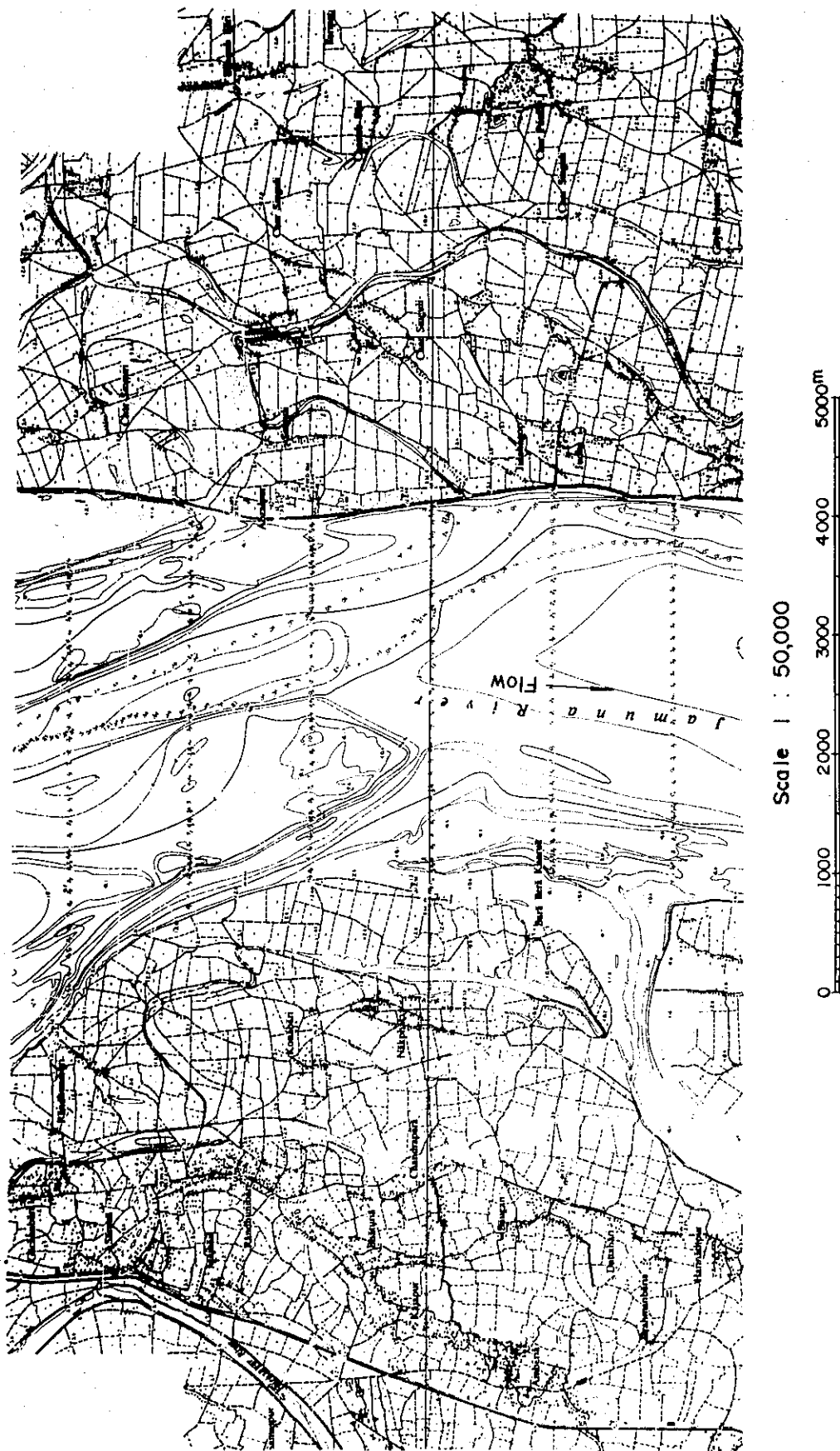
Distance between guide banks (km)	Span (m)	Super- structure	Sub- structure	Bridge approach	Sub total	Transporta- tion costs	Total	Remarks
5.6	100	252	598	159	1,009	83	1,092	Continuous truss Br. (R.C. slab)
	150	343	402	159	904	102	1,006	
	200	461	412	159	1,032	138	1,170	Continuous truss Br. (S.D. plate)
	200	471	412	159	1,042	144	1,186	
	200	483	320	159	962	146	1,108	Cantilever truss Br. (S.D. plate)
	250	604	463	159	1,226	179	1,405	
	350	939	337	159	1,435	268	1,703	
4.2	100	194	446	147	787	63	850	Continuous truss Br. (R.C. slab)
	150	269	305	147	721	81	802	
	200	350	304	147	801	103	904	Continuous truss Br. (S.D. plate)
	200	358	304	147	809	107	916	
	200	374	243	147	764	110	874	Cantilever truss Br. (S.D. plate)
	250	506	379	147	1,032	147	1,179	
	350	726	253	147	1,126	204	1,330	
4.2 ^{km}	175	302	264	147	713	91	804	Continuous truss Br. (R.C. slab)

Note: R.C. slab : Reinforced concrete slab.

S.D. plate: Steel deck plate.

Br. : Bridge.

Fig.5-2 Topographical Map of Bridge Site
and Bridge Axis
(Sirajganj Site)



(c) To avoid scouring along toe of slope of the guide bank, it is better to employ a larger distance between the guide-bank slope and the pier nearest to the guide bank. Even in unavoidable circumstances, the nearest distance of the pier to toe of the guide-bank slope must be greater than two times the diameter of the well. For span length of 175m, the distance of the toe of guide bank to the nearest pier is much greater than span length of 150m.

The flow of current is not always in parallel with the guide banks. When well foundation is oblong in shape and flow of current is oblique, local scouring may occur on the foundation resulting in the unstability of the structure as a whole. To avoid such occurrences, it would be desirable to employ a circular shape dimension well foundations and it was determined that a circular shaped well of 12m in diameter can be employed for maximum span length of 175m.

Based on the above results of comparative analysis, the optimum span length was decided to 175m.

2. Design Conditions and Criteria.

2.1. Topographical plan at the proposed site for bridge construction.

As mentioned above, the bridge axis was decided and the topographical survey was newly executed. Fig. 5-2 shows the topographical plan.

2.2. Geological conditions.

2.2.1. Contents of geological survey.

For a reason that the strata can be assumed from the research data of the preliminary design process and the domain of the bridge construction was considerably restricted, researches at the domain of bridge construction put the main point on confirmation of bearing layer and its bearing characteristics, technical certification of deformation modulus and researches on the continuity of each layer.

At the investigation of a base and subbase course of the bridge approaches, the Swedish method sounding test was executed and disturbed soil was sampled by hand auger and pit excavation at necessary points and indoor CBR test was examined. From these test results, soil characteristics for design were deduced. As banking materials, design data were deduced on the promise that the existing soil shall be used. Investigated positions at the domain of bridge construction and summaries of researches were shown in Fig. 5-3.

2.2.2. Geological outline.

Based on Fig. 5-3, the upper part over A₁ layer is alluvium and the lower part is diluvium. Geological texture is composed of the silty fine sand at the most upper part and grain size gradually becomes large increasing its depth and the soil density also grows large gradually. At the lowest part of alluvium, continuous and excellent gravel zones containing huge man-head size cobbles are lying and this surface is nearly on the same

level to EL-70m. On the other hand, the dilivium is composed of gravel layer, sand layer with gravel, hardened clay layer of a very high density and occasionally presenting a soft bed-rock. The so-called basal gravel layer lies in the lowest part of alluvium.

It is reported that during the process of boring, the layer was found to have consisted of 10~20% cobble over 60mm in diameter with a good grain distribution. From the observation mode, the strata would be satisfactory as the bearing layer of foundation for piers since it has a good grain distribution.

In the bridge-approach area, silt and fine sand were found to be predominant to a depth of 3m or 5m. Below this elevation, sandy soil was excellently found. The foundation of the embankment of bridge approaches was found to be consisting mostly of silty soil which have a poor soil mechanical strength. However, since the silty layer is comparatively thin and the sand layer is rather thick, we believe no trouble will arise on the foundation during settlement due to consolidation.

2.2.3. Design soil factors.

Volume VI of the report prepared by the Soil Survey Team shows the important design soil mechanical values that is, N , C , ϕ , γ_s , γ_t and E values. The investigations conducted are listed in Table 5-2.

Table 5-3 listed the compilation of the design soil factors from the report proposed by the Soil Survey Team for the foundation of embankment.

Table 5-4 showed the design soil factors for embankment materials by compaction test and CBR test results.

2.3. River conditions.

Fig. 5-4 showed the results of the investigations on many design conditions of rivers performed by the River Control Study Team which designed based on the investigations conducted on the flood data of 1974, in addition to the standard cross section of the guide bank. In this figure, the design high water level is +15.25m PWD, mean lowest low water level +6.22m PWD and lowest river-bed height -24.5m PWD, respectively.

As mentioned previously, the scouring depth around the well when its width in a normal direction to the stream is approx. 12 m, is assumed as 1.8 times of the water depth of river under a water surface. Hence, the height of river bed after local scouring shall become $15.25 - (15.25 + 24.50) \times 1.8 = -56.30$ m PWD. And more, the guide-bank span in this stage of the study is 4,680 m.

Table 5-2 Design Soil Factor for Pier Foundation

Strata	Typical N-Value	Estimated soil mechanical indices				Deformation modulus E-Value (kg/cm ²)	
		C	ϕ	γ_s	γ_t		
Au2	Silty part	8	0.1	13	2.70	1.8	77
	Sand	10	0	32	2.70	1.9	77
	Au1	30	0	34	2.70	2.06	89
	Aml	38	0	36	2.70	2.17	111
	AL3	78	0	>40	2.70	2.21	114
	AL2	78	0	>40	2.70	2.21	114
	AL1	>80	0	>40	2.70	2.26	230
	Du3	>80	0	>40	2.70	2.26	-

Notes: C : Cohesion (kg/cm²). ϕ : Internal friction (degree). γ_s : Specific gravity of soil (g/cm³). γ_t : Unit weight (g/cm³).

Table 5-3 Design Soil Factor for Foundation

Strata	Material	Typical N-Value	γ_t	w	γ_d	C	ϕ
1	Sand contained silty soil	<6	1.8	32	1.36	0.1	13
2	Silty sand to sand	6~10	1.9	20	1.58	0	28
3	Sand	10~20	1.9	20	1.58	0	32

Note: W : Water contents.

Table 5-4 Bank Material for Embankment

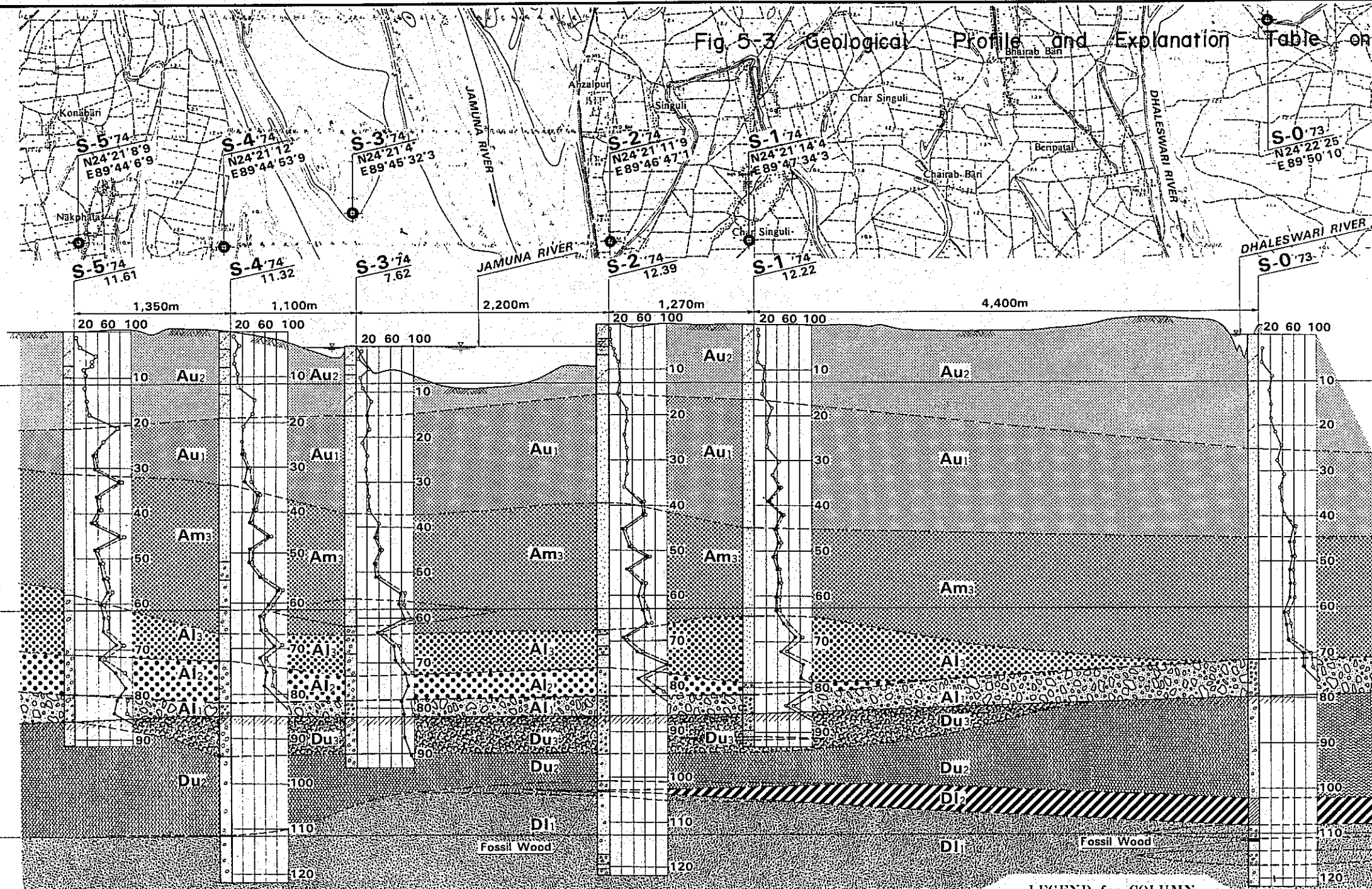
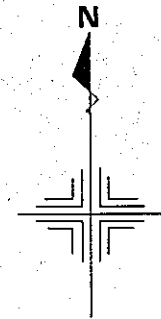
Strata	Material		γ_d	w	γ_t	C	ϕ	Design C.B.R
1	Sand contained silty soil	*A	1.7	22	2	0.2	20	6
		*B	1.6	26	2	0.15	17.5	5
2	Silty sand to sand	A	1.75	20	2.1	0	30	8
		B	1.65	22	2	0	27	7

*A 95% Modified on D-ratio of AASHO compaction.

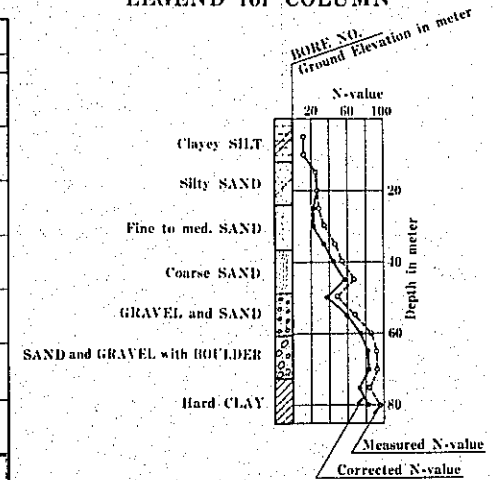
*B 90% Modified on D-ratio of AASHO compaction.

Fig 5-3 Geological Profile and Explanation Table on Bridge Site

ELEVATION IN METER

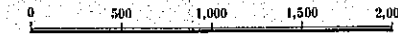


LEGEND for COLUMN



GEOLOGICAL AGE	STRAIT- -GRAPHY		STRATA	DESCRIPTION			TYPICAL GRAIN SIZE DISTRIBUTION						UNIFIED SOIL CLASSIFICATION	CORRECTED N-VALUE		DEFORMATION MODULUS (E-VALUE) (kg cm ²)			ESTIMATED SOIL MECHANICAL VALUE					
				CHARACTER	COLOR	FACIES	AVERAGE OF			D ₁₀ (mm)	D ₆₀ (mm)	C _u		by UTO'S FORMULA	by INSITU DATA	E ₁	E ₂	E ₃	C	φ	γ _t			
						20	40	60	80				%											
HOLOCENE	YOUNG ALLUVIAL DEPOSITS	UPPER	Au2	SILT and Fine SAND	GRAY	Fluvial to deltaic	M		SI			0.035	0.15	4.3	S M	8	10	56	28	77	0 ~ 0.1	13 ~ 32	1.8 ~ 1.9	
			Au1	Fine to Med. SAND	-do-	-do-							0.06	0.3	5	S M	30	36	210	101	89	0	34	2.06
			Am3	Fine to Med. SAND	-do-	Terrace to Fluvial							0.045	0.3	6.7	S M	38	40	266	112	111	0	36	2.17
	OLD ALLUVIAL DEPOSITS	LOWER	Al3	GRAVEL and coarse SAND	-do-	Basal of Alluvium			SI			0.065	0.55	8.5	S-Mg	78	60	546	168	114	0	40 <	2.21	
			Al2	GRAVEL and coarse SAND	-do-	-do-							0.05	0.7	14	S-Mg	78	60	546	168	114	0	40 <	2.21
			Al1	SAND and GRAVEL with BOULDERS	-do-	-do-							0.2	3.6	18	G-M	80 <				230	0	40 <	2.26
PLEISTOCENE	YOUNG DILUVIAL DEPOSITS	UPPER	Du3	Coarse SAND with small gravels	-do-	Upper of Diluvium						0.043	0.75	17.4	S Mg						0	40 <	2.26	
			Du2	Coarse SAND scattered small gravels	-do-	-do-							0.04	0.35	8.8	S Mg								
	OLD DILUVIAL DEPOSITS	LOWER	DI2	Hard CLAY	greenish GRAY	Lower of Diluvium	M		SI			0.009	0.07	7.8	M H									
			DI1	Gravel and SAND, dense	GRAY	-do-			SI		SC			0.028	0.35	12.5	S M							

SCALE for distance in meter



- 93 ~ 94 -

JAPAN INTERNATIONAL COOPERATION AGENCY	
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
GEOLOGICAL PROFILE AND EXPLANATION	
TABLE ON BRIDGE SITE	
DRAWN	DATE 14-NOV-75
APPROVED	DATE 15-NOV-75
NIPPON KOEI CO. LTD	

Table 5-2 Design Soil Factor for Pier Foundation

Strata	Typical N-Value	Estimated soil mechanical indices				Deformation modulus E-Value (kg/cm ²)	
		C	ϕ	γs	γt		
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	Au1	30	0	34	2.70	2.06	89
	Aml	38	0	36	2.70	2.17	111
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	AL1	>80	0	>40	2.70	2.26	230
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Notes: C : Cohesion (kg/cm²).
 ϕ : Internal friction (degree).
 γ_s : Specific gravity of soil (g/cm³).
 γ_t : Unit weight (g/cm³).

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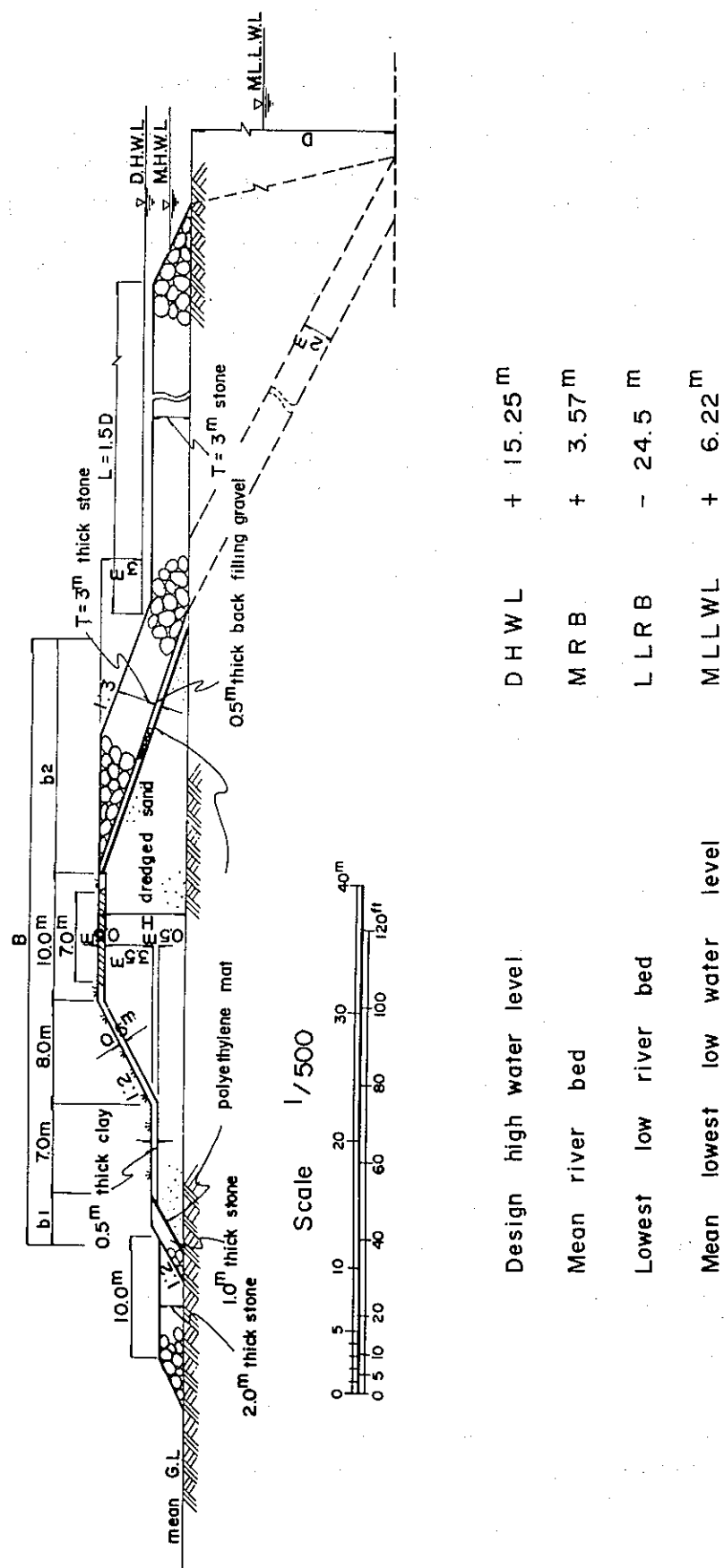
Note: W : Water contents.

Table 5-4 Bank Material for Embankment

Strata	Material		γ_d	w	γ_t	C	ϕ	Design C.B.R
1	Sand contained silty soil	*A	1.7	22	2	0.2	20	6
		*B	1.6	26	2	0.15	17.5	5
2	Silty sand to sand	A	1.75	20	2.1	0	30	8
		B	1.65	22	2	0	27	7

*A 95% Modified on D-ratio of AASHO compaction.
*B 90% Modified on D-ratio of AASHO compaction.

Fig.5-4 Standard Cross Section of Guide Banks



2.4. Bridge conditions.

Bridge conditions in this section mean some principal values necessary to bridge plannings as same as above-mentioned geological and river conditions. The bridge consists of two portions, bridge approaches and bridge structure. Based on the researches up to the present, the following values were obtained.

(a) Bridge structure

As the type of the Jamuna Bridge, Superstructure has been decided, as previously stated, to adopt a railway-cum-roadway bridge of a 3-span steel continuous Warren truss of span length 175m and substructure has been decided, as will be mentioned later, the circular well foundation of 13m in outside diameter. In due consideration of the navigation clearance and structural dimension of the superstructure, the formation level of the railway was fixed at EL = +30.0m PWD. Moreover, since the navigation clearance between guide banks is required to be secured, the longitudinal slope of the bridge was made horizontal.

(b) Approach portions

With the regard given to powers of locomotives, a longitudinal slope of 1/300 was taken in the maximum grade of railway in the approach portions. Stations must be installed at intervals of 6km considering future railway traffic and efficiency. In view of the bridge length, block stations are to be constructed at an interval of 6km on both side of the bridge as a waiting stations for in-coming trains. Therefore, the maximum grade of 1/400 was adopted in the block stations.

Because of the maximum grade for the road is 3%, the road embankment was descended faster than the railway.

As the Hurasagar River is on railway and road links near the bridge approach at the right bank side of the Jamuna River, the links cross by bridges. And at left bank of the Jamuna, the Dhaleswari River is in the bridge approach and this river was coffered by a causeway and the embankment was constructed on the top of the causeway. Furthermore, the single track railway was located downstream and the 2-lane road was located upstream of the river. In the arrangement of the railway and the roadway, from connecting plan with each link and the purpose of protecting the railway against floods, the railway was set on the downstream side and the roadway on the upstream side.

2.5. Alignment.

As to the horizontal alignment of the railway and the roadway, the railway was laid in a straight line along the bridge axis but the roadway on the right side of the Jamuna goes in parallel to the railway from the bridge to the existing embankment. After passing this embankment, the roadway turns considerably to the upstream. As the roadway at left side of the Jamuna crosses the Dhaleswari River which was planned to close by cross dam, the roadway goes straight along the bridge axis as well as the railway.

As for the longitudinal alignment, the railway on the right bank side, via the longitudinal slope of 1/400 of the block station from the railway formation level EL = +30.0m of the bridge, goes down the approaches as 1/300 and is fitted on the formation level EL = 15.9m of the bridge which crosses the Hurasagar River. The longitudinal slope of the railway on the left bank side is as same as the right bank side, but as the Dhaleswari River as previously stated is not required to be crossed by a bridge, it is kept the free board of one meter above the inland floods water level. As to the roads, the right bank is on a longitudinal slope of 3% from the proposed height EL = 30.58m of road of the bridge and is fitted to EL = +17.1m height of the existing embankment, and goes directly to existing embankment with a proposed height of EL = 17.1m. And then leaving the approaches, it is connected to the road link. As there is no embankment at the left bank side such embankment as at the right bank side of the Jamuna, it is fitted at a slope of 3% gradient to the proposed height keeping the free board of one meter above the inland floods water level.

When the relations of above alignment are graphically indicated, they become as shown in Fig. 5-5. Areas located 7,500m each of the left and right bank side from the center of the bridge are the boundaries of the bridge section and railway links. Hence, the longitudinal extension of the bridge becomes 15,000m long.

2.6. Determination of bridge-span arrangement.

2.6.1. Factors for bridge-span arrangement.

To determine the span length based on the previous investigation is most important in the determination of the future study. That is to say, the river width is most closely related to the determination of the span arrangement.

Important factors deciding the arrangement of bridge spans are shown as follows.

(a) Design discharge with respect to the width of the river.

Results of investigations made by the River Control Study Team show that the proposed width of the river $B = 4.2\text{km}$ and the design discharge $Q = 96,850\text{m}^3/\text{sec}$ (3,420,000 cfs) are necessary at the design high water level.

(b) Bridge span $\ell = 175\text{m}$

(c) Width of pier $D = 13\text{m}$

(d) Relations between guide bank and location of pier

In view of the protection of bank slope and preventing scouring, a minimum distance between the pier and the toe of guide-bank slope is generally considered to be $L_1 > 2D$. However, since several uncertain factors affecting the stability of the river are not yet solved, the minimum distance of the nearest pier to the toe of guide-bank slope was taken as $L_1 > 3d$. For this reason, $L = 140 \sim 145\text{m}$ is required (See Fig. 5-6 for notations).

2.6.2. Determination of span arrangement.

In due consideration of the above studies, arrangement of spans was adopted with the following results.

Total bridge length: $L = 4,745\text{m}$ (distance between both end shoes)

Span arrangement: 27 @175m (9 sets of 3-span continuous truss)

Guide-bank span: $B = 4,680\text{m}$

Effective width of flow $B_0 = 4,680 - 26 \times 13 \times 1.25$
 $= 4,680 - 422.5 = 4,257.5\text{m} > 4,200\text{m}$

As a result, the minimum distance from piers to the toe of bank slope can be illustrated as shown in Fig. 5-7. The stability of the guide bank for this case can be ascertained. Fig. 5-8 shows the composition of spans of the Jamuna bridge.

2.7. Geometric and structural design conditions.

2.7.1. Railway gage.

a. Track gage

Single broad gage track 5'6" as shown in (3), 1.4.1., CHAPTER II.

b. Construction gage

Construction gage is based on the Schedule of Dimensions 5'6", Bangladesh Railway, in consideration of future electrification of railway system (See Fig. 5-9).

2.7.2. Highway width.

Two-lane carriageway of total width 24ft and the composition of width is based on those shown in Fig. 5-10.

2.7.3. Structural width of bridge.

Structural width of bridge is based on those shown in Fig. 5-10.

2.7.4. Alignment.

Horizontal alignment and vertical slope are based on those shown Fig. 5-11.

2.7.5. Navigation clearance.

As shown in 1., CHAPTER II,

Minimum horizontal distance: 250ft,

Minimum vertical distance: 40ft.

2.7.6. Railway load.

Railway loads are based on those stated in (a), 1, CHAPTER II (Fig. 2-1).

Fig. 5-6 Descriptive Sketch of the Relation
between Guide Banks and Pier

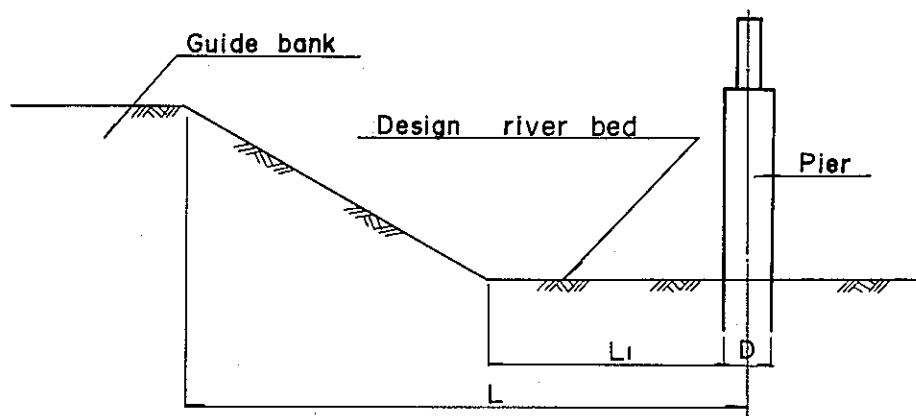


Fig 5-7 Relative Position of Guide Bank and Pier

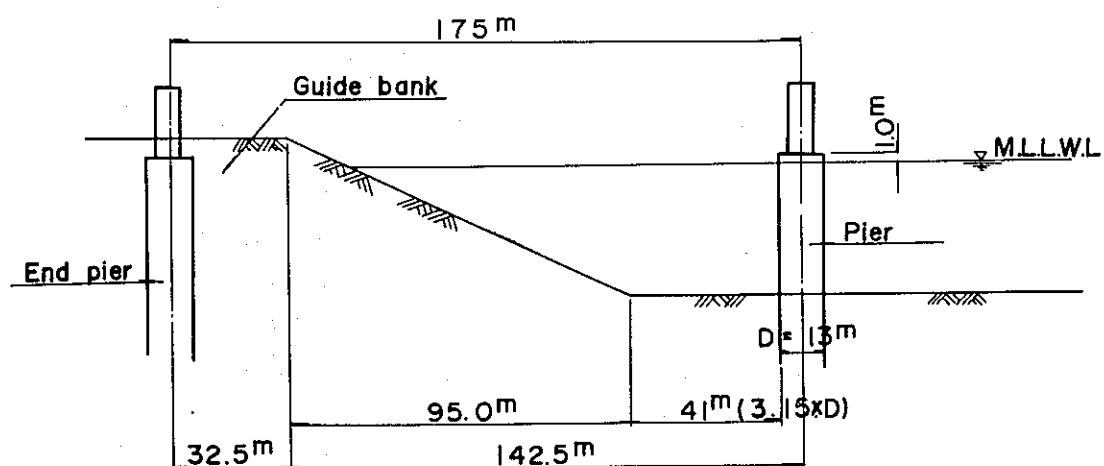
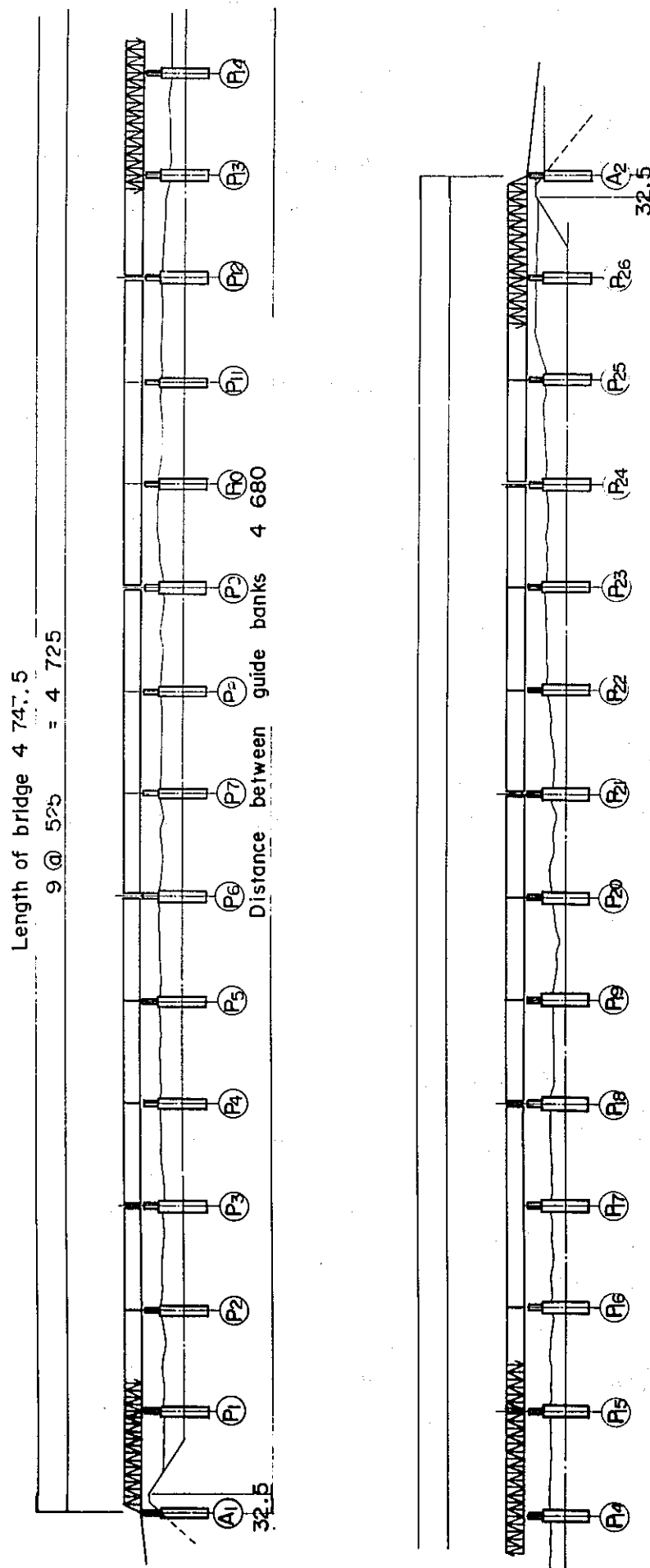


Fig. 5 - 8. Composition of Spans and Length of Bridge
(in meter)



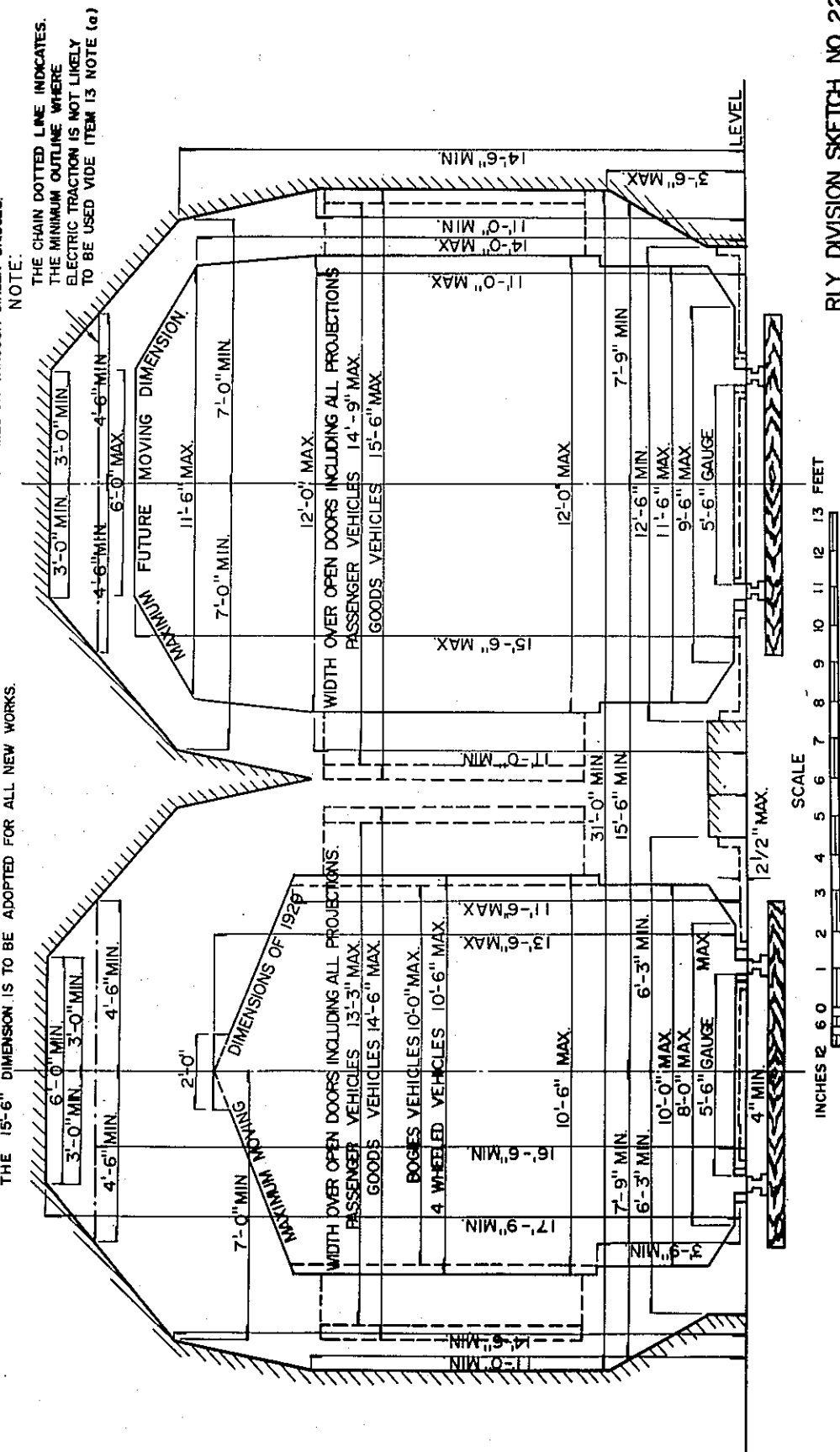
Standard Dimensions for Tunnels & Through Girder Bridges

Fig. 5 - 9

SCHEDULE 1 - CHAPTER 1

DIAGRAM NO 1A
5 FT 6 IN GAUGE
1939

- (1) WHERE THE LINE IS ON A CURVE, THE HORIZONTAL DISTANCE OF ANY STRUCTURE FROM THE CENTER OF ADJACENT TRACK AND THE DISTANCE BETWEEN CENTERS OF TRACKS ARE TO BE INCREASED ACCORDING TO THE APPENDIX.
- (2) WHEN RE-SPACING EXISTING LINES, THE MINIMUM DISTANCE CENTER TO CENTER OF TRACKS MAY BE PRODUCED FROM 15'-6" TO NOT LESS THAN 14'-9" FOR THE PURPOSE OF AVOIDING HEAVY ALTERATIONS TO TUNNELS OR THROUGH GIRDER BRIDGES. THE 15'-6" DIMENSION IS TO BE ADOPTED FOR ALL NEW WORKS.



RLY. DIVISION SKETCH NO. 226

Fig. 5 - 10 Width System of Bridge

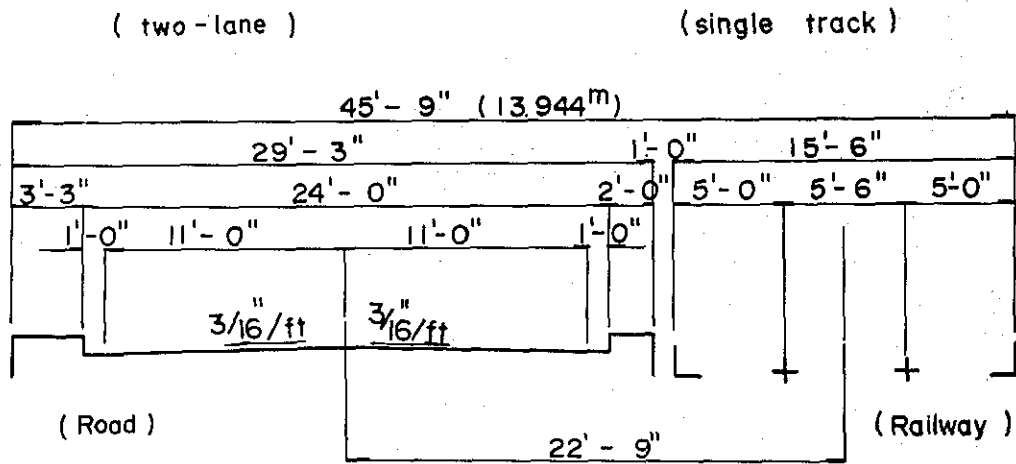
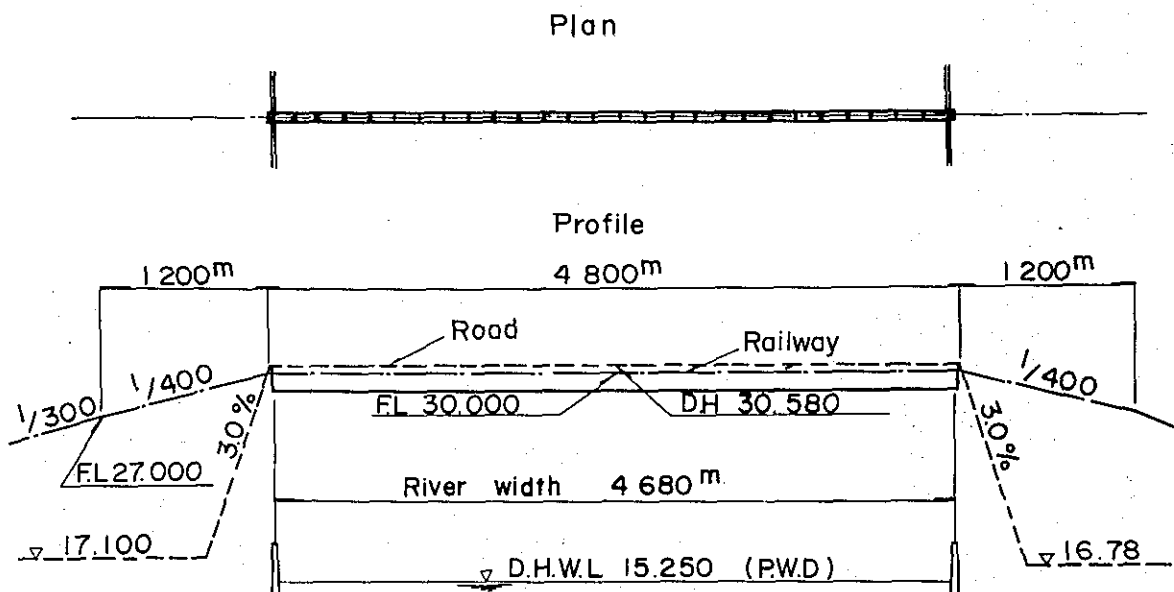


Fig. 5 - 11 Diagrammatic Sketch of the Bridge



2.7.7. Highway load.

Highway loads are based on those started in Chapter II (Fig. 2-2).

2.7.8. Impact coefficient.

(1) Impact coefficient of railway load

Impact coefficient for design is based on the Bridge Rules and the Indian Railway standard. Impact coefficient "i" is as follows.

$$i = \frac{20}{14 + L}$$

(2) Impact coefficient of highway loads

Impact coefficient for design is based on I.R.C. Standards Vehicle class "A". Impact coefficient "i" is as follows.

$$i = \frac{15}{20 + L}$$

2.7.9. Braking load.

Braking load is based on Standard Specifications for Railway Bridges (by the Japan Society of Civil Engineers), is this load acts in the direction of bridge axis at the height of 1.8m over rail level and its value is 15% of train load. But it should not exceed the value multiplied by the frictional coefficient of shoe on the vertical load of the superstructure.

2.7.10. Current pressure.

Current pressure is as follows.

$$P = K.V^2.A$$

where P: Total of current pressure (t)

K: Constant determined by the shape of piers and K = 0.04 for a circular section

V: Velocity of flow (m/sec)

A: Vertical area of pier (m²)

Furthermore, the acting point of current pressure P is a point of 0.6H (H is water depth in meter) from the bottom of flow.

2.7.11. Wind load.

In determining a wind speed which will become a calculation basis of wind load for design, based on the observing data of the last five years at three observing sites in Bangladesh (Bogra, Sirajganj and Faridpur), the maximum wind speed is observed as 12m/sec at Bogra, 9m/sec at Sirajganj and 27m/sec at Faridpur, respectively and basic wind speed was determined as 35m/sec considering cyclone and gust.

The wind speed which revised the basic wind speed by the height and horizontal length of structure is adopted as the design wind speed. These calculations for correction and load intensity are based on the following bibliographys and specifications. Furthermore, the maximum wind velocity for the last five years and its monthly mean value in every year at each observing point are shown in Table 5-5.

- o Research report on wind-proofing for the Honshu-Shikoku Bridges
(Established by Honshu-Shikoku Bridge Authority)
- o Standard Specifications for Highway Bridges
(Established by Japan Road Association)

Table 5-5 Maximum Wind Speed and Its Mean Value
(1964.4 , 1969.3)

Meteorological Observating Station	Month Occured	Maximum Wind Speed (m/sec)	Mean Maximum Wind Speed (m/sec)
Bogra	Jul.	12	7.5
Sirajganj	Apr.	9	5.5
Faridpur	Oct.	27	11.0

2.7.12. Range of tempeature.

The range of temperature for design covers the order of 0°C to 45°C, including minimum and maximum temperatures, based on the observing data at 3 meteorological stations in Bangladesh (Bogra, Sirajganj, and Faridpur) for a 5 year period from April 1964 to March 1969.

Furthermore, in addition to the above range, with due regard for 15°C, the thermal difference in steel materials between portions directly affected by sunlight and portions of shadow, the thermal variation of 0°C~60°C shall be taken into consideration for the design of this bridge. The maximum and minimum atmospheric temperatures for the last 5 years at each meteorological observation station are shown in Table 5-6.

Table 5-6 Maximum and Minimum Atmospheric Temperatures
(For 5 years)

Meteorological Station	Maximum Temp. (°C)		Minimum Temp. (°C)	
	Date	Degree	Date	Degree
Bogra	3 May 1966	43.4	4 Feb. 1968	1.7
Sirajganj	2 May 1966			
	17 Apr. 1966	41.7	1~2 Jan. 1965	6.7
	3~5 May 1966			
Faridpur	1~2 May 1965	41.7	4~5 Feb. 1968	6.7

2.7.13. Horizontal acceleration of earthquake.

Horizontal acceleration $K_h = 0.1G$ from Chapter III

2.7.14. Fatigue and secondary stress.

(1) Allowable stresses for fatigue

Allowable stresses for fatigue are designated in the Standard Specifications for Railway Bridges (Established by the Japan Society of Civil Engineers). K value on allowable stresses for fatigue is based on the following.

$$K = \frac{d}{d + \ell}$$

where, K: Coefficient for allowable stresses for fatigue,
d: Stresses due to dead load,
 ℓ : Stresses due to live load.

(2) Secondary stresses

Secondary stresses shall occur on members of truss by the effects of eccentricity of members, rigidity of panel points, deflections of cross beams, deformation of floor system due to the variation of member length and the deflection of members due to dead load, etc. Therefore, the proper allowance approx. 200 kg/cm² for design section was considered in this design.

2.7.15. Designation of deflection.

The maximum deflection of main girder cross beam and stringer due to the live load (excluding impact load) are not defined in the railway-cum-highway bridge, but in this bridge it was defined as follows.

a. Deflection of main girder

(By Standard Specifications for Railway Bridge)
L/1000 (for truss type)

- b. Deflection at the connection point of cross beam and stringer should be maximum 4 mm at end cross beams and should be maximum 5 mm at intermediate cross beams.
- c. Deflection of stringer
Highway side : $L^2/20,000$
(by Standard Specifications for Highway Bridges)
Railway side : $L/800$
(by Standard Specifications for Railway Bridges)
where, L = span length (m)

CHAPTER VI

DESIGN

1. Classification of Structure.

After the optimum span length and the span arrangement at the Sirajganj site were determined through various examinations in preliminary design, the type and scale of the structure to be taken as the object of design have been made clear.

Though the design river width shall become 4.680 km by constructing the guide banks at the design bridge axis in the Jamuna River, the river flow is a half of the width in the dry season, and the other half of the width which is a river bed appears exposed and becomes land. Since it is required to take the due consideration both conditions shown above, in design of the structure works, a demarcation is made by naming the former as the stream area and the latter as the land area. This demarcation is used not only in design but also in the executing works of both superstructure and substructure, as the classification of execution methods.

Numbering is made in the substructure works of the piers and end-piers from the right bank to the left bank those located in land side of the Guide Bank shall be marked with A_1 and A_2 as the end-piers, and piers located between Guide Banks shall be marked with P_1 to P_{26} , respectively. Among these mark, the land area has 14 piers and end piers including A_1 , A_2 , P_1 to P_{11} and P_{26} , while the remaining 14 piers are located on the stream area.

The superstructure of the main bridge consists of nine set (27 spans) in total and T_1 to T_9 shall be marked from the right bank to the left bank.

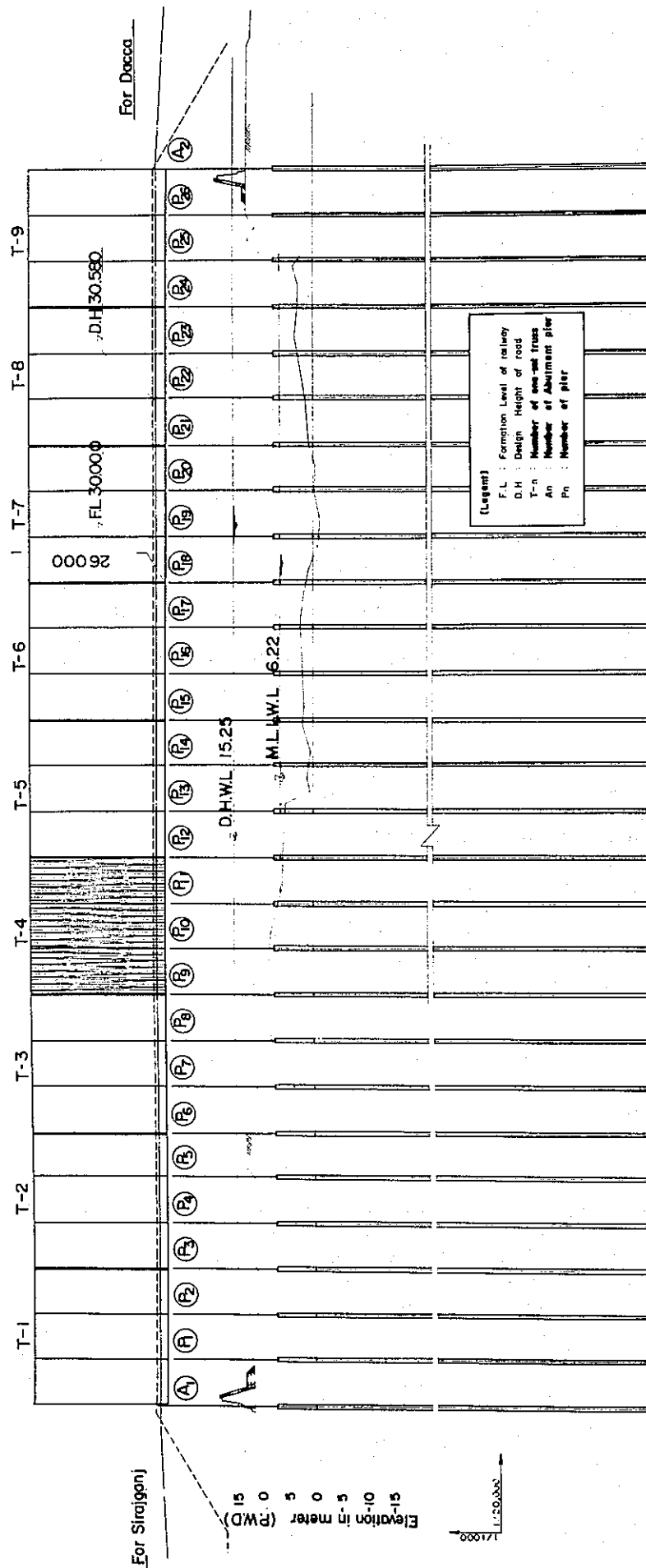
Figure 6-1 indicates the marks and numbers of the bridge structure.

2. Superstructure.

2.1. Outline.

The contents reported here are related to the superstructure works of the main bridge over the Jamuna River of this bridge project, and in due consideration of the bridge scale, appearances of bridging point, workabilities and economics, a brief description was made by each item on the process, in which the selection of the type of structure and its fundamental factors have been decided, and the main basic superstructure has been specified. At the same time, as to the member forces of truss obtained by design calculation by the determined type of structure and various sizes, and as to the required sections, main truss, sway bracing, lateral bracing and floor system are specified and by that description the calculated materials in use have been specified together.

Fig. 6-1 Marking Diagram of Jamuna Bridge



Moreover, as to the construction of the main bridge, since it is the work only capable during the dry season, it has been planned to adopt the staging method as for the land area and the flat barge method in respect of the stream area. As a result of examining the effects by erection stress, since there is no difference in erection between both methods as shown above at the present stage.

Further, the design calculation has been conducted on the standards as stated before (in CHAPTER V) and dimensions and design conditions to be stated later.

2.2. Design Conditions.

(a) Type	Steel 3-span continuous Warren Truss (road-cum-railway bridge)	
(b) Slab	Reinforced concrete slab	
(c) Composition of spans	3 @175m = 525m	
(d) Design load	Road	I.R.C. Standard Vehicle Class A
	Railway	I.R.B.C. "ML"
(e) Width	Road	2-lane carriageway 24ft
	Railway	Broad gage 5ft 6in (Single track)
(f) Design wind velocity	35m/sec	
(g) Ranges in temperature	0°~60°C	
(h) Design seismic horizontal acceleration	Kh = 0.1G	
(i) Unit bulk density	Reinforced Concrete $\gamma_c = 2.5 \text{ t/m}^3$ Asphalt Pavement $\gamma = 2.3 \text{ "}$ Steel material $\gamma = 7.85 \text{ "}$	
(j) Material in use	Steel material	SS41, SM41, SM53
	Joint material	H.T.B. (F11T, F10T)
	Reinforcing Bar	SD30
	Concrete	$\sigma_{ck} = 240 \text{ kg/cm}^2$

Other materials for use and strength of materials shall be in conformity with the JIS and other standard instructions are shown as follows.

(k) Standard instructions and literatures

Standard Specifications for Highway Bridges: Japan Road Association

Standard Specifications for Railway Bridges: Japan Society of
Civil Engineers
Data for Honshu-Shikoku Bridges : Honshu-Shikoku
Bridge Authority

I.R.C.
I.R.B.C.

2.3. General dimensions.

The structural dimensions of this bridge were finally determined and are shown in Fig. 6-2.

2.4. Selection of structural type of main truss.

2.4.1. Type of main truss.

As to the type of main truss, the following types can be considered as shown in Fig. 6-3.

(a) Parallel chord truss

Warren truss
Pratt truss

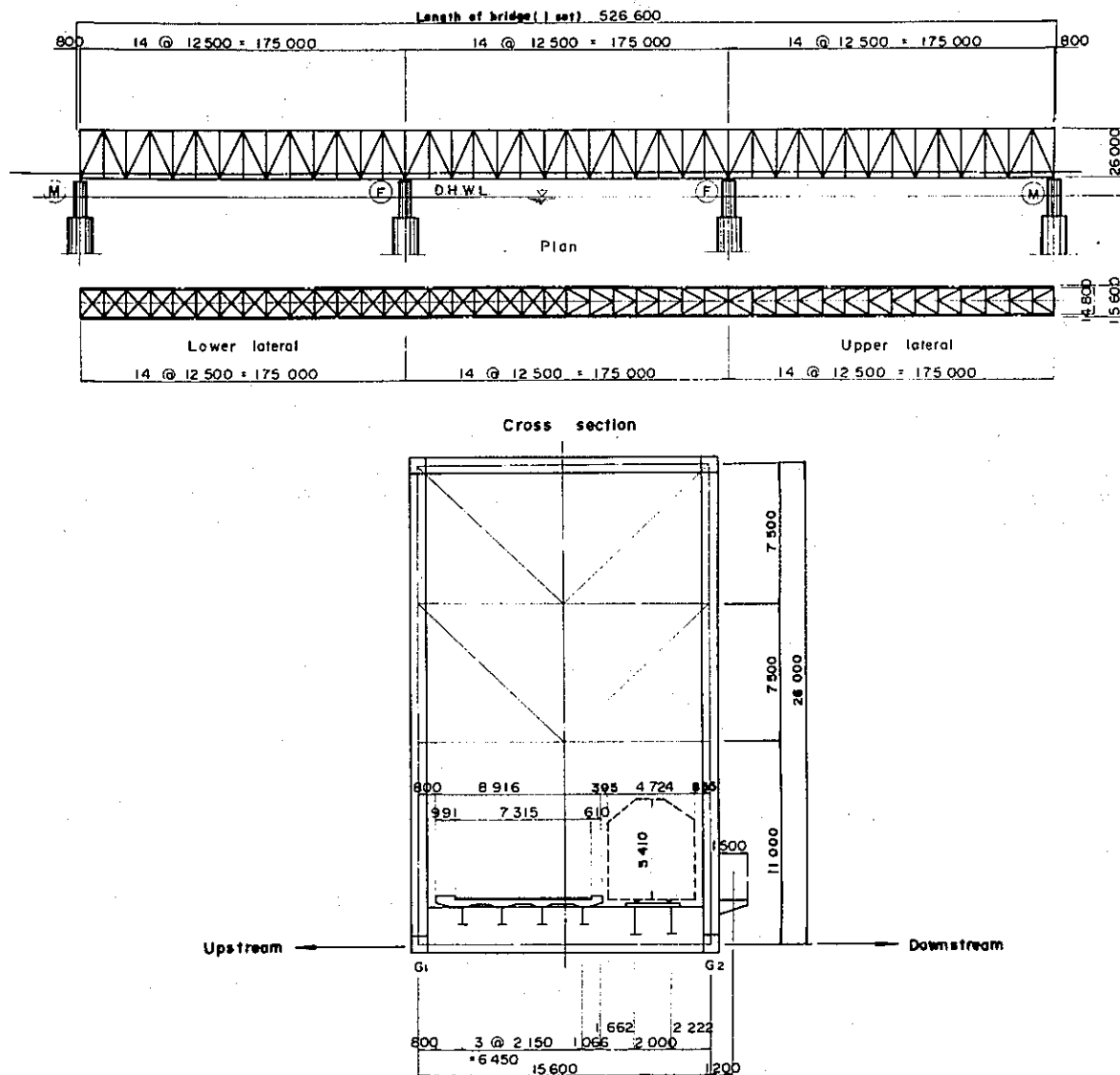
(b) Curved chord truss

In the parallel chord truss, even though the Warren truss is generally inferior in rigidity of bridges body compared with the Pratt truss but by installing auxiliary vertical members, it is capable of heightening rigidity and, moreover, diagonal member of the Pratt truss is a tensile member after the bridge was erected but in the erection stage, it is considered that some of the diagonal members will turn to be compressive members and, hence, steel weight may be considered to increase.

The curved chord truss type has merits in case of uneven span continuous truss in which equilibrium of sectional forces is effected between the span center and the supporting point, and also in case of adopting an erection method (such as the cantilever method) which causes a great erection stress on the supporting point at erection time. However, since this bridge is an even span type and the staging method can be adopted, it has no merit to adopt the curved truss type. Moreover, due to multi-set which continuous, its profile becomes non-object and it is insensible to beauty. Hence, the parallel chord truss type was adopted for this bridge.

The parallel chord truss has 2 types, namely the Warren truss and Pratt truss. As to the decision to select more better one of these two, examination was made on the deflection by live load which determines the height of main truss, the Warren truss having vertical sub-member was judged as having the minimum height $h = 26.0\text{m}$ and the height of truss became lower than the Pratt truss and, hence, the former is better than the latter. Moreover, the former is more reasonable seen

Fig. 6-2 General Dimension of Superstructure
Profile



from cross-section constitution of members and more favorable with low structural height from a viewpoint of erection and execution, and the Warren truss has been adopted.

2.4.2. Panel length.

In deciding the panel length of this bridge, the following factors have been taken into consideration.

(a) Sections for stringers and cross beams should be decided from a viewpoint of sectional structure as floor system of stringers and cross beams, particularly seen from allowable deflection, and economics should be also considered.

(b) The positions of joints in a single member must be reduced as much as possible.

(c) Inclination of diagonal member should be such an angle that will heighten the rigidity of bridge.

In due consideration of above factors and, moreover, by dividing the span length of 175m into seven equal parts and the panel length as truss frame should be 25.0m. Further, the length of effective span as the floor system was decided at 12.5m by setting up sub-vertical members at the center of panel in due consideration of sectional structure of the floor system, reduction in secondary stress by deformation and increasing the rigidity of bridge.

2.4.3. Space between main trusses.

Space of the main truss between upstream and downstream sides was, in view of economics, determined to have 15.6m width.

2.5. Decision of main truss height.

Factors that will decide the main truss height of this bridge are given in the following.

(a) The deflection by live load observes the regulations satisfactorily.

(b) There should not be anything unnatural in shape and dimensions in section and in thickness of steel plate of main truss and hence, steel weight does not increase.

(c) It is more advantageous to have main truss height as low as possible from a viewpoint of erection and execution.

In the above factors, the factor (a) becomes a main cause for deciding the height of main truss as the deflection is larger in railway load than in roadway load. Hence, as a result the deflection in live load was investigated on each case.

The Warren truss	Main truss height	$h = 28 \text{ m}$
		$h = 26 \text{ m}$
The Pratt truss	Main truss height	$h = 28 \text{ m}$

As a result of above examination and as shown in Table 6-1, in case of the Pratt Truss, the main truss height showed value close to the allowable deflection in truss height $h = 28\text{m}$. On the other hand, in the case of Warren Truss, seen from a viewpoint of deflection, it is possible to make the minimum height $h = 26\text{m}$. And also judging from the force of members, there is no trouble in the thickness of steel plate of main truss and that economics will not be spoiled. Moreover, it has more merits in erection and execution than in the Pratt Truss. Consequently, it was determined to make this bridge with truss height $h = 26\text{m}$ in the Warren Truss.

2.6. Structural type of floor system.

Two types of structure to floor system as shown below can be considered.

- (a) Those with stringers that are placed on cross beam (Fig. 6-4-1).
- (b) Those with stringers that are fixed to the web of cross beams (Fig. 6-4-2).

In the case of (a), it is advantageous in erection and execution but it requires lateral bracing and sway bracing for the maintenance of stability of horizontal direction and rigidity. Further, due to a difference between roadway stringer height and that of railway portion there will be a difference between the road surface and rail level.

On the other hand, in the case of (b) it is disadvantageous with many joints in a single stringer in point of erection and execution while it is advantageous for the stability of horizontal direction and rigidity and that it maintains the same level between the road surface and rail level. Its steel weight becomes more or less lighter than that of Type (a). Further, what the road surface and rail level are lower than Type (b) has a merit that will reduce the level of bridge approach embankment lower than Type (a).

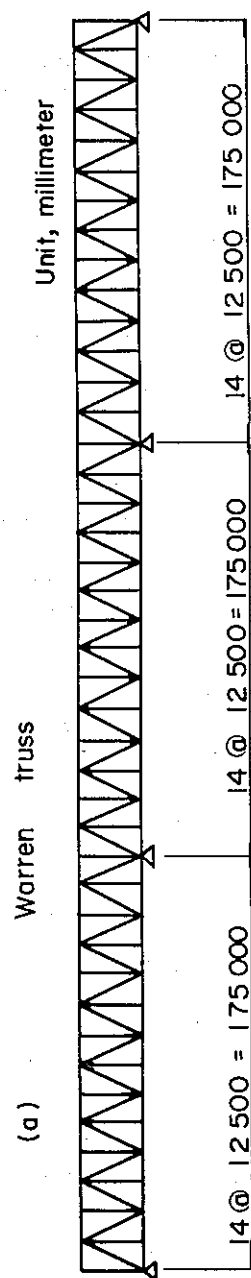
In comparison of the above 2 types, (a) and (b), it is clear that Type (b) is more advantageous than (a) and for that reason, Type (b) was selected in its floor system. Also for the purpose of securing the stability of the floor system, sway bracings were set at the span center of stringer. In this case an open-floor type was selected for the railway portion.

In case the deflection of the floor system is big, it will not only impede the trains in running but the secondary stress of main truss increases, consequently it is unfavourable from a structural viewpoint. Hence, for reducing the deflection of the floor system, it is better to give adequate height on cross beams. For this purpose, the height of cross beams was determined at 2.5m by the trial balance.

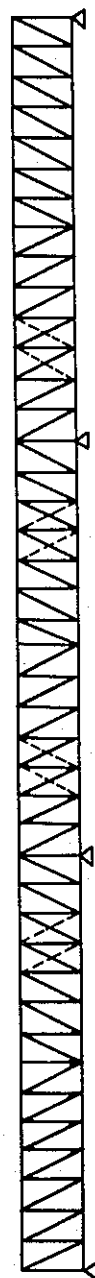
Heights of cross beams and stringers are shown in Fig. 6-5.

Fig. 6-3 Structural Type of Main Truss

(1) Parallel - chord Truss



(b) Pratt truss



(2) Curved - chord Truss

(c)

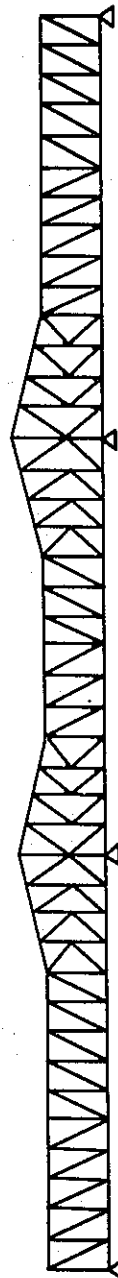
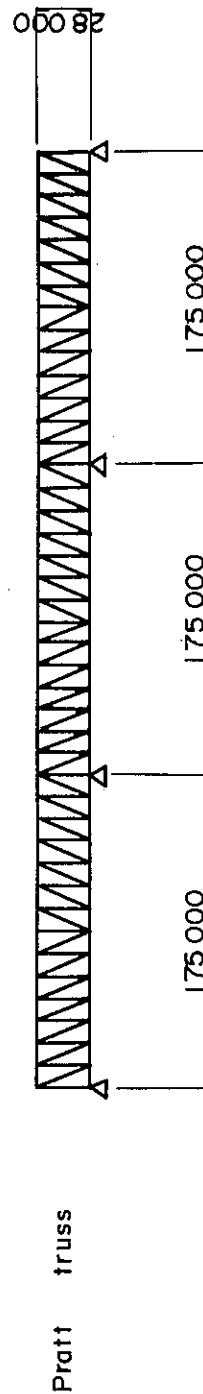
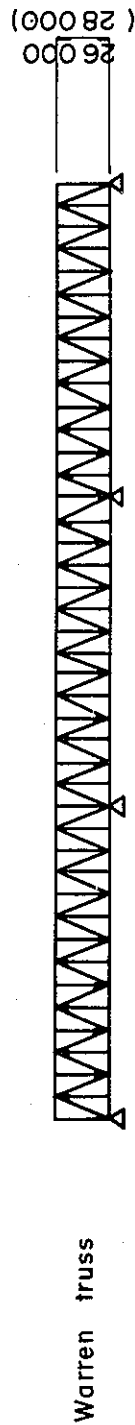


Table. 6 - 1 Maximum Deflection

Items Type	Height of truss (m)			Live load deflection (mm)		Max allowable deflection(mm)	Remarks
				Road	Railway		
Pratt	28.0	Side span	G2	23.9	142.9	175	
		Center span		23.4	143.9		
Warren	28.0	Side span	G2	21.1	122.9	175	
		Center span		20.0	122.7		
	26.0	Side span	G1	40.1	32.7	175	
		Side span	G2	21.5	125.1		
		Center span	G1	36.9	31.7		
		Center span	G2	19.7	121.3		



Note :

- 1) G1 : Upstream truss , G2 : Downstream truss
- 2) Maximum allowable deflection was specified by the standard specifications for railway bridges adopted by the Japan Society of Civil Engineers.

Fig. 6-4-1 Stringers Placed on the Upper Flange of Cross Beams

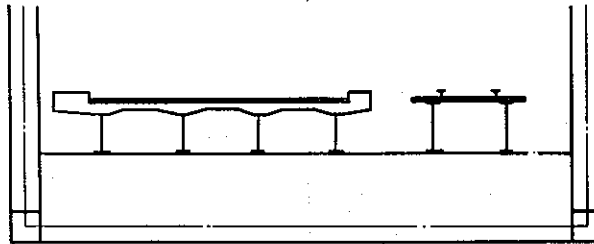


Fig. 6-4-2 Stringers fixed to the Web of Cross Beams

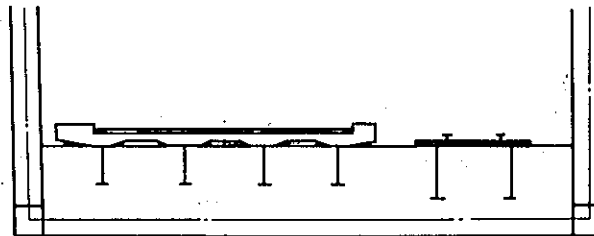
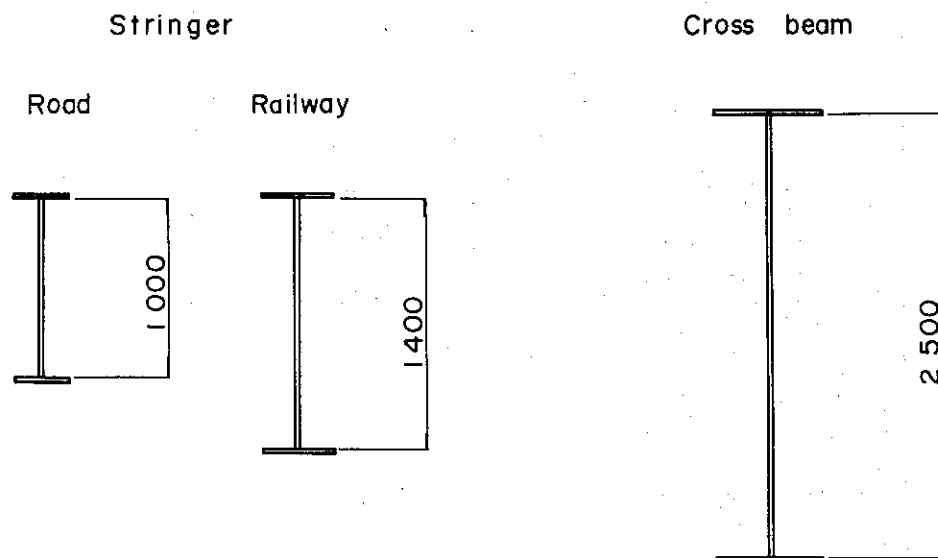


Fig. 6 - 5 Web Height of Floor System



2.7. Stability and type of structure against lateral force.

To maintain the rigidity and also the stability for lateral direction, it is required to install upper lateral bracing on upper chord and lower lateral bracing on lower chord. Further the end sway bracing and intermediate one are needed.

2.8. Dispersion method of lateral forces acted along the direction of bridge axis during earthquake.

2.8.1. Dispersion of lateral forces.

In a 3-span continuous bridge, it is ordinary practice to set one fixed end and three movable ends. In this case, the seismic force along the direction of bridge axis concentrates to the fixed end and is transmitted to the substructure. Therefore, in our case, as the pier with fixed end is attacked by large lateral seismic force, large embedment of foundation will be requested. This requests very long foundation well and is uneconomical. Then we adopted to set special fixed shoes on two intermediate piers in order to disperse the horizontal forces to these piers. In this case, above-mentioned special fixed shoe is required to have the following functions.

- a) To be of a structure capable of dispersing, by any means, the horizontal forces of the bridge axial direction from the super-structure to each pier.
- b) Not to cause any redundant force on both super-and substructures by expansion and contraction due to temperature change.
- c) Structure is required to be simple and that it must be capable of supporting comparatively large reaction.

Since we consider that the structural type (Fig. 6-6) presently adopted by the Tokaido New Trunk Line of Japanese National Railways is appropriate for dispersion structure of this bridge, we adopted the same structural type.

2.8.2. Structure.

Main part consists, structurally, of a steel bar with square section to be fixed on the end cross beams of intermediate span and a steel box to be buried in a bridge pier. An essential difference between fixed stopper and movable stopper is that the former contains inside plate springs to keep the neutral position of the steel bar, the latter has not. Since a viscous material is tightly closed so that it will prevent leakage when the steel bar will change their position in a steel box, the viscous material has to flow through a narrow opening between the steel bar and steel box.

This will never resist to low-speed motions but resist rapid movements. Though there are many properties to be required for the viscous material, a stable quality and durability are most important. For example, a certain type in which asphalt mixed with polyisoprene polymer and various additives, is filled in but hereafter this will material require a further investigation.

2.8.3. Dispersion ratio of horizontal forces.

A fixed stopper is set on one side of cross beams at intermediate supports of 3-span continuous truss and a movable stopper is installed on the other side, and a pier set with the fixed stopper will be compelled to resist the horizontal forces at ordinary state but the horizontal forces caused by the earthquake shall be dispersed and resisted by both stoppers. The force dispersed by the stoppers is determined according to a difference in free standing length of bridge piers, in rigidity of structures, property of ground around piers and in depth of local scouring around piers. In respect of this bridge, however, since the rigidity and the height of the piers are nearly equal, the dispersed force is expected to be equalized but in due consideration of structural differences between fixed and movable stoppers and effects of local scouring, it was decided to calculate 60% of the total horizontal force as a allotted load. Shapes and dimensions of the stoppers are as shown in Fig. 6-6. The relation between relative velocity of the truss against the pier and resisting force of the stopper in this form is shown in Fig. 6-7.

2.9. Section of members.

In determining the section of members, the selection should be made considering the maximum or minimum stresses and arrangements of splice bolts. In case of this bridge, however, since a continuous truss of long spans was adopted and used members in use are long, special considerations should be paid for the increase in plate thickness by the plate buckling and the deterioration of allowable stresses of members by truss buckling.

In due consideration of above affairs and through various trial calculations, and with careful regard to economics, manufacture and execution, the composition of section, and its dimensions were determined as shown in Fig. 6-8. Table 6-2 indicates the quality of steel used for both main trusses.

2.10. Design of splices of truss members.

The process of manufacture and erectionworks of the bridge are greatly affected by position of splice of members. In this bridge, the maximum length of members for transportation was set at 12.5m in principle, so that the all members shall be spliced. High-tension bolts were adopted in all cases as a splice material, and it was decided that quality and size shall be in conformity with JIS as follows.

(a) Primary member	F11T	M24
(b) Secondary member	F10T	M22

A chord member of the main trusses shall be fabricated as one block and a diagonal as two blocks. The maximum weight of one block is 22 tons in chord members and 20 tons in diagonals. The design of splice bolts of main trusses was made with respect to the main truss on railway side, and the splice bolts of the road-side truss were in accordance with the railway-side truss. The splice bolts were adopted as a double friction system at all primary members but in secondary members, either a single friction system or a double friction system was applied.

The arrangement of splice bolts is shown in Fig. 6-9.

2.11. Erection stress.

Erection works are scheduled to be conducted during a dry season of approx. 6.5 months (early November to mid-May). As the erection methods, we adopted a staging erection method by crawler crane on land and a method by flat barge in stream. Since the stagings are set at each panel point in the staging method, erection stresses are beside the question. In the erection by flat barge, erection stresses are larger than the stresses in the staging erection.

- a. Structural system at towing.
- b. Structural system after setting on piers as a overhanging truss stretching by one panel toward both sides.

As the above mentioned two structural systems are imperfect structures, the erection stresses by their own weights should be taken into consideration. The results of calculation showed that the sections determined by design in complete system were completely safe for the erection stresses.

The above structural systems in the erection by flat barge are shown in Fig. 6-10.

2.12. Design.

2.12.1. Main truss.

Since this bridge is a railway-cum-highway bridge of 3-span continuous Warren-truss with reinforced concrete slab, main trusses shall charge live loads on a railway and a road and dead loads of steel weights and others. Erection stresses were calculated by loading the steel weights on the structural systems under erecting and section determination was made together with design of the complete system of bridge. Further, since there is a difference in stress intensity of both main trusses resulting from unbalance between both live loads on railway and road, structural analysis was given on both main trusses. In deciding the section, effect of fatigue was also taken into consideration.

Results of design for main trusses are shown in Fig. 6-11-1 and -2.

(In millimeter)

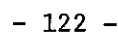


Fig. 6 - 7 Resisting Force of Stopper

The relation between relative velocity of truss and resisting force of stopper.

V (cm/sec): Relative velocity between bridge and stopper.

$F(t)$: Resisting force

$$F = 52 \times 10^{-3} (0.048 \ell + 3.6) (40 + t)^{-1.4} (S_0/S)^{-1.4} \times S \cdot V^{0.5}$$

Where t = Temperature ($^{\circ}\text{C}$)

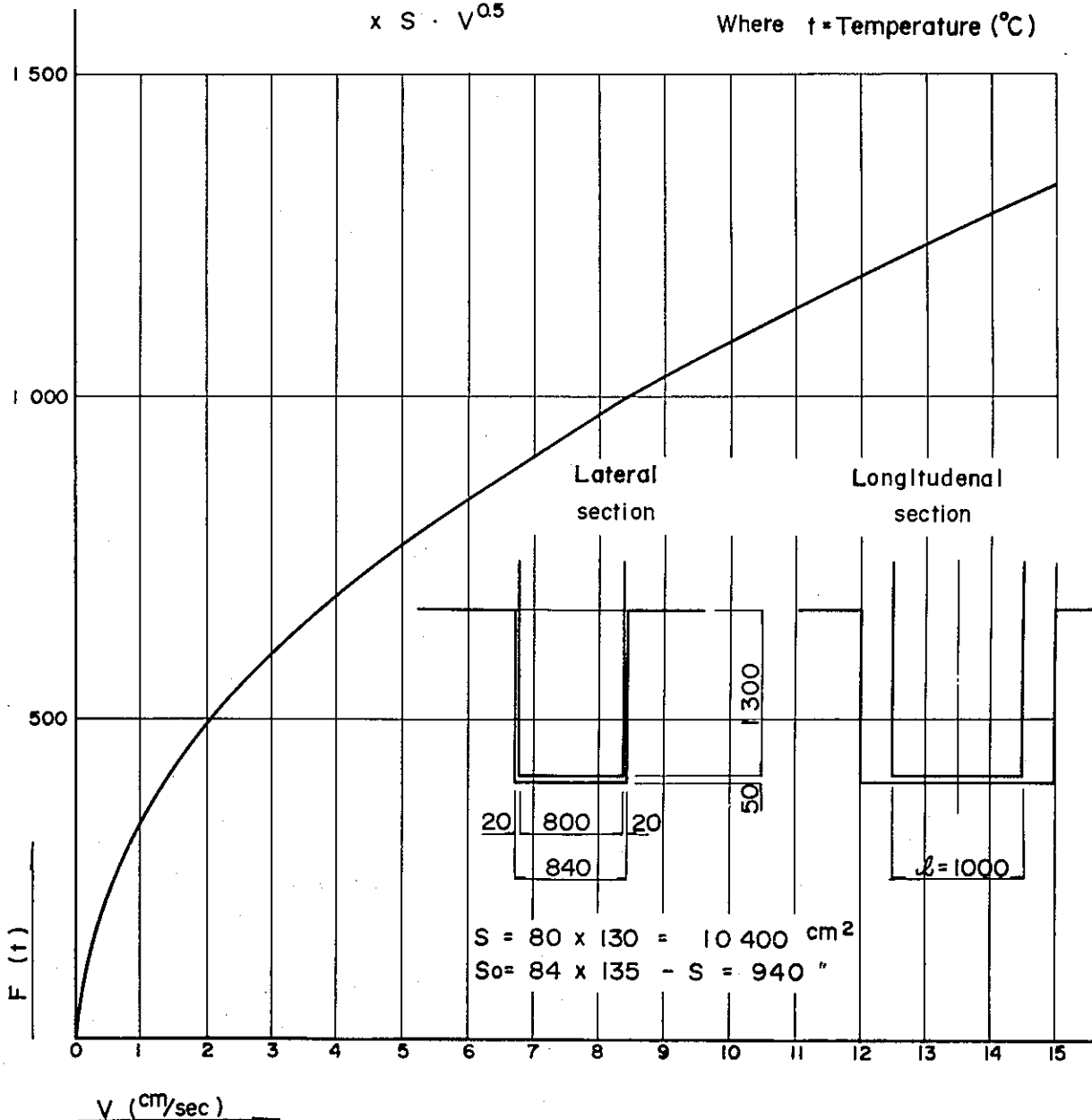
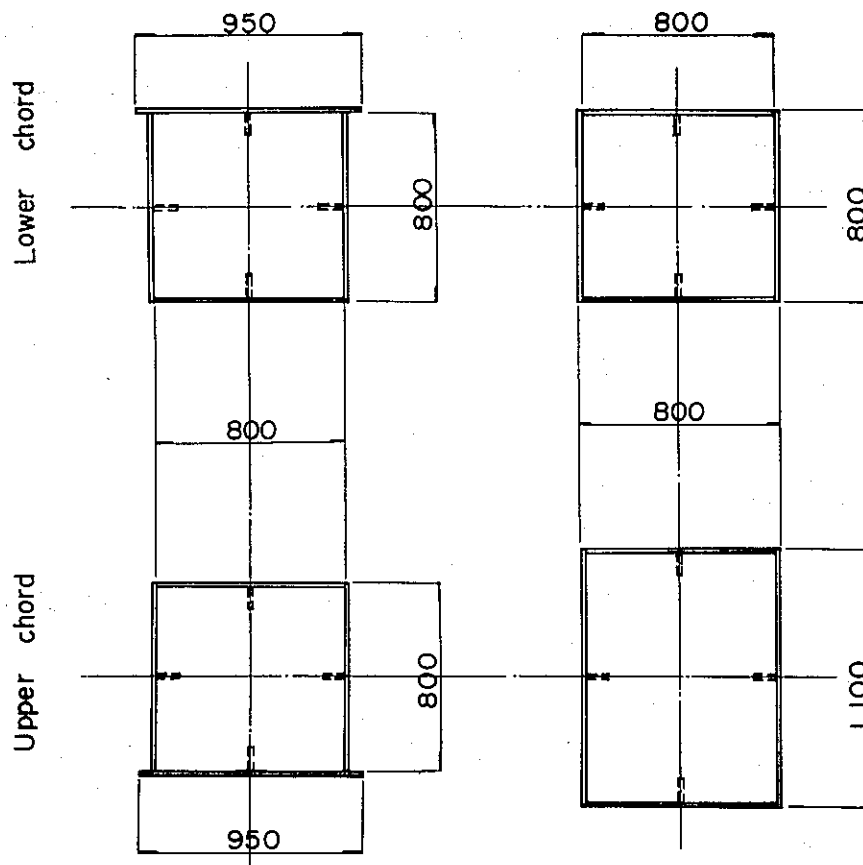


Fig. 6 - 8 Section of Main Truss
(in millimeter)

1) Chord member

2) Diagonal member



Note

Area of ribs is disregarded from net area of tension members.

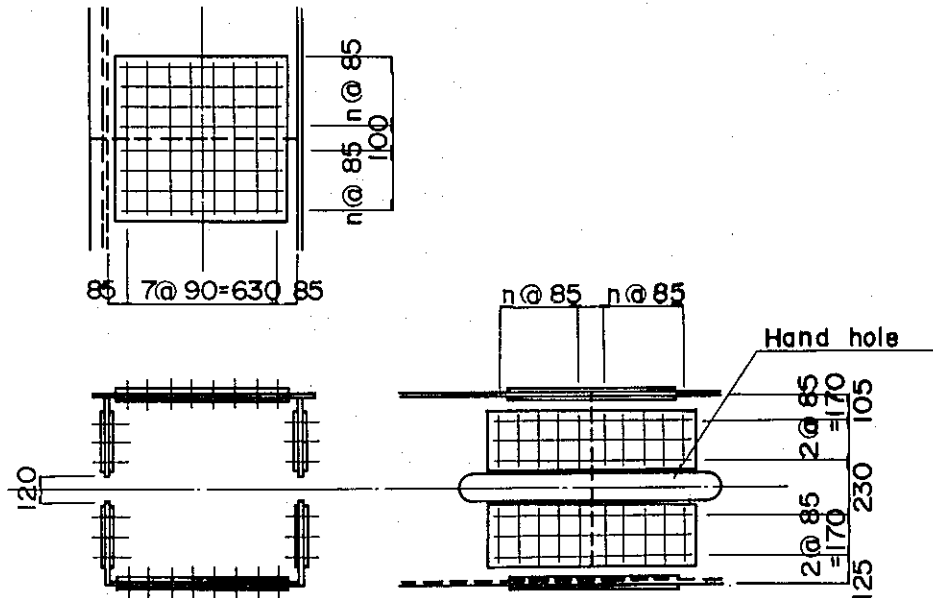


Note:

Vertical member :	All	SS 41
G1 Main truss :	Road	side truss
G2 Main truss :	Railway	side truss

Fig. 6-9 Arrangement of Splice Bolts (Hightension Bolts)
(in millimeter)

1) Upper and lower chord



2) Diagonal member

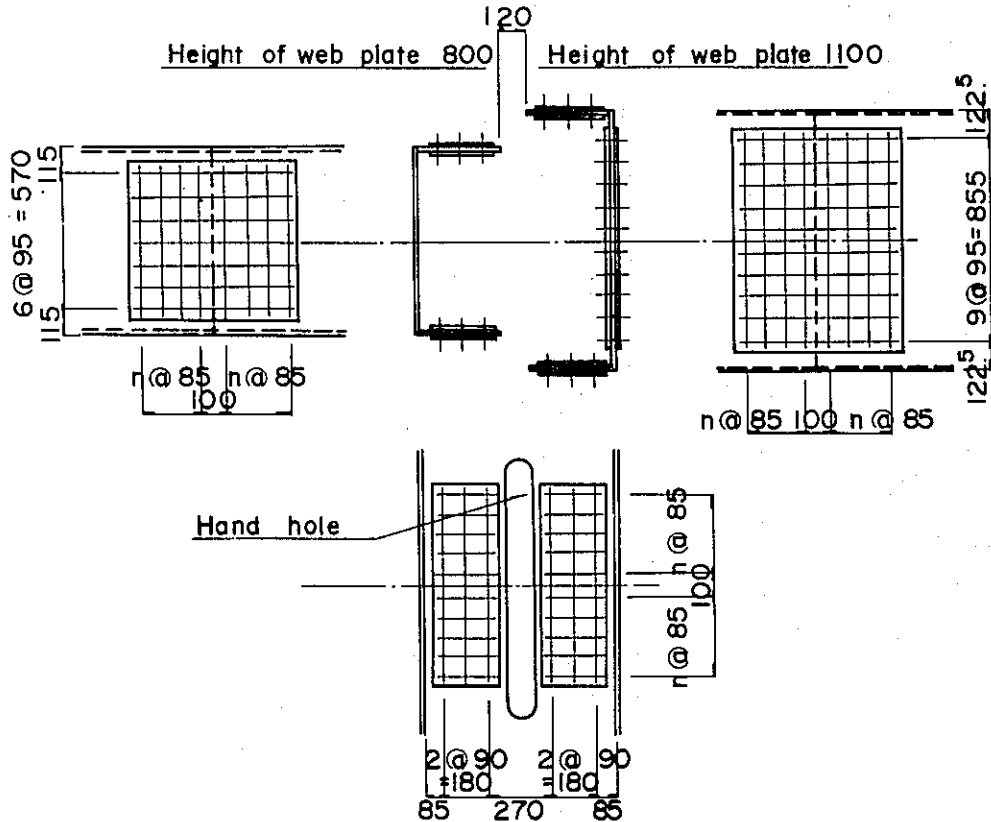
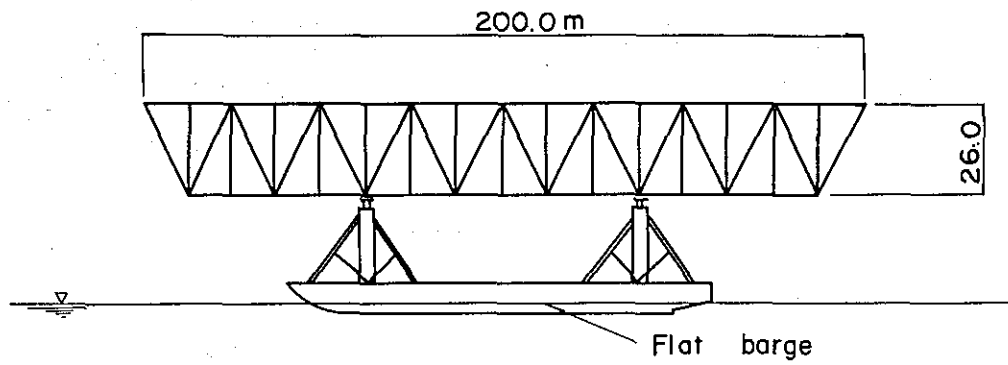
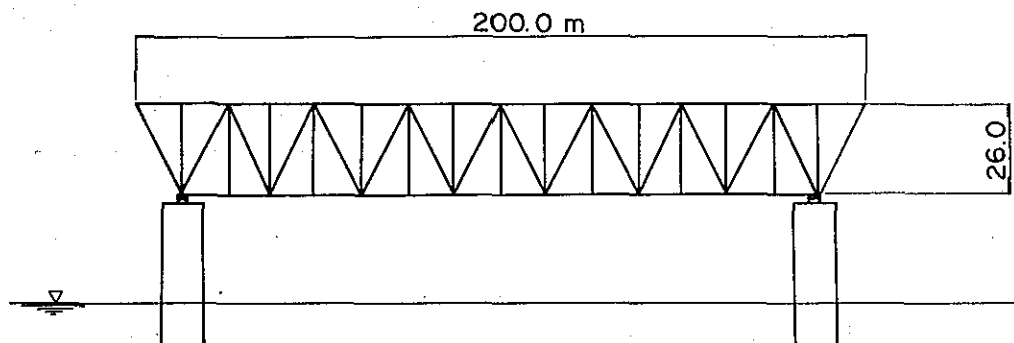


Fig. 6-10 Structural System at Erection Time

(a) Under towage



(b) After setting on the pier



2.12.2. Floor system.

The design was made by considering stringers as continuous beams and activating wheel loads and 'I'-shape section was selected for a section and SS41 for quality of materials was specified for stringers of road portion and SM41 for railway portion in due regard of effect of fatigue.

Since cross beams become supporting points for stringers, design was made as a simple beam which takes stringer reaction as load. The fact that cross beam has large displacement poses problems in train service and as to joints with stringers and further, effect of secondary stress will grow large to main truss. Hence, cross beam of this bridge took 'I'-shape section and SM53 was adopted for material. In view of allowable deflection, cross beam height was fixed at $h = 2.5\text{m}$. Further, for the stabilization of lateral direction, sway bracings that will joint each stringer were installed at the center between cross beams.

Calculation results of floor system are shown in Fig. 6-11-1.

2.12.3. Lateral bracing.

Since lateral bracing must resist horizontal forces, upper lateral bracing took K-truss type to shorten the length of diagonal member and wind load was taken for the design. Sections are affected by the alternating stress in both diagonal members and struts, but diagonal members are attacked by the large compressive force, therefore, the box type made section was adopted, and I-section was adopted for the strut and web height was made $h = 790\text{mm}$.

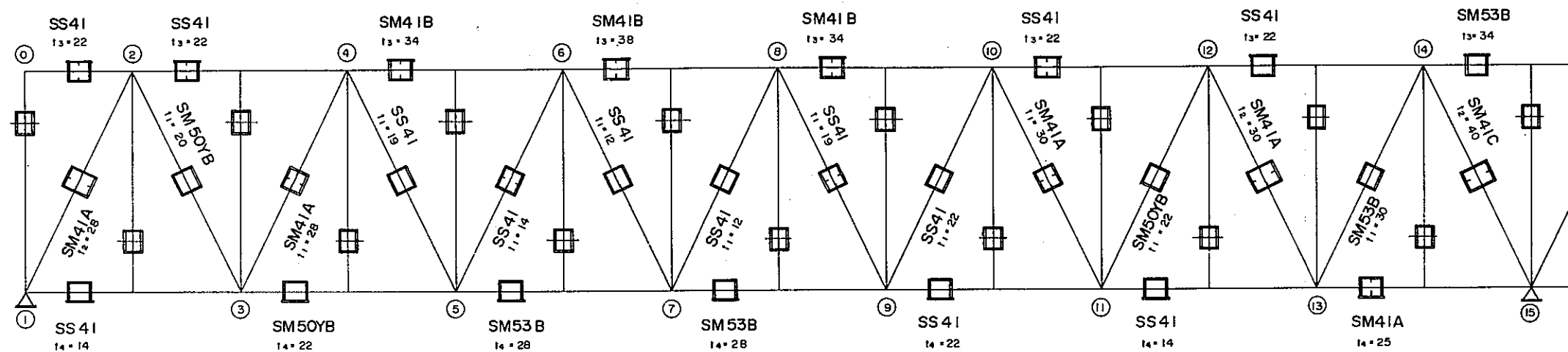
Lower lateral bracing was designed as the Pratt truss type which consists of diagonal member and floor beam, and seismic load was taken for design.

2.12.4. Sway bracing.

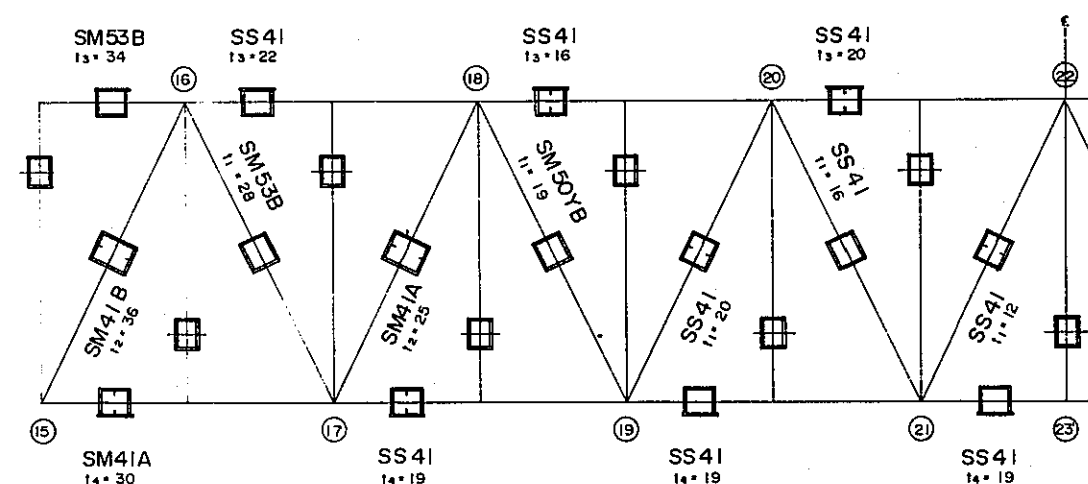
Since sway bracing is to resist horizontal force, K-truss was adopted. End sway bracing was designed against lateral reaction at support. Intermediate sway bracing was designed by lateral load per one panel. Since the end sway bracing is attacked by the alternating force and in this case the compressive stress is larger than the tensile stress, a box section was adopted, and H-shape for the intermediate sway bracing.

Calculation results of lateral bracing and sway bracing are shown in Fig. 6-12.

GI- MAIN TRUSS and FLOOR SYSTEM SCALE: SHEET 1: 600
(ROADWAY SIDE) DETAIL 1: 200



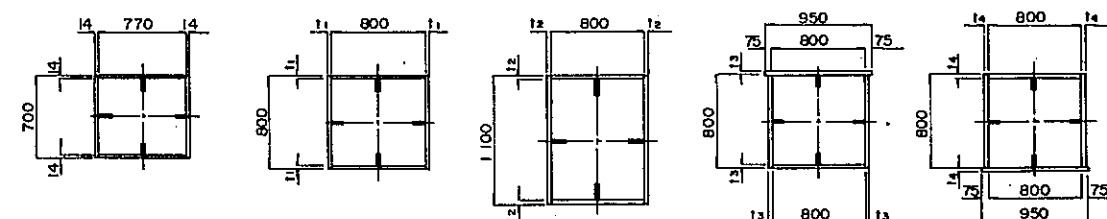
MEMBER		① - ②	① - ③	② - ③	② - ④	③ - ④	③ - ⑤	④ - ⑤	④ - ⑥	⑤ - ⑥	⑤ - ⑦	⑥ - ⑦	⑥ - ⑧	⑦ - ⑧	⑦ - ⑨	⑧ - ⑨	⑧ - ⑩	⑨ - ⑩	⑨ - ⑪	⑩ - ⑪	⑩ - ⑫	⑪ - ⑫	⑪ - ⑬	⑫ - ⑬	⑫ - ⑭	⑬ - ⑭	⑬ - ⑮	⑭ - ⑮	⑭ - ⑯
AXIAL FORCE	ton	- 1 005	429	1 005	- 858	- 604	1 108	604	- 1 360	- 222	1 428	222	- 1 503	337	1 394	- 337	- 1 290	717	1 003	- 717	- 723	1 132	259	- 1 132	491	1 539	- 1 040	- 1 539	1 738
AREA	cm ²	1 064	469	640	737	896	737	608	1 139	448	938	384	1 273	384	938	608	1 139	704	737	960	737	704	469	1 140	737	960	8375	1 520	1 139
I_x / y_x	—	61.31	37.80	81.01	37.78	81.62	37.78	80.94	37.72	80.56	37.75	80.38	35.66	80.38	37.75	80.94	37.72	81.16	37.78	81.78	37.78	81.16	37.80	61.38	37.78	81.78	37.76	61.77	37.72
I_y / y_y	—	41.36	37.16	43.36	36.91	43.03	36.91	43.40	36.53	43.59	36.71	43.67	34.44	43.67	36.71	43.40	36.53	43.28	36.91	42.96	36.91	43.28	37.16	41.27	36.91	42.96	36.81	40.86	36.53
ACTUAL STRESS	kg/cm ²	945	915	1 570	1 164	674	1 503	993	1 194	496	1 522	578	1 181	678	1 486	554	1 131	1 018	1 351	747	981	1 608	552	993	666	1 603	1 242	1 013	1 526
ALLOWABLE STRESS	kg/cm ²	1 053	1 400	2 100	1 251	882	2 100	1 400	1 251	891	2 100	1 400	1 268	1 400	2 100	888	1 251	1 400	1 400	881	1 251	2 100	1 400	1 052	1 400	2 100	1 251	1 049	2 100
				452			2 464				2 436				2 436							2 508				2 525			2 492



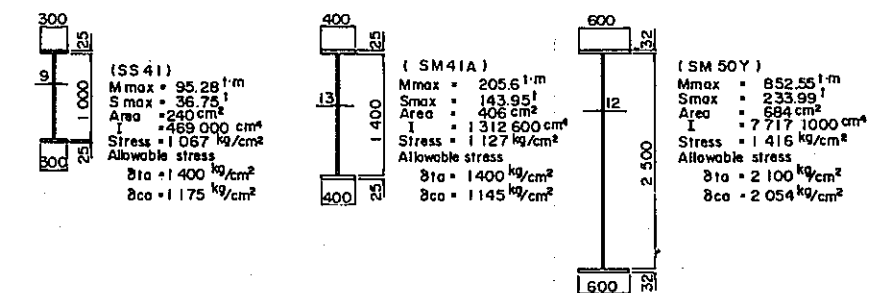
MEMBER		(5 - 16)	(5 - 17)	(6 - 17)	(6 - 18)	(7 - 18)	(7 - 19)	(8 - 19)	(8 - 20)	(9 - 20)	(9 - 21)	(20 - 21)	(20 - 22)	(21 - 22)	(21 - 23)
AXIAL FORCE	ton	- 301	- 1190	1301	686	- 897	- 395	897	- 291	- 480	467	480	- 647	- 108	644
AREA	cm ²	1368	1005	896	737	950	6365	608	536	640	6365	512	670	384	636
1x / rx	—	61.61	37.74	81.62	37.78	61.19	37.79	80.94	37.80	81.01	37.79	80.71	37.78	80.38	37.79
1y / ry	—	41.03	36.65	43.03	36.91	41.47	36.99	43.40	37.09	43.36	36.99	43.51	36.91	43.67	36.99
ACTUAL STRESS	Kg / cm ²	951	1184	1425	931	944	621	1475	543	750	734	938	966	339	1012
ALLOWABLE STRESS	Kg / cm ²	1050	1251	2100	1400	1054	1251	2100	1250	888	1400	1400	1251	893	1400

SECTION SCALE 1:60

VERTICAL MEMBER	DIAGONAL MEMBER	UPPER CHORD MEMBER	LOWER CHORD MEMBER



STRINGER (ROAD) STRINGER (RAILWAY) FLOOR BEAM SCALE 1: 80
END SPAN END SPAN



NOTE
Rib.P1 : ONLY COMPRESSION MEMBER

SWAY BRACING SCALE 1:100

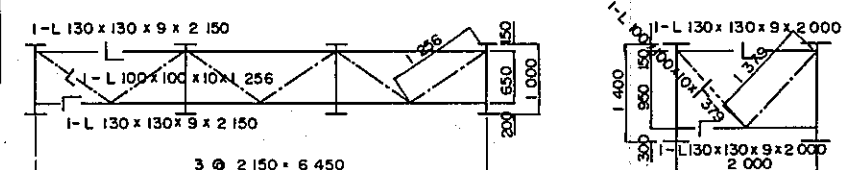
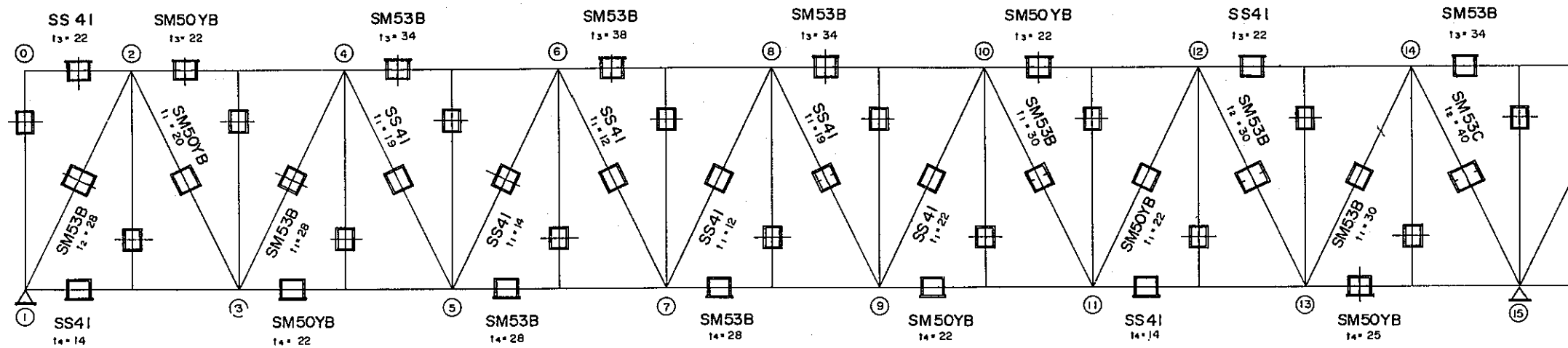
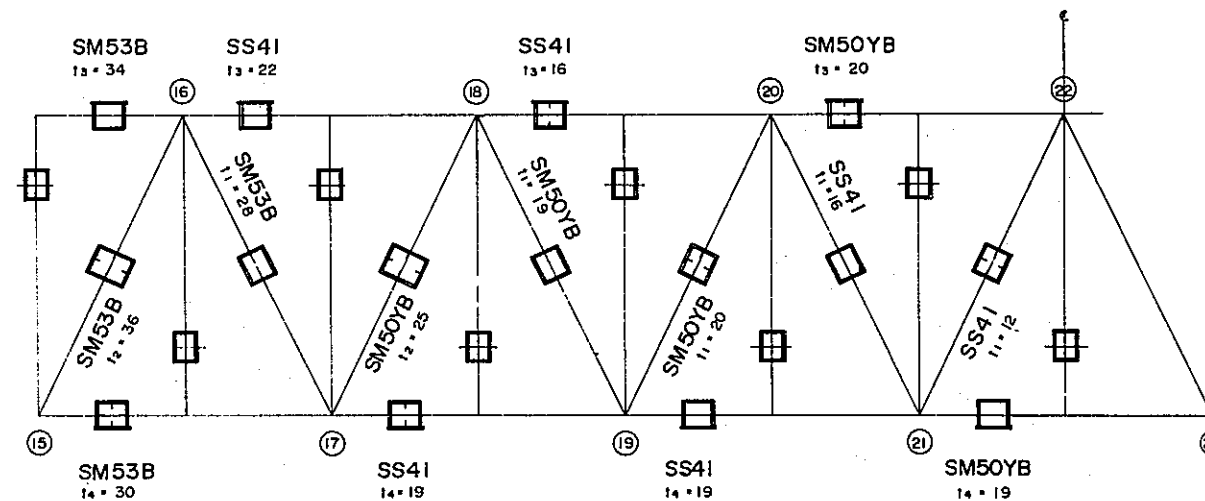


Fig. 6-11-2 Stress Sheet for Main Truss(2)

G₂ - MAIN TRUSS SCALE: SKELETON 1:600
(RAILWAY SIDE) DETAIL 1:200

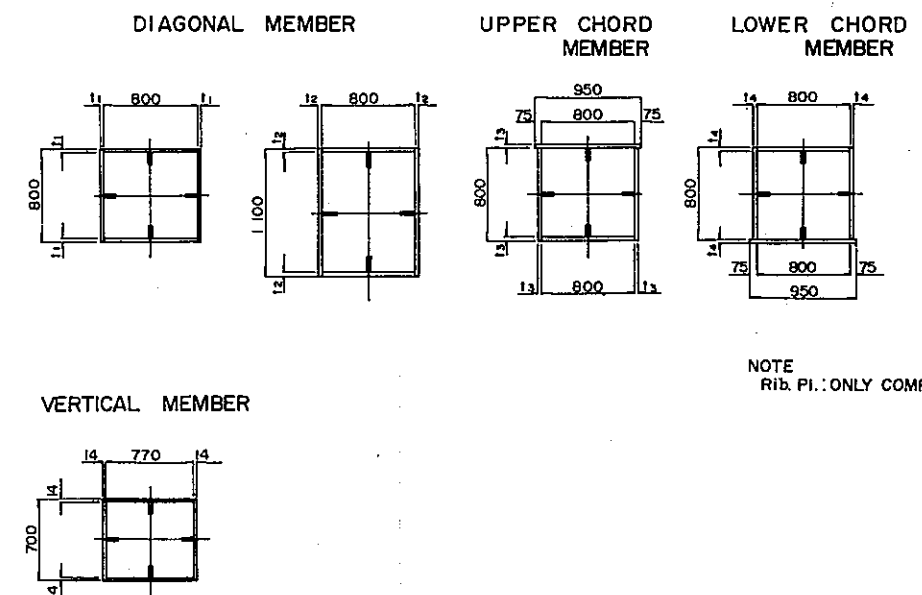


MEMBER	1-2	1-3	2-3	2-4	3-4	3-5	4-5	4-6	5-6	5-7	6-7	6-8	7-8	7-9	8-9	8-10	9-10	9-11	10-11	10-12	11-12	11-13	12-13	12-14	13-14	13-15	14-15	14-16
AXIAL FORCE ton	-1228	523	1228	-1045	-759	1352	759	-1666	-334	1756	334	-1857	416	1735	-416	-1625	839	1285	-839	-971	1361	428	-1366	678	1845	-1845	2110	1139
AREA cm ²	1064	469	640	737	896	737	608	1139	448	938	384	1273	384	938	608	1139	704	737	960	737	704	469	1140	737	960	8375	1520	1139
I _x / r _x	61.31	37.80	81.01	37.78	81.62	37.78	80.94	37.72	80.56	37.75	80.38	35.66	80.38	37.75	80.94	37.72	81.16	37.78	81.78	37.78	81.16	37.80	61.38	37.78	81.78	37.76	61.77	37.72
I _y / r _y	41.36	37.16	43.36	36.91	43.03	36.91	43.40	36.53	43.59	36.71	43.67	34.44	43.67	36.71	43.40	36.53	43.28	36.91	42.96	36.91	43.28	37.16	41.27	36.91	42.96	36.81	40.86	36.53
ACTUAL STRESS kg/cm ²	1154	1115	1918	1418	847	1834	1248	1463	746	1872	870	1459	1083	1850	684	1427	1192	1744	874	1318	1933	913	1198	920	1922	1385	1214	1853
ALLOWABLE STRESS kg/cm ²	1390	1400	2100	1743	1075	2100	1400	1744	891	2100	1400	1775	1400	2100	888	1744	1400	2100	1073	1743	2100	1400	1389	1400	2100	1744	1383	2100



MEMBER	15-16	15-17	16-17	16-18	17-18	17-19	18-19	18-20	19-20	19-21	20-21	20-22	21-22	21-23
AXIAL FORCE ton	-1603	-1446	1603	854	-1125	-577	1125	-537	-586	743	586	-961	-181	954
AREA cm ²	1368	1005	896	737	950	6365	608	536	640	6365	512	670	384	6365
I _x / r _x	61.61	37.74	81.62	37.78	61.19	37.79	80.94	37.80	81.01	37.79	80.71	37.78	80.38	37.79
I _y / r _y	41.03	36.65	43.03	36.91	41.47	36.99	43.40	37.09	43.36	36.99	43.51	36.91	43.67	36.99
ACTUAL STRESS kg/cm ²	1172	1439	1789	1159	1184	907	1850	1002	916	1167	1145	1434	500	1499
ALLOWABLE STRESS kg/cm ²	1386	1744	2100	1400	1392	1251	2100	1250	1085	1400	1400	1743	893	1990

SECTION SCALE 1:60

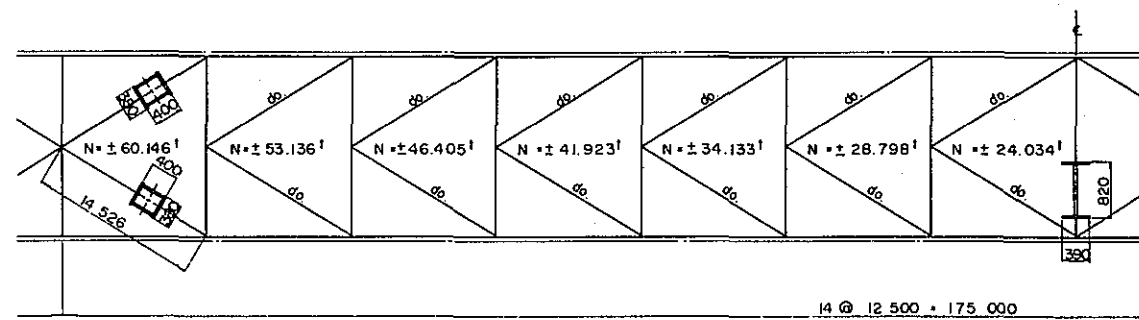
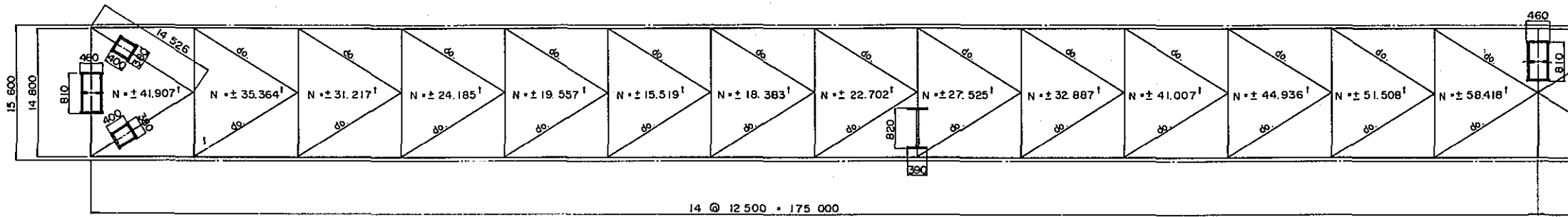


NOTE
Rib. Pl.: ONLY COMPRESSION MEMBER

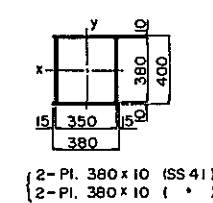
Fig. 6-12 Stress Sheet for Lateral Bracing and Sway Bracing

UPPER LATERAL BRACING

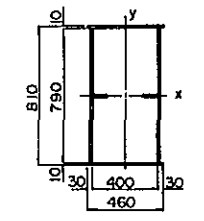
SCALE SKELETON 1:600
DETAIL 1:100



UPPER LATERAL

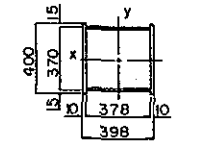


$A_g = 152.0 \text{ cm}^2$
 $I_x = 38,044 \text{ cm}^4$
 $I_y = 31,109 \text{ cm}^4$
 $r_x = 15.8 \text{ cm}, r_y = 14.3 \text{ cm}$
 $i_f = 103$

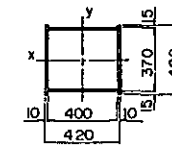


$A_g = 250.0 \text{ cm}^2$
 $I_x = 229,373 \text{ cm}^4$
 $I_y = 82,623 \text{ cm}^4$
 $r_x = 30.3 \text{ cm}, r_y = 18.2 \text{ cm}$
 $i_f = 86$

SWAY BRACING (SW-1)



$A_g = 155.6 \text{ cm}^2$
 $I_x = 35,154 \text{ cm}^4$
 $I_y = 39,110 \text{ cm}^4$
 $r_x = 15.0 \text{ cm}, r_y = 15.9 \text{ cm}$
 $i_f = 69$

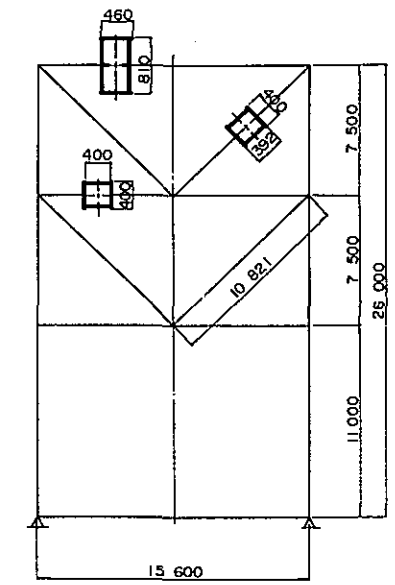


$A_g = 160.0 \text{ cm}^2$
 $I_x = 36,587 \text{ cm}^4$
 $I_y = 42,667 \text{ cm}^4$
 $r_x = 15.2 \text{ cm}, r_y = 16.3 \text{ cm}$
 $i_f = 96$

PORTAL BRACING

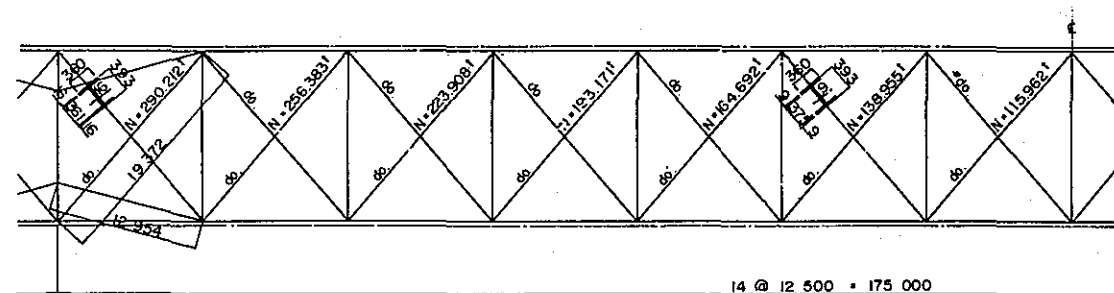
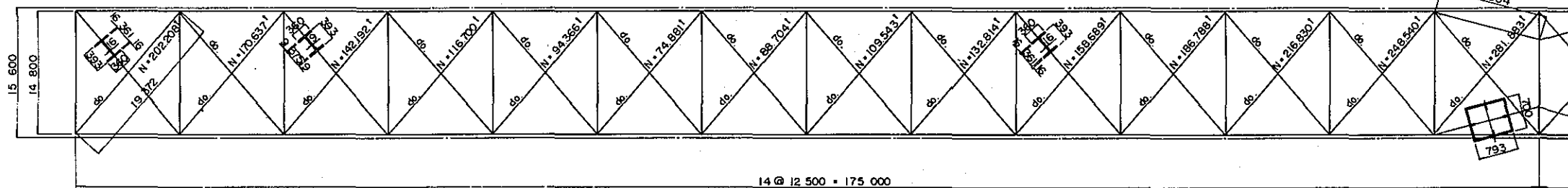
SCALE 1:400

SW-1

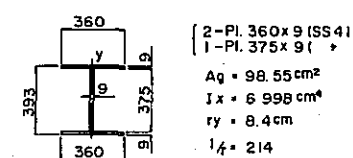


LOWER LATERAL BRACING

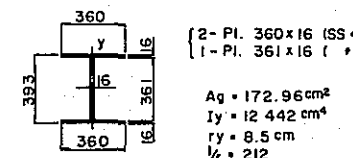
SCALE SKELETON 1:600
DETAIL 1:100



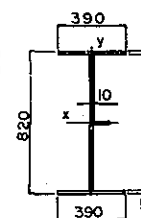
LOWER LATERAL



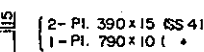
$A_g = 98.55 \text{ cm}^2$
 $I_x = 6,998 \text{ cm}^4$
 $r_y = 8.4 \text{ cm}$
 $i_f = 214$



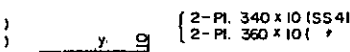
$A_g = 172.96 \text{ cm}^2$
 $I_y = 12,442 \text{ cm}^4$
 $r_y = 8.5 \text{ cm}$
 $i_f = 212$



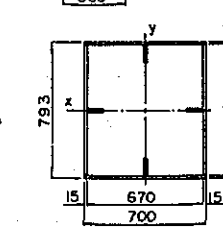
SWAY BRACING (SW-2, SW-3)



$A_g = 196.0 \text{ cm}^2$
 $I_x = 189,547 \text{ cm}^4$
 $I_y = 14,837 \text{ cm}^4$
 $r_x = 31.1 \text{ cm}, r_y = 8.7 \text{ cm}$
 $i_f = 90$



$A_g = 140.0 \text{ cm}^2$
 $I_x = I_y = 28,601 \text{ cm}^4$
 $r_x = r_y = 14.29 \text{ cm}$
 $i_f = 109$

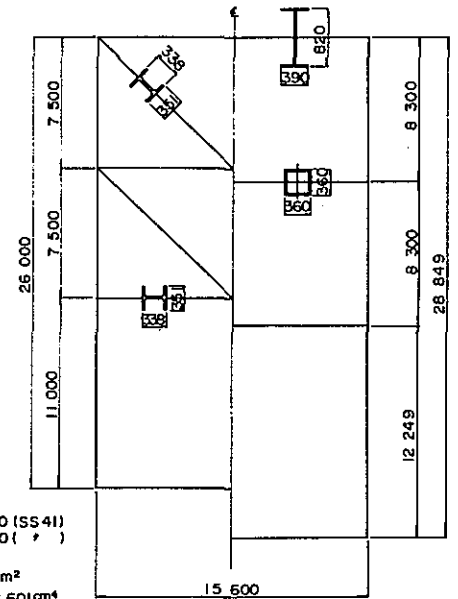


$A_g = 438.9 \text{ cm}^2$
 $I_x = 428,852 \text{ cm}^4$
 $I_y = 354,264 \text{ cm}^4$
 $r_x = 31.2 \text{ cm}, r_y = 28.4 \text{ cm}$
 $i_f = 41$

INTERMEDIATE SWAY BRACING

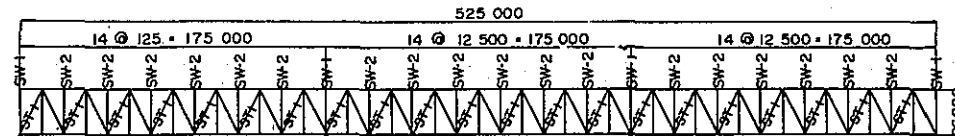
SCALE 1:400

SW-2 ST-1



MARKING DIAGRAM

SCALE 1:4,000



2.13. Bearing shoe

Since it was decided to fix this bridge by 2 piers with stoppers in bridge axial direction, all of bearing shoes took movable shoes and multi-roller bearing shoes were adopted. The design reaction is as large as $R = 3467$ tons at intermediate supporting point and $R = 1315$ tons at end-supporting point, and for promoting minimization of each member, of the support shoes, cast steel was used. Further, concrete for the crown height of pier was decided at $\sigma_{28} = 210 \text{ kg/cm}^2$. Approximate dimensions of shoe are shown in Appendix 6-14.

2.14. Deflection.

This bridge is a railway-cum-road bridge having a large vertical deflection due to live load. Specification for deflection by live load are based on the following.

Main trusses	}	Standard Specifications for Railway Bridges (Japan Society of Civil Engineers)
Lateral bracings		
Stringers for railway portion		
Stringers for road portion		Standard Specifications for Highway Bridges (Japan Road Association)

Tables 6-3-1~2 indicates deflection by live load.

3. Substructure.

3.1. Outline.

Contents reported in this chapter are related to the substructure works of Jamuna River bridge of the construction project, and in due consideration of scale of bridge piers, circumstances of bridge site, river and geological conditions, workability and economics, a brief description was made by each item on the process, in which the structural type was selected and data were determined, and main fundamental structure was made clear. At the same time, as to the design load by a combination of external forces such as load transferred from the superstructure, current water pressure and dynamic water pressure, the design calculation was given based on the determined structural type, shape, dimension and modulus of subgrade reaction, and from the forces to act pier shafts, a bar arrangement was prepared and based on the stability calculation of well foundation and sectional calculation, a rough plan of bar arrangement of each well portion was laid out.

Further, regarding the execution of substructure works, since it is a work centered in and around the dry season, the land area works will adopt the normal well method but the stream area is being planned, from its workability, steel-made-caisson method and prestressed concrete structure by precast concrete block. Investigations were carried out on these circumstances.

Design of pier shaft and foundation well was made on the intermediate pier, end pier and abutment-pier.

The design was given based on the above stated in CHAPTER V, 2. Design Conditions and Criteria, and structural dimensions and design conditions which will be stated later.

Table 6-3-1 Deflection of Main Truss by Live Load

Description	Deflection		Total	Allowable deflection
	Road	Railway		
Maximum deflection of side span				
for road side truss	40.1	32.7	72.8	175
for railway side truss	21.5	125.1	146.6	175
Maximum deflection of intermediate span				
for road side truss	36.9	31.7	68.6	175
for railway side truss	19.7	121.3	141.0	175

Allowable deflection $\delta a = L/1000 = 175/1000 = 0.175 \text{ m} = 175 \text{ mm}$

Table 6-3-2 Deflection of Floor System by Live Load

Description	Calculated deflection	Allowable maximum deflection	Unit: mm	
			Remarks	
Stringer of road portion	7.3	7.8	$\delta a = L^2/20,000 = 12.5^2/20,000$	
Stringer of railway portion	3.3	15.6	$\sigma a = L/800 = 12.5/800$	
Cross beam	4.8	5.0		

Note: L means Span length.

3.2. Design conditions.

Type: Reinforced concrete pier-shaft shaped inverted triangle
Circular foundation well made of reinforced or prestressed concrete

Dimension: Pier-shaft: Thickness 7 m
Well : Diameter 13 m, Thickness of wall 2.2 m
or 2.5 m

Design High Water Level (DHWL): +15.25 m PWD
Mean Lowest Low Water Level (MLLWL): +6.22 m PWD
Design River Bed (DRB): -24.50 m PWD

Maximum Mean Velocity: 4.0 m/sec

Local Scouring Depth around Pier: 1.8 times of water depth from water surface

Acceleration of Earthquake: Horizontal component 0.1 G
Vertical component 0

Internal Friction Angle of Earth: Natural soil $\phi=30^\circ, 35^\circ$
Banked soil $\phi=30^\circ$

Unit Weight: Reinforced concrete: $\gamma_c=2.5 \text{ t/m}^3$
Earth and sand (natural): $\gamma_s=2.0 \text{ ''}$
" (in water): $\gamma'=1.0 \text{ ''}$

Strength of Materials:

Reinforced concrete:

28-day compressive strength $\delta_{28}= 210 \text{ kg/cm}^2$
Allowable bending compressive stress $\delta_{ca}= 70 \text{ kg/cm}^2$

Prestressed concrete:

28-day compressive strength $\delta_{28}= 450 \text{ kg/cm}^2$
Allowable bending compressive stress $\delta_{ca}= 150 \text{ kg/cm}^2$

Reinforcing bar:

Yielding point $\delta_{cy}=3,000 \text{ kg/cm}^2$
Allowable tensile stress $\delta_{sa}=1,800 \text{ kg/cm}^2$

Prestressing bar:

Yielding point $\delta_{py}= 110 \text{ kg/mm}^2$
Ultimate stress $\delta_{pu}= 135 \text{ kg/mm}^2$

Refer to the following for other regulations:

*Standard Specifications for Concrete.	Society of Civil Engineers
*Specifications for Substructure of Highway Bridges.	Japan Road Ass'n
*Specifications for Earthquake-Proof of Highway Bridges.	" " "
*Standard Specification for Highway Bridges.	" " "
*Standard Specifications for Railway Bridges.	Society of Civil Engineers

These specifications are authorized by the Ministry of Construction of Japan.

3.3. General dimensions.

The structural dimensions finally determined on the structure of this bridge are indicated in Figs. 6-13-1 and -2.

3.4. Loads affecting the substructures.

3.4.1. Reactions of superstructure.

Since superstructure is a railway-cum-road bridge of single deck type, load is apt to become eccentric load and, hence, the reactions differ between the main truss of railway side (downstream) and that of road side (upstream). Dead load in each main truss and live load to railway and road, and reactions due to wind velocity and seismic load are shown in Table 6-4. However, since the shoes are taken the scattering structure, to the intermediate 2 supports, 60 per cent of the horizontal force induced by earthquake of one set bridge (3-span continuous truss) is assumed as reacting on each intermediate support. The horizontal force due to temperature range is regarded as being absorbed into shoe structure and not taken into consideration.

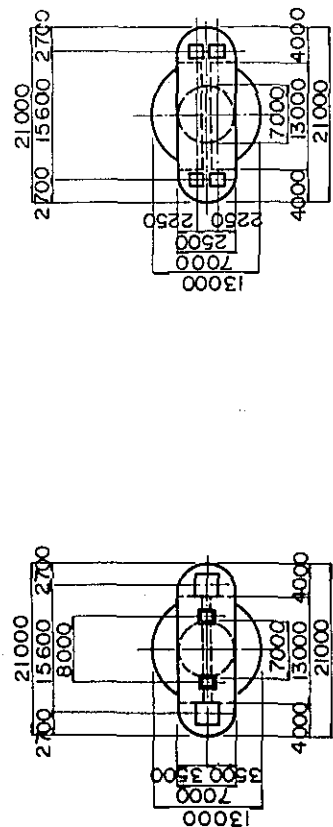
3.4.2. Dynamic water pressure during earthquake.

Structures in water are affected in complexity by water during earthquake but in designing, generally speaking, a force proportioned to vibrating acceleration of earthquake is conducted as being received as dynamic water pressure from water. Hence, here in this design it is calculated according to the following formula. However, the working direction of dynamic water pressure should be made consistent with the direction of inertia force of earthquake. (Fig. 6-14)

$$\begin{aligned} \text{In the case of } B/H \leq 2.0, \quad P &= 3/4 \cdot K_h \cdot W_o \cdot B^2 \cdot H \quad (1-B/4H) \\ \text{" " " " } B/H > 2.0, \quad P &= 3/8 \cdot K_h \cdot W_o \cdot B^2 \cdot H \end{aligned}$$

$$H_g = 1/2H$$

Let P is the total dynamic water pressure applied to structure (t),
 K_h is the horizontal seismic coefficient (≈ 0.1),
 W_o is the unit weight of water ($= 1.0 \text{ t/m}^3$),



Technical drawing of a bridge structure showing four piers (Intermediate pier B, Intermediate pier A, Intermediate pier B, Intermediate pier A) with dimensions and elevations. The drawing is divided into 'In stream' and 'On land' sections. Key dimensions include pier widths (21000, 4000, 13000), pier heights (26620, 26120), and elevations (7.220, 24.500, 56.250, 71.780). The structure is labeled 'Steel-made-caisson'.

Table 6-4 Reaction of Superstructure

1. End support

Vertical reaction

Item		Road side	Railway side	Total
Dead load		775	672	1,447
Live load	Road portion(Max.)	167	89	256
"	Railway portion(Max.)	130	499	629
Total		1,072	1,260	2,332

Horizontal force

	Longitudinal	Transverse
Dead load	72*	145*
Train load	32*	63*
Braking load	92	----
Wind load	----	215

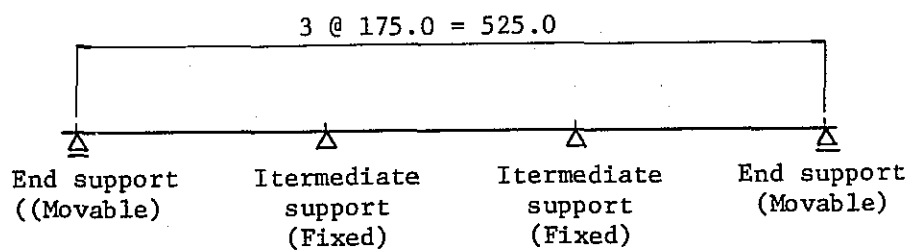
2. Intermediate support

Vertical reaction

Item		Road side	Railway side	Total
Dead load		2,110	1,829	3,939
Live load	Road portion(Max.)	402	216	618
"	Railway portion(Max.)	334	1,281	1,615
Total		2,846	3,326	6,172

Horizontal force

	Longitudinal	Transverse
Dead load	646*	394*
Train load	263*	161*
Braking load	240*	----
Wind load	----	278



Note: The figures with (*) in above table are horizontal forces induced by earthquake.

All of unit used in table are metric tons.

Let H is the water depth (m),
 Hg is the distance from the design ground level to acting point of resultant force of the total dynamic water pressure,
 B is the projected width of the structure toward the working direction of dynamic water pressure.

3.4.3. Seismic force.

As for the seismic forces, the followings are taken into consideration:

- i. Horizontal force from the superstructure during earthquake.
- ii. Dynamic water pressure against the pier shaft and foundation well during earthquake.
- iii. The inertia force by the dead weight of pier shaft and of foundation well during earthquake.

3.4.4. Earth pressure.

Earth pressure is dealt with as a distributed load which acts on the wall surface and its intensity is based on the following formula. However, at ordinary times it is based on Coulomb's theory but Mononobe-Okabe theory is applicable during earthquake. (Fig. 6-15)

(1) Normal earth pressure

$$P_a = \gamma_s \cdot K_a \cdot X + K_a \cdot q$$

$$K_a = \frac{\cos^2 \phi}{\cos \delta \left[1 + \sqrt{\frac{\sin(\phi + \delta) \sin \phi}{\cos \delta}} \right]^2}$$

(2) Earth pressure during earthquake

$$P_a = \gamma_s \cdot K_{ea} \cdot X$$

$$K_{ea} = \frac{\cos^2 (\phi - \theta_o)}{\cos^2 \theta_o \left[1 + \sqrt{\frac{\sin \phi \sin (\phi - \theta_o)}{\cos \theta_o}} \right]^2}$$

where, γ_s : the bulk density of earth (t/m^3),
 P_a : the active earth pressure in depth X (t/m^3),
 K_a : the active earth pressure coefficient by Coulomb's theory,
 X : the depth in which earth pressure P_a acts on the wall surface (m),
 q : the intensity of surcharge at ordinary times (t/m),
 K_{ea} : the active earth pressure coefficient during earthquake,
 ϕ : the angle of internal friction of earth.

Fig. 6-14 Distribution of Dynamic Water Pressure during Earthquake

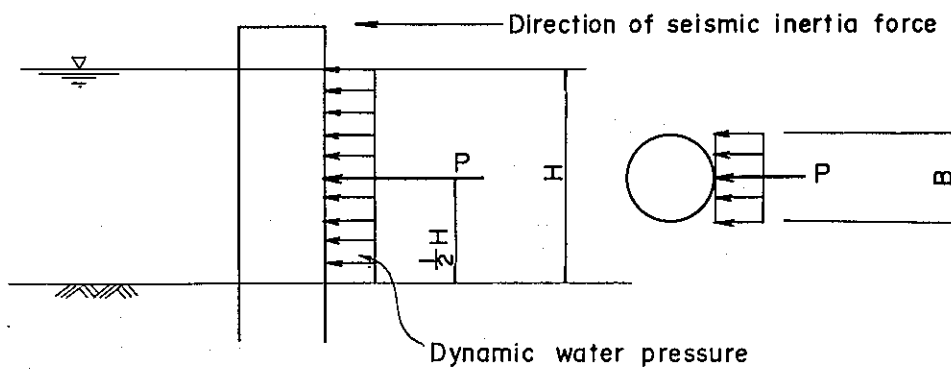
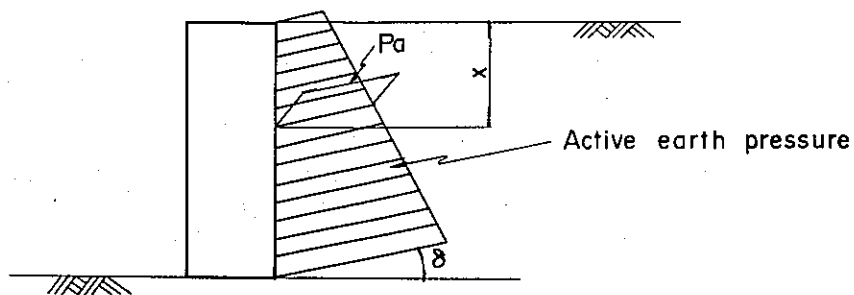


Fig. 6-15 Distribution of Active Earth Pressure during Earthquake.



δ : the angle of wall friction between the wall and soil,
 θ_0 : $\tan^{-1}K_h$,
 K_h : the lateral seismic coefficient of earthquake (= 0.1).

3.4.5. Combination of design load.

As to the combination of load, the following cases should be taken into consideration.

Case 1 : $D + LC + LT + (C)$
Case 2 : $D + LT + W + (C)$
Case 3 : $D + LT + B + (C)$
Case 4 : $D + E + (C)$
Case 5 : $D + LT + E + (C)$

where, D : Dead load,
 LC : Live load (Roadway),
 LT : Live load (Railway),
 W : Wind load,
 B : Braking load,
 E : Seismic load (including dynamic water pressure),
 C : Current water pressure.

The current water pressure and dynamic water pressure are external forces that acts only on the substructure, and each of them has two values, namely at high water level and at low water level, respectively. The external forces applied on the top of piers are shown in Table 6-5.

3.5. Soil foundation.

3.5.1. Properties of soil foundation.

As to the properties of soil foundation, the Geological Survey Team conducted actual surveys at the bridge site for a 2-year period from 1974, and hence, the results of the team's investigation were utilized. Since the results of surveys were given in Fig. 6-16, the values referred to the figure were used.

3.5.2. Modulus of foundations.

The moduli of foundation were calculated from the moduli of deformation of soil against various ground heights as shown in Fig. 6-17.

3.5.3. Allowable bearing power.

The allowable bearing capacity of the bearing layer for foundation well is calculated at each effective embedment depth of the well when the angle of internal friction is supposed at $\phi=35^\circ$ and $\phi=40^\circ$ as shown in Fig. 6-18.

Table 6-5 Working Forces from Superstructure to Substructure

1. End support

	Vertical force			Horizontal force	
	G1	G2	Total	Longitudinal	Transverse
Case-1	2118	2483	4601	---	---
Case-2	1803	2315	4118	---	215
Case-3	1803	2315	4118	184	---
Case-4	1550	1344	2894	144	290
Case-5	1803	2315	4118	206	413

2. Intermediate support

	Vertical force			Horizontal force	
	G1	G2	Total	Longitudinal	Transverse
Case-1	2846	3326	6172	---	---
Case-2	2444	3110	5554	---	278
Case-3	2444	3110	5554	240	---
Case-4	2110	1829	3939	646	394
Case-5	2444	3110	5554	909	555

In the above mentioned cases, the following combinations of several loads were considered.

- Case-1 D + LC + LT
- Case-2 D + LT + W
- Case-3 D + LT + B
- Case-4 D + E
- Case-5 D + LT + E

Where, D: Dead load(t),
 LC: Live load on road portion(t),
 LT: Live load on railway portion(t),
 WW: Wind load(t),
 B: Braking load(t),
 E: Seismic force during earthquake(t),

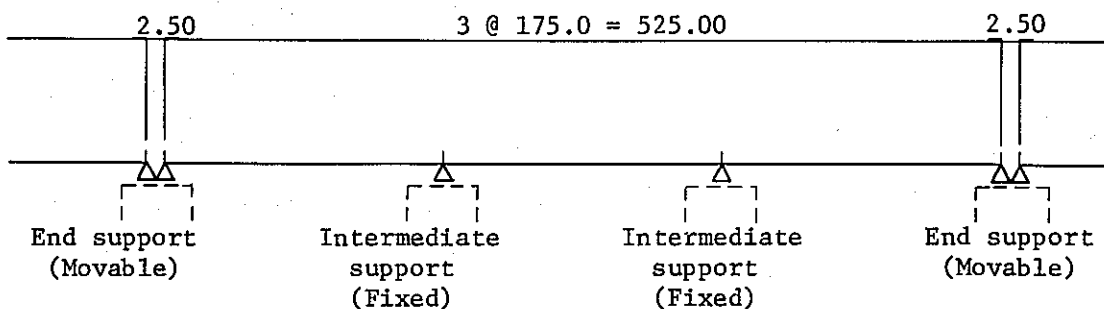


Fig. 6-16 Soil Mechanical Properties of Foundation at Bridge Site (Sirajganj Site)

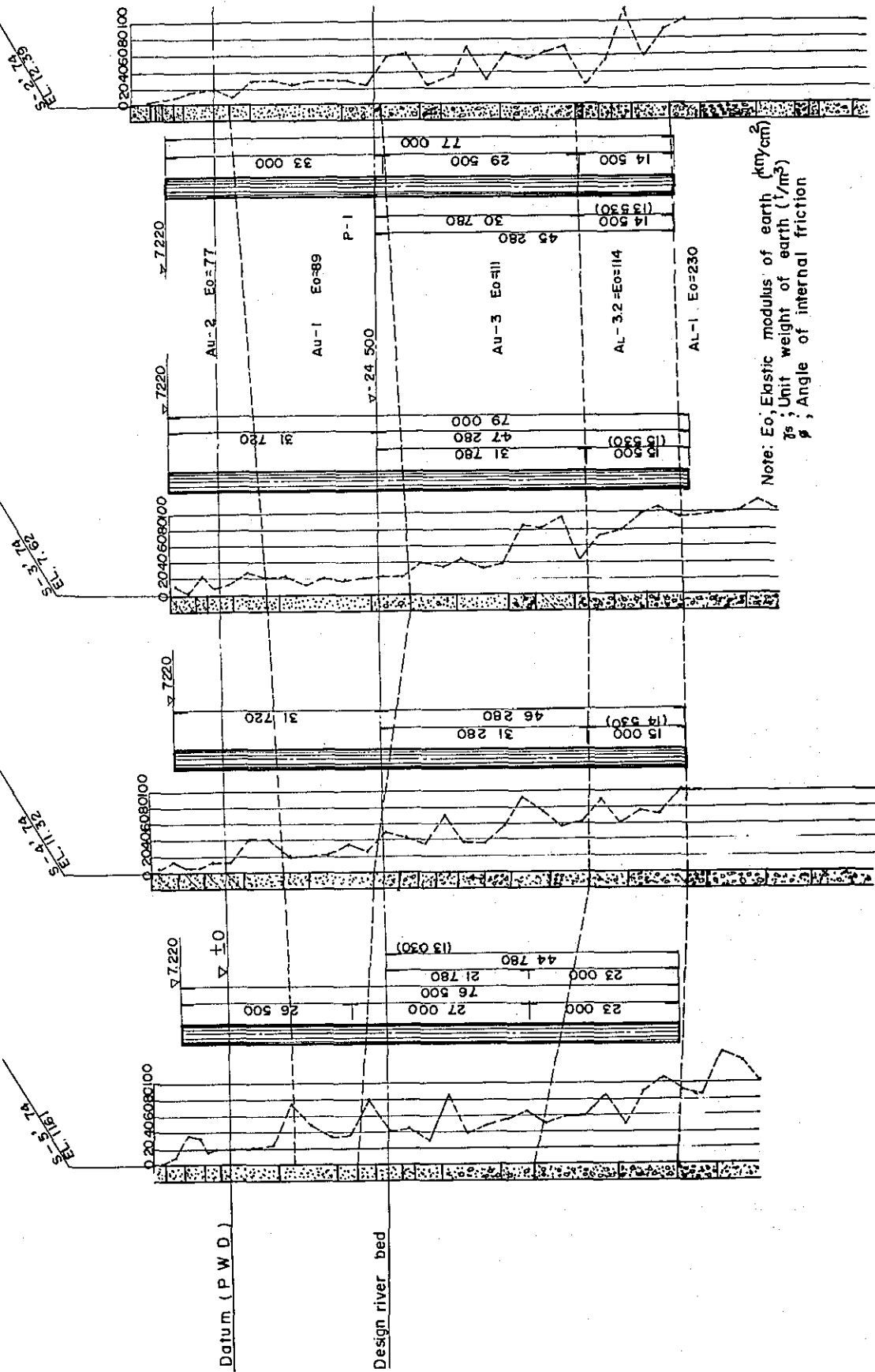
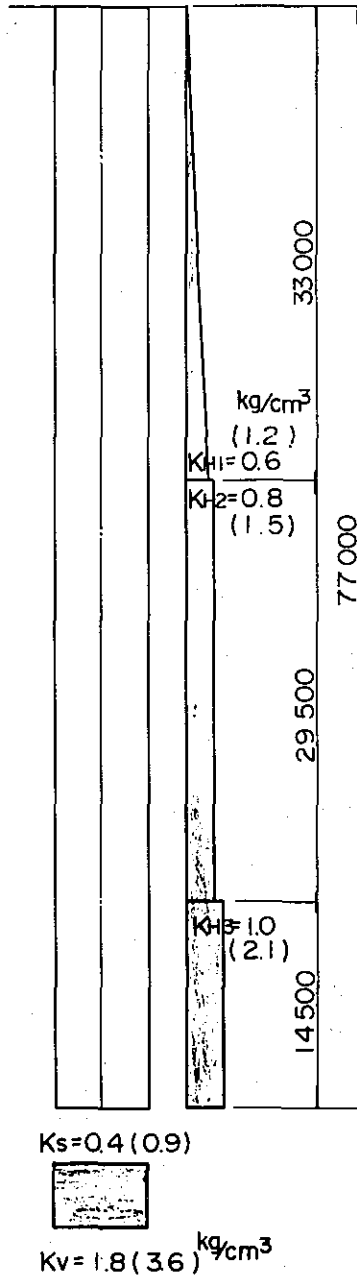


Fig. 6-17 Modulus of Foundation

For end pier foundation



For intermediate pier foundation

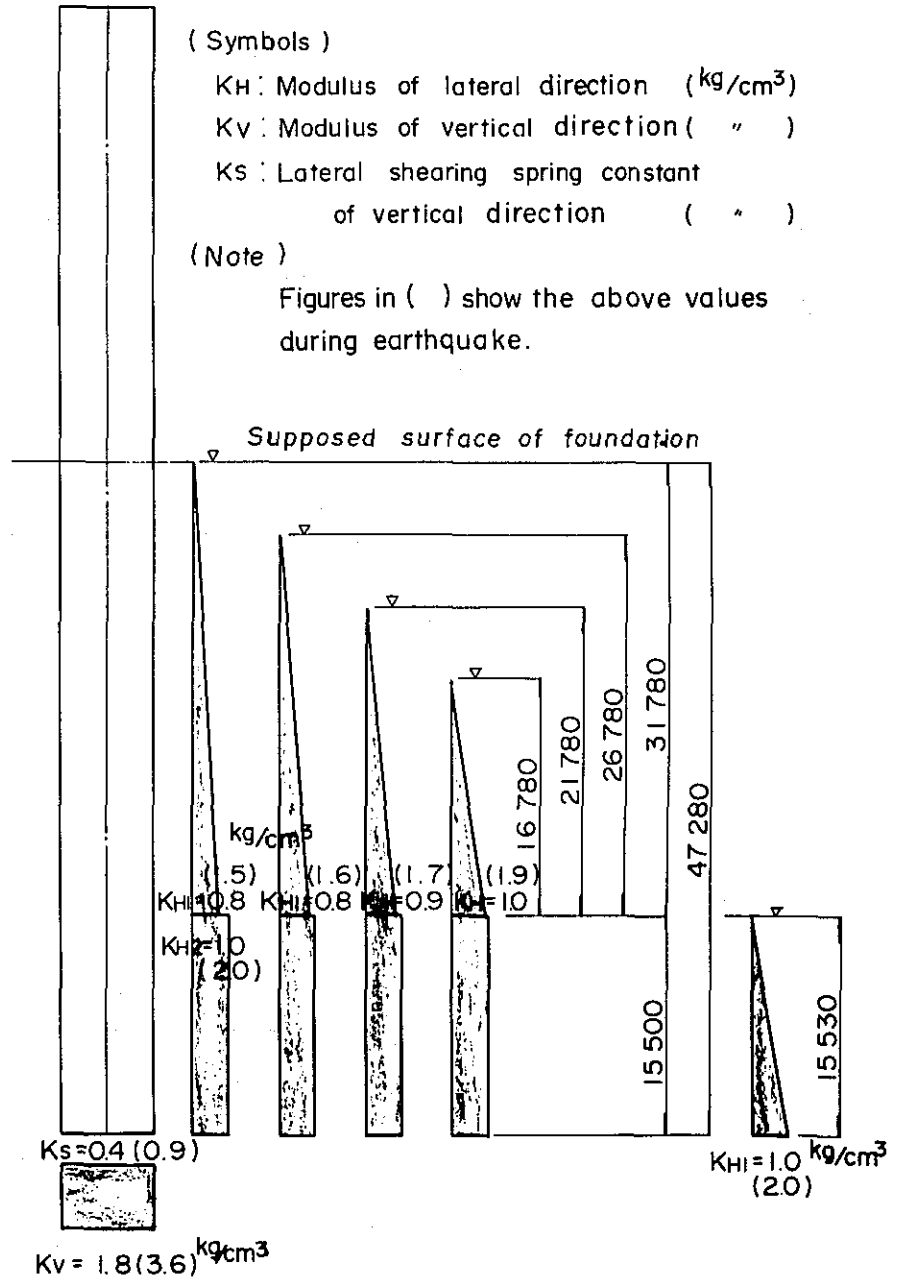
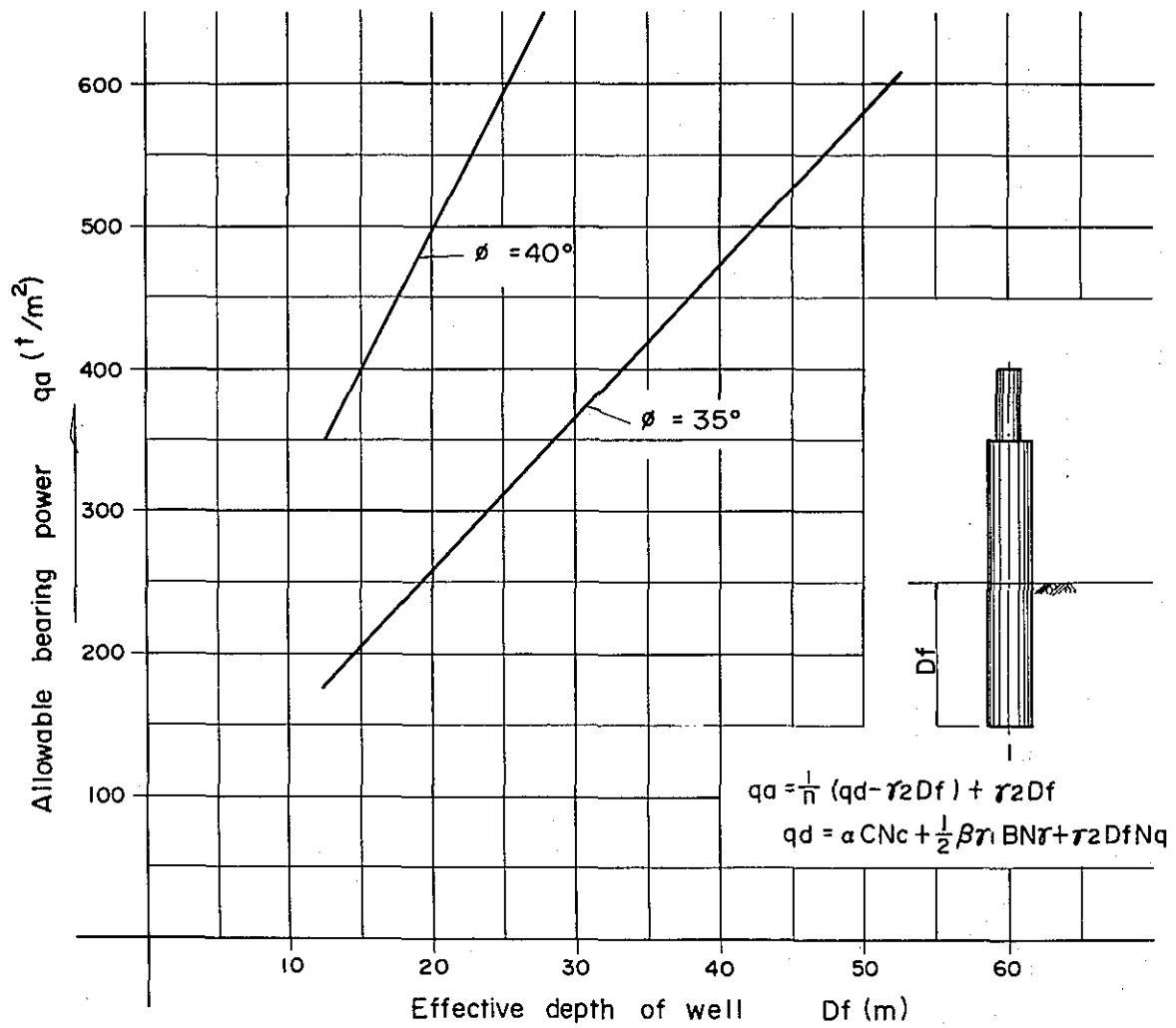


Fig. 6-18 Relation between Allowable Bearing Power and Effective Depth of Well



3.6. Selection of structural dimension.

3.6.1. Well foundation.

The structural dimension of the well foundation was decided at 12m in outside diameter through investigations which were made in the preliminary design at the first stage.

However, as a result of further study in the second stage, the outside diameter of the well was finally determined at 13 meter, in due consideration of its workability, structural function and stability, and in due regard paid to the required section of bottom of pier-shaft, the eccentricity of well during sinking and scrupulous cares for the safety side of bearing capacity on the bed layer.

The allowable maximum eccentricity during sinking of well was expected $1/50$ of the well length.

There are two sorts of well foundations in its loading conditions, namely abutment and piers. The other hand, from viewpoint of the construction method, the well foundations are classified into executions on land and in stream. However, providing for a case when the river may be expanded in its width in future, the abutments were endowed with a function of pier as the abutment-piers. Consequently, the shape of foundation of abutment-piers is all the same to piers. It is proper that the earth pressure was considered for the abutment-piers.

The wall thickness of well should be determined not only by design stress but also required total weight of well itself for the sinking in excavation. In this case, the wall thickness was determined by the total weight of well rather than design stress. Therefore, in this design, the wall thickness of well was decided on the premise that it will sink naturally by the weight of well itself as much as possible. As a result, the thickness of well was determined at 2.5m thick on land and at 2.2m thick in stream.

As the dry season was chosen for the construction period of the substructure, steel-made-caisson was adopted for lower portion of well in the stream area seen from a viewpoint of execution and erection schedule but as a precaution for the stability of steel-made-caisson for the scour on the river bed, the length was decided to be 19m including an allowance for the scouring depth of 1.8 times of the water depth during execution on the most dangerous side. Also in the same reason to reduce the construction period for the upper portion of well in the stream area, precast concrete ring blocks (4.0m high) of plant manufacture are used and the well is constructed by piling upon and prestressing to block one by one.

The shape of curb shoe of well was decided at 5.0m height paying due regard to the thickness of well, the shape and dimension of bottom concrete slab and external force, and the end of curb shoe was decided to be 0.3m thick from a structural precaution. The curb shoe was provided in the inside surface with tapers and friction cuts were made on the outside. For concrete of the bottom slab, prepacked concrete was applied and also its thickness was decided at 5m as same as height of the curb shoe.

The top slab requires a 5m-thickness for conveying loads charged to the pier shaft accurately to the well. The parapet wall is required to be 0.8m thick and over the parapet a 6.0m thick coffering wall is installed to cope with the rise of river.

Moreover, the crown height of the well was decided at EL=+7.22, one meter higher than MLLWL +6.22m in due consideration of execution.

3.6.2. Pier shaft.

The pier shaft is required to be a structure that will convey with ease the loads from the superstructure to the foundation. This superstructure has a dead load of approx. 4,000 tons of reaction and live load of approx. 2,000 tons, comparatively larger, while during earthquake since a bending moment of maximum approx. 16,000 t.m acts to the bottom of pier and in due consideration of these working loads and also for exterior view, a structure that will stand these premises was determined.

The space between main trusses of the superstructure is 15.6m and the bottom of pier needs 7m in diameter at least, the pier naturally has a front form of reversed triangle. Consequently, it is capable of supporting only by triangular frame as a shape and it may also decrease its net weight but as a precaution against water flow, the pier was with concrete filled up to DHWL + 15.25m and on the upper part in due regard paid to structure and materials, a partition wall of 1m in thickness was made for securing the absolute safety of the pier as a statically determinate structure. Moreover, in due consideration of the space between main trusses and shoe arrangements, the top surface of piers was applied the oblong with 21m in long diameter and 7m in short.

The abutment-piers at both ends, having a function to serve as abutment, are made similar in appearance to other piers but as earth pressure will affect, they are made 8.0m wide in diameter at bottom of shaft.

3.7. Stability calculation of well foundation.

Investigations were conducted on the stability calculation as to the load situation including ordinary times and instances during earthquake which can be suspected by every conceivable means. As to the object of investigation, the well of abutment-pier, the wells of intermediate pier and end pier on land, and the wells of intermediate pier and end pier in stream, totalling 5 wells were chosen.

Through investigations given by the River Control Study Team, it has been concluded that the lowest river bed level of the Jamuna River is -24.5m (PWD), even after the guide bank was built, and it is required to design on the assumption that there is always a danger to be this depth at any place in streams between left and right of the guide bank. Hence, the above lowest river bed was adopted as the design river bed (DRB).

According to the Reports of River Control Study Team, it was reported that the local scouring depth around piers will reach to

1.8 times of water depth under the water surface. The design high water level is +15.25m PWD, and the other hand the height of bed by local scouring reaches -56.3m PWD.

From the above mentioned conditions, the results were obtained that well foundations will be stable in usual time but cannot stabilize during earthquake without any artificial protection against the local scouring. Base on the conclusion, as to the local scouring, design was made to prevent scouring on the premises that riprapping will be applied up to the height of the design river bed. Moreover, investigation was conducted as to a situation in which local scouring already occurred to some extents.

As regards the wells of abutment-piers, since they will be built on land side of the guide banks, further investigation was made by dealing these piers as not affected by local scour but receiving earth pressure.

As a result of the above investigation, it is perfectly safe at ordinary times, even if the local scour is allowed but the piers are only safe against the scoured depth up to approx. 13m when the lateral seismic acceleration is 0.1G. Therefore, against local scour, it is recommended to fix limits requiring protection by means of riprapping, that is to fix a guard line at a height of -35.0m PWD, approx. 10m below the design river bed height of -24.5m PWD. And then the riprapping shall be applied to the extent reaching the river bed in the necessary protection zone. Results of above stability calculations of well foundation are given in Figs. 6-19-1 and -2.

3.8. Section determinations.

3.8.1. Foundation well.

As a result of calculation, the bending moments and normal forces acting longitudinal section of the well are shown in Figs. 6-20-1 and -2. However, considering a difference in execution methods, the wells for abutment-piers and those executed on land were decided to be reinforced concrete structure but the wells in stream are prestressed concrete structure. Number of reinforcing bars and prestressing bars required for wells is given in the above figure.

The number of reinforcing bars required for other sections of the well are shown in Figs. 6-21 and -22. Further, the bar arrangements drawing of main cross sections are shown in Figs. 6-23-1~3 and Fig. 6-24.

3.8.2. Pier shaft.

Investigation was made as to the load situation described in 2.4.5. for the safety at ordinary times and during earthquake, and particularly the designing sections of the bridge axial direction and orthogonal direction of bridge axis are shown in Fig. 6-25.

As a result, main reinforcement of sections are shown in Fig. 6-26. Moreover, the bar arrangement drawings of intermediate supports to be executed in the land area are given in Figs. 6-27-1, 2, and Fig. 6-28 deals with parapets and wings of abutments.

3.8.3. Steel-made-caisson.

It was already stated that the well to be constructed in the stream area should be the steel-made-caisson up to the 19m height from the cutting edge and accordingly it was decided to design the steel-made-caisson based on the following instructions.

At the time of execution, the steel-made-caisson should be hung up by filling up concrete in the 5m high from the cutting edge which weighs approx. 700 tons by its dead load. As the hanging method, an 8-point hanging was adopted, and the longitudinal truss is made at 8 points along the circumferential direction and for the sake of safety, the overhanging load per one point was designed at 100 tons, for which the longitudinal beams and metal fittings for hanging purpose were designed. Moreover, for water pressure and concrete pressure, steel plates and horizontal ring were designed, and examination was also made on the horizontal truss.

Based on the above examination results, a sketch drawing of steel-made-caisson is indicated in Fig. 6-29.

4. Embankment of Bridge Approaches.

As shown in Fig. 5-5, the length of embankment on the bridge approaches is 5.1km each both right and left banks. Elevation of the existing ground level is approx. 11.50m PWD and elevation of the top on the design embankment near the abutment becomes 30.58m. Therefore, height of the embankment on the highest embankment section is approx. 19.0m.

The shape of typical cross section of embankment requires a berm each time when the banking exceeds 7.0m in height and the berm was arranged to be 10.0m wide. Hence, the berm becomes two steps in the case of 19.0m of banking height. This formula was determined based on the actual circumstances of banking in the past and for the stabilization of the banking near the bridge approaches.

The banking materials for the embankment on the approaches are using sand taken by dredging from river bed and char, and upper layer soils (silty sand) of around downstream side at the embankment on the approaches. The former mostly consists of fine sand and there is no anxiety as a banking material but in case the latter is used for this purpose, the Geological Survey Team estimated its values as shown in Table 5-4.

Furthermore, as the foundation ground, values are indicated in Table 5-3, naming them strata No. 1, No. 2 and No. 3, counting from the ground surface. It is reported that this foundation ground poses no problem regarding the effects of land subsidence for high embankments.

According to the results of the stability analysis of the embankment by the circular arc method to take up the highest cross section as the gradient of slope is 1:2.5, the minimum factor of safety was obtained as 1.27 in consideration of the surcharge by trains and vehicles. This means that the section of this embankment will have the enough safety. The results of stability analysis were shown in Fig. 6-30.

As shown above, the stability of the embankment was confirmed but piles should be driven at the back of abutment-pier because of loads of embankment will be transferred directly to a favourable supporting layer.

A range driven piles shall be set on the rear side of the abutment-pier and located at 40m in the bridge axial direction and at 100m in the orthogonal direction. The piles are of reinforced concrete and the cross section is a regular square in shape with each side of 40cm in length and the overall length of a pile shall be 12m. The piles shall be driven at intervals of 1.0m and the pile head must have a design of +15.0m PWD.

5. Design Quantity of Materials.

Based on the results of design calculation of the superstructure, the substructure and the embankment on approaches, the design quantities were determined by each item as follows:

As to the superstructure, materials required for one set of 3-span continuous truss were shown in Table 6-6 and those for one entire bridge were given in Table 6-7.

As regards the substructure, the design quantities classified by the land area and the stream area were given in Table 6-8. The design quantities of materials for embankment on approaches were shown in Table 6-9. The soil volume was itemized in Table 6-10 while Table 6-11 deals with an area of the land acquisition for embankment.

The total railway length over the bridge and approaches is 15km and since materials needed for this area is determined by the Railway Survey Team, they are shown in Table 6-12.

Fig. 6-19-2 Diagram of Necessary Length of Embedment and Guard Line

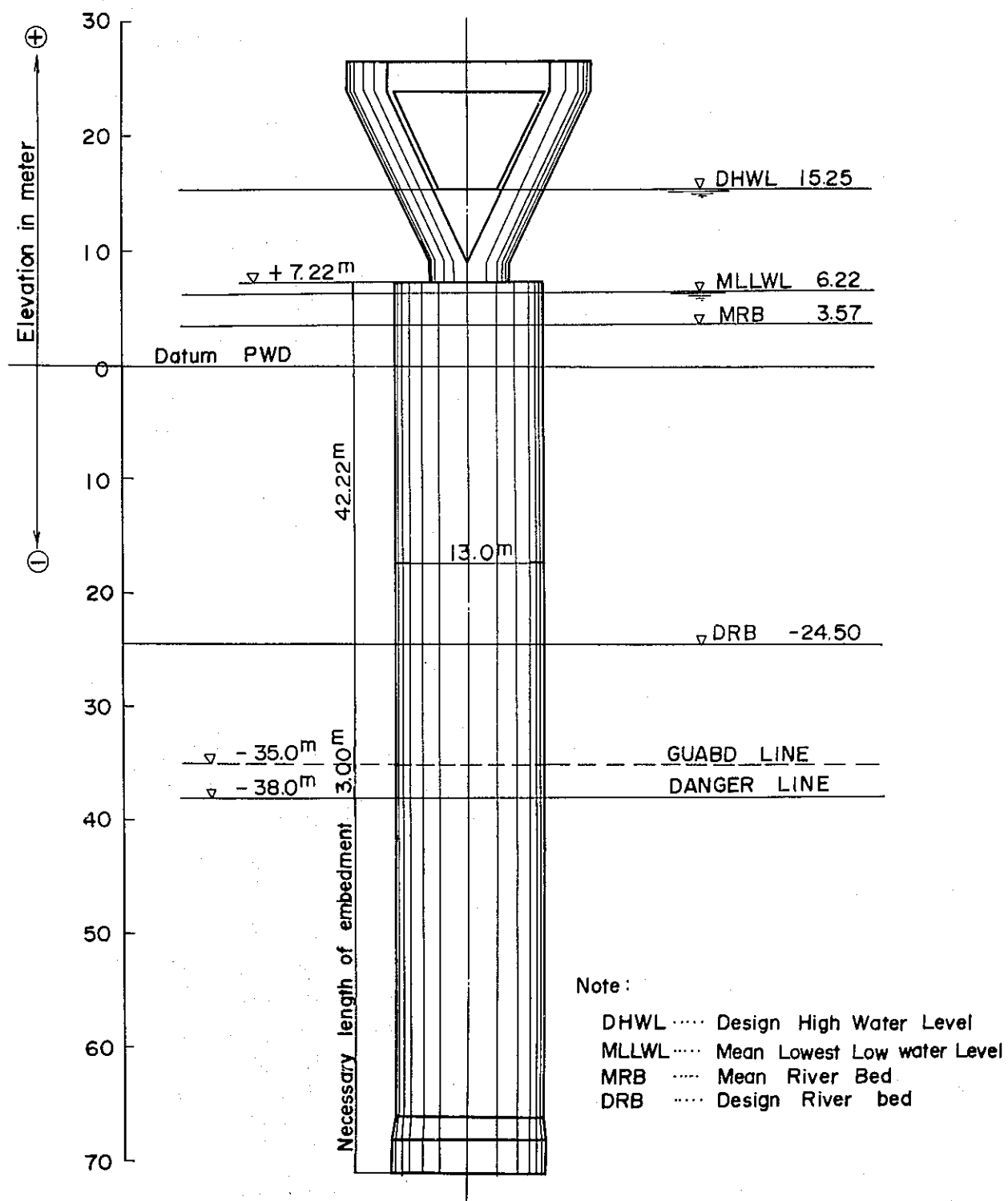


Fig. 6-20-1 Bending Moment and Axial Force Diagram and Necessary Number of Reinforcing and Prestressing Bars for Piers

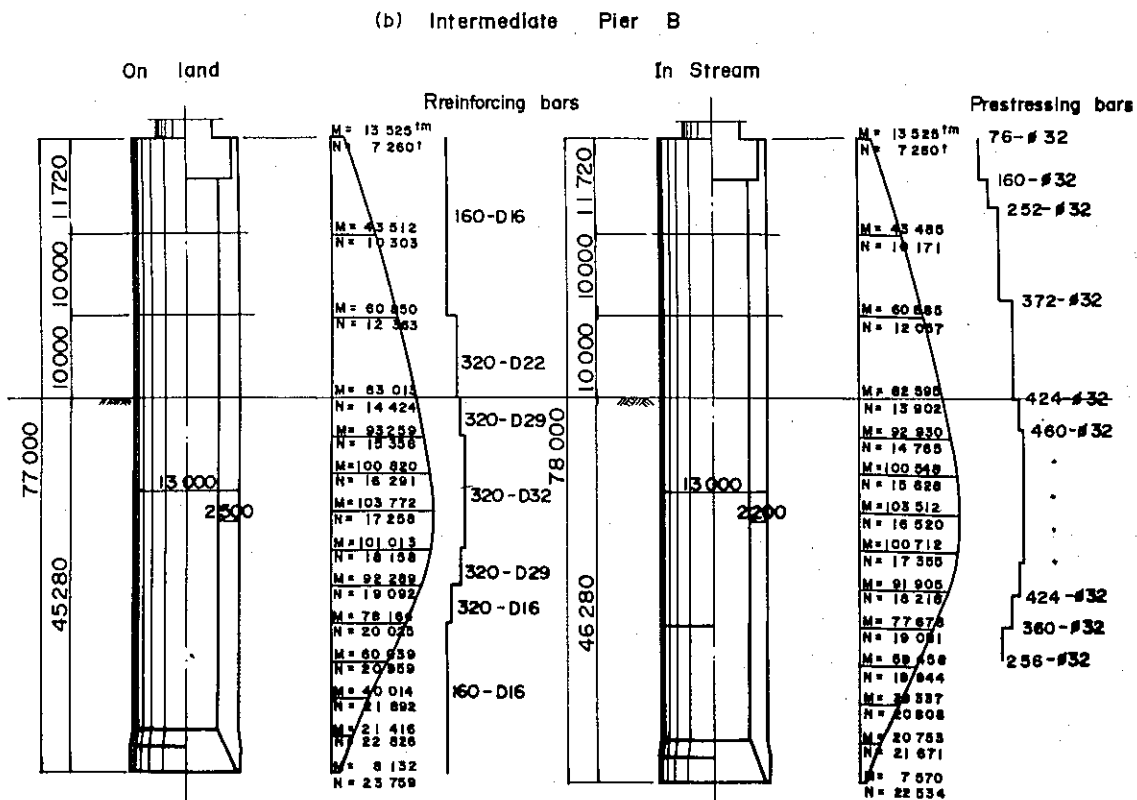
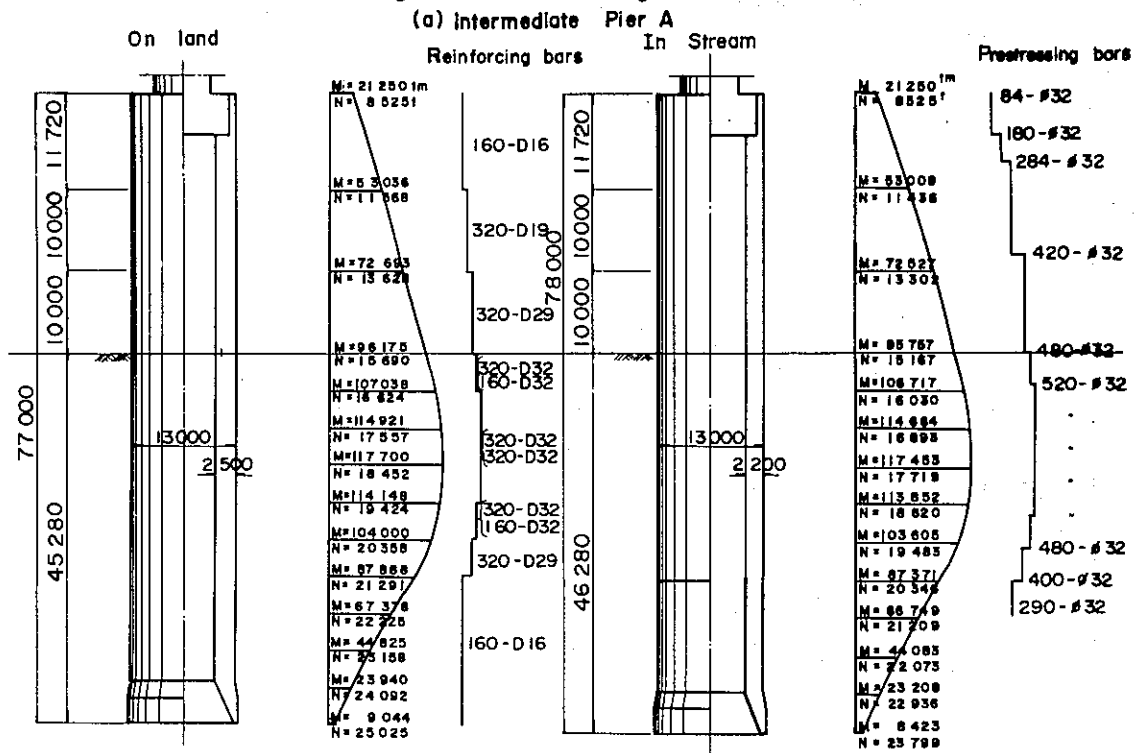


Fig.6-20-2. Bending Moment and Axial Force Diagram and Necessary Number of Reinforcing Bars for End Pier

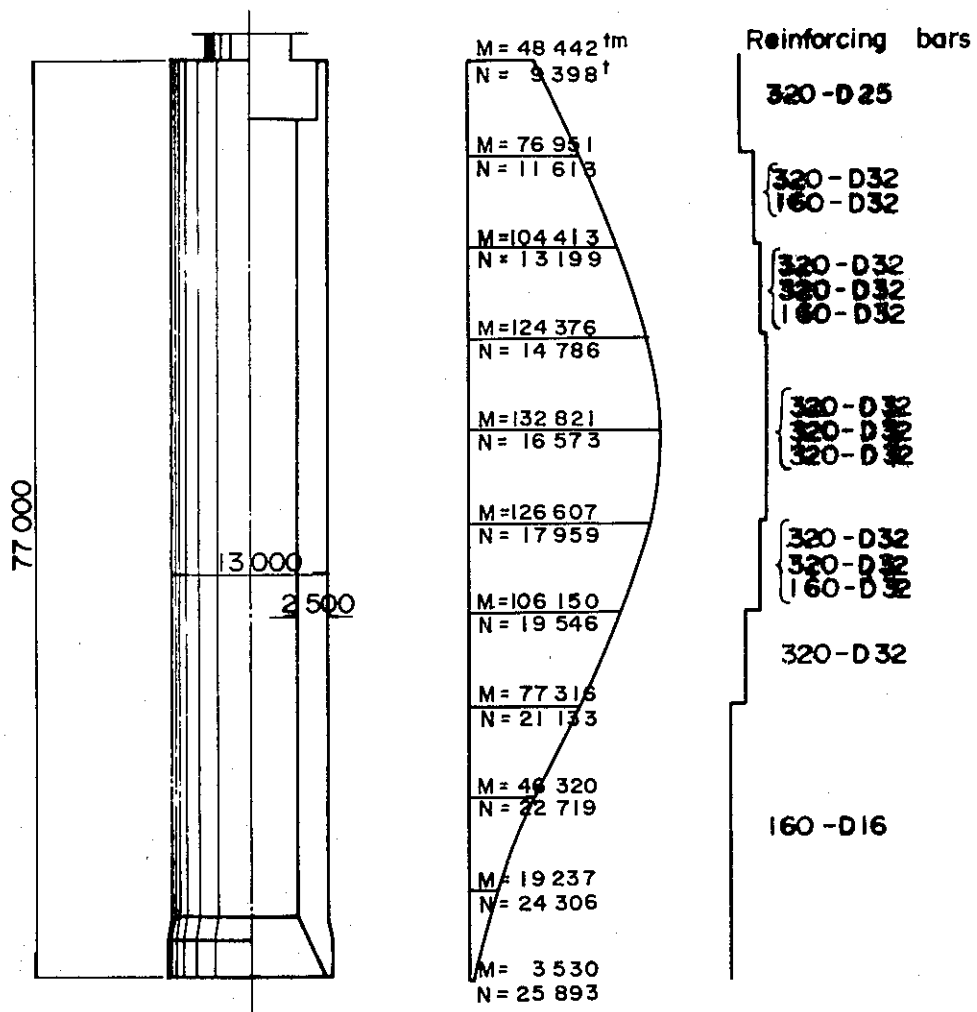


Fig.6-21 Necessary Reinforcing Bars at Each Section

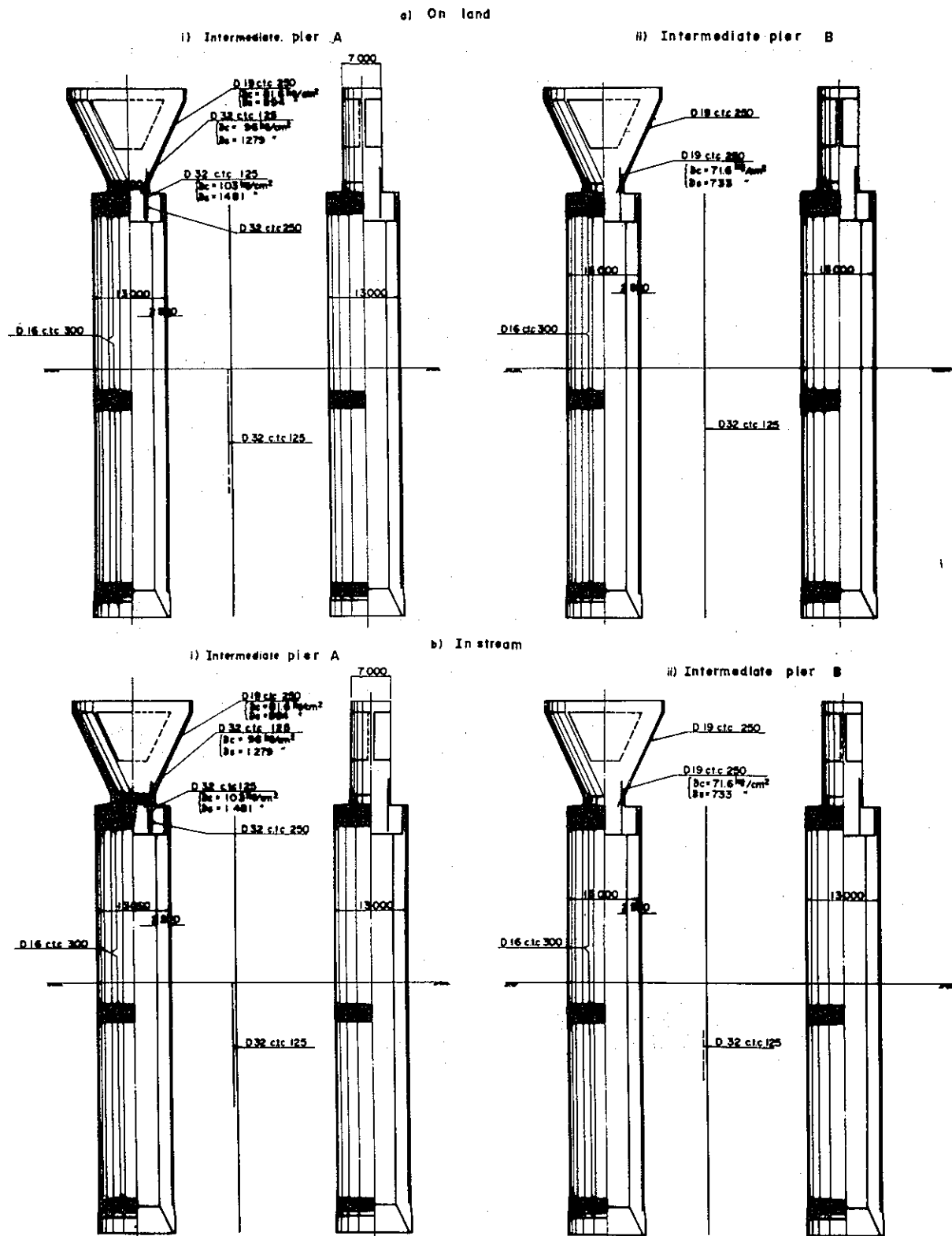


Fig. 6-22 Necessary Reinforcing Bars of End Pier

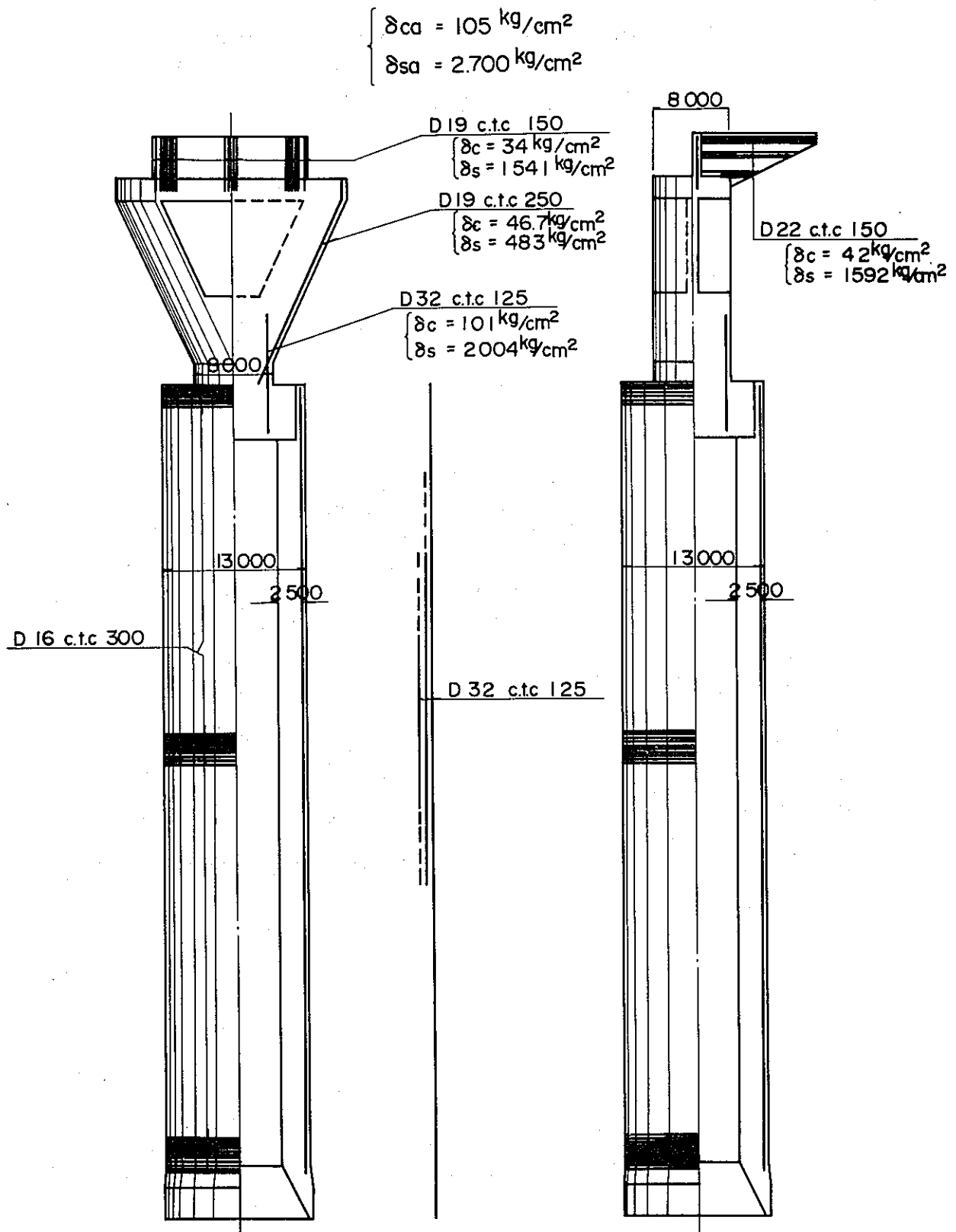


Fig. 6-23-1 Arrangement of Reinforcing Bars
of Wells (I)
(in millimeter)

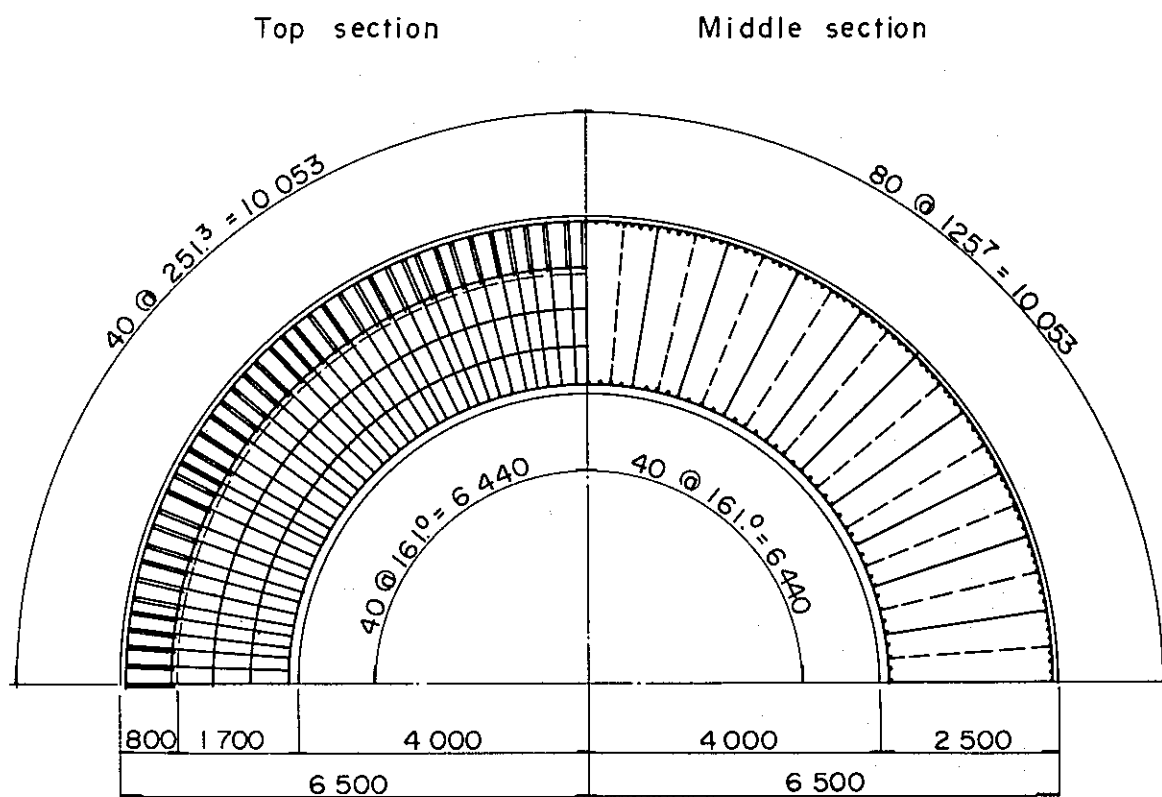


Fig 6-23-2 Arrangement of Reinforcing Bars of Wells (2)

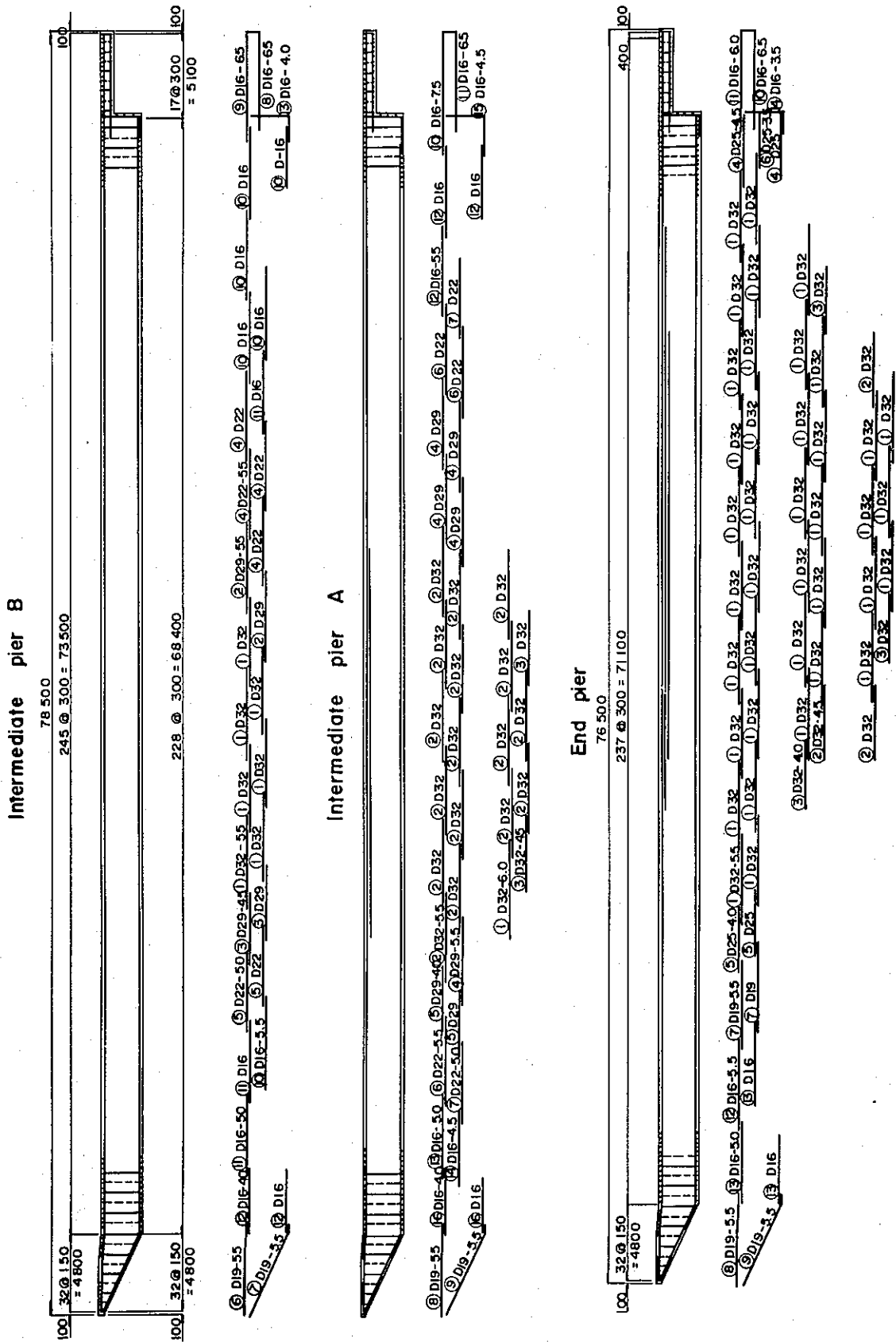
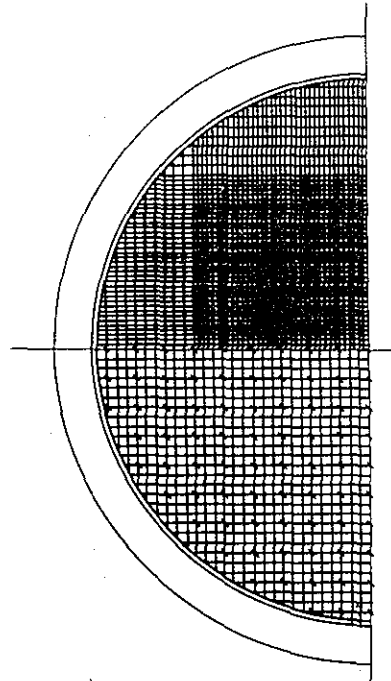


Fig 6-23-3 Arrangement of Reinforcing Bars of Top Slab

(a) Intermediate pier A



(b) Intermediate pier B

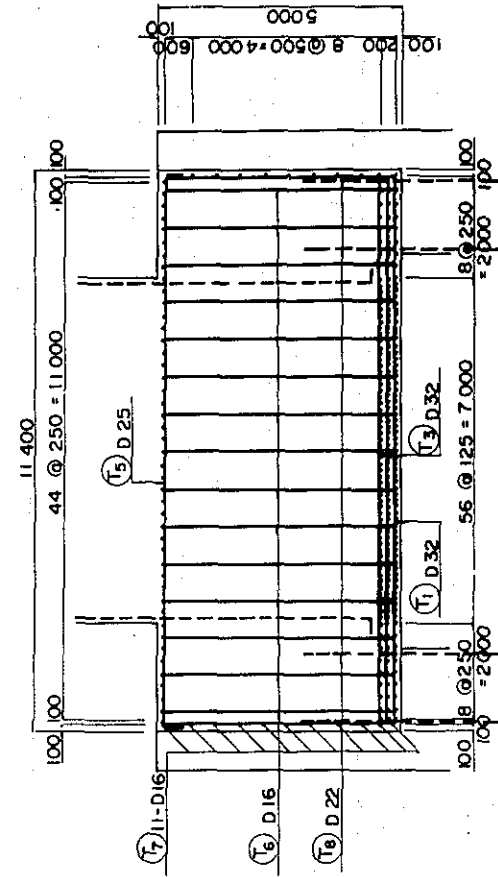
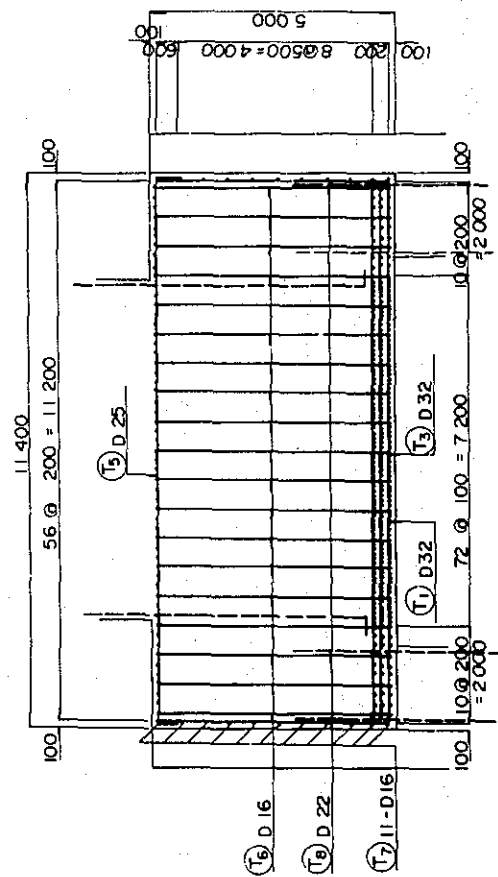
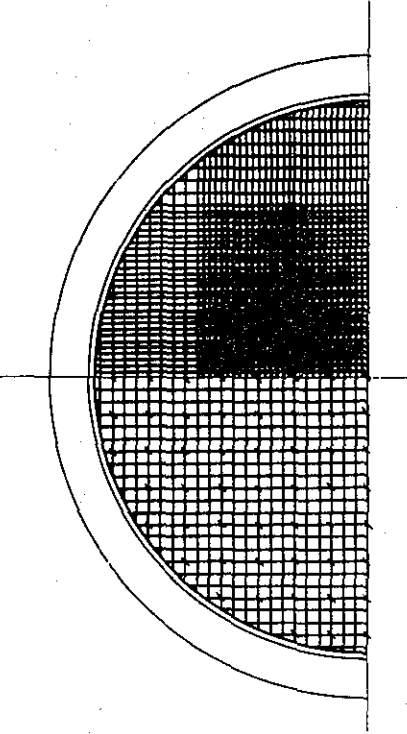
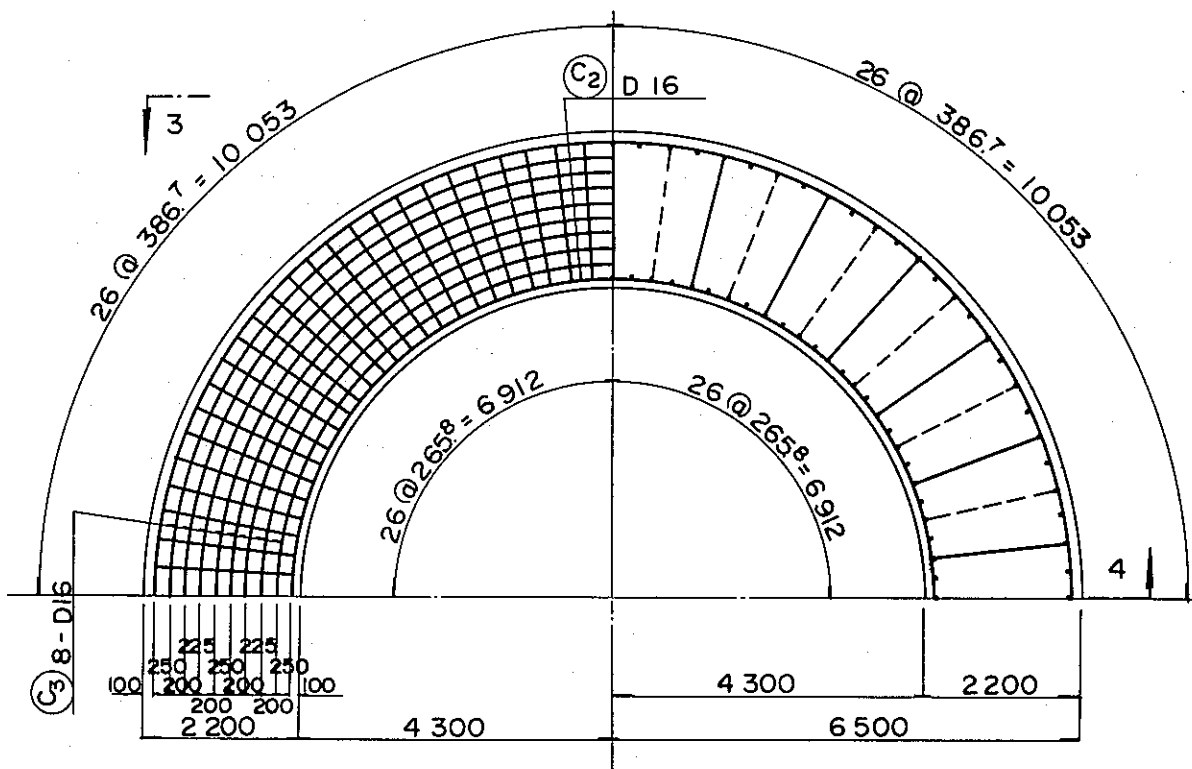


Fig. 6-24 Arrangement for Precast Tubular Block of Well in Stream

1 - 1 Section

2 - 2 Section



3 - 3 Section

4 - 4 Section

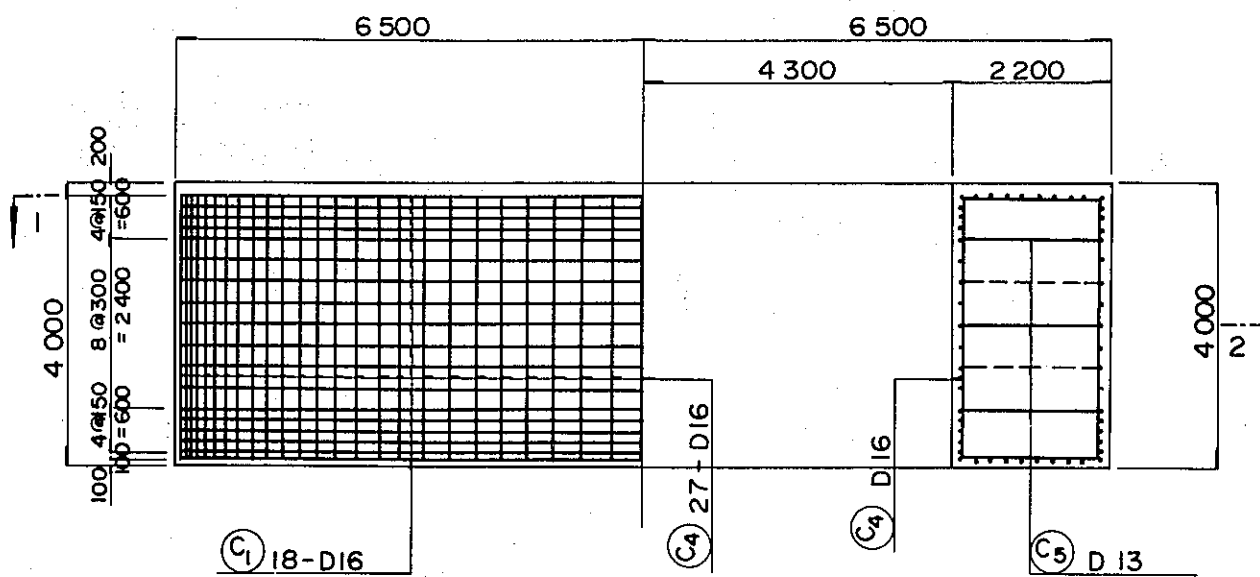
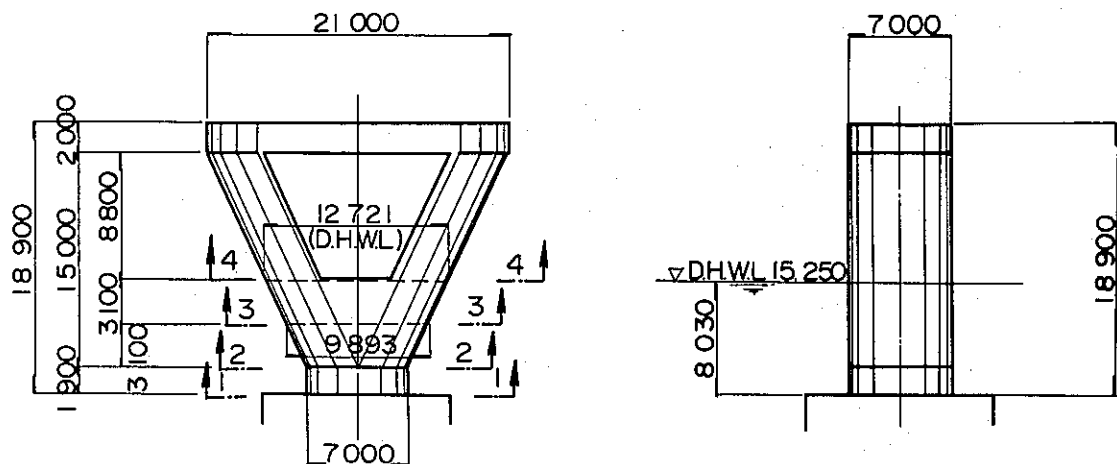


Fig. 6 - 25 Structural Dimension of Piers
(in millimeter)

a) Intermediate pier A



b) End pier

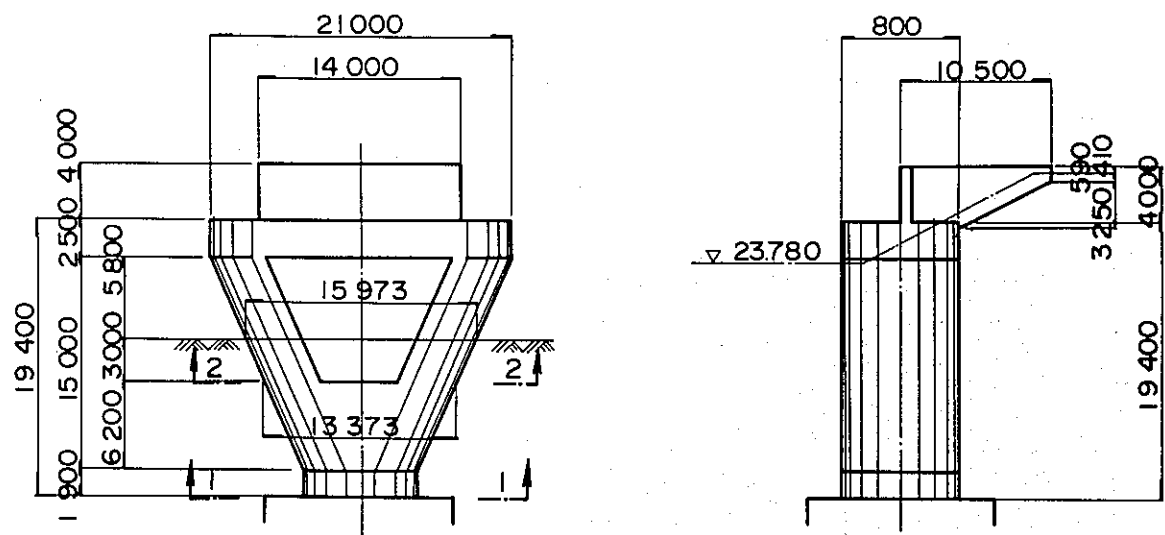
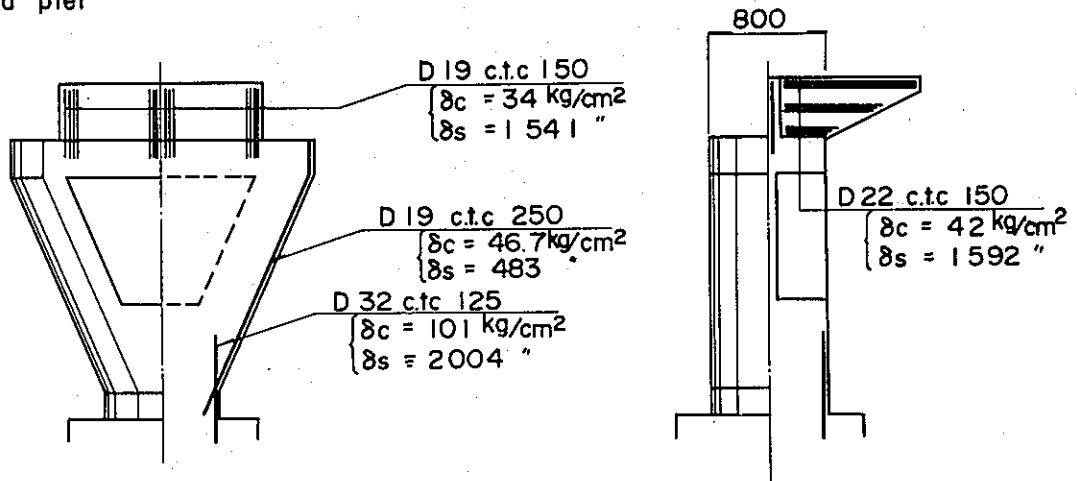
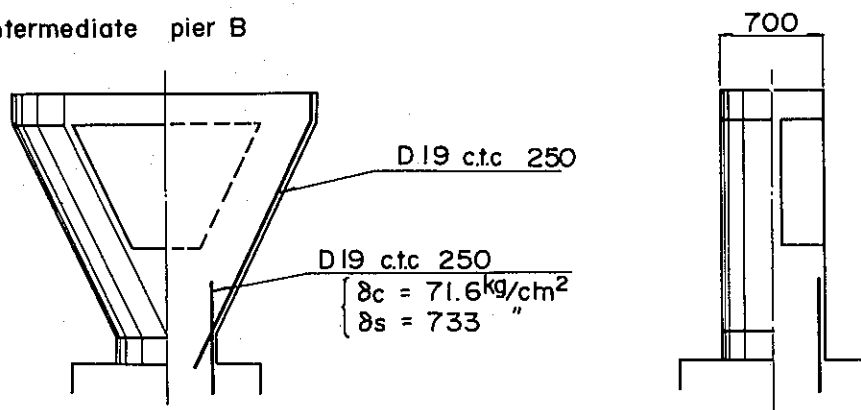


Fig. 6 - 26 Necessary Reinforcing Bars for Piers

(a) End pier



(b) Intermediate pier B



(c) Intermediate pier A

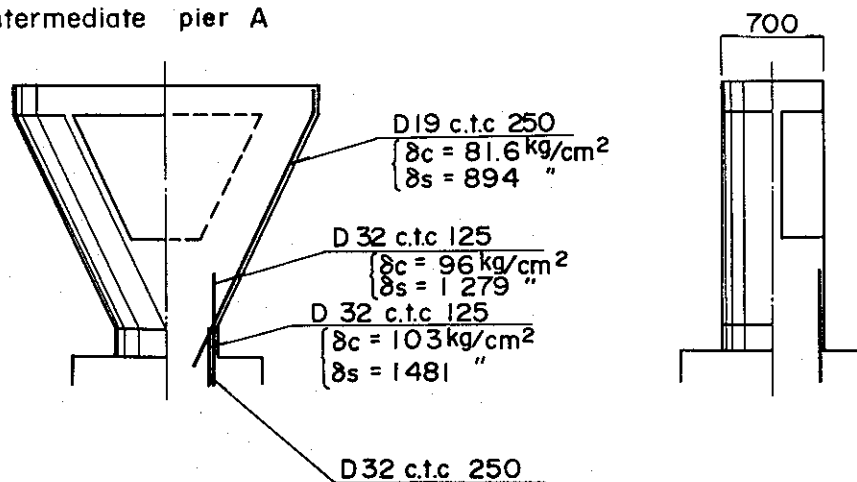


Fig.6-27-1

Arrangement of Reinforcing Bars of Intermediate

Pier A

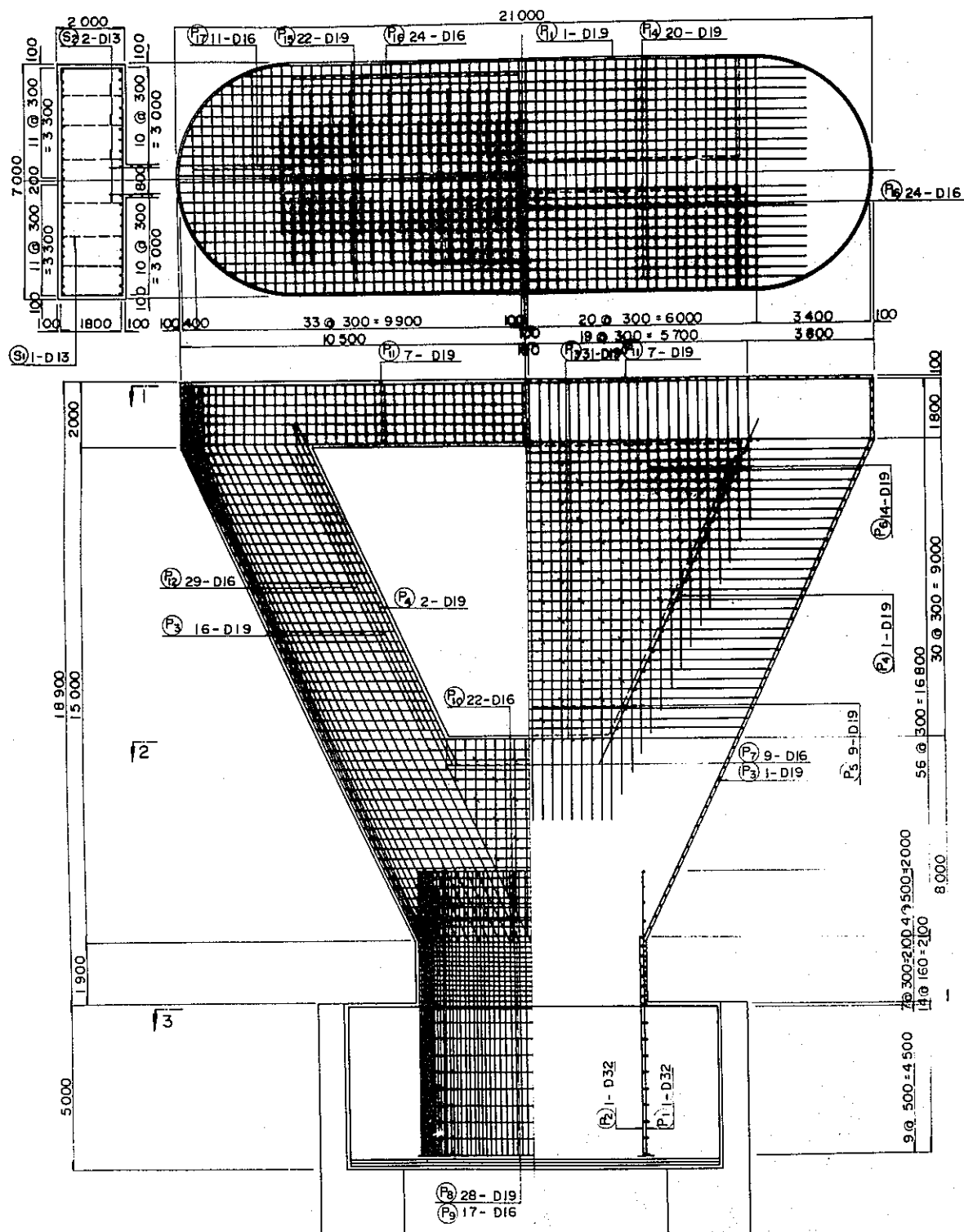
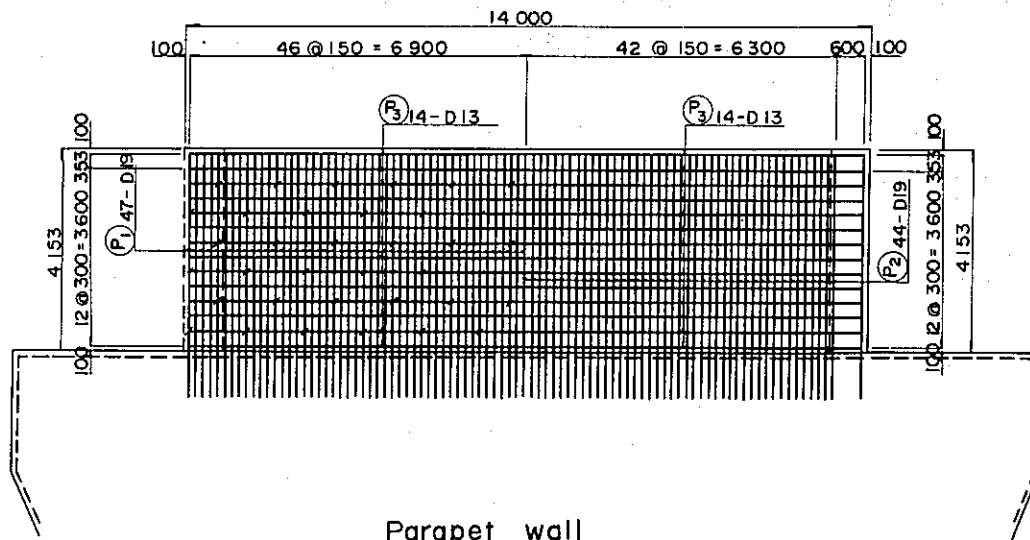
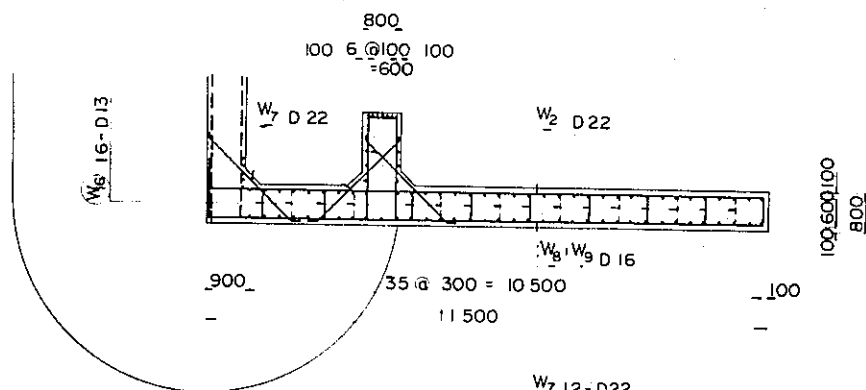
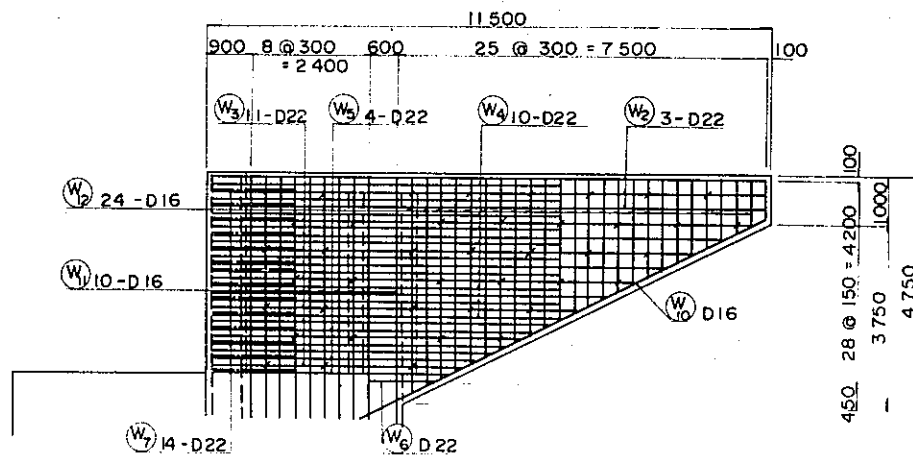


Fig.6-28 Arrangement of Reinforcing Bars for Wing and Parapet Wall of End Pier



Parapet wall



Wing wall

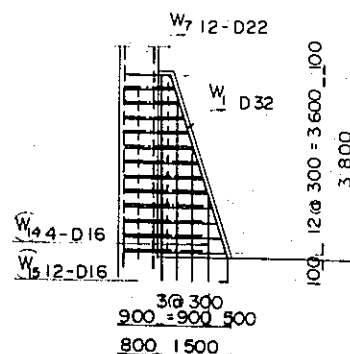


Fig.6-29 Details of Steel-made-caisson
Section C-C

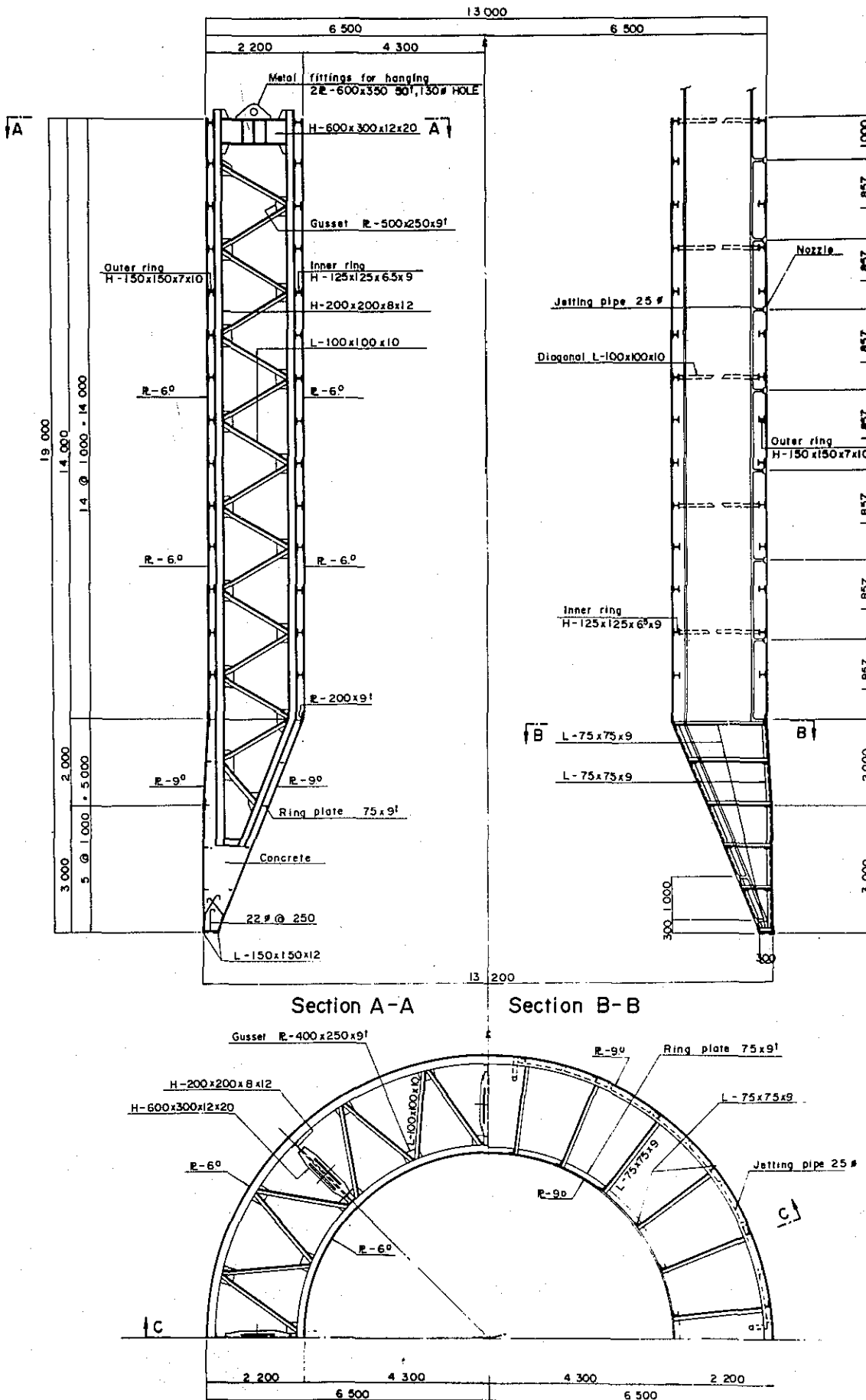


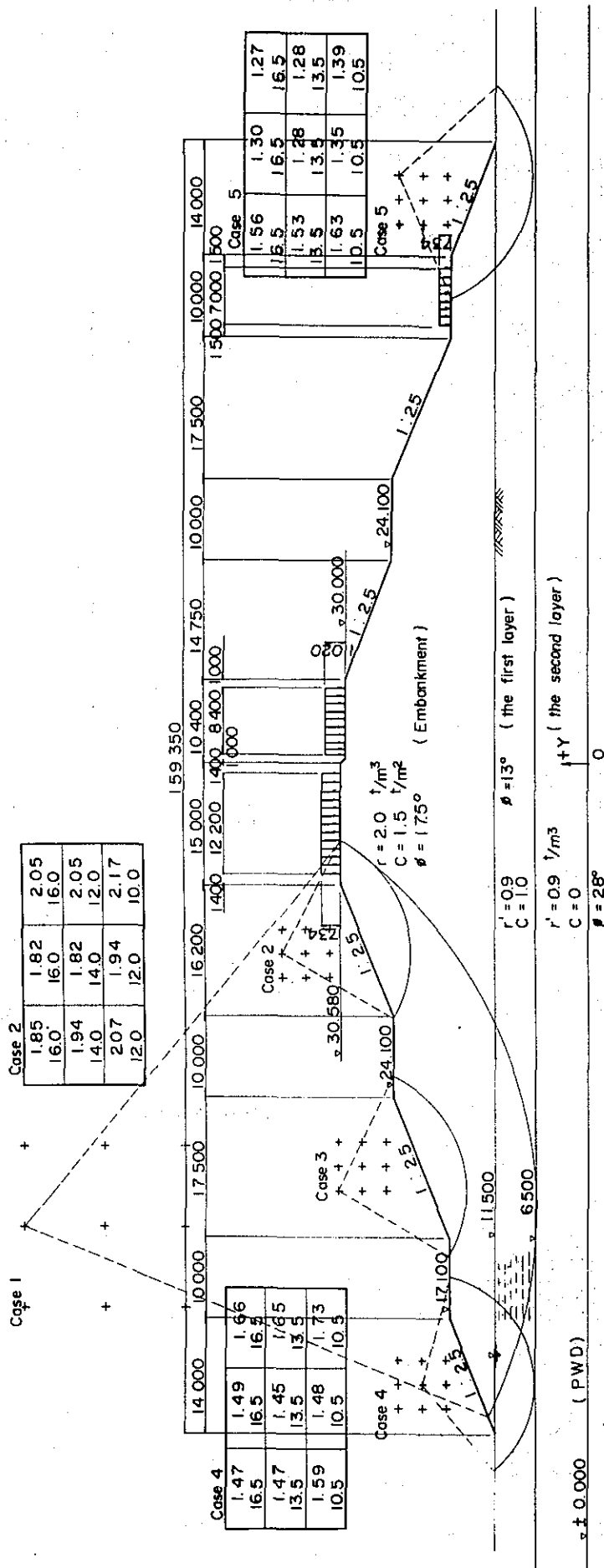
Fig. 6 -30 Slope Stability Analysis of Embankment by the Circular Arc Method

Case 1

F _s	1.54	1.50	1.55
R	62.0	62.0	62.0
F _s	1.52	1.54	1.53
R	52.0	52.0	52.0
F _s	1.48	1.65	1.56
R	42.0	42.0	42.0

Each figure in the tables is the factor of safety (F_s) conforming to the assumed radius of circular arc
 Each assumed radius of circular arc is also shown in the tables respectively

Each assumed radius of circular arc is also shown in the tables respectively



Case 3	1.82	1.93	2.27
	16.0	16.0	16.0
	1.87	1.93	2.27
	13.0	13.0	13.0
	2.04	2.05	2.36
	10.0	10.0	9.0

Surcharge on railway	2.041	1/m ²
" " road	1.467	

Table 6-6 Materials used for Superstructure (One set)

Main bridge work										Unit: Ton
Main truss	Floor system			Lateral bracing			Sway bracing	Sub total		
	Stringer	Cross beam	Sub total	Upper	Lower	Sub total				
SM 53 & SM 50Y	2,016	336	336						2,352	
SS 41 & SM 41	2,271	706	836	153	225	378	504		3,989	
H.T. Weight	102	30	44	2	6	8	10		164	
Bolt Number	116690	50740	73730	4030	9630	13660	16820		220900	
Total	4,389	736	1,216	155	231	386	514		6,505	

Incidental bridge work										Unit: Ton	
Expan-sion joint	Drainage	Hand rail	Bridge side-walk	Shoe	Sub total	Total	Slab work				
							Concrete	Form area	Reinforcing bar		
SM 53 & SM 50Y						2,352	1,241m ³	4,937m ²	298t		
SS 41 & SM 41		79	105	11	195	4,184			3,852m ²		
Cast steel	13	5		89	107	107					
H.T. Weight						164	Painting area				
Bolt Number						220900	Shop			119,484m ²	
Total	13	5	105	100	302	6,807	Field			119,484m ²	

Table 6-7 Total Materials used for Superstructure (Nine sets)

Main bridge work											Unit: Ton
	Main truss	Floor system			Lateral bracing			Sway bracing	Sub total	Sub total	
		Stringer	Cross beam	Sub total	Upper	Lower	Sub total				
SM 53 & SM 50Y	18,144		3,024	3,024						21,168	
SS 41 & SM 41	20,439	6,354	1,170	7,524	1,377	2,025	3,402	4,536		35,901	
Weight	918	270	126	396	18	54	72	90		1,476	
H.T. bolt	1050210	456660	206910	663570	36270	86670	122940	151380		1988100	
Total	39,501	6,624	4,320	10,944	1,395	2,079	3,474	4,626		58,545	

Incidental bridge work											Unit: Ton
	Expan-sion joint	Drainage	Hand rail	Bridge side-walk	Shoe	Sub total	Total	Slab work			
								Concrete	Form area	Reinforcing bar	Asphalt pavement
SM 53 & SM 50Y							21,168	11,169m ³	44,433m ²	2,682t	
SS 41 & SM 41			711	945	99	1,755	37,656				
Cast steel	117	45			801	963	963				
Weight							1,476				
H.T. bolt							1988100				
Total	117	45	711	945	900	2,718	61,263				

Painting area				Painting area			
Shop	Field	Shop	Field	Shop	Field	Shop	Field
1,075,356m ²	1,075,356m ²	1,075,356m ²	1,075,356m ²	1,075,356m ²	1,075,356m ²	1,075,356m ²	1,075,356m ²

Table 6-8 List of Materials for Substructure

1) On land

			A1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P26	A2	Total	Remarks
			M	F	F	M,M	F	F	M,M	F	F	M,M	F	F	F	M		
Length of well		m	76.5	76.5	76.5	76.5	76.5	77.0	77.5	77.5	78.0	78.0	78.5	78.5	77.0	77.0	1,081.5	
Excava- tion	General	cu.m	5,500	4,700	5,900	3,800	5,900	5,900	5,900	5,900	2,300	2,300	2,300	1,600	5,400	5,900	63,300	
	Well	"	10,200	10,200	10,200	10,200	10,200	10,300	10,300	10,300	10,400	10,400	10,500	10,500	10,300	10,300	144,300	
	Total	"	15,700	14,900	16,100	14,000	16,100	16,200	16,200	16,200	12,700	12,700	12,800	12,100	15,700	16,200	207,600	
Concrete	Pier	cu.m	1,630	1,190	1,190	1,260	1,190	1,190	1,260	1,190	1,190	1,260	1,190	1,190	1,190	1,630	17,750	
	Well	"	6,400	6,400	6,400	6,400	6,400	6,450	6,490	6,490	6,530	6,530	6,570	6,570	6,450	6,450	90,530	
	Total	"	8,030	7,590	7,590	7,660	7,590	7,640	7,750	7,680	7,720	7,790	7,760	7,760	7,640	8,080	108,280	
	Prepacked	"	430	430	430	430	430	430	430	430	430	430	430	430	430	430	6,020	Bottom slab
Form area		sq.m	6,390	6,040	6,040	6,070	6,040	6,080	6,130	6,110	6,140	6,170	6,170	6,170	6,080	6,420	86,050	
Reinfor- cement	D32 - D29	ton	357	233	233	119	233	234	120	235	236	121	237	237	234	359	3,188	
	D25 - D16	"	135	123	123	132	123	123	133	124	125	134	125	125	123	135	1,783	
	D13	"	2	1	1	1	1	1	1	1	1	1	1	1	1	2	16	
	Total	"	494	357	357	252	357	358	254	360	362	256	363	363	358	496	4,987	
Structural steel		ton	40	40	40	40	40	40	40	40	40	40	40	40	40	40	560	Curb shoe

(Note) General ; Excavation up to well-setting ground.

2) In stream

			P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	Total	Remarks
			M,M	F	F	M,M	F	F	M,M	F	F	M,M	F	F	M,M	F		
Length of well		m	78.5	78.5	78.5	79.0	78.5	78.5	78.5	78.0	78.0	78.0	78.0	78.0	77.5	77.5	1,095.0	
Well excavation		cu.m	9,900	9,900	9,900	10,000	10,000	10,100	10,100	9,700	9,600	9,700	9,900	9,900	10,100	10,000	138,800	
Concrete	Pier	"	1,260	1,190	1,190	1,260	1,190	1,190	1,260	1,190	1,190	1,260	1,190	1,190	1,260	1,190	17,010	
	Top slab	"	750	750	750	750	750	750	750	750	750	750	750	750	750	750	10,500	
	Total	"	2,010	1,940	1,940	2,010	1,940	1,940	2,010	1,940	1,940	2,010	1,940	1,940	2,010	1,940	27,510	
	In water	"	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	14,700	Deposit in well shell
	Precast	"	4,220	4,220	4,220	4,260	4,220	4,220	4,220	4,180	4,180	4,180	4,180	4,180	4,140	4,140	58,760	
	Prepacked	"	450	450	450	450	450	450	450	450	450	450	450	450	450	450	6,300	Bottom slab
Form area		sq.m	6,090	6,070	6,070	6,140	6,070	6,070	6,090	6,030	6,030	6,050	6,030	6,030	6,010	5,980	84,760	
Reinfor- cement	D32 - D29	ton	37	55	55	37	55	55	37	55	55	37	55	55	37	55	680	
	D25 - D16	"	98	99	99	99	99	99	98	98	98	97	98	98	97	98	1,375	
	D13	"	13	13	13	13	13	13	13	13	13	13	13	13	13	13	182	
	Total	"	148	167	167	149	167	167	148	166	166	147	166	166	147	166	2,237	
Structural steel		ton	150	150	150	150	150	150	150	150	150	150	150	150	150	150	2,100	Steel-made-caisson
Prestressing bar		"	159	180	180	161	180	180	159	179	179	158	179	179	157	178	2,408	
Coffe- ring wall	Concrete	cu.m	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1,400	
	Form area	sq.m	420	420	420	420	420	420	420	420	420	420	420	420	420	420	5,880	
	Reinforcement	ton	5	5	5	5	5	5	5	5	5	5	5	5	5	5	70	D25 - D16

Table 6-9 Materials used for Bridge Approaches

DESCRIPTION	UNIT	RIGHT BANK	LEFT BANK	TOTAL
Volume of earth	cu.m	2,894,200	3,367,500	6,261,700
Slope protection works				
Slope dressing	sq.m	329,730	334,950	664,680
Sodding	"	150,730	124,050	274,780
Brick work	"	130,910	134,710	265,620
Wire cylinder(Filled with bricks)	"	50,310	58,450	108,760
Drainage works				
Side ditch 200x200	m	21,500	28,800	50,300
" 250x250	"	5,600	5,700	11,300
Conduit ϕ 350	"	2,600	3,600	6,200
Inlet 500x500x700	nos.	450	580	1,030
Pavement works				
Subbase coarse t=450 mm	sq.m	22,920	37,450	60,370
Surface coarse t= 50 mm	"	22,920	37,450	60,370
Asphalt mixture	t	4,370	7,140	11,510
Stone	cu.m	---	65,000	65,000

Table 6-10 Earth Works for Bridge Approach Embankment

1) Net volume of earth

Right bank side	(cu.m)	2,894,200	
Left bank side	(")	3,224,500	
"	(")	143,000	(For Dhaleswari river closing work)
Total	(cu.m)	6,261,700	

2) Volume in borrow pit

Right bank side	(cu.m)	3,289,000
Left bank side	(")	3,827,000
Total	(cu.m)	7,116,000

3) Excavated earth

Right bank side	(cu.m)	4,111,000
Left bank side	(")	4,784,000
Total	(cu.m)	8,895,000

Table 6-11 Area of Land Acquisition

For right embankment of bridge approach	1,956,000 sq.m (483 acre)
For left embankment of bridge approach	2,230,000 " (551 acre)
Total area	4,186,000 sq.m (1,034 acre)

Table 6-12 Material List of Permanent Way of Railroad

DESCRIPTION	UNIT	QUANTITY	REMARKS
Length of permanent way	m	15,000	
Length of permanent way on bridge	"	4,747.5	
Length of permanent way on embankment	"	10,252.5	
Length of siding	"	1,900	
Rail (90 lbs./yd.)	ton	1,537	
Guard rail (90 lbs./yd.)	"	424	Second-hand rail
Fish plate	pcs.	6,760	
"	"	1,899	Second-hand fish plate
Bolt and washer	"	17,318	
Sleeper (wooden)	"	25,378	9' x 5" x 10"
Tie plate	"	46,234	
Rail-spike	"	236,411	
Hook bolt	"	18,040	
Anticreeper	"	2,051	
Guard timber	m	9,495	0.1 x 0.1 x 1.0
Scaffold board	"	4,748	0.03 x 0.4 x 1.0
Ballast	cu.m	19,064	
Switch and crossing #16	set	2	
" #12	"	2	
" # 8	"	2	
Various marks	ls.	1	

CHAPTER VII
BRIDGE CONSTRUCTION WORKS

1. Outline of Works.

Project Name: The Jamuna River Bridge Construction Project
Construction Site: Approx. 10 kilometers downstream of the Sirajganj Town, the People's Republic of Bangladesh

Term of Construction Works

Construction Bases: (Preparatory term)	4 years
Substructure Works:	5 years
Erection Works of Superstructure:	5 years
Slab Works for Superstructure:	4 years
Bridge Approaches Works:	6 years

Outline of Structure:

Superstructure

Type:	Steel through bridge 3-span continuous truss with parallel chords Railway-cum-road bridge with single broad-gage track and 2-lane carriageway
Span arrangement:	9 x (3@175 m) = 525 m
Total bridge length:	4,725.0 m
Space of main chords:	15.6 m
Height of chord:	26.0 m
Slab:	Reinforced concrete slab
Pavement:	Asphalt pavement

Substructure

Pier shaft: Reinforced concrete inverted triangle

Height:	19.4 m
Thickness:	7.0 m

Foundation well: Reinforced and prestressed concrete well

Height:	76.5 - 79.0 m
Outside diameter:	φ13 m
Wall thickness:	2.2m - 2.5m

Bridge approaches:

Total length:	5.1 x 2 = 10.2 km
Maximum height:	19 m
Railway portion:	Single broad-gage track
Road portion:	2-lane carriageway Asphalt pavement

Contents of Works:

Substructure Works:

Land area:	14 piers, A1 A2 P1-11 P26
Stream area:	14 piers, P12-P25
Total:	28 piers

Superstructure Works:

Total steel weight:	61,300 t
Volume of reinforced concrete:	11,170 m ³
Area of asphalt pavement:	34,670 m ²

Bridge approaches:

Design banking volume:	6,261,700 m ³
Design volume of boulder:	65,700 m ³
Area of asphalt pavement:	60,370 m ²
Area of land acquisition:	4,186,000 m ²

2. Selection of Execution Methods.

2.1. Conditions for selecting execution methods.

In selecting the execution methods and the order to carry out execution, economics, safety, security, and reduction of execution period should be taken into consideration but in this bridge construction project, the following features were made the conditions for selecting execution methods and our consistent efforts were concentrated at a complete grasp of the subject.

- a. A certain spot on the Sirajganj Site, the People's Republic of Bangladesh, was chosen for the proposed bridge site.
- b. Since the bridge is to be built over the Jamuna River, well known as one of the largest rivers in the world, the bridge has a length of approx. 4.75 kilometers which can be said as extremely long.
- c. The construction project covers the two seasons, namely, dry and flood seasons. Generally speaking, the dry season sets in October and end in May while the wet season is from June to September. Between the flood and dry seasons, a considerable difference is noted in temperature, precipitation, wind velocity, and water level.

- d. There is an embankment on the right bank of the Jamuna while the left bank has none. As a matter of fact, during the dry season, the river width swells to approx. 6 kilometers. The discharge of the Jamuna river reaches as large as 96,850 m³/sec.
- e. In the dry season the river becomes narrow to approx. 2.1 kilometers wide and the depth in that case reaches 1 to 7 meters. Even in that season the surface velocity of flow is approx. 2.3m/sec.
- f. The difference in water level totals about 7 meters between the dry and wet seasons.
- g. In the flood season, the project is affected in the total number of working days.
- h. The geology in the area shows that the uppermost layer mostly consists of silty fine sand and this soil is unstable against the water flow.
- i. Gravel pebbles stretching to the depth of EL-70m PWD are used as the supporting strata of the well foundation and this layer is quite deep.
- j. Abutment-piers and piers total 28 units in number and the foundations are all well-type. Abutment-piers and piers are 76.5-79.0 meters tall. Since the height of pier-shaft is approx. 19.7 meters, the bridge substructure reaches approx. 100 meters in a total height.
- k. The guide bank that will control the river are to be built along the stream on its both sides at interval of 4.68 kilometers.
- l. Since the bridge has a 3-span (equal span length) continuous truss (175m per span), its effective span length is long.
- m. Due to the nature as a railway-cum-road bridge, the truss height becomes 26 meters.
- n. The bridge is in a large scale with 9 sets of 3-span continuous trusses (525m long per 1 set).
- o. Since the navigation clearance of height of 40 ft is required for the bridge, the formation level of the superstructure naturally becomes EL=+30.0 meters.
- p. Embankment is constructed for an about 5km long distance on each of the right and left riversides and it rises to a height of approx. 20 meters at the maximum at near the abutments.
- q. For the approach embankment, it is required to reclaim the Dhaleswari River which is approx. 500m wide.
- r. Due to very few construction equipment and machines procured at the site and as most of them will depend on imports, the transportation of these equipments is expected to grow in a large scale.

- s. Construction bases, cambers, canals, cargo-handling piers and living quarters must be built in the neighbourhood of the bridge site.

2.2. Selection of execution methods.

2.2.1. Substructure works.

It must be our first thought that, in due consideration of the bridge in its scale, topographical situation and surrounding natural conditions, the execution of the bridge's substructure including foundations and pier-shafts should be completed by any means within a single dry season. In another word, in the event we fail to sink the foundation well into the desired depth during one dry season, there is a danger that these piers may tumble down by scoures resulting from floods during the rainy season. This condition gives a very grave restriction on the execution but seeing from the river situation, it is the minimum and essential prerequisite to the completion. As to the pier shafts, unless they are completed as scheduled, the erection works of superstructure cannot start and, if deferred to the next year, the completion target will be delayed by another year.

As the period of execution is concentrated upon the dry season, the construction needs a rapid execution method and as for the construction equipment used, it is desirable to adopt those with highest efficiency as far as possible. At the same time, in selecting the execution methods, steady efforts were concentrated at the choice of the methods with clear, systematic and effective process of execution.

In the execution of the substructure works, with these things in our mind, after we have grasped the types, merits and demerits, we have selected the methods, roughly classifying them into the works on land and the works in stream.

(1) Well works

In case the well is constructed in the river, concrete placing of the first rod of well is mostly by means of a temporary island or a cofferdam. In shallow stream, it is simplest to build a simple coffering and fill sand in it. On the other hand, in deep stream, it is customary to use a cofferdam by steel sheet-piles. In the case of this bridge now planned, due to a restriction in its construction period, it is almost impossible to complete the substructure during a period from the end of a rainy season and to the beginning of the next rainy season, including the constructing and the removing of the cofferdam. Since the cofferdam in this project has a diameter of about 20m, the depth of embedment is required to be deep as much as possible to cope with local scour. Consequently, as the cofferdam will grow large in scale and it is clear that the method is unless to adopt from a view point of time schedule, economics and workability.

In order to eliminate disadvantages in works by cofferdam or temporary island and to facilitate the sinking of the well, a method to drive piles and to set the execution frame as a scaffolding on

piles can be considered. This will serve to decrease the hindrance by streams and the construction period will be capable of shortening by setting on piles in lump as a large block of the execution frame.

The execution frame is, as a matter of fact, assembled on a yard and will be positioned at a well-construction spot by a floating crane. Moreover, the execution frame is required to be a structure that will be diverted to some other wells. The execution frame must be firmly so that it will prevent the declining and deviation of the well at the time of positioning and sinking works of well can be executed with stability.

(2) Construction works of well itself

It is very difficult to complete the foundation well by placing of concrete by one rod from the cutting edge, because takes a long time in the time schedule which is limited to a very short period.

It is possible to shorten the construction period on land by adopting the slip-form system for form which will give a certain cycle to give a continuous execution to concrete placing.

Meanwhile, in the stream area, restrictions in the time schedule are far stricter than in the land area so that a conventional well construction method is difficult. Hence, if the whole of well was adopted the steel-made-caisson, the placing period of concrete can greatly be shortened but that method cost much. Therefore, the plan to make the entire well into a steel body is not desirable. This being the case, in view of the workability for sinking of the well and its economics, it is most efficient to use steel only on the end portion and the length of this portion should be minimized in consideration of the water depth and local scour.

It is very difficult from a viewpoint of construction period as stated above to construct the upper part of well above the steel-made-caisson by one rod by concrete placing but by applying a method in which precast concrete blocks are piles one by one, the period of construction can be shortened.

(3) Excavation for well-sinking

The excavation method for well-sinking can be roughly classified into 2 ways. Namely, a simple excavation method (by bucket system and other implements) as a conventional way which has been widely adopted up to this date. For example, the clamshell, hammer grab, etc., belong to this type. The other method is the excavation by sludge exhausting, which is a process to exhaust earth and sand as a mixture of those and water. For example, the river circulation drill and sand pump (with cutter) can be named in this type.

Since this works require a large depth of excavation, the former is extremely inefficient, as it takes too much time in a construction period.

However, in the initial stage of excavation from a reason to secure stability of the well, the former, namely the simple excavation method, was adopted. After the stability had been secured, it is more efficient to adopt the latter method and unless by this method, the project cannot be completed as scheduled. Hence, the combined method of both processes was regarded as the best in this work.

(4) Concrete plant

The mixing of concrete to be used on land is generally made at a concrete mixing plant at the construction base. There are two methods in stream, namely a method to carry and place ready-mixed concrete for the structure, and another process to manufacture concrete by a barge mounted concrete mixing plant and place it at the spot.

In the case of this bridge, however, the mixing plant is built at the construction base on land side, and since the distance of carrying concrete grow longer and the stream area will be required to change the transportation method over a method by water, it is unfavorable in point of execution and economics. Hence, it has more play to mobile power and will do much toward expediting the construction schedule, to mix up concrete on the concrete mixing barge in respect of the stream area. On board the concrete-plant barge, concrete pumps are set up and concrete is sent out by a conveyor or pumped out.

2.2.2. Superstructure works.

It is desirable for the erection method of superstructure works to bear in mind, the bridge in its scale and surrounding natural conditions, and also to endeavour to cut the erection schedule and through these efforts the whole year erection schedule should be made feasible. Particularly, in this case the erection method during the rainy season will create some discussion, and that it is most essential to select an efficient method based on simple jobs.

With the above situation always in mind, the selection was made after grasping types, merits and demerits of the erection methods, which can roughly be classified into methods taken by both stream area and land area, and as a result the following three methods are mentioned.

(1) Staging method by crawler crane

- (a) Erection stresses are small and that there is no residual stress.
- (b) Erection works are comparatively simple.
- (c) Few equipments and materials are well enough for erection and that small in scale.
- (d) It is economical in erection costs.
- (e) It is unfit to erect in stream.

This method will become effective for the erection on land during the dry season.

In case the staging is established at some points in stream where water flows at a rapid speed, local scour occurs around these points and, for the safety of the points themselves, a deep-foundation is needed for the staging. However, since the ground is a sand stratum and due to a light weight of the staging itself, there is a fear that the staging may be washed away by a flood. To ensure the absolute safety, it will need a considerably large scale foundation for staging and the method is not regarded as effective in the stream area.

(2) Cantilever erection method

- (a) Though this method is applied jointly with other processes (such as the staging, etc.), it is required to extend at the same time toward both sides by means of piers.
- (b) Adequate consideration must be given in the stability of the horizontal direction and the balance of the vertical direction.
- (c) In some points, member sections are determined by erection stress and hence, it is uneconomical.
- (d) In case there is no stress adjustment, it is also uneconomical due to residual erection stress.

When the staging can be established between both piers like the case of the land area in the dry season, the method is regarded as effective next to the above staging method. However, by establishing the staging in stream, it will pose problems regarding the stability of the staging itself against the water flow, i.e. a large scale of staging is needed, and that a small flat barge and tug boats are necessary for carrying in materials, it is unprofitable in economics. On the other hand, when the cantilever method is adopted, erection stress is big and many of member sections are determined at the erection time and at the same time the transfer of support for the stress adjustment increases in scale. Therefore, since there are many problems, this method is unfavourable in stream. However, if a method by a flat barge saying later was impossible, this method will become the object to be investigated as the alternative one in stream.

(3) Erection method by flat barge

- (a) Superstructure is erected on the yard by one span at the construction base.
- (b) In case of erection conducted only by the stream area, it is capable of setting on the piers within a short time those prefabricated trusses at the yard.
- (c) The depth of water is required to be deeper than 2 meters.
- (d) A slow velocity is needed.
- (e) The stress at erection time is little.

- (f) The flat barge becomes large in scale and it requires a considerable technique and training in manning the barge and setting the truss on piers.

In executing this method, the velocity becomes a vital problem but the prefabricated truss is set on piers during a period from March to mid-May when the dry season is changing to a wet season, the towing of the flat barge is made by tug boats and it is led from the downstream side by a mooring cable with anchors and sinkers, and fixing at the prescribed position, the velocity can be disposed of. When compared with the staging erection method, the erection cost rises but this is a demerit which can be written off by the shortening of the erection schedule. Many points such as the velocity, its direction and effect of anchor are left for further on-the-spot investigations.

As to the depth of water, it is capable of maintaining a required depth by selecting a period when the water level starts to rise.

Other erection methods than those three mentioned above are impractical under the existing circumstances, seen from the conditions of location. Under these circumstances, the erection methods were selected from the above three methods in due consideration of merits and demerits of each method.

Since it is anticipated that a period when the river exposes its bed partially between early November and mid-May, it is judged most proper to apply the staging erection method by crawler cranes by taking advantage of this period.

As to the erection works in stream, since the river differs from ordinary rivers in circumstances, and as it is very difficult to set up the staging in stream, the staging method must be excluded from this case. Meanwhile, as to the cantilever method, for some reasons such as its erection stress grows bigger and steel weight increases due to the reinforcement of member section, and the adjustment of erection stress becomes larger in scale and the setting of the staging between piers is very difficult, it cannot be regarded as profitable. As stated above, detail investigation is required on the velocity and flow direction, changes in the water depth, and effect of anchor, but through investigation so far made up to this day, it was decided to adopt the erection method by flat barge. It goes without saying that the cantilever erection method is, as stated above, the next to the best method and may serve as a substitute to the above.

In the next place, changes in water depth and clearance under truss during March/May period are shown in Table 7-1 and Table 7-2.

3. Workdays.

The natural conditions surrounding the bridge site are as stated in 4.1, Chapter III of this report and in due consideration of these circumstances, the workdays at the execution period was sought based on the following conditions.

3.1. Velocity.

The stream has a width of approx. 2.1km even in a dry season. The water depth is more than 2.0 meters in stream at MLLWL+6.22m PWD, and this poses no problems in the execution by ships but if there is some place not deep enough for ship's draught in water, it can be solved by a dredger which is provided with.

However, through investigations will be required so long as it is concerned with the velocity.

Seen from the relationship between the cross section and water level of the existing Jamuna River, the surface velocity was sought regarding the river-bed height of -1.0m PWD (a part of maximum depth) and the river-bed height of +3.0m PWD (a part of mean depth) and the results of monthly changes are shown in Fig. 7-1 which also deals with monthly changes of water level.

3.2. Conditions at execution time.

In consideration of the scale of works and construction equipment, the favourable natural conditions and workdays are based on the conditions mentioned below.

- a. Precipitation: Those with daily precipitation of 0.5 in/day or less shall be made workdays.

Table 7-1 Water Depth of the River in the Period of the Execution

Place	March	April	Unit: m
			May
P14 ~ P15	5.0 ~ 6.0	6.0 ~ 7.0	7.0 ~ 8.5
P15 ~ P16	4.0 ~ 5.0	5.0 ~ 6.0	6.0 ~ 7.5
P16 ~ P17	4.0 ~ 5.0	5.0 ~ 6.0	6.0 ~ 7.5
P17 ~ P18	3.5 ~ 5.0	4.5 ~ 6.0	5.5 ~ 7.5
P18 ~ P19	4.0 ~ 6.0	5.0 ~ 7.0	6.0 ~ 8.5
P19 ~ P20	7.0 ~ 8.5	8.0 ~ 9.5	9.0 ~ 11.0
P20 ~ P21	7.0 ~ 8.5	8.0 ~ 9.5	9.0 ~ 11.0
P21 ~ P22	5.0 ~ 7.0	6.0 ~ 8.0	7.0 ~ 9.5
P22 ~ P23	3.5 ~ 5.5	4.5 ~ 6.5	5.5 ~ 8.0
P23 ~ P24	2.5 ~ 3.5	3.5 ~ 4.5	4.5 ~ 6.0
P24 ~ P25	3.0 ~ 4.0	4.0 ~ 5.0	5.0 ~ 6.5

Table 7-2 Monthly Variation of Vertical Clearance

	March	April	Unit: m May
Clearance	22.0 ~ 21.0	21.0 ~ 20.0	20.0 ~ 18.5

- b. Wind velocity: Those with a wind velocity of 10m/sec or less shall be made workdays.
- c. Current velocity: Those with a current velocity of 2.3 m/sec or less at towing time of barges and floating crane, shall be made workdays.
- d. Temperature: There is none of non-workday by temperature.
- e. Water depth: The water depth is required to be 2.0 m and more.
- f. Holiday: Non-workdays are assumed two days per month, including possible uncertain rest from labor due to mishaps in construction equipment, vessels and facilities.

3.3. Workdays of substructure works.

3.3.1. Stream area.

The lowest level of well top under construction is set at E.L. +9.22m PWD and when the works are to start after falling of the water level of Jamuna River at 9.00 m PWD, it will be early November. In the like manner, if the well structure is completed by the time when the level rises up to 9.00m PWD and, by erecting a coffering ring wall, the term of works can be scheduled for a period from early November to end of June when the water level rises up to 11.50m PWD. The above estimation was sought by the diagram of workable period in accordance with the variation of water level given in Fig. 7-2. Hence, the workdays will be as shown in Table 7-3, 198 workdays and 44 non-workdays to the total of 242 calendar days, calculated from the monthly total from November to June period. The ratio of the term of works will be:

$$198 \div (242 - 9) = 0.85$$

Consequently, the annual ratio of workdays for the substructure works will be:

$$198 \div 365 = 0.54$$

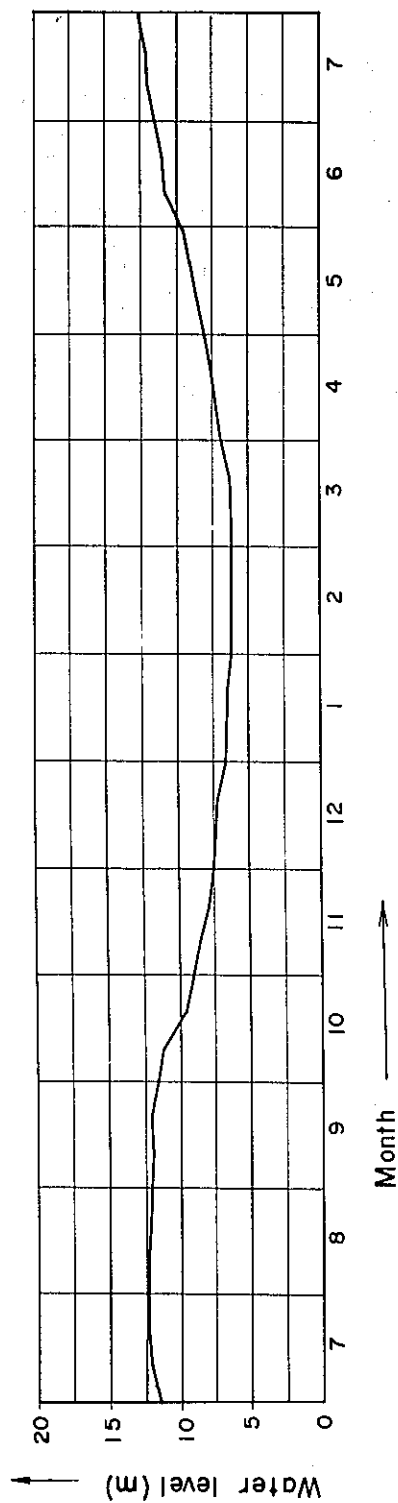
3.3.2. Land area.

On land, the well construction place below a ground level of 11.5m PWD shall be made up to 11.50m PWD. At the same time, the setting height of the curb shoe of well is fixed at 5.00m PWD by the primary excavation and at the time when the water level of the river falls at 11.0m PWD, the works start. The starting time will become in the early part of October. On the other hand, the upper limit for the rising of water level is to mid-June. Hence, the period for these months shall be made the term of works. The above estimation was sought by the diagram as shown in Fig. 7-3. Accordingly, the total workdays in works on land will be as shown in Table 7-4, 211 workdays and 62 non-workdays to the total of 273 calendar days based on the monthly total of the October/June period. As the works are scheduled to start on October 10 and end on June 15, the ratio of workdays will be:

$$211 \div (273 - 9 - 15) = 0.85$$

Fig. 7-1 Monthly Water Level and Surface Velocity

a) Monthly mean water level



b) Mean surface velocity

For deepest river bed

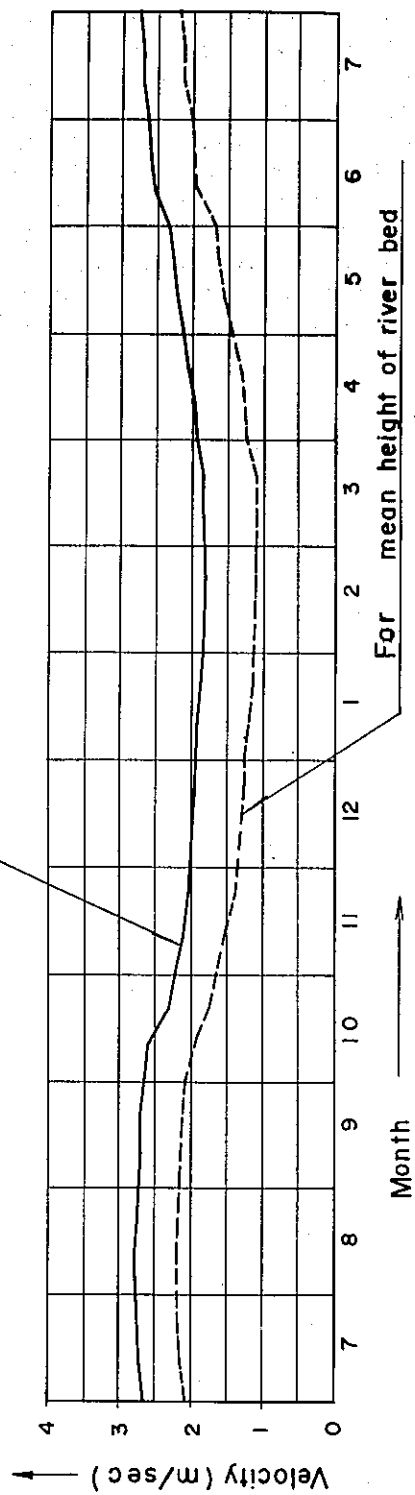


Fig.7-2 Diagram of Workable Period for Well Construction
in Accordance with the Variation of Water Level
(in stream)

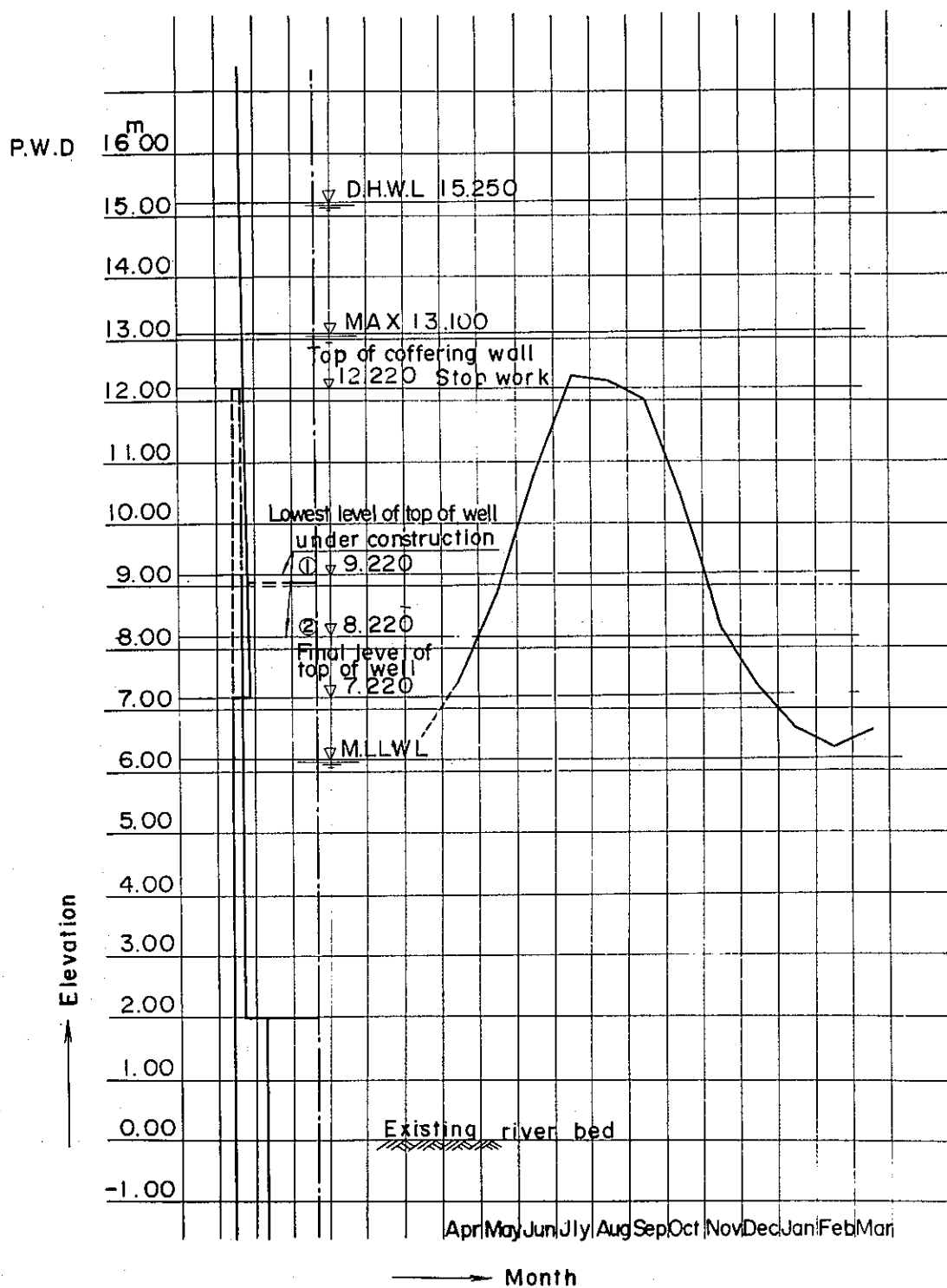


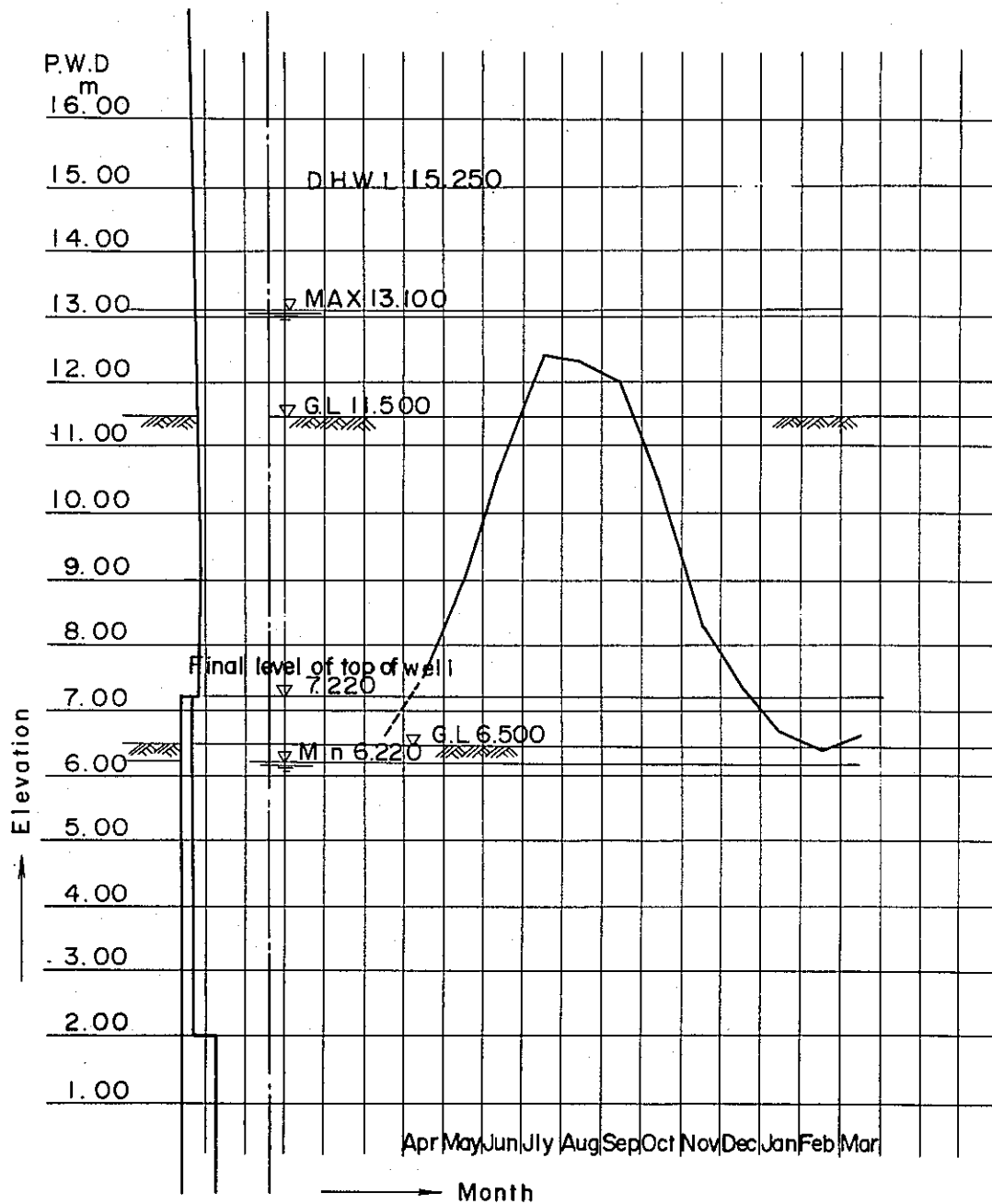
Table 7-3 Workdays for Well Construction Work in Stream

Month	Days in month	Non workdays			Total	Working days
		by high water	by rainy	by holidays		
Jul.	31	31	8	2	31	0
Aug.	31	31	8	2	31	0
Spt.	30	30	6	2	30	0
Oct.	31	31	4	2	31	0
Nov.	30	10	1	2	13	17
Dec.	31	0	1	2	3	28
Jan.	31	0	1	2	3	28
Feb.	28	0	0	2	2	26
Mar.	31	0	2	2	4	27
Apr.	30	0	1	2	3	27
May	31	0	5	2	7	24
Jun.	30	0	7	2	9	21
Annual total days						
	365	138	44	24	172	198
Total workdays from Nov. to Jun.						
	242	10	18	16	44	198

Table 7-4 Workdays for Well Construction Work on Land

Month	Days in month	Non workdays			Total	Working days
		by high water	by rainy	by holidays		
Jul.	31	31	8	2	31	0
Aug.	31	31	8	2	31	0
Spt.	30	30	6	2	30	0
Oct.	31	10	4	2	16	15
Nov.	30	0	1	2	3	27
Dec.	31	0	1	2	3	28
Jan.	31	0	1	2	3	28
Feb.	28	0	0	2	2	26
Mar.	31	0	2	2	4	27
Apr.	30	0	1	2	3	27
May	31	0	5	2	7	24
Jun.	30	15	7	2	21	10
Annual total days						
	365	117	44	24	154	211
Total workdays from Nov. to Jun.						
	273	25	22	18	62	211

Fig.7-3 Diagram of Workable Period for Well Construction
in Accordance with the Variation of Water Level
(on land)



3.4. Workdays of superstructure works.

The construction of the superstructure works is as will be stated later conducted by a flat barge in stream and by crawler crane on land. The former is as shown in Fig. 7-1 conducted by selecting a period in which the current velocity is small as far as possible, due to monthly changes of the velocity, and rises in the water level. That is, a period between March and May shall be chosen for the setting-on works. On the other hand, for the latter the term of works can be selected during the whole 6.5-month period from early November to mid-May when a greater part of the area named 'the land area' is exposed. Accordingly, the workdays will, as shown in Table 7-5, be 177 days based on the monthly totals of the November/May period, including 35 non-workdays to the total of 212 calendar days. As the starting date will be November 1 and the closing date May 15, the ratio of workdays will be:

$$177 \div (212 - 16) = 0.90$$

3.5. Workdays of bridge approach works.

The monthly mean temperature is between 19°C - 31°C throughout the year and it is 7°C even in January when the temperature falls lowest. Hence, there is no such a phenomenon as freezing soil during the banking works. Hindrance by wind velocity has never been experienced. As to rainfalls, seen from the nature of the soil, days having daily precipitation of 25.4mm and more were made unworkable. In the wet season, days having a water level up to G.L.+11.50m were made workable and those having a water level higher than above unworkable. Accordingly, a period from June 25 to September 25 is the work-suspended period. Seen from the above circumstances, the total number of the annual working days will, as shown in Table 7-6, be 237 days (workdays) with 66 non-workdays to 303 calendar days calculated based on the total number of a September/June period. Since the works start on September 26 and end on June 24, the ratio of workdays will be:

$$237 \div (303 - 25 - 6) = 0.87$$

3.6. Unworkable days during the rainy season.

Even in the rainy season the construction is partially capable. However, the environs of the construction base are totally submerged except for temporary railways and roads and, furthermore, due to much precipitation, the work will be greatly retarded in efficiency. Hence at the midst of the rainy season the work is suspended but auxiliary jobs such as overhauls and maintenance work can be carried out.

4. Temporary Works.

4.1. Outline.

Prior to the commencement of the main construction works, it is required to have the temporary equipment and facilities completed. In planning the term desired and the predetermined construction schedule,

Table 7-5 Workdays for Bridge Erection Work

Month	Days in month	Non workdays				Working days
		by high water	by rainy	by holidays	Total	
Jul.	31	31	6.8	2	31	0
Aug.	31	31	7.6	2	31	0
Spt.	30	30	8.0	2	30	0
Oct.	31	15	3.4	2	20.4	10.6
Nov.	30	0	0.2	2	2.2	27.8
Dec.	31	0	0.2	2	2.2	28.8
Jan.	31	0	0.2	2	2.2	28.8
Feb.	28	0	0	2	2.0	26.0
Mar.	31	0	1.4	2	3.4	27.6
Apr.	30	0	1.0	2	3.0	27.0
May	31	16	2.1	2	20.1	10.9
Jun.	30	25	6.8	2	30	0
Annual total days						
	365	148	35.9	24	177.5	187.5
Total workdays from Nov. to May						
	212	16	5.1	14	35.1	176.9

Table 7-6 Workdays for Bridge Approach Construction Work

Month	Days in month	Non workdays				Working days
		by high water	by rainy	by holidays	Total	
Jul.	31	31	5	2	31	0
Aug.	31	31	5	2	31	0
Spt.	30	30	3	2	30	0
Oct.	31	0	3	2	5	26
Nov.	30	0	0	2	2	28
Dec.	31	0	0	2	2	29
Jan.	31	0	0	2	2	29
Feb.	28	0	0	2	2	26
Mar.	31	0	2	2	4	27
Apr.	30	0	1	2	3	27
May	31	0	2	2	4	27
Jun.	30	5	5	2	12	18
Annual total days						
	365	92	26	24	128	237
Total workdays from Spt. to Jun.						
	303	30	16	20	66	237

decision was made in close connection with the term of works which are allocated to each itemized work.

The temporary works can be divided into the preparatory works and the temporary works. The preparatory works are facilities indirectly related to the main construction works. In this chapter, it is included in the range of superstructure, substructure and bridge approach works of this project. Housing quarters and the construction bases were planned. As for the Jamuna River Project, they are dealt collectively with other works, independently in Volume VIII.

The temporary works include equipment and facilities related to the main construction works such as concrete plant, asphalt plant, temporary roads, precast concrete block, steel-made-caisson, execution-frame and well points works all of which were outlined.

Time schedules of works of both preparatory and temporary works were planned.

4.2. Temporary works.

4.2.1. Concrete mixing plant.

The concrete mixing plant shall be used in common by works on land, works for precast concrete blocks and slab works of superstructure, and the plant is to be built in the main construction base on the right bank of the Jamuna.

The daily concrete-placing volume is approx. 370 m^3 for well works and approx. 300 m^3 for precast-concrete block-works. Except for these, there is no overlapping work in concrete placing. Since concrete is not placed during the period of concrete curing and sinking of wells, the concrete placing for precast-concrete block-works can be made during that time. Even if both works are overlapped at the same time, the latter can be carried out at night. Consequently, as the daily concrete-placing volume of 370 m^3 is assumed, it will be $370 \text{ m}^3 \div 7 \text{ hr/day} = 53 \text{ m}^3/\text{hr}$, and if the capacity of plant is fixed at $80 \text{ m}^3/\text{hr}$ and the ratio of operating hours at 85%, the total concrete mixing volume will be $80 \times 0.85 = 68 \text{ m}^3/\text{hr}$, which will fully secure the required daily concrete placing volume. The plant personnel will consist of 10 persons.

4.2.2. Barge mounted concrete mixing plant.

The barge is used for mixing concrete for the top slab of the well in stream, for the wells on left bank side at the land area and for the slab of superstructure near the left bank.

The daily concrete placing volume (maximum) being 565 m^3 for the top slab of the well, a plant barge with a capacity of $70 \text{ m}^3/\text{hr}$ of concrete mixing will be planned. If the ratio of operation is fixed at 80%, it will be $565 \text{ m}^3 \div (70 \text{ m}^3/\text{hr} \times 0.8) = 10 \text{ hr}$ and this will be capable

of finishing the whole concrete placing within one day. However, aggregate, cement and water must be supplied whenever necessary by a supply ship.

The plant barge is equipped with cranes to transship various materials. Further, the plant barge will load concrete pumps and must be capable of placing concrete both by conveyors and pressure pumping.

4.2.3. Prepacked concrete plant.

The bottom slabs of wells at both land area and stream area are constructed by prepacked concrete because of the deep position of the bottom slab and unstability of concrete placing by the tremie method. The bottom slab is required to be constructed one by one. The plan is drawn per one slab 457m^3 (in stream).

If the volume of mortar required per one slab is calculated at a percentage of void of 45%, a medium size mixing plant with a capacity of $20\text{m}^3/\text{hr}$ will be sufficient. The number of pumps shall be 5 and when in consideration of the operating ratio, the pressure feeding volume is fixed at $70\%/ \text{min}$, it will be $0.07\text{m}^3 \times 60 \text{ min} \times 5 = 21\text{m}^3/\text{hr}$. Hence, five pumps will be well.

4.2.4. Asphalt plant.

Asphalt mixtures are used for road pavement on the approaches and surface pavement on the bridge and an asphalt plant is built in the main construction base.

The asphalt volume required is approx. 8,100 tons for the bridge approaches and approx. 4,100 tons for the slab works. If the mixing capacity of the asphalt plant is now assumed at $45\text{t}/\text{hr}$ and the mechanical efficiency as 0.9, the result will be $45\text{t}/\text{hr} \times 0.9 = 40\text{t}/\text{hr}$. When the operating ratio of execution is fixed at 70%, the result will be $12,200 \text{ t} \div 40\text{t}/\text{hr} \div 7\text{hr}/\text{day} \div 0.7 = 62 \text{ days}$ and seen from the paving schedule, it has sufficient margin. The plant will be operated by the personnel consisting of 9 members.

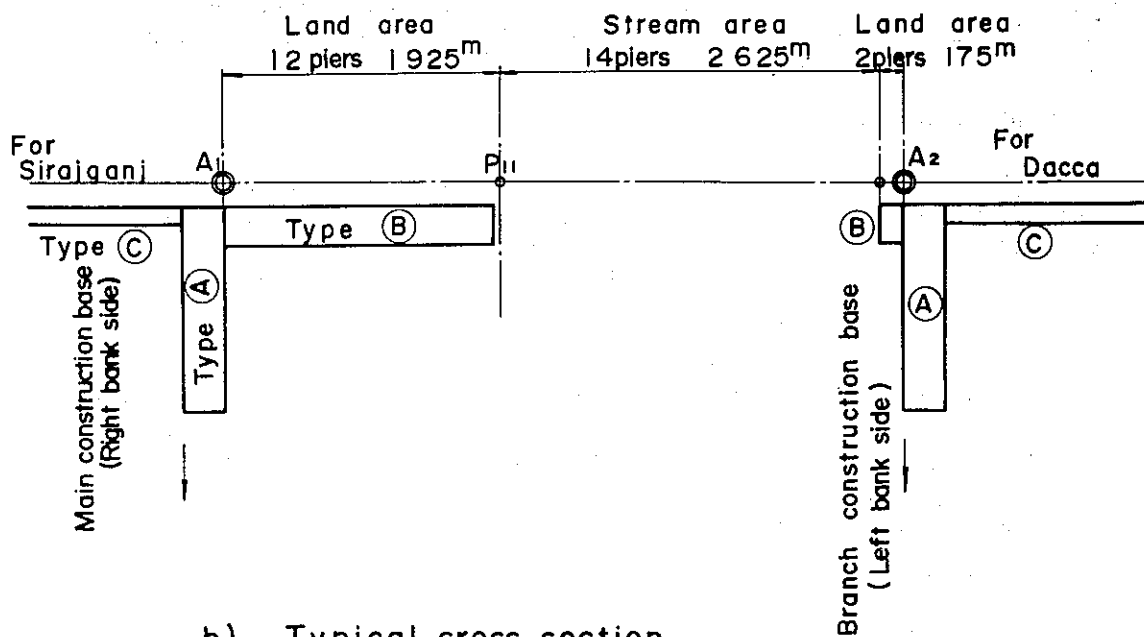
4.2.5. Temporary road.

Roads for the construction works of substructures on land, superstructures and approaches shall be built starting from the main construction base on the right bank and the branch construction base.

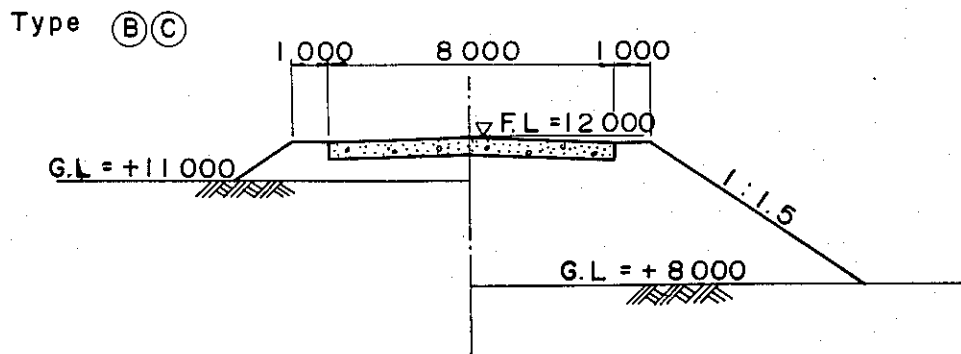
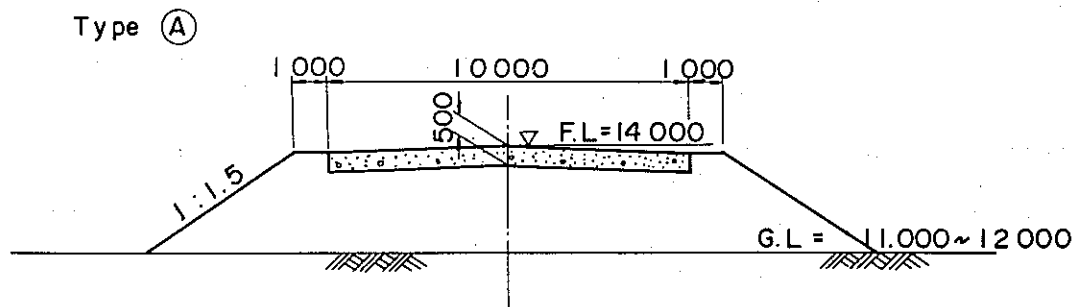
For the precaution of the wet season, both roads, namely, one road covering an area between A1 and the main construction base on the right riverside and another road covering an area between A2 and the branch construction base on the left riverside must be of a structure serviceable for all season. Further, A1-P11 of the land construction area of the substructure and P26-A2 must be constructed so that it will not hinder the water flow in the rainy season. Further, A1-P11 of the land construction area of the substructure and P26-A2 must be constructed so that it will not hinder the water flow in the rainy season.

Fig.7-4 Diagrammatic Sketch of Temporary Road

a) Marking diagram



b) Typical cross section



Accordingly, despite the repetition of construction works and flood damages throughout the year, a simple structure capable of construction each year shall be located on the down stream side of the bridge axis. The overall layout and typical cross sections are shown in Fig. 7-4. Roads Type A shall be built from both construction bases on right bank and left bank to the neighbourhood of A1 and A2, respectively. Road Type B shall be built between from A1 to P11 and between A2 and P26. Road Type C is planned for 1.0km landside along the bridge axis from A1 or A2 on both right and left banks.

4.2.6. Surveying plan.

As for the surveying of substructure works, basic execution surveying, control point surveying and pier-position surveying shall be conducted. As surveying for the road construction, control point surveying, surveying of center-line, longitudinal-levelling and cross-levelling shall be conducted. Furthermore, as for the superstructure, surveying of the bridge axial line, surveying of spans and levelling shall be conducted.

4.2.7. Electric power planning for construction works.

The electric power planning for construction works is classified into two, namely, power supply from a power station at construction base and power supply by portable generators.

4.2.8. Quality control plan.

In the execution of each work, facilities that will conduct quality control of construction materials shall be installed at construction bases. The items of test include various tests such as concrete, steel, asphalt and soil.

4.2.9. Precast-concrete block-yard.

Precast concrete blocks (circular hollow cylinder) are used for the well in the stream area and its yard and plant shall be built in the main construction base.

In view of a total number of piers constructed per year, the plant capacity was decided. Since the maximum number of construction of the piers is 4 piers per year, the total block number per year is $16 \times 4 = 64$. The process flow chart of precast blocks is shown in Fig. 7-5.

One piece of block is 4m high, and since the setting and sinking cycle takes 5 days on the average, the overhanging job out of the quay-wall will take $5 \text{ days} \div 4 \text{ piers} = 1.25 \text{ days}$, i.e. the production at a rate of one block per 1.25 days is required. For that purpose, 8 moulds were fabricated for block production.

The productive facilities include plant-shed, large trolleys to carry the precast concrete blocks of 750 tons, large rails and quay-walls for overhanging purposes. The self weight of a trolley is 370 tons. Hence, steel piles are used for the foundations of rails.

4.2.10. Caisson yard.

The steel-made-caisson shall be manufactured to be divided into eight blocks, and shall be transported to the site. As the steel-made-caisson is composed of a steel shell and a portion of filled concrete when completed, its total weight is 750 tons including weight of itself 150 tons.

The caisson yard for assembling and quay-wall for carrying of steel-made-caisson should be constructed on the main construction base. And, as the purpose of assembling of steel-made-caisson, the assembling stages shall be installed on the caisson yard, and foundations of stages must be made pile-foundations which is not acted any loads from the stages to the quay-wall.

The structure of the assembling stage is as shown in Fig. 7-6.

4.2.11. Execution frame of well.

In the construction of well in stream, since the sinking of wells must be completed during the dry season, the work cannot be executed by the cofferdam method. It will make up this disadvantage to make the steel-made-caisson up to the height of 19 meters from the bottom. However, for accurate positioning and for facilitating on-the-spot jobs, the execution frame shall be constructed. The flow chart of execution-frame construction works are as shown in Fig. 7-7.

When the steel-made-caisson works are being executed, due to ununiformity in distribution of frictional force and point resistance, some inclination and displacement are anticipated to occur. In particular, as the inclination and displacement at the time of setting will greatly affect the accuracy in execution of wells, extra care is required in this respect.

In due consideration of current velocity and scouring, a structure of the execution frame is adopted a pile structure and a truss frame. The structure of the execution frame is shown in Fig. 7-8.

The execution frame manufactured at its yard can be installed at a predetermined place by a floating crane but in due regard to poor conditions for installation and workability, it is required to have 10 temporary piles driven previously into a desired position and the supporting frame is temporarily fixed with these piles and after that 35 bearing piles shall be driven. The top surface of the executing frame is covered with deck-plates which will be made to serve as a working deck. On this working deck, a girder for travelling the large-diameter ($\phi 2.0\text{m}$) boring machine of reverse circulation system and a crawler crane is set. Moreover, gangway ladders and fenders are provided for mooring vessels and barges alongside the frame. Scour-prevention piles are driven against scouring during execution of well at 10m upstream of the frame.

Fig. 7-5 Flow Chart of Precast Block Works

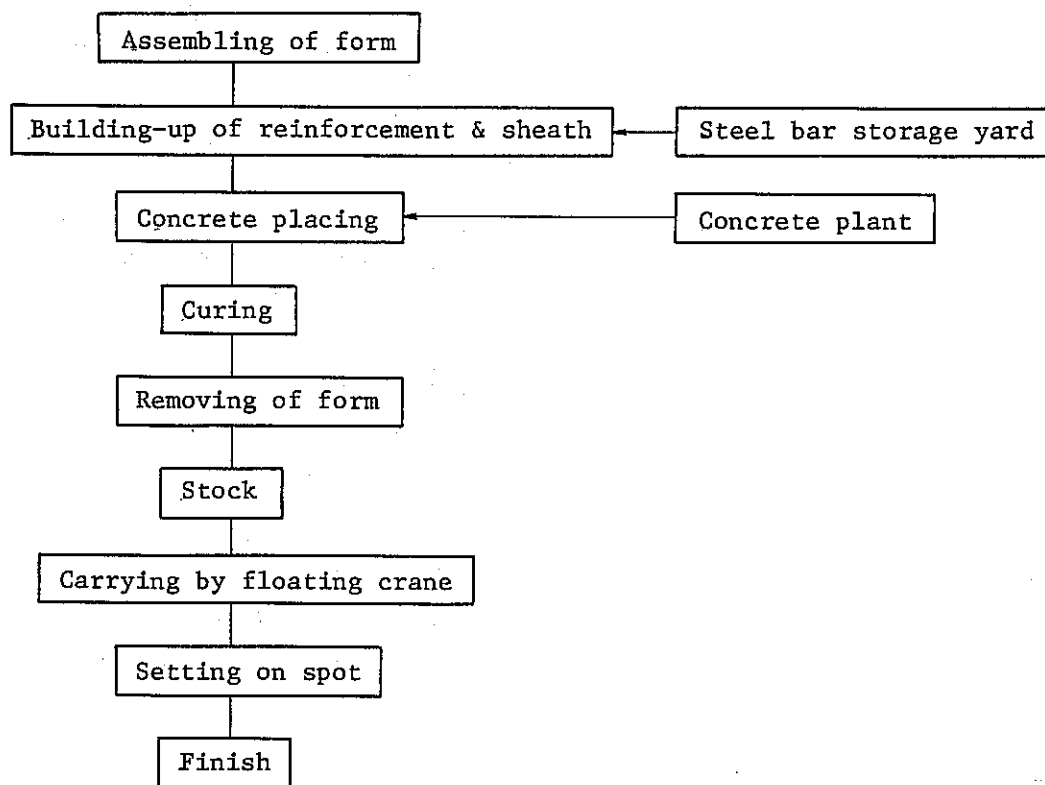


Fig. 7-7 Flow Chart of Execution Frame Construction Works

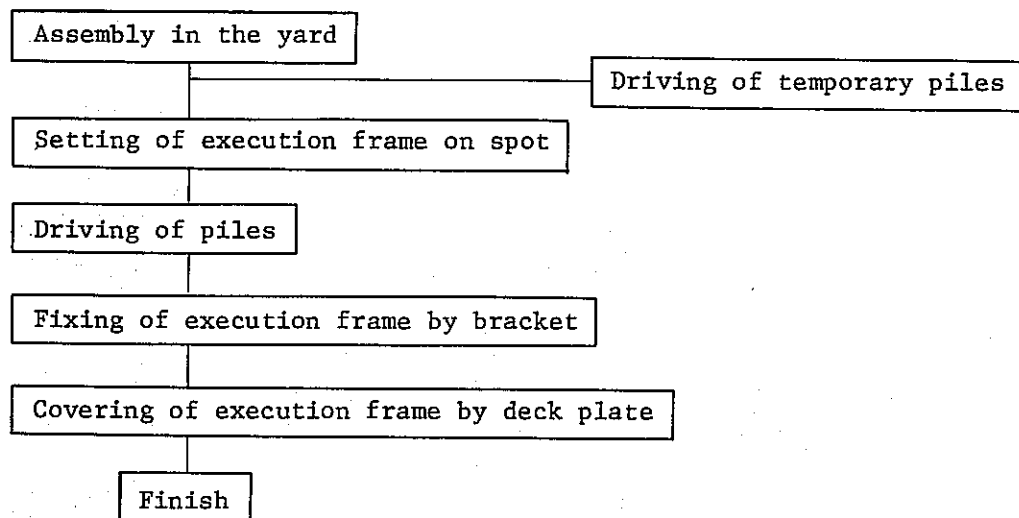
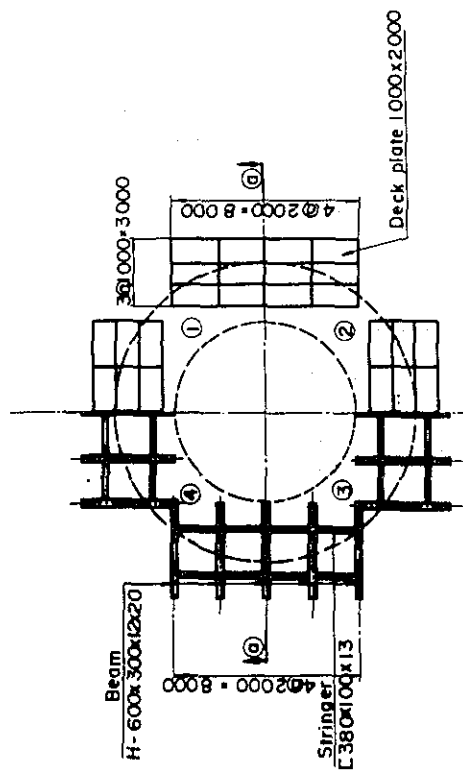
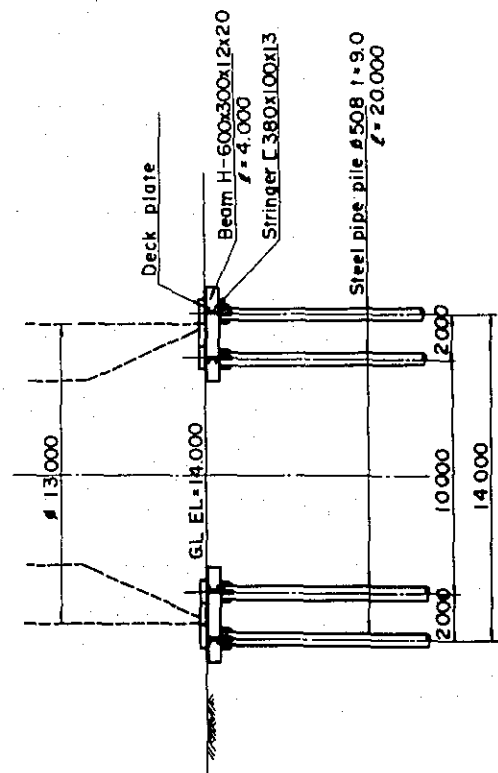


Fig. 7 - 6. Assembling Stage of Steel-made-caisson
(in millimeter)

Plan



①-① Section



Details

S = 1 : 40

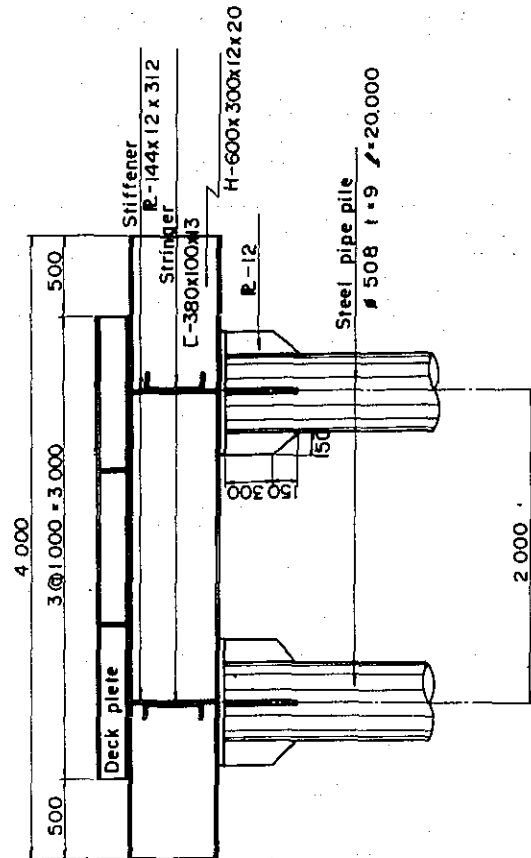


Fig.7-8 General Structure of Execution Frame of Well

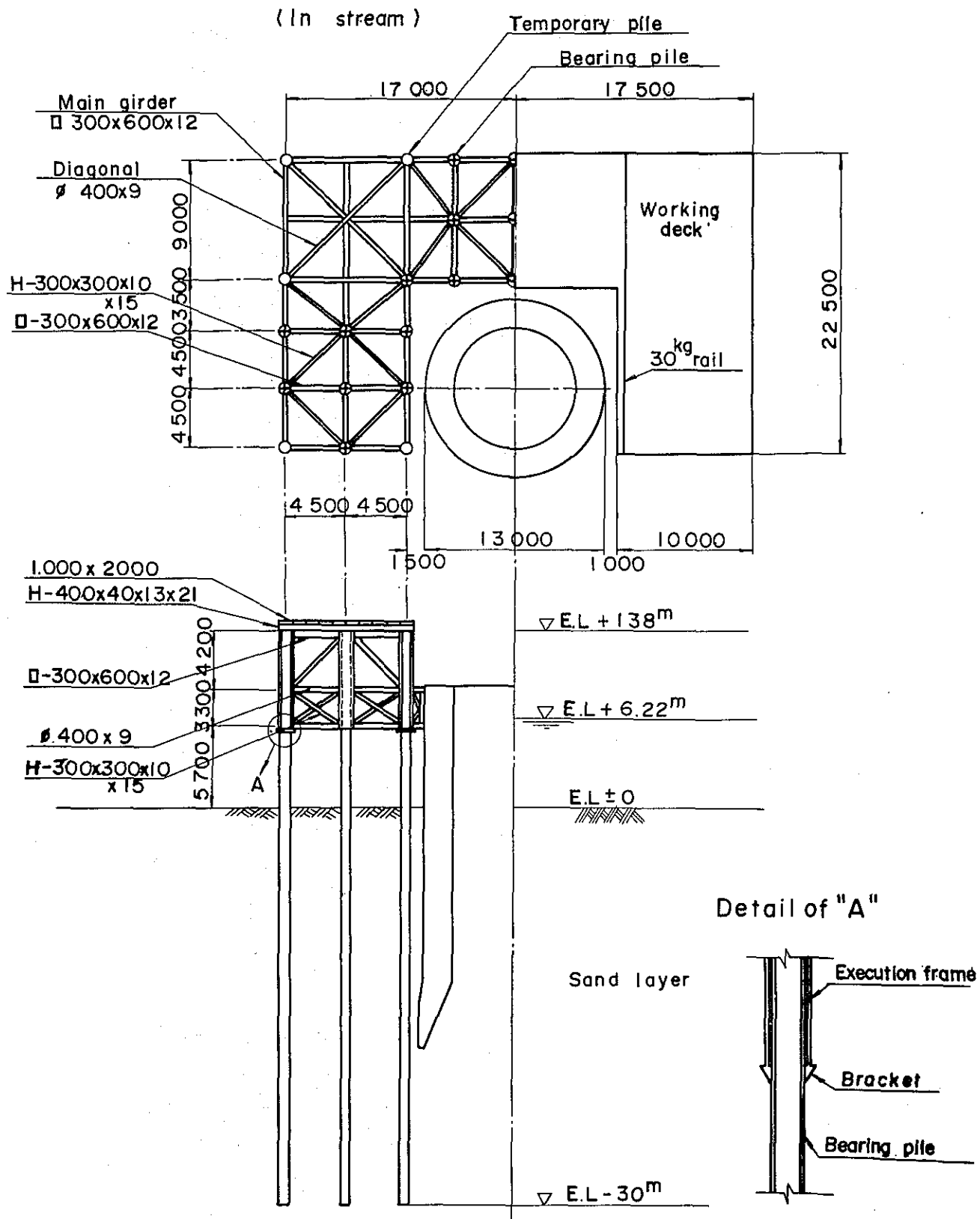


Fig.7-9-1 General Structure of Execution Frame of well (I)
(On land)

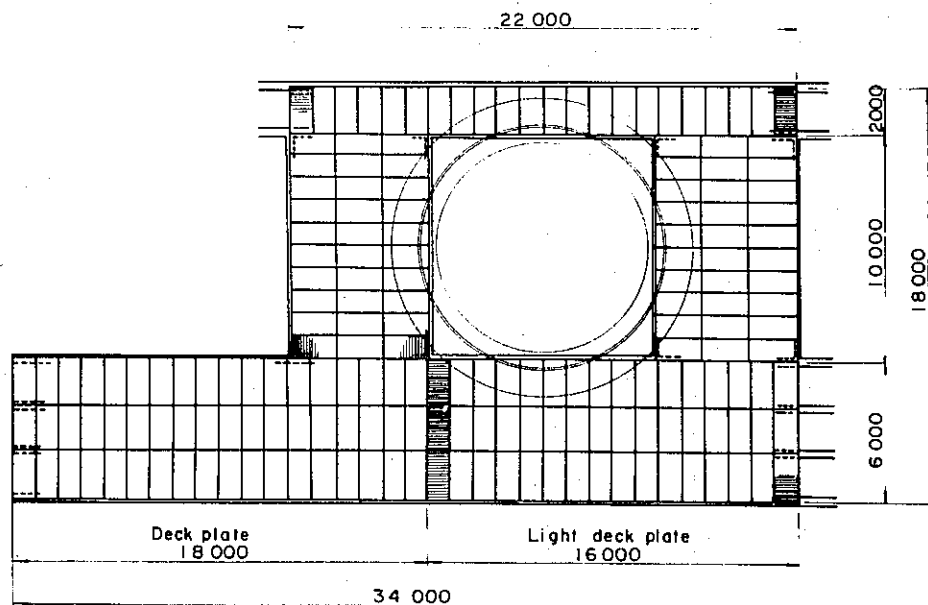
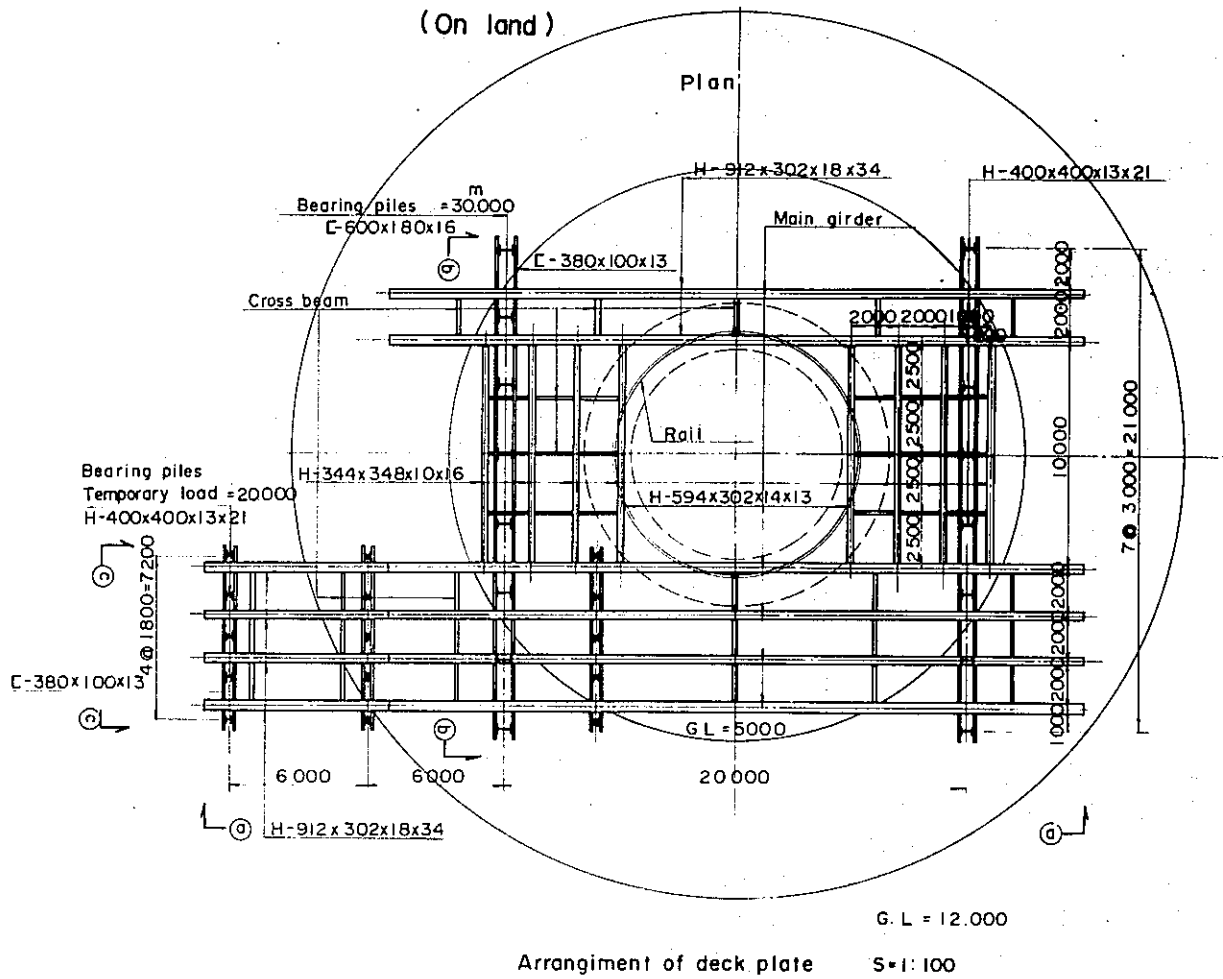
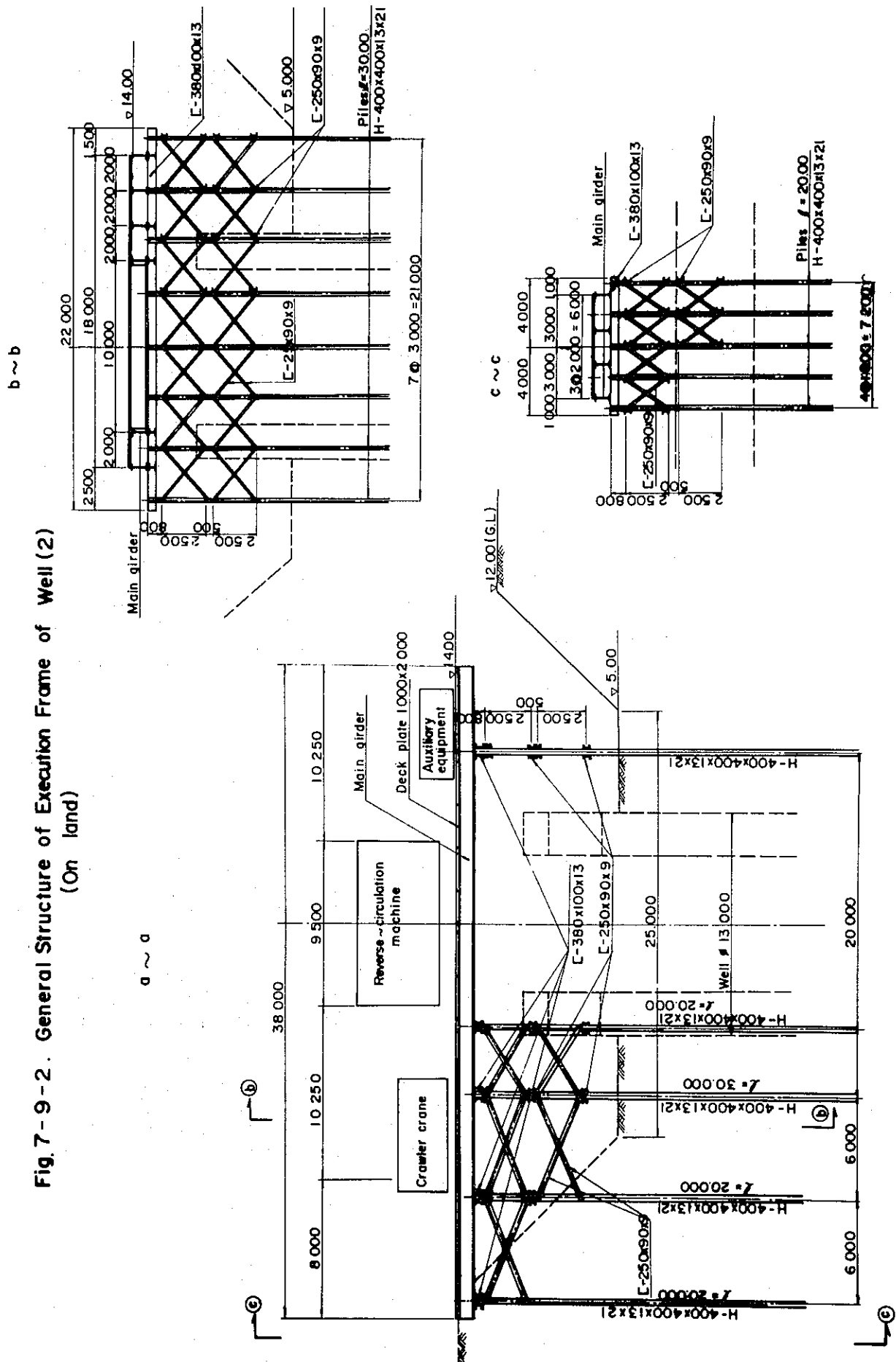


Fig. 7-9-2. General Structure of Execution Frame of Well (2)
(On land)



By the way, this execution frame of well shall be removed after the works ended and repaired for reuse in the next year but for a precaution of a case in which the removal is impossible, spare supporting frames were provided three sets.

4.2.12. Execution stage of well on land.

The execution of wells on land shall have excavation works carried out in two stages, namely the primary excavation and the excavation inside wells. In the existing ground the primary excavation deals with excavation up to the ground for setting the curb shoe of wells at the ground with E.L.=5.0m. The excavation for well sinking is made by installing the execution stage over the top of the well and by a large caliber boring machine provided with facilities for reverse circulation.

The structure and dimension of execution stage is shown in Figs. 7-9-1/2.

4.2.13. Well point works.

The curb shoe is set on the formation level of +5.0m PWD after primary excavation from the average ground level of 11.5m PWD. However, it is required to give land improvement and to let down the water level for setting the curb shoe. As a method, the well-point method was adopted on land. The arrangement of wellpoints is made at a position which is 5.0m away from the periphery of foundation well of 13m and at intervals of 1.5m. The pumped water shall be directly disposed into the river.

4.2.14. Time schedule.

The overall time schedule of temporary works is shown in Fig. 7-10.

4.3. Preparatory works.

This project is a very big-project which is composed of bridge construction, river control, road construction and railway construction and the construction works require a lot of materials, workers and equipment.

The preparatory works are roughly classified as a construction base and a dwelling. Since the works are divided by the river, the bases shall be laid out on both sides of river as the main is on the right bank.

The preparatory works are important not only for bridge construction works, but also for many other construction works. Therefore, preparatory works were collectively planned on VOLUME VIII of this study as the harmonious plan for all construction works.

5. Bridge Works.

5.1. Outline.

Fig. 7-10 Time Schedule of Temporary Works

Description		6th	7th	8th	9th	10th	11th	12th	13th
Construction year		JASON	JASON	JASON	JASON	JASON	JASON	JASON	JASON
Month		DJF	DJF	DJF	DJF	DJF	DJF	DJF	DJF
Construction works	Substructure								
	On land								
	In stream								
	works								
Construction works	Superstructure								
	On land								
	In stream								
	works								
Construction works	Slab								
	On land								
	In stream								
	works								
Construction works	Bridge-approach								
	On land								
	In stream								
	works								
Construction works	Right bank side								
	On land								
	In stream								
	works								
Construction works	Left bank side								
	On land								
	In stream								
	works								
Construction works	Concrete mixing plant								
	On land								
	In stream								
	works								
Construction works	Concrete plant barge								
	On land								
	In stream								
	works								
Construction works	Prepacked concrete plant								
	On land								
	In stream								
	works								
Construction works	Asphalt plant								
	On land								
	In stream								
	works								
Construction works	Temporary road works								
	On land								
	In stream								
	works								
Construction works	Surveying								
	On land								
	In stream								
	works								
Construction works	Electric works								
	On land								
	In stream								
	works								
Construction works	Quality control works								
	On land								
	In stream								
	works								
Construction works	Precast block yard								
	On land								
	In stream								
	works								
Construction works	Steel calsson yard								
	On land								
	In stream								
	works								
Construction works	Execution frame works of well								
	On land								
	In stream								
	works								
Construction works	Dredging works								
	On land								
	In stream								
	works								
Construction works	Well point works								
	On land								
	In stream								
	works								
Construction works	Execution equipment for slab works								
	On land								
	In stream								
	works								
Construction works	Assembling yard for superstructure								
	On land								
	In stream								
	works								
Construction works	Facility miscellaneous works for superstructure								
	On land								
	In stream								
	works								

In the bridge construction works, in due regard to the natural conditions surrounding the bridge site, plans for execution must be drawn up so that the most suitable erection method could be adopted and the works may be completed within the term of works. To execute the project in a most appropriate way, in due consideration of the following items, plans were provided.

- (a) To limit works for temporary structures and various running expenses on the spot to the irreducible minimum of a demand.
- (b) To use repeatedly construction equipment and tools to decrease the number of them as much as possible.
- (c) To endeavour to let a limited number of labourers through the term of works.
- (d) To prevent losses inflicted on labour and equipment, resulting from useless preparatory plans of construction and delay in material supply.

The principal substance of the bridge works includes the well works, pier shaft works, superstructure-erection works, slab works, and bridge approach works. In this chapter each construction method will be outlined and plans drawn up on the erection schedule will be explained.

5.2. Substructure works.

5.2.1. Outline of execution method.

The execution of the substructure is conducted as shown in 2.2.1 of this Chapter. The execution work on land and in stream shall be classified as follows:

- (a) Execution on land (A1-P11, P26, A2) 14 piers
 - (b) Execution in stream (P12-P25) 14 piers
- (1) Steel-made-caisson
 - (i) Assembling

Steel wells are fabricated and manufactured abroad and then brought in to the site. The steel-made-caisson of 19m in height which is vertically divided into 4 blocks and also horizontally divided into 4 blocks and hence, the steel caisson consists of 16 blocks. One block weights about 10 tons.

At the field plant (steel-caisson yard), the initial stage block is assembled and filling concrete is placed inside the well. Later from the 2nd stage to the 4th stage, the wells are vertically added up in their upright position and the overall height of 19 meters in completed. The steel-made-caisson itself weighs approx. 150 tons and the filling concrete is approx. 600 tons in weight, totalling approx. 750 tons.

Scaffolds are previously set inside and outside the steel caisson and the concrete placing is made by pumping trucks.

(ii) Transport

Since the caisson yard is established close to the quay-wall, the steel caisson is hung directly from the quay-wall by a 1,000-ton flating crane and carried on the setting spot.

In towing, if the towing speed is estimated at 1m/sec (2 knots), the design wind velocity at 11m/sec and the design current velocity at 3.3m/sec, 2 tugboats of 1,000 PS will be sufficient. However, in view of a case when the tugboats are fanned by the wind load and the current pressure from a horizontal direction in the towing course, it is recommended to arrange 2 auxiliary tugboats along the both sides of the floating crane and a total of 4 tugboats will assure the safety and the capacity of towing.

(iii) Setting of wells

For the accurate and assured positioning of wells, the floating crane is piloted by anchor wire manipulation other than by tugboats, freely to the desired position. The method to fix the floating crane is to use anchors and sinkers and to use the execution frame.

The floating crane which lifted the steel-made-caisson will go into the predetermined position from the downstream and hang down the wells by the execution frame. For inducing the well to resist the flow, the steel caisson is required to increase its weight and the increasing of 1,045 tons can be made by pouring water into the caisson shell.

When the cutting edge of a steel-made-caisson approaches the river bed, it is regarded that the stream will become turbulent and creates scours on the river bed and accordingly the well's cutting edge will cut into the ground, comparatively deeper than the water depth. Even though the cutting edge touches the ground, because of the local scour occurring around the cutting edge, the setting of the steel well will continue to lack stability for a while but resulting from the well's net weight, it will sink to some degree and the wire with a holder will get loose. After that, each time the water inside the steel shell increases, the sinking is promoted and again when the wire with a holder loosens, lend time to the well till it becomes steady. In the next place, by using the tremie tube place the filling concrete at a height of 4.0m and conduct excavation by a clamshell to make the well sunken. Thus in this way till the cutting edge of the well sinks to a level of EL=-10m PWD, carry out the sinking of the wells. Later the works will proceed to the setting of precast concrete blocks and excavation by reverse circulation system (to be stated afterward).

The flow chart of steel caisson works is shown in Fig. 7-11.

(2) Precasting of concrete blocks

Based on the calculation of prestressing to the concrete blocks, the compressive strength of concrete for blocks shall be $\delta 28 = 450 \text{ kg/cm}^2$.

(3) Setting of precast concrete blocks

The portion of the well to be constructed by using of the precast concrete blocks which shall be prestressed after setting into the position, is composed of 14 rods and its execution flow-chart is shown in Fig. 7-12.

When a precast concrete block shall be set on its position, a steel-made-wedge is placed between a block to be set by a floating crane and a block already set on the well under construction and a working space of 1.5m in height is kept. After, prestressing bars are connected by couplers and surfaces of blocks to be jointed are pasted by bonding materials. And then, the block is set down by removing the wedge and prestressed by using of center-hole jacks. This process is repeated.

(4) Excavation

(i) Excavation equipment

The depth lower than -10m PWD after the steel-made-caisson was completely sunk, shall be excavated by 2 units of L-2 type extra-ordinary boring machine of large diameter (ϕ 2.0 m) (hereafter called as 'excavator') and for improving the efficiency of the excavator, travelling girders which can move independently to 2 directions, must be provided. These girders are previously assembled in the yard and after transported by a floating crane, they are positioned. Further, a mechanism was adopted so that at the time of setting precast blocks, the girders are moved on the working deck to give no hindrance to the positioning work.

(ii) Excavator

Data for the excavator are as follows:

Excavation speed:	1.0 - 2.0m/hr
Bit load:	6 tons
Torque at excavating:	1,600 - 2,000 kg.m
Bit revolution:	8 rpm
Exhaustion method:	Air-lift method
Bit type:	ϕ 2.0 m 3-blade bit

The power unit and the rotary table weight approx. 6.8 tons. A jib crane with a maximum load capacity of 25 t is equipped on the trolley for a smooth excavation work.

(5) Sinking promotion works

For accelerating sinking, it is required to reduce the resistance at the cutting edge of wells to zero and lessen the peripheral friction. Hence, the friction cut by the air jet method is adopted. An area below the cutting edge will accept no drilling effect, and it is pumped up by mixing and agitation of sand and water by the air lift method. Air is used for jetting.

For reducing the peripheral frictions, 36 pipes are needed on the periphery of well and are arranged at intervals of 4.0m in vertical direction. In the steel-made-caisson, the pipes are arranged at intervals of 2.0m for the vertical direction.

(6) Instrumentation system for well excavation and sinking control

In order to insure the accuracy of excavation and sinking of well, various types of gages buried in well concrete and centralized control are made by automatic recordings.

(7) Bottom slab works

The bottom-slab concrete is applied by the prepacked concrete method. Hence, the removal of slimes is made by airlift method by water jetting which will dredge the bottom base and then by using a high pressure water jet, dispose of the ground with a loosen bottom and make the supporting ground assured of security.

The bottom-slab concrete is made 5m thick but with no reinforcing bars. The grain size of aggregates is required to be 40 - 150 mm and the flow and ascending situation of mortar is detected by using the sensing tube. The design strength of prepacked concrete shall be 210 kg/cm^2 .

(8) Top slab

Since the concrete for top slab is 5m thick, it is placed concrete divided in two times. The placing of concrete is made by concrete pump cars which are installed on board the mixing plant barge and concrete is placed up to $30\text{m}^3/\text{hr}$.

(9) Piper shaft works

(i) Form

A pier shaft consists of 3 parts, namely lower part (1.9m high), middle part (15m high) and upper part (2.0m or 2.5m high). Forms for inclined portion (middle part) are made all at once for reducing the erection period. Form-assembling is conducted by a 1000-ton floating crane and a crawler crane (boom length 15m, working range 12m and load capacity 75t) on the temporary stage. However, in order to conduct the work to remove the execution frame half way at the same time, the above crawler crane is operated by being loaded on

board a flat barge. These cranes are those used for form-assembling in stream. The other hand, since 1000-ton floating crane cannot be used on land, a crawler crane and single winches are jointly used.

(ii) Concrete placing

The placing of concrete is made by means of a pump car which has a capacity of transport height max. 30m, transporting distance max. 70m and real discharging volume (average) 60m³/hr. For compaction efforts, 5 electric vibrators are used and concrete is compacted up to 50cm thickness each. The flow chart including from form-assembling to concrete placing and form removal is shown in Fig. 7-13. The full process requires about 45 days.

(10) Well works on land

(i) Primary excavation

The existing ground level is E.L.=+12.0m on the average and the level of the setting ground of the curb shoe of wells become E.L.=+5.0m. Hence, in case of the ground level of E.L.=+12.0m, the excavated depth is expected to become 7.0m. The excavation is carried out by 2-stage excavation and 1.5m berms are built here and there on the way. The side slope surface is 1:1.5.

(ii) Slip-form system

Because of its effectiveness, the slip-form system is adopted in the construction of well walls. The well will be divided into 24 rods and the treatment must be completed with 4 days per cycle. The flow chart is shown in Fig. 7-14. As to the concrete curing, at first concrete is kneaded with cooled water into a mixture and it is placed at a temperature of 20°C (Placing temperature). After concrete was placed, curing is made by water sprinkling. The working stage was attached with slip-form. Fig. 7-15 indicates the slip-form equipment.

5.2.2. Work schedule.

The well in stream is composed of two parts, namely, upper part and lower part. The lower part is the steel-made-caisson and upper part is the prestressed concrete well which consists of 24-rods of precast concrete blocks. The composition of rods of well in stream is as shown in Fig. 7-16 and the flow chart of well-sinking works in Fig. 7-17.

The well on land is constructed by slip form after excavation up to the setting ground (+5.0 PWD) of curb shoe. The composition of rods of well on land is shown in Fig. 7-18 and the chart of flow of well-sinking works on land in Fig. 7-19.

As a result of detailed calculations of time schedule based on the substance of works and its corresponding quantity, the charts of time schedule in stream and on land per one pier were obtained as shown in Fig. 7-20.

Fig. 7-11 Flow Chart of Execution of Steel Caisson Works

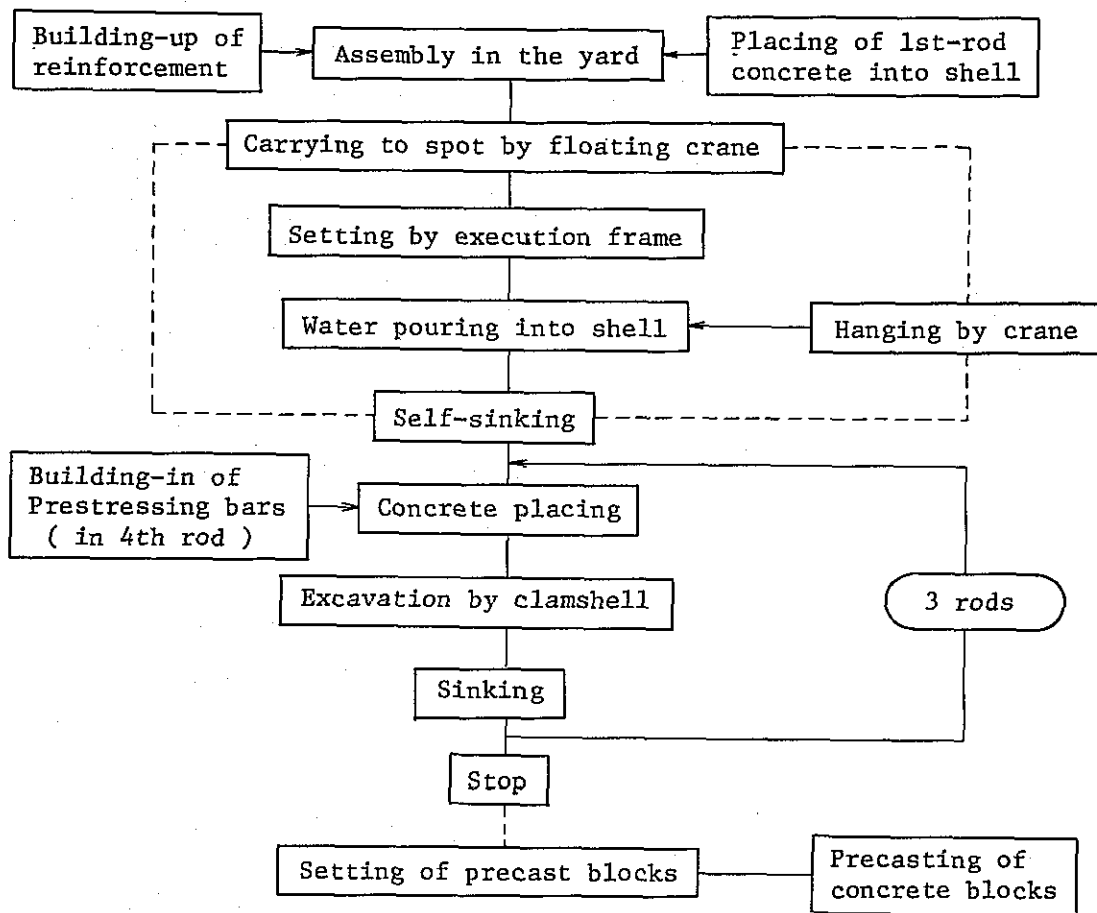


Fig. 7-12 Flow Chart of Setting Works of Precast-concrete Blocks

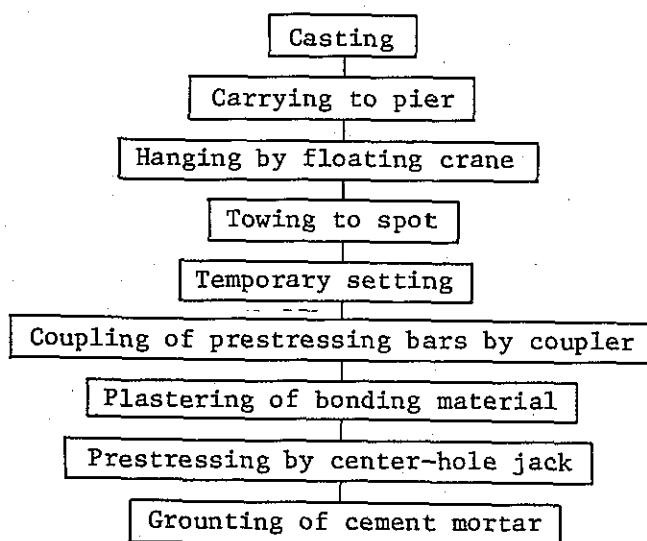


Fig. 7-13 Flow Chart of Form Works for Pier Construction

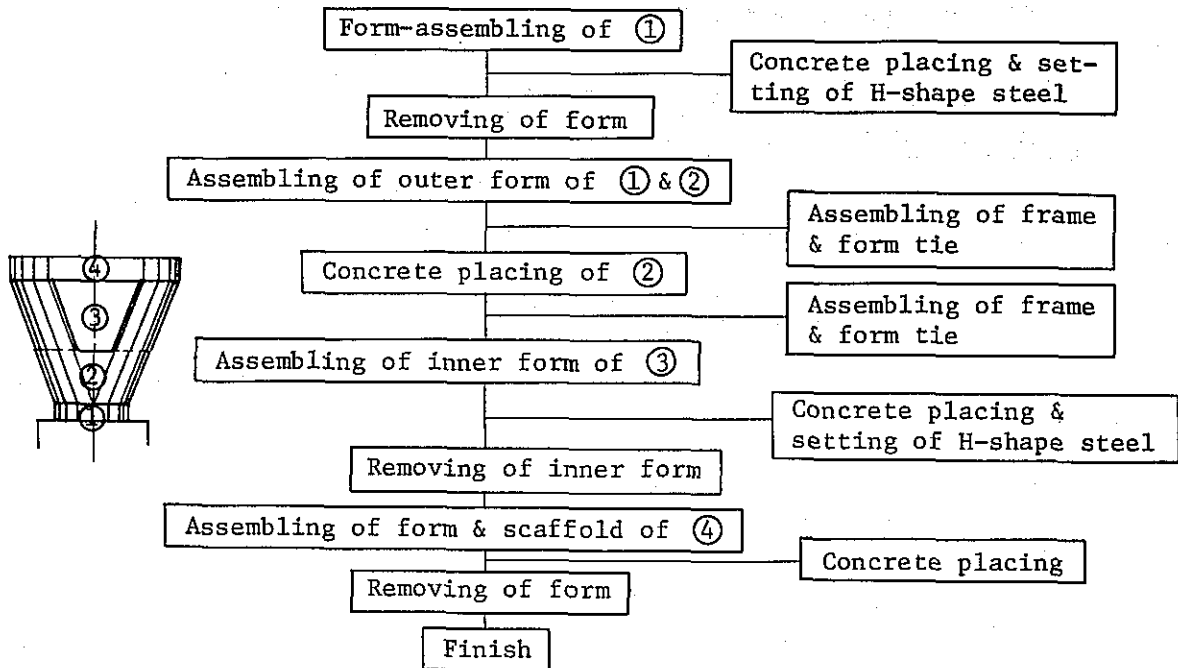


Fig. 7-14 Flow Chart of Slip-form Works for Well Construction

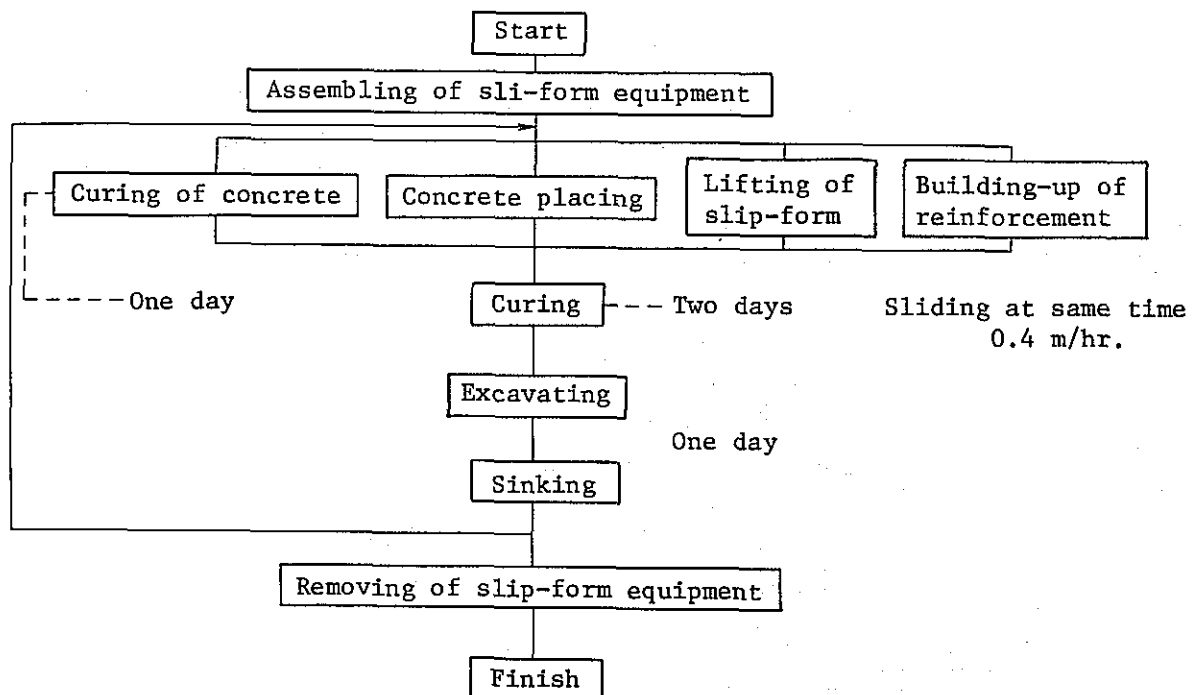
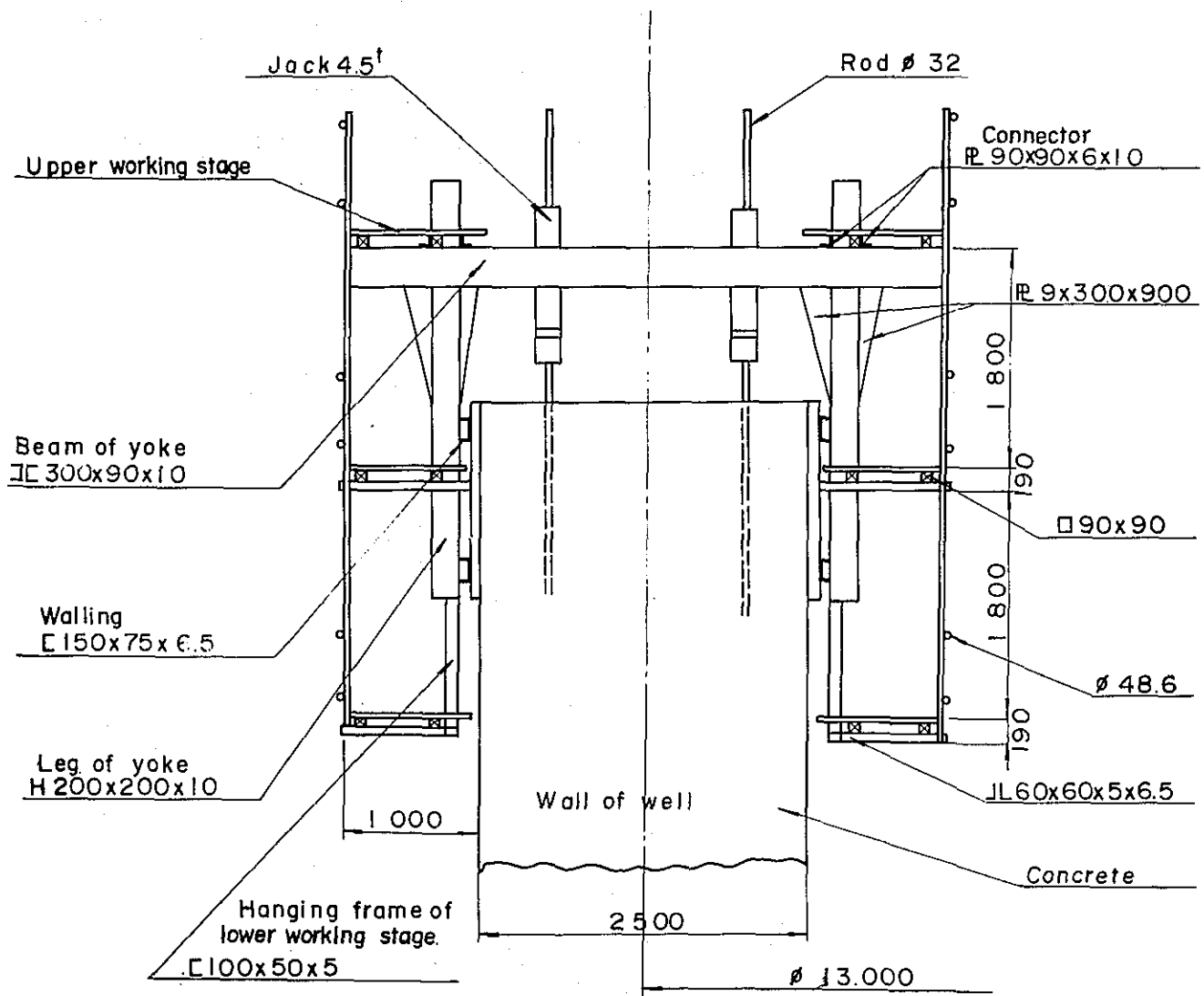


Fig. 7-15 Slip Form (On land)



Numbers of using jack are 28

Fig. 7-16 Composition of Rods of Well in Stream

(in meter)

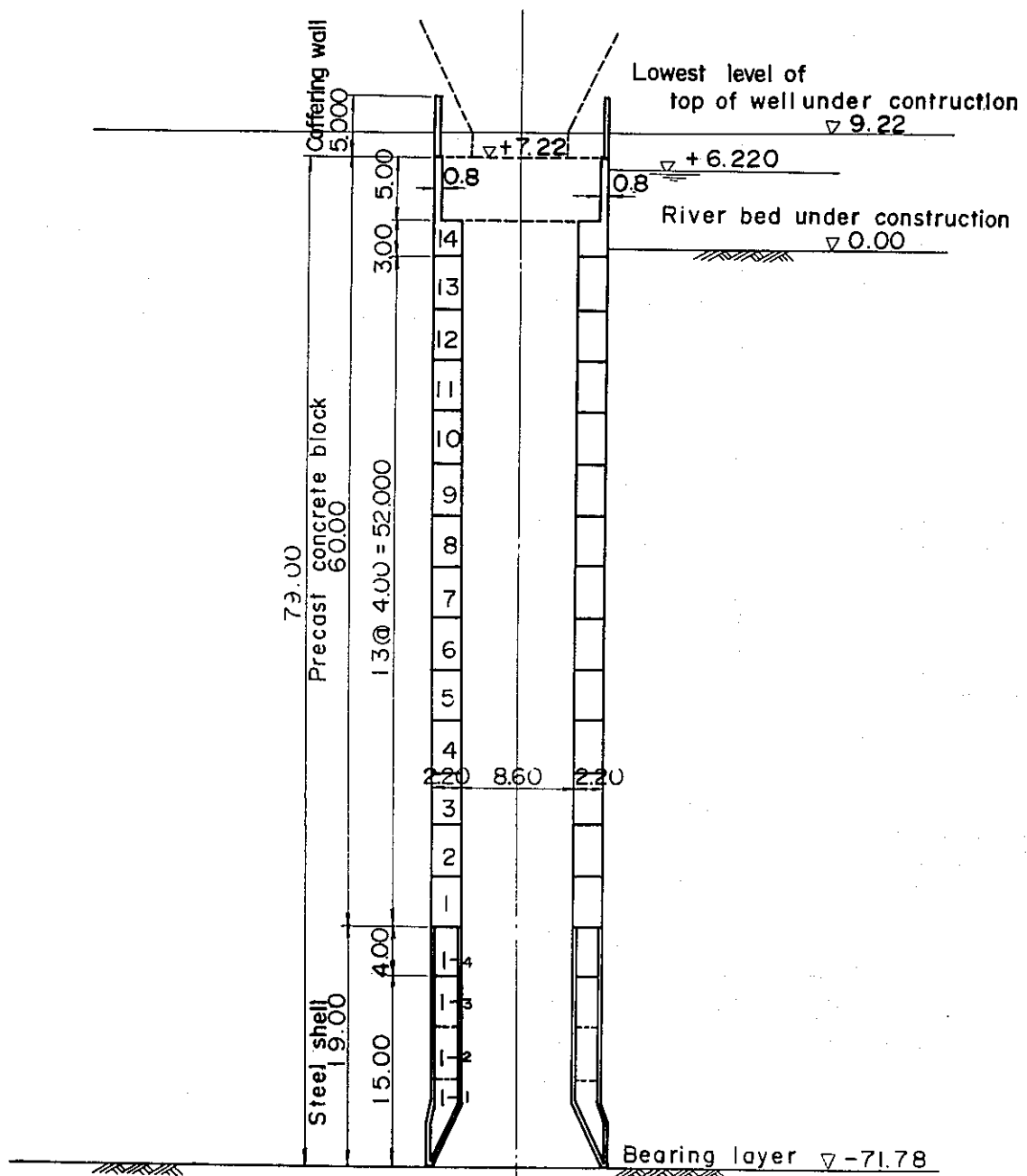
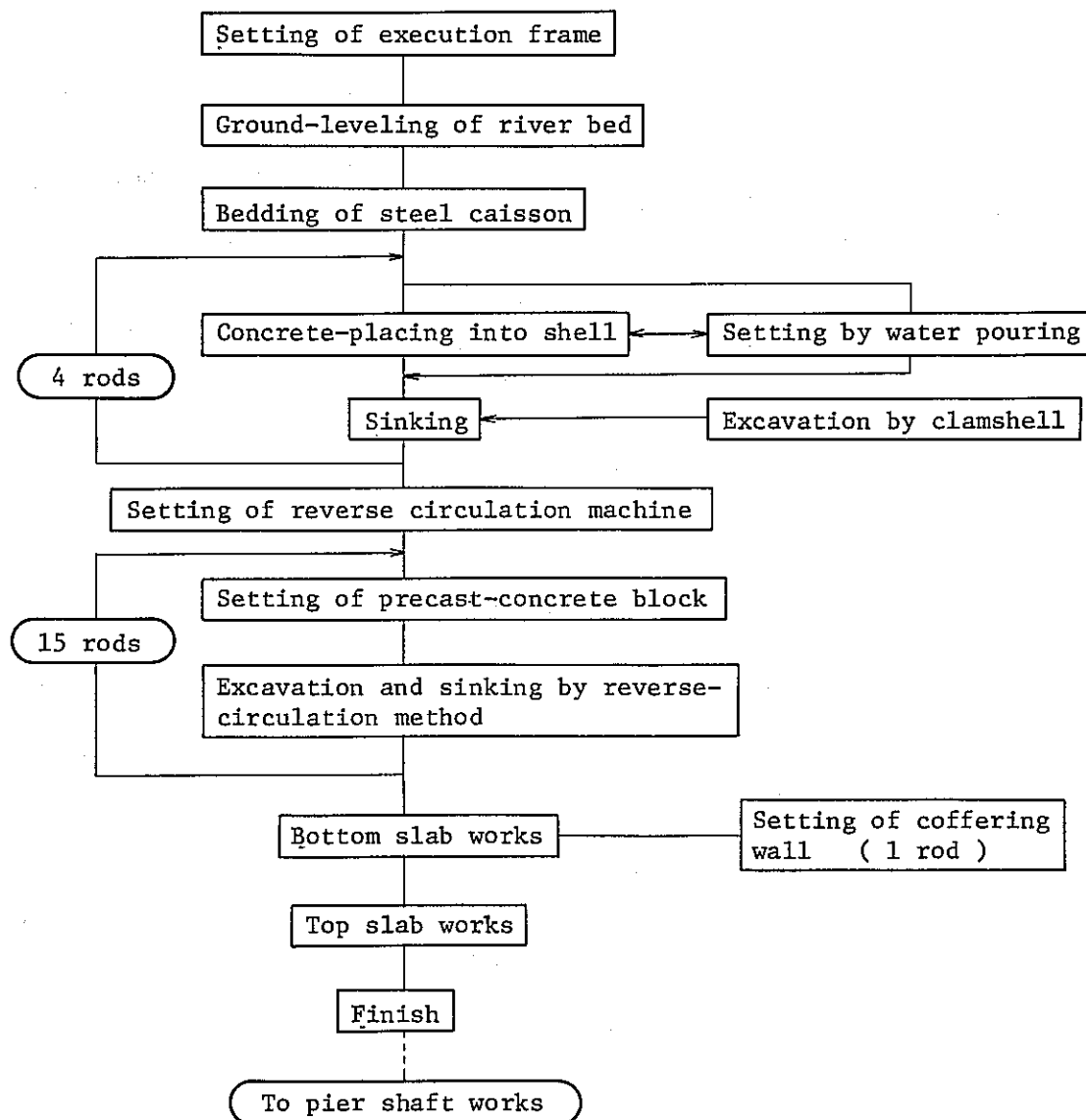


Fig. 7-17 Flow Chart of Well-sinking Works in Stream



(in meter)

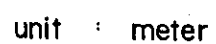


Fig. 7-19 Flow Chart of Well-sinking Works on Land

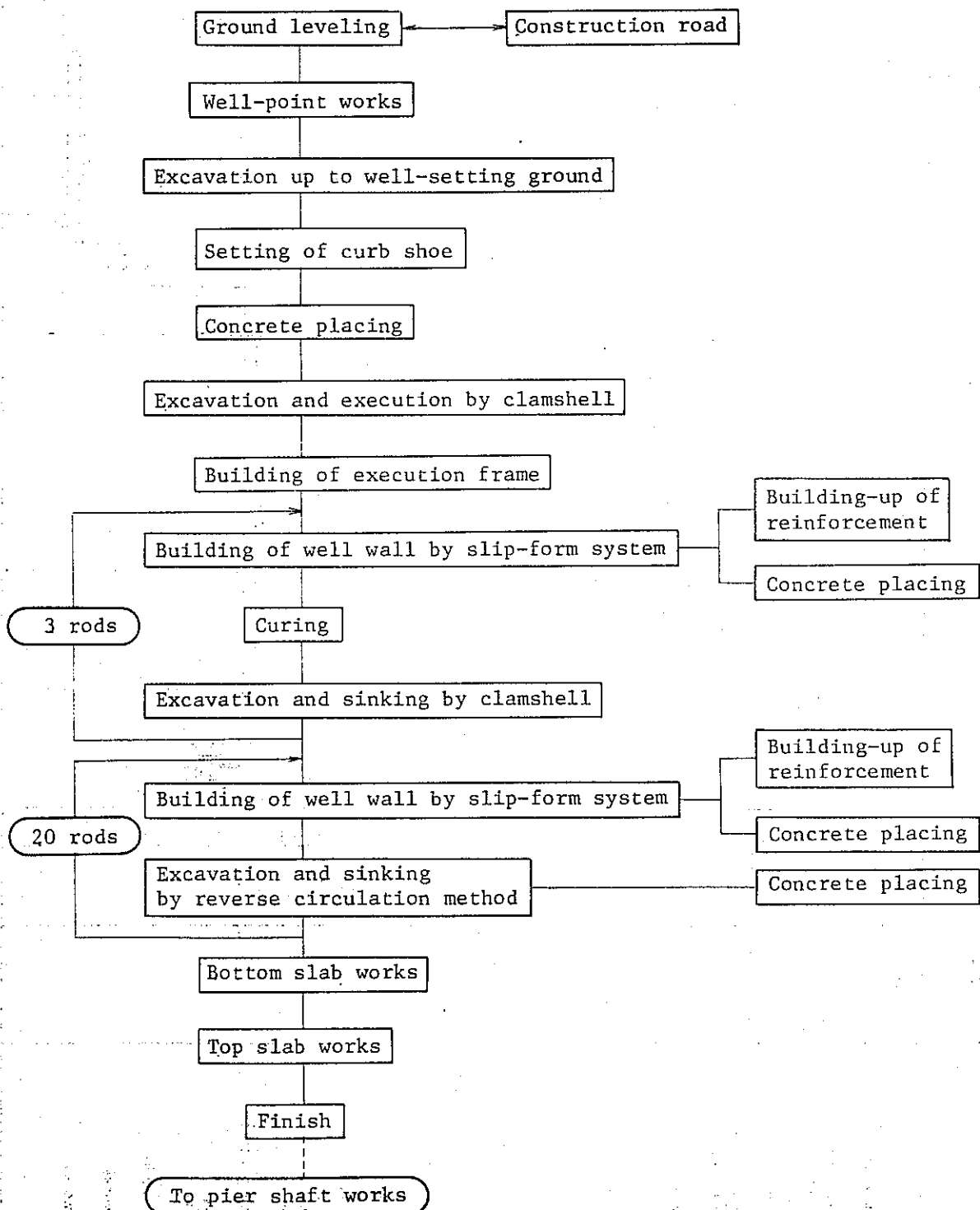
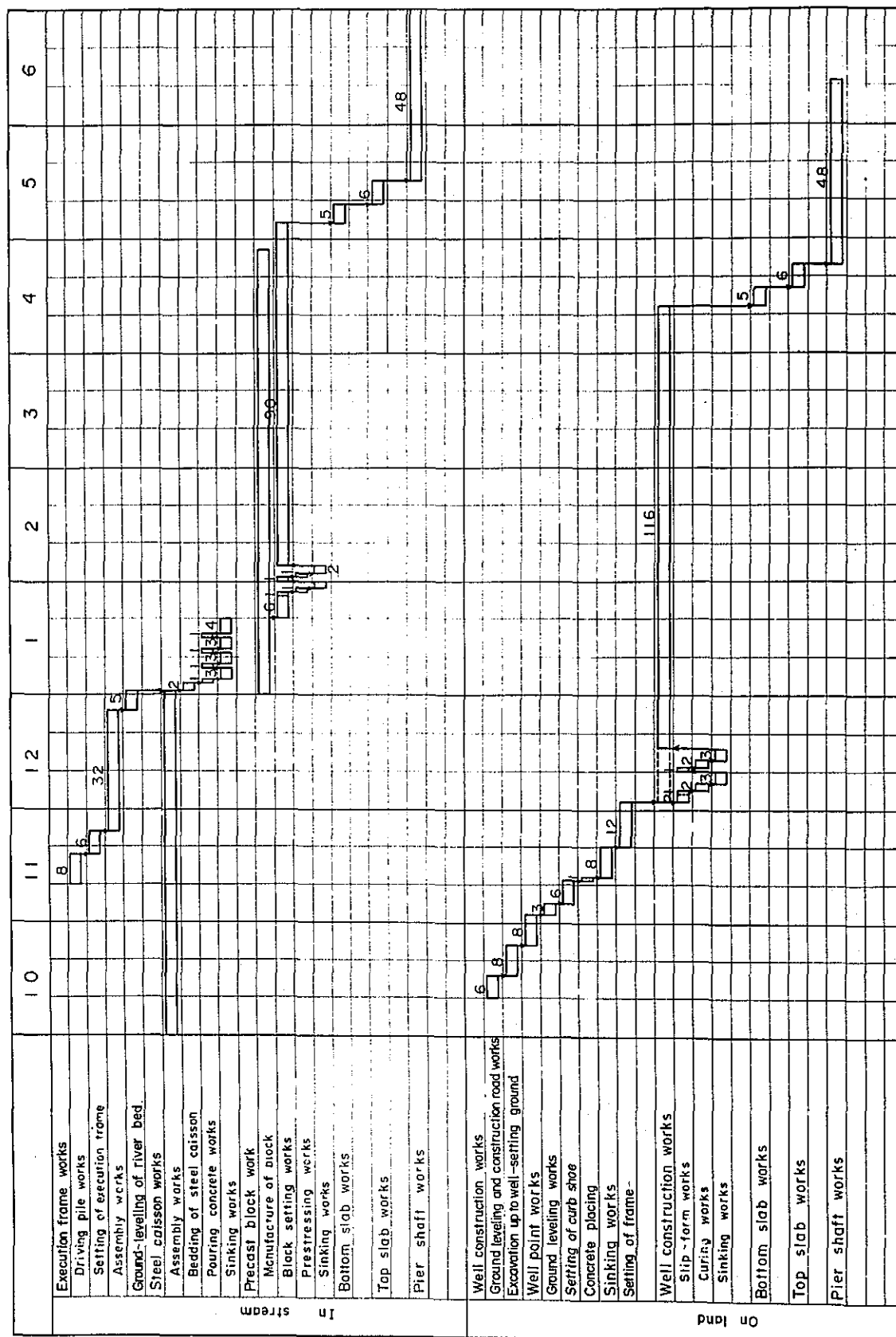


Fig.7-20 Time Schedule of Pier Works (One Pier)



5.3. Superstructure works.

5.3.1. Outline of erection works.

The erection of this bridge conformed to the descriptions given in 4.3.2., CHAPTER VII.

- (a) On land ($A_1 - P_{13}$, $P_{25} - A_2$) Staging-erection method
- (b) In stream ($P_{13} - P_{25}$) Flat-barge erection method

The schematic drawing of the bridge erection is shown in Fig. 7-21 and the above two erection methods are briefly explained in the following.

(1) Staging erection method by crawler crane

It is the method to be applied to 15 spans between $A_1 - P_{13}$ and $P_{25} - A_2$, and the outline of this method is shown in Fig. 7-22. The erection is made by advantage of a period of approx. 6.5 months during the dry season (November to mid-May) when the water level of the river lowers. Hence, since the period capable of erection works is restricted like this, several construction parties will start erection simultaneously under the imperative necessity of quickening progress in the works.

In that time, as the weight of superstructure is large, stagings are built at every two panels and pile foundations are adopted. Moreover, the roller shoes on the intermediate supporting points which will become basic points for erection, shall be temporarily fixed during the erection period.

In erecting the superstructure works, first start with the works of lower chords, floor system and lower lateral bracing and after these works are completed, verticals, diagonals, upper chords, upper lateral bracing and sway bracing shall be erected.

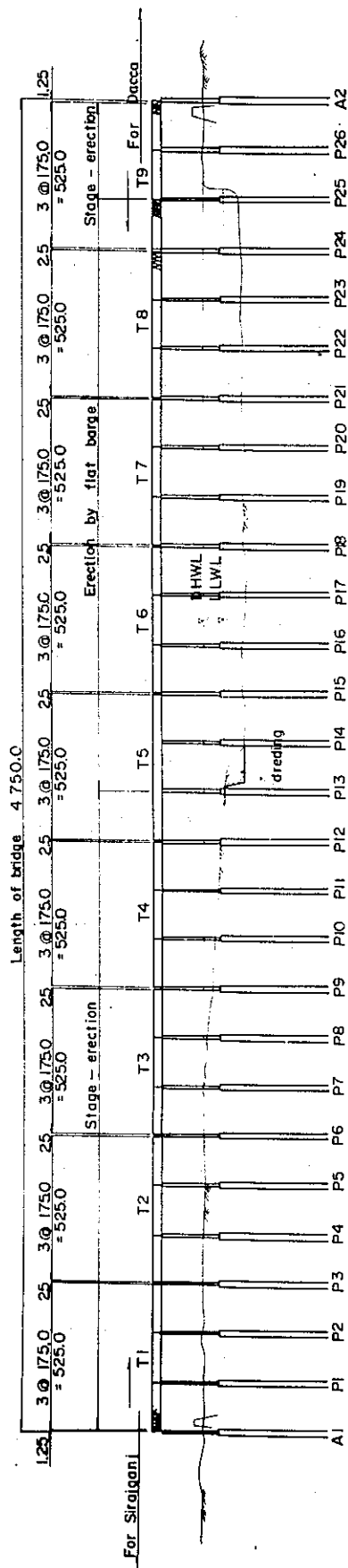
(a) Adjustment

Adjustment for bridge axis and camber is gradually made on each staging at the time of erecting lower chords. The camber adjustment is made by jack at the time when lower chords are erected. If the sinking of staging occurs under assembling of upper chords, readjustment is made by using jacks on the panel points.

(b) Tightening of high-tension bolts

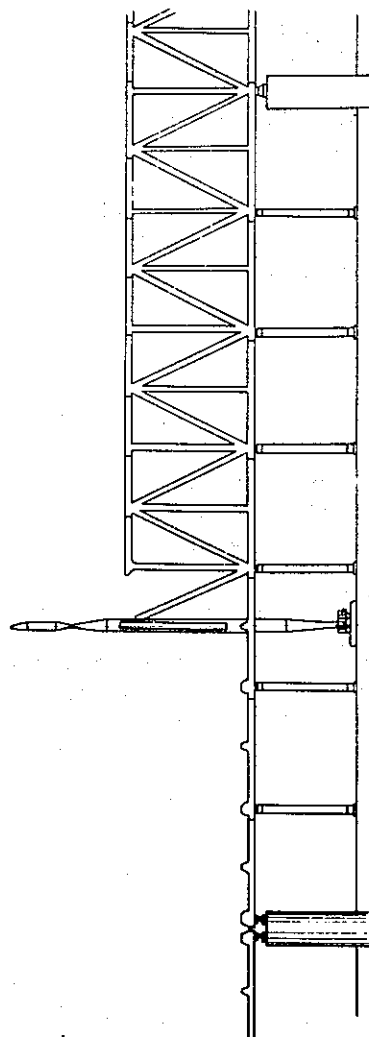
During the rainy season high-tension bolts should not be tightened. The tightening is made during the erection time and the tightening progresses by 2 panel distance delayed later than the erection progress.

Fig. 7-21 Erection Diagram
(in meter)



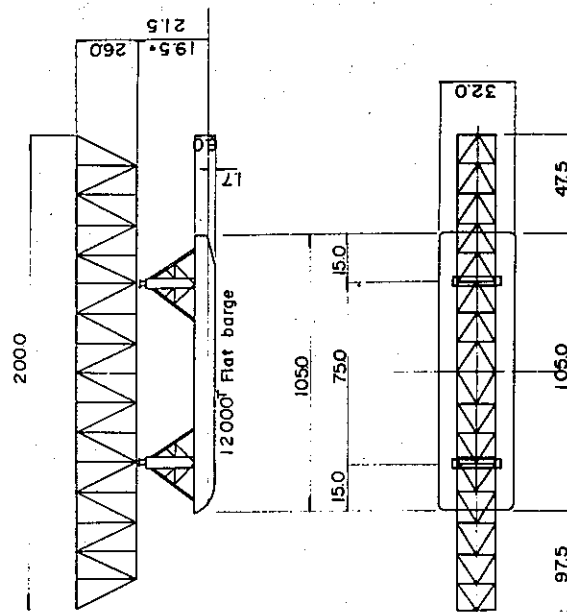
Erection method by crawler crane

A1 ~ P13, P25 ~ A2 (15 Span)



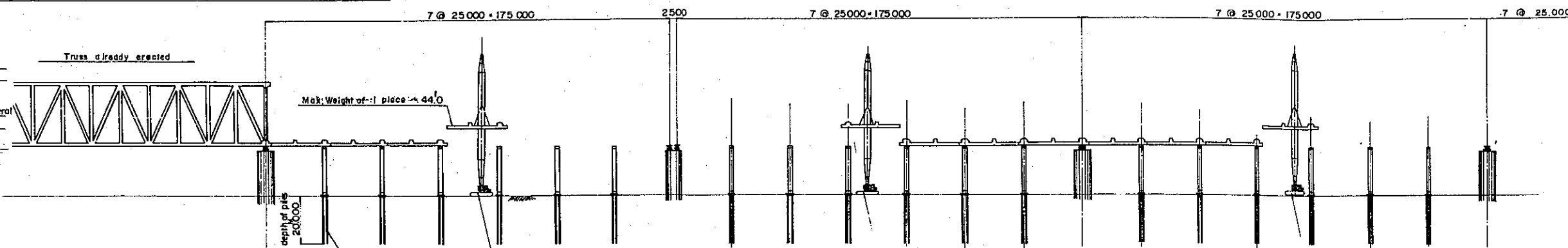
Erection method by flat barge

P13 ~ P25 (12 Span)



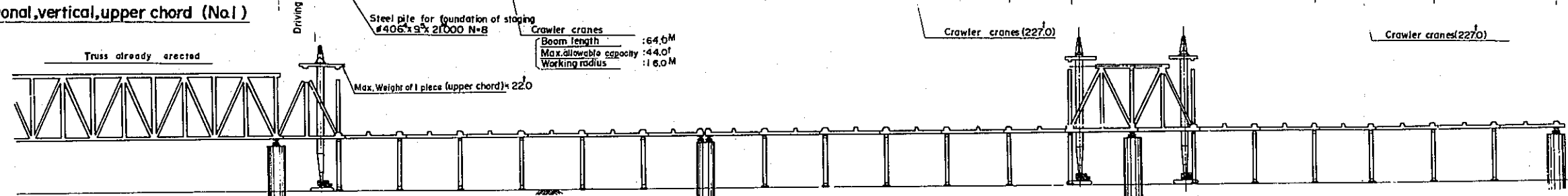
Step 1 Construction of stagings and erection of lower chords and floor systems Scale 1:2000

1. Steel piles shall be driven by crawler crane (35') installed desol pile driver.
2. Stagings shall be erected by two crawler cranes. (3.5')
3. Member of lower chord, lower lateral and floor system shall be erected by six crawler cranes (227.0) Three cranes shall be arranged respectively on both sides of main truss

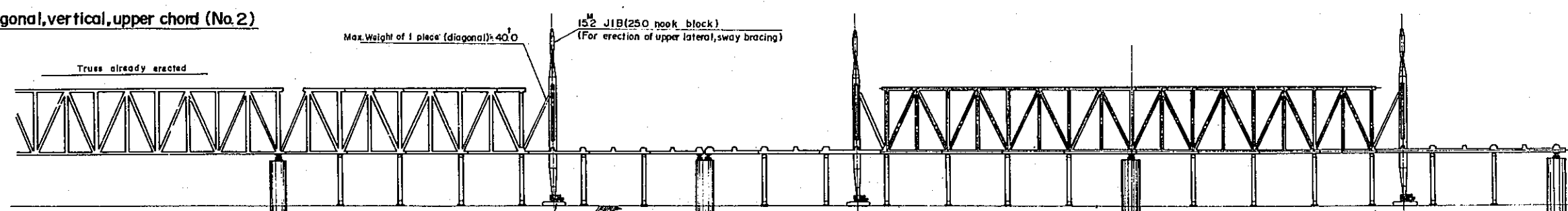


Step 2 Erection of diagonal, vertical, upper chord (No.1)

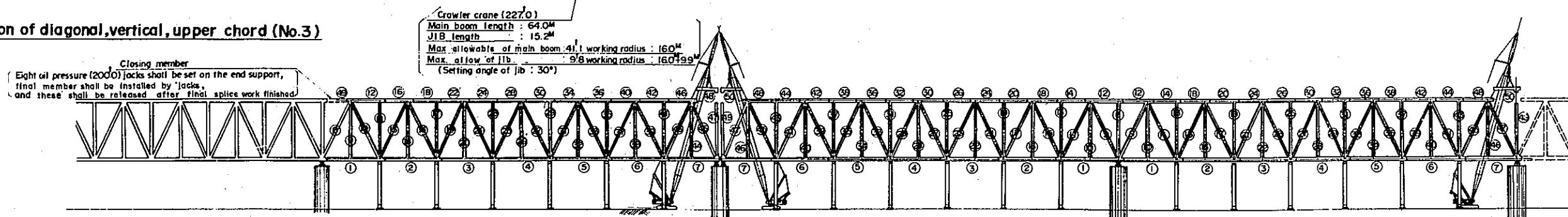
1. Members of diagonal, vertical, upper chord, upper lateral and sway bracing shall be erected by six crawler cranes (227.0)



Step 3 Erection of diagonal, vertical, upper chord (No.2)

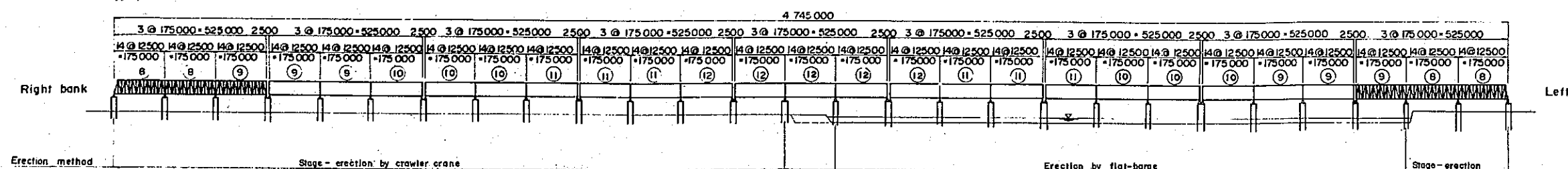


Step 4 Erection of diagonal, vertical, upper chord (No.3)



- Notes:
1. The erection of members shall be performed in order of number in a circle in the diagram of step 4.
 2. The erection of each span shall be performed according to the year described by the number in a circle in the marking diagram.

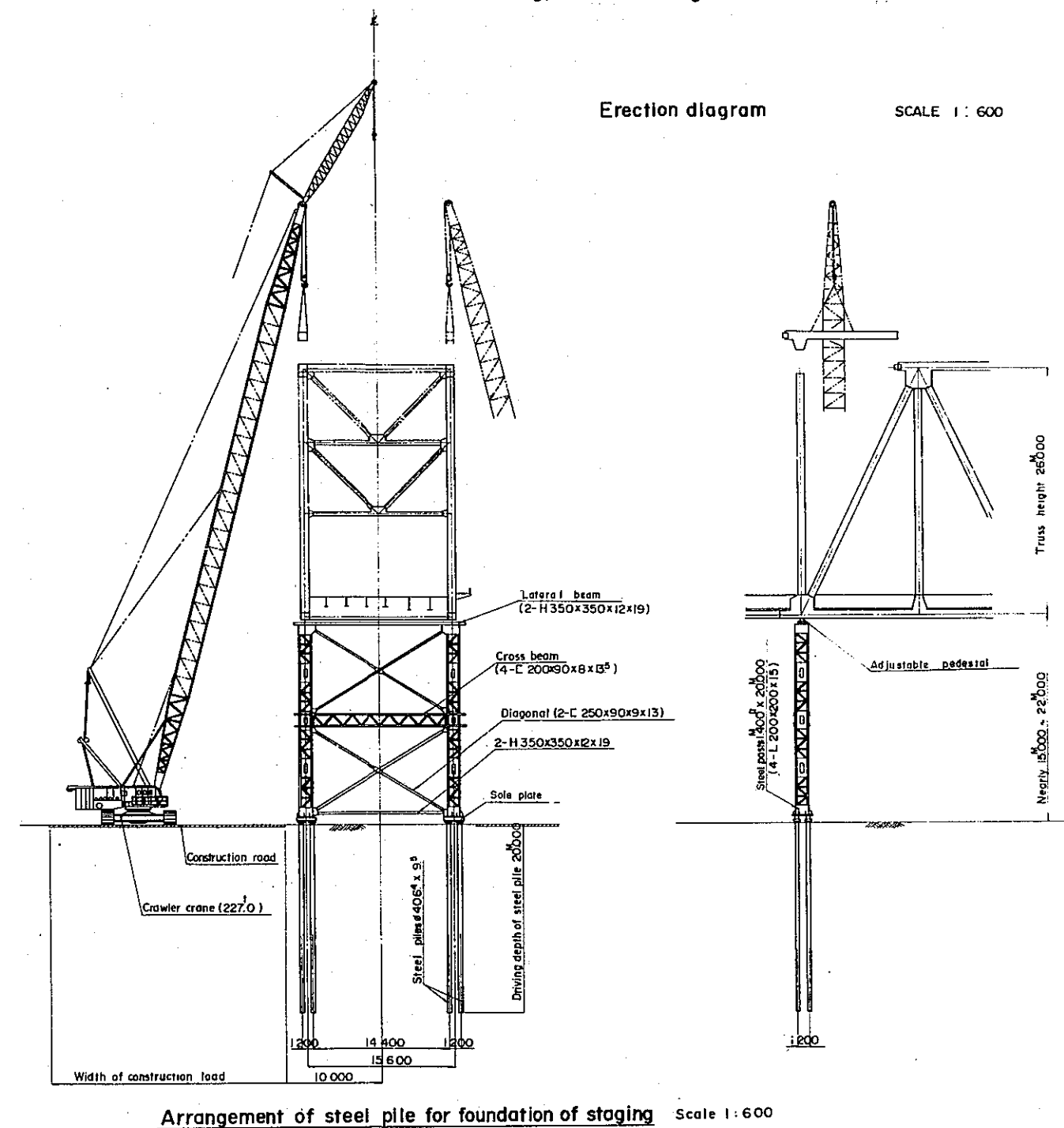
Marking diagram



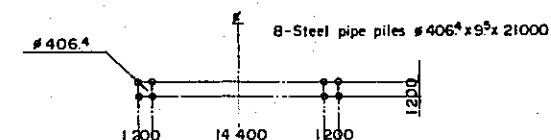
Erection diagram

[illegible]

Left bank



Arrangement of steel pile for foundation of staging Scale 1 : 600



In the first place, bolts of lower chords, lower lateral bracing and floor system are tightened, and then bolts of verticals, diagonals, upper cords and upper lateral bracing are tightened. The tightening of high-tension bolts is made by impact wrenches with torque controller and hydro-torque wrenches and tightening is made twice.

(2) Flat-barge erection-method

The flat-barge erection is applied to 12 spans between P13 and P25. One-span truss is assembled in the yard beside the camber of the main construction base. Next, the assembled one-truss is loaded on 12,000-ton flat barge (Fig. 7-23) and towed to the spot by six tugboats and set on both piers.

(a) Assembling of truss in the yard

The assembling of truss in the yard is outlined in Fig. 7-24. The assembly yard is established beside the camber of the main construction base at the downstream of the bridge axis. The one-span truss is assembled by transporting of single members from the storage yard to assembly yard and three one-span trusses are assembled in the yard from November to February in each dry season.

(b) Shipping

The flat barge shall be led to approach the loading pier by the adjustment of mooring wires which were fitted to the mooring posts and then the draft of barge is adjusted by water pouring into the barge. Then one-span truss which had already been assembled in the yard, is horizontally shifted, loaded and pulled out from the Jeffy.

(c) Towing and setting

The assembled truss loaded on the 12,000-ton flat barge towed to the erection spot by six tugboats along the canal which had been dredged. Then the flat barge is moored by wires to the anchor which were previously fitted in the river and after the plane position was adjusted, the assembled truss is set on the piers. However, the setting is collectively made by adjusting the height by oil jacks on the flat-barge and the water weight in the barge adjusted by drainage pumps. The towing and setting are conducted according to the natural circumstances during a March/May period as previously stated. Essential points for instructions in the towing and setting are shown in Fig. 7-25.

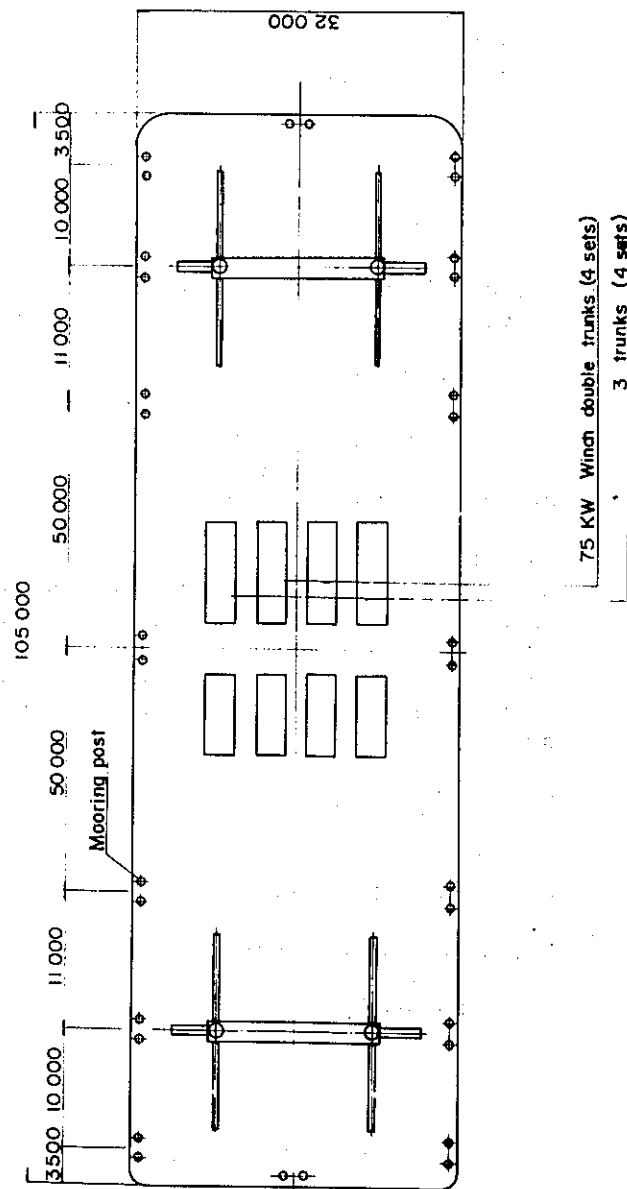
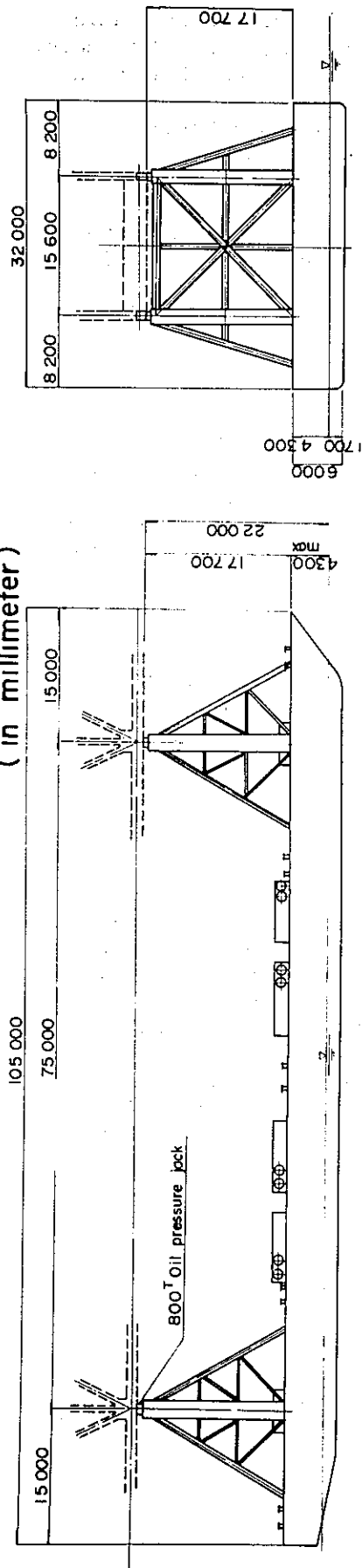
5.3.2. Flow charts of erection works.

The flows of erection works both on-land and in-stream are shown in Figs. 7-26 and -27.

5.3.3. Erection order.

The erection order of superstructure by span is shown in Fig. 7-28.

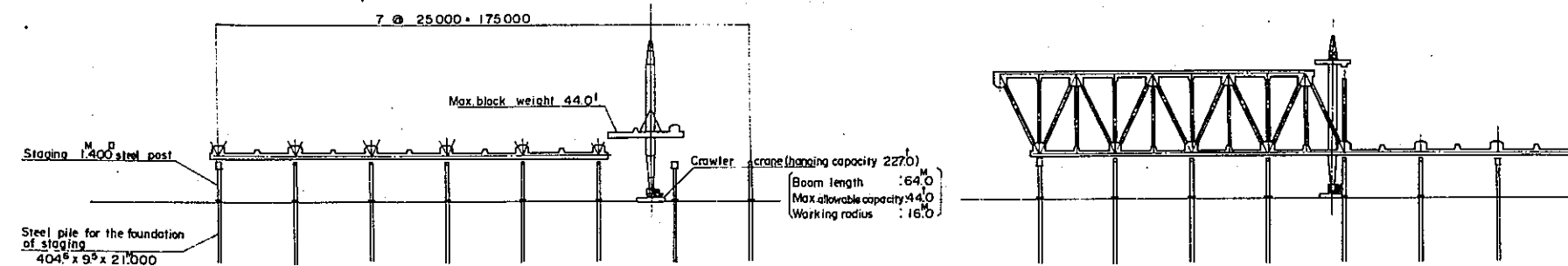
Fig. 7-23 Detail of Flat Barge (12,000 TON)
(in millimeter)



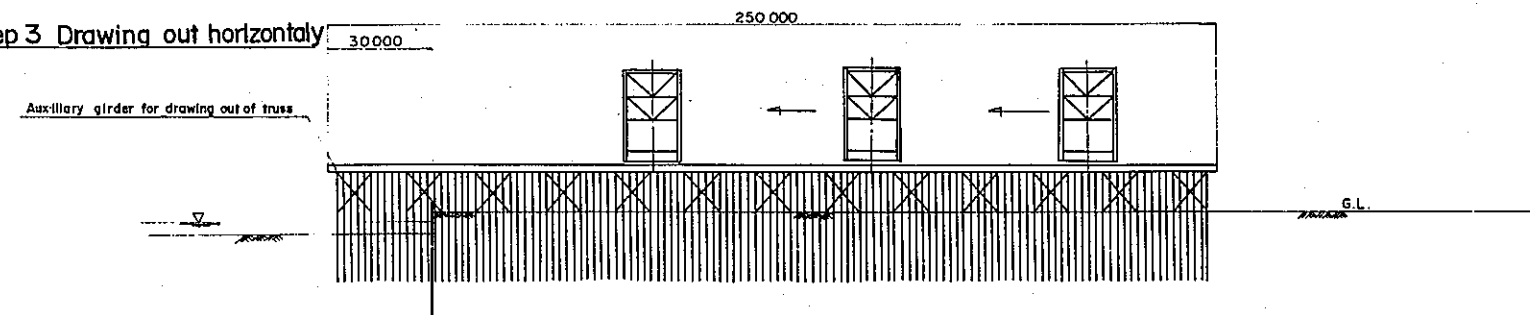
Step I Erection of
lower chord and floor system etc. at yard.

Step 2 Erection of diagonal, vertical and upper chord etc. at yard.

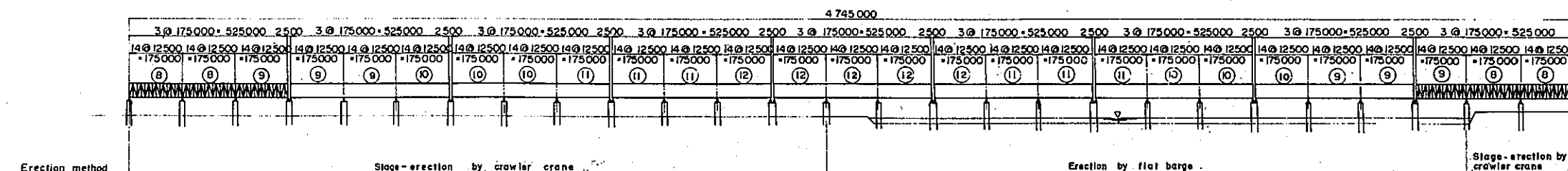
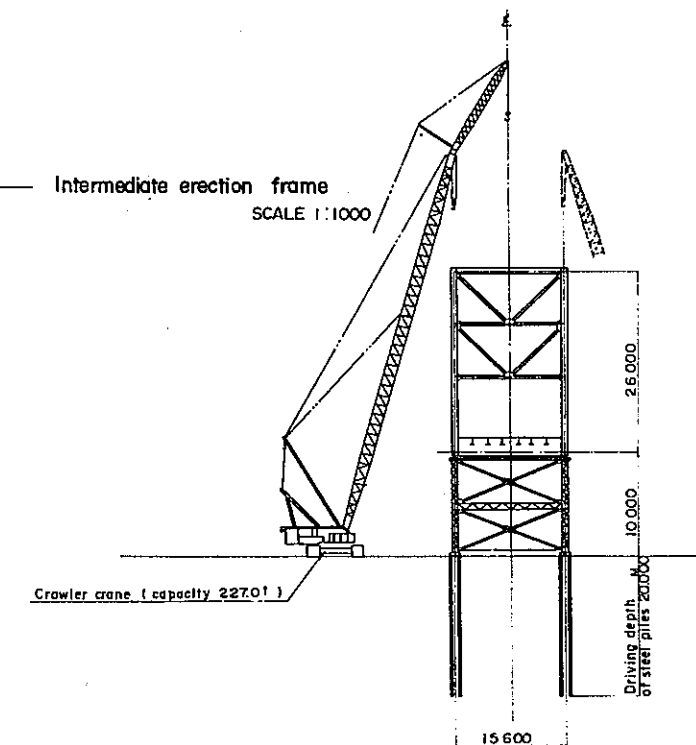
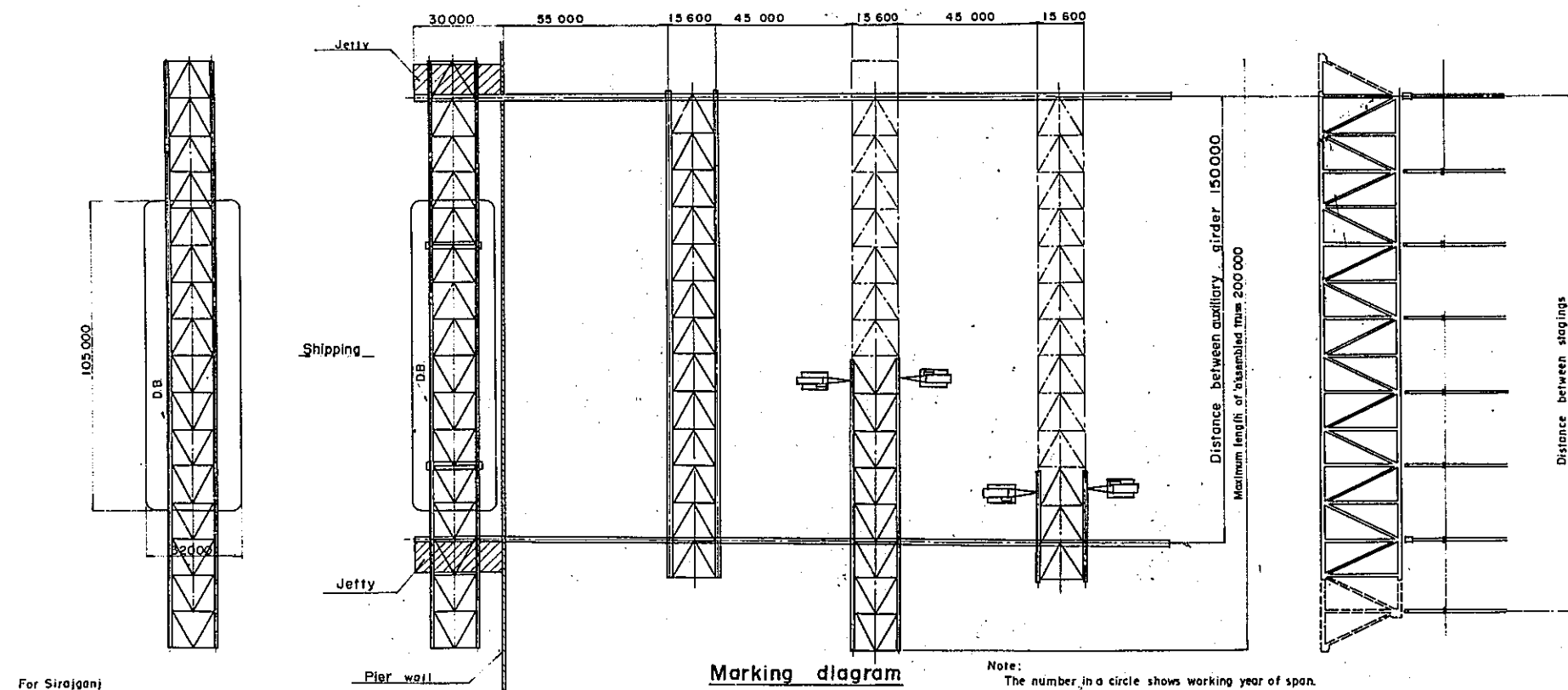
Fig. 7-24 Erection of Truss at Yard and Shipping Diagram.



Step 3 Drawing out horizontally



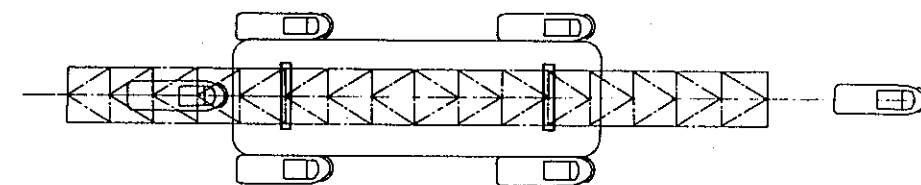
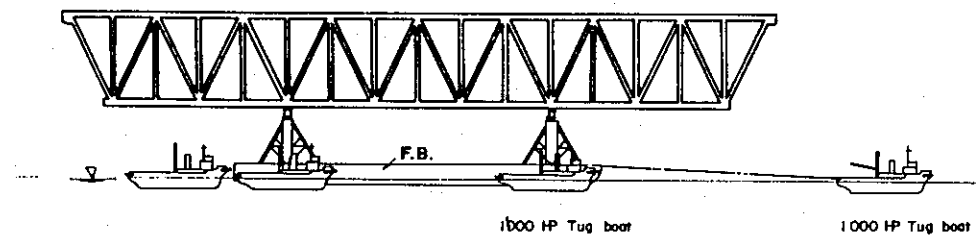
Step 4 Shipping



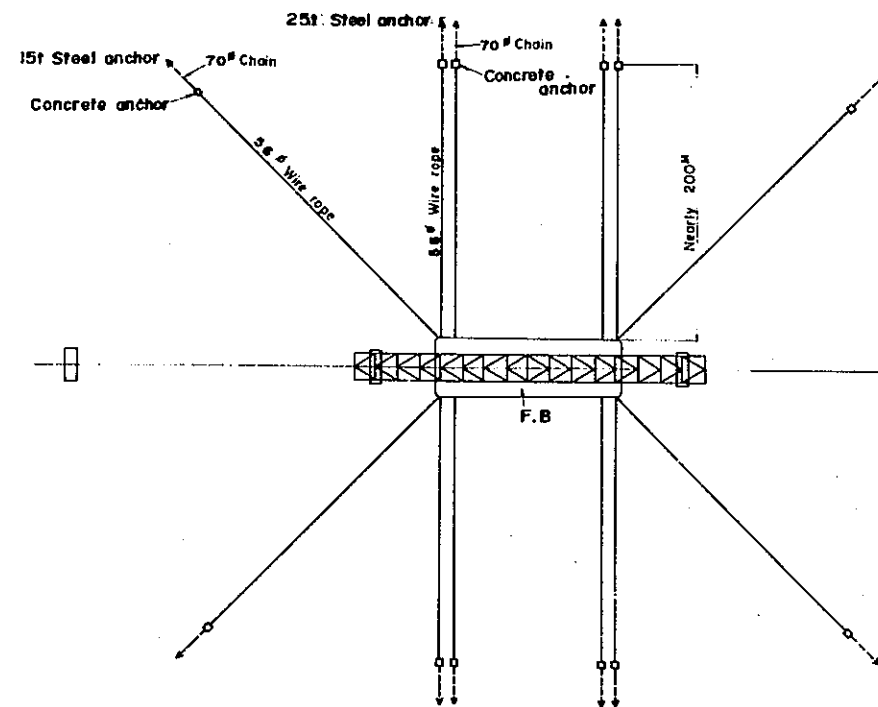
Right bank

Left bank

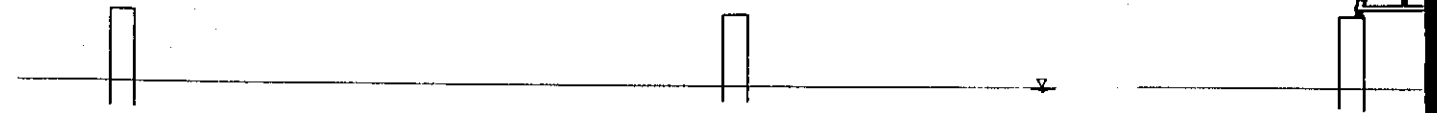
Step.5 Towing to the site



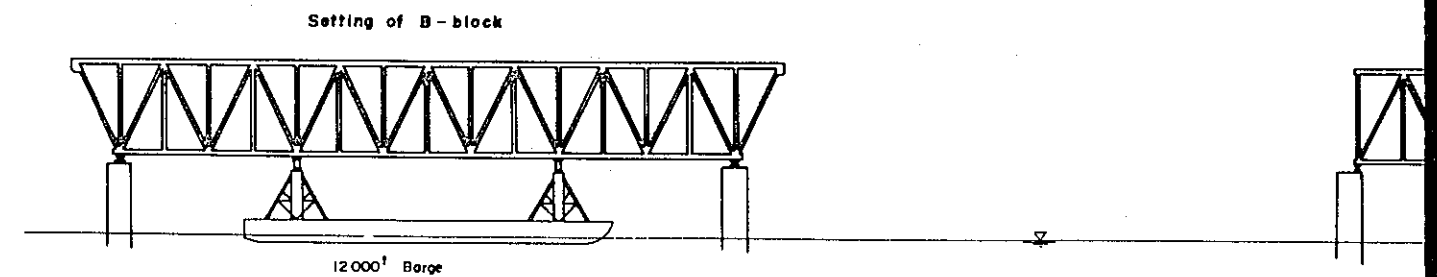
System of mooring



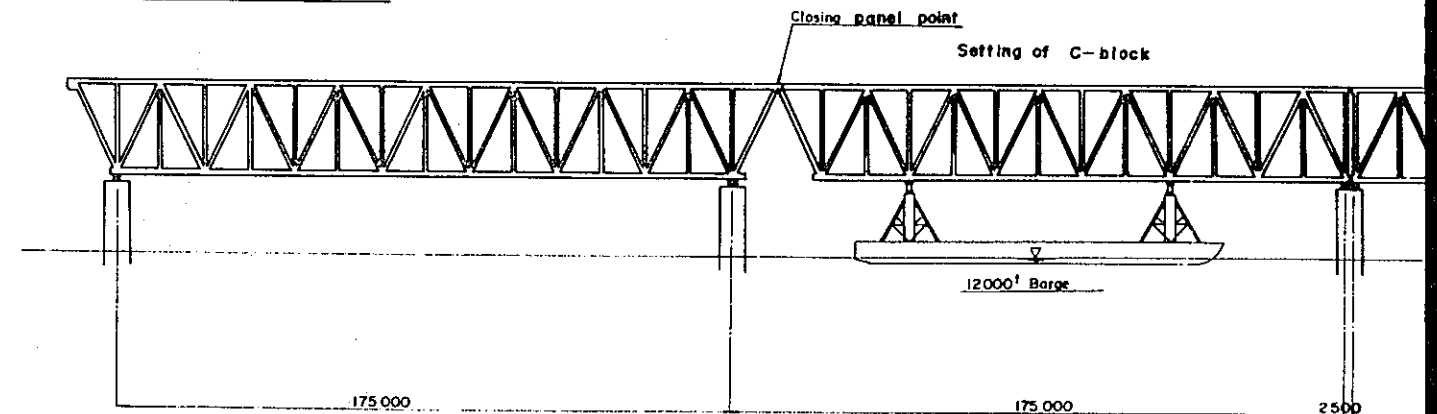
Step 6 Setting on the piers (No.1)



Step.7 Setting on the piers (No.2)



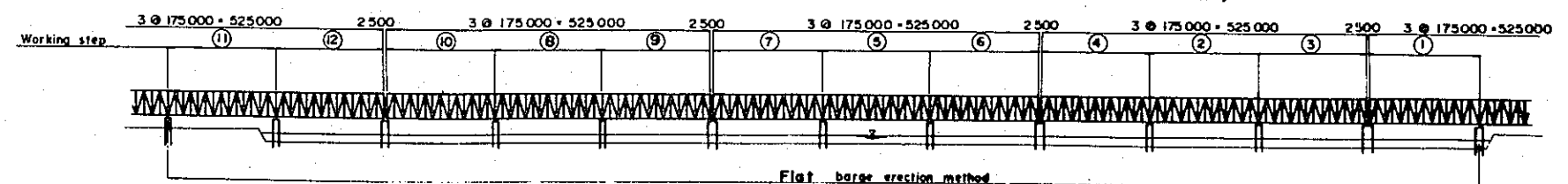
Step.8 Setting on the piers (No.3)



Note. A, C - block E
B - block E

Marking diagram

Note: Number in a circle shows the order of setting



Setting of A-block

Closing panel point

12,000' Barge

105,000

The diagram illustrates a bridge structure with a series of A-blocks (truss sections) supported by piers. A barge, labeled '12,000' Barge', is positioned below the bridge. The text '105,000' is written below the barge. The diagram is labeled 'Setting of A-block' and 'Closing panel point'.

1600 HP Tug boat

1000 HP Tug boat

A diagram of a railway track layout. On the left, a signal box is shown with a signal arm pointing down. A train is approaching from the left. The track splits into two parallel tracks, each with a dashed line in the center. A train is on the top track, moving away from the signal box. The tracks converge back into a single track on the right, where another train is approaching.

A schematic diagram of a bridge structure. The bridge is supported by four vertical piers. The span between the piers is divided into several bays by vertical truss members. A barge is shown positioned under the bridge, between the second and third piers from the left. The barge is labeled "12 000' Barge".

Technical drawing of a bridge structure, likely a truss bridge, showing a central span supported by piers. A barge is shown passing under the bridge. Labels include "Closing panel point", "Setting of C-block", and "12000' Barge". Dimensions are given as 175 000, 175 000, 2500, and 175 000.

Marking diagram

Note : Number in a circle shows the order of setting

Working step

3 @ 175,000 - 525,000 2,500 3 @ 175,000 - 525,000 2,500 3 @ 175,000 - 525,000 2,500 3 @ 175,000 - 525,000 2,500 3 @ 175,000 - 525,000

(11) (12) (10) (8) (9) (7) (5) (6) (4) (2) (3) (1)

z

Fig. barge erection method

Fig. 7-26 Erection of Superstructure by Staging

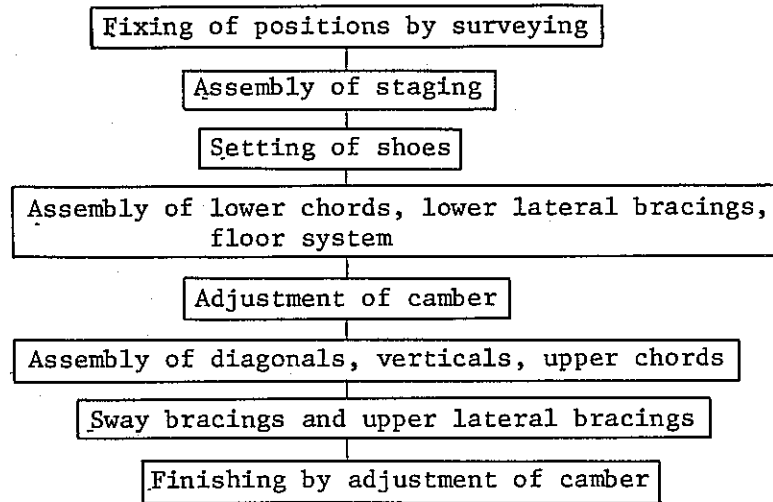


Fig. 7-27 Erection of Superstructure by Flat Barge

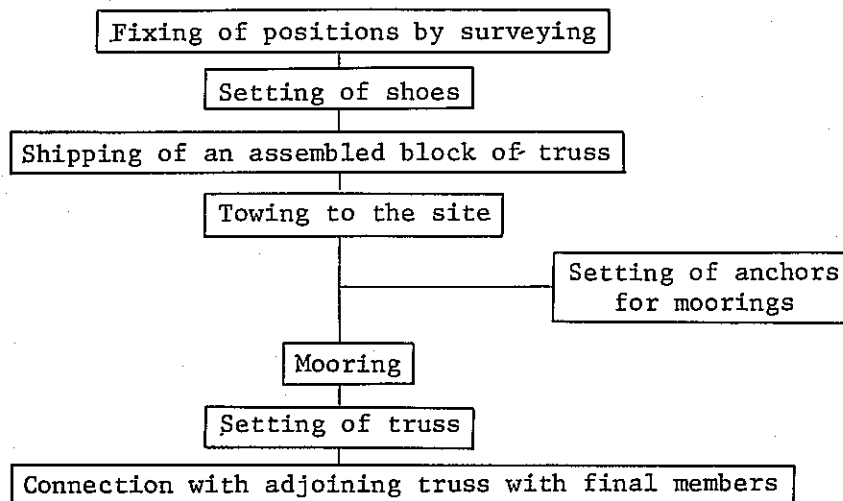
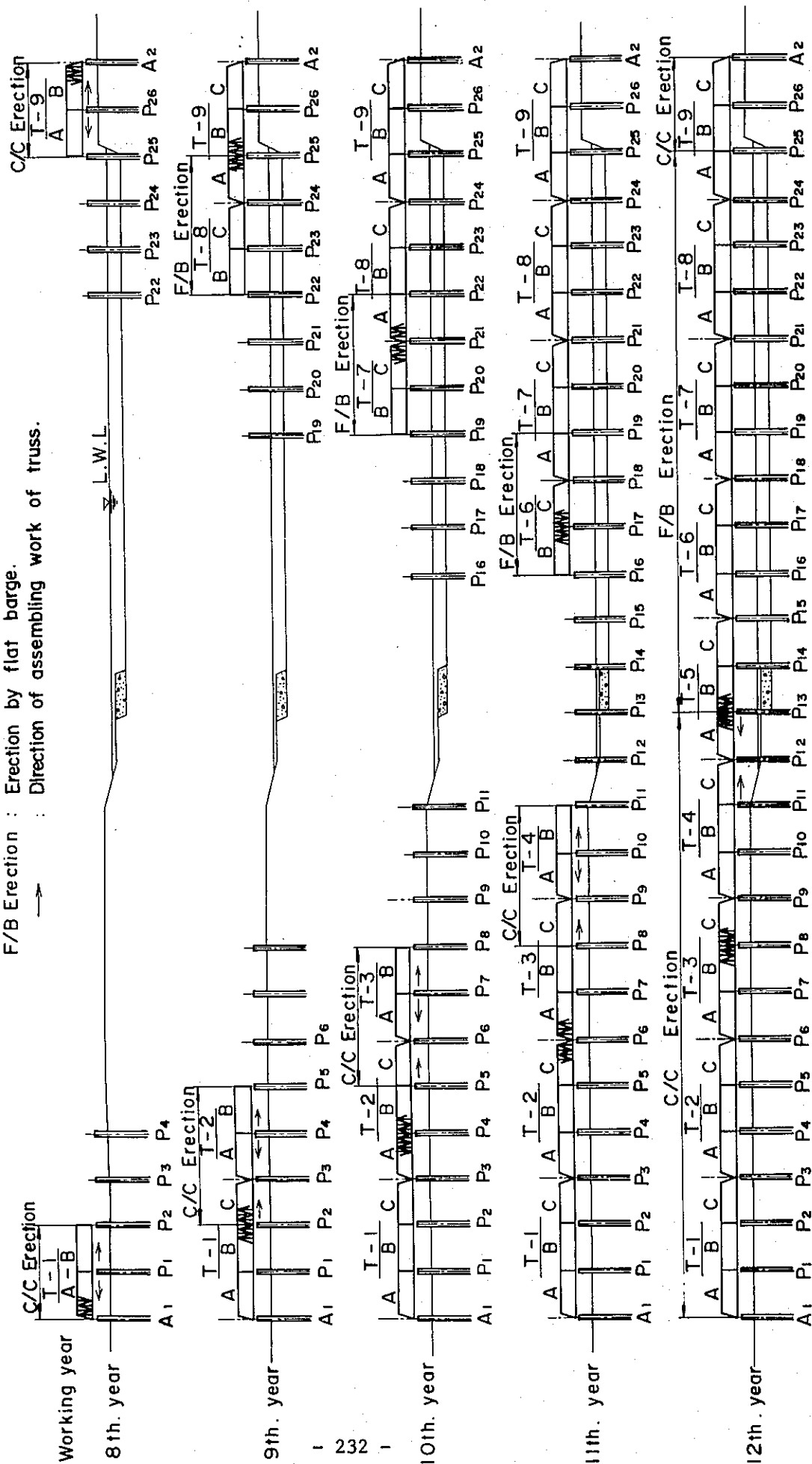


Fig. 7-28 Diagram of Working Step

Legend: C/C Erection : Stage erection by crawler crane.

F/B Erection : Erection by flat barge.

→ : Direction of assembling work of truss.



5.3.4. Stability and mooring of flat barge.

(1) Stability of flat barge

A 12,000-ton barge (each 105m long, 32m wide, and full height: 6m) in the scale of 0.8m no-load draught but 1.7m when loaded, is used. The largest assembled truss to be loaded on the barge is 200m long, 15.6m wide and 26m high and weights 2,600 tons. The barge is required to have an angle of inclination by wind and water flow, and this angle must fully qualify the Vessel's Stability Regulations which stipulated the standard of critical angle of stability which must reach a 80% of angle in which the ship's board-edge must reach the water surface. (In this case the angle of inclination: 0.6° , critical angle of inclination: 6.28° , fully satisfying.)

When the design wind velocity is 11m/sec and the design current velocity 3.3m/sec, the towing speed of the flat barge can be assumed as 2 knots and in this case 2 tugboats (1000PS each) assigned in front and at the rear of the barge are sufficient used for towing. Furthermore, in case the barge faces the wind loads and current loads at a right angle in the towing course, 2 auxiliary tugboats having the 1,000 PS as same as the main tugboat, shall be positioned on each side of the barge. Accordingly, the four auxiliary tugboats in all will maintain the stability of barge.

(2) Mooring system

The mooring system of the 12,000-ton flat barge is shown in Fig. 7-29. The barge towed to the setting point shall be moored as instructed in the following points. Anchors and sinkers should be prepared in the river prior to the setting of the assembled truss. The points for instructions for mooring shall be explained in stages according to Fig. 7-29.

(a) When flat barge reaches a point approx. 100m downstream of the bridge axis, the barge is moored at anchors A and B which had been fixed up-stream of the bridge axis. And the auxiliary anchors are set to piers.

(b) By winches on the flat barge and tugboats, the flat barge shall be moored at the setting spot of the assembled truss.

(c) The flat barge completely moored by adjusting of whole to use the anchor C. Four tugboats are assigned downstream to be used for managing of the flat barge and two tugboats for guard are up-stream.

5.3.5. Painting works.

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

Fig. 7-29 System of Mooring

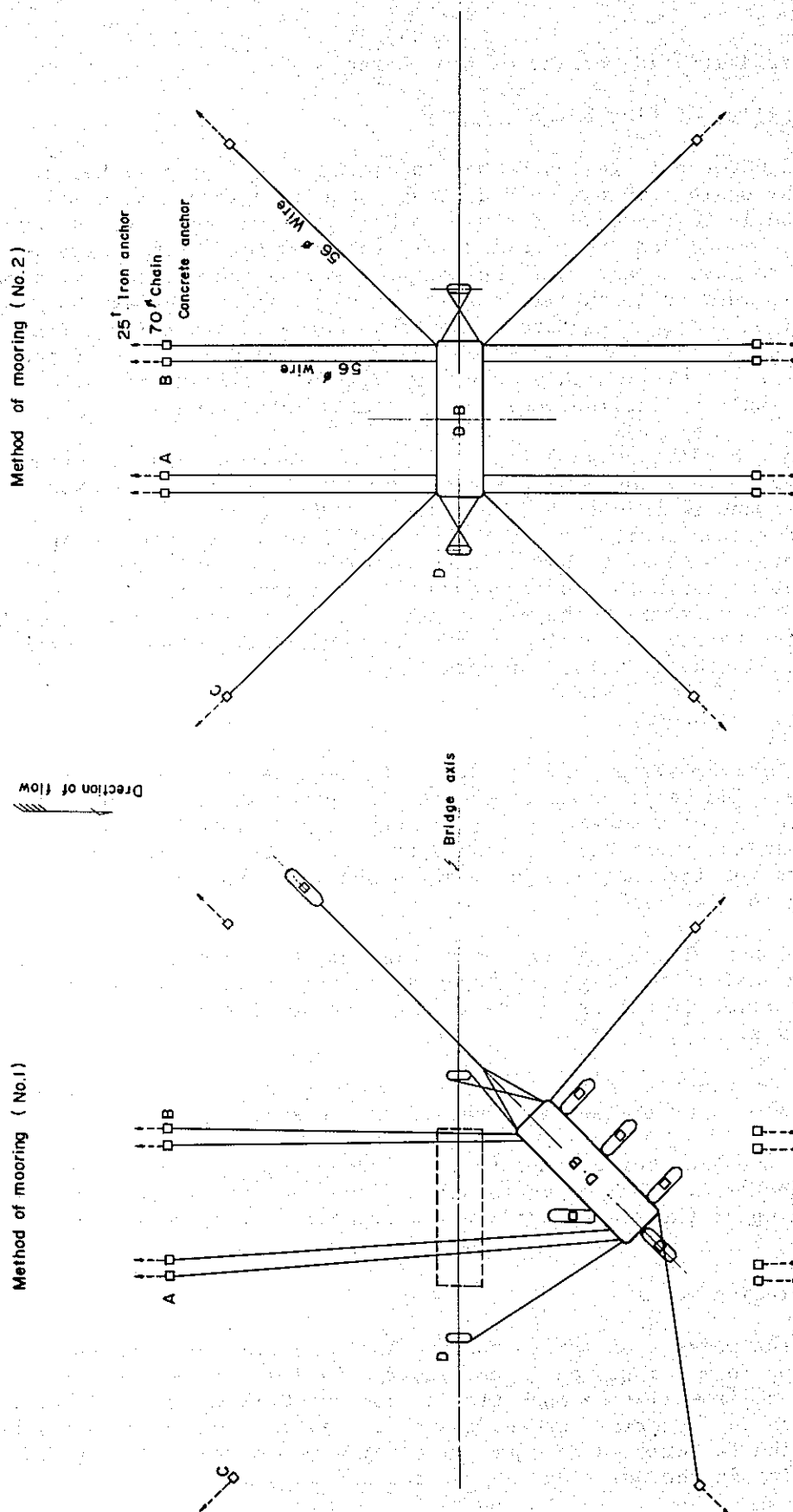
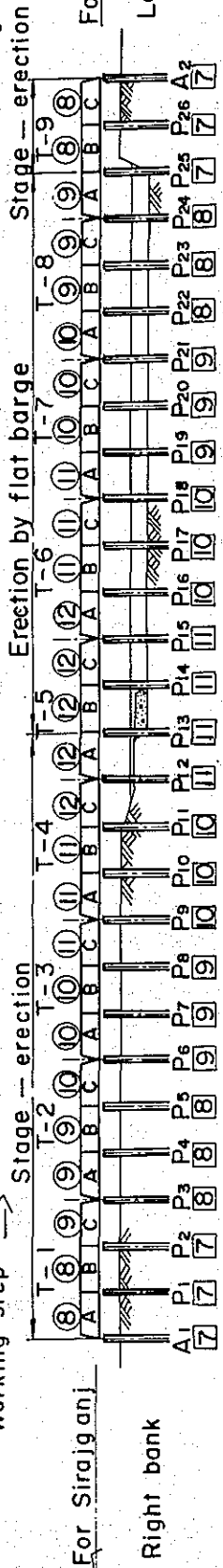


Fig. 7-30 Time Schedule of Erection for Superstructure

Works	Year	6th.	7th.	8th.	9th.	10th.	11th.	12th.	13th.
Preparation	Month	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J	A O D F A J
Erection of T - 1									
Erection of T - 2									
Erection of T - 3									
Erection of T - 4									
Erection of T - 5									
Erection of T - 6									
Erection of T - 7									
Erection of T - 8									
Erection of T - 9									

Working step ⇒ Stage — erection ⇐ Working step



Legend : C/C : Stage erection by crawler crane
 S/E : Stage erection at yard.
 S : Removing of scaffold.
 ↓ : Continued to the erection scaffolding by flat barge

5.3.6. Time schedule of superstructure works.

The time schedule of the superstructure works is shown in Fig. 7-30.

5.4. Slab works.

5.4.1. Outline of slab works.

The slab works shall be conducted in sequence of the completion of the superstructure works. Since the slab construction is a work executed at a considerable eminence, extra care must be used for safety.

Since the railway portion is on the downstream side and the road is on the upstream side, the carrying of materials such as reinforcing bars and forms will be made by temporary rails which are constructed on the railway portion, and the setting of supporting members and unloading of materials shall be carried out by a jib crane set on the rail.

Removal of timbering and forms after curing concrete, will be made by mobile cranes. The carrying and placing of concrete in stream are made by the concrete-mixing barge near the working site.

5.4.2. Sequence of slab works.

(a) Scaffolding works

The scaffolding is composed of timbers and pipes and suspended by chains, and for the sake of safety, protective nets are set.

(b) Timbering works

Seen from a viewpoint of the safety and the time schedule, the lower lateral bracings and the stringers are utilized. The overhanging portion of the slab is supported by H-shape steels and pipe-supports which are arranged on the cross beams of the main trusses and the inner portion is supported by pipe-supports on timbers which are fixed to the stringers with bolts.

(c) Forms

Since the slabs are of the same shape, forms including deformed forms are made of steel for the diversion to some other slabs.

(d) Reinforcing bars

Reinforcing bars fabricated at a manufacturing plant of the construction bases shall be carried to the site where bars are assembled.

(e) Preparatory plan for concrete placing

It is required to plan for arrangement of bars for pumping out concrete, and vibrators and trowels must be prepared.

(f) Concrete placing

Concrete is placed from the center of span towards the end of span. Deflection shall be adjusted by camber.

(g) Curing

Due to a high temperature governing the site, complete curing is sufficiently required. Sprinkling equipment should be provided.

(h) Removal of forms

When the desired strength of concrete was obtained, forms are removed.

(i) Removal of timbering and scaffolding

Next to the removal of forms, timbering and scaffolding are removed.

(j) Asphalt pavement

The asphalt pavement shall be 50cm thick.

5.4.3. Time schedule.

The time schedule for the slab works for one set of 3-span continuous truss is shown in Table 7-31.

5.5. Bridge approaches.

5.5.1. Banking plan.

Quantity of banking earth for the bridge approaches amounts to 8,900,000 cu.m. If they are supplied by excavation from the existing ground, the very long period and the many construction equipments shall be required. 4,800,000 cu.m shall be supplied on the both banks (2,400,000 cu.m on each bank) by a 4,000-PS dredger from the Jamuna River. The remaining 4,100,000 cu.m shall be supplied by excavation from the borrow-pit downstream of approaches.

The marking diagram of borrow-pit is shown in Fig. 7-32.

(1) Banking

For the purpose to obtain the quantity 2,400,000 cu.m of banking earth for the bridge approaches, the pump dredger shall supply 3,200,000 cu.m of earth into an area 1,500 m long and 600 m wide to 3.5 m high on each side of the river.

Dredged earth shall be excavated, carried and banked by 32.4-cu.m motorscrapers and earth of borrow-pit shall be excavated by 3.0-cu.m backhoes from the ground level to 2.0-m depth and carried by 32-ton dumptrucks to the spot. Dumped earth shall be leveled by bulldozers (35 tons to 50 tons) together with motorgraders. The spreading thickness of each executing layer is about 0.2 to 0.3 m thick. Compaction shall be carried out by 12-ton tirerollers and repeated eight times.

The works shall be stopped during the rainy season. The works shall be begun with the banking of the right approach and finishing in two years, shifted to the left approach.

The works are carried out in 3.5 m high at the initial stage of works along the whole of approaches and its elevation is +14.0 m PWD.

(2) Side slope

The side slope will be 1 : 2.5 gradient for the stability of the slope surface.

For the protection of the side slope in the rainy season, wire cylinder filled with bricks will be set up to +14.0 m PWD on the toe of slope and later up to the first berm, local turfs shall be sodded. The sodding period must be before each rainy season. Even during the sodding works, according to meteorological circumstances, water sprinkling shall be made by sprinkler. The slope upper than the sodded area shall be covered by bricks of one layer.

(3) Drainage works

The drainage works are necessary for the protection of the roads against weakening by rainfalls, scouring on the slope surface, and for the prevention of vehicle accidents by slipping due to pools on the road surface.

The side ditches and inlets shall be made of brick, inlets, vertical drainage along side slope and conduit shall be executed at intervals of 50 m.

(4) Pavement works

In due consideration of actual examples of the road construction in Bangladesh and banking earth of large degree of consolidation, the flexible pavement was adopted. The typical section of pavement is shown in Appendix 7-17.

(5) Closing of the Dhaleswari River

The approach embankment in the Dhaleswari River shall be banked after closing of the Dahleswari River.

For closing the Dhaleswari River, stone dikes are first constructed up to a height of 9.0 m PWD on both sides of the approach.

to be built, and then the portion between the both stone dikes is reclaimed by earth and banked up to 12.0 m PWD which is the mean ground height.

The cross section of the Dhaleswari River along the bridge axis is shown in Fig. 7-33 and the typical cross section of this embankment in Fig. 7-34.

5.5.2. Time schedule.

The time schedule of the bridge-approach works is shown in Fig. 7-35.

6. Material, Labour and Equipment.

Based on the predetermined construction schedule and the anticipated progress of various works, together with lists of desired materials of each of works, various materials required at each desired period were sought by classification. With these requirements which are integrated, lists of material plans showing changes of desired various materials were prepared.

The scale of yards of materials and various godowns was determined based on the estimation of a maximum difference between the volume of materials carried in and those consumed.

Changes of workers required by various jobs for each works were sought in due regard to requirements and conditions for obtaining machinery sought in due regard to requirements and conditions for obtaining machinery and equipment, etc., and by grasping the optimum execution method for each of works and workability by the selection of sets of machines for use.

Meanwhile, schedules of labour plans were prepared by finding the total of the workers of each job needed by the above works, temporary structure works and by classifying the personnel by each period or season.

Next, the equipment-use plan was drawn up collectively by estimating the planned progress in work of each work and by the total work load by each work and then by determining the number of required sets of equipment used during the working period based on the work capacity of 1 set of each equipment used in each work and summing up these totals and by grasping changes of the required number of machines.

The total quantities of principal materials used in temporary works and the main works can be summed up as follows:

<u>Item</u>	<u>Unit</u>	<u>Quantity</u>
Cement	ton	85,000
Sand	m ³	192,000
Gravel	m ³	200,000
Reinforcing bar	ton	12,300
Steel material	"	106,000
Cast steel	"	1,100
Prestressing bar	"	2,700
Brick	pcs	39,500,000
Crushed brick	m ³	158,000
Stone	"	281,500
Crushed stone	"	8,100
Heavy oil	kl	24,100
Light oil	"	55,800
Gasoline	"	2,300
Lubricants	"	4,500
Paint	ton	1,700

The total number of laborers is summed up as follows:

Classification	Foreigner	Local labor
Skilled labor	840,000 man-day	1,140,000 man-day
Unskilled labor	---	1,710,000 man-day

The itemization of materials and laborers was shown in classifying by works and year. Table 7-7 indicates the total consumption of materials for the bridge and approach works and Table 7-8 shows the total number of laborers classified by year and works while the numerals shown in Tables 7-9 to -13 are the itemization of those shown in Tables 7-7 and -8.

As to the plan for using construction equipment and machinery, Table 7-14, Equipment and Machinery Use Schedule, deals with items classified in the sequence of substructure works, bridge-approach works, slab works and superstructure works.

In estimation of total quantities required for the bridge-construction works, 5-percent loss was estimated to the design-net quantities of steel materials and reinforcing bars and 10-percent loss to cement, gravel, sand, stone, asphalt and brick.

As for the coarse aggregate for making concrete, those produced in Bholaganj shall be used. Since the maximum annual consumption of aggregate for the bridge construction is approx. 47,000 cu.m per year against about 57,800 cu.m per year of the total output of aggregate in Bholaganj, the supply-demand position is tentatively satisfactory for the bridge construction.

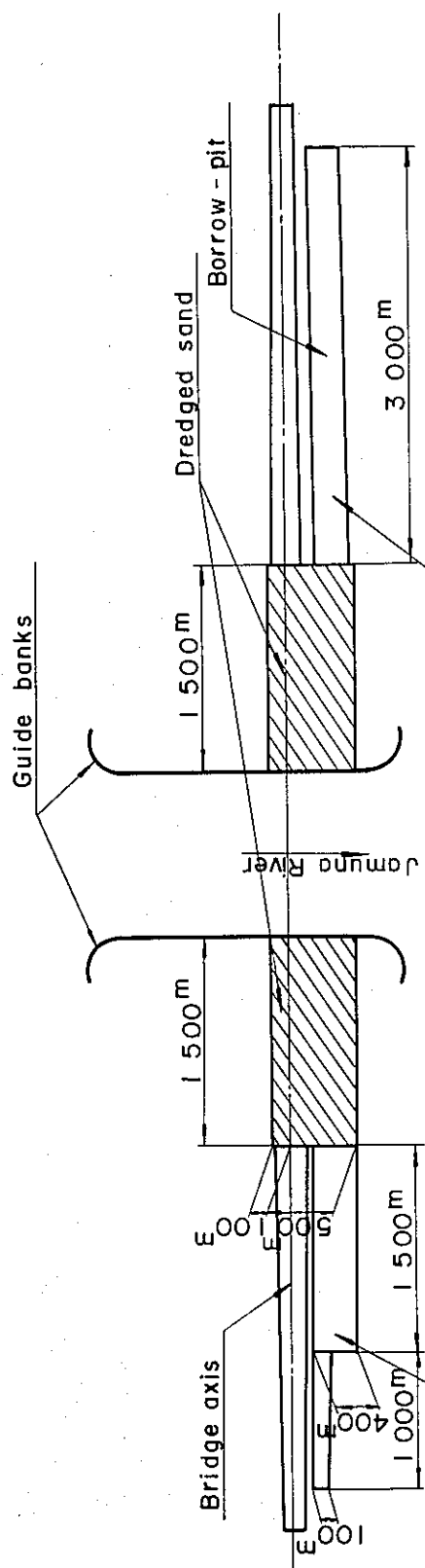
7. Overall Work Schedule.

As previously explained, the bridge-construction works mean the joint works combining the bridge itself and the bridge approaches. In due consideration of the correlation among the preparatory works which will start first, the temporary works, super- and substructure works, approach-embankment works, pavement works and permanent way works, the overall work schedule was prepared. Fig. 7-36 shows the bridge-construction work-schedule.

Fig. 7 - 31 Time Schedule of Slab Works (1 set of Bridge)

Works	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Remark
Preparatory works													
Scaffolding works													15 men/day
Timbering works													15 men/day
Building-up of form													30 men/day
Fabricating and building-up of reinforcement													30 men/day
Preparatory works for concrete placing													
Concrete placing													
Curing works													
Clearing works													

Fig. 7-32 Marking Diagram of Borrow-pit



In the borrow-pit, the periphery of the portion to be excavated should be separated as far as twenty times of depth of excavation from the bottom of the slope of approach embankment.

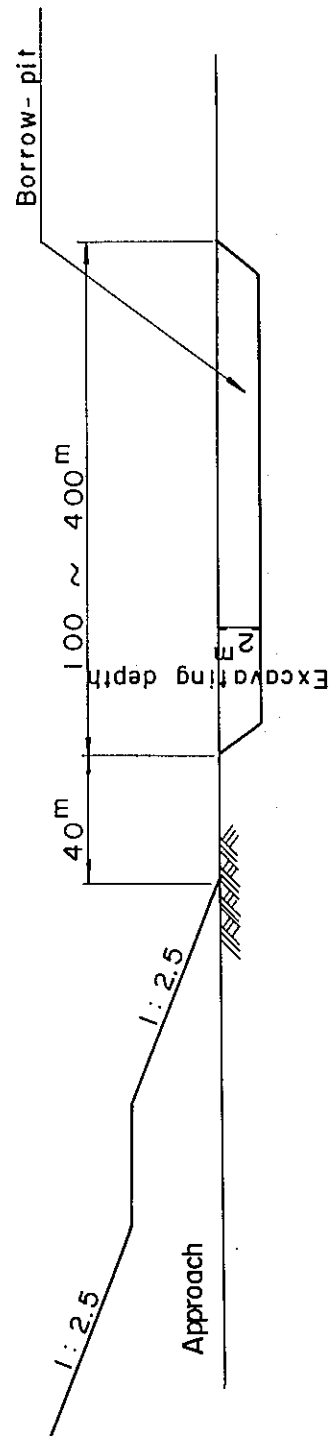


Fig. 7-33 Cross Section of the Dhaleswari River on Bridge Axis

Scale : $H=1/5\ 000$, $V=1/500$

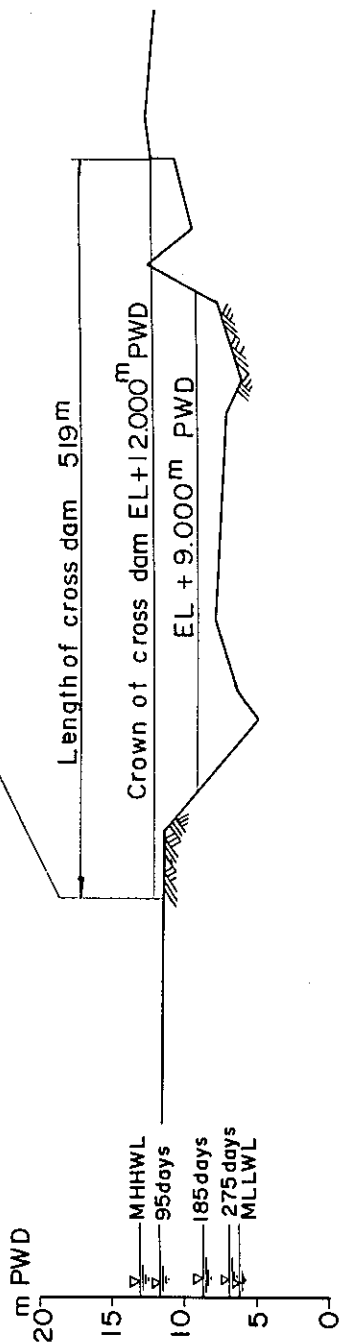


Fig. 7-34 Typical Cross Section of Cross Dike (NO26 + 399)

Scale : 1:500

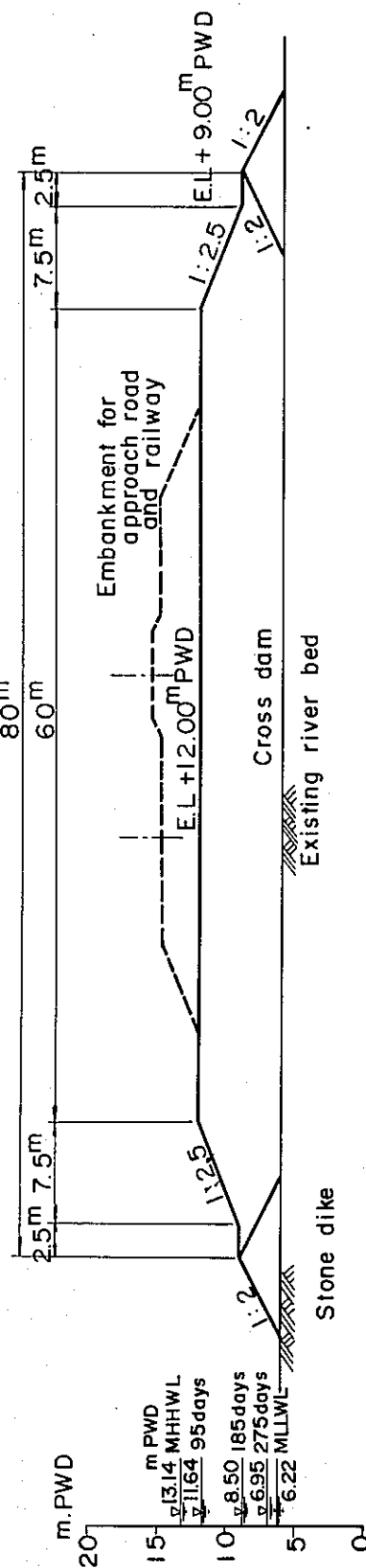
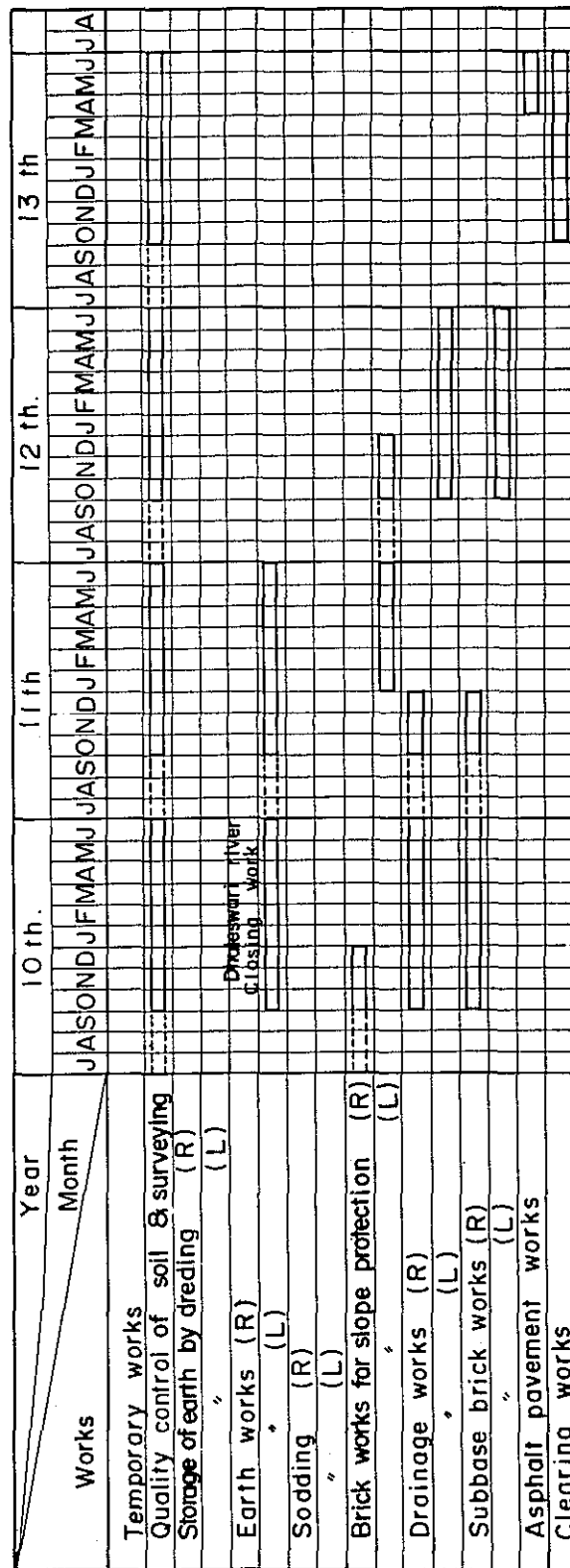
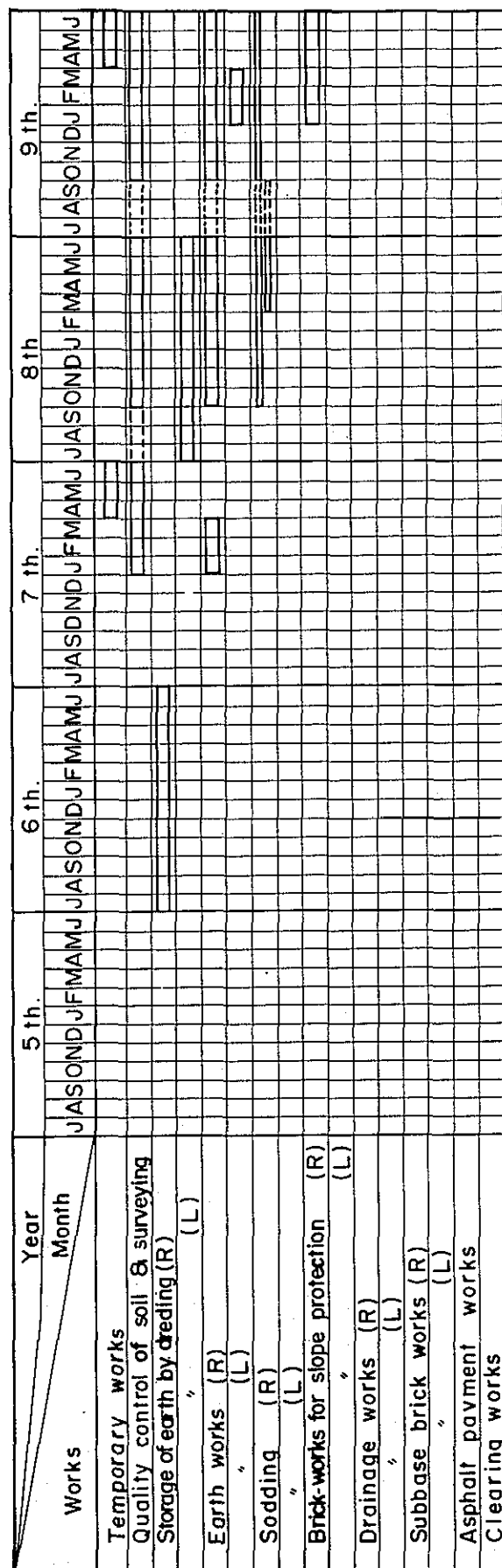


Fig. 7-35 Time Schedule of Bridge Approach Works



Note R : Right bank side of Jamuna river.
L : Left

Table 7-7 Amount of Materials to be used for Bridge Construction

	Unit	6th year	7th year	8th year	9th year	10th year	11th year	12th year	13th year	Total
1. Imported goods										
Portland cement	t	100	16,760	16,765	18,080	17,240	12,780	1,470	1,230	84,425
Admixture	kg	---	32,200	32,700	32,700	32,870	22,570	170	255	153,465
Steel deformed bar	t	12	2,994	1,959	2,172	2,254	1,357	625	938	12,311
Structural steel	"	6,833	4,206	20,915	19,821	20,272	20,453	12,029	1,059	105,588
Cast steel	"	---	---	172	178	268	259	146	55	1,078
Prestressing bar	"	---	189	567	567	567	756	---	---	2,646
Sheath	m	---	31,200	93,600	93,600	93,600	124,800	---	---	436,800
Tie rod	"	---	464	1,392	1,392	1,392	1,856	---	---	6,496
Vinyl pipe $\phi 16$	"	---	14,000	42,000	42,000	42,000	56,000	---	---	196,000
" $\phi 20$	"	---	4,020	4,020	4,020	4,020	2,680	---	---	18,760
" $\phi 25$	"	---	8,615	8,770	8,770	8,770	6,000	---	---	40,925
" $\phi 50$	"	---	1,500	4,500	4,500	4,500	6,000	---	---	21,000
Grout pipe $\phi 2B$	"	---	720	2,160	2,160	2,160	2,880	---	---	10,080
Nut & washer	pcs	---	7,900	23,700	23,700	23,700	31,600	---	---	110,600
Anchor plate	"	---	7,900	23,700	23,700	23,700	31,600	---	---	110,600
Coupler	"	---	5,750	17,250	17,250	17,250	23,000	---	---	80,500
Water-jet-hole	"	---	6,300	6,300	6,300	6,300	4,200	---	---	29,400
Welding electrode	t	---	---	300	300	300	300	300	---	1,500
Paint	"	---	---	244	367	367	367	306	---	1,651
Bonding materials	"	---	5	15	15	15	20	---	---	70
Asphalt	"	385	39	39	39	39	39	39	724	1,343
Stone dust	"	---	---	---	---	---	---	---	640	640
Stone	cu.m	---	15,000	45,000	45,000	110,000	60,000	---	---	275,000
Timber	"	490	20	24	22	640	45	31	342	1,614
Mat	sq.m	---	---	---	33,540	16,770	38,970	19,480	---	108,760
Thinner	kl	---	---	20	30	30	30	25	---	135
Heavy oil	"	4,951	2,179	7,192	2,876	2,717	2,876	649	649	24,089
Light oil	"	2,855	5,227	10,524	10,738	11,611	11,087	2,452	1,268	55,762
Gasoline	"	7	14	354	394	394	396	388	363	2,310
Lubricants	"	221	385	848	848	897	872	266	146	4,483
2. Domestic products										
Sand	cu.m	42,900	23,065	25,747	27,832	30,602	18,382	13,551	10,165	192,244
Gravel	"	---	44,610	39,309	43,130	40,160	25,280	3,750	3,000	199,239
Crushed stone	"	---	---	---	---	---	---	---	8,080	8,080
1st class bats	"	62,690	16,098	11,249	16,049	11,249	11,175	6,675	23,025	158,210
1st class bricks	10 ³ nos.	588	59	59	9,414	8,115	10,540	10,618	59	39,452
Drain pipe	m	---	---	---	---	2,600	---	3,600	---	6,200
Net volume of earth	cu.m	---	---	1,447,100	1,447,100	1,690,900	1,676,600	---	---	6,261,700
Volume in borrow pit	"	---	---	1,644,500	1,644,500	1,922,000	1,905,000	---	---	7,116,000
Excavated earth	"	---	---	2,055,500	2,055,500	2,402,500	2,381,500	---	---	8,895,000
Dredged earth	"	3,200,000	---	3,200,000	---	---	---	---	---	6,400,000

Table 7-8 Number of Labourers

	(Unit ; man-day)								
	6th year	7th year	8th year	9th year	10th year	11th year	12th year	13th year	Total
1. Substructure									
Temporary works									
Skilled (Foreign)	8,580	5,850	7,050	7,650	7,050	7,650	2,460	2,550	48,840
" (Domestic)	9,160	6,070	6,830	7,570	6,830	7,280	2,670	2,780	49,190
Unskilled(Domestic)	75,480	30,860	30,260	33,260	30,260	30,930	19,130	15,010	265,190
Main works									
Skilled (Foreign)	---	29,370	42,110	42,110	42,110	41,450	---	---	197,150
" (Domestic)	---	65,320	83,260	83,260	83,260	72,750	---	---	387,850
Unskilled(Domestic)	---	95,540	140,510	140,510	140,510	138,550	---	---	655,620
Subtotal									
Skilled (Foreign)	8,580	35,220	49,160	49,760	49,160	49,100	2,460	2,550	245,990
" (Domestic)	9,160	71,390	90,090	90,830	90,090	80,030	2,670	2,780	437,040
Unskilled(Domestic)	75,480	126,400	170,770	173,770	170,770	169,480	19,130	15,010	920,810
2. Superstructure									
Temporary works									
Skilled (Foreign)	2,500	13,350	11,600	11,600	11,600	11,600	11,600	6,000	79,850
" (Domestic)	13,100	14,800	6,000	6,000	6,000	6,000	6,000	2,800	60,700
Unskilled(Domestic)	13,100	14,800	6,000	6,000	6,000	6,000	6,000	2,800	60,700
Main works									
Skilled (Foreign)	6,126	6,126	60,636	75,687	75,398	75,398	65,847	5,750	370,968
" (Domestic)	9,550	9,550	59,423	73,963	73,552	73,552	64,142	6,290	370,022
Unskilled(Domestic)	9,550	9,550	57,250	72,192	71,893	71,893	62,712	6,290	361,330
Subtotal									
Skilled (Foreign)	8,626	19,476	72,236	87,287	86,998	86,998	77,447	11,750	450,818
" (Domestic)	22,650	24,350	65,423	79,963	79,552	79,552	70,142	9,090	430,722
Unskilled(Domestic)	22,650	24,350	63,250	78,192	77,893	77,893	68,712	9,090	422,030
3. Slab works									
Skilled (Foreign)	---	---	---	---	15,500	15,500	15,500	23,250	69,750
" (Domestic)	---	---	---	---	31,700	31,700	31,700	47,550	142,650
Unskilled(Domestic)	---	---	---	---	18,000	18,000	18,000	27,000	81,000
4. Bridge approach works									
Skilled (Foreign)	17,060	450	25,480	8,890	12,120	9,410	2,100	1,560	77,070
" (Domestic)	---	6,430	10,100	17,560	13,970	12,460	2,020	530	63,070
Unskilled(Domestic)	---	7,830	10,420	45,810	77,160	40,470	66,140	4,380	252,210
5. Permanent way works									
Skilled (Domestic)	---	---	---	---	---	---	---	68,600	68,600
Unskilled(Domestic)	---	---	---	---	---	---	---	35,300	35,300
6. Total									
Skilled (Foreign)	34,266	55,146	146,876	145,937	163,778	161,008	97,507	39,110	843,628
" (Domestic)	31,810	102,170	165,613	188,353	215,312	203,742	106,532	128,550	1,142,082
Unskilled(Domestic)	98,130	158,580	244,440	297,772	343,823	305,843	171,982	90,780	1,711,350

Table 7-9 Amount of Materials and Labourers to be used for Construction of Substructure

Items	Unit	Year							Total
		6th	7th	8th	9th	10th	11th	12th	
1. Materials									
Portland cement	t	100	14,620	15,940	15,940	15,940	11,960	---	74,500
Admixture	kg	---	32,200	32,700	32,700	32,700	22,400	---	152,700
Steel deformed bar	t	12	2,451	1,629	1,629	1,629	732	---	8,082
Structural steel	"	6,833	4,206	6,164	5,538	4,286	5,909	---	32,936
Prestressing bar	"	---	189	567	567	567	756	---	2,646
Sheath	m	---	31,200	93,600	93,600	93,600	124,800	---	436,800
Tie rod	"	---	464	1,392	1,392	1,392	1,856	---	6,496
Nut & washer	pcs	---	7,900	23,700	23,700	23,700	31,600	---	110,600
Anchor plate	"	---	7,900	23,700	23,700	23,700	31,600	---	110,600
Coupler	"	---	5,750	17,250	17,250	17,250	23,000	---	80,500
Water-jet-hole	"	---	6,300	6,300	6,300	6,300	4,200	---	29,400
Vinyl pipe $\phi 16$	m	---	14,000	42,000	42,000	42,000	56,000	---	196,000
" $\phi 20$	"	---	4,020	4,020	4,020	4,020	2,680	---	18,760
" $\phi 25$	"	---	8,615	8,770	8,770	8,770	6,000	---	40,925
" $\phi 50$	"	---	1,500	4,500	4,500	4,500	6,000	---	21,000
Grout pipe $\phi 2B$	"	---	720	2,160	2,160	2,160	2,880	---	10,080
Bonding materials	t	---	5	15	15	15	20	---	70
Stone	cu.m	---	15,000	45,000	45,000	45,000	60,000	---	210,000
Timber	"	490	20	24	22	18	14	---	588
Heavy oil	kl	712	1,829	1,577	1,609	1,609	1,609	649	10,243
Light oil	"	1,728	4,056	4,170	4,170	4,170	3,906	---	22,200
Gasoline	"	7	14	14	14	14	14	7	91
Lubricants	"	91	233	226	227	227	214	2	1,222
Sand	cu.m	150	15,460	20,100	20,100	20,100	12,880	---	88,790
Gravel	"	---	38,380	36,900	36,900	36,900	23,280	---	172,360
1st class bats	"	19,940	11,823	6,974	11,774	6,974	6,900	2,400	66,785
2. Labour									
Skilled (Foreign)	m.d	8,580	35,220	49,160	49,760	49,160	49,100	2,460	245,990
" (Domestic)	"	9,160	71,390	90,090	90,830	90,090	80,030	2,670	437,040
Unskilled (")	"	75,480	126,400	170,770	173,770	170,770	169,480	19,130	920,810

Table 7-10 Amount of Materials and Labourers to be used for Superstructure

Items	Unit	Year										Total
		6th	7th	8th	9th	10th	11th	12th	13th			
1. Materials												
Portland cement	t	---	---	825	---	---	---	---	---	---	---	825
Steel deformed bar	"	---	---	330	---	---	---	---	---	---	---	330
Steel plate	"	---	---	8,863	13,155	13,369	13,348	11,005	237	---	---	59,977
Shape steel	"	---	---	4,577	362	362	362	352	---	---	---	6,015
Steel (Jetty)	"	---	---	36	---	---	---	---	---	---	---	36
Steel (for shipping)	"	---	---	20	---	---	---	---	---	---	---	20
Steel pipe pile	"	---	---	956	330	330	330	220	---	---	---	2,166
Cast steel	"	---	---	172	178	268	259	146	55	---	---	1,078
H.T. Bolt	"	---	---	214	331	326	324	272	---	---	---	1,467
Bolt	"	---	---	105	105	105	105	105	---	---	---	525
Welding electrode	"	---	---	300	300	300	300	300	---	---	---	1,500
Paint	"	---	---	244	367	367	367	306	---	---	---	1,651
Asphalt	"	385	39	39	39	39	39	39	39	---	---	658
Thinner	kl	---	---	20	30	30	30	25	---	---	---	135
Heavy oil	"	168	350	1,544	1,267	1,109	1,267	---	---	---	---	5,705
Light oil	"	1,127	1,171	2,327	2,547	2,574	2,688	2,082	897	---	---	15,413
Gasoline	"	---	---	340	381	381	383	381	357	---	---	2,223
Lubricants	"	130	152	421	420	406	434	246	125	---	---	2,334
Sand	cu.m	42,750	4,275	5,647	4,402	4,402	4,402	4,381	4,275	---	---	74,534
Gravel	"	---	---	2,409	---	---	---	---	---	---	---	2,409
1st class bats	"	42,750	4,275	4,275	4,275	4,275	4,275	4,275	4,275	---	---	72,675
1st class bricks	nos.	588,000	59,000	59,000	59,000	59,000	59,000	59,000	59,000	59,000	1,001,000	
2. Labour												
Skilled (Foreign)	m.d	8,626	19,476	72,236	87,287	86,998	86,998	77,447	11,750	---	---	450,818
" (Domestic)	"	22,650	24,350	65,423	79,963	79,552	79,552	70,142	9,090	---	---	430,772
Unskilled (")	"	22,650	24,350	63,250	78,192	77,893	77,893	68,712	9,090	---	---	422,030

Table 7-11 Amount of Materials and Labourers to be used for Slab Works

Items	Unit	Year				Total
		10th	11th	12th	13th	
1. Materials						
Portland cement	t	820	820	820	1,230	3,690
Admixture	kg	170	170	170	255	765
Steel deformed bar	t	625	625	625	938	2,813
Structural steel	"	1,494	75	75	822	2,466
Timber	cu.m	622	31	31	342	1,026
Light oil	kl	231	154	77	231	693
Lubricants	"	12	8	4	12	36
Sand	cu.m	1,100	1,100	1,100	1,650	4,950
Gravel	"	2,000	2,000	2,000	3,000	9,000
2. Labour						
Skilled (Foreign)	m.d	15,500	15,500	15,500	23,250	69,750
" (Domestic)	"	31,700	31,700	31,700	47,550	142,650
Unskilled (")	"	18,000	18,000	18,000	27,000	81,000

Table 7-12 Amount of Materials and Labourers to be used for Bridge Approach

Items	Unit	Year											Total
		6th	7th	8th	9th	10th	11th	12th	13th				
1. Materials													
Portland cement	t	---	2,140	---	2,140	480	---	650	---	---	---	---	5,140
Steel deformed bar	"	---	543	---	543	---	---	---	---	---	---	---	1,086
Asphalt	"	---	---	---	---	---	---	---	---	---	685	---	685
Stone dust	"	---	---	---	---	---	---	---	---	---	640	---	640
Stone	cu.m	---	---	---	---	---	---	---	---	---	---	---	65,000
Mat	sq.m	---	---	---	33,540	16,770	38,970	19,480	---	---	---	---	108,760
Heavy oil	kl	4,070	---	4,070	---	---	---	---	---	---	---	---	8,140
Light oil	"	---	---	4,027	4,021	4,635	4,339	293	140	---	---	---	17,455
Lubricants	"	---	---	201	201	252	217	15	7	---	---	---	893
Sand	cu.m	---	3,330	---	3,330	5,000	---	8,070	4,240	---	---	---	23,970
Gravel	"	---	6,230	---	6,230	1,260	---	1,750	---	---	---	---	15,470
Crushed stone	"	---	---	---	---	---	---	---	8,080	---	---	---	8,080
1st class bats	"	---	---	---	---	---	---	---	18,750	---	---	---	18,750
1st class bricks	10 ³ nos.	---	---	---	9,355	8,056	10,481	10,559	---	---	---	---	38,451
Drain pipe	m	---	---	---	---	2,600	---	3,600	---	---	---	---	6,200
Net volume of earth	cu.m	---	---	1,447,100	1,447,100	1,690,900	1,676,600	---	---	---	---	---	6,261,700
Volume in borrow pit	"	---	---	1,644,500	1,644,500	1,922,000	1,905,000	---	---	---	---	---	7,116,000
Excavated earth	"	---	---	2,055,500	2,055,500	2,402,500	2,381,500	---	---	---	---	---	8,895,000
Dredged earth	"	3,200,000	---	3,200,000	---	---	---	---	---	---	---	---	6,400,000
2. Labour													
Skilled (Foreign)	m.d	17,060	450	25,480	8,892	12,124	9,414	2,101	1,563	---	---	---	77,084
" (Domestic)	"	---	6,429	10,096	17,561	13,968	12,468	2,024	525	---	---	---	63,071
Unskilled (")	"	---	7,827	10,418	45,807	77,160	40,473	66,144	4,375	---	---	---	252,204

Table 7-13 Machinery and Equipment Use Schedule

Items	Year							
	6th	7th	8th	9th	10th	11th	12th	13th
<u>Substructure</u>								
Bulldozer(for swamp) 16 t	4	4	4	4	4	4	4	--
Bulldozer 14 t	--	5	3	3	3	--	--	--
Tractor shovel 1.2 cu.m	2	2	2	2	2	2	--	--
Back hoe 0.6 cu.m	2	3	3	3	3	--	--	--
Clamshell bucket 2.0 cu.m	--	1	3	3	3	4	--	--
" 0.6 cu.m	4	4	4	4	4	--	--	--
Reverse-circulation machine	--	12	12	12	12	8	--	--
Crawler crane 955 ALC	2	8	8	8	8	6	--	--
" 20 t	4	4	4	4	4	4	--	--
Truck crane 30 t	1	1	1	1	1	1	1	--
" 20 t	2	2	2	2	2	2	2	--
" 10 t	3	3	3	3	3	3	3	--
Jibcrane 0.4 t	2	2	2	2	2	2	--	--
Motor grader	--	1	1	1	1	1	1	1
Diesel pile hammer 4 t	--	3	3	3	3	3	3	--
Vibro-hammer 90 KVA	--	1	3	3	3	3	--	--
" 60 KVA	--	2	2	2	2	2	--	--
" 40 KVA	2	2	--	--	--	--	--	--
Steam-hammer	3	3	3	3	3	3	--	--
Pile driver	--	3	3	3	3	3	3	--
Soil compactor	--	2	2	2	2	--	--	--
Vibrator 0.75 KW	--	40	40	40	40	40	10	10
Baby conveyer	10	10	10	10	10	10	10	10
Belt conveyer	10	10	10	10	10	10	10	10
Bar bender	7	7	7	6	5	5	5	5
Bar cutter	7	7	7	6	5	5	5	5
Concrete breaker	10	10	10	10	10	10	10	10
Concrete pick	10	10	10	10	10	10	10	10
Concrete bucket	--	--	6	6	6	--	--	--
Air compressor 17 cu.m/min.	--	6	6	6	6	4	--	--
Engine-operated air compressor 5cu.m/min.	2	2	2	2	2	2	2	2
Concrete pump	1	1	1	1	1	1	1	1
Dump truck 15 t	--	3	3	3	3	3	1	1
" 11 t	10	10	10	10	7	7	--	--
" 8 t	10	15	13	13	18	15	14	2
" 4 t	5	5	5	5	5	5	5	5
Truck 11 t	--	--	10	10	10	10	--	--
Agitator car 4.5 cu.m	--	15	15	10	10	--	--	--
Concrete pump car 20 cu.m/hr.	--	10	6	6	6	4	--	--
Tank-rolley 6 t	--	5	3	3	3	--	--	--
Road-sprinkler 8 t	5	5	5	5	5	5	--	--
Trolley 750 t	2	2	2	2	2	2	--	--
Center hole jack 100 t	--	12	36	36	36	48	--	--
Slip form jack 4.5 t	--	130	78	78	78	78	--	--

----- Continued -----

Table 7-13 Machinery and Equipment Use Schedule (Continued)

Items	Year							
	6th	7th	8th	9th	10th	11th	12th	13th
<u>Substructure</u>								
Winch 20 KW	--	3	3	3	3	4	--	--
Generator 300 KVA	--	1	3	3	3	3	--	--
" 125 KVA	20	20	20	20	20	20	--	--
Electric separator	1	1	1	1	1	1	1	1
Electric arc welding machine 300 A	--	10	10	8	8	--	--	--
" 200 A	10	10	10	10	10	10	10	--
Electric motor	8	8	8	8	8	8	8	8
Underwater pump ϕ 150	--	10	6	6	6	--	--	--
" ϕ 100	--	10	6	6	6	--	--	--
" ϕ 50	--	10	9	9	9	10	--	--
Underwater cutter	--	4	4	4	4	4	--	--
Asphalt plant 45 t/hr.	--	--	--	--	--	--	--	1
Concrete mixing plant	1	1	1	1	1	1	1	1
Prepacked concrete mixing plant	--	1	1	1	1	1	--	--
Well point machine	--	5	3	3	3	--	--	--
Soil testing equipment	1	1	1	1	1	1	1	1
Concrete testing equipment	1	1	1	1	1	1	1	1
Asphalt testing equipment	--	--	--	--	--	--	--	1
Universal testing machine	1	1	1	1	1	1	1	1
Lighting equipment	1	1	1	1	1	1	1	1
Tug-boat 1,500 pcs	--	5	5	5	5	5	3	1
Flat barge 1,000 t	3	3	3	3	3	3	3	3
Anchor barge	4	4	4	4	4	4	4	4
Floating crane 1,000 t	2	2	2	2	2	2	--	--
" 300 t	3	3	3	3	3	3	3	3
Barge-mounted concrete mixing plant	1	1	1	1	1	1	1	1
Supply ship	1	1	1	1	1	1	1	1
Working boat for divers	3	3	3	3	3	3	--	--
<u>Superstructure</u>								
Bulldozer 16 t	8	8	8	8	8	8	8	8
Back hoe 1.2 cu.m	2	2	2	2	2	2	2	--
Crawler crane 227 t	--	--	8	12	12	12	10	--
" 35 t	8	8	8	8	8	8	6	6
" 20 t	4	4	4	4	4	4	4	4
Portal crane 50 t	2	2	2	2	2	2	2	2
" 10 t	2	2	2	2	2	2	2	2
Ceiling crane 5 t	3	3	3	3	3	3	3	3
Motor grader	2	2	2	2	2	2	2	2
Pile driver	2	2	2	2	2	2	2	--
Tire roller 12 t	4	4	4	4	4	4	4	--
Crusher 30 t/hr.	4	4	4	4	4	4	4	--
Compressor 50 HP	5	5	21	21	21	21	20	--

----- Continued -----

Table 7-13 Machinery and Equipment Use Schedule (Continued)

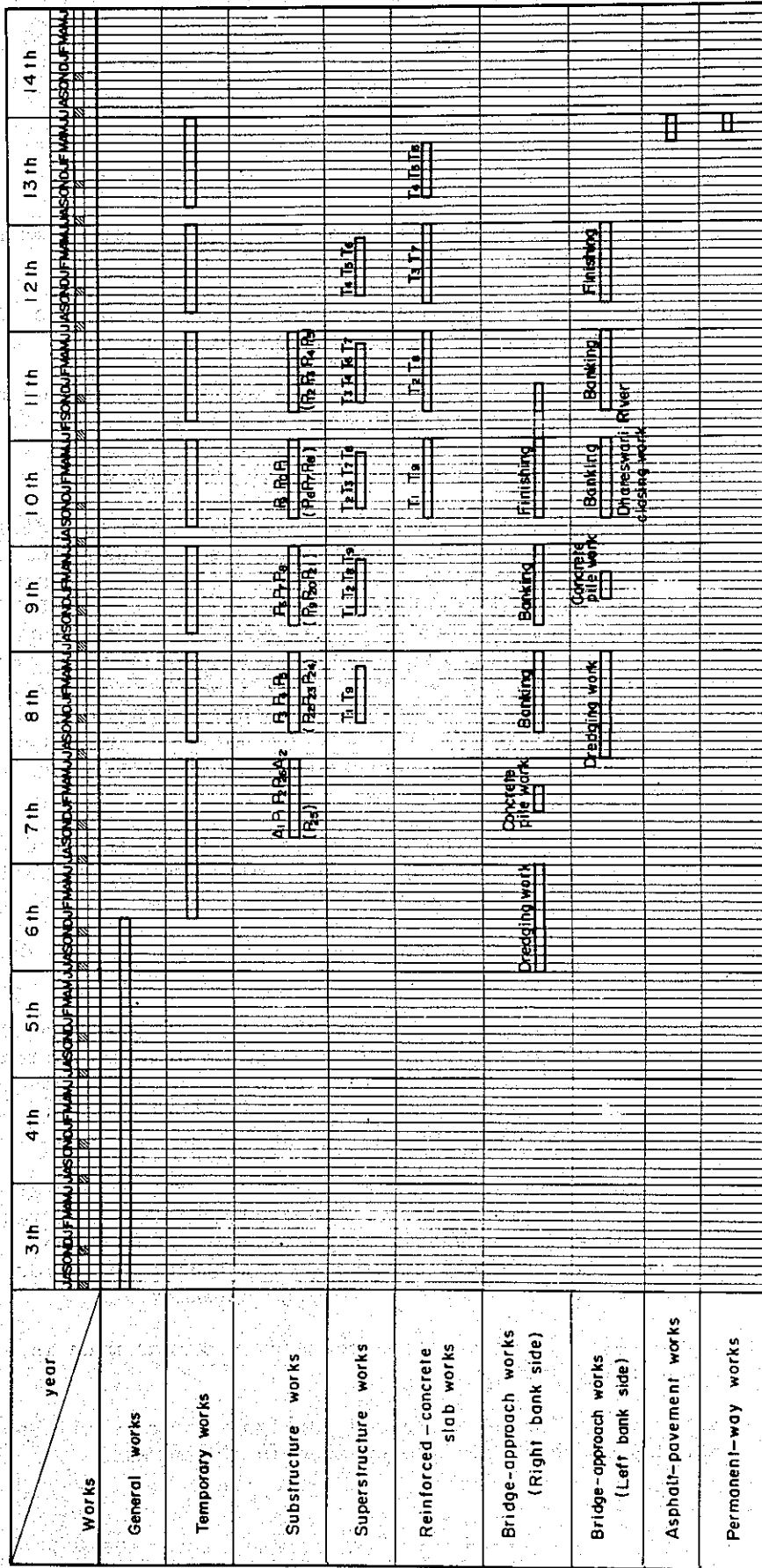
Items	Year							
	6th	7th	8th	9th	10th	11th	12th	13th
<u>Superstructure</u>								
Fork lift 3 t	10	10	10	10	10	10	10	10
Trolley 50 t	4	4	4	4	4	4	4	4
" 30 t	6	6	6	6	6	6	6	6
" 10 t	6	6	6	6	6	6	6	6
Truck 11 t	6	6	6	6	6	6	6	6
" 4 t	13	13	13	13	13	13	13	13
Dump truck 8 t	20	20	20	20	20	20	20	--
Trailer truck 45 t	--	--	6	6	6	6	6	--
Resistor 600 A	30	30	70	70	70	70	70	10
" 500 A	--	--	4	4	4	4	--	--
Generator 200KVA	5	5	16	16	16	16	10	--
Jack 800 t	--	--	4	4	4	4	--	--
" 200 t	--	--	20	20	20	20	20	--
" 100 t	10	10	20	20	20	20	20	--
" 50 t	50	50	200	200	200	200	200	--
Electric cubicle 300 KVA	--	--	4	4	4	4	4	--
Winch 15 t	--	--	4	8	8	8	--	--
" 8 t	--	--	4	4	4	4	--	--
Underwater pump 150 cu.m/hr.	--	--	20	20	20	20	--	--
Dryer	1	1	1	1	1	1	1	1
Sand blaster	10	10	10	10	10	10	10	10
Hoist 2 t	12	12	12	12	12	12	12	12
Floating crane 50 t	1	1	1	1	1	1	1	1
Tug-boat 1,000HP	1	1	6	6	6	6	1	1
Flat barge 12,000 t	--	--	1	1	1	1	--	--
" 500 t	--	--	1	1	1	1	--	--
Launch	--	--	5	5	5	5	--	--
High speed launch	--	--	2	2	2	2	--	--
Electric facility	2	2	2	2	2	2	2	2
Pneumatic equipment (For blower)	1	1	1	1	1	1	1	1
Lighting facility	1	1	1	1	1	1	1	1
Gas cutting machine	1	1	1	1	1	1	1	1
<u>Slab work</u>								
Crawler crane 20 t	--	--	--	--	4	4	4	4
Truck crane 10 t	--	--	--	--	2	2	2	2
Mobil crane 4.5 t	--	--	--	--	2	2	2	2
Jibcrane 4.5 t	--	--	--	--	2	2	2	2
Truck 4 t	--	--	--	--	2	2	2	3
Agitator car 4.5 cu.m	--	--	--	--	5	5	5	5
Vibrator 0.75 KW	--	--	--	--	10	10	10	15
Concrete pump	--	--	--	--	4	4	4	4

----- Continued -----

Table 7-13 Machinery and Equipment Use Schedule (Continued)

Items	Year							
	6th	7th	8th	9th	10th	11th	12th	13th
<u>Bridge approach</u>								
Bulldozer 35 t	--	--	5	5	5	5	--	--
" 14 t	--	--	--	2	3	3	1	--
Tractor shovel 1.2 cu.m	--	--	--	--	2	2	2	1
Back hoe (Crawler) 3.0 cu.m	--	--	4	4	5	5	--	--
Shovel loader 2.1 cu.m	--	--	1	1	2	1	2	1
Tire roller 12 t	--	--	3	3	4	4	1	2
Macadam roller 12 t	--	--	--	--	--	--	--	1
Vibrating roller 2.5 t	--	--	--	--	1	1	1	1
Pile driver	--	3	--	3	--	--	--	--
Motor scraper 32.4 cu.m	--	--	8	8	8	8	--	--
Motor grader	--	--	3	3	3	3	--	--
Engine sprayer 600 l	--	--	--	--	--	--	--	1
Asphalt finisher	--	--	--	--	--	--	--	1
Dump truck 32 t	--	--	16	16	20	20	--	--
" 11 t	--	--	2	2	3	3	--	--
Road-sprinkler 8 t	--	--	--	--	--	2	2	2

Fig 7-36 Construction Schedule of Bridge



Legend

Diagram illustrating the layout of the flood season monitoring stations along the Sirajganj side (Right bank) and Tangail side (Left bank) of the river. The stations are labeled T₁ through T₉ on the Sirajganj side and T₁ through T₉ on the Tangail side. The diagram also shows the flood season (J, J, A, S, O) and the flood season (J, J, A, S, O) for the flood season.

CHAPTER VIII

COSTS

1. Construction Costs.

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

- a. The construction costs shall be estimated based on the unit prices in July, 1975 which were collected by our study team.
- b. As for the unit prices of domestic products, the market prices at the job site shall be adopted. As for the wages or salaries of domestic workers, the wages or salaries of workers who are engaged in similar domestic works shall be adopted.
- c. Purchasing of imported goods shall be made under the direct control of the Government and the import duties and sales taxes shall be excluded from the cost estimation. Therefore, the costs of imported goods shall be first estimated based on the FOB prices at a port of departure except some kinds of goods. Then the CIF prices in Bangladesh shall be estimated respectively. Hence, the costs of imported goods at the job site shall be estimated by adding the transportation costs and other expenses to the CIF prices. The costs of foreign workers shall be estimated based on salaries, travel expenses and overhead, but their taxes in Bangladesh shall be exempted.
- d. Expenses required for the strengthening of the existing facilities for transportation, loading and unloading equipment shall be included in their unit prices respectively.
- e. The classification of domestic and foreign currencies shall be made in accordance with the following conditions.
 - i. All the cost estimation of imported equipment and materials, the amount of CIF prices shall be counted in foreign currency and such additional costs as inland transportation expenses shall be counted in domestic currency. The labour costs for foreign workers shall be counted in foreign currency.
 - ii. In the cost estimation of imported equipment and materials, the amount of CIF prices shall be counted in foreign currency and such additional costs as inland transportation expenses shall be counted in domestic currency. The labour costs for foreign workers shall be counted in foreign currency.
- f. Allotment of the construction costs by year was made in accordance with the following conditions.
 - i. Labour costs for domestic and foreign workers shall be counted in the year that they are engaged in the works.

- ii. Costs of domestic materials and equipment shall be counted in the year that they are used in the works.
- iii. Costs of such materials as fuel, lubricant, paint, asphalt and stone materials shall be counted in the year previous to the use considering the time necessary for purchasing and transportation.

The unit prices and wages to be used for estimation of construction costs were shown in Tables 8-1 to 8-4. But the unit prices of such imported materials as fuel, lubricant, paint, asphalt and stone materials in Table 8-3 are unit costs at job site and the prices of other materials in Table 8-3 are the FOB prices at the port of departure. And all the prices of construction equipment in Table 8-4 are the FOB prices in an exporting country.

The bridge construction costs were estimated based on the unit prices and wages shown in the Tables 8-1 to 8-4.

The total costs by works of construction were shown in Tables 8-5 and 8-6. In these tables, the inland transportation costs and other expenses were added to the CIF prices respectively.

As shown in Tables 8-7-1 to 8-7-4, the construction costs were broken down by year according to the construction schedule.

The construction costs classified by materials, labour and equipment were shown in Tables 8-8-1 to 8-8-4 and the construction costs by year were shown in Tables 8-9-1 to 8-9-3. However, in these tables, costs such imported materials as fuel, lubricant, paint, asphalt and stone materials were estimated by prices at the job site and the costs of other imported materials and equipment were estimated on the basis of FOB prices. The transportation costs of above-mentioned imported materials and equipment were intensively calculated and added to the results of estimation.

The total construction costs of the bridge and its approaches were estimated as follows.

Total cost	TK 4,552,620,000
Domestic currency	TK 347,810,000
Foreign currency	US \$ 323,447,000 (TK 4,204,810,000)

2. Maintenance Costs.

For the purpose of maintenance of the bridge and the approaches, surveying, patrolling, inspecting and repairing works should be needed in future. Logitudinal levelling, surveying of the center line of the bridge and sounding around piers during flood season shall be included in the above surveying works.

The following maintenance and repairing works shall be provided in accordance with the informations which are given by the above-mentioned surveying, patrolling and inspection.

- * Scour-protection works around piers.
- * Repainting works of bridge superstructure.
- * Renewing works of expansion joints of superstructure.
- * Repairing works of bridge deck-slab.
- * Mending works of slope protection of approach embankment.
- * Supplemntary works of wire cylinders filled with bricks arranged along the toe of slope of approach embankment.

Table 8-1 Wages per Man-day

Labourer	Foreign Labourer (Dollars)	Local Labourer (Taka)
Skilled labour		
Foreman	66.50	45.00
Special operator	85.30	45.00
Operator	66.50	28.00
Driver	66.50	28.00
Carpenter	66.50	28.00
Barbender	66.50	28.00
Scaffolding man	66.50	28.00
Reinforcement worker	66.50	28.00
Welder	66.50	28.00
Electrician	66.50	34.00
High class prestressing worker	100.00	
Prestressing worker	66.50	
Diver	160.00	
Steel worker	66.50	28.00
High class crew	110.00	45.00
Crew	81.80	
Bridge erection worker	86.70	
Skilled labour	66.50	23.00
Unskilled labour		
Assistant operator		20.00
Crew		20.00
Other unskilled labour		17.00

Table 8-2 Market Price of Local Materials

Items	Unit	Rate (Taka)
Sand	per % cft.	366.00
Gravel (Bholaganj)	"	620.00
1st class brick	per % nos.	700.00
1st class bats	per % cft.	595.00
Ballast for railway	per cu.m	184.00
Turfing	per % sft.	50.00
Land acquisition	per acre	12,000.00

Table 8-3 Costs for Imported Materials

Description	Unit	Rate	
		Foreign Currency (Dollars)	Local Currency (Taka)
Portland cement	per ton	31.00	---
Admixture	"	670.00	---
Steel deformed bar	"	233.00	---
Prestressing tendon	"	710.00	---
Steel sheet pile	"	230.00	---
Steel pipe pile	"	240.00	---
Structural steel			
SM 53 & SM 50 Y	"	266.70	---
SS 41 & SM 41	"	230.00	---
Bearing shoe	"	3,667.00	---
Shape steel	"	230.00	---
Stone	per % cft.	20.15	208.00
Bitumen or asphalt	per ton	115.40	194.00
Paint	per I.G.	11.38	0.92
Heavy oil	"	0.29	0.88
Light oil	"	0.28	0.80
Gasoline	"	1.22	0.80
Lubricant	"	3.26	1.93
Bonding material	per ton	53,000.00	---
Vinyl pipe ϕ 16 mm	"	0.19	---
ϕ 20 "	"	0.22	---
ϕ 25 "	"	0.32	---
ϕ 50 "	"	1.10	---

Table 8-4 Costs of Machinery and Equipment by F.O.B.

Description		Rates (Dollars)	Life (Years)	Repair in Place (%)
Bulldozer	35 t	167,000	6	30
"	(For swamp) 16 t	63,400	5	30
"	14 t	55,000	5	30
Tractor shovel	1.2 cu.m	49,500	5	25
Back hoe (Crawler)	3.0 cu.m	403,300	7	25
"	1.2 cu.m	142,700	7	25
"	0.6 cu.m	10,300	6	25
Shovel loader	2.1 cu.m	42,000	7	25
Clamshell bucket	2.0 cu.m	33,300	5	25
"	0.6 cu.m	7,500	5	25
Reverse-circulation machine		384,000	5	30
Crawler crane	955 ALC	275,000	6	25
"	35 t	105,000	6	25
"	20 t	91,700	6	25
Truck crane	30 t	111,800	6	25
"	20 t	56,100	6	25
"	10 t	39,200	6	25
Portal crane	50 t	333,300	7	25
"	10 t	66,700	7	25
Ceiling crane	5 t	33,300	7	25
Mobil crane	4.5 t	20,200	7	25
Jimcrane	4.5 t	27,500	7	25
"	0.4 t	1,500	7	25
Tire roller	12 t	18,400	7	20
Macadam roller	12 t	20,700	7	20
Vibrating roller	2.5 t	8,800	6	25
Motor scraper	32.4 cu.m	347,600	6	30
Motor grader		33,000	6	25
Diesel pile hammer	4.0 t	50,800	4	30
"	2.2 t	27,000	4	30
Steam-hammer		920,000	4	30
Vibro-hammer	90 KVA	37,800	4	30
"	60 KVA	28,600	4	30
"	40 KVA	23,500	4	30
Pile driver (Crawler)		148,000	5	30
"		13,000	5	30
Soil compactor		890	3	30
Crusher	30 t/hr.	23,300	4	30
Vibrator	0.75 KW	430	3	30
Baby conveyer		590	4	30
Belt conveyer		1,430	4	30
Bar bender		1,340		30
Bar cutter		1,070		30
Concrete breaker		950	2	35
Concrete pick		920	2	35
Concrete bucket	1.0 cu.m	1,100	3	30

----- Continued -----

Table 8-4 Costs of Machinery and Equipment by F.O.B. (Continued)

Description	Rates (Dollars)	Life (Years)	Repair in Place (%)
Concrete pump	33,000	4	30
Air compressor 17 cu.m/min.	20,000	6	25
" 50 HP	7,000	6	25
Engine-operated air compressor 5 cu.m	810	6	25
Engine sprayer 600 l	8,100	3	30
Asphalt finisher	29,000	6	30
Dump truck 32 t	135,600	5	30
" 15 t	27,200	5	30
" 11 t	23,000	4	30
" 8 t	14,300	4	30
" 4 t	13,100	4	30
Truck 11 t	24,000	4	30
" 8 t	23,200	4	30
" 4 t	10,000	4	30
Fork lift 3 t	7,400	5	20
Semi-trailer-truck 45 t	97,700	5	30
Agitator car 4.5 cu.m	28,100	4	30
Concrete pump car 20 cu.m/hr.	64,000	4	30
Tank roller 6 t	17,700	5	30
Road-sprinkler 8 t	15,800	5	30
Trolley 750 t	800,000	5	30
" 50 t	13,300	5	30
" 30 t	8,000	5	30
" 10 t	2,700	5	30
Jack 800 t	23,300	5	30
" 200 t	3,300	5	30
" 100 t	1,830	5	30
" 50 t	500	5	30
Center hole jack 100 t	4,700	5	30
Slip form jack 4.5 t	570	5	30
Winch 15 t	43,300	7	30
" 8 t	30,000	7	30
" 30 HP	7,200	7	30
" 20 KW	5,000	7	30
Generator 300 KVA	35,800	6	30
" 200 KVA	25,300	6	30
" 125 KVA	17,100	6	30
" 50 KVA	9,200	6	30
Resistor 600 A	570	7	30
" 500 A	500	7	30
Electric separator	7,000	10	30
Electric cubicle 300 KVA	13,300	10	30
Electric arc welding machine 300 A	730	7	30
" 200 A	260	7	30
Electric motor	3,340	10	30
Underwater pump ϕ 150	5,000	5	30

----- Continued -----

Table 8-4 Costs of Machinery and Equipment by F.O.B. (Continued)

Description	Rates (Dollars)	Life (Years)	Repair in Place (%)
Underwater pump ϕ 100	3,100	5	30
" ϕ 50	1,300	5	30
" 150 cu.m/hr.	2,000	6	30
Underwater cutter	8,200	5	30
Dryer	1,000	5	30
Sand blaster	10,000	5	30
Tool	6,700	5	30
Asphalt plant 45 t/hr.	151,600		
Concrete mixing plant	319,000		
Prepacked concrete mixing plant	263,500		
Well point machine	6,000		
Soil testing equipment	11,000		
Concrete testing equipment	12,000		
Asphalt testing equipment	7,600		
Universal testing machine	24,000		
Lighting equipment	1,000		
Tug-boat 1,500 HP	550,000	14	30
" 1,000 HP	500,000	14	30
Flat barge 12,000 t	1,600,000	12	30
" 1,000 t	83,330	12	30
" 500 t	83,300	14	30
High speed launch	76,700	12	30
Launch	46,700	12	30
Floating crane 1,000 t	3,300,000	12	25
" 300 t	1,050,000	12	25
" 50 t	360,000	12	25
Barge-mounted concrete mixing plant	500,000	12	30
Anchor barge	689,300	12	30
Supply ship	125,000	12	30
Working boat for divers	16,670	12	30
Hoist	1,250	7	30
Electric facility	16,000	10	30
Pneumatic equipment (For blower)	73,300	6	25
Lighting facility	3,300		
Gas cutting machine	166,700		

Table 8-5 Total Costs of Bridge Construction

Description	Foreign Currency (Dollars)	Domestic Currency (Taka)	Total (Taka)
Substructure works	107,609,000	156,990,000	1,555,910,000
Superstructure works	194,557,000	104,760,000	2,634,000,000
Bridge approach works	19,834,000	56,490,000	314,330,000
Permanent way works	1,447,000	17,160,000	35,970,000
Land acquisition	---	12,410,000	12,410,000
Total	323,447,000	347,810,000	4,552,620,000

Table 8-6 Bridge Construction Costs

Works	F.C (Thousand \$)	D.C (Thousand Tk)	Total (Thousand Tk)
<u>SUBSTRUCTURE</u>	(107,609)	(156,990)	(1,555,910)
Well foundation (On land)	71,497	70,463	
Well foundation (In stream)	24,668	47,007	
Pier	9,292	19,419	
Miscellaneous	2,152	20,101	
<u>SUPERSTRUCTURE</u>	(194,964)	(109,058)	(2,643,590)
Fabrication & erection	169,583	76,682	
Slab	7,869	9,251	
Painting	13,168	7,587	
Permanent way	407	4,306	
Pavement	84	1,243	
Miscellaneous	3,853	9,989	
<u>BRIDGE APPROACH</u>	(20,874)	(69,349)	(340,710)
Embankment	17,505	11,253	
Stone pitching	529	4,923	
Slope protection	918	23,176	
Permanent way	1,096	13,122	
Pavement	474	12,781	
Miscellaneous	352	4,094	

Table 8-7-1 Construction Costs of Substructure by Year

Works: Substructure	Equipment		Materials		Labour		Total	
	Year				Skilled		Unskilled	
	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)
1st.								
2nd.								
3rd.								
4th								
5th	9,248	27,697	2,535	3,775			11,783	31,472
6th	3,713	11,119	8,881	5,783	320	571	14,194	17,473
7th	712	2,133	20,542	8,859	2,280	2,385	25,684	13,377
8th	495	1,483	21,608	8,515	2,860	3,302	27,863	13,300
9th	610	1,826	21,900	7,433	2,900	3,378	28,370	12,637
10th	630	1,887	21,904	8,934	2,860	3,292	28,294	14,113
11th	177	531	13,630	933	2,580	3,279	19,267	4,743
12th	15	46	630	45	80	176	1,055	267
13th			130	45	90	182	480	227
Total	15,600	46,722	111,760	44,322	13,970	16,565	156,990	107,609

Table 8-7-2 Construction Costs of Superstructure by Year

Year	Equipment		Materials		Labour		Total	
	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	Skilled		Unskilled	
					D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)
Ist.								
2nd.								
3rd.								
4th								
5th	1,182	8,997					1,182	8,997
6th	170	1,292	15,270	219	590	830	410	16,440
7th	2,600	19,788	8,353	16,629	660	1,774	440	12,053
8th	824	6,271	10,961	20,795	1,810	6,243	1,130	14,725
9th	526	3,995	10,863	22,515	2,140	7,385	1,420	14,949
10th	414	3,151	11,232	21,951	3,070	8,391	1,720	16,436
11th	479	3,648	9,738	18,105	3,070	8,391	1,720	15,007
12th	162	1,235	3,194	2,353	2,850	7,635	1,530	7,736
13th			3,830	307	1,700	2,657	700	6,230
Total	6,357	48,377	73,441	102,874	15,890	43,306	9,070	104,758
								194,557

Table 8-7-3 Construction Costs of Bridge-approach by Year

Works: Bridge-approach									
Year	Equipment		Materials		Labour			Total	
	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	Skilled		Unskilled		
					D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	
1st.									
2nd.									
3rd.									
4th									
5th									
6th			943	486		1,516	943		2,002
7th	725	7,602	1,770		190	31		130	2,815
8th	35	366	1,901	1,000	270	2,075		180	2,386
9th	160	1,682	9,172	472	510	592		780	10,622
10th	44	463	12,501	1,071	400	806		1,310	14,255
11th	6	63	8,265	520	360	626		690	9,321
12th	14	144	8,993	38	80	140		1,120	10,207
13th			5,940	57		84			5,940
Total	984	10,320	49,485	3,644	1,810	5,870		4,210	56,489
									19,834

Table 8-7-4 Construction Costs of Permanent-way by Year

Works: Permanent way		Labour				Total	
Year	Equipment	Materials		Unskilled		Total	
	D.C. (10 ³ Tk)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)
1st.							
2nd.							
3rd.							
4th							
5th							
6th							
7th							
8th							
9th							
10th							
11th							
12th							
13th		14,640	1,447	1,920		17,160	1,447
Total		14,640	1,447	1,920		17,160	1,447

Table 8-8-1 Construction Costs of Substructure
(Transportation Costs were Excluded)

Items	Temporary works		Main works		Total	
	F.C.	D.C.	F.C.	D.C.	F.C.	D.C.
	10 ³ \$	10 ³ Tk	10 ³ \$	10 ³ Tk	10 ³ \$	10 ³ Tk
1. Materials	9,709	14,448	27,449	70,532	37,158	84,980
Portland cement*	2	---	2,307	---	2,309	---
Admixture*	---	---	103	---	103	---
Steel deformed bar*	3	---	1,880	---	1,883	---
Structural steel*	9,624	---	13,012	---	22,636	---
Prestressing bar*	---	---	1,879	---	1,879	---
Vinyl pipe*	---	---	94	---	94	---
Bonding materials*	---	---	3,710	---	3,710	---
Timber*	80	---	15	---	95	---
Rail	---	455	---	---	---	455
Sand	---	41	---	11,369	---	11,410
Gravel	---	---	---	37,169	---	37,169
1st class bats	---	13,952	---	72	---	14,024
Stone	---	---	1,495	15,424	1,495	15,424
Heavy oil	---	---	658	2,008	658	2,008
Light oil	---	---	1,390	3,951	1,390	3,951
Gasoline	---	---	24	16	24	16
Lubricant	---	---	882	523	882	523
2. Labour	3,370	6,260	13,195	23,370	16,565	29,630
Skilled labour	3,370	1,750	13,195	12,220	16,565	13,970
Unskilled labour	---	4,510	---	11,150	---	15,660
3. Equipment	---	---	42,016	---	42,016	---
4. Total	13,079	20,708	82,660	93,902	95,739	114,610

Note: F.C.: Foreign currency.
D.C.: Domestic currency.

Items with * show the cost in F.O.B.

Table 8-8-2 Construction Costs of Superstructure (Transportation Costs were Excluded)

Items	Temporary works		Main works		Slab works		Total	
	F.C. 10 ³ \$	D.C. 10 ³ Tk	F.C. 10 ³ \$	D.C. 10 ³ Tk	F.C. 10 ³ \$	D.C. 10 ³ Tk	F.C. 10 ³ \$	D.C. 10 ³ Tk
1. Materials	76	25,470	88,891	6,310	1,617	3,870	90,584	35,650
Portland cement*	---	---	26	---	114	---	140	---
Admixture*	---	---	---	---	1	---	1	---
Steel deformed bar*	---	---	77	---	655	---	732	---
Structural steel*	---	---	73,359	---	567	---	73,926	---
Cast steel*	---	---	3,713	---	---	---	3,713	---
Steel pipe pile*	---	---	531	---	---	---	531	---
H.T bolt*	---	---	1,027	---	---	---	1,027	---
Bolt*	---	---	226	---	---	---	226	---
Welding electrode*	---	---	1,245	---	---	---	1,245	---
Thinner*	---	---	45	---	---	---	45	---
Timber*	---	---	---	---	164	---	164	---
Sand	---	9,375	---	240	---	839	---	10,454
Gravel	---	---	---	519	---	2,830	---	3,349
1st class bats	---	15,263	---	---	---	---	---	15,263
1st class brick	---	701	---	---	---	---	---	701
Asphalt	76	131	---	---	33	50	109	181
Paint	---	---	3,731	292	---	---	3,731	292
Miscellaneous	---	---	1,289	---	---	---	1,289	---
Heavy oil	---	---	367	1,118	---	---	367	1,118
Light oil	---	---	965	2,744	47	135	1,012	2,879
Gasoline	---	---	602	396	---	---	602	396
Lubricant	---	---	1,688	1,001	36	16	1,724	1,017
2. Labour	6,947	2,580	31,702	16,730	4,657	5,650	43,306	24,960
Skilled labour	6,947	1,550	31,702	10,120	4,657	4,220	43,306	15,890
Unskilled labour	---	1,030	---	6,610	---	1,430	---	9,070
3. Equipment	---	---	36,997	---	1,098	---	38,095	---
4. Total	7,023	28,050	157,590	23,040	7,372	9,520	171,985	60,610

Note: Items with * show the cost in F.O.B.

Table 8-8-3 Construction Costs of Bridge-approach
(Transportation Costs were Excluded)

Items	Foreign Currency (10 ³ \$)	Domestic Currency (10 ³ Tk)
1. Materials	3,521	48,900
Porland cement*	168	---
Steel deformed bar*	253	---
Mat*	326	---
Stone dust*	11	---
Sand	---	2,890
Gravel	---	3,330
1st class bats	---	3,940
1st class brick	---	26,920
Crushed stone	---	1,550
Drain pipe	---	200
Turf	---	150
Stone	463	4,770
Asphalt	46	80
Heavy oil	523	1,600
Light oil	1,089	3,090
Lubricant	642	380
2. Labour	5,870	6,020
Skilled labour	5,870	1,810
Unskilled labour	---	4,210
3. Equipment	9,816	---
4. Total	19,207	54,920

Note: Items with * show the cost in F.O.B.

Table 8-8-4 Construction Costs of Permanent-way
(Transportation Costs were Excluded)

Items	Foreign Currency (10 ³ \$)	Domestic Currency (10 ³ Tk)
1. Materials	1,447	14,640
Rail(90 lbs./yd.)	220	1,140
" (Second-hand)	---	550
Fish plate	39	200
" (Second-hand)	---	100
Bolt & washer	9	60
Sleeper (Wooden)	468	1,520
Tie plate	103	510
Rail-spike	43	220
Hook bolt	2	20
Guard timber	---	90
Scaffold board	---	60
Ballast	---	3,510
Switch & crossing	15	50
Various marks	28	90
Electric lighting power & telecommunication	104	3,150
Signalling	416	2,920
Equipment	---	450
2. Labour	---	2,520
Skilled labour	---	1,920
Unskilled labour	---	600
3. Total	1,447	17,160

Construction costs of permanent-way which were divided in two, namely the bridge portion and the approach portion, are as follows.

Items	Superstructure		Bridge-approach	
	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)
1. Materials	407	3,630	1,040	11,010
2. Labour	---	670	---	1,850
Skilled labour	---	510	---	1,410
Unskilled labour	---	160	---	440
3. Total	407	4,300	1,040	12,860

Table 8-9-1 Construction Costs of Substructure by Year
(without Transportation Costs)

Works: Substructure		Total							
Year	Equipment		Materials		Labour		Total		
	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	Skilled		Unskilled		
					D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	
1st.									
2nd.									
3rd.									
4th									
5th	24,907			3,097				28,004	
6th	9,999	5,150	4,783		320	571	1,280	6,750	
7th	1,918	15,030	7,384		2,280	2,385	2,150	19,460	
8th	1,334	16,470	7,138		2,860	3,302	2,900	22,230	
9th	1,642	17,470	6,251		2,900	3,378	2,960	23,330	
10th	1,697	16,470	7,482		2,860	3,292	2,900	22,230	
11th	478	13,630	933		2,580	3,279	2,880	19,090	
12th	41	630	45		80	176	330	1,040	
13th		130	45		90	182	260	480	
Total	42,016	84,980	37,158		13,970	16,565	15,660	114,610	
								95,739	

Table 8-9-2 Construction Costs of Superstructure by Year
(without Transportation Costs)

Works: Superstructure									
Year	Equipment		Materials		Labour			Total	
					Skilled		Unskilled		
	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	
1st.									
2nd.									
3rd.									
4th									
5th		7,085							7,085
6th		1,017	15,270	219	590	830	410	16,270	2,066
7th		15,582	1,840	14,513	660	1,774	440	2,940	31,869
8th		4,938	3,200	18,268	1,810	6,243	1,130	6,140	29,449
9th		3,146	2,530	19,803	2,140	7,385	1,420	6,090	30,334
10th		2,481	3,120	19,314	3,070	8,391	1,720	7,910	30,186
11th		2,873	3,160	15,965	3,070	8,391	1,720	7,950	27,229
12th		973	2,700	2,195	2,850	7,635	1,530	7,080	10,803
13th			3,830	307	1,700	2,657	700	6,230	2,964
Total		38,095	35,650	90,584	15,890	43,306	9,070	60,610	171,985

APPENDICES

Table 8-9-3 Construction Costs of Bridge-approach by Year
(without Transportation Costs)

Works: Bridge-approach		Labour						Total	
Year	Equipment	Materials		Skilled		Unskilled		D.C. (10 ³ Tk)	F.C. (10 ³ \$)
		D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)	D.C. (10 ³ Tk)	F.C. (10 ³ \$)		
1st.									
2nd.									
3rd.									
4th									
5th									
6th		800	455		1,516			800	1,971
7th	7,231	1,770		190	31	130		2,090	7,262
8th	348	1,680	952	270	2,075	180		2,130	3,375
9th	1,600	9,120	462	510	592	780		10,410	2,654
10th	440	12,410	1,052	400	806	1,310		14,120	2,298
11th	60	8,200	507	360	626	690		9,250	1,193
12th	137	8,980	36	80	140	1,120		10,180	313
13th		5,940	57		84			5,940	141
Total	9,816	48,900	3,521	1,810	5,870	4,210		54,920	19,207

APPENDICES

APPENDIX 1

SCHEDULE FOR FIELD STUDY AT BANGLADESH IN 1974

7 Jan. '74	Departure from Tokyo. Arrival in Bangkok
8 Jan. '74	Arrival in Dacca. Adjustment of work schedule.
9 Jan. '74	Greeting to MOC.
10 Jan. '74	Interview to the Minister of MOC. Discussion with counterparts.
11 Jan. '74	Examination of surveying schedule and items.
12 Jan. '74	Inspection of Sitarakya Bridge and discussion.
13 Jan. '74	Inspection of roads, ferries and bridges in the Meghna River region.
14 Jan. '74	Inspection of King George VI Bridge at Bhairab Bazar.
15 Jan. '74	Discussion with R & H and collection of data.
16 to 18 Jan. '74	Reconnaissance of Jamuna River.
19 Jan. '74	Discussion with Highway, Railway, Ferry Team and R & H.
20 Jan. '74	Inspection of Vivekanada Bridge and Howrah Bridge at Calcutta.
21 to 22 Jan. '74	Collection and arrangement of data at Dacca.
23 to 24 Jan. '74	Inspection of Hardinge Bridge at Paksey.
25 Jan. '74	Reconnaissance of near Tangail at Sirajganj site.
26 Jan. '74	Final discussion of schedule. Data arrangement.
27 Jan. '74	Data arrangement.
28 to 29 Jan. '74	Inspection of Chittagong port, Khulna port and Chalna port.
30 Jan. '74	Data collection and arrangement.
31 Jan. '74	Greeting to MOC. Departure from Dacca.
2 Feb. '74	Arrival in Tokyo.

APPENDIX 2

CONTENTS OF ACCUMULATED DATA

NO.	DATA	SOURCE	GIVEN LENT BUY	REMARKS
1	Roads and Highways Directnate Schedule of Rate for Construc- tion of BRIDGE	Road & Highways M.O.C.	Given	
2	Roads and Highways Directnate Schedule of Rate for Road Works	"	"	
3	Monthly Rainfall Statement on Sirajganj at 1973.		"	
4	Daily Report Sheets MITSUI- OHBAYASHI J.V.	OHBAYASHI Office	"	
5	Report of the National Pay Commission		Buy	
6	Plan and Profile of Dacca- Aricha Highway Bridge. Mirpur Br. Bangshi Br. Kaliganga Br.	R. & H. M.O.C.	Fiven	
7	Sinking Record of Caisson of KALIGANGA Br.	"	"	
8	Sinking Report of No. 4 Caisson of Sitarakya Br.	OHBAYASHI office	"	
9	Road Map of Bangladesh scale 1 inch=8 miles	R. & H. M.O.C.	"	
10	Bangladesh Land & People		Buy	
11	1st 5 years Plan		"	
12	General Rules and Schedules for Working of the Chittagong Port (Railway) from January 1959	Chitta- gong Port Trust	"	
13	Manual of Standard Bridge Design (East Pakistan)		"	
14	Power Development in Bangladesh		Given	

NO.	DATA	SOURCE	GIVEN LENT BUY	REMANRKS
15	Law of Evidence & Limitation		Buy	
16	Constitutional Law in Bangladesh		"	
17	Law of Tort		"	
18	Interim Report on Remedial Works Required to Harding Bridge & King George V Br.	Jamuna Br, Survey Office	Given	
19	Re-Openning of King George VI Bridge over the Meghna	Jamuna Br, Survey Of.	Given	
20	The Hardinge Bridge over the Lower Ganges at Sara	Bangladesh Railway (Paksey)	"	
21	Modorn Road Construction Procedures	R & H M.O.C.	"	
22	Bangladesh Consultants Limited		"	Consulting Firm
23	Associated Consulting Engineers Ltd.		"	"
24	Prachi Prakaushali Sangstha Limited		"	"
25	Prakaushali Sangsad Limited		"	"
26	Messrs Rahman & Associated Ltd.		"	"
27	Engineering Consultants & Associated Ltd.		"	"
28	Brixton & Brixton Ltd. Consulting Engineers		"	"
29	Bureau of Consulting Engineers Ltd.		"	"
30	Associated Architects and Engineers Ltd.		"	"
31	Bangladesh Survey Organization Ltd.		"	Land Survey
32	The Engineers Ltd.		"	Construction Firm
33	Bengal Development Corporation Ltd.		"	"

NO.	DATA	SOURCE	GIVEN LENT BUY	REMANRKS
34	Stonevill Engineers Ltd.		Given	Construction Firm
35	National Builders & Engineers Ltd.		"	"
36	Delta Constructions Ltd.		"	"
37	Hardinge Bridge-Section of Scouring Taken at Centre Line from July to December 1973	Bridge Engineer, West Paksey	"	

APPENDIX 3

BANGLADESH RAILWAY.

No. XEN/J/G/74.

Dated:- 28 - 1 - 1974.

From:- XEN/J.B.S/Dacca.

To:- The Director,
Jamuna Bridge Survey/DA.

Sub:- Confirmation of Datas.

Mr. Tezuka, Leader of Bridge Planning Team wanted confirmation of the following datas in connection with designing of Bridge Girders of proposed Jamuna Bridge.

1. Bridge Girders to be designed as per Main Line loading of Indian Railway Bridge Code.
2. All structures to be designed keeping the provision of Electrification in future.

The above Datas are hereby confirmed.

Executive Engineer,
Jamuna Bridge Survey,
Bangladesh Railway, Dacca.

Copy to ENC/CRB for information. Since the Team wanted the confirmation of the above Datas by 31.1.74, so the undersigned confirmed the above Datas on behalf of Bangladesh Railway.

Executive Engineer,
Jamuna Bridge Survey,
Bangladesh Railway, Dacca.

APPENDIX 4

MATTERS TO BE DETERMINED PRIOR TO THE PLANNING OF THE JAMUNA RIVER BRIDGE

THE FEASIBILITY STUDY TEAM

The Feasibility Study Team for the Jamuna River Bridge Construction Project wishes to obtain a consent of the Government of Bangladesh on the following items.

I. Measuring Units

Metric System will be applied to all engineering quantities except some important quantities which will be converted in Foot-Pound System.

II. Bridge Specifications

The following specifications will be applied to the design of the Jamuna River Bridge.

a. Superstructure.

(a) Highway Bridge.

(1) Loads.

All loads to be used for design will be specified by the Standard Specifications for Highway Bridges adopted by AASHO.

(2) Construction gauge.

The construction gauge will be specified by the Standard Specifications for Highway Bridges adopted by AASHO.

(3) Structures.

All structures will be designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association.

(4) Materials.

All materials to be used for design will be specified by the Japanese Industrial Standard.

(b) Railway Bridge.

(1) Loads

All loads to be used for design will be specified by the Bridge Code for Indian Railways.

(2) Construction gauge.

The construction gauge will be specified by the Bridge Code for Indian Railways.

(3) Structures.

All structures will be designed by the Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers.

(4) Materials.

Same as above.

(c) Highway/Railway Bridge.

(1) Loads.

All loads to be used for the design of highway floor will be specified by the Standard Specifications for Highway Bridge adopted by AASHO.

All loads to be used for the design of railway floor will be specified by the Bridge Code for Indian Railways.

(2) Construction gauge.

The construction gauge for highway part will be specified by the Standard Specifications for Highway Bridges adopted by AASHO, and, for railway part, will be specified by the Bridge Code for Indian Railways.

(3) Structures.

All structures will be designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association except railway floor system.

The railway floor system will be designed by the Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers.

(4) Materials.

Same as above.

b. Substructure.

All substructures will be designed by the Standard Specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers.

MINUTES OF THE MEETING HELD BETWEEN THE JAPANESE FEASIBILITY
STUDY TEAM FOR THE JAMUNA BRIDGE PROJECT AND THE RAILWAY
DEPARTMENT, GOVERNMENT OF BANGLADESH.

The following members from the Japanese Feasibility Study Team and the Railway Department held the meeting on 8th August, 1973 in the chamber of Joint Secretary and discussed the matters to be determined prior to the planning of the Jamuna River Bridge according to the Agenda (ANNEX attached herewith) presented by the Study Team.

The matters mentioned in the Agenda were agreed between both the parties with the following addendum :

MEMBERS FROM FEASIBILITY STUDY TEAM:

1. Dr. S. Inose : Leader.
2. Mr. I. Kawasaki : Adviser to the team.
3. Mr. I. Iizuka : "
4. Dr. S. Sato : Member of the team.
5. Mr. J. Ebihara : Director of the Jamuna Bridge Survey Office.

MEMBERS FROM RAILWAY DEPARTMENT:

1. Mr. Ahmed Ibrahim : Additional Secretary.
2. Mr. M. A. Ghafur : Member/Engineering, Railway Board.
3. Mr. M. Rahman : Engineer-in-Chief, Railway.
4. Mr. Syed Hossain : Bridge Engineer.

1. The gauge length to be used for design shall be 5' 6".
2. The Japanese Study Team will present the following copies to the Railway Department for reference translating some important articles into English :
 - a. The Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers.
 - b. The Standard Specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers.
 - c. The Japanese Industrial Standard for structural steel.

The Japanese Feasibility Study
Team for Jamuna River Bridge
Construction.

Leader

Dr. S. INOSE

The Railway Department,
Government of Bangladesh.

Leader

Mr. A. Ghafur.
Member (Engineering),
Bangladesh Rly Board,
Rail Bhaban, Ramna, Dacca.

MINUTES OF THE MEETING HELD BETWEEN THE JAPANESE
FEASIBILITY STUDY TEAM FOR THE JAMUNA BRIDGE
PROJECT AND THE ROADS AND HIGHWAYS DIRECTORATE,
GOVERNMENT OF BANGLADESH.

The following members from the Japanese Feasibility Study Team and the Roads and Highways Directorate, Government of Bangladesh held a meeting on 9th August, 1973 in the chamber of Deputy Chief Engineer, Roads and Highways Directorate, Government of Bangladesh and discussed the matters to be determined prior to the planning of the Jamuna River Bridge according to the Agenda (ANNEX attached herewith) presented by the Study Team.

The matters mentioned in the Agenda were agreed between both the parties except the following :

MEMBERS FROM FEASIBILITY STUDY TEAM:

1. Dr. S. Inose : Leader.
2. Mr. I. Kawasaki : Adviser to the team.
3. Mr. I. Iizuka : "
4. Dr. S. Sato : Member of the team.
5. Mr. J. Ebihara : Director of the Jamuna
Bridge Survey Office.

MEMBERS FROM ROADS & HIGHWAYS DIRECTORATE:

1. Mr. Md. Shafiullah : Deputy Chief Engineer.
2. Mr. Anwar Hossain : Executive Engineer.
3. Mr. A. Samad : Senior Structural Designer.

1. Article a. Superstructure in the Agenda

(a) Highway Bridge

(1) Loads

Live load to be used for design will be specified by the I.R.C. Standard Vehicle Class A.

(2) Construction gauge

The construction gauge will be specified by I.R.C.

(c) Highway/Railway Bridge

(1) Loads

Live load to be used for design of highway floor will be specified by I.R.C. Standard Vehicle Class A.

(2) Construction gauge

The construction gauge for highway part will be specified by I.R.C.

2. The Japanese Study Team will present the following copies to the Roads and Highways Directorate for reference translating some important articles into English.
 - a. The standard specifications for Highway Bridges adopted by the Japan Road Association.
 - b. The standard specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers.
 - c. The Japanese Industrial Standard for structural steel.

Dr. S. INOSE
Leader of the
Japanese Feasibility Study
Team for Jamuna River Bridge
Project.

MD. SHAFIULIAH
Deputy Chief Engineer,
Roads & Highways Directorate,
Government of Bangladesh,
Dacca.

APPENDIX 5

Memo. No. CE/JB/J-AID/3400

Dated: February 5, 1974.

Mr. Junji Ebihara,
Director, Jamuna Bridge Survey Office,
783, Dhanmondi P.A., Road No. 19,
Dacca-5.

Sub : Jamuna Bridge - Minimum horizontal and vertical
clearances to meet navigational requirements.

Ref : Your letter No. BIWTA-II/341/74 dated 30.1.74
addressed to Chairman, BIWTA.

Dear Sir,

The undersigned is directed to refer to your above mentioned
letter addressed to Chairman, BIWTA and to inform that the following
are the minimum navigational requirements in so far as the proposed
rail-cum-road bridge across the Jamuna is concerned:

1. Minimum horizontal clearnncce
between two piers 250 (two hundred and
fifty) feet.
2. Minimum vertical clearnace under
the soffit of the sirders 40 (forty) feet.

(Anwar Hossain)
Secretary.

Dated: February 5, 1974.

APPENDIX 6

PLANNED TRAFFIC VOLUME AND TRAFFIC CAPACITY OF THE ROAD ON THE JAMUNA RIVER BRIDGE

1. Planned Traffic Volume

The planned traffic volume is assumed as the average annual daily traffic (AADT). The future mixed traffic volume is estimated in the following by the Traffic and Economic Study Team as its targeted year set in 2020.

Passenger cars	5,495	vpd (AADT)
Buses	480	vpd (AADT)
Trucks	577	vpd (AADT)
Total	6,522	vpd (AADT)

vpd: vehicles per day

Based on the above estimated traffic volume (planned volume) at the year of 2020, the design hourly traffic volume is calculated. The design traffic volume is expressed by following formula.

$$\text{Design Traffic Volume} = \text{Planned Traffic Volume} \times \frac{K}{100} (\text{per hour})$$

Here K indicates the percentage of the design traffic volume (30th hourly traffic volume) to the planned traffic volume (that is AADT). Hence, K is set at 12% about the design hourly traffic volume.

$$\text{Design Traffic Volume} = 6,552 \times \frac{12}{100} = 787 \text{ vph (vehicles per hour)}$$

Since the factor of passenger car equivalent of large-size vehicle is 3, when denoted in the passenger car equivalent (P.C.E.); planned traffic volume is $5,495 + (480 + 577) \times 3 = 8,666$ vpd, the design hourly traffic volume becomes 1,040 vph.

2. Traffic Capacity

The traffic capacity of two-lane road of the Jamuna Bridge is calculated by the road width as shown in Fig. 5-10 in this VOLUME III BRIDGE WORKS. The calculation of the traffic capacity is made in accordance with the Rule of Road Geometric Design (Ministry of construction, Government of Japan).

a) Basic road capacity C_B

$$C_B = 2,500 \text{ vph}$$

b) Possible traffic capacity C

$$C = C_B \times G_L \times G_C \times G_T$$

Where, C_B : Basic road capacity (=2,500 vph)

G_L : Correction factor for lane width (=0.96)

G_C : Correction factor for lateral clearance (=0.86)

G_T : Correction factor for large-size vehicle and based on the following formula

$$G_T = \frac{100}{100 - P_T + E_T P_T}$$

P_T : Mixing ratio of large-size vehicles

$$\left(= \frac{480+577}{6,552} \times 100 = 15.8\% \right)$$

E_T : Factor of passenger-car equivalent for large-size car (=3)

$$\text{Then, } G_T = \frac{100}{100 - 15.8 + 3 \times 15.8} = 0.76$$

Accordingly, the possible traffic capacity is as follows;

$$C = 2,500 \times 0.96 \times 0.86 \times 0.76 = 1,568 \text{ vph}$$

and the possible traffic capacity denoted by the passenger car equivalent becomes as follows;

$$C = 2,500 \times 0.96 \times 0.86 = 2,064 \text{ vph (P.C.E.)}$$

c) Design traffic capacity C_D

When the service level of the road traffic stipulated by the Rule of Road Geometric Design is "1", the Demand Volume/Capacity ratio is $(V/C) = 0.75$, then the design traffic capacity C_D becomes as follows.

$$C_D = (V/C) \times C = 0.75 \times 1,568 = 1,176 \text{ vph}$$

When denoted in the number of passenger car equivalent, C_D is as follows.

$$C_D = 0.75 \times 2,064 = 1,548 \text{ vph (P.C.E.)}$$

The design average daily traffic capacity (ADT) is based on the following formula.

$$ADT = \frac{100}{K} C_D \text{ vpd (K=12\%)}$$

When the aboves are summarized, those are as follows.

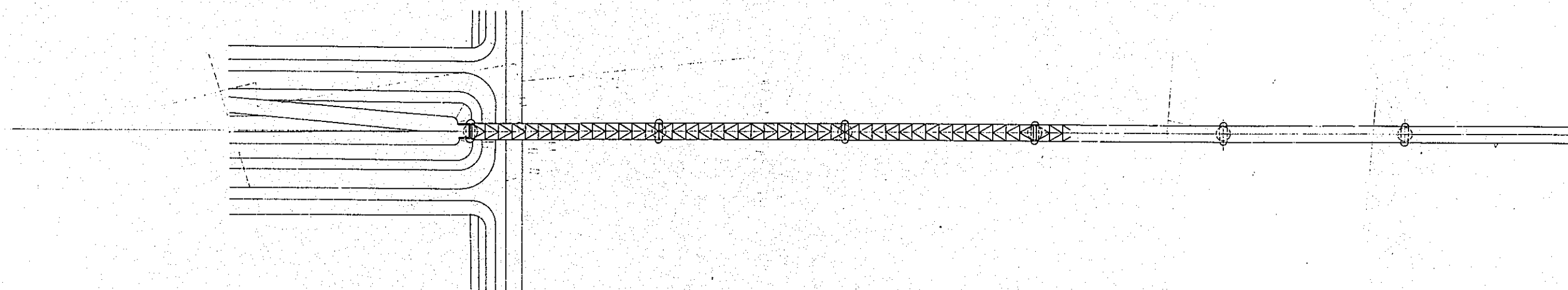
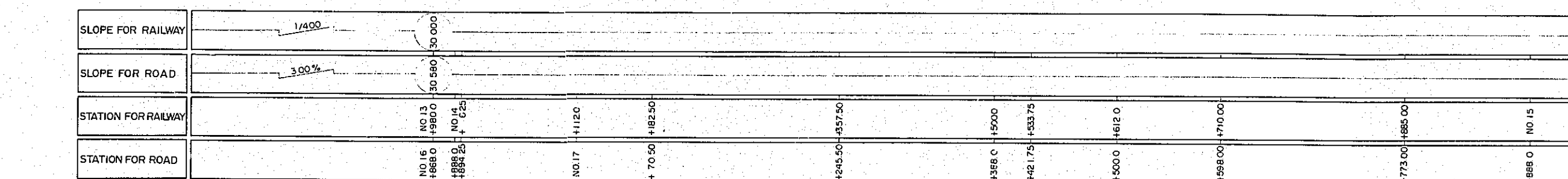
Description	Cars mixed	P.C.E.
Planned Traffic Volume	6,552 vpd	8,666 vpd
Design Traffic Capacity	9,800 vpd	12,900 vpd

From the above table, the design traffic capacity has sufficient allowance for the planned traffic volume.

APPENDIX 7

D R A W I N G S

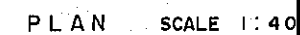
DRAWING NO.	CONTENTS
1.	GENERAL VIEW OF JAMUNA BRIDGE
2.	GENERAL VIEW OF BRIDGE APPROACH ON RIGHT BANK
3.	GENERAL VIEW OF BRIDGE APPROACH ON LEFT BANK
4.	GENERAL VIEW OF ONE-SET CONTINUOUS TRUSS
5.	MAIN TRUSS OF DOWNSTREAM SIDE (G2)
6.	MAIN TRUSS OF UPSTREAM SIDE (G1)
7. to 8.	DETAILS OF MAIN TRUSS
9.	SWAY BRACING AND STRUT
10.	UPPER LATERAL BRACING
11.	LOWER LATERAL BRACING
12.	FLOOR BEAM
13.	STRINGER
14.	SHOE
15.	GENERAL STRUCTURE OF END PIER (ABUTMENT-PIER)
16.	GENERAL STRUCTURE OF INTERMEDIATE PIER
17.	DIAGRAM OF PROTECTION WORKS FOR BRIDGE APPROACH
18.	WORKING PROCESS OF EXECUTION OF PIERS



SCALE



LEVEL

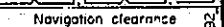


Length of bridge

3 @ 175 00

3 @ 175 00

14 @ 12 50



D H.W.L. * 15 250

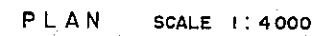
M I I W I 6 320

Note. (M) Movable.

⑤ **MOVABLE**

⑤ **MOVABLE**

PROFILE SCALE 1: 4000 4 747 500



Length of bridge 4 747 500

3 @ 175 000 = 525 000

14 @ 12 500 = 175 000

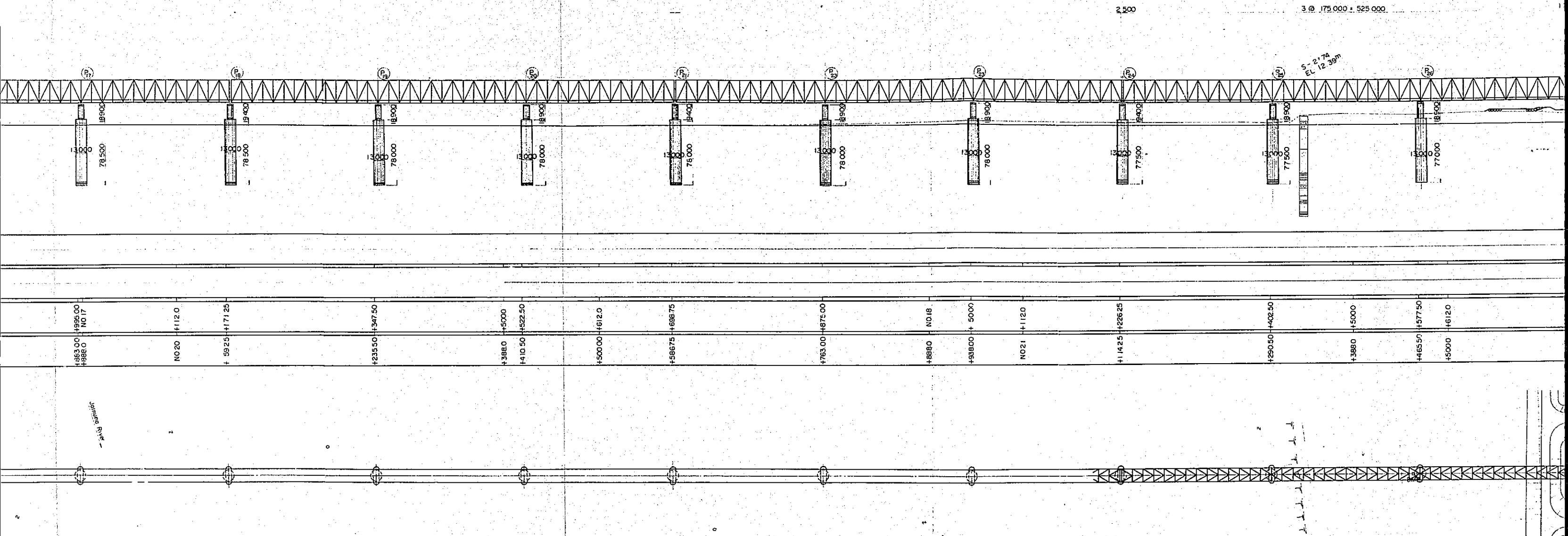
14 @ 12 500 = 175 000

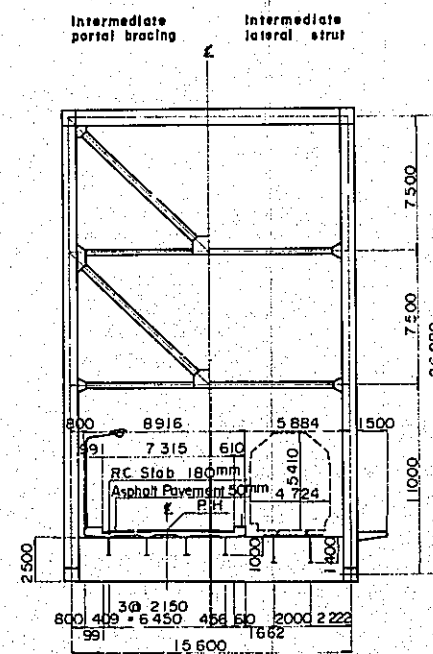
Navigation clearance

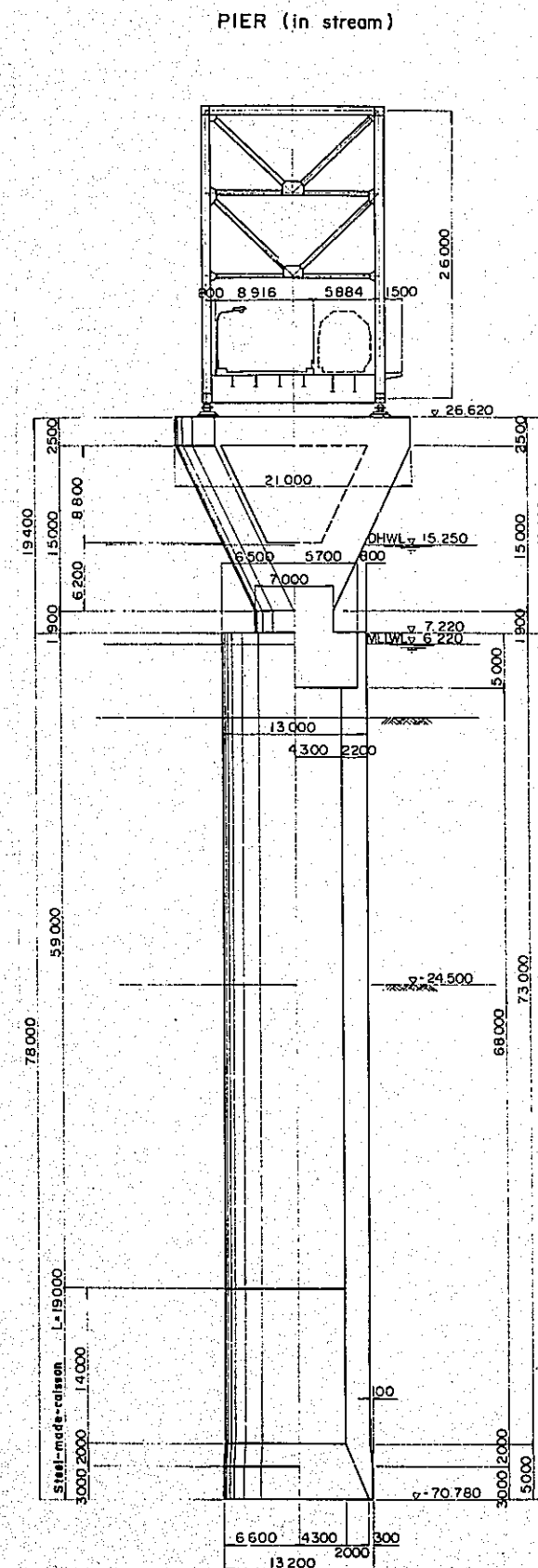
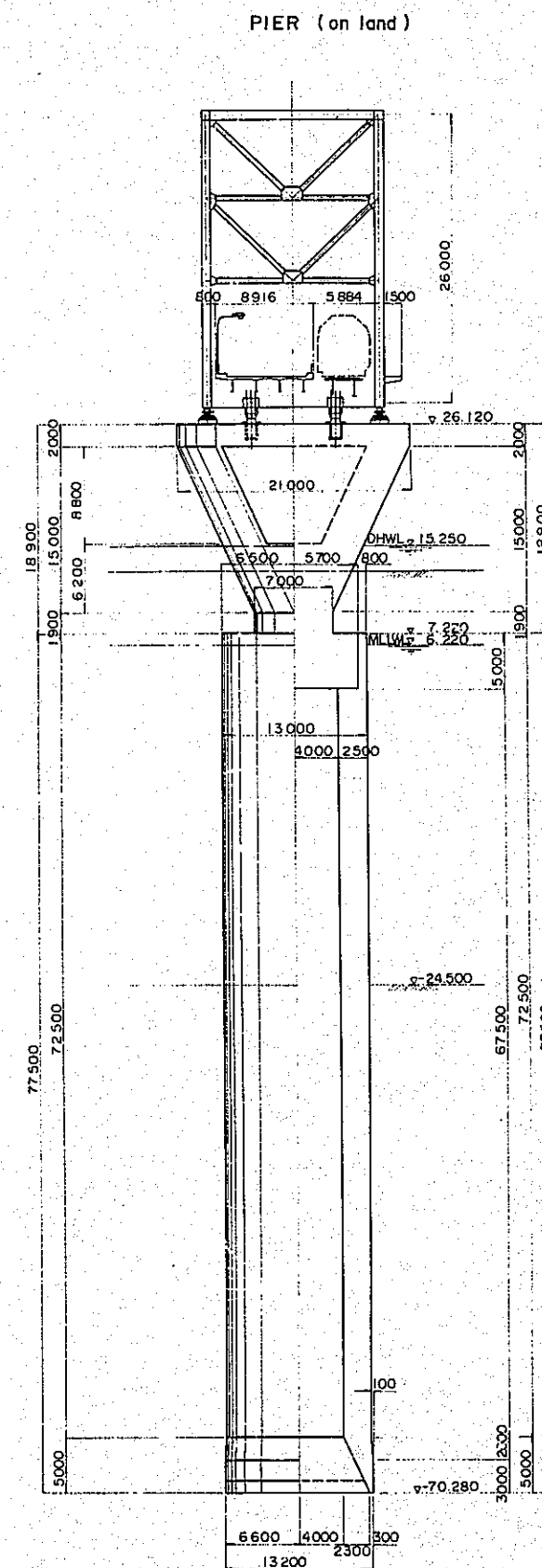
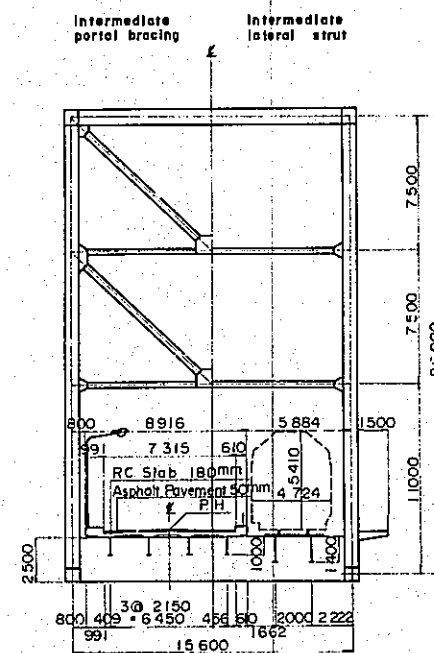
DHWL = 15250

MLLWL = 6 220

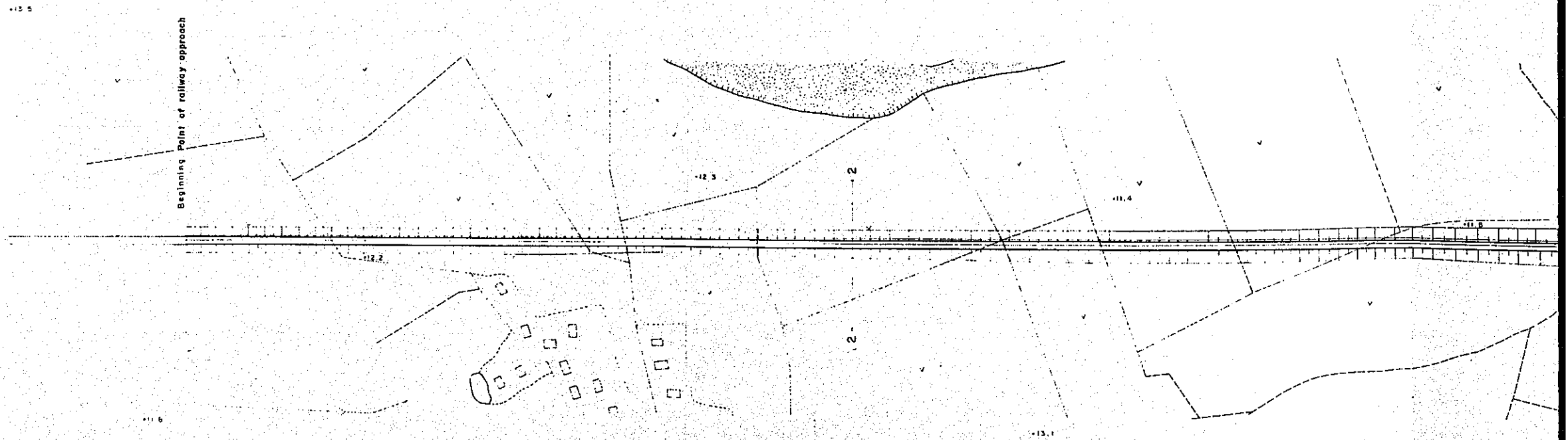
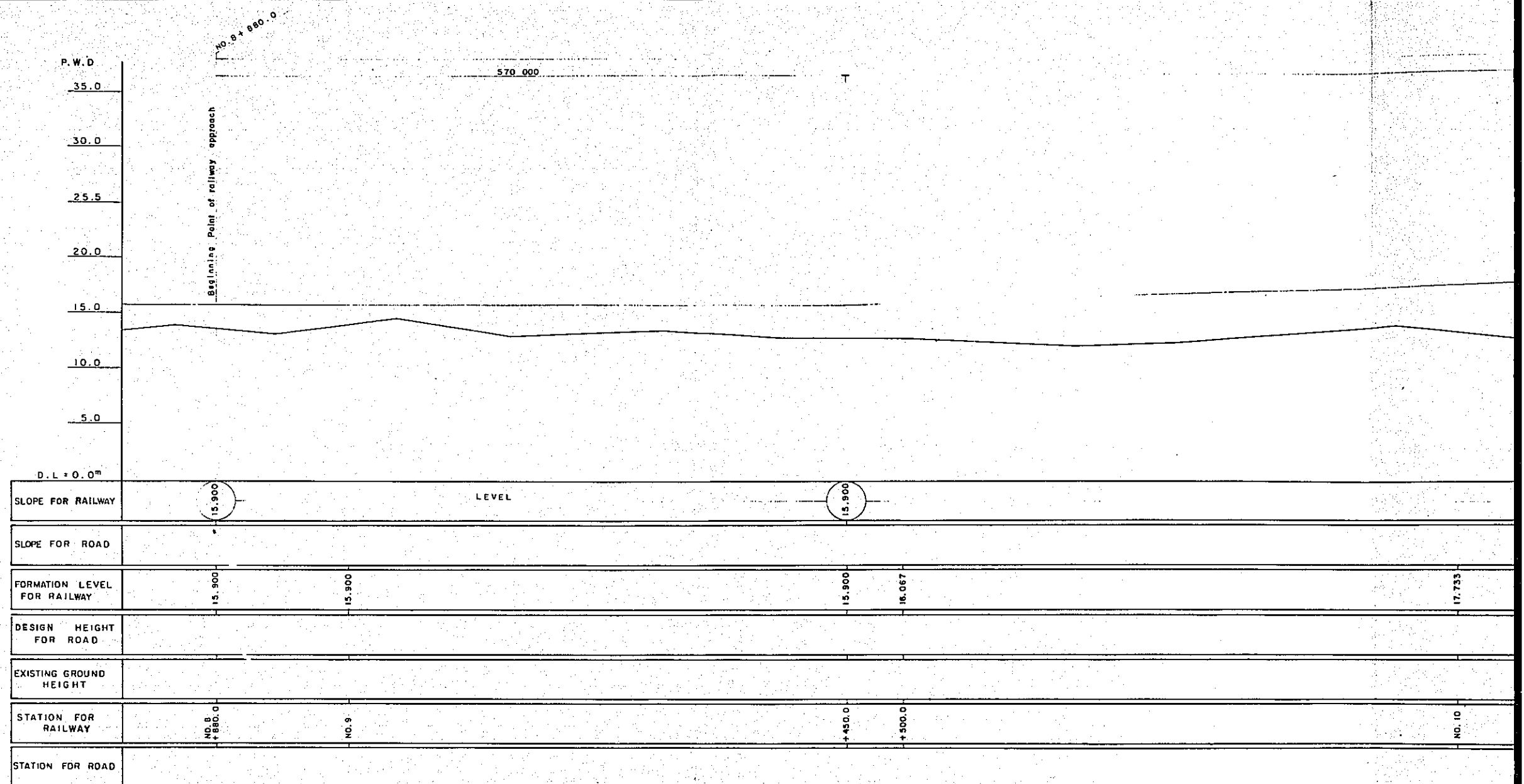
Note. (M) Movable shoe
(F) Fixed shoe with stopper

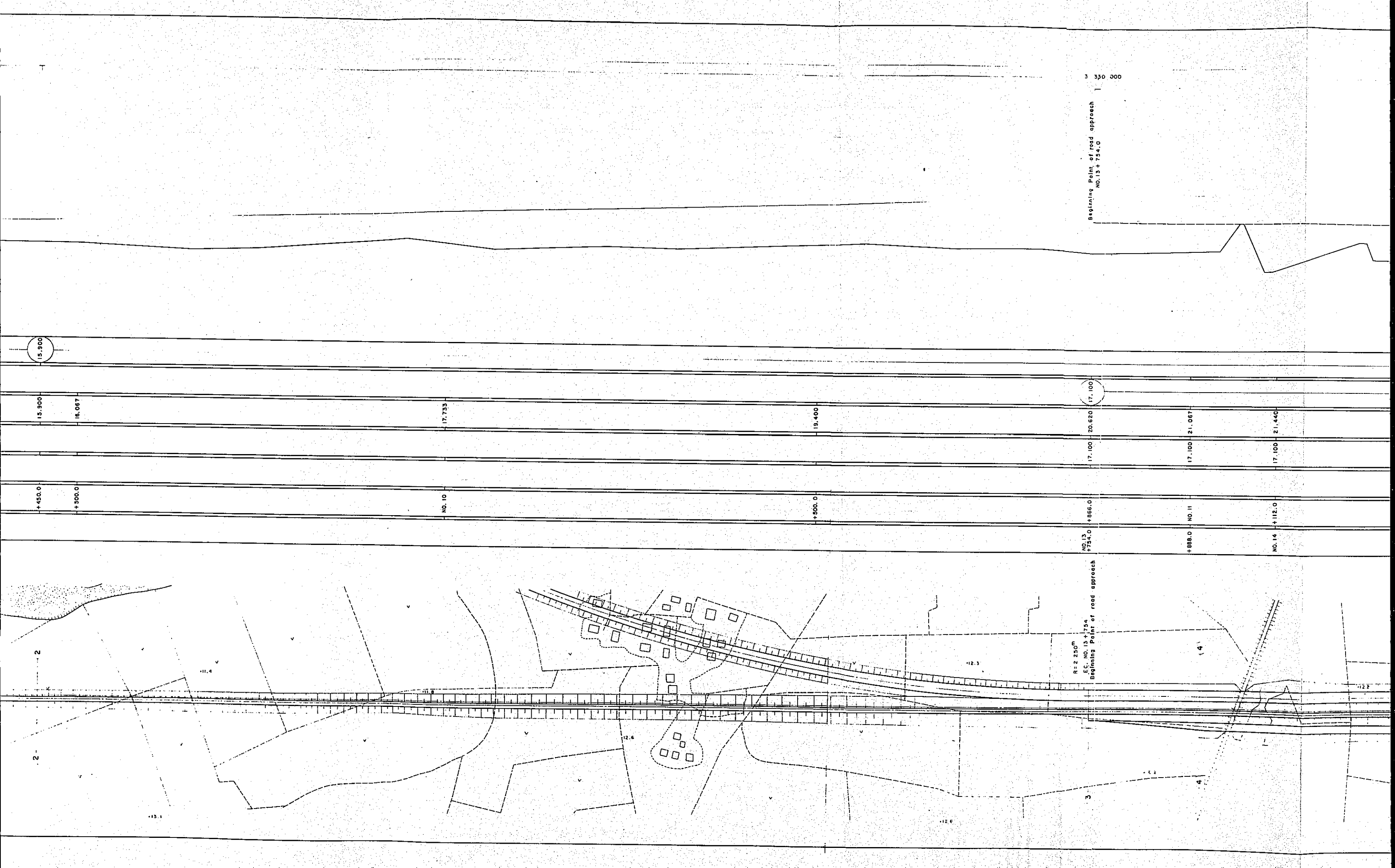




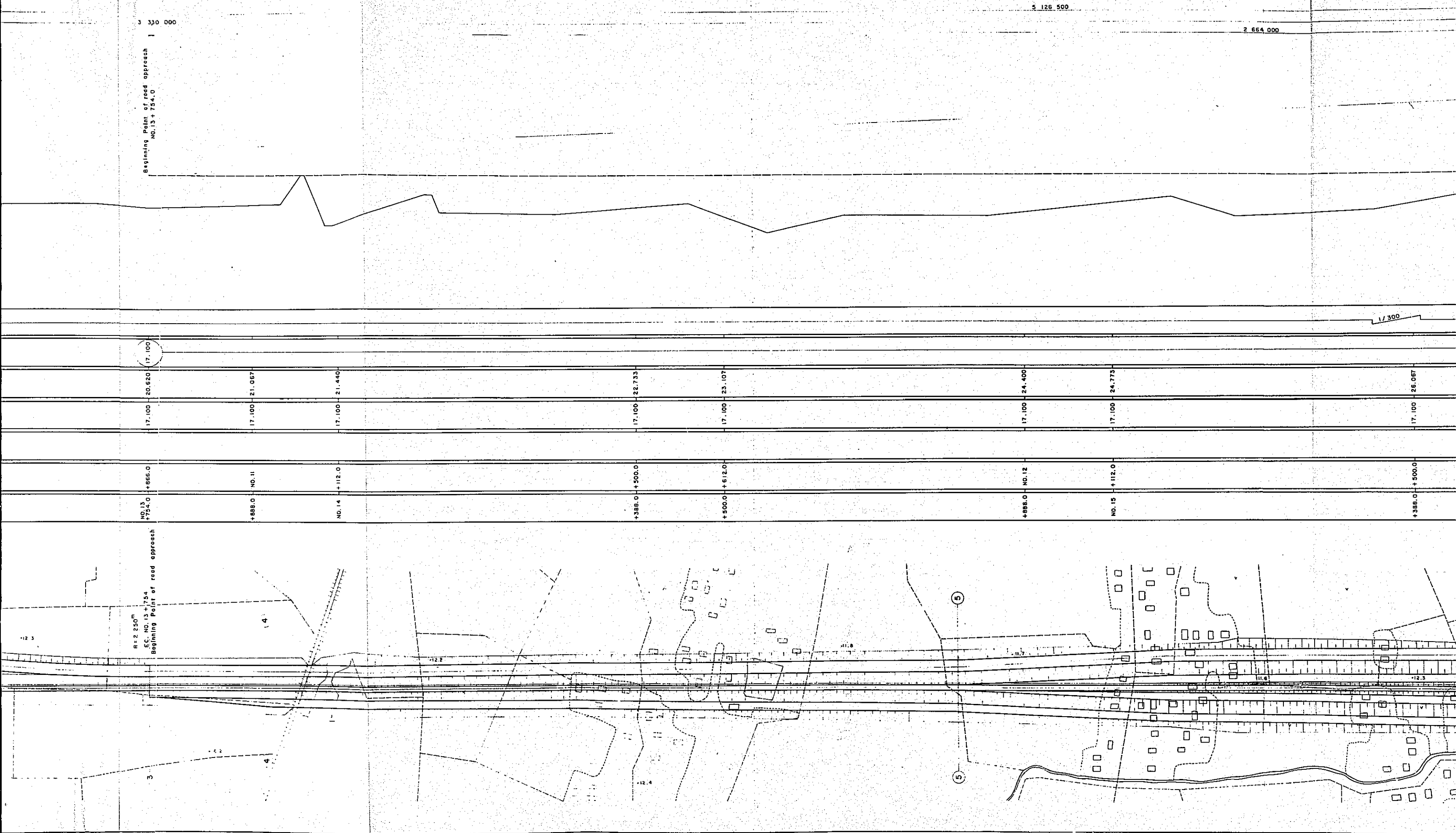


PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
GENERAL VIEW	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>T. Karim</i>	
Approved <i>K. K. Karim</i>	DRW. NO. 1





GENERAL VIEW (BRIDGE APPROACH OF RIGHT BANK)



ACH OF RIGHT BANK)

PROFILE

BLOCK STATION 1 200.000

2 664.000

450.000

VCL=30.000
R=1 000.000

Rejection. Piling work for high embankment
4 040-□ 4 000x400x12 000

1/300

27.000

1/400

LEVEL

3.00%

17.100 24.773

17.100 26.067

17.100 26.440

17.100 27.000

17.100 27.550

17.100 27.830

17.100 28.800

17.213 28.875

19.560 29.080

NO. 15 +112.0

+388.0 +500.0

+500.0 +612.0

+668.0 +780.0

+888.0 NO.13

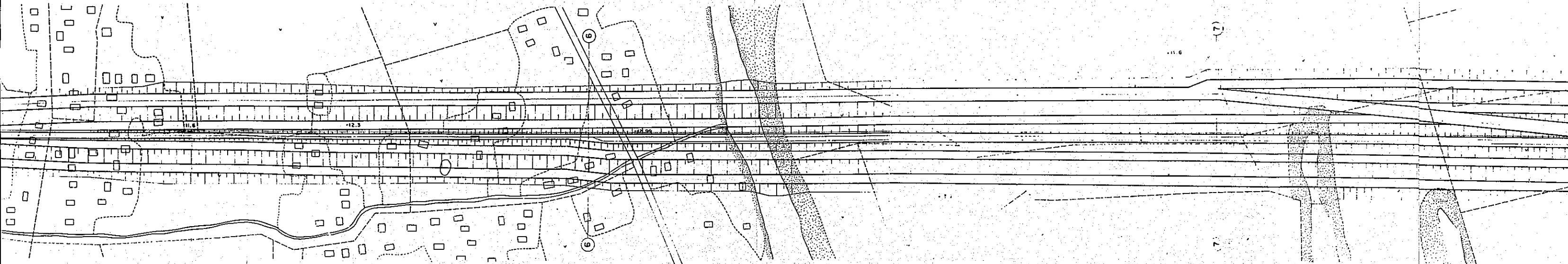
NO.16 +112.0

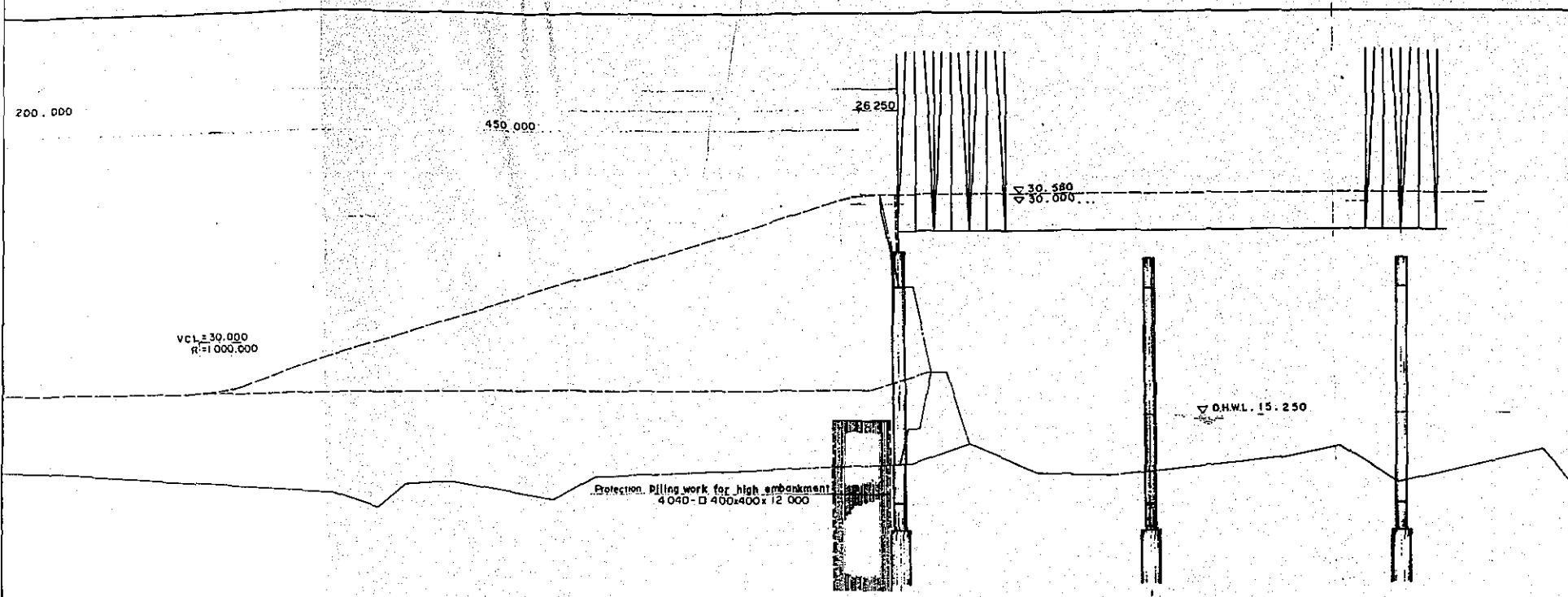
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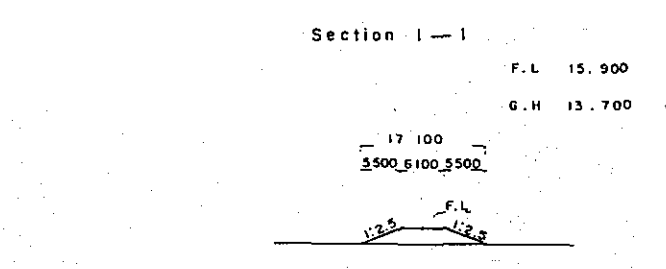
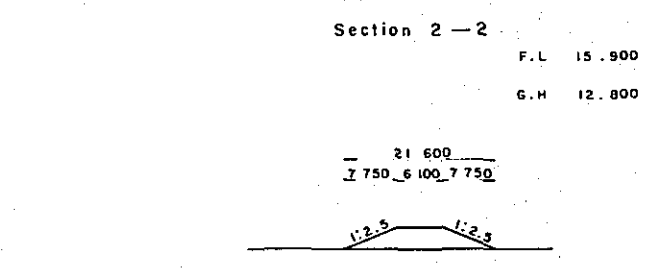
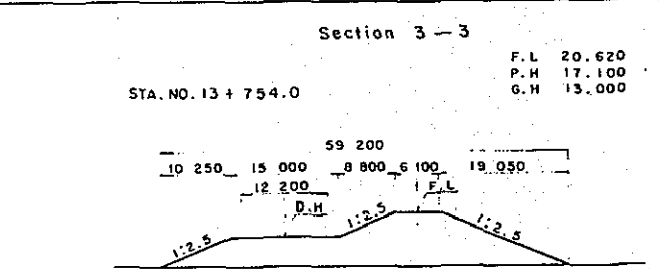
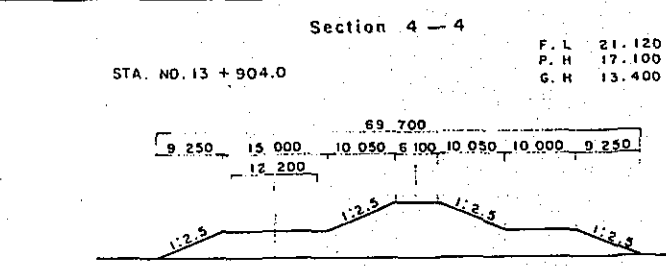
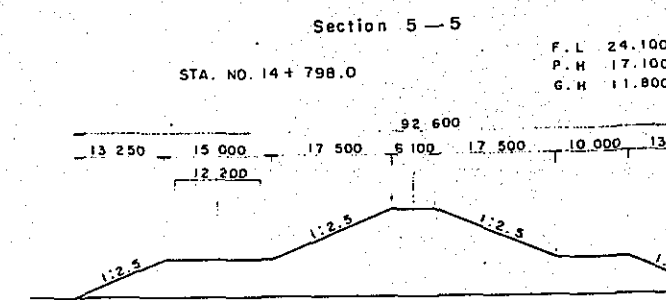
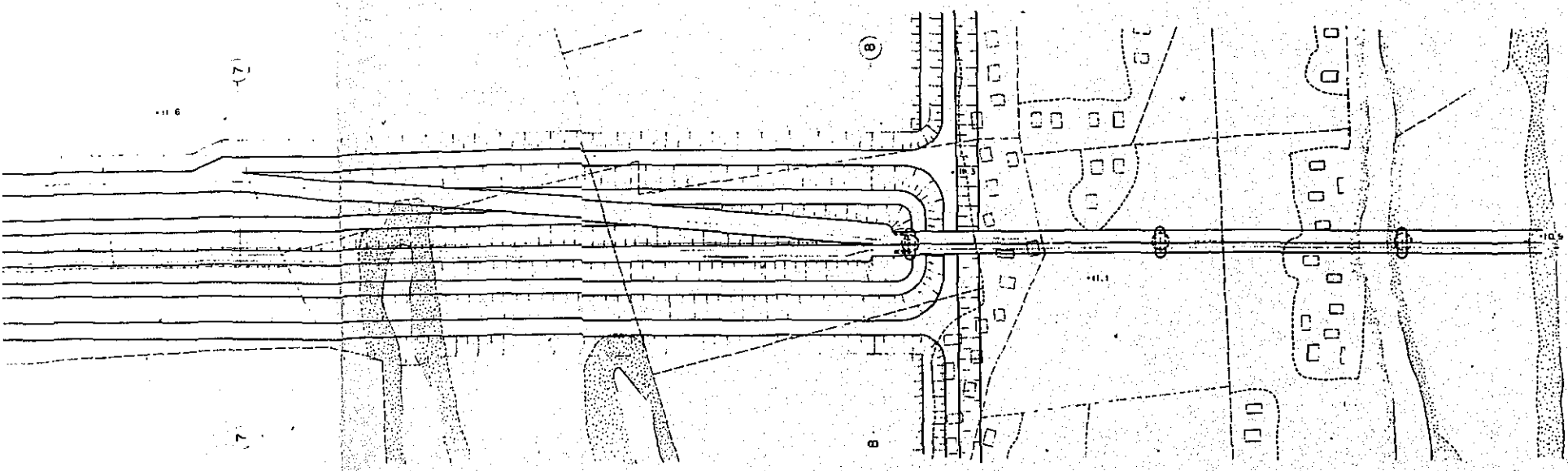
+418.0 +530.0

+500.0 +612.0

PLAN

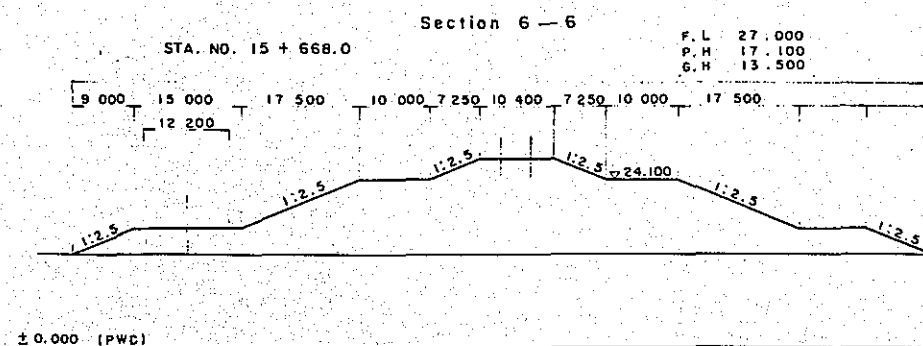
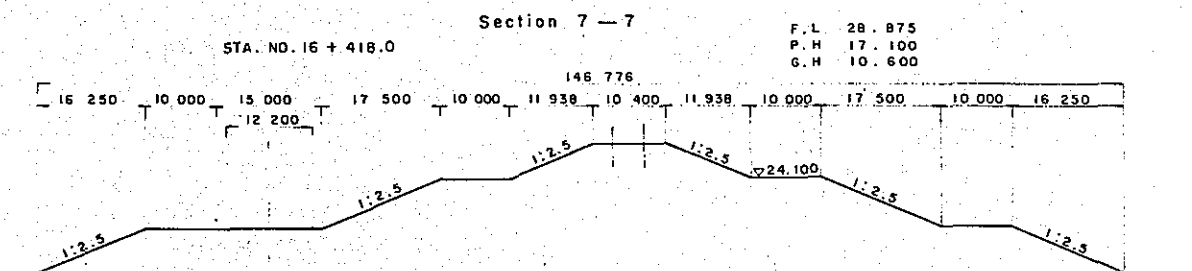
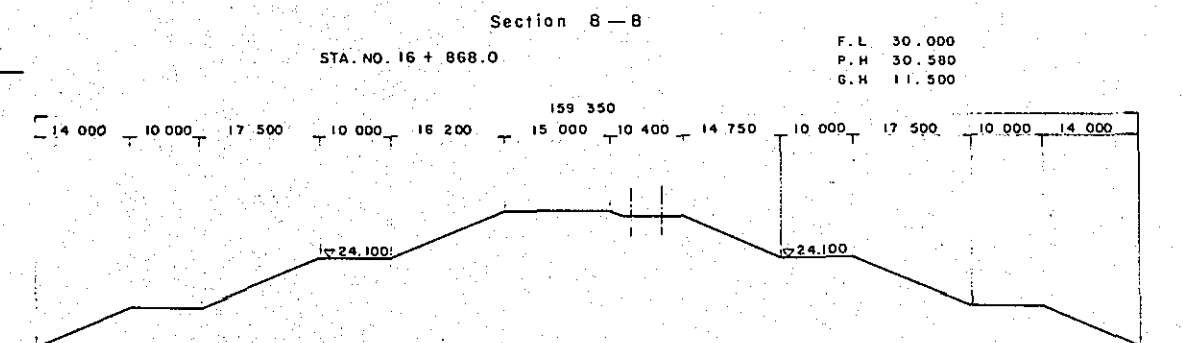
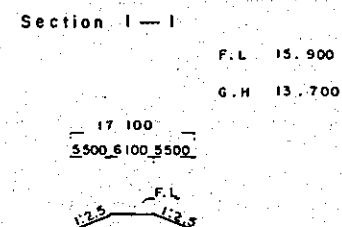
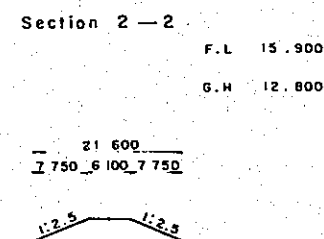
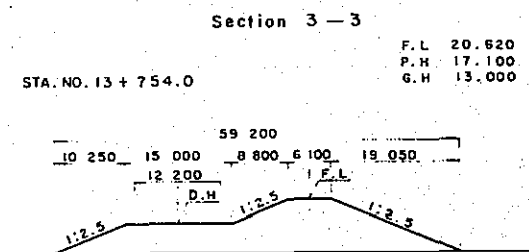
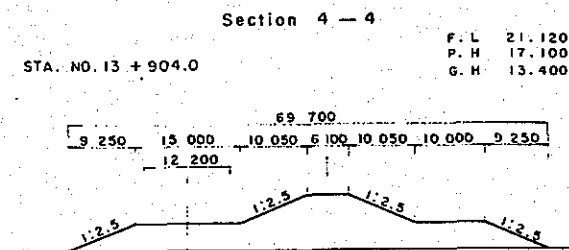
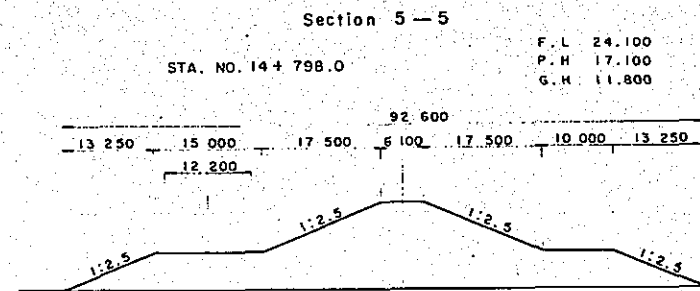






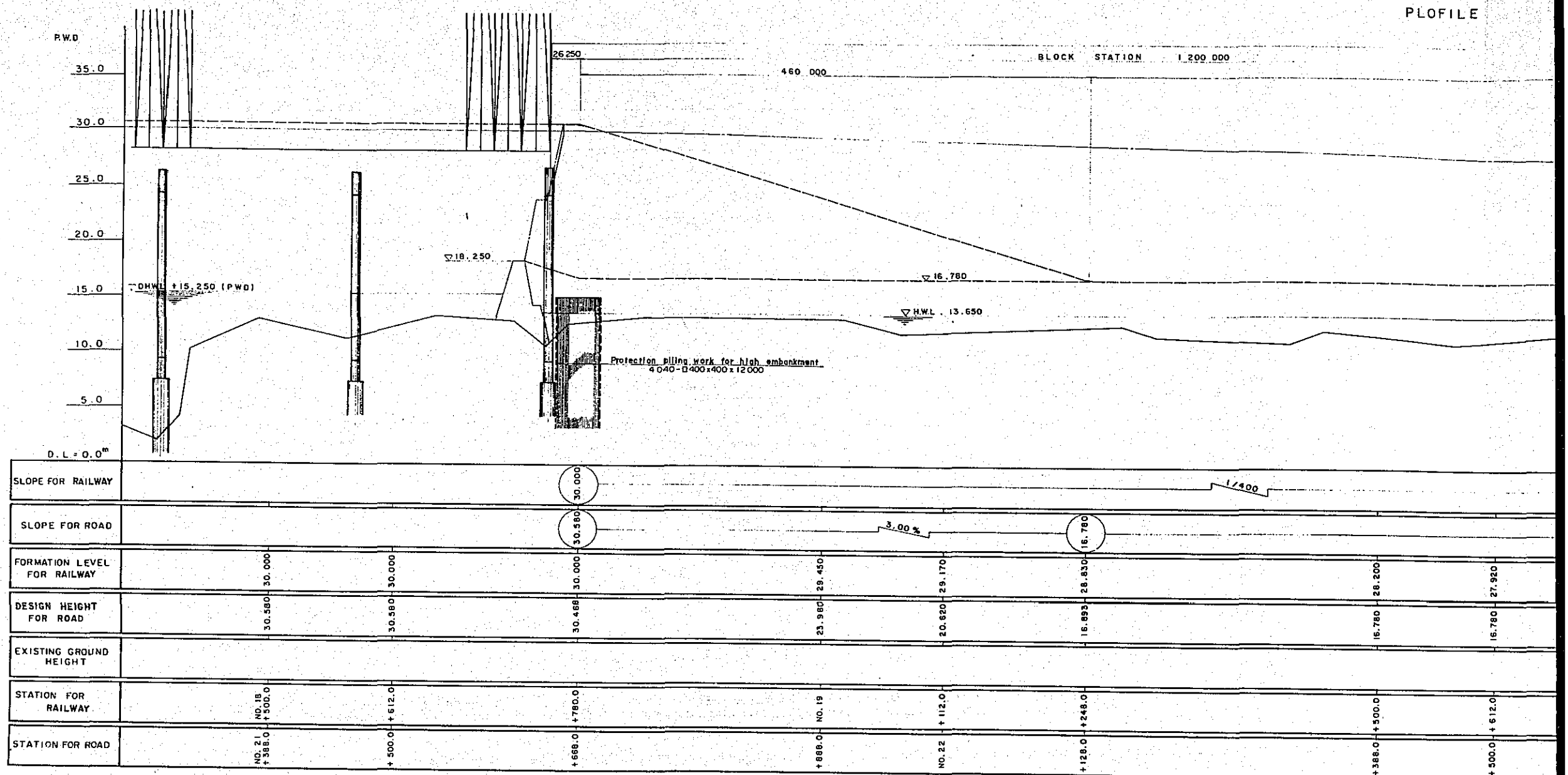
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CROSS SECTION

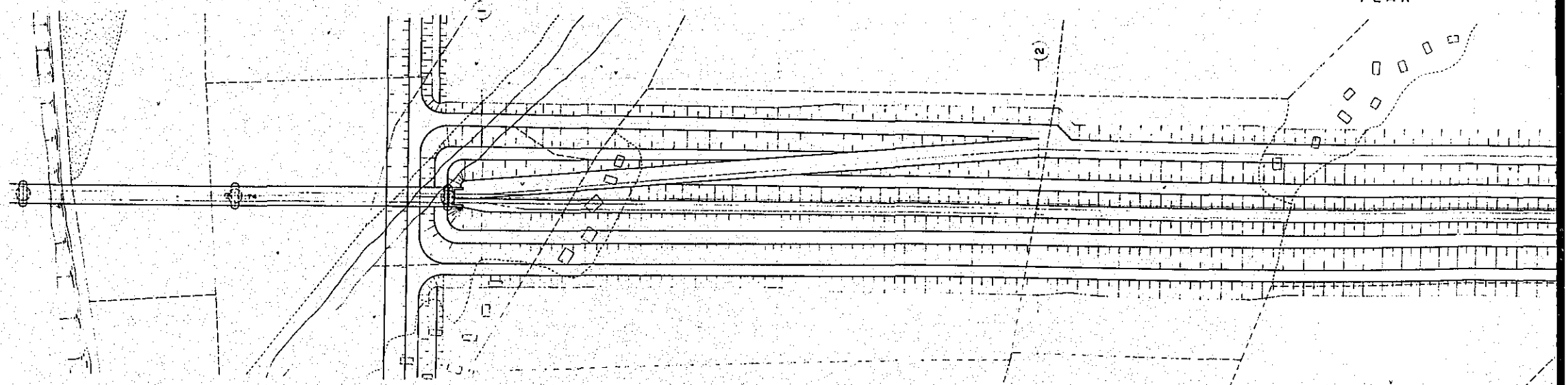


PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME II BRIDGE	
GENERAL VIEW	
(BRIDGE APPROACH OF RIGHT BANK)	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>T. Kondo</i>	DRW. NO. 2
Approved <i>K. Fujita</i>	

PROFILE



PLAN



PROFILE

BLOCK STATION 1 200 000

2 872 000

16.780

WL 13.650

1/400

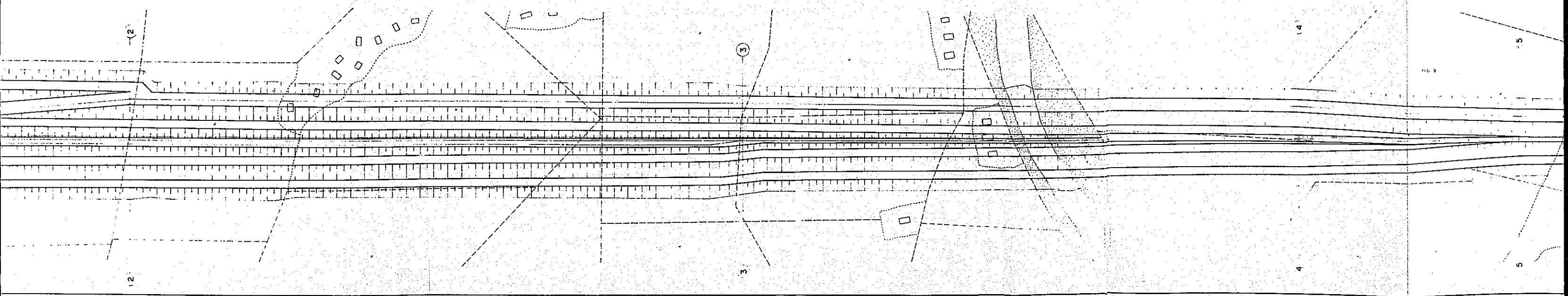
1/300

27.000

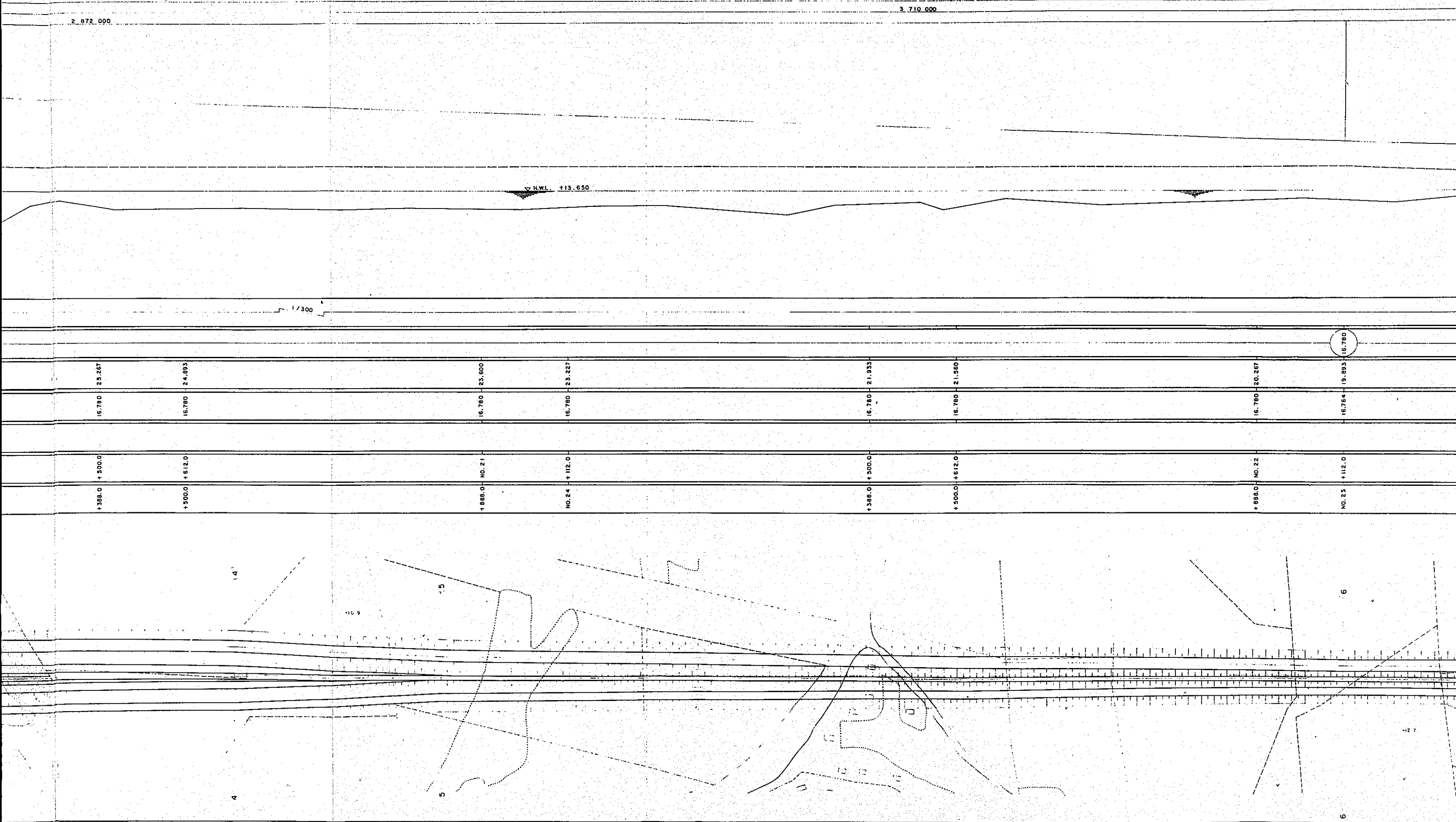
16.780

20.620	23.170	16.893	28.830	16.780	28.200	16.780	27.920	16.780	27.000	16.780	26.933	16.780	26.560	16.780	25.267	16.780	24.893	16.780	24.500
NO. 22	+112.0	+126.0	+246.0	+388.0	+500.0	+500.0	+612.0	+868.0	+980.0	+868.0	NO. 20	+112.0	+388.0	+500.0	+500.0	+612.0			

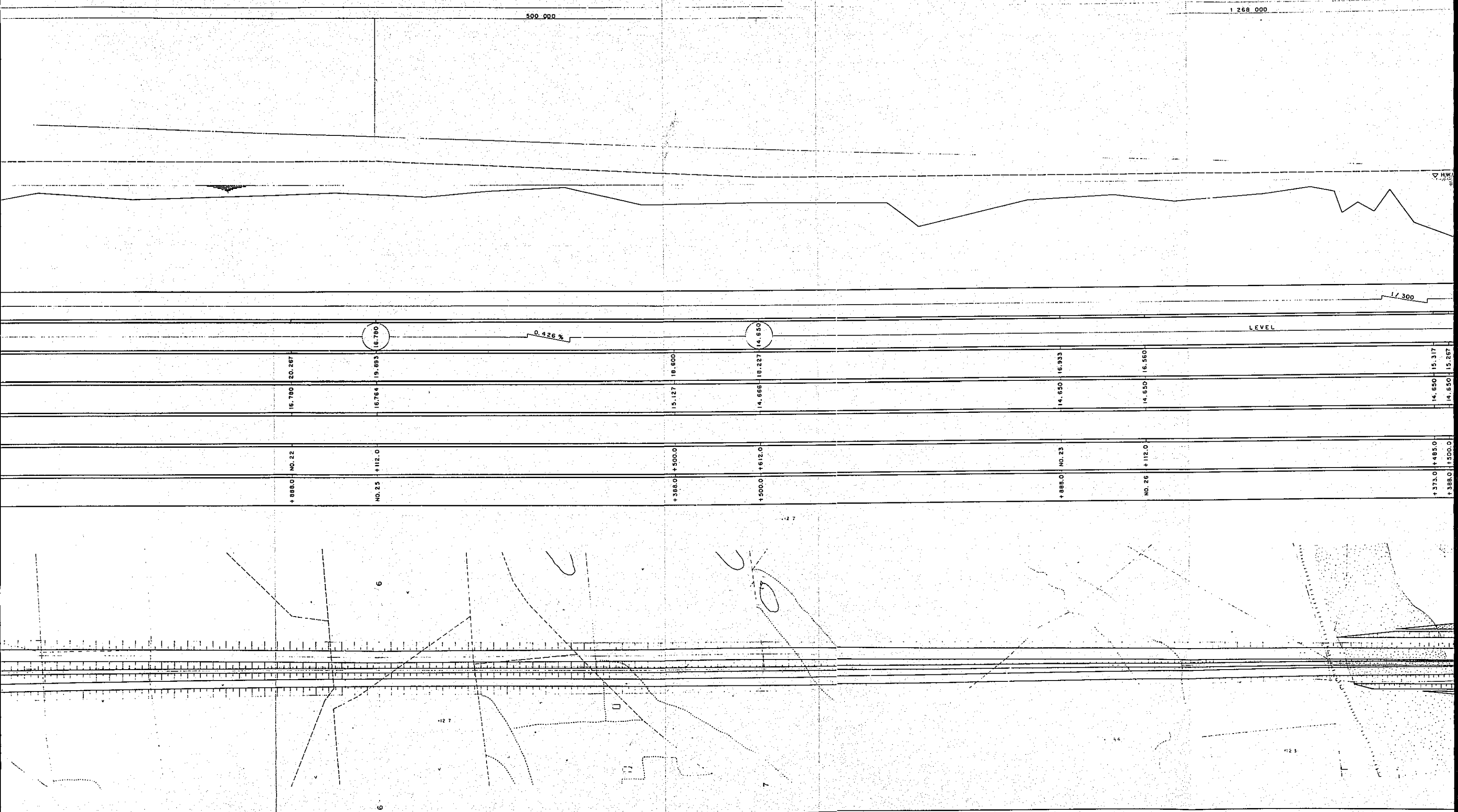
PLAN

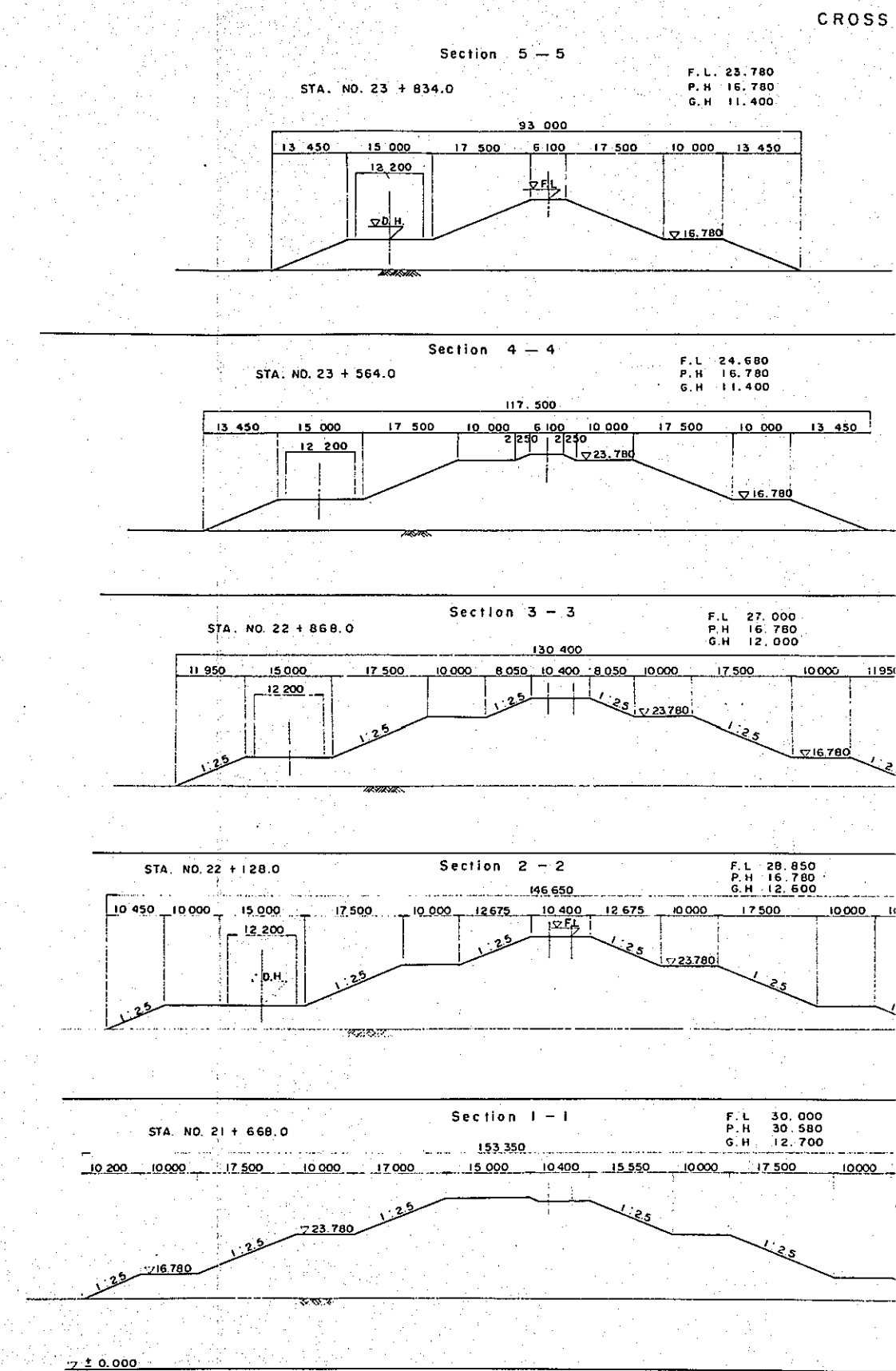


GENERAL VIEW (BRIDGE APPROACH OF LEFT BANK)



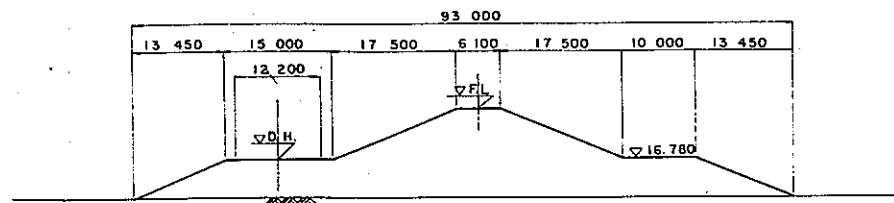
W (BRIDGE APPROACH OF LEFT BANK)



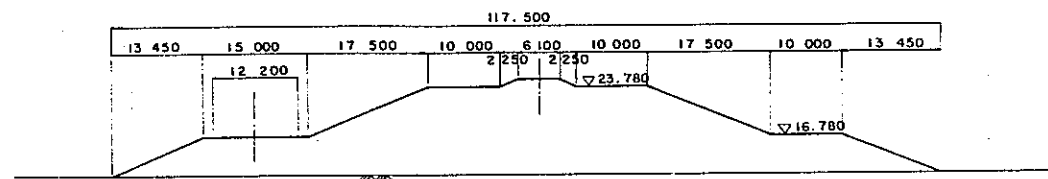


CROSS SECTION

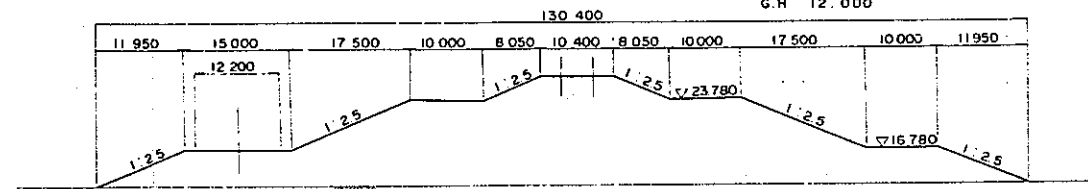
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STA. NO. 23 + 834.0
F.L. 23.780
P.H. 16.780
G.H. 11.400



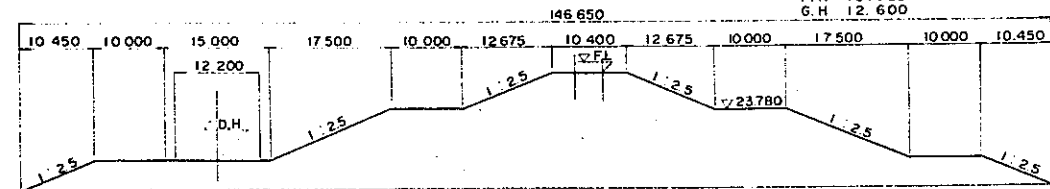
Section 4 - 4
STA. NO. 23 + 564.0
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P.H. 16.780
G.H. 11.400



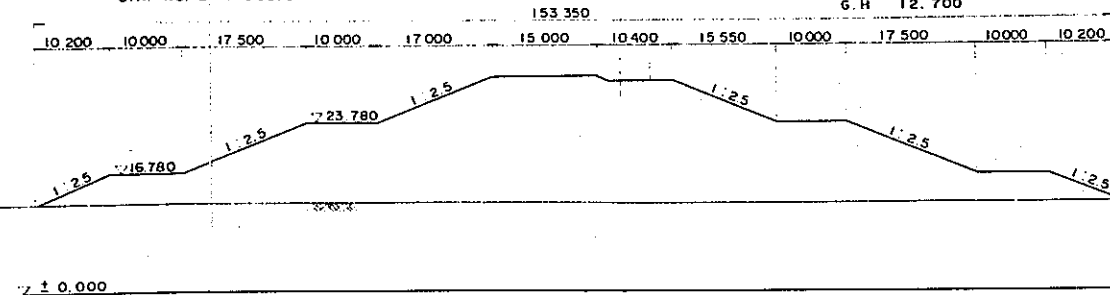
Section 3 - 3
STA. NO. 22 + 868.0
F.L. 27.000
P.H. 16.780
G.H. 12.000



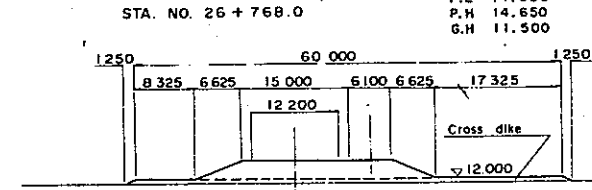
Section 2 - 2
STA. NO. 22 + 128.0
F.L. 28.850
P.H. 16.780
G.H. 12.600



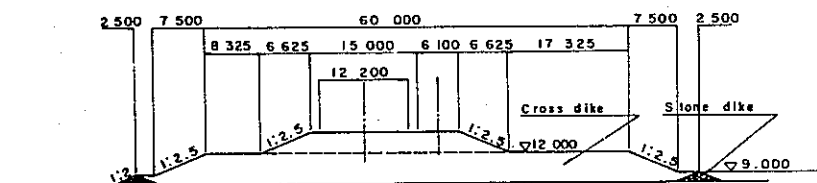
Section 1 - 1
STA. NO. 21 + 668.0
F.L. 30.000
P.H. 30.580
G.H. 12.700



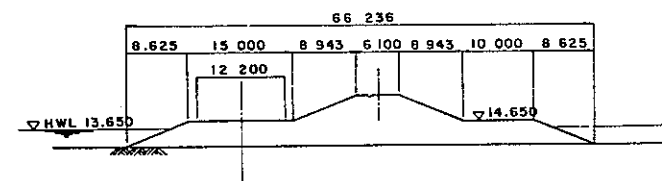
Section 9 - 9
(End of Approach)
STA. NO. 26 + 768.0
F.L. 14.650
P.H. 14.650
G.H. 11.500



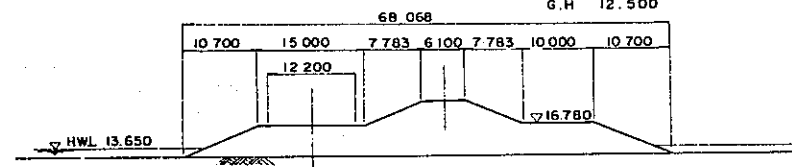
Section 8 - 8
STA. NO. 26 + 578.0
F.L. 14.650
P.H. 14.650
G.H. 7.500



Section 7 - 7
STA. NO. 25 + 500.0
F.L. 18.227
P.H. 14.650
G.H. 11.200



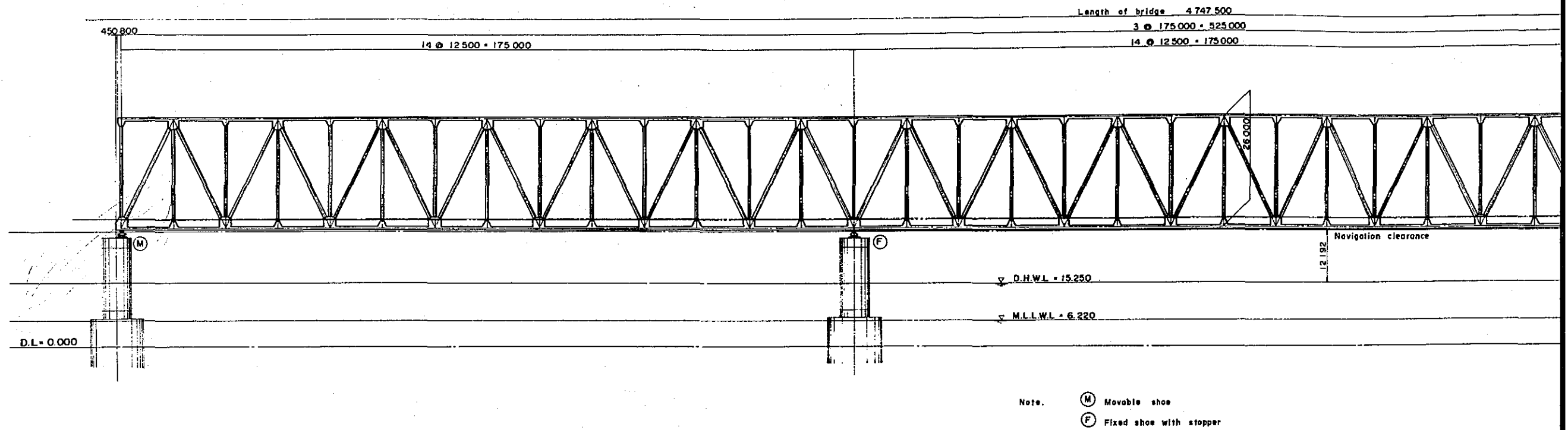
Section 6 - 6
STA. NO. 25 + 0.0
F.L. 19.893
P.H. 16.780
G.H. 12.500



PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
GENERAL VIEW	
(BRIDGE APPROACH OF LEFT BANK)	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>T. K. Saha</i>	DRW. NO. 3
Approved <i>K. Saha</i>	

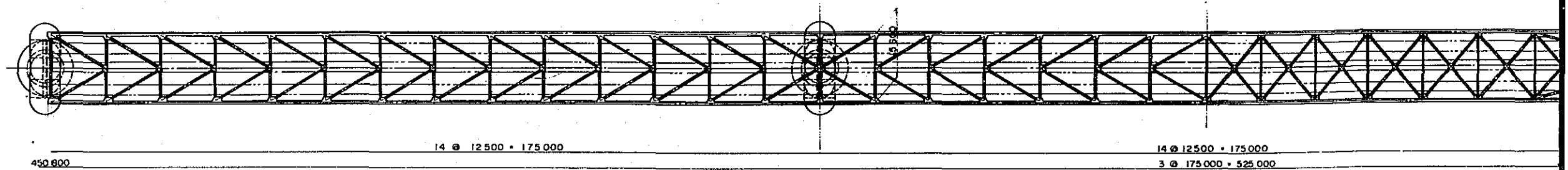
GENERAL VIEW OF CONTINUOUS TR

PROFILE Scale 1:1000



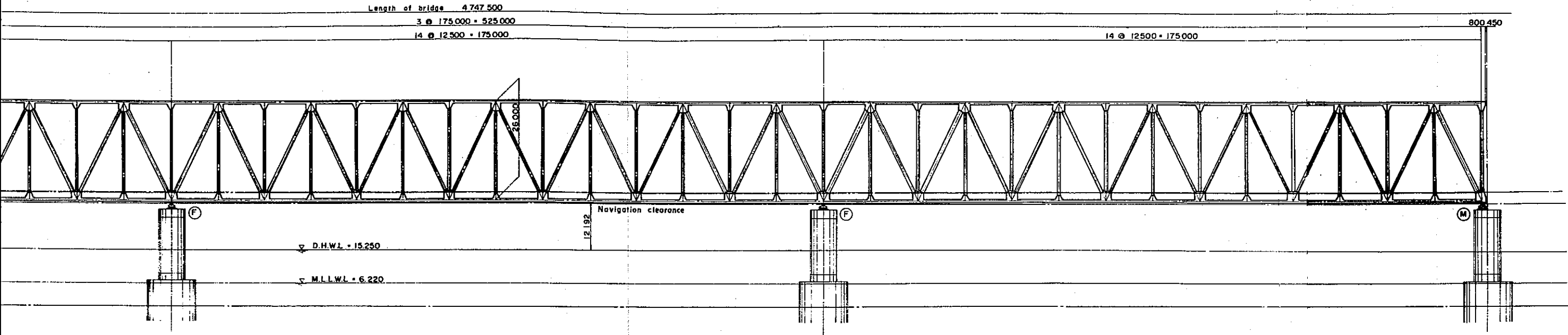
PLAN Scale 1:1000

Upper lateral



GENERAL VIEW OF CONTINUOUS TRUSS (1 SET)

PROFILE Scale 1:1000



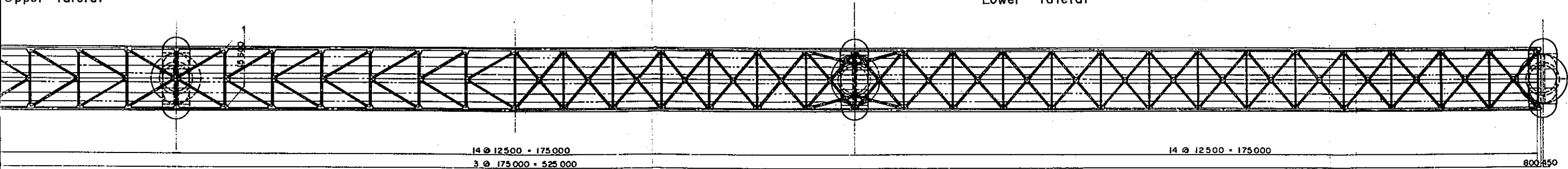
Note.

- (M) Movable shoe
- (F) Fixed shoe with stopper

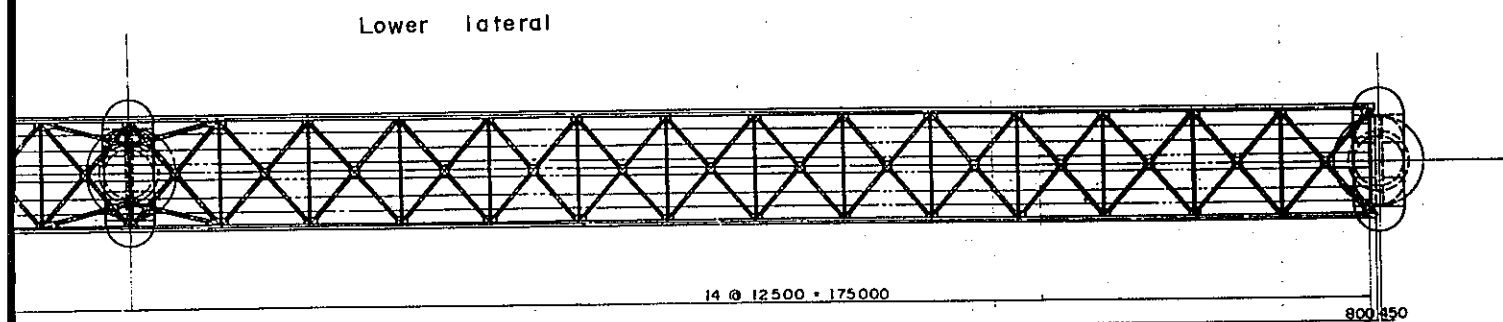
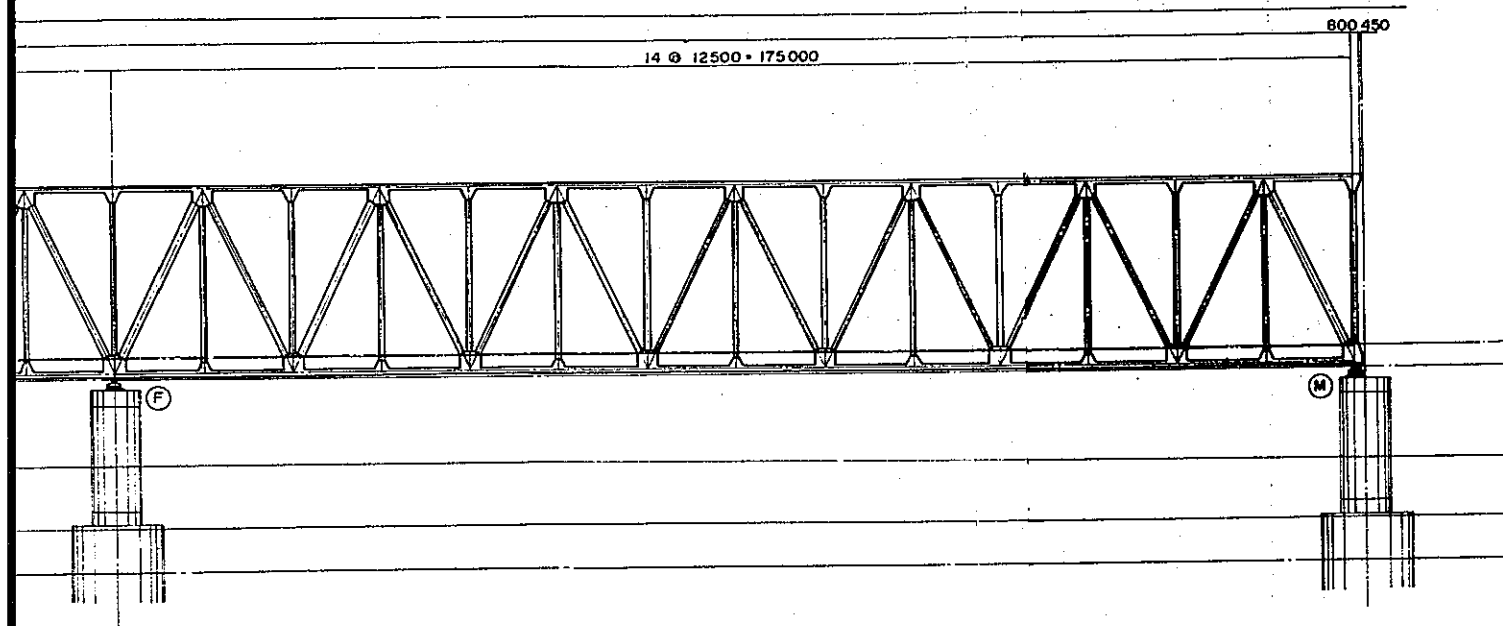
PLAN Scale 1:1000

Upper lateral

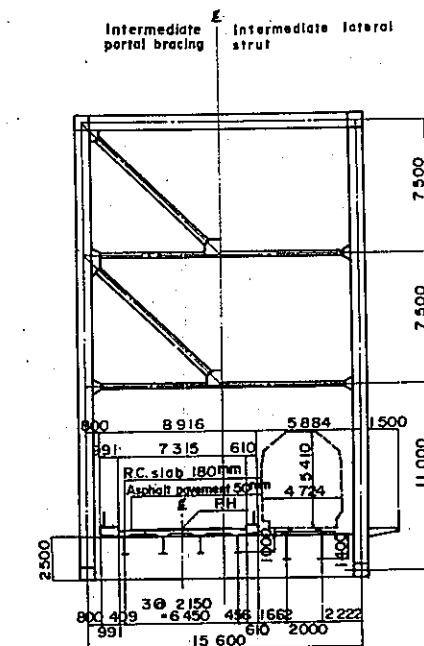
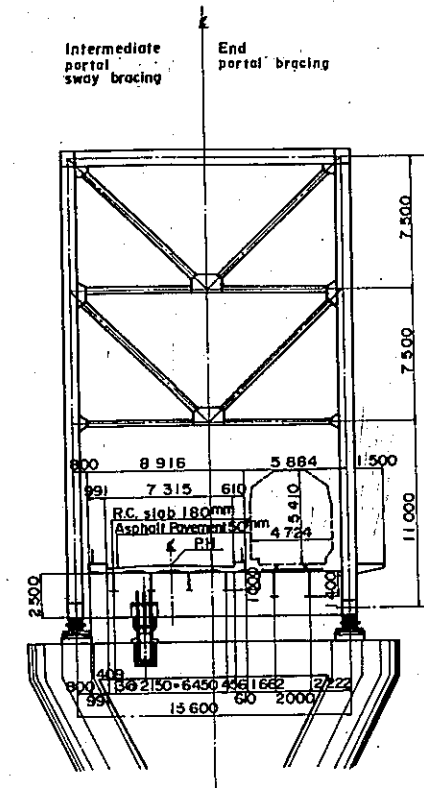
Lower lateral



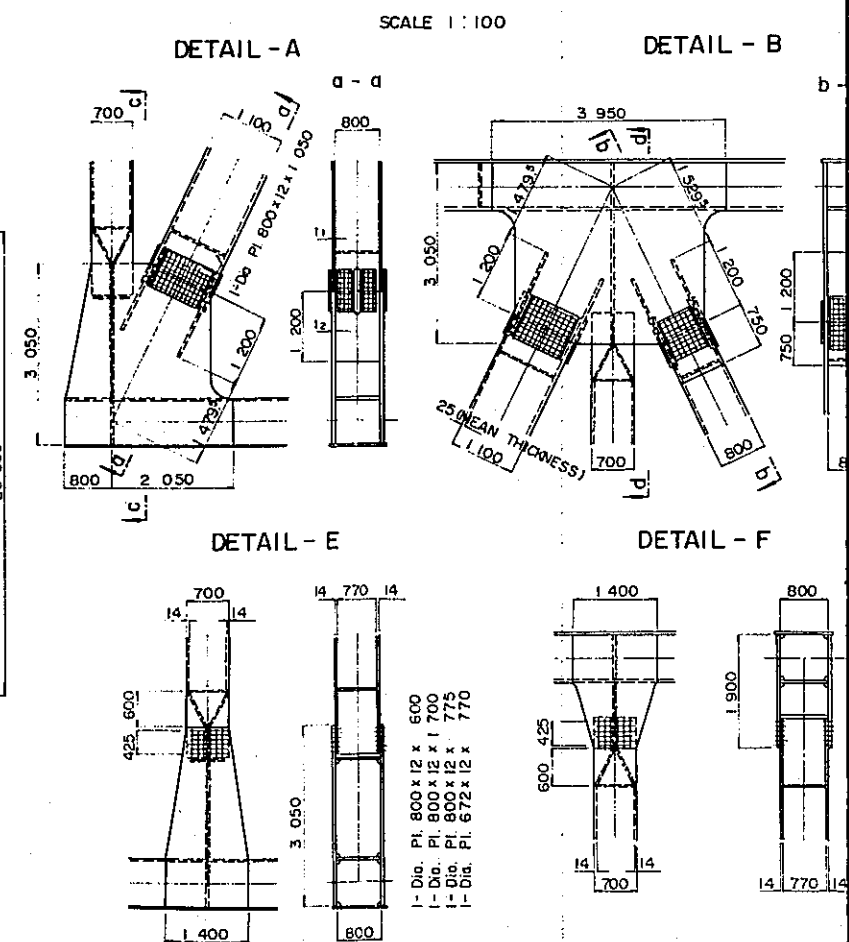
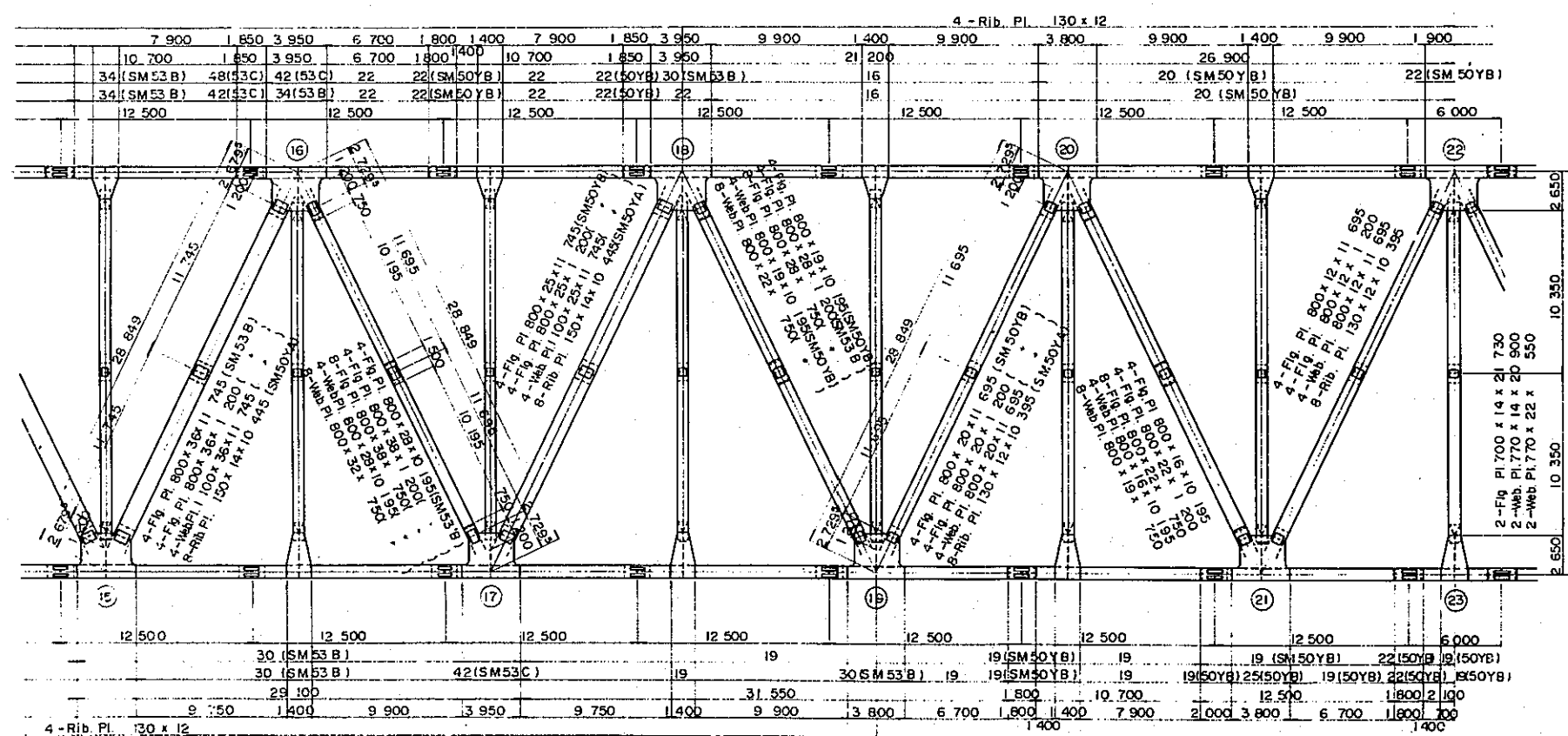
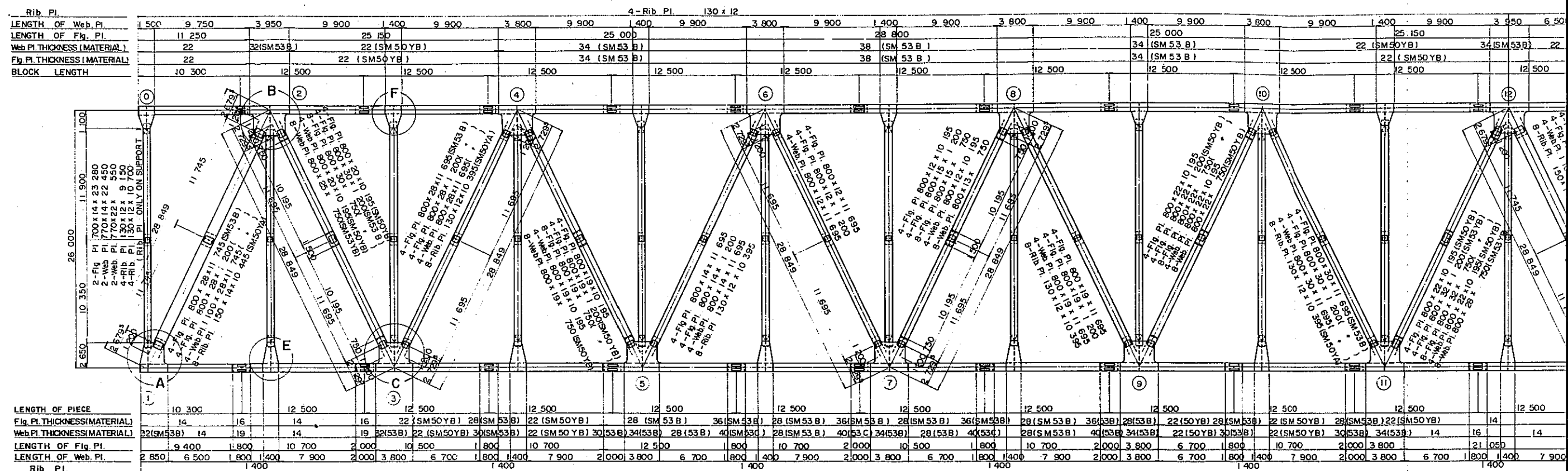
TRUSS (1 SET)

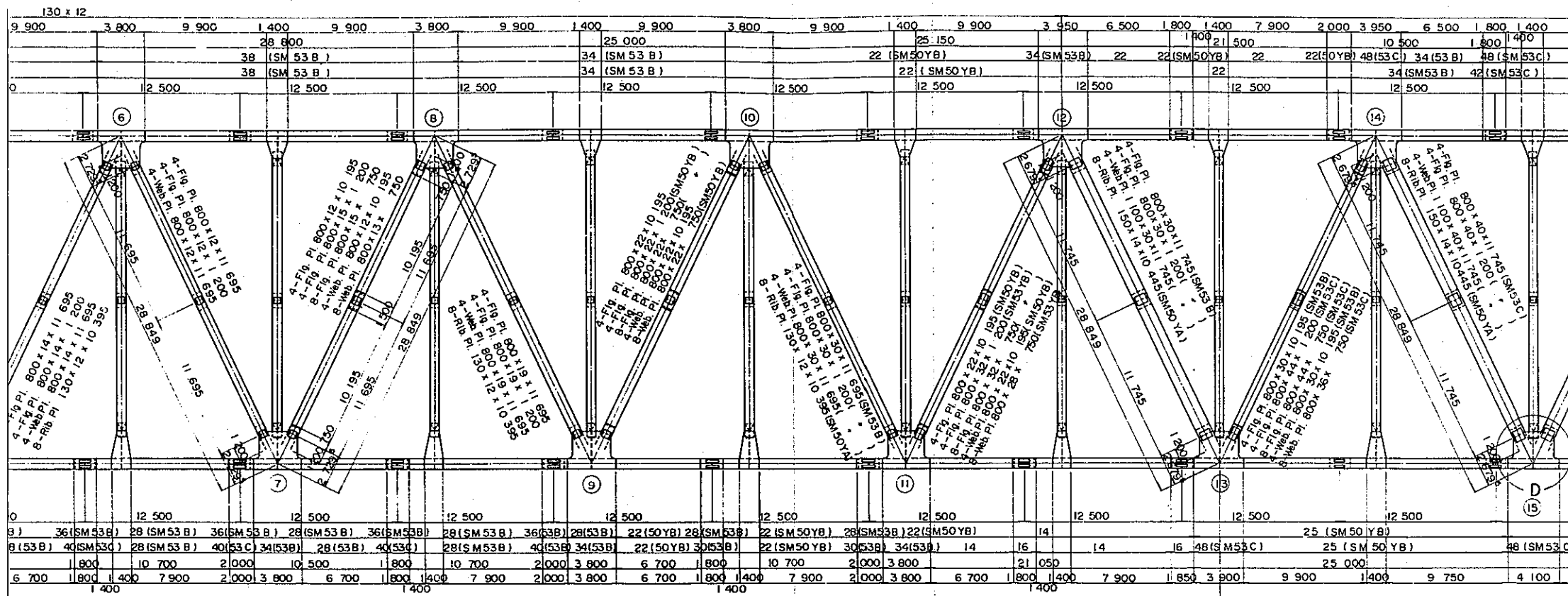


CROSS SECTION Scale 1:400

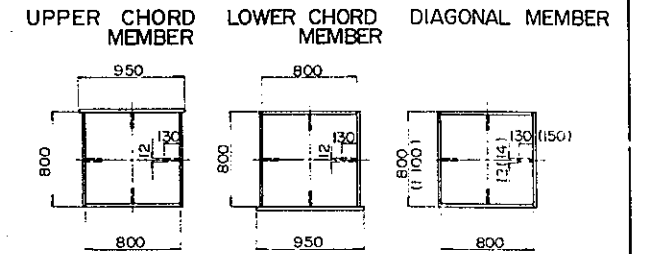


PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
GENERAL VIEW OF CONTINUOUS TRUSS (1SET)	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>T. Honda</i>	DRW. NO. 4
Approved <i>K. Suzuki</i>	

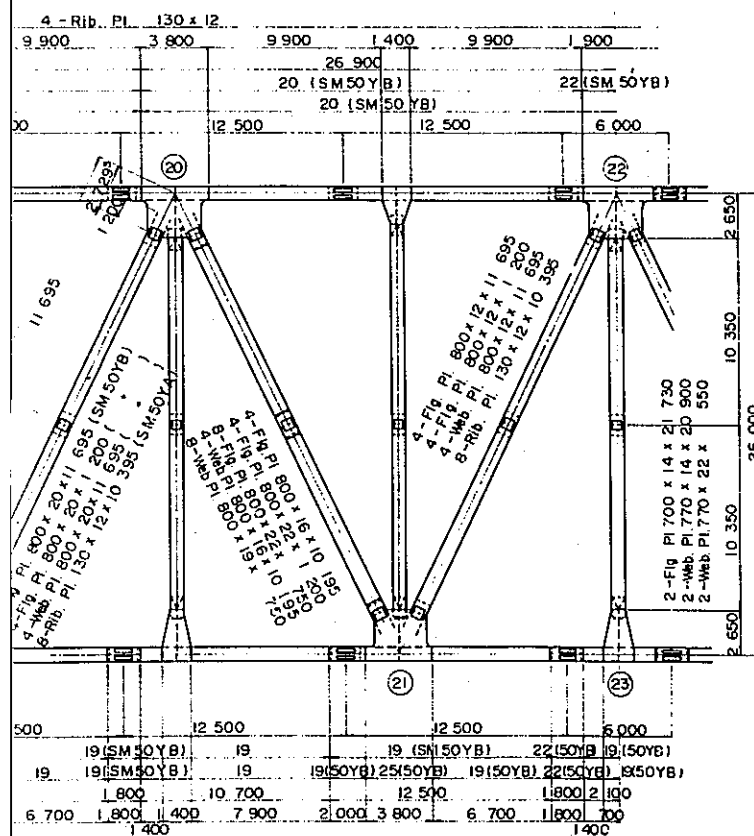
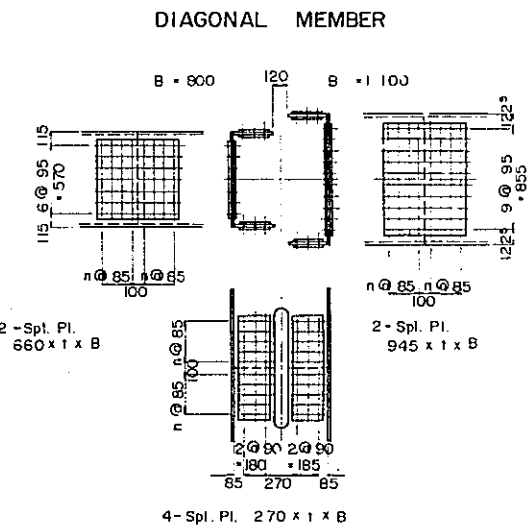




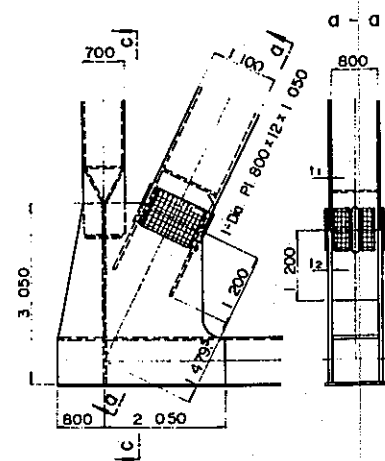
SECTION OF BUILD-UP MEMBERS SCALE 1:60



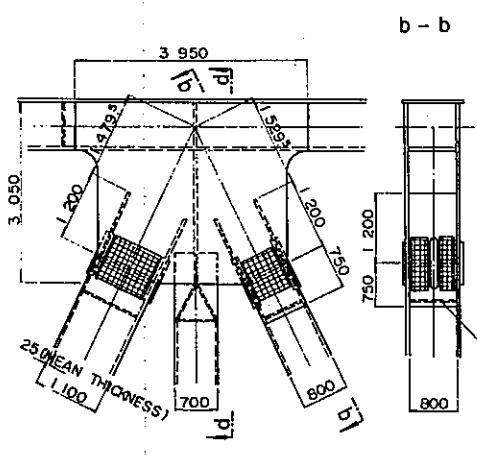
ARRANGEMENT OF SPLICE BOLTS SCALE 1:60



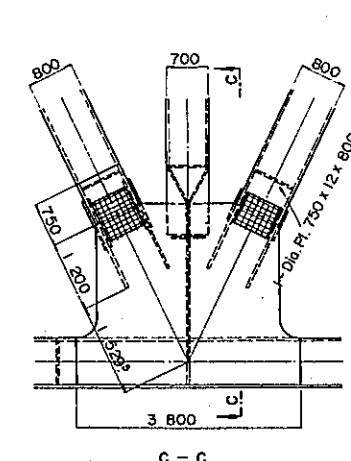
DETAIL - A



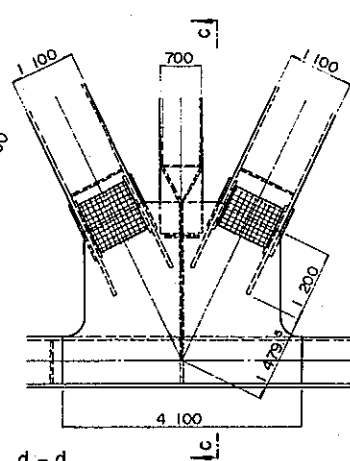
DETAIL - B



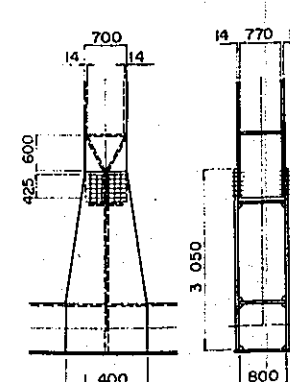
DETAIL - C



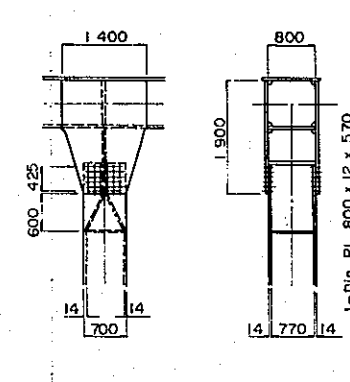
DETAIL - D



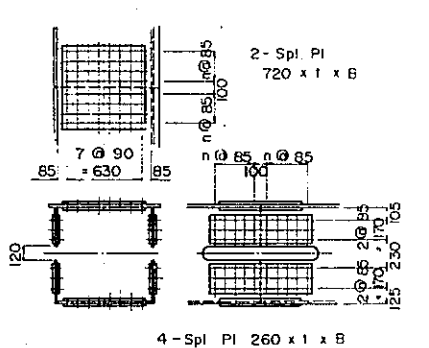
DETAIL - E



DETAIL - F

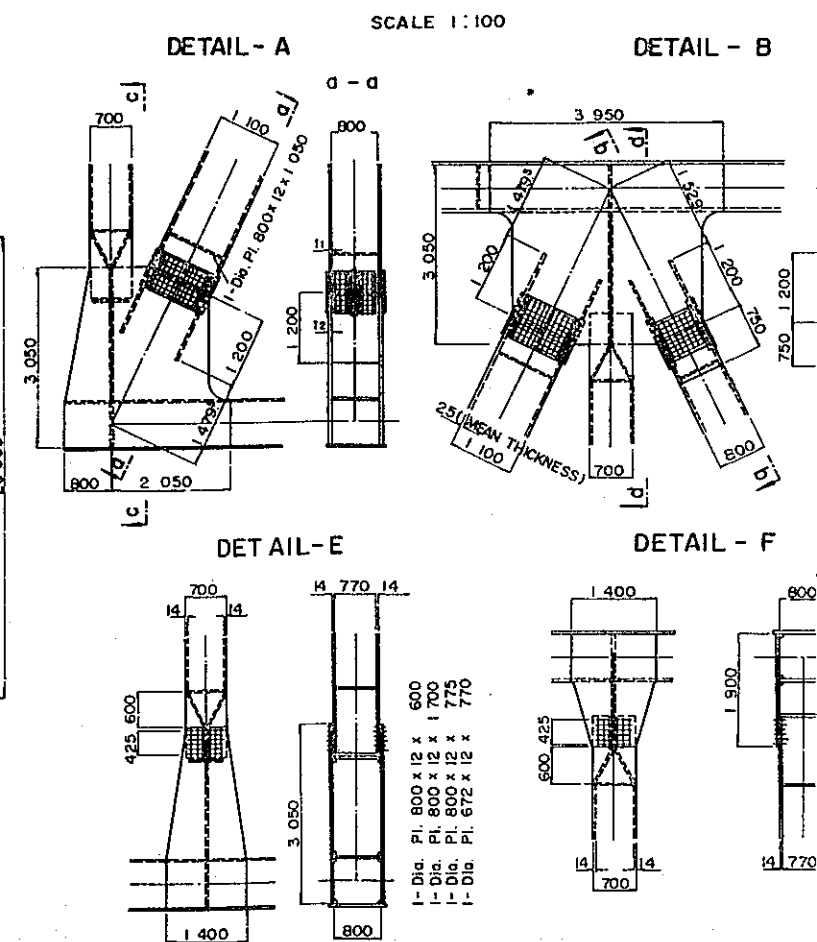
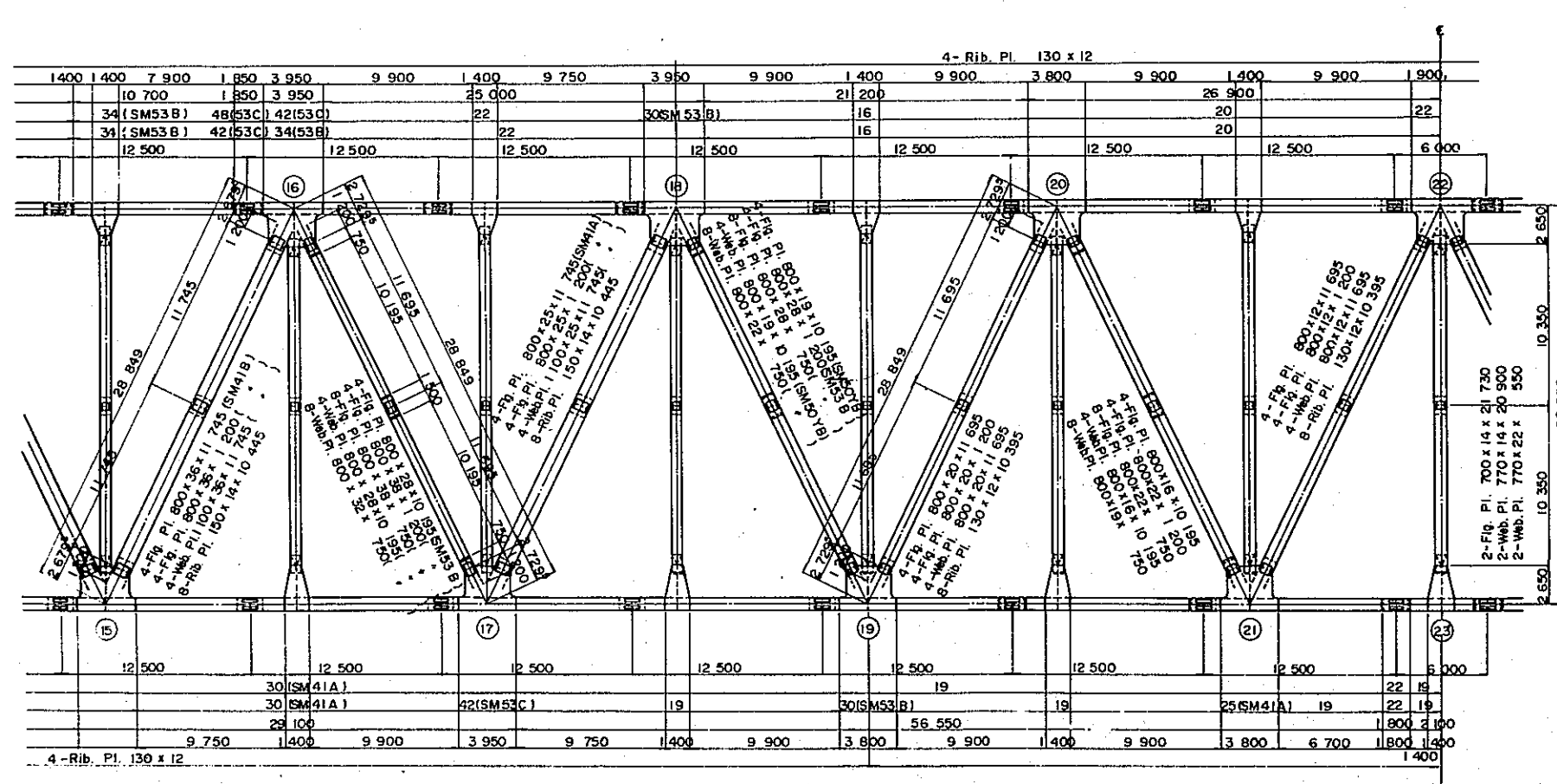
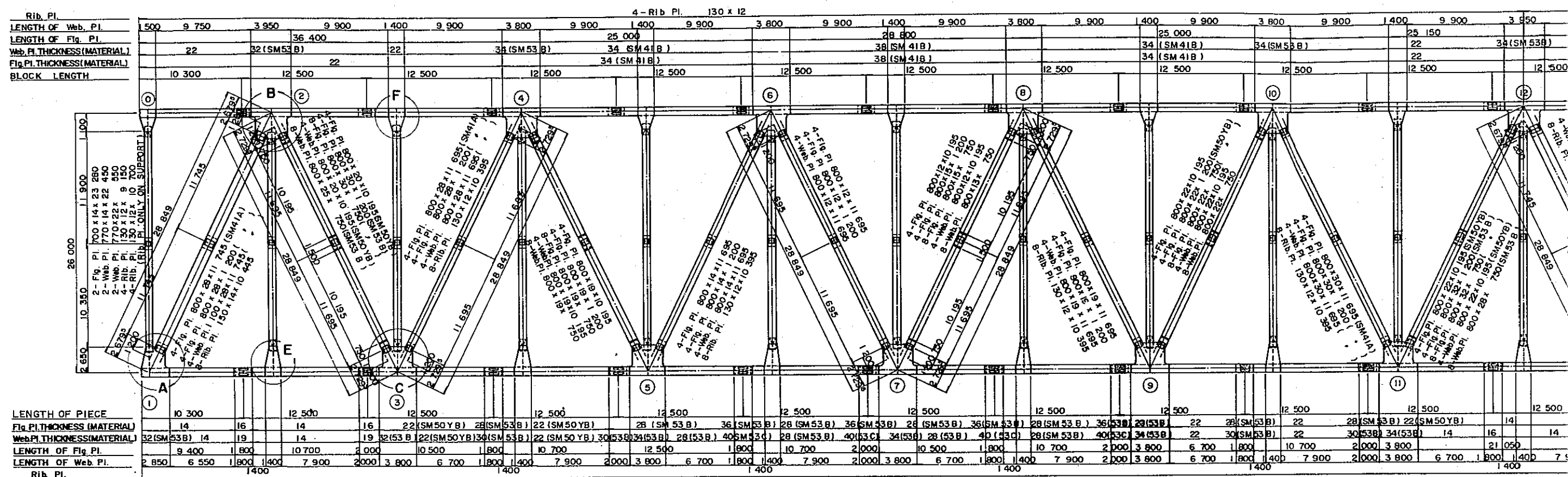


CHORD MEMBER



NOTE
MATERIAL: SS41 UNLESS AS NOTED
Dia. Pl. ALL 12 mm THICKNESS
Flt. Pl. (t₂ - t₁) THICKNESS
Rib. Pl. ONLY COMPRESSION MEMBER

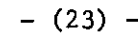
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
MAIN TRUSS (G2)	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale 1:400	Date
Drawn <i>Handa</i>	DRW. NO. 5
Approved <i>K. Legubha</i>	

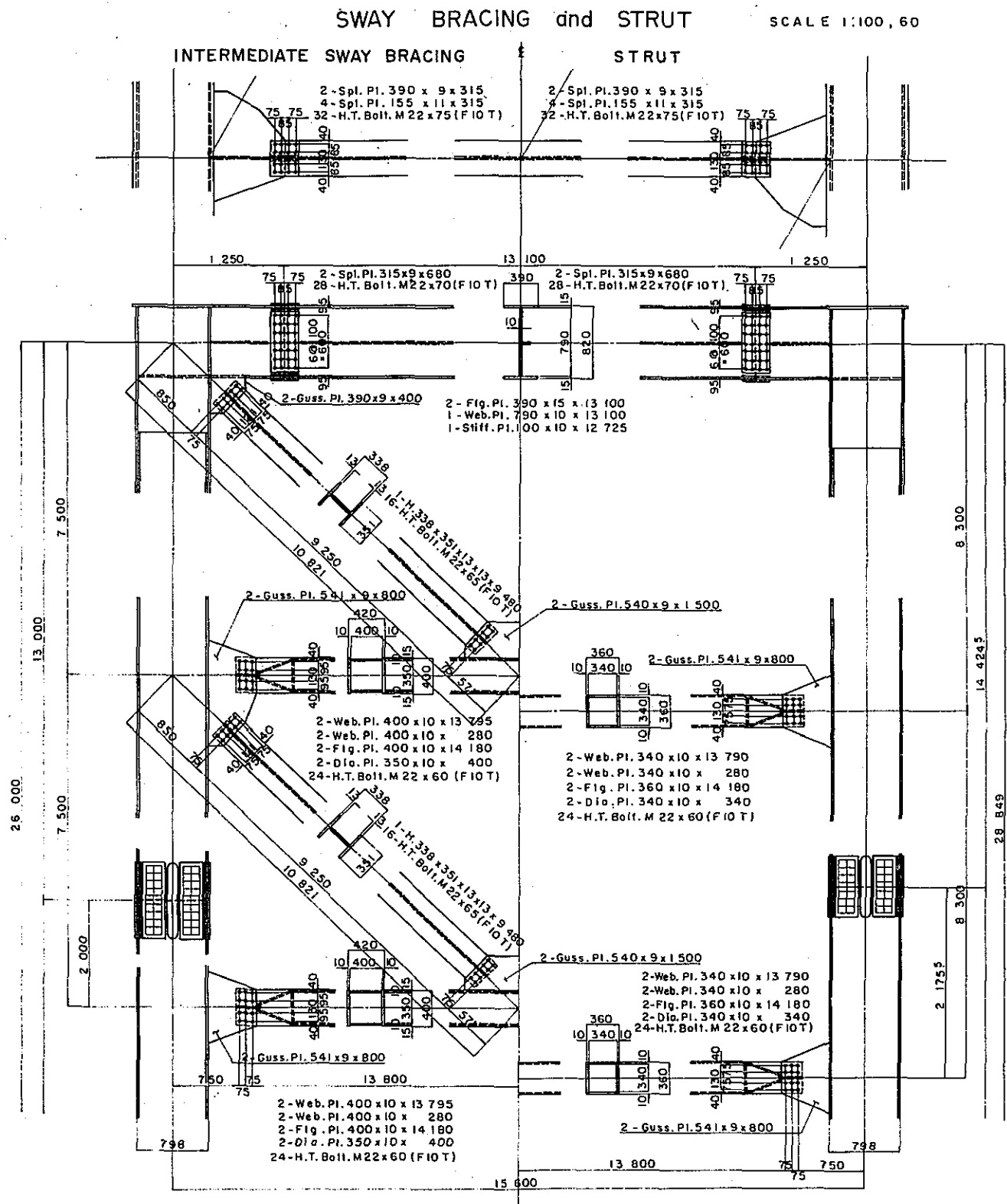


- (21) -

[illegible]

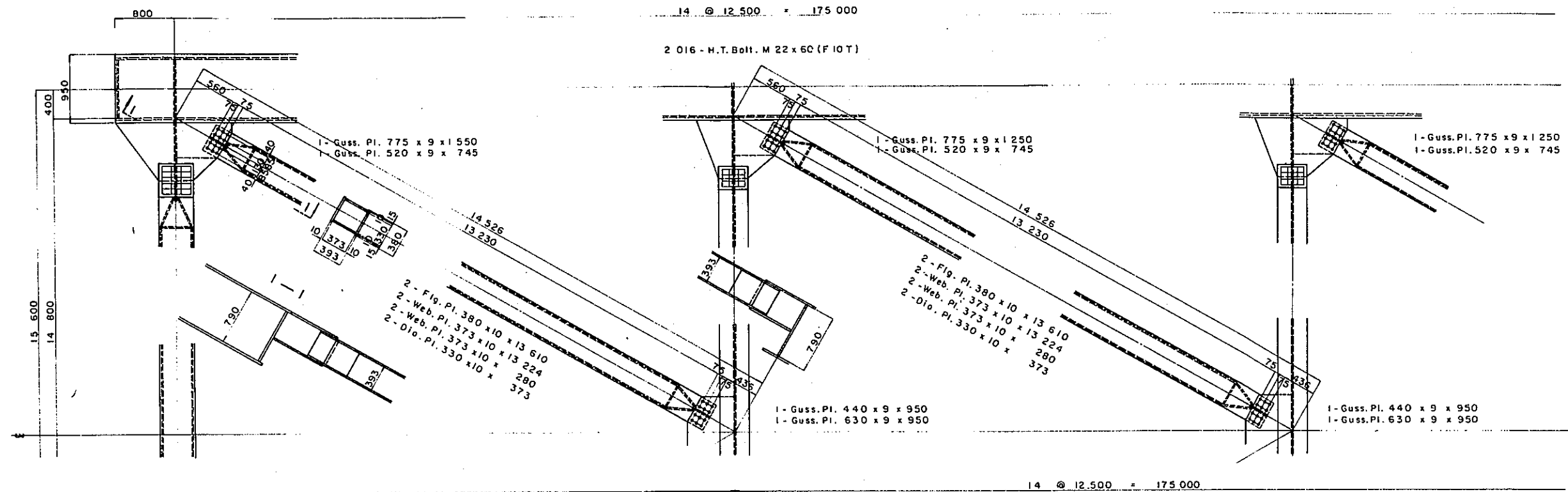
SCALE 1:200,80



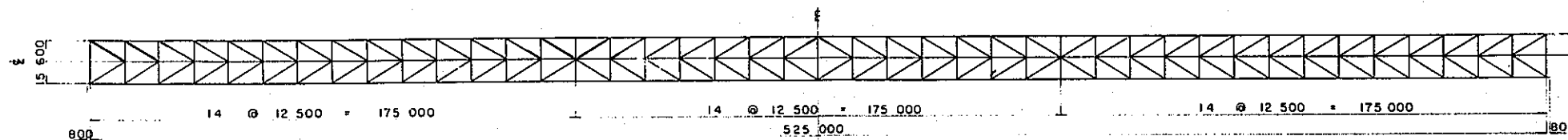


Technical drawing of a roof truss system. The drawing shows a side elevation of a truss with a series of triangular bays. A cross-section detail on the left shows a square truss joint with a diagonal member. Dimensions are given in meters (m). The total length is 525.000 m, divided into three sections of 175.000 m each, with 14 bays per section at a spacing of 12.500 m. Vertical dimensions include 15.500 m for the truss height and 86.000 m for the total roof height. A 800 unit dimension is also shown at the bottom left.

UPPER LATERAL BRACING SCALE 1:100,60

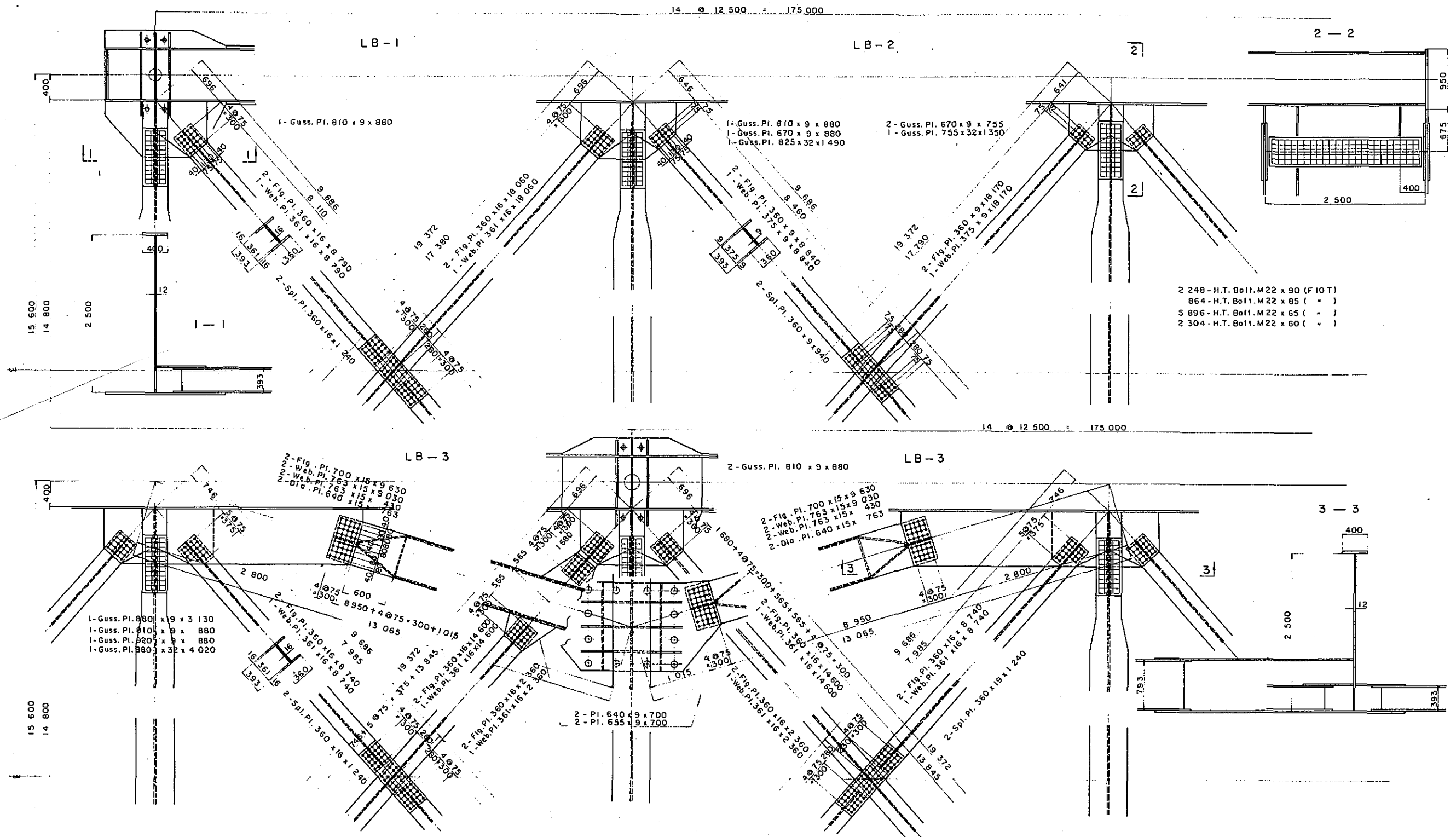


MARKING DIAGRAM SCALE 1:2 000

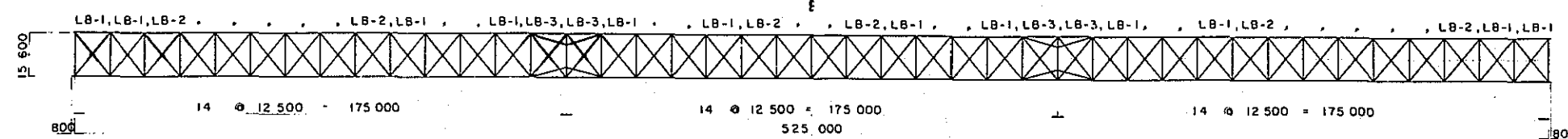


PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
UPPER LATERAL BRACING	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale 1:100,60	Date
Drawn <i>T. Tanaka</i>	DRW. NO. 10
Approved <i>K. Leguha</i>	

LOWER LATERAL BRACING SCALE 1:100,60



MARKING DIAGRAM SCALE 1:2000

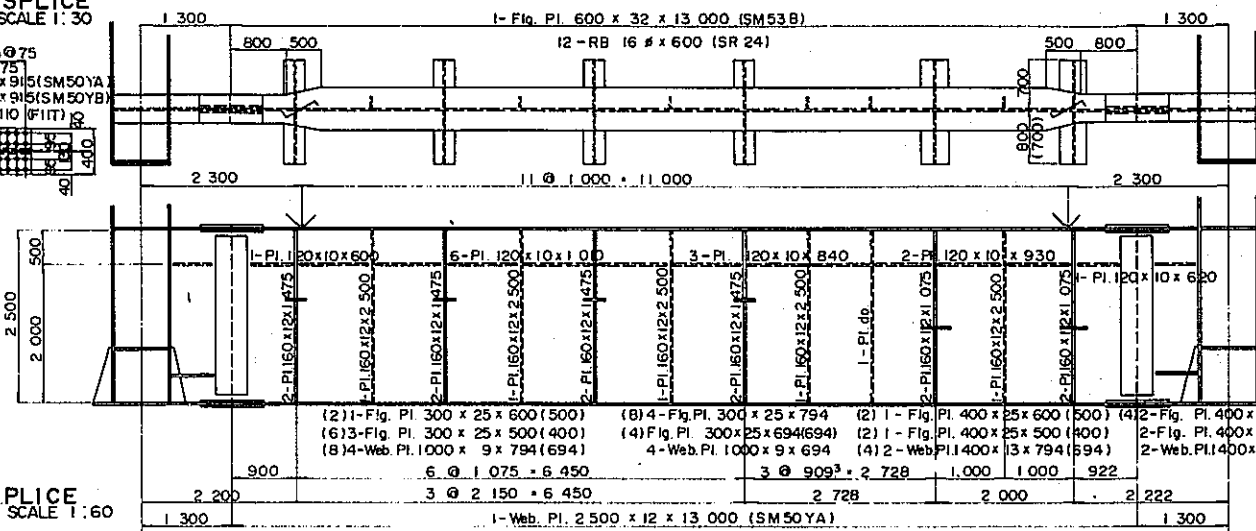


PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
LOWER LATERAL BRACING	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>Prasanna</i>	
Approved <i>K. Demba</i>	DRW NO 11

FLANGE SPICE SCALE 1:30

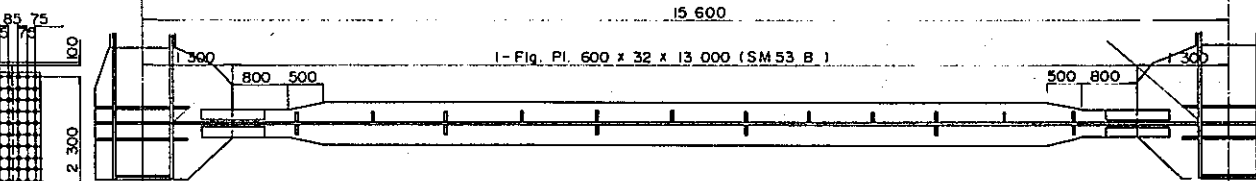
5 @ 75 85 5 @ 75
1-Spl. Pl. 400 x 16 x 915 (SM50YA)
2-Spl. Pl. 175 x 10 x 915 (SM50YB)
H-T.Bolt M22 x 110 (F11T)

FB-1 (FB-2)

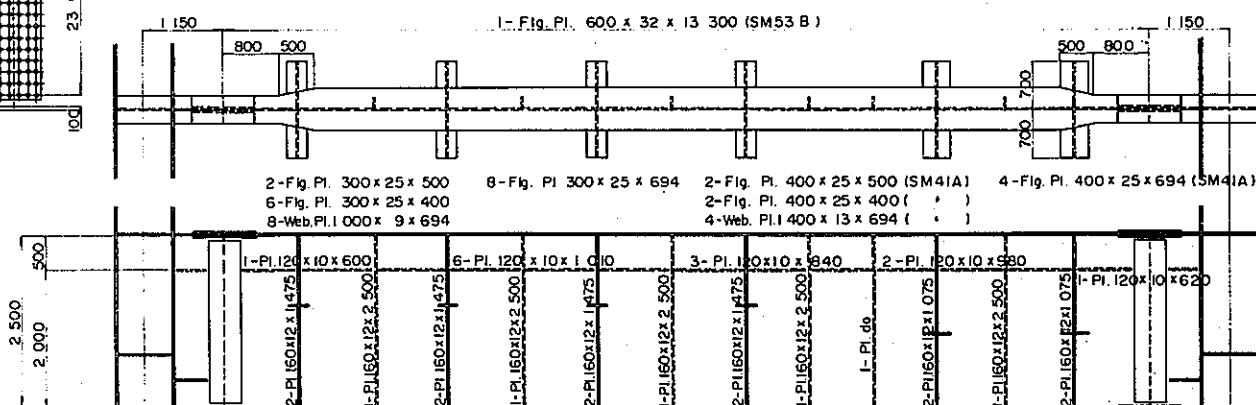


WEB SPICE SCALE 1:60

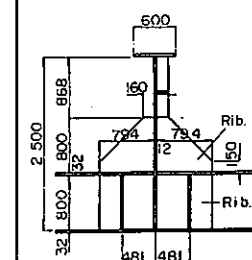
2-Spl. Pl. 465 x 9 x 2,380 (SM50YA)
144-H.T.Bolt M22 x 70 (F11T)



FB-3

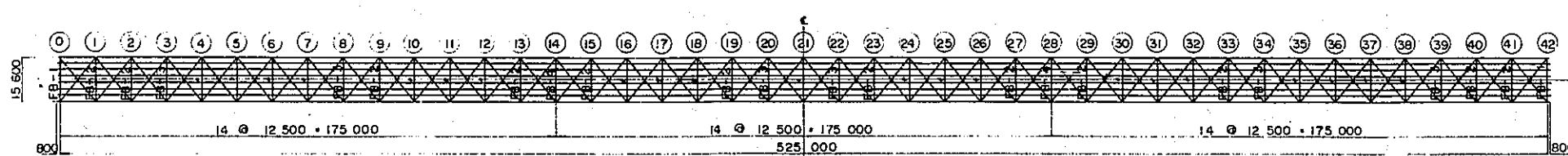


1-1 SCALE 1:100

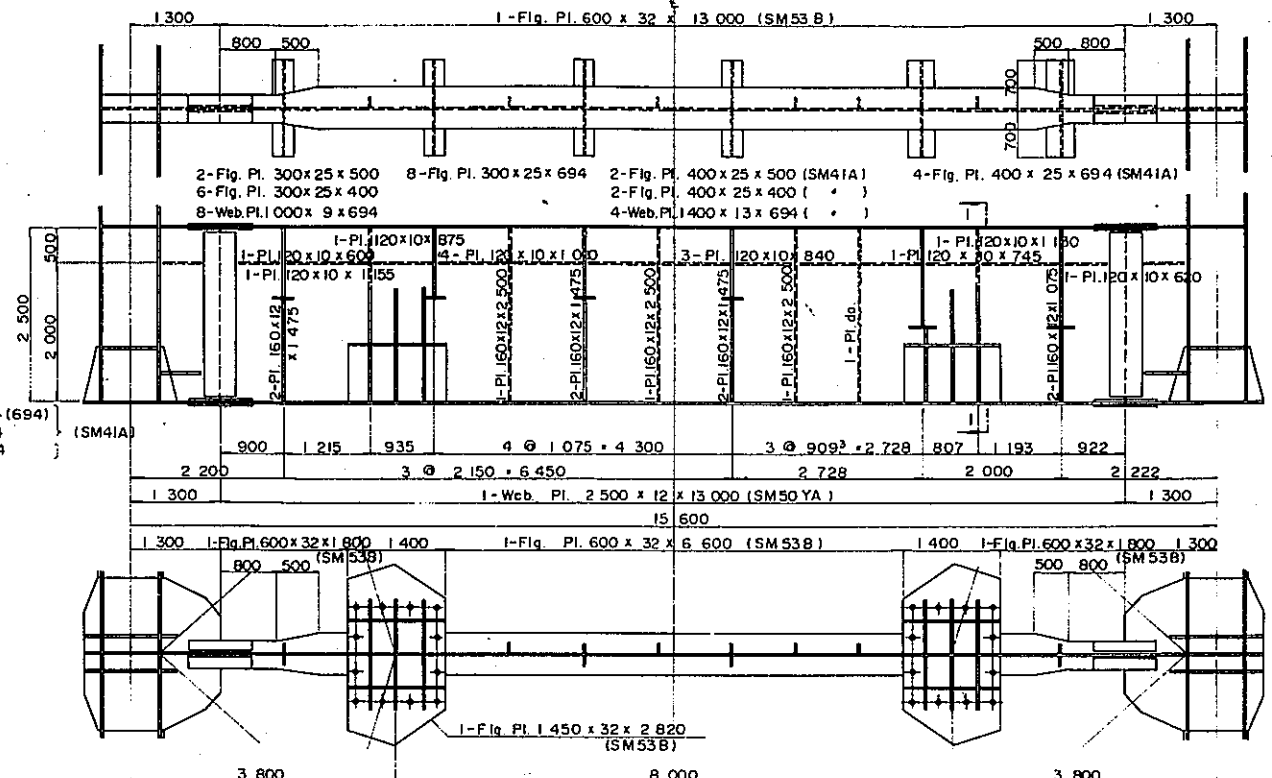


2-Guss. Pl. 1,410 x 32 x 1,450 (SM41A)
6-Rib. Pl. 794 x 22 x 800
4-Rib. Pl. 363 x 22 x 800
4-Rib. Pl. 304 x 22 x 800
6-Rib. Pl. 794 x 22 x 800
1-Stiff. Pl. 160 x 12 x 868

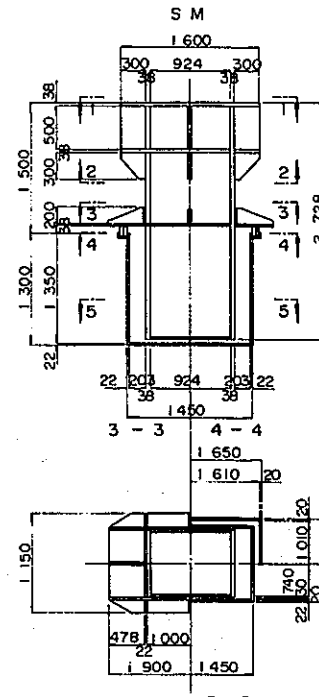
MARKING DIAGRAM SCALE 1:2,000



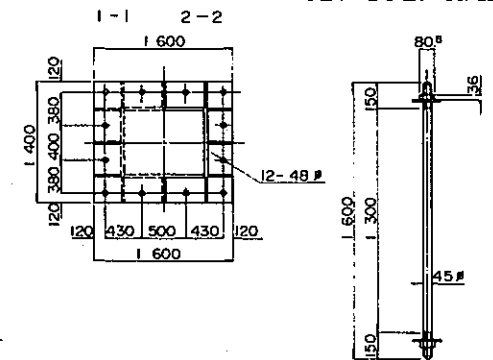
FB-4



STOPPER SCALE 1:80

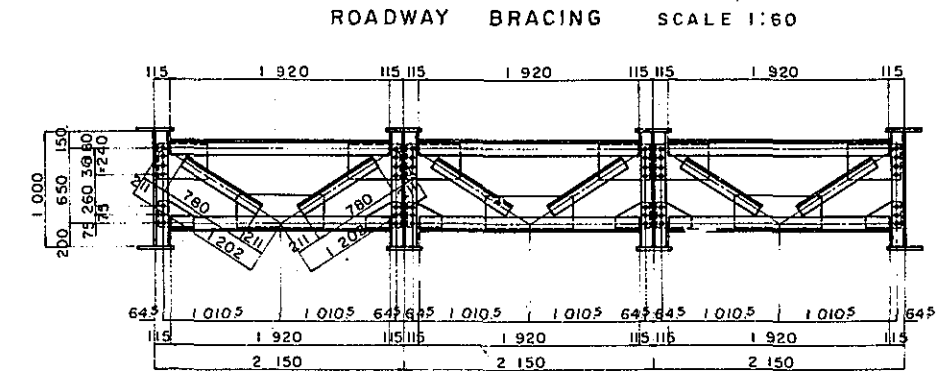
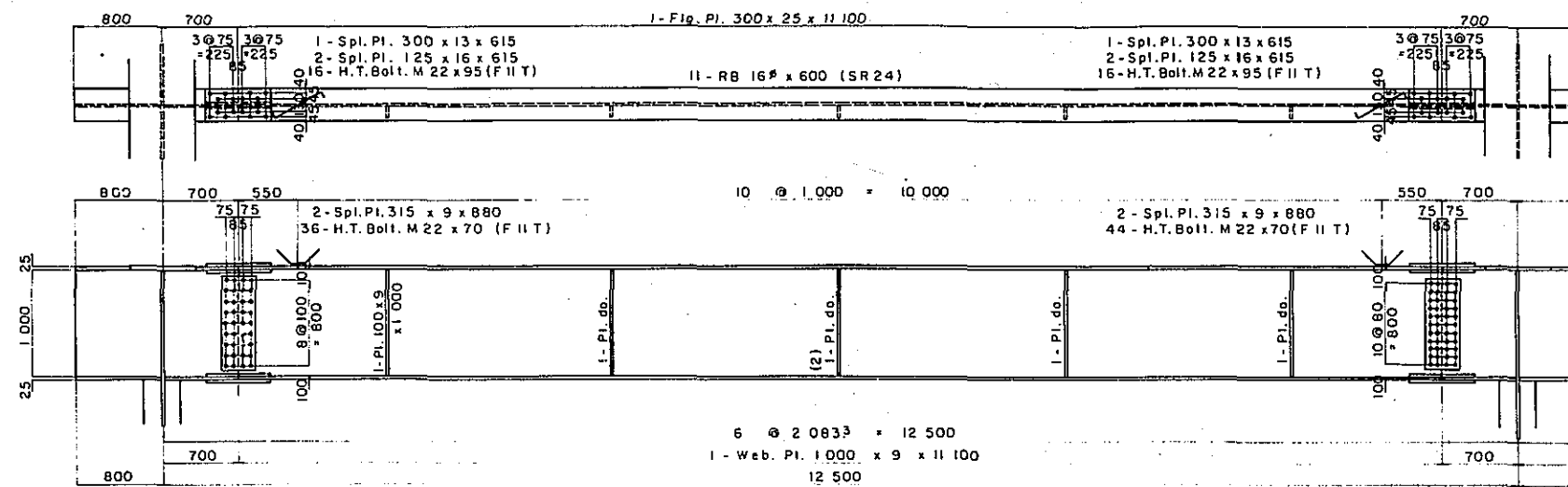


SET BOLT SCALE 1:40



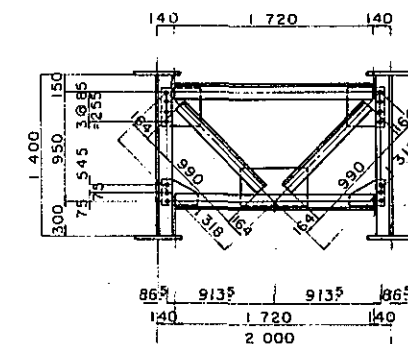
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
FLOOR BEAM	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale 1:100	Date
Drawn <i>Manaka</i>	DRW.NO. 12
Approved <i>K. Logubha</i>	

STRINGER SCALE 1:60



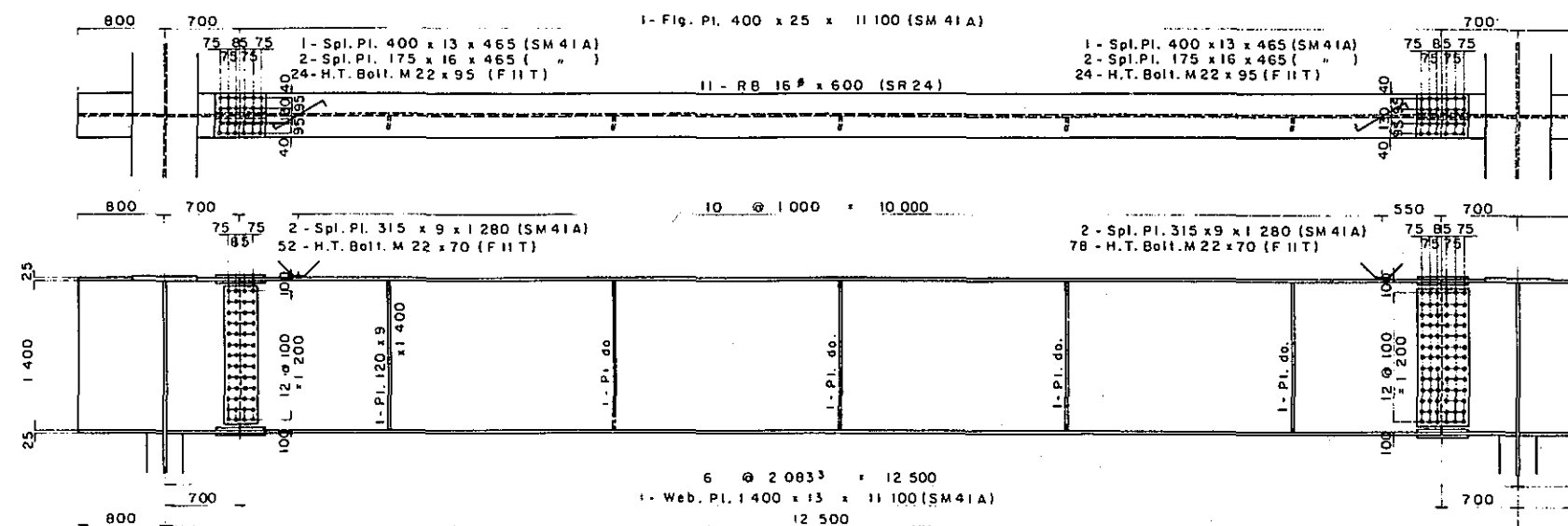
- 6 - L 130 x 130 x 9 x 1 920
6 - L 100 x 100 x 10 x 780
6 - Pl. 320 x 9 x 420
6 - Pl. 230 x 9 x 300
3 - Pl. 290 x 9 x 750
42 - H.T. Bolt, M 22 x 60 (F 10 T)

RAILWAY BRACING SCALE 1:60

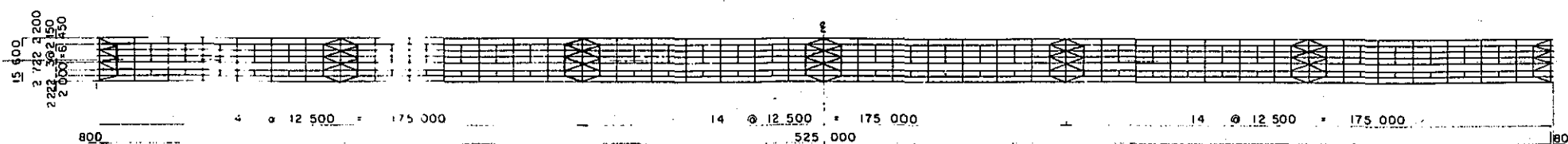


- 2 - L . 130 x 130 x 9 x 1 720
2 - L . 100 x 100 x 10 x 990
2 - P1. 330 x 9 x 335
2 - P1. 230 x 9 x 300
1 - P1. 340 x 9 x 570
14 - H.T. Bolt, M22 x 60 (F 10 T)

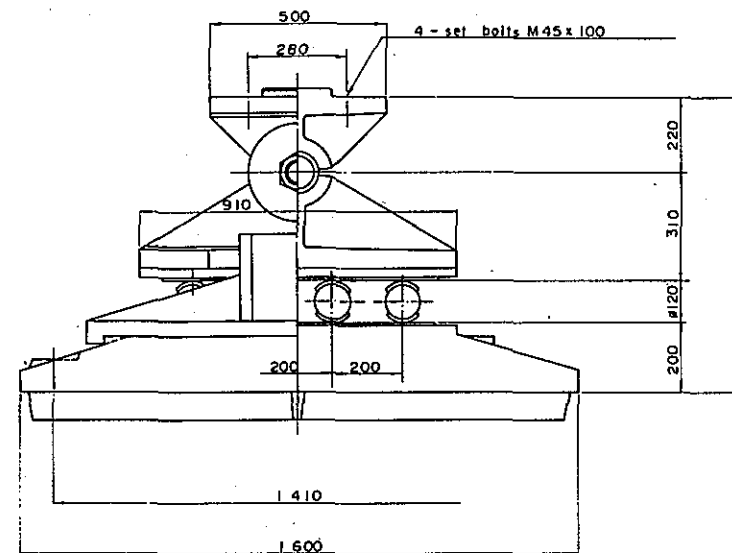
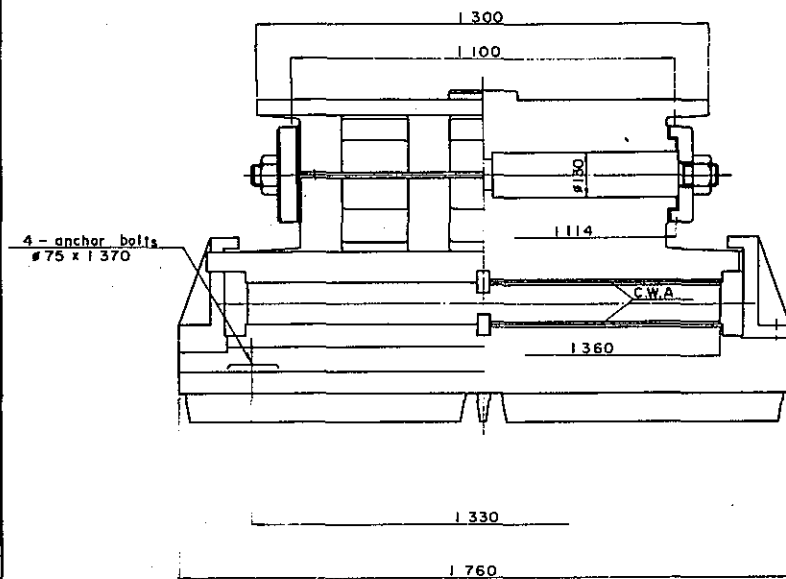
RAILWAY STRINGER SCALE 1:60



MARKING DIAGRAM SCALE 1:2000



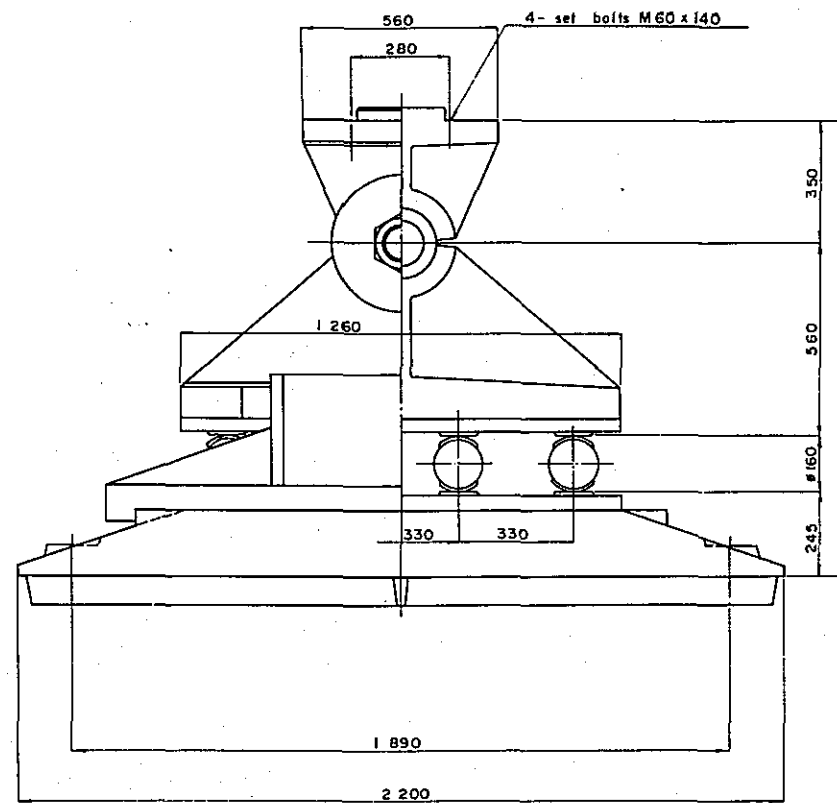
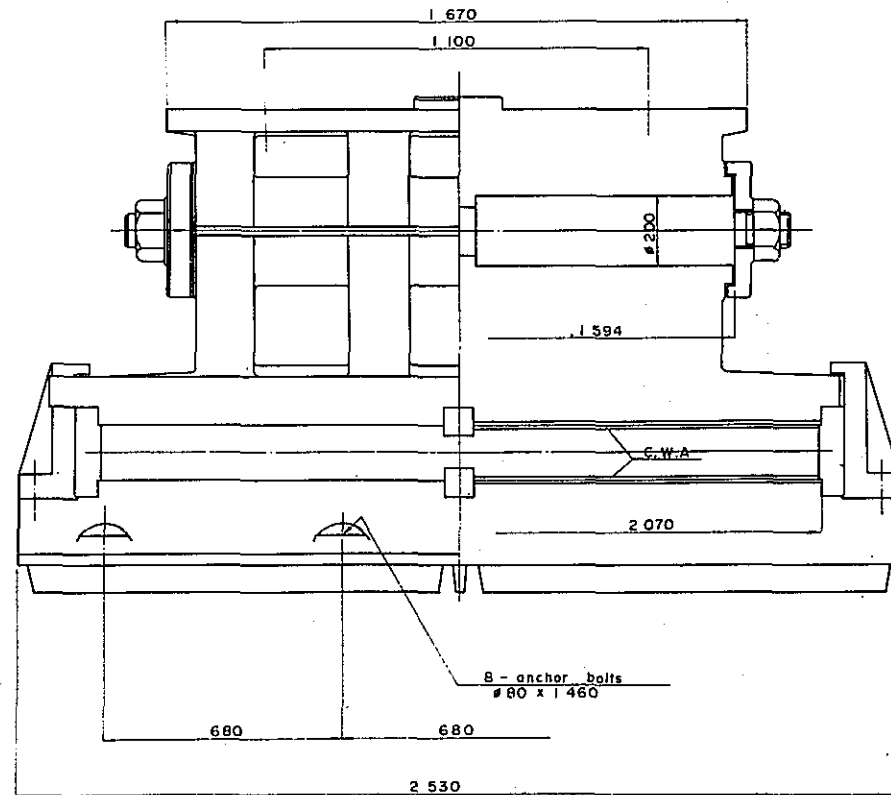
For 1315 ton



List of material

No.	Item	Material	Number	Weight (kg)
1	Upper shoe	SCMn 2A	1	523.7
2	Lower shoe	SCMn 2A fC.W.A	1	1 527.7
3	Base plate	SCMn 2A fC.W.A	1	3 385.1
4	Roller	SCMn 2A fC.W.A	4	483.2
5	Anchor bolt	SS 41	4	197.5
6	The others			
Total weight (kg)				7 000

For 3467 ton



List of material

No.	Item	Material	Number	Weight (kg)
1	Upper shoe	SCMn 2A	1	1 305.4
2	Lower shoe	SCMn 2A fC.W.A	1	4 985.5
3	Base plate	SCMn 2A fC.W.A	1	7 920.3
4	Roller	SCMn 2A fC.W.A	4	1 129.6
5	Anchor bolt	SS 41	8	484.0
6	The others			
Total weight (kg)				18 000

GENERAL STRUCTURE OF END PIER

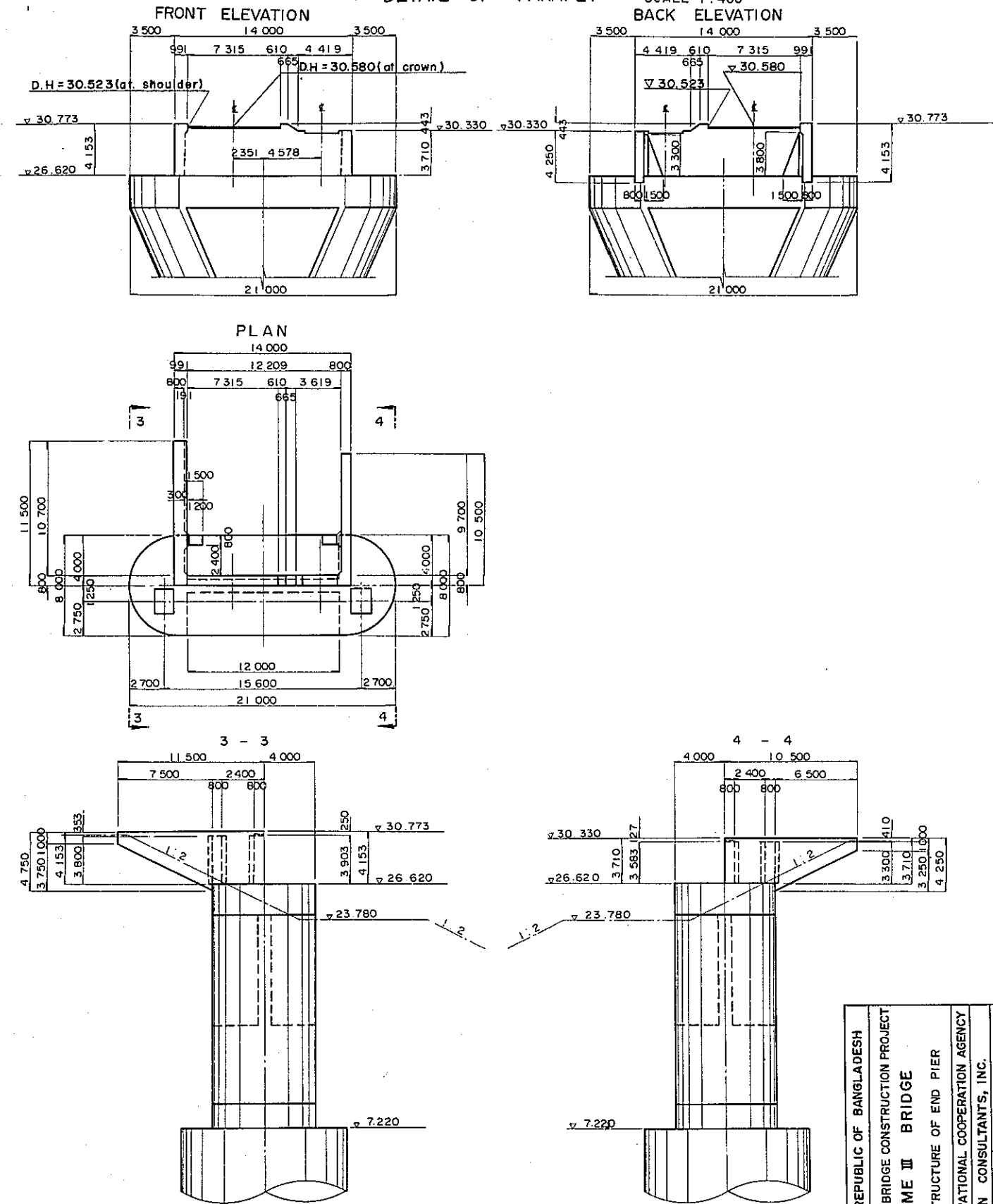
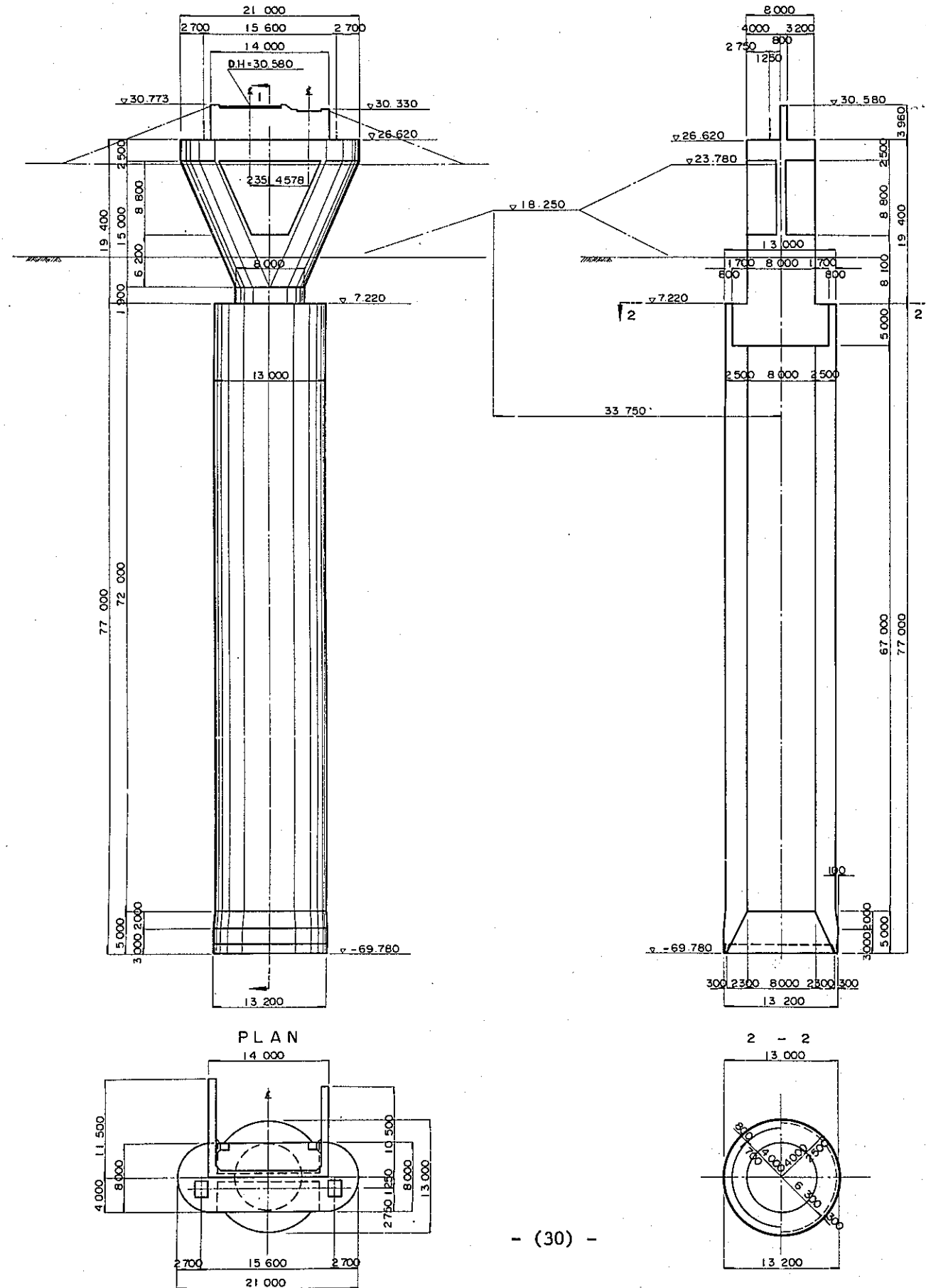
SCALE 1:600

FRONT ELEVATION

A2

DETAIL OF PARAPET

SCALE 1:400
BACK ELEVATION



- (30) -

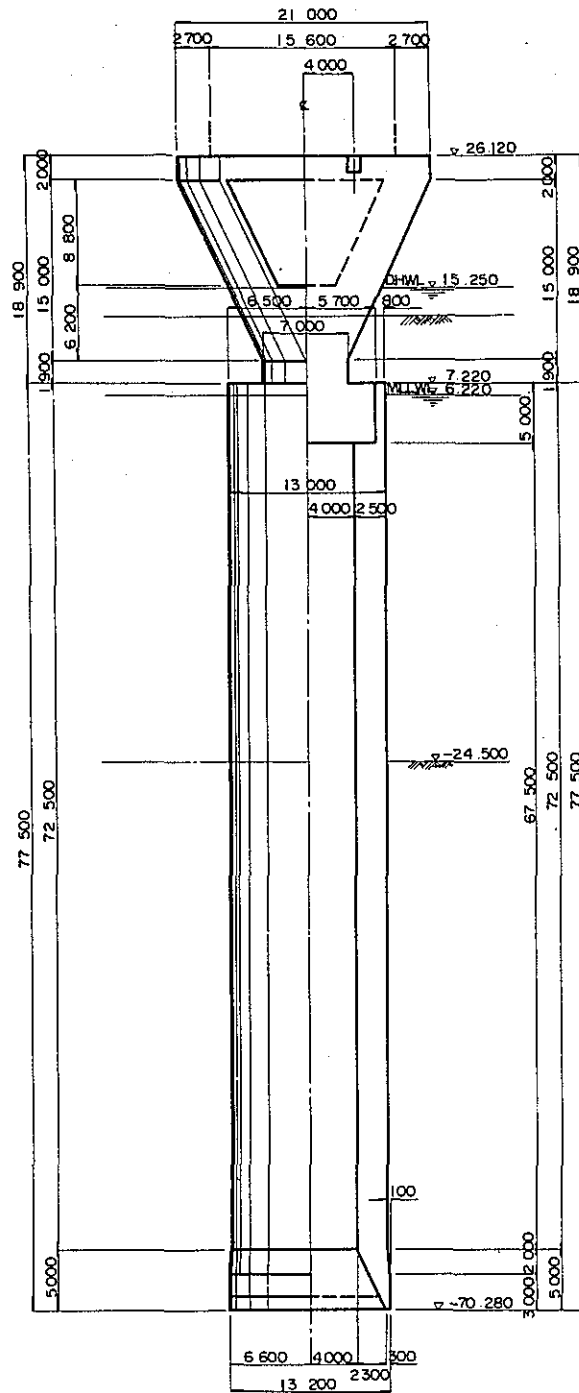
PEOPLES REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME II BRIDGE	
GENERAL STRUCTURE OF END PIER	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale 1:400, 600	Date
Drawn <i>[Signature]</i>	DRW. NO. 15
Approved <i>[Signature]</i>	

GENERAL STRUCTURE OF INTERMEDIATE PIER

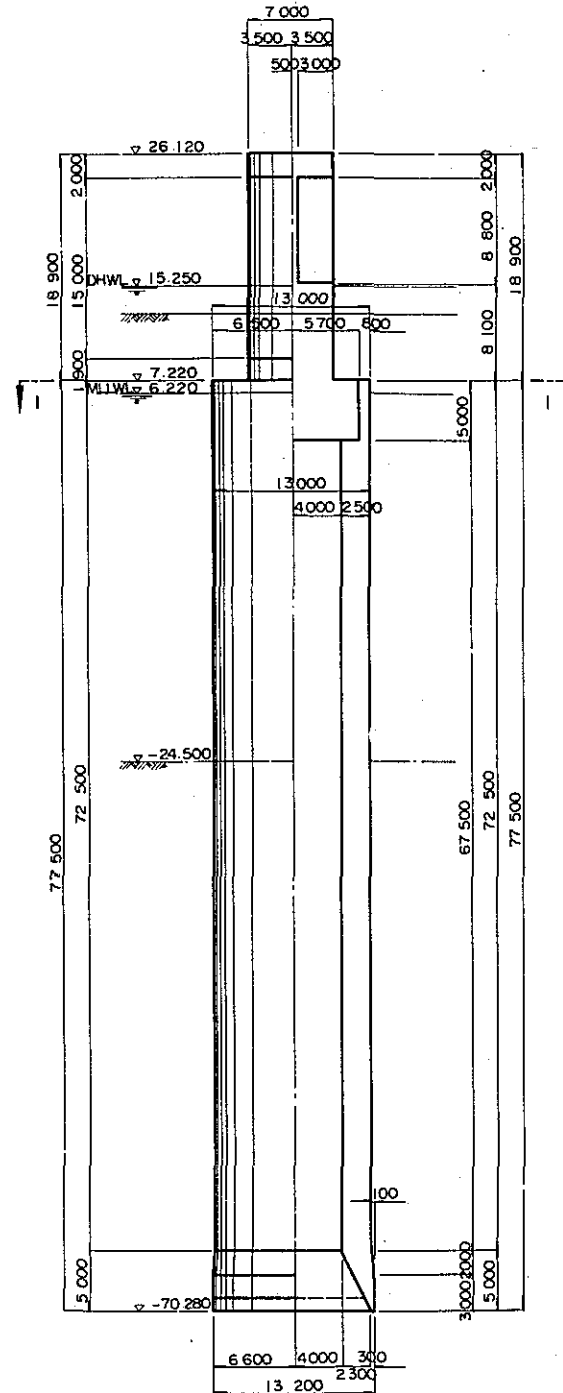
SCALE 1:600

P7

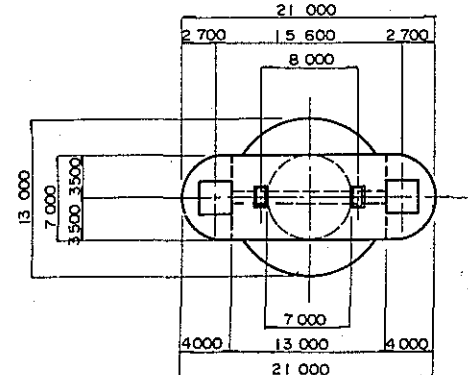
FRONT ELEVATION



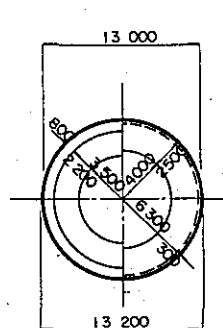
SIDE ELEVATION



PLAN



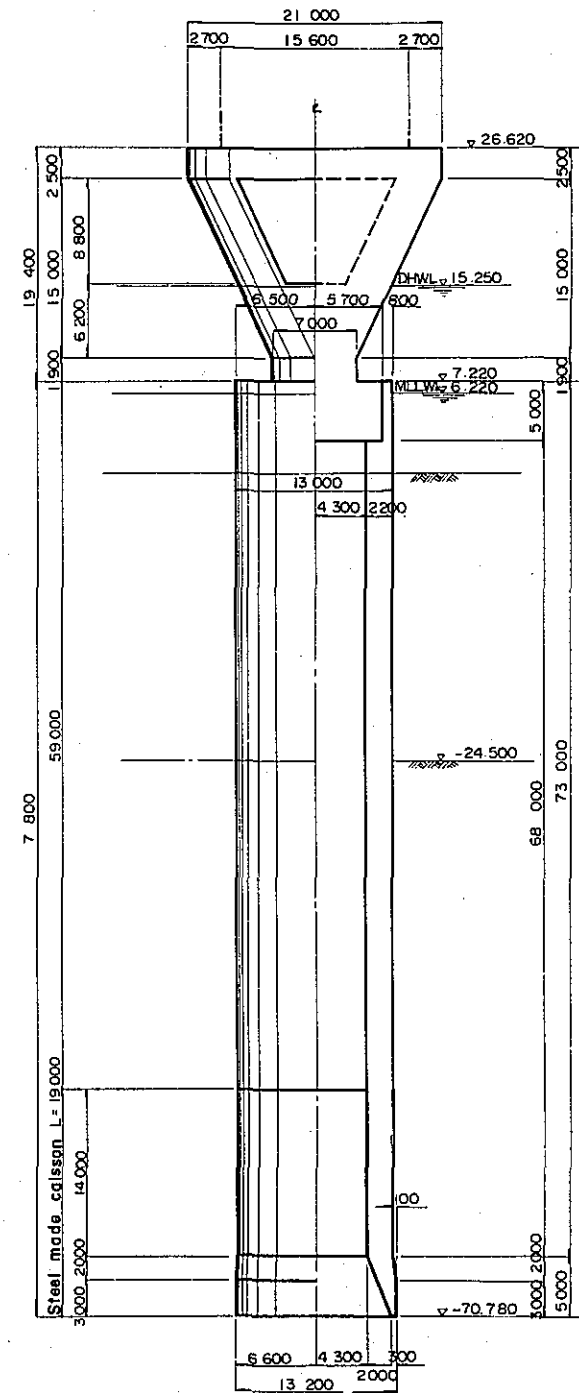
1 - 1



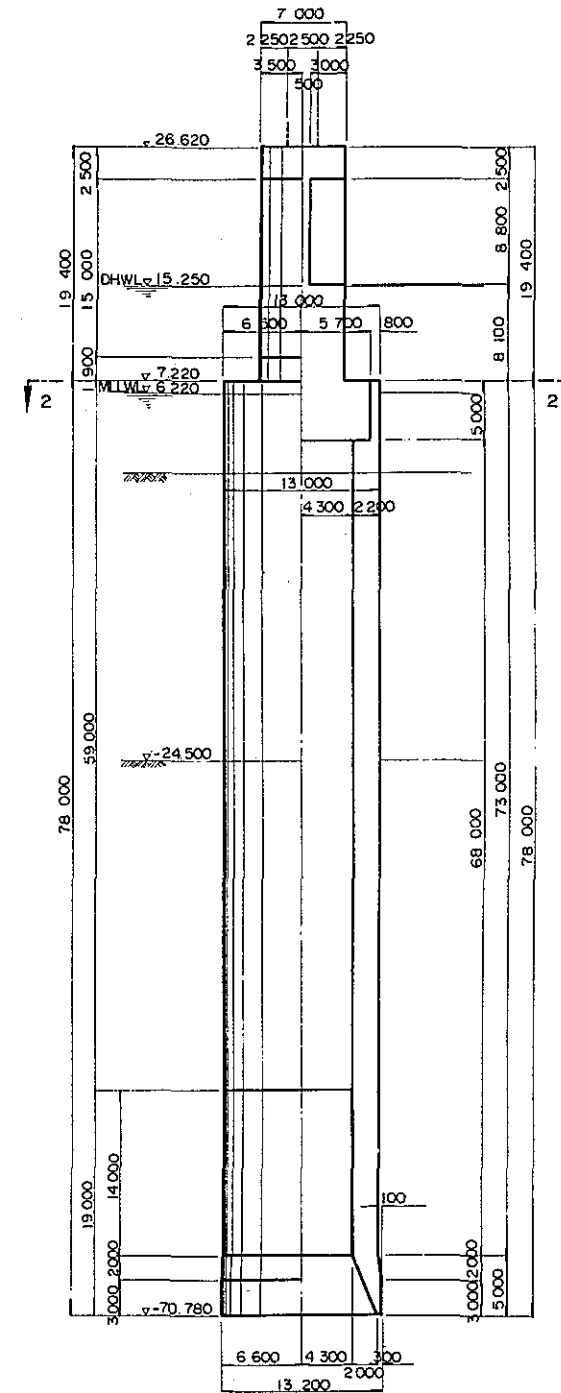
- (31) -

P21

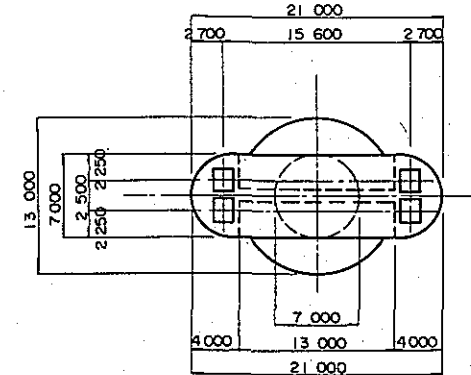
FRONT ELEVATION



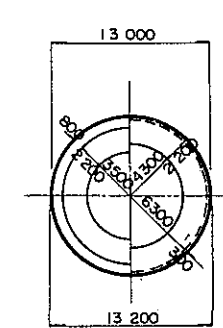
SIDE ELEVATION



PLAN



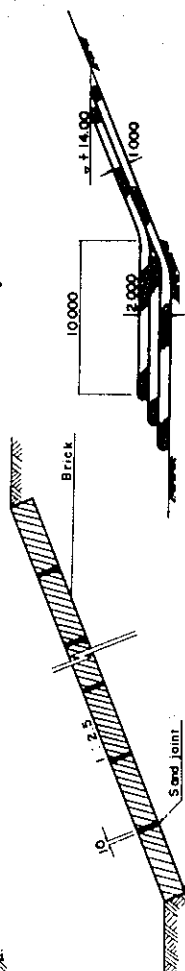
2 - 2



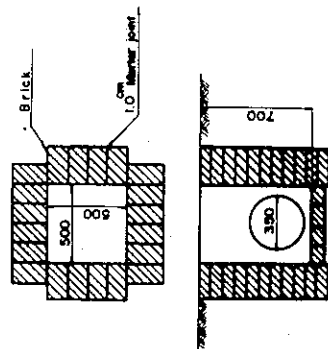
PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME III BRIDGE	
GENERAL STRUCTURE OF INTERMEDIATE PIER	
JAPAN INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale 1:600	Date
Drawn T. K. Saha	DRW. NO. 16
Approved K. K. Saha	

Figure 1 is a cross-sectional diagram of the test structure. The structure is composed of several layers: a top layer of Bituminous concrete (1.2 ft thick), followed by a layer of Cracked bricks (0.8 ft thick), a large Shoulder (8'-00" wide), a concrete layer (2.2 ft thick), and a base layer of Sand (1.2 ft thick). A 3.0% slope is indicated at the base of the concrete layer. The total height of the structure is 9.5 ft.

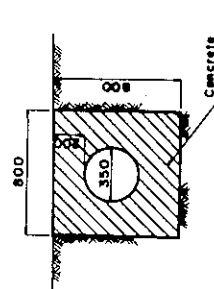
(3) Wire cylinder (filled with brick)



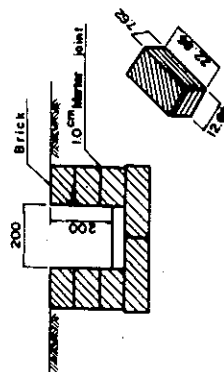
(6) Indent



(5) Drain pipe



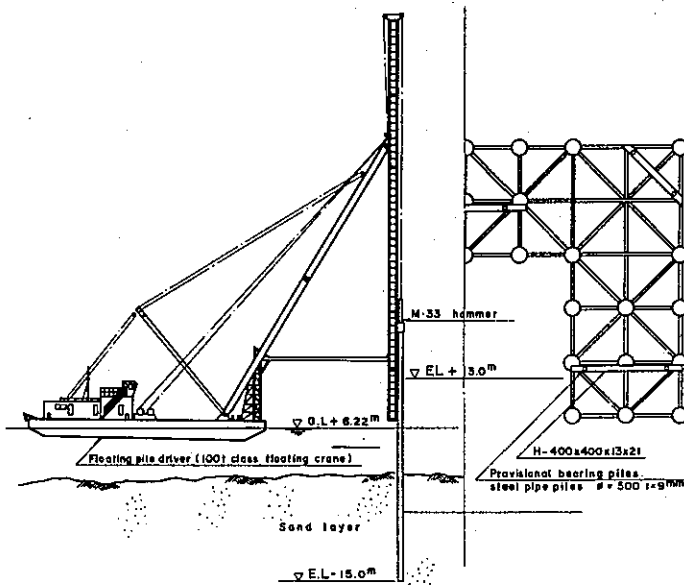
(4) Side ditch



PEOPLE'S REPUBLIC OF BANGLADESH	
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT	
VOLUME II BRIDGE	
DIAGRAM OF PROTECTION WORKS FOR BRIDGE APPROACH	
JAPANI INTERNATIONAL COOPERATION AGENCY	
NIKKEN CONSULTANTS, INC.	
Scale	Date
Drawn <i>T. K. Saha</i>	DWG. NO. 17
Approved <i>K. D. Saha</i>	

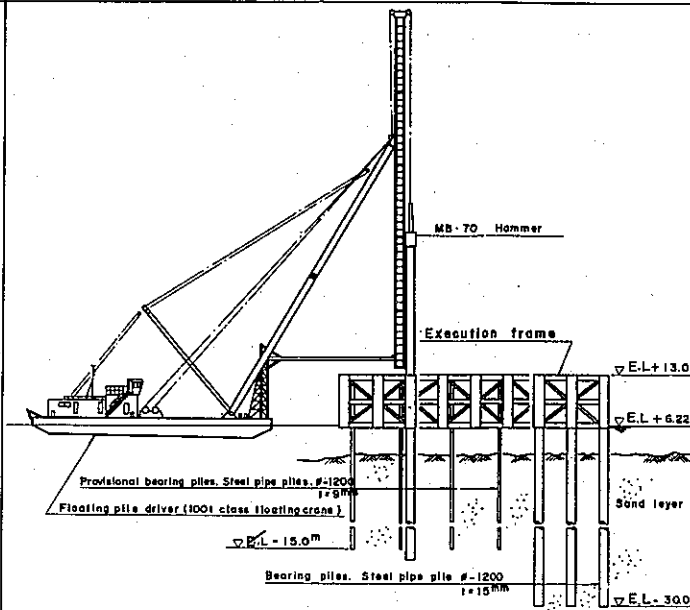
WORKING PROCESSES OF EXECUT

① Preliminary works.



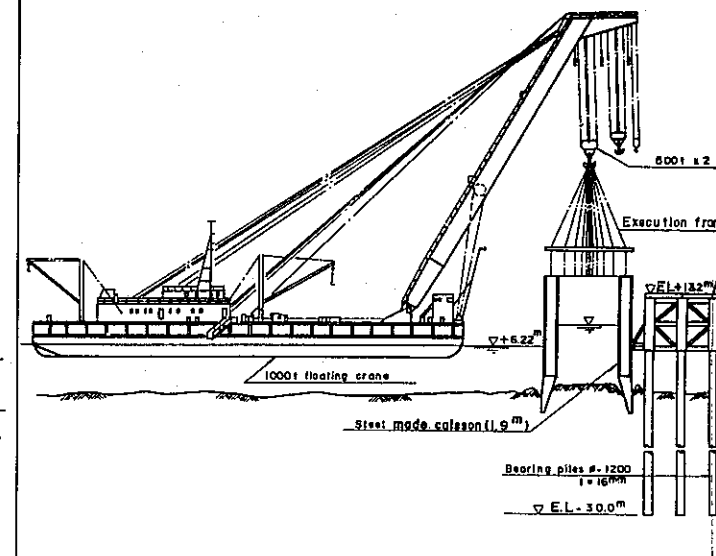
- 1) Temporary piles shall be driven by floating pile driver to support the execution frame, to be used for execution of well.

③ Driving of bearing piles



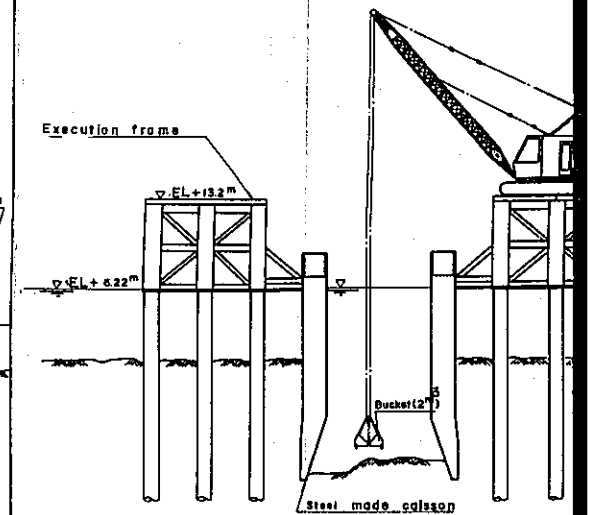
- 1) After the setting of frame on the temporary piles, bearing piles (steel pipe pile $d=1200\text{ mm}$) shall be driven through the holes of vertical members of frame.
- 2) In order to make a working deck, pre-fabricated deck plates shall be arranged on the upper surface of the frame. The dimension of pre-fabricated deck plates is $5\text{ m} \times 5\text{ m} \times 0.208\text{ m}$.

⑤ Setting of steel-made caisson



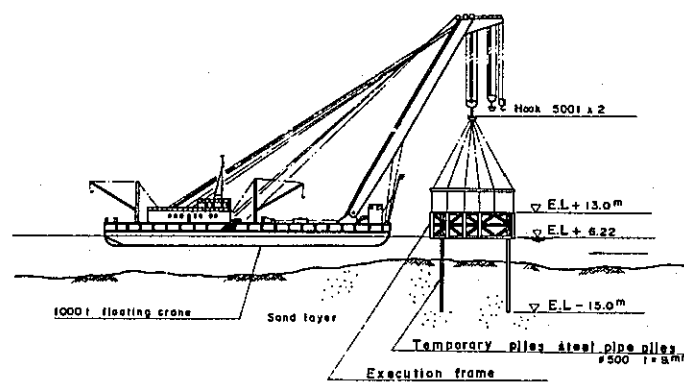
- 1) Steel-made caisson already assembled at yard shall be transported by 1000ton floating crane and set in place by the aid of frame.
- 2) Then the caisson shall be sunk uniformly by the additional weight which controlled by the water poured into the hollow space of caisson until the caisson reaches to the self-standing position.

⑦ Excavation by clamshell bucket



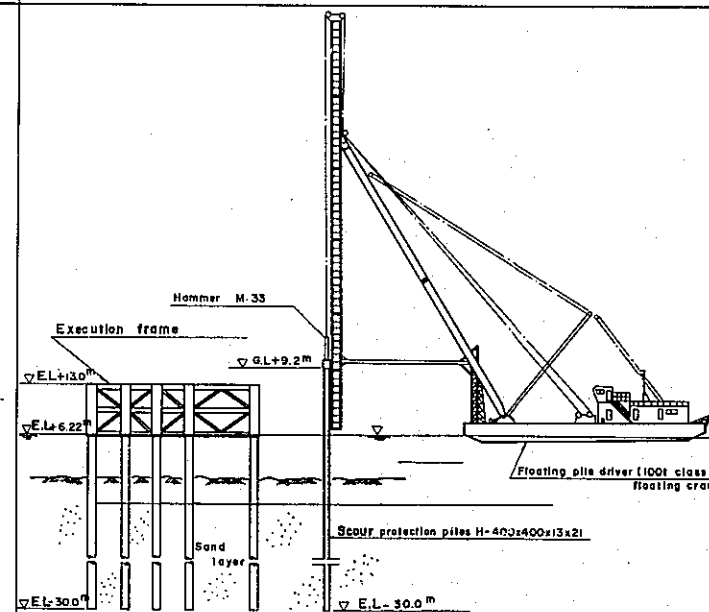
- 1) Crawler crane (type 955-ALC) then will be brought out on the deck of the frame.
- 2) This type of excavation is continued until the bottom caisson reaches to the depth of $EL=-10\text{ m}$.

② Setting of execution frame



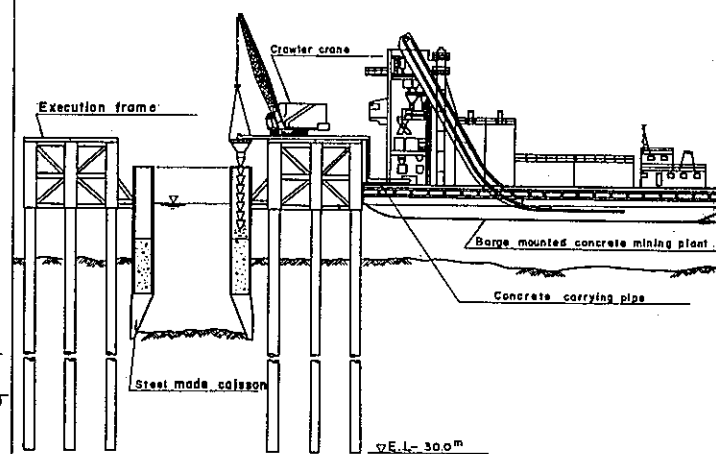
- 1) Execution frame will be lifted by 1000ton floating crane at execution frame yard and transported to the site.
- 2) Setting the frame in place on the temporary piles and securing.

④ Driving of scour protection piles



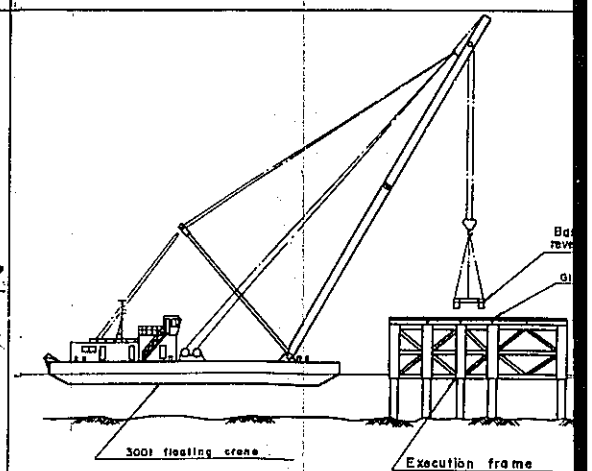
- 1) Drive the scour protection piles by floating pile driver.
- 2) Scour protection pile is H-shaped and its dimension is $400 \times 400 \times 13\text{ (mm)}$ and driven 10 m upstream of the frame at intervals 1.5 m . The length of protection work is 50 m and 34 H-piles shall be needed.

⑥ Placing of concrete into the wall of caisson



- 1) The concrete shall be placed into the wall of caisson uniformly using barge-mounted concrete mixing plant. In this case, water filled the space of caisson shall not be pumped out in order to keep the stability of caisson.

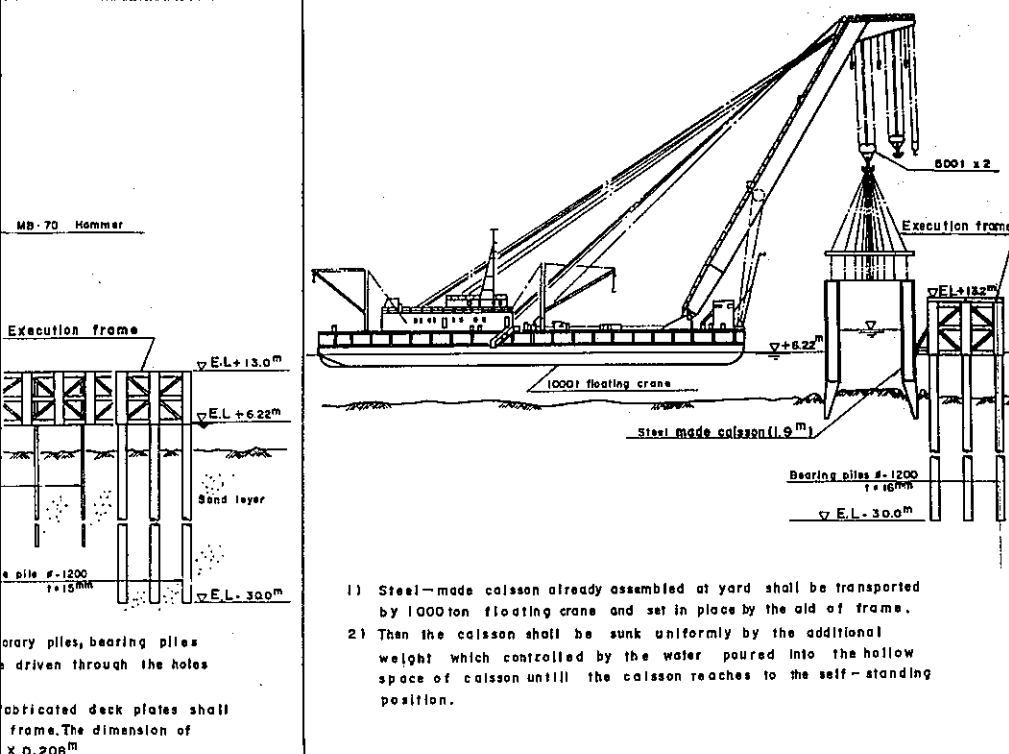
⑧ Assembling of reverse circulation machine



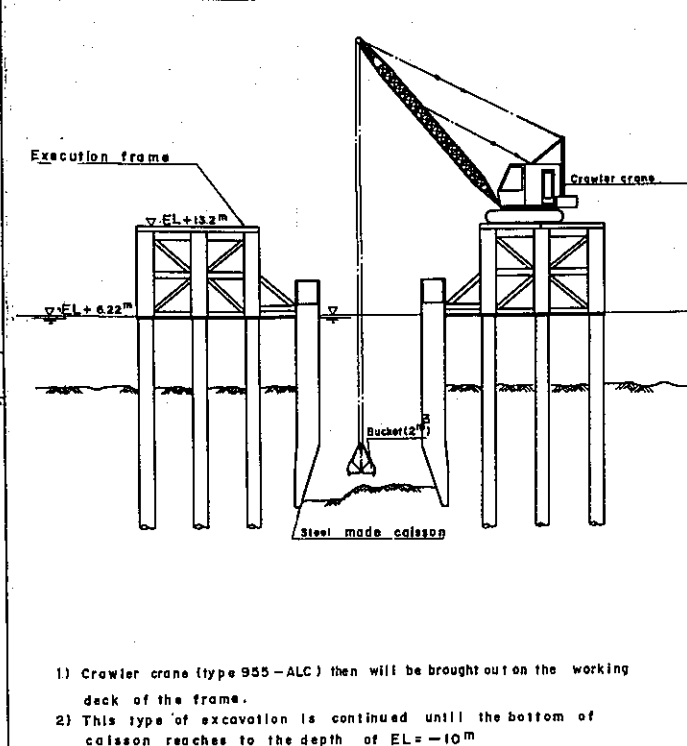
- 1) Using floating crane, reverse circulation machine will be assembled on the working deck of the frame after the removal of clamshell bucket.

WORKING PROCESSES OF EXECUTION OF PIERS

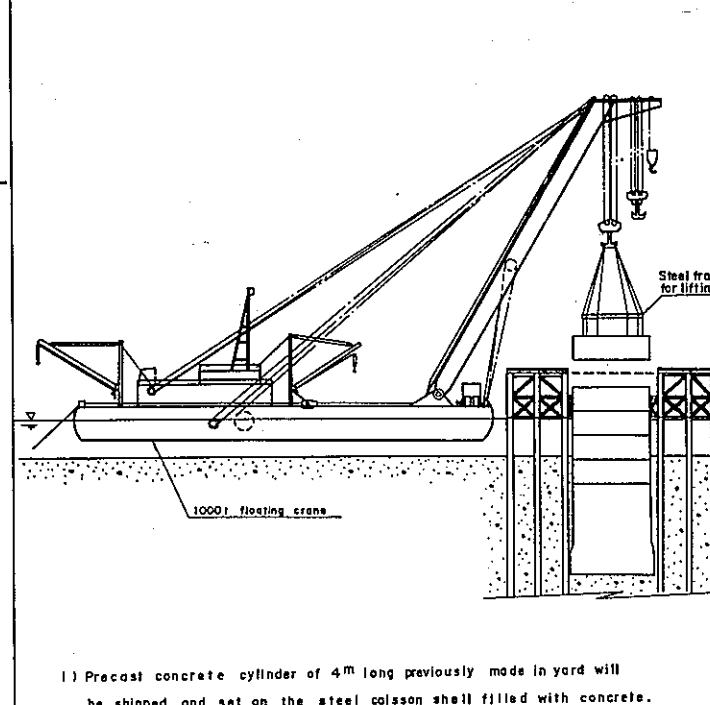
⑤ Setting of steel-made caisson



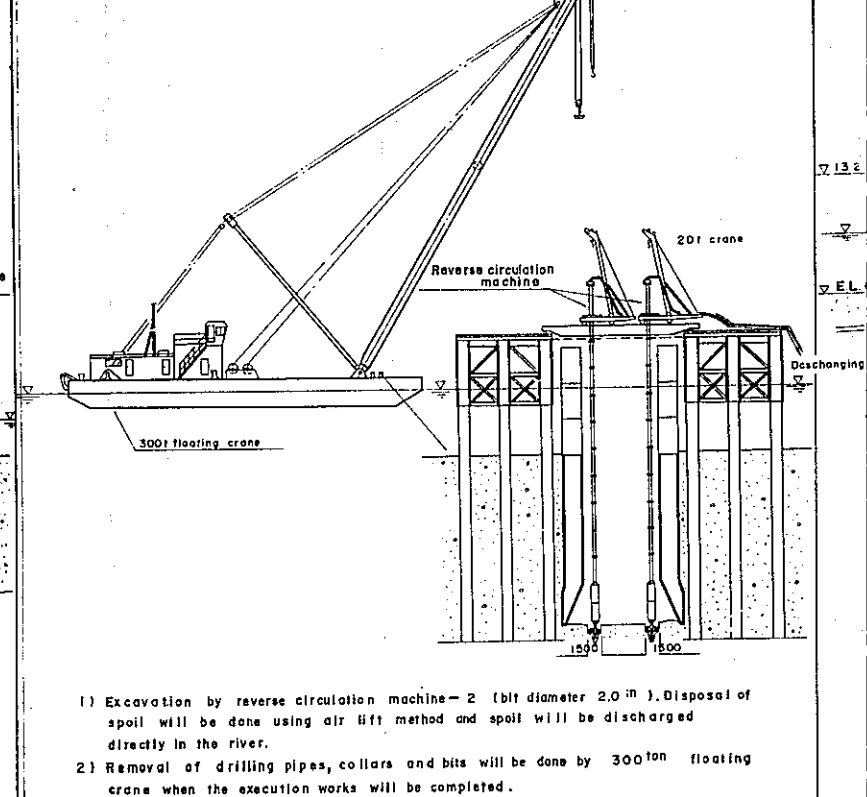
⑦ Excavation by clamshell bucket



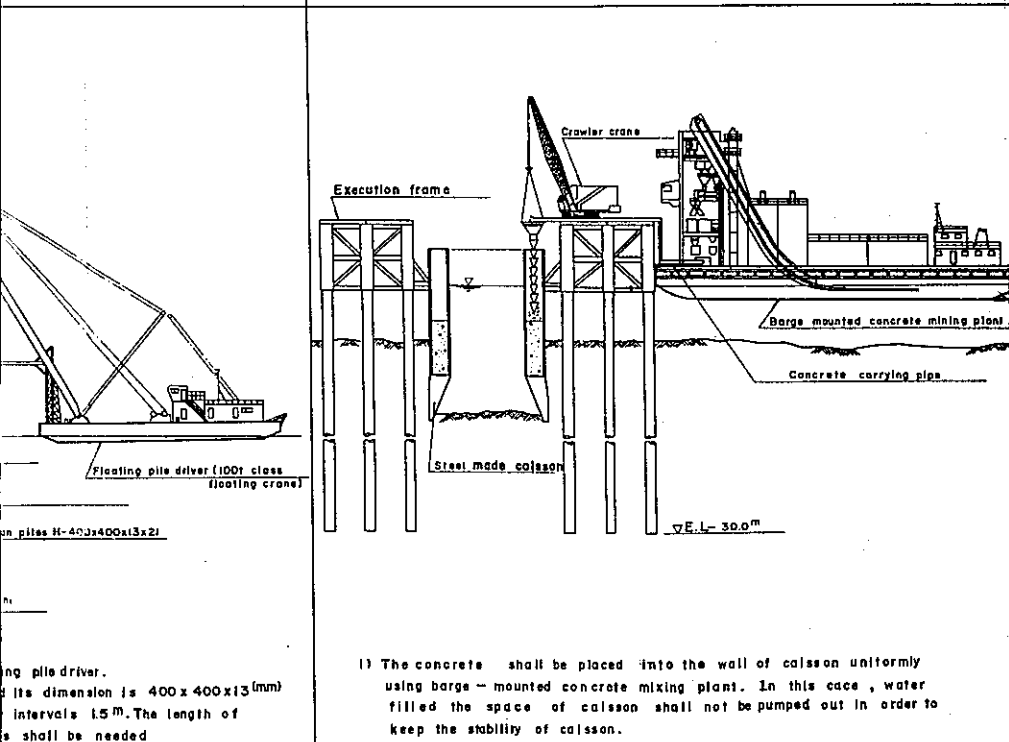
⑨ Setting of precast concrete cylinder.



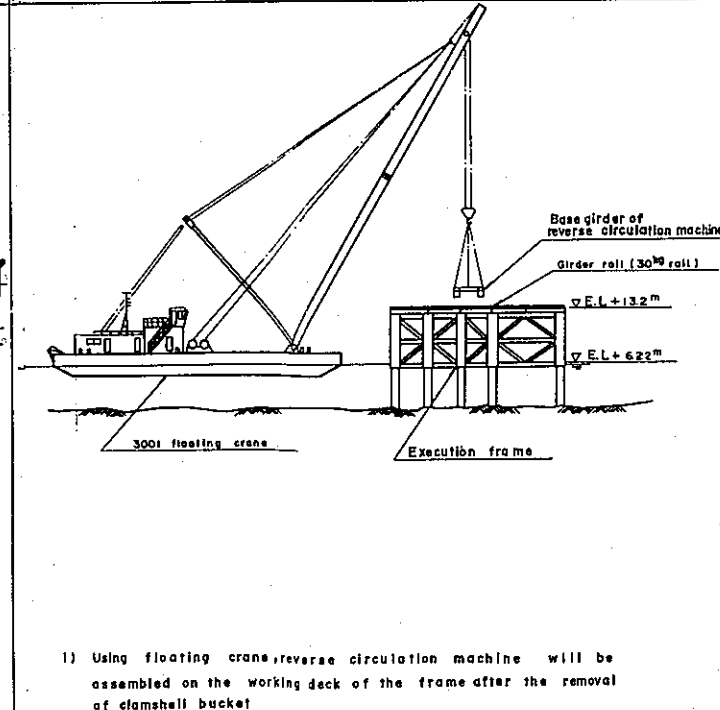
⑪ Sinking operation.



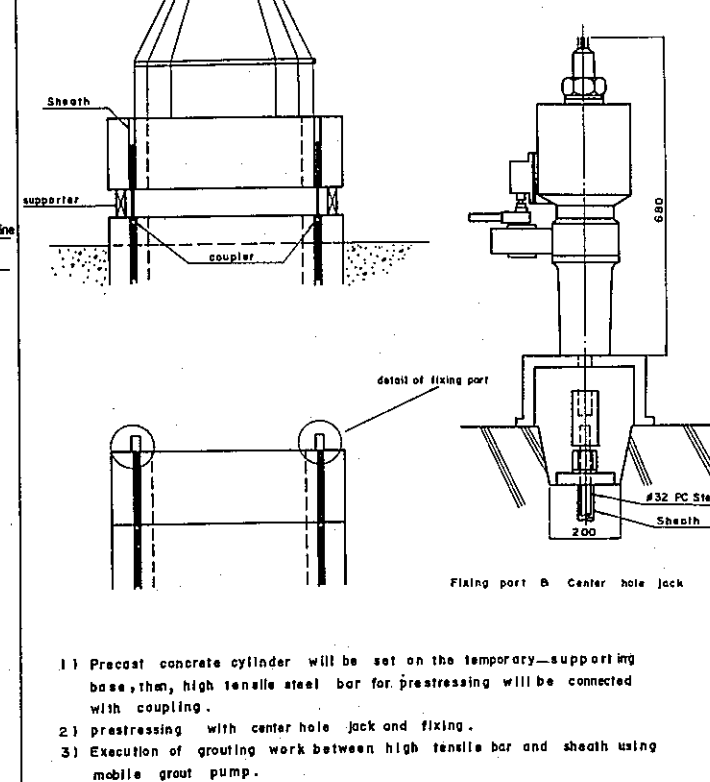
⑥ Placing of concrete into the wall of caisson



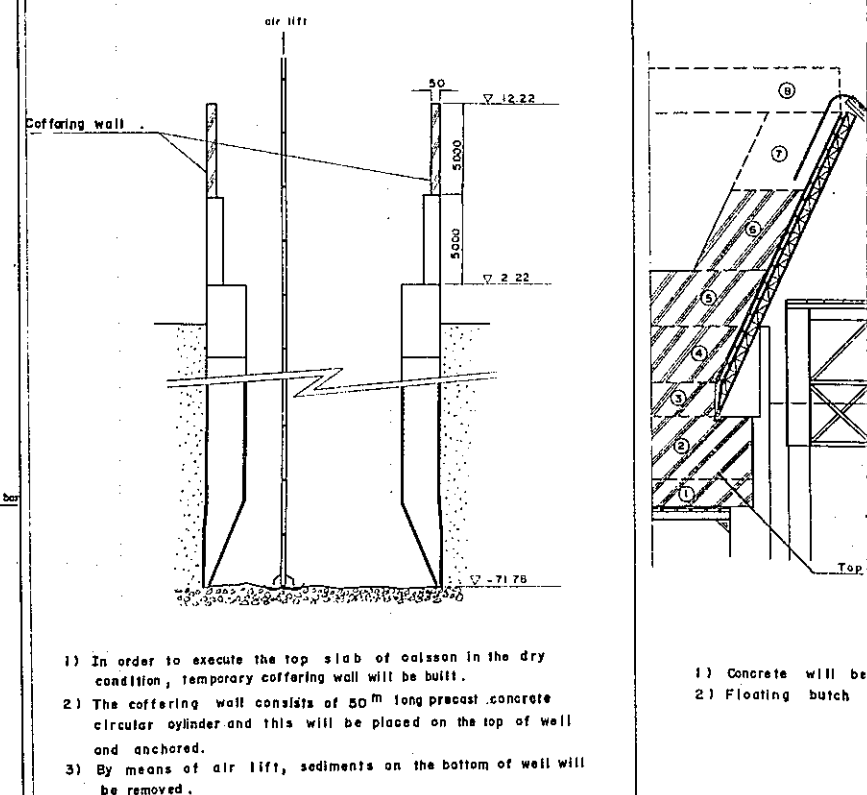
⑧ Assembling of reverse circulation machine.



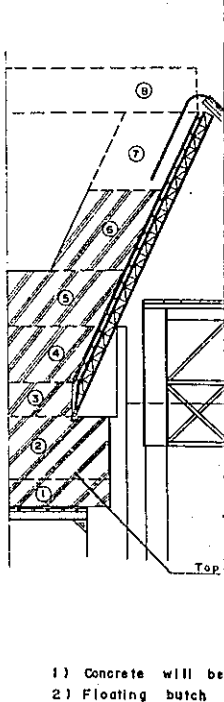
⑩ Prestressing and grouting.



⑫ Temporary coffering wall and cleaning of bed

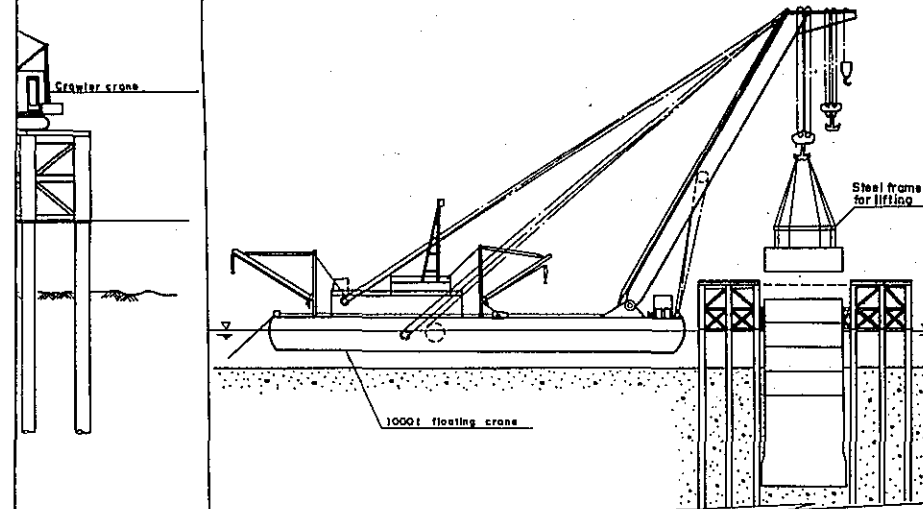


⑭ Construction



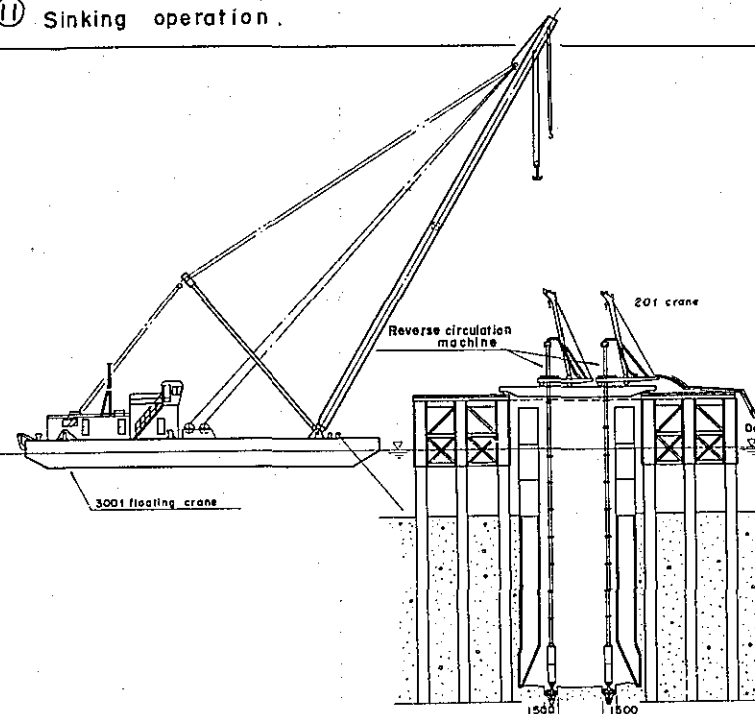
ION OF PIERS

⑨ Setting of precast concrete cylinder.



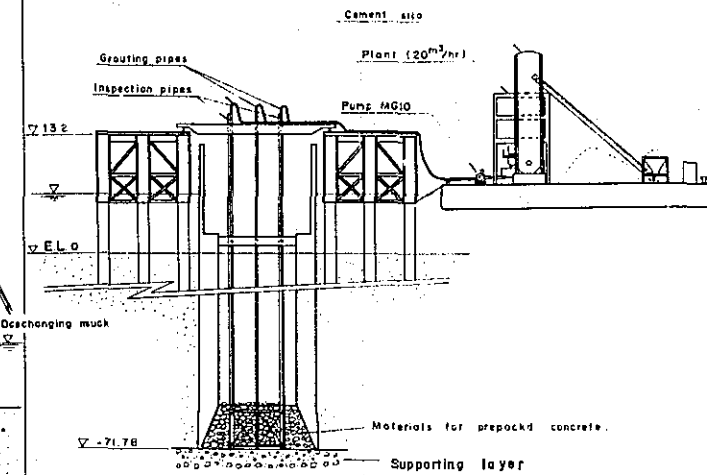
- 1) Precast concrete cylinder of 4m long previously made in yard will be shipped and set on the steel caisson shell filled with concrete.

⑪ Sinking operation.



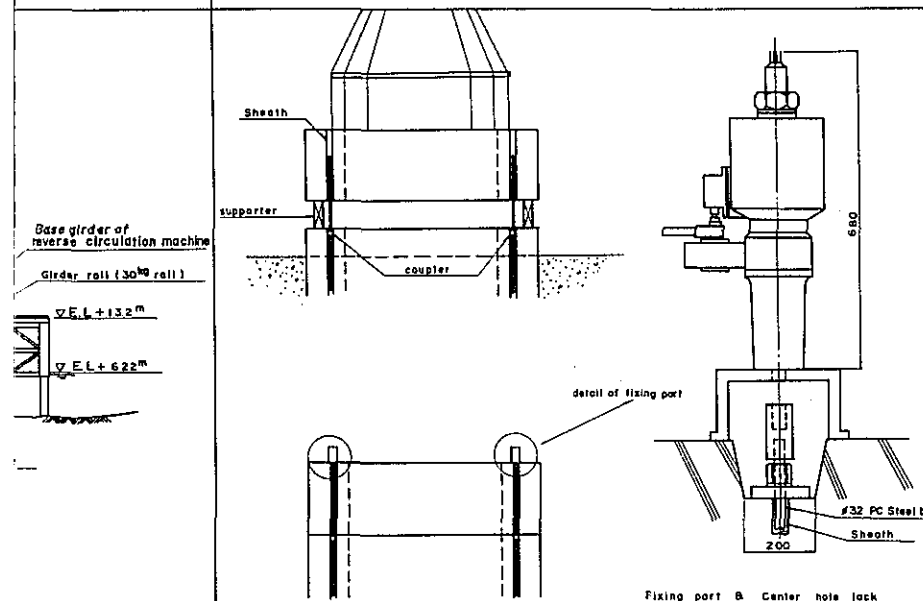
- 1) Excavation by reverse circulation machine—2 (bit diameter 2.0 m). Disposal of spoil will be done using air lift method and spoil will be discharged directly in the river.
- 2) Removal of drilling pipes, collars and bits will be done by 300th floating crane when the execution works will be completed.

⑬ Underwater concreting for caisson bottom.



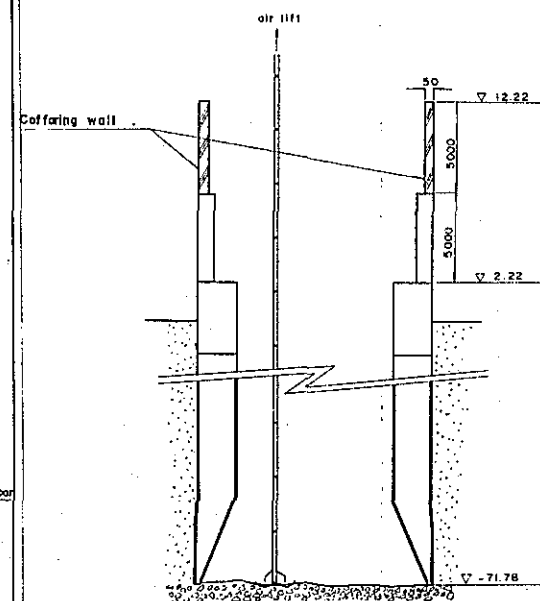
- 1) Aggregates will be placed by grab type dredger.
- 2) Then, 5 grouting pipes and 4 detecting pipes will be set.
- 3) Prepacked mortar will be grouted using 5 MG-10 grouting pump and 20m³/h prepacked mortar mixing plant.

⑩ Prestressing and grouting.



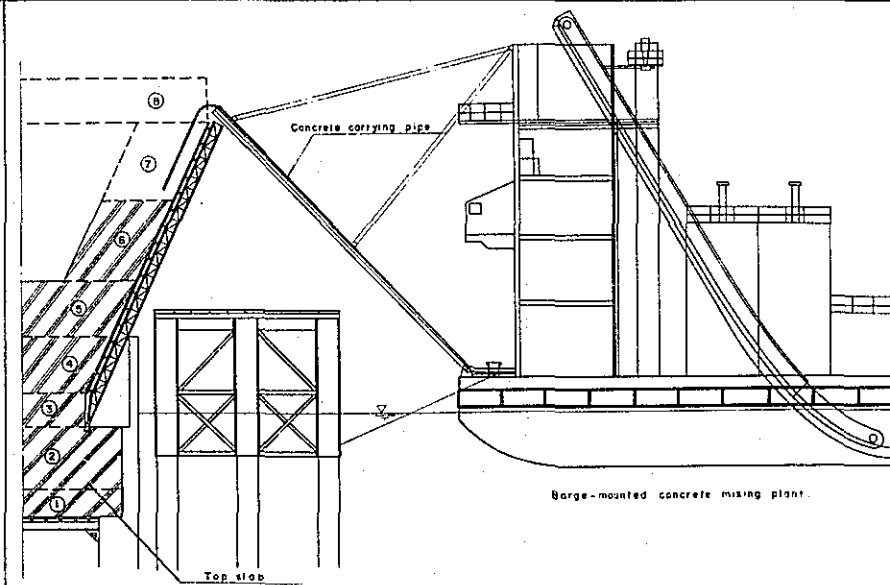
- 1) Precast concrete cylinder will be set on the temporary—supporting base, then, high tensile steel bar for prestressing will be connected with coupling.
- 2) prestressing with center hole jack and fixing.
- 3) Execution of grouting work between high tensile bar and sheath using mobile grout pump.

⑫ Temporary coffering wall and cleaning of bed



- 1) In order to execute the top slab of caisson in the dry condition, temporary coffering wall will be built.
- 2) The coffering wall consists of 50m long precast concrete circular cylinder and this will be placed on the top of well and anchored.
- 3) By means of air lift, sediments on the bottom of well will be removed.

⑭ Construction of top slab of well and pier.



- 1) Concrete will be placed from ① to ⑧ as shown.
- 2) Floating batch plant will be used for concreting.

PEOPLES REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT
VOLUME III BRIDGE
WORKING PROCESS OF EXECUTION OF PIERS
JAPAN INTERNATIONAL COOPERATION AGENCY
NIKKEN CONSULTANTS, INC.
Scale _____ Date _____
Drawn *T. Kamada* DRW NO 18
Approved *K. Tezuka*

