5/IX

STUDY REPORT ON JAMUNA BRIDGE PROJECT

BRIDGE WORKS

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PEOPLE'S REPUBLIC OF BANGLADESH

STUDY REPORT

ON

JAMUNA RIVER BRIDGE CONSTRUCTION PROJECT

BRIDGE WORKS

(FIRST STAGE)

MARCH 1975

JAPAN INTERNATIONAL COOPERATION AGENCY

NIKKEN CONSULTANTS, INC.

JAPAN ENGINEERING CONSULTANTS CO. LTD.

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ABBRIVIATION AND UNIT

Bangladesh	The people's Republic of Bangladesh
MOC	Ministry of Communications
BIWTA	Bangladesh Inland Water Transport Authority
MFCWRP	Ministry of Flood Control, Water Resources and Power
BWDB	Bangladesh Water Development Board
SOB	Survey of Bangladesh
Jamuna River	The Brahmaputra-Jamuna River
R & H	Roads and Highways Directorate
WAPDA	Water and Power Development Authority
JICA	Japan International Cooperation Agency
OTCA	Former name of JICA
Prefeasibility Report	Prefeasibility Report on the Jamuna River Bridge Construction Project prepared by the Preliminary Study Team of OTCA, MAR., 1973 (Written in Japanese)
Inception Report	Inception Report on Feasibility Study for Jamuna River Bridge Construction Project submited by the OTCA
DHWL	Design High Water Level
GL	Ground Level
WL	Water Level
GWL	Ground Water Level
HWL	High Water Level
LWL	Low Water Level
LLWL	Lowest Low Water Level

MLLWL	Mean Lowest Low Water Level
PWD	Public Works Department
PH	Proposed Height
B	Width
H	Height, Water depth
I	Slope
RB	River Bed
HRB	Height of River Bed
GH	Ground Height
L,l	Length
Q	Discharge
V	Velocity or Volume
N	N-value, given by Standard Penetration Test
JIS	Japanese Industrial Standard
DIN	Deutsche Industrie Norm (German Industrial Standard)
ASTM	American Society of Testing Materials
BS	British Standard
B,D	Diameter of foundation pile
C	Cohesion of soil
ϕ	Internal friction angle of soil
E	Modulus of Elasticity
K	Coefficient of soil reaction
m	meter
s,sec	second
cm	centimeter
mm	millimeter

km	kilometer
g, gr.	gram
kg	kilogram
lb	pound
t, ton	ton (metric)
f, ft, (')	foot
m^3/s	cubic meter per second
cfs	cubic foot per second
gal	gallon
in, (")	inch
yd	yard
mi	mile
ac	acre
hr	hour
mon	month
yr	year
sq	square
cu	cubic
max.	maximum
min.	minimum
kt.	knot

1 TK = 36 YEN

1 YEN = 0.0278 TK

1 YEN/m^3 = 0.0007866 TK/cft.	1 TK/cft. = 1271.3 YEN/m^3
1 YEN/m^2 = 0.002581 TK/sft.	1 TK/sft. = 387.5 YEN/m^2
1 YEN/m = 0.008467 TK/ft.	1 TK/ft. = 118.1 YEN/m

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
3.92727		

2. Area

(a)

m^2	ft^2
	10.764
0.09290	1
0.09183	0.9884

$1ft^2 = 144in^2$ $1in^2 = 0.006946ft^2$

(b)

ha	km^2	acre (エーカー)	$mile^2$
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

	m^3	ft^3	yd^3	gal
1	0.001	0.03531	0.001308	0.2642
1000	1	35.31	1.308	264.17
28.317	0.02832	1	0.03704	7.481
764.6	0.7646	27.00	1	201.97
3.7854	0.003785	0.1337	0.00495	1

4. Weight

kg	t	oz avdp	lb	t(sh)
1	0.001	35.27	2.2046	0.00110
1000	1	3.527×10^{4}	2204.6	1.1023
0.02835	2.835×10^{-5}	1	0.06250	3.125×10^{-5}
0.4536	4.536×10^{-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 (to °F from °C)

°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

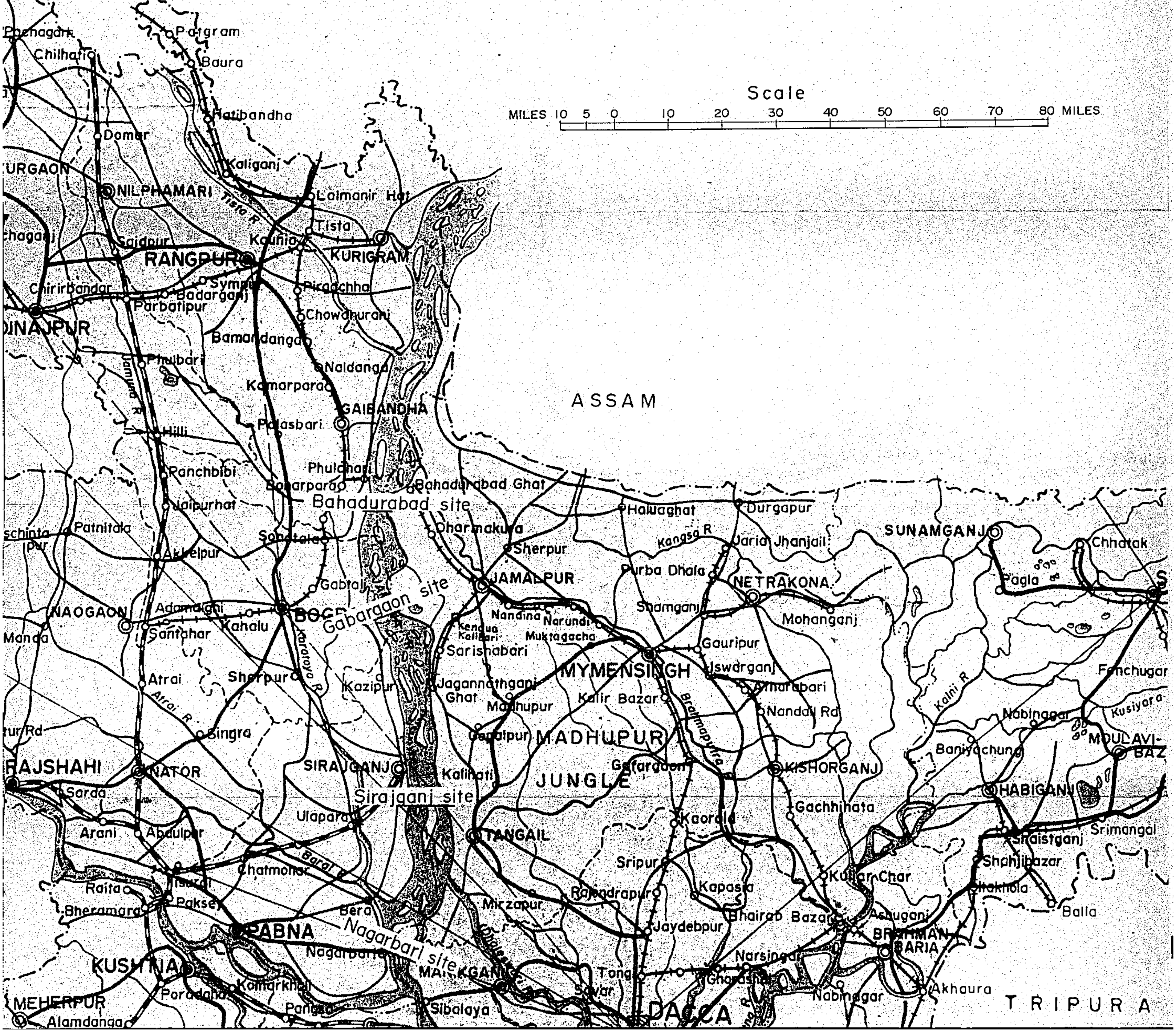
°C	0	10	20	30	40	50	60	70	80	90
0	32	50	68	86	104	122	140	158	176	194
100	212	230	248	266	284	302	320	338	356	374
200	392	410	428	446	464	482	500	518	536	554
300	572	590	608	626	644	662	680	698	716	734
400	752	770	788	806	824	842	860	878	896	914
500	932	950	968	986	1004	1022	1040	1058	1076	1094
600	1112	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

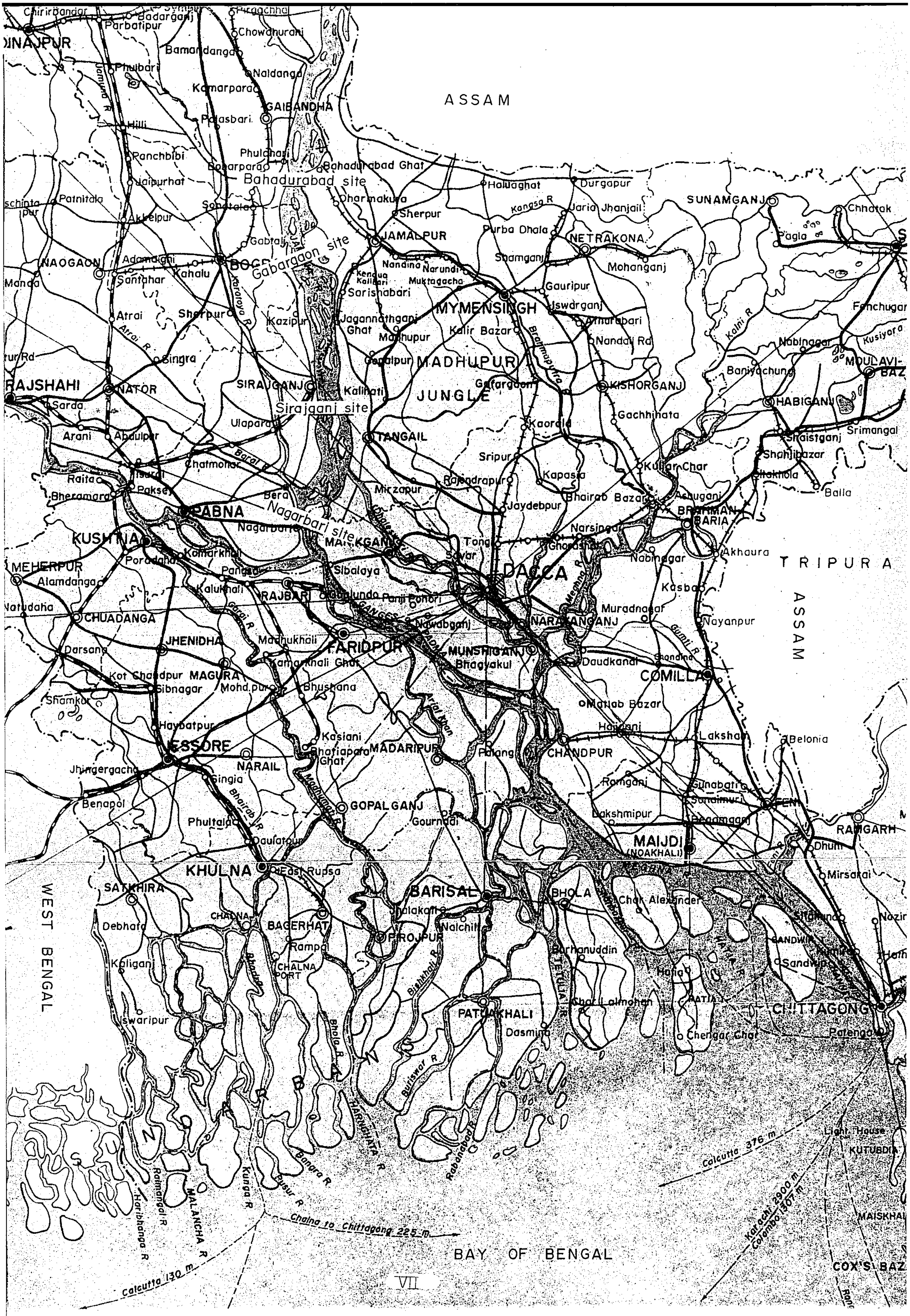
Inter-polation										
	°C	1	2	3	4	5	6	7	8	9
	°F	1.8	3.6	5.4	7.2	9.0	10.8	12.6	14.4	16.2

$5(t°F-50)=9(t°C-10)$

BANGLADESH

Map of proposed sites





ASSAM
TRIPURA
ASSAM
WEST BENGAL
BAY OF BENGAL
DINAJPUR
GAIBANDHA
Bahadurabad Ghat
Bahadurabad site
Gabargaon site
Sirajganj site
Nagarbari site
SUNAMGANJ
NETRAKONA
MYMENSINGH
JAMALPUR
MADHUPUR
JUNGLE
KISHORGANJ
HABIGANJ
RAJSHAHI
NATOR
NAOGAON
SIRAJGANJ
TANGAIL
PABNA
KUSHTIA
MEHERPUR
CHUADANGA
JHENIDHA
MAGURA
RAJBARI
FARIDPUR
DACCA
NARAYANGANJ
MUNSHIGANJ
COMILLA
BRAHMANBARIA
CHANDPUR
MAIJDI
(NOAKHALI)
JESSORE
NARAIL
MADARIPUR
GOPALGANJ
KHULNA
SATKHIRA
BAGERHAT
BARISAL
PIROJPUR
PATUAKHALI
BHOLA
CHITTAGONG
RAMGARH
KUTUBDIA
MAISKHAL
Light House
Chalna to Chittagong 225 m
Calcutta 130 m
Calcutta 376 m
Karachi 2900 m
Colombo 1307 m

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SUMMARY

For the purpose of river training, the guide-bank system was introduced and three types of guide banks were considered at each of the four proposed sites. The widths between a pair of guide banks which were considered are as follows.

Unit: km (mile)

Site	A-Type	B-Type	C-Type
Bahadurabad	2.0(1.2)	4.2(2.6)	5.6(3.5)
Gabargaon	2.0(1.2)	4.2(2.6)	5.2(3.2)
Sirajganj	2.0(1.2)	4.2(2.6)	5.6(3.5)
Nagarbari	2.0(1.2)	4.2(2.6)	5.2(3.2)

1. Width of bridge.

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

Considering the results of economic and traffic study of our team and referring to the Report of the Bangladesh Transport Survey, the following two cases were studied.

Case a.

Railway part:	Single broad gage track
Highway part:	Two-lane carriageways of total width 24 ft.

Case b.

Railway part:	Double broad gage tracks
	Four-lane carriageways of total width 48 ft.

2. Selection of materials.

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

Each clear span of the bridge will be determined by the horizontal clearance of navigation channel which is specified by the BIWTA, that is 250 ft.

Considering the above conditions, steel and concrete (prestressed concrete) are recommended as for the construction materials.

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

3. Superstructure of bridge.

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

As is generally known, cantilever truss type and/or continuous truss type is suitable for long span. Therefore, the structural type of main girder and its composition of span are selected as follows taking the minimum horizontal clearance of navigation channel and cost of bridge piers into consideration.

Three equal span continuous truss
(each span length is 100 m (328 ft))
Three equal span continuous truss
(each span length is 150 m (492 ft))
Multi-equal span cantilever truss
(each span length is 250 m (820 ft))
Multi-equal span cantilever truss
(each span length is 350 (1148 ft))

Comparing the merits and the demerits of the above-mentioned four types in consideration of cost of construction, we concluded that three span continuous truss (each span length is 492 ft) is more economical than the other cases in the case of the Jamuna Bridge.

4. Substructure of bridge.

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

According to the results of our test boring, we found that the reliable layer of thickness 7-10 m (23 - 33 ft) exists at several ten meters below ground level at every proposed site. It seems that such a gravel layer is suitable for the supporting layer of bridge foundation. This means that deep foundation will be needed for every pier of the bridge.

In general, bridge piers should be sunk enough to stand by themselves without any protection around them. In our case, if well foundation is applied, the scour depth at piers is estimated to be as about 1.8 times as the water depth, and if the multi-pile type foundation is applied, the scour depth at piers is assumed at about 10 m. The special consideration was given to the above-mentioned conditions for the design of bridge piers.

Because of the necessity of very deep foundation, well and multi-pile types were studied as types of foundation in consideration of simplicity of execution.

From the results of our studies, it has been calrified that the well foundation is more beneficial than the multi-pile foundation from the structural and economical point of view. Therefore, we concluded that the well is suitable for the substructure of the Jamuna Bridge.

5. Construction costs

The total costs of bridge construction (included approaches) at each of four proposed sites and two cases of the bridge types are shown as the table of next page.

Total costs of bridge construction

	Proposed site	Distance btw. guide banks	Total costs (10^6 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	1,008
	Nagarbari	4.2 km	878
		5.6 km	1,024
Case b Four lanes Double tracks	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

CHAPTER I

INTRODUCTION

1. General.

This report was prepared to summarize the results of the first stage investigations which were carried out by the Bridge Study Team for 14 months, from Aug. 1973 to Oct. 1974 conforming to the Inception Report which submitted to the People's Republic of Bangladesh by JICA (former OTCA) in Aug. 1973.

Japanese Preliminary Study Team (The chief, Mr. Ishio Kawasaki) was organized in Dec. 1972 by JICA to be sent to the People's Republic of Bangladesh. As for the Jamuna Bridge Construction Project, the Team proposed the following four sites. Namely, these are, in order of the site from upstream to downstream of the Jamuna River, just downstream site from Bahadurabad, adjacent site to Gabargaon, the site about 10 Km downstream from Sirajganj and the site about 20 Km upstream from Aricha.

The purpose of the bridge study is to obtain the fundamental data for selection of the most suitable structural type of superstructure and substructure for the bridges at four proposed sites and for the decision of their priority from technical and economical stand point of view based on the data collected by the Bridge Study Team in Bangladesh and Japan in 1973 and utilizing the data collected by the Geological Study Team, the River Trainning Team and the other Study Teams.

To attain the purpose of this study, JICA sent five members Mr. Tezuka, Mr. Sakurai, Mr. Tanaka, Mr. Wakabayashi and Mr. Kamide to Bangladesh for reconnaissance and collection of data from 7th. Jan. to 27th. Jan. 1973. After the collection of these data in Bangladesh and Japan, these members accomplished the basic plan for this bridge construction project in Japan, and preliminary design for the composition of width and span, and for superstructure and substructure were made in every case in accordance with the requirements and the standards for design. At the same time, the bridges in the domain of access parts were examined in the same way and the rough construction costs for each one of four proposed sites were estimated respectively.

Outlines of chapters are as follows.

Appendices contain the exchange notes and the data collected in Bangladesh.

2. Organization of the study team.

The organization chart for the Jamuna Bridge Study Team is shown in Fig. I-1. The Bridge Study Team consists of following three companies and the study works were carried out in collaboration.

The Members of the Team are as follows.

i) NIKKEN Consultants, Inc.

ii) Japan Engineering Consultants Co., Ltd.

iii) Japan Bridge & Structure Institute, Inc.

3. Major staffs.

The works in 1973 were laid stress on field study, and in 1974 the works were done chiefly by the staffs who carried out the field study. Dr. Inose, the Leader in general, instructed the staffs at all times.

Major staffs who were engaged in the study are as follows.

Mr. Kaoru Tezuka Leader of Bridge Study Team

Mr. Takeo Sakurai

Mr. Toshio Tanaka

Mr. Yoshihiko Wakabayashi

Mr. Tadao Kamide

4. Schedule for works and field study.

The work schedule of the Bridge Study Team in 1974 are shown in Table I-1.

Fig. I-1

ORGANIZATION CHART OF JAMUNA BRIDGE FEASIBILITY STUDY TEAM, JICA, JAPAN

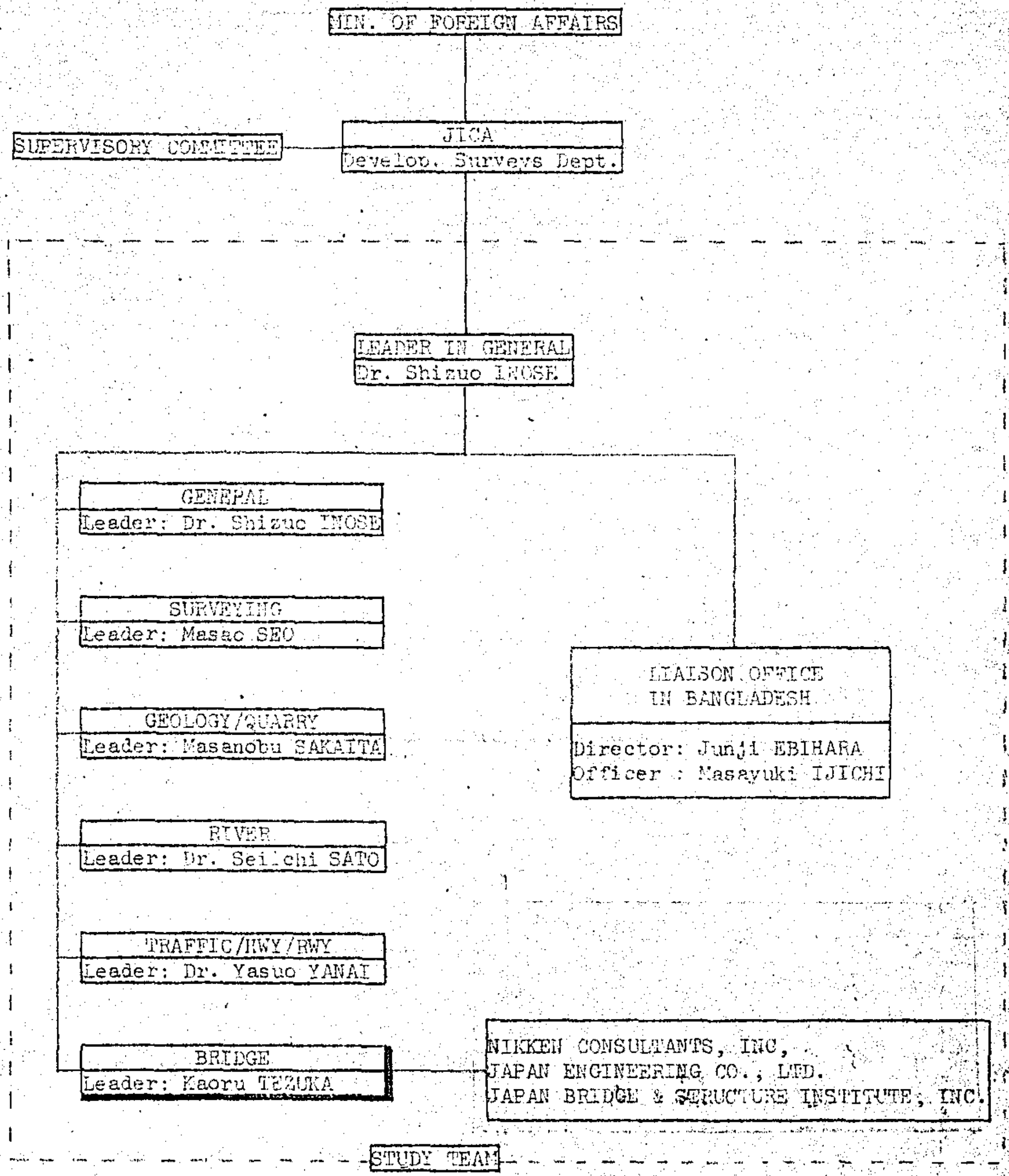


Table 1-1 Work Schedule (First Stage)

Items of study works	1974									1975			Remarks
	4	5	6	7	8	9	10	11	12	1	2	3	
General study	□	□	□										■ in Bangladesh
Study of types and basic dimensions		□	□	□									□ in Japan
Study of approaches	□	□	□	□									A : Meeting in Tokyo
Preparation of general view	□	□	□	□									B : Meeting in Dacca
Study of execution method		□	□	□	□								
Study of unit price		□			□								
Estimation of amount of materials			□		□	□							
Rough estimate of construction costs			□		□	□							
Draft and print of reports				□	□		□	□			□		
Meeting					□ A		■ B						

In Bangladesh, the Bridge Study Team carried out the field study in 1973 and the Team took part in the Dacca meeting in 1974. Tables I-2 and I-3 show the schedule for them.

Table I-2 Schedule for field study at Bangladesh in 1973

7 Jan. '74 Mon.	Departure from Tokyo. Arrival in Bangkok.
8 Jan. '74 Tue.	Arrival in Dacca from Bangkok. Discussion and adjustment of work schedule.
9 Jan. '74 Wed.	Greeting to MOC and Embassy. Preparation of schedule in English.
10 Jan. '74 Thu.	Greeting to MOC and interview to the Minister of MOC. Discussion of Surveying Items with counterparts.
11 Jan. '74 Fri.	Examination of surveying schedule and items.
12 Jan. '74 Sat.	Inspection of Sitarakya Br. and discussion.
13 Jan. '74 Sun.	Inspection of roads, ferries and bridges contained in district of Meghna Rv.
14 Jan. '74 Mon.	Inspection of King George VI Br. at Bhairab Bazar.
15 Jan. '74 Tue.	Discussion in R & H, collection of data. Departure from Dacca St. by train.
16 Jan. '74 Wed.	Arrival in Jagannathganj Ghat, inspection of the banks of Jamuna Rv. Arrival in Sirajganj.
17 Jan. '74 Thu.	Inspection of Sirajganj site of proposed sites and Char.
18 Jan. '74 Fri.	Departure form Sirajganj by speedboat, inspection of surrounding conditions of Jamuna Rv. Arrival in Aricha. Inspection of several bridges between Aricha and Dacca. Arrival in Dacca.
19 Jan. '74 Sat.	Discussion among Highway, Railway and Ferry Team. Arrival in Calcutta from Dacca by airway.
20 Jan. '74 Sun.	Inspection of Vivekanada Br. and Howrah Br. Arrival in Dacca from Calcutta.
21 Jan. '74 Mon.	Discussion of schedule. Collection and arrangement of data.
22 Jan. '74 Tue.	Collection of data.
23 Jan. '74 Wed.	Inspection of Hardinge Br. at Paksey.
24 Jan. '74 Thu.	Inspection of Isurdi St. Arrival in Dacca.

25 Jan. '74 Fri.	Reconnaisance of near Tangail at Sirajganj site.
26 Jan. '74 Sat.	Final discussion of schedule. Data arrangement.
27 Jan. '74 Sun.	Data arrangement.
28 Jan. '74 Mon.	Inspection of Port of Chittagon and Khulna.
29 Jan. '74 Tue.	Inspection of surroundings at Kaptai.
30 Jan. '74 Wed.	Data collection and arrangement.
31 Jan. '74 Thu.	Greeting to MOC and Japan Embassy. Arrival in Calcutta from Dacca.
1 Feb. '74 Fri.	Arrival in Bangkok from Calcutta.
2 Feb. '74 Sat.	Arrival in Tokyo from Bangkok.

Table I-3 Schedule for Dacca meeting in 1974

28 Oct. '74 Mon.	Arrival in Bangkok from Tokyo.
29 Oct. '74 Tue.	Arrival in Dacca from Bangkok. Greeting to the Embassy. Discussion and adjustment of schedule.
30 Oct. '74 Wed.	Greeting to MOC and its related divisions.
31 Oct. '74 Thu.	Conference: explanation of Agenda, costs and materials.
1 Nov. '74 Fri.	Discussion for each division after conference.
2 Nov. '74 Sat.	Conference.
3 Nov. '74 Sun.	Preparation of Agreed minutes.
4 Nov. '74 Mon.	Conference, adjustment of Agreed minutes.
5 Nov. '74 Tue.	Ceremony for signature of Agreed minutes. Greeting to Embassy. Arrival in Bangkok from Dacca.
6 Nov. '74 Wed.	Arrival in Tokyo from Bangkok.

CHAPTER II

GENERAL CONSIDERATION

1. Reconnaissances at the Bangladesh.

The Bridge Planning Team carried out some reconnaissances, collection of data necessary for planning and design of bridge and some confirmation and discussion with the Bangladesh government authorities concerned from 8th Jan. to 1st Feb. in 1974 in Bangladesh. These data were reviewed and studied, and used as the base of this report.

The contents of data collected during the reconnaissance at the bridge site are found in ANNEX-1.

As for the general design specifications of railway and highway bridge, a meeting was held between the Japanese Feasibility Study Team and the delegates of the Government of Bangladesh, and general items were agreed between both the parties as follows. While, details of design specifications will be stated in CHAPTER III, DESIGN CONDITIONS AND STANDARD.

a. Live Load.

Live load to be used for design of railway bridge will be specified by Main Line Loading of Bridge Code for Indian Railways. (Fig. II-1) Live load for highway bridge will be specified by the I.R.C. Standard Vehicle Class A. (Fig. II-2)

b. Track Gage.

The track gage for design shall be 5'6" (Broad gage).

c. Navigation Clearance.

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

Minimum horizontal clearance .... 250 feet.

Minimum vertical clearance .... 40 feet.

Fig. II - I BROAD GAUGE STANDARD LOADINGS OF 1926

AXIAL LOAD OF 22.5 TONS

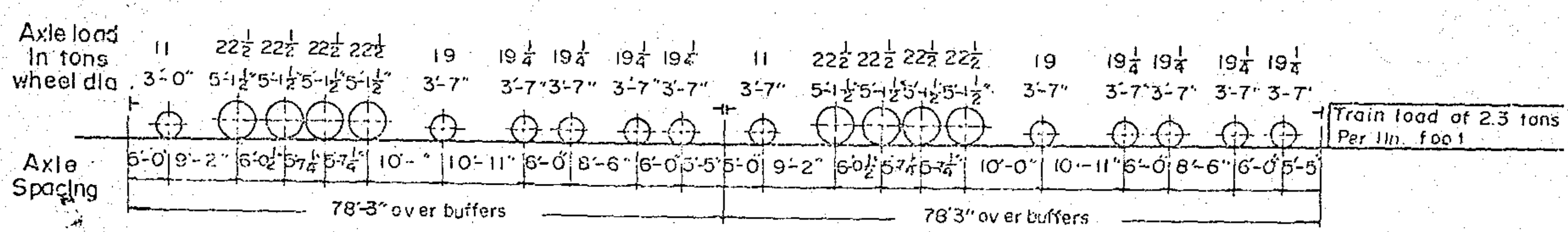
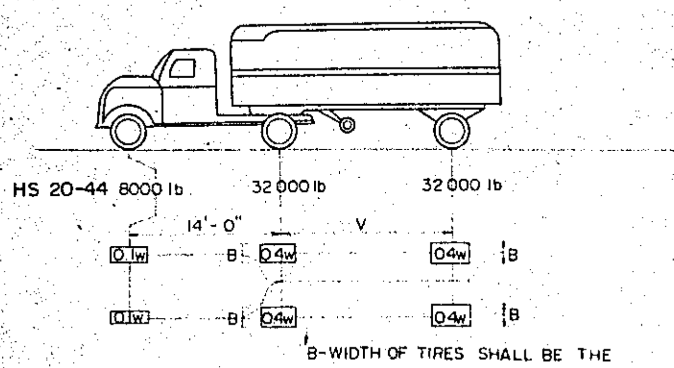
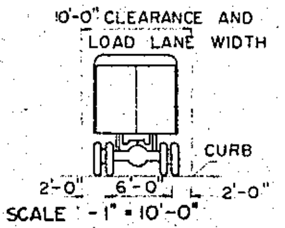


Fig. II-2 IRC STANDARD VEHICLE

A ASHO HS20-44-16-44 STANDARD VEHICLE



SCALE :- 1" = 10'-0"



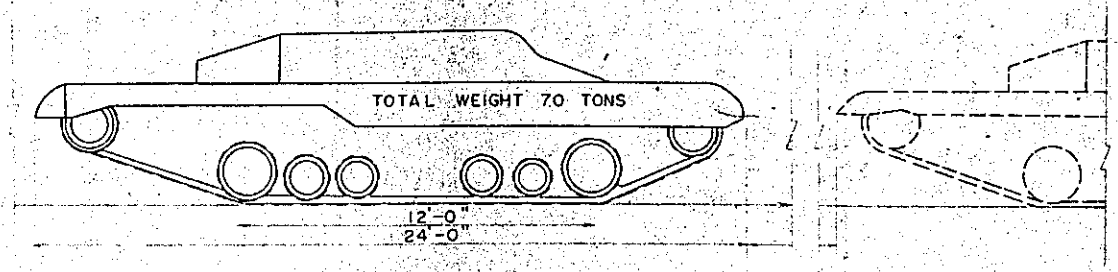
SCALE :- 1" = 10'-0"

W = COMBINED WEIGHT ON THE FIRST TWO AXLES WHICH IS THE SAME AS FOR THE CORRESPONDING H TRUCK

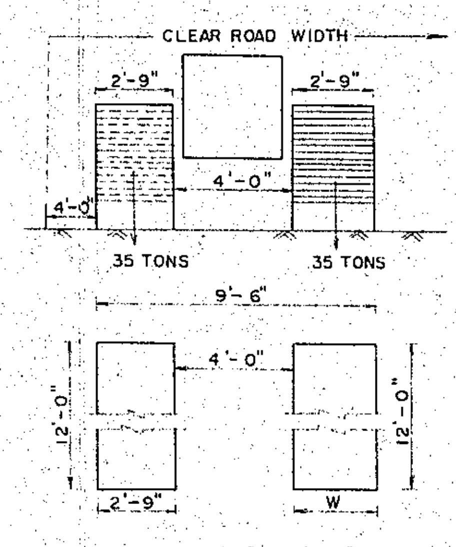
V = VARIABLE. SPACING - 14 FT TO 30 FT INCLUSIVE. SPACING TO BE USED IS THAT WHICH PRODUCES MAXIMUM STRESSES

IMPACT FACTOR I HS-20 = $\frac{50}{L+125}$ ≯ 30 PERCENT

IRC CLASS 'AA' TRACKED VEHICLE



SCALE :- 1" = 4'-0"



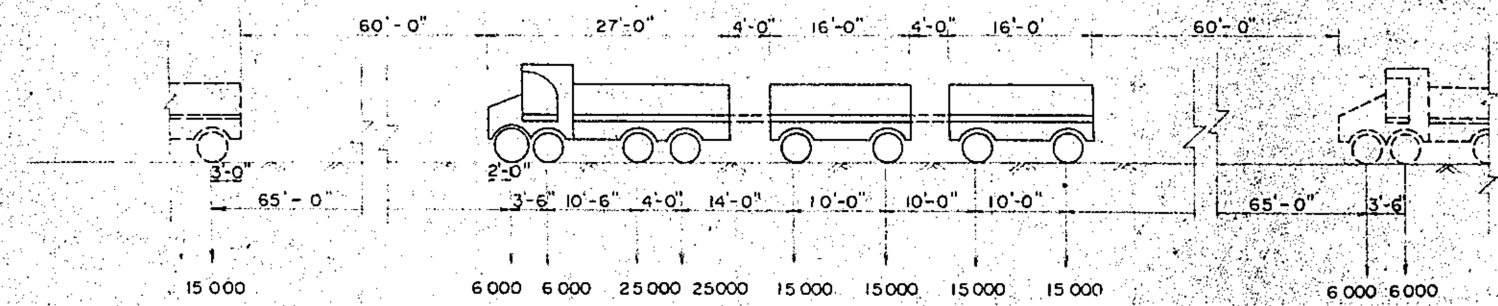
SCALE :- 1" = 4'-0"

IMPACT FACTOR $I = \frac{15}{L+20}$ ≯ 25 PERCENT

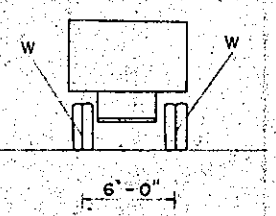
NOTES :-

1. THE NOSE TO TAIL SPACING BETWEEN TWO SUCCESSIVE VEHICLE SHALL NOT BE LESS THAN 300 FT
2. NO OTHER LIVE LOAD SHALL COVER ANY PART OF THE CARRIAGEWAY OF THE BRIDGE WHEN THIS VEHICLE IS CROSSING THE BRIDGE

IRC STANDARD VEHICLE CLASS 'A'

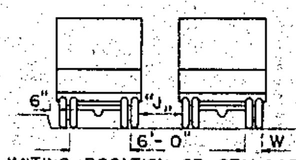


SCALE : - 1" = 12'-0'



SCALE :- 1" = 8'-0"

IMPACT FACTOR I IRC = $\frac{15}{L+20}$ ≯ 50 PERCENT



LIMITING POSITION OF STANDARD TRUCK-TRAIN LOADING WITH REFERENCE TO A TRAFIC LANE
(FOR ground conpact area and value of "J" see table 1 and 2)

CLASS OF LOADING	AXLE LOAD (Lbs)	GROUND COTACT AREA (in) B	GROUND COTACT AREA (in) W
"A"	25 000	10	20
	15 000	8	15
	6 000	6	8
"B"	15000	8	15
	9 000	6	12
	3600	5	7

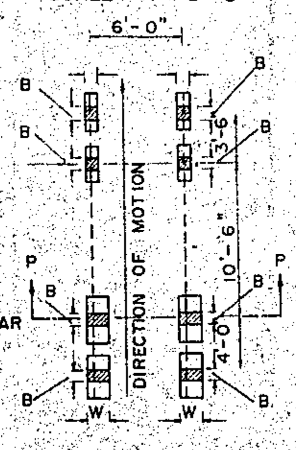
TABLE 1

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

CLEAR ROAD WIDTH	"J"
16'-8" or Less	0
16'-8" to 18'-0"	Increasing uniformly from 0 to 1'-4"
18'-0" to 24'-0"	ditto 1'-4" to 4'-0"
Above 24'-0"	4'-0"

TABLE 2

LOADING CLASS "A" FOR HIGHWAY BRIDGES



SCALE :- 1" = 8'-0"

REFERENCE :-
COPIED FROM OLD BLUE PRINT

OFFICE OF THE SENIOR STRUCTURAL DESIGNER R&H GOVT. OF EAST. PAKISTAN, DACCA.		
DETAILS OF IRC CLASS-"A" & CLASS-"AA" LOADING & AASHO-Hs20-44 LOADING		
DRAWN By		DRG. NO. S.D.II / 19/70 - 7
TRACED By	SR. STR. DESIGNER (R & H) / STR. DESIGNER NO. II.	DATE 12 - 12 - 70
CHECKED By	ASSTT. STR. DESIGNER	SCALE AS SHOWN

2. Proposed sites of bridge.

The Preliminary Survey Team has proposed the following four sites for bridge crossing.

Site - 1 Bahadurabad

Site - 2 Gabargaon

Site - 3 Sirajganj

Site - 4 Nagarbari

At the first stage of this study, the study team shall compare the four proposed sites for bridge construction and decide the most suitable site in accordance with the three criteria mentioned in the Inception Report.

3. Selection of bridge types from the aspect of transportation system.

The following types of bridge can be considered.

a. Highway bridge.

b. Railway bridge.

c. Railway-cum-highway bridge.

The transport network in the People's Republic of Bangladesh consists of railway transport, highway transport, inland water transport and air-route transport, among which railway and inland water transport are most important.

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 takes precedence of highway bridge. But according to the recent study for land transportation in Bangladesh, highway transportation is increasing gradually by the strengthening of capacity of road ferry. Such transport tendency can not be disregarded. It is natural that the highway bridge across the Jamuna River is also necessary for the improvement of future highway network in Bangladesh.

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

We judged that it is the best way to construct railway-cum-highway bridge considering future transport network and economic development of Bangladesh. Therefore the assumed type of bridge which is selected at the most suitable site shall be the railway-cum-highway bridge.

According to the Feasibility Report performed by Freeman, Fox and Partners (stage 1), it is reported that the estimated benefit-cost ratio of railway-cum-highway bridge will be about double of that of highway bridge.

4. Width of bridge.

The determination of effective width of the Jamuna Bridge is one of the most important matter 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 an effective width of the Jamuna bridge. One way is to determine the effective width of bridge so as to minimize the total cost of construction of the bridge. This will be done by giving the least necessary width to the bridge considering future increase of traffic volume. The other way is to determine the effective width of bridge taking future increase of traffic volume through the bridge and also future economical development of the Bangladesh into consideration. In this case, higher cost of construction will be needed than previous case but is desirable for the future development of Bangladesh.

Taking above-mentioned two ways of thinking into consideration, we carried out the study of following two cases.

Case a.

Railway part: Single broad gage track. (5ft 6in)

Highway part: Two-lanes carriageway of total width 24ft.

Case b.

Railway part: Double broad gage track.

Highway part: Four-lanes carriageway of total width 48ft.

In case b, so far as 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 is added in accordance with an increase of traffic volume through the bridge.

The standard cross section of above-mentioned two cases are shown in Fig. II-3.

5. Scopes of works for bridge planning.

The proposed bridges were classified into the next two scopes.

a. Main bridge over the Jamuna River
Main bridge over the Jamuna River and banking, viaduct included in approach road.

b. Bridges included in link parts
Railway bridges included in the rail links and Road bridges included in the road links.

Above-mentioned classifications and definitions shall be shown in Fig. II-4.

6. Preliminary selection of bridge type.

6-1 Main bridge over the Jamuna River.

Choice of type for bridge may be considered from the following three aspects.

Selection of materials.
Selection of types of superstructure.
Selection of types of substructure.

6-1-1 Materials for superstructure.

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

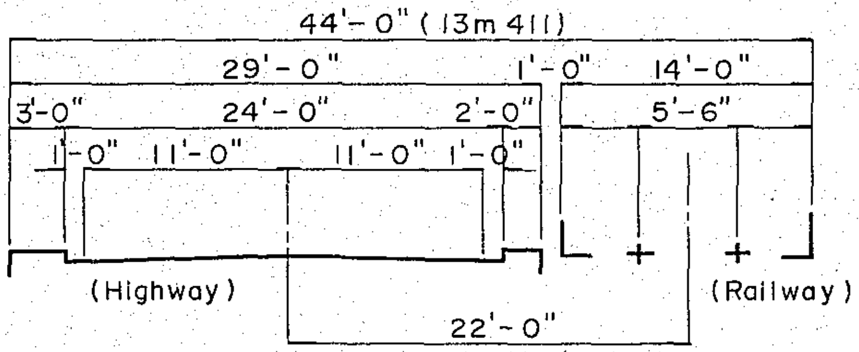
The each clear span of the bridge will be determined by the width of navigation clearance which is specified by the BIWTA, that is 250 ft.

Considering above conditions, steel and concrete (prestressed concrete) are recommended as for the construction materials.

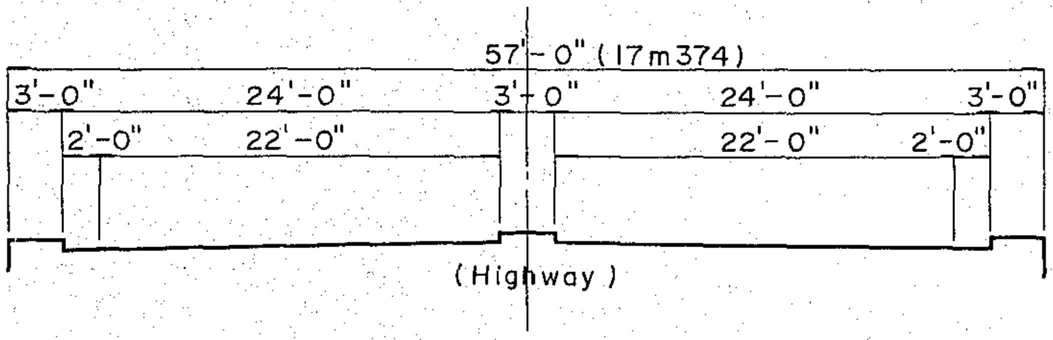
The merits of steel bridge as compared with prestressed concrete bridge are as follows.

Fig. II-3 STRUCTURAL WIDTH OF BRIDGE

a) In case of two lanes, single track.



b) In case of foure lanes, double track
(for double decks)



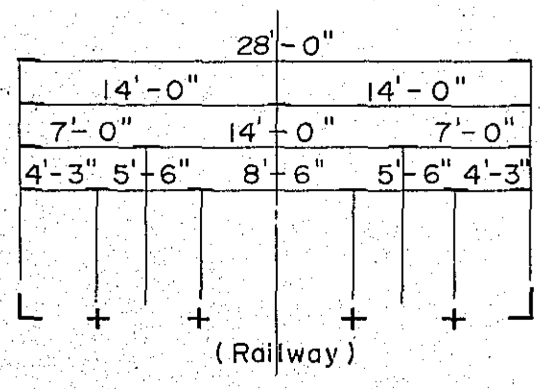
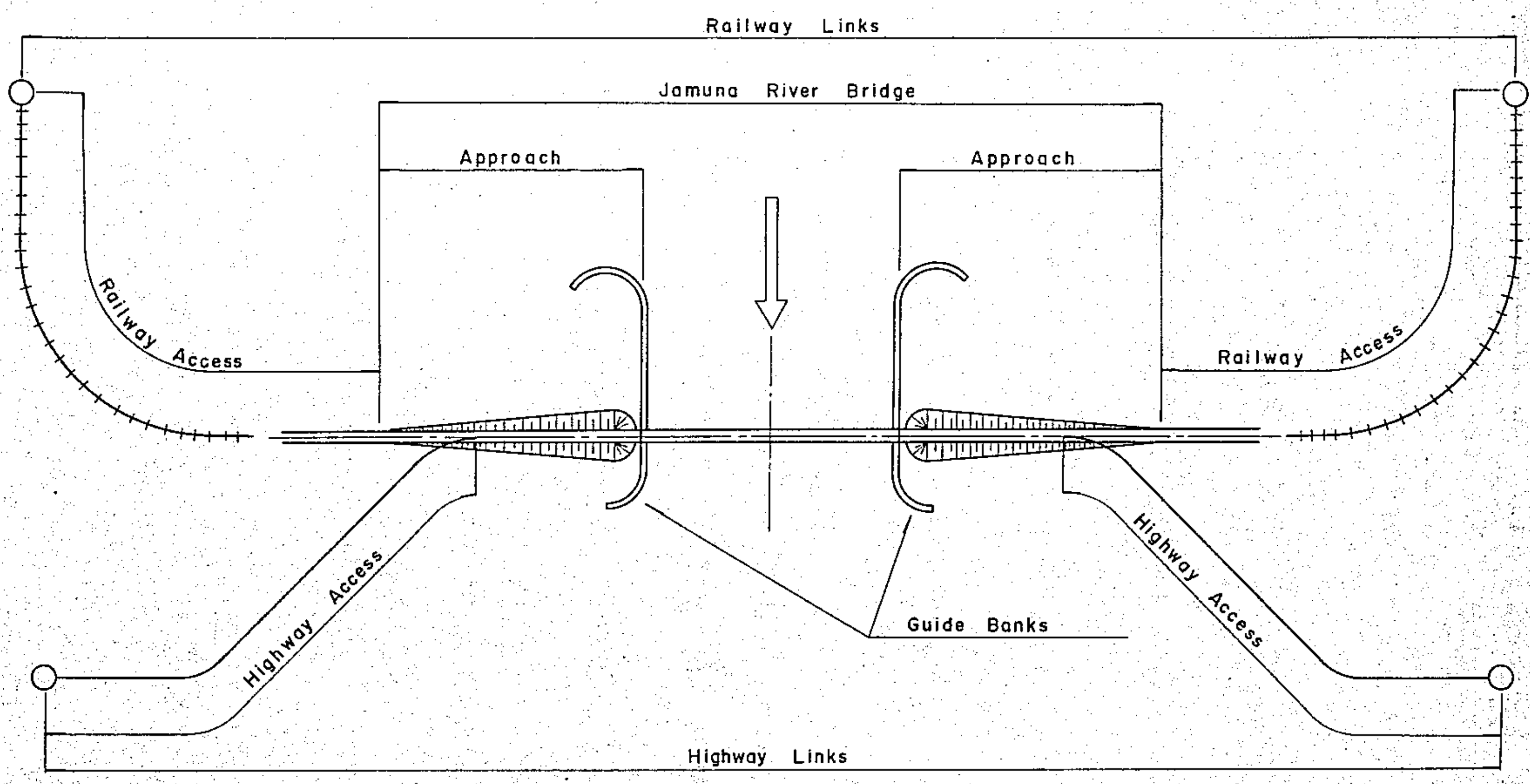


Fig. II-4 Descriptive figure of the study



a. The weight of steel bridge is lighter than that of prestressed concrete bridge, therefore the inertia force of steel bridge due to earthquake acted to substructure of the bridge is smaller than that of prestressed concrete bridge when the supported length is equal. This means that the cost saving of substructure can be expected.

b. Steel bridge is more practicable and advantageous to apply to longer span than prestressed concrete bridge.

Erection of steel bridge is easier and faster than that of prestressed concrete bridge, so it is possible to cut the period of construction work.

c. When the multipile foundation system is applied to the substructure, such system will be deflected horizontally by current pressure. Effect of horizontal displacement of bridge shoe due to such deflection can be easily treated in the case of steel bridge.

The demerits of steel bridge are as follows.

a. Higher cost of maintenance will be needed. (for example, cost of repainting etc.)

b. Possibility of application of domestic materials will be limited.

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

6-1-2 Superstructure.

It is clear that very deep foundation is needed for the Jamuna River Bridge and its cost is high. This means that the proportion of cost of substructure to total construction cost of bridge is high. In order to minimize the total construction cost of bridge, it is expected that the structural types of bridge should be selected among various types of bridge applicable to long span.

As is generally known, cantilever truss type and/or continuous truss type is suitable for long span bridge. Therefore, now we are carrying out bridge planning work taking three equal span continuous truss (length of each span is 328 ft and 492 ft) and multiequal span cantilever truss (length of each span is 820 ft and 1148 ft) into consideration.

6-1-3 Substructure.

The Jamuna River is braided river, so even if the guide bank system is applied for the river training in order 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 foundation of all piers should have equal depth.

According to the result of our test boring, reliable gravel layer exists several ten meters below ground level at every four proposed sites. This means that the deep foundation will be needed for every pier of the bridge.

Accordingly, in order to determine a composition of span, it is necessary not only to consider harmony and simplicity of structure but also to reduce the total cost of construction as much as possible.

Because of the necessity of very deep foundation, well and multipile foundation were assumed as the types of substructure in consideration of simplicity of execution. Well foundations are frequently applied in Bangladesh, but in this type, though there will be no primary difficulties, very large scale work should be necessary because it is requested to sink the well about 230-300 ft. under the high water level.

In the case of multipile foundation systems, it is necessary to drive in large steel piles in the bearing layer and to connect with heads of these steel piles rigidly above the water level.

This type is superior in execution than the former, but may be more flexible due to its structural mechanism, and in the case of pile foundation as mentioned above, local scouring around the pier is comparatively less than in the case of well foundation.

6-1-4 Approaches.

It is the cheapest way to connect a bridge with access railway by embankment provided that the bearing power of ground under such an embankment is to resist enough to the weight of embankment.

If these conditions should not be satisfied, many short span bridges for railway approach should be requested. But these details will be studied in the 2nd stage of this project.

This embankment crosses the guide banks at right angle each other and the embankment with a length of about 2.6 mile will be needed provided that the allowable maximum longitudinal slope of railway is 1/200. This length of embankment is also required from the river training view point and the alignment of embankment is preferable to be a straight line.

The center line of highway approach must be shifted from the center line of railway approach in the case b in order to connect the carriageway of bridge with the carriage way of access road.

As the level of carriageway of bridge is comparatively high and the center line of highway approach consists of curved part, it is easier to construct a steel bridge than to construct a reinforced or prestressed concrete bridge. Therefore we selected a steel bridge at the first stage of this project. Comparison of reinforced or prestressed concrete bridge with steel one will be performed at the second stage of this project in accordance with necessity.

These viaduct shall be supported by pile foundation

6-2 Access parts.

The bridges of span over 300 ft included in the domain of railway access or highway access part are shown in Table II-1 and II-2 with the data of names of rivers, total bridge length and minimum navigation clearance in each proposed route respectively.

Navigation clearances are generally shown in the map of BIWTA. Besides these data, 12 ft in min. vertical clearance and 100 ft in min. horizontal one are necessary as the navigation clearance in the Bangali River, Karatoya River (upstream of Bogra city) and Chatal River.

Navigation clearances about the other rivers were assumed by reference to the scale and capacity of rivers and navigation clearance of the existing bridges.

These clearance of bridges included in the domain of the proposed railway or highway axcess parts, must be ascertained at the second stage of this project.

Bridges in access part have medium spans in design, so reinforced or prestressed concrete bridges are preferable as construction system in this domain in order to be available for the application of domestic materials and to give a chance to the local constructors. In this case, reinforced concrete or prestressed concrete bridge will be cheeper than steel bridge.

Table II-1 Data of Bridges (longer than 330 ft.) in the Domain of Railway Access

No. of Site	Right Side of River-Bank					Left Side of River-Bank					Numbers of Bridges
	Location (mile)	Name of the River	Total Bridge Length (ft)	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	Location (mile)	Name of the River	Total Bridge Length (ft)	Min. Horizontal Clearance (ft)	Min. Vertical Clearance (ft)	
1	4.8	Bangali	980	100	12	—	—	—	—	—	2
	7.8	"	660	100	12	—	—	—	—	—	
2	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	—	—	—	—	—	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	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.II-2 Data of Bridges in the Domain of Highway Access.

No. of Site	Right Side of River Bank					Left Side of River Bank					Numbers of Bridges
	Location (km)	Name of the River	Bridge Length (ft.)	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance (ft.)	Location (km)	Name of the River	Bridge Length (ft.)	Min. Horizontal Clearance (ft.)	Min. Vertical Clearance (ft.)	
1		Bangali	980	100	12		—	330	100	12	3
		Bangali	660	100	12		—	—	—	—	
2		Karatoya	330	100	12		—	330	60	6	5
		Bangali	980	100	12		Chatal	1 310	180	25	
		—	—	—	—		—	330	60	6	
3											
4		Hurasagar	1 970	180	25		Old Dhaleswari	660	60	6	4
		—	980	60	6			330	60	6	

CHAPTER III

DESIGN CONDITIONS AND STANDARDS

1. Guide bank.

Distance between guide banks in Chapter IV "Study of River Training Works" is shown in Fig. III-1 at the four proposed sites respectively.

2. Design high water level, river bed height and ground height.

The part where the center line of bridge crosses a guide bank is called the body of guide bank and Design High Water Level (DHWL), Height of River Bed (HRB) and Ground Height (GH) for the cross section of river along the center line of bridge are shown as in Table III-1. In this table, height of river bed means height of the deepest part of river bed.

3. Local scouring around piers.

Depth of local scouring around piers is estimated about 1.8 times of water depth. But in this case, it is assumed that width of foundation which is measured perpendicular to the direction of flow is 33-39 ft., this case implies a well foundation.

In the case of multi-pile system when diameter of each pile is 6 ~ 10 ft. the estimation of depth of local scouring around piers is estimated 33 ft. and in this case, necessary distance between center to center of pile is 3 times of diameter of pile.

The estimated depth of local scouring around piers in the case of A, B and C type (width of water channel) at the four proposed sites are shown in Figs. III-2 ~ III-5 with soil maps "Design river bed and soil map".

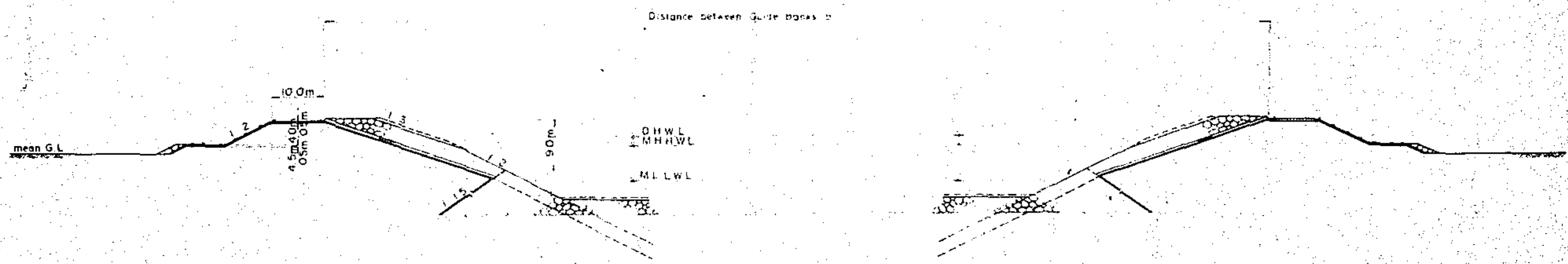
4. Design discharge and velocity.

The design discharge Q (m^3/sec), the mean velocity Vm (m/sec) and the mean velocity at the deepest part of river channel V (m/sec) at the four proposed sites are shown in Table III-2 considering in the case of A, B and C type.

5. Soil texture.

According to the result of boring at the every proposed sites, the

Fig. III-1 Distance between Guide Banks



KM (MILE)

SITE \ TYPE	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. NAGRBARI	2.0 (1.2)	4.2 (2.6)	5.2 (3.2)

Table. III-1 D.H.W.L., R.B and G.H

(m) PWD

Site \ Item	D.H.W.L.	RB			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. Sirajganj	15.24	− 38.60	− 25.50	− 18.20	11.38
4. Nagarbari	14.01	− 42.13	− 28.37	− 22.82	9.45

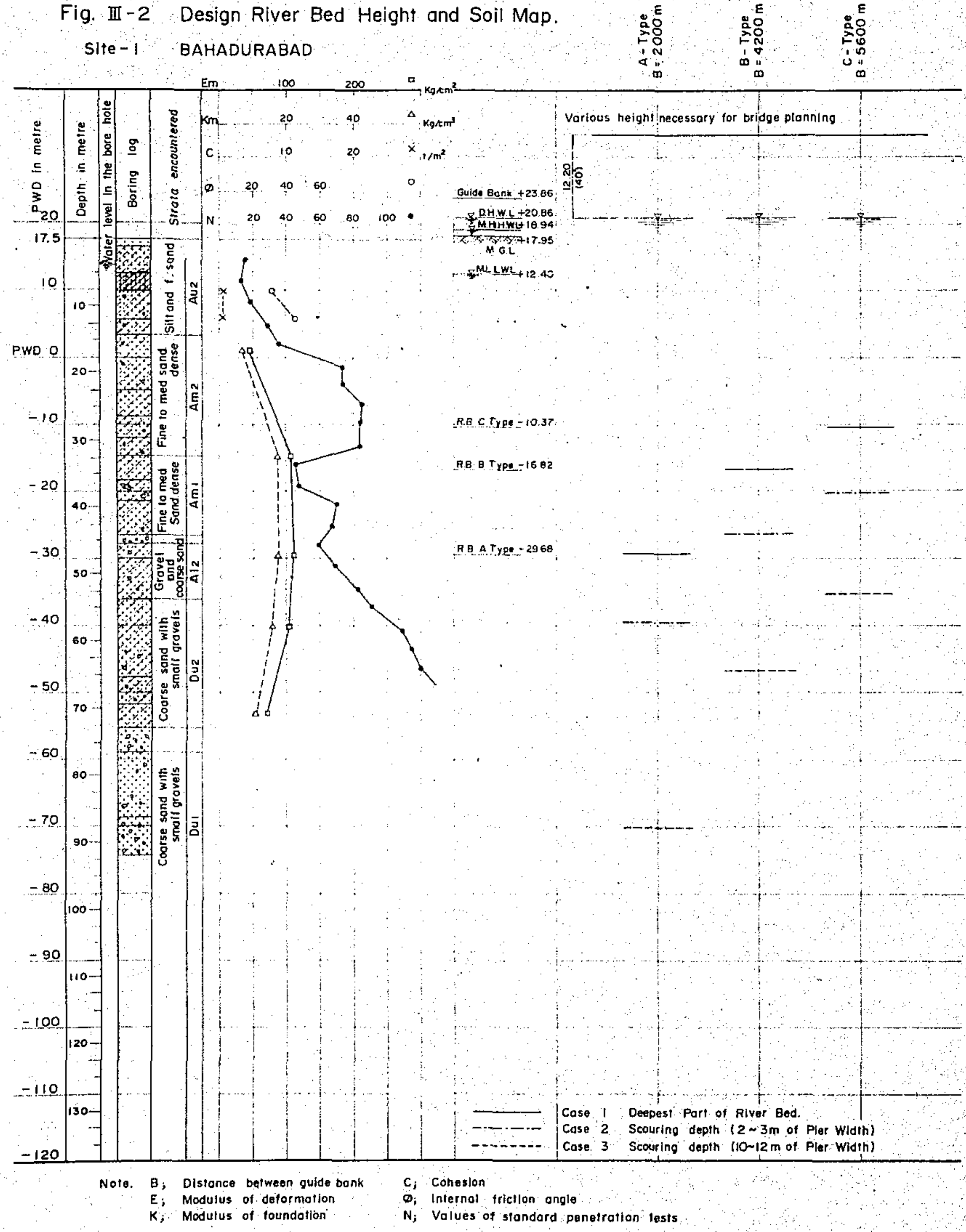
Table. III-2 Q, Vm and V

Site	Type \ Item	Q (m^3/s)	Vm (m/s)	V (m/s)
1. Bahadurabad	A	89600	2.40	4.66
	B	〃	1.93	4.35
	C	〃	1.74	3.94
2. Gabargaon	A	89600	2.21	4.29
	B	〃	1.77	4.00
	C	〃	1.65	3.73
3. Sirajganj	A	89600	225	4.36
	B	〃	1.78	4.03
	C	〃	1.63	3.68
4. Nagarbari	A	82700	1.99	3.87
	B	〃	1.58	3.57
	C	〃	1.47	3.32

Note; 1 km = 0.621 mile 1 m = 3.28 feet 1 m^3 = 35.3 cu.feet

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

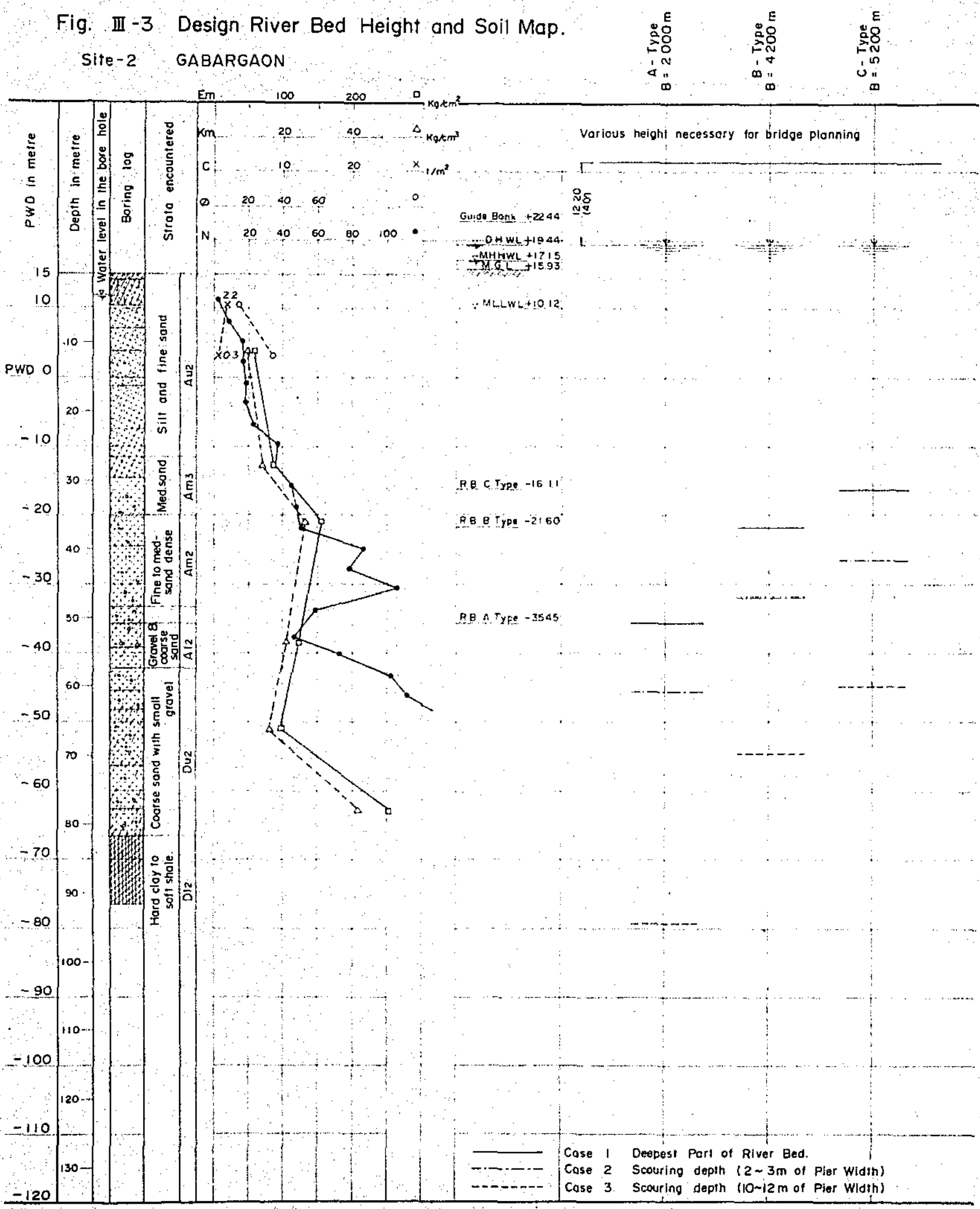
Site-1 BAHADURABAD



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

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

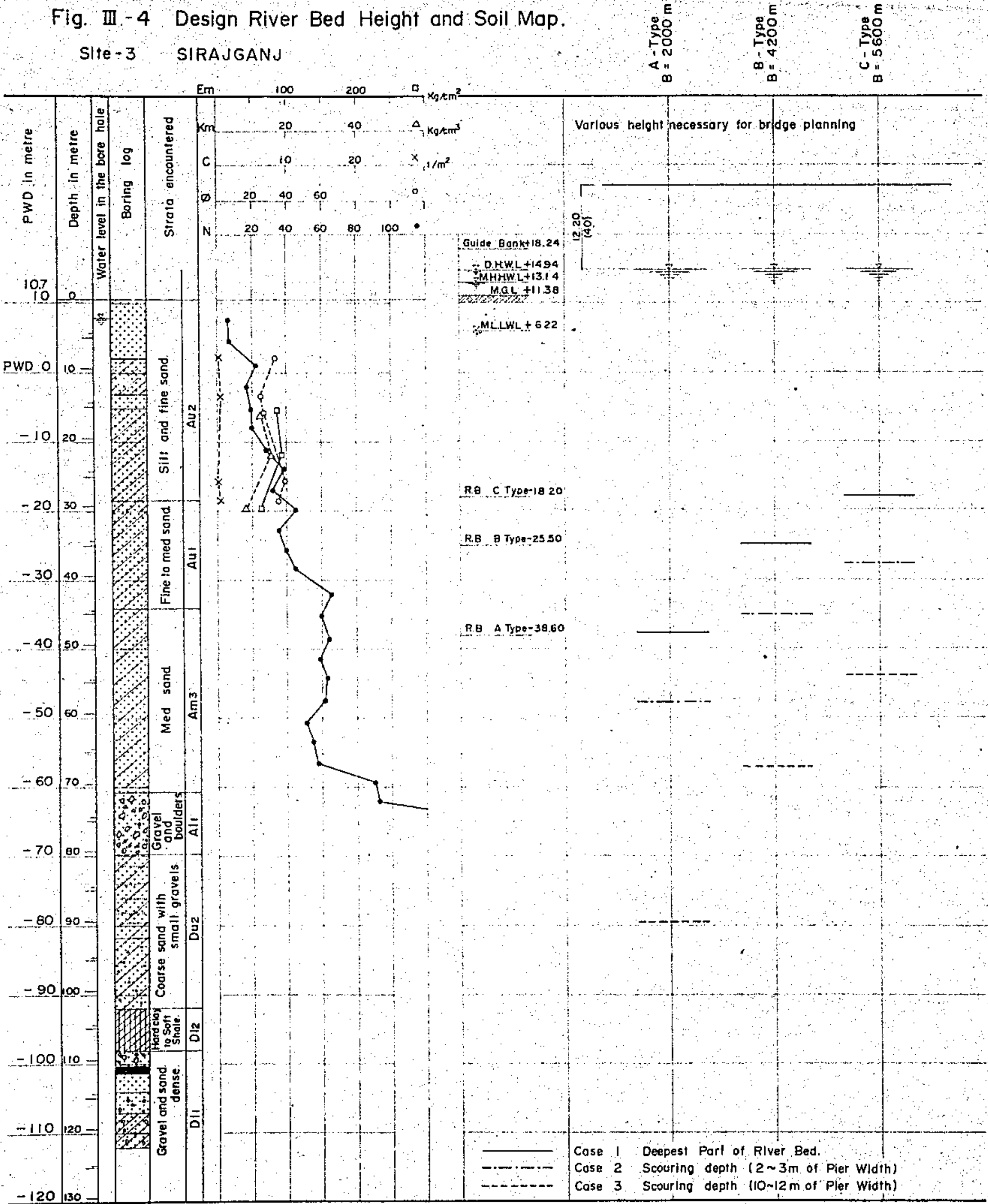
Site-2 GABARGAON



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

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

Site-3 SIRAJGANJ

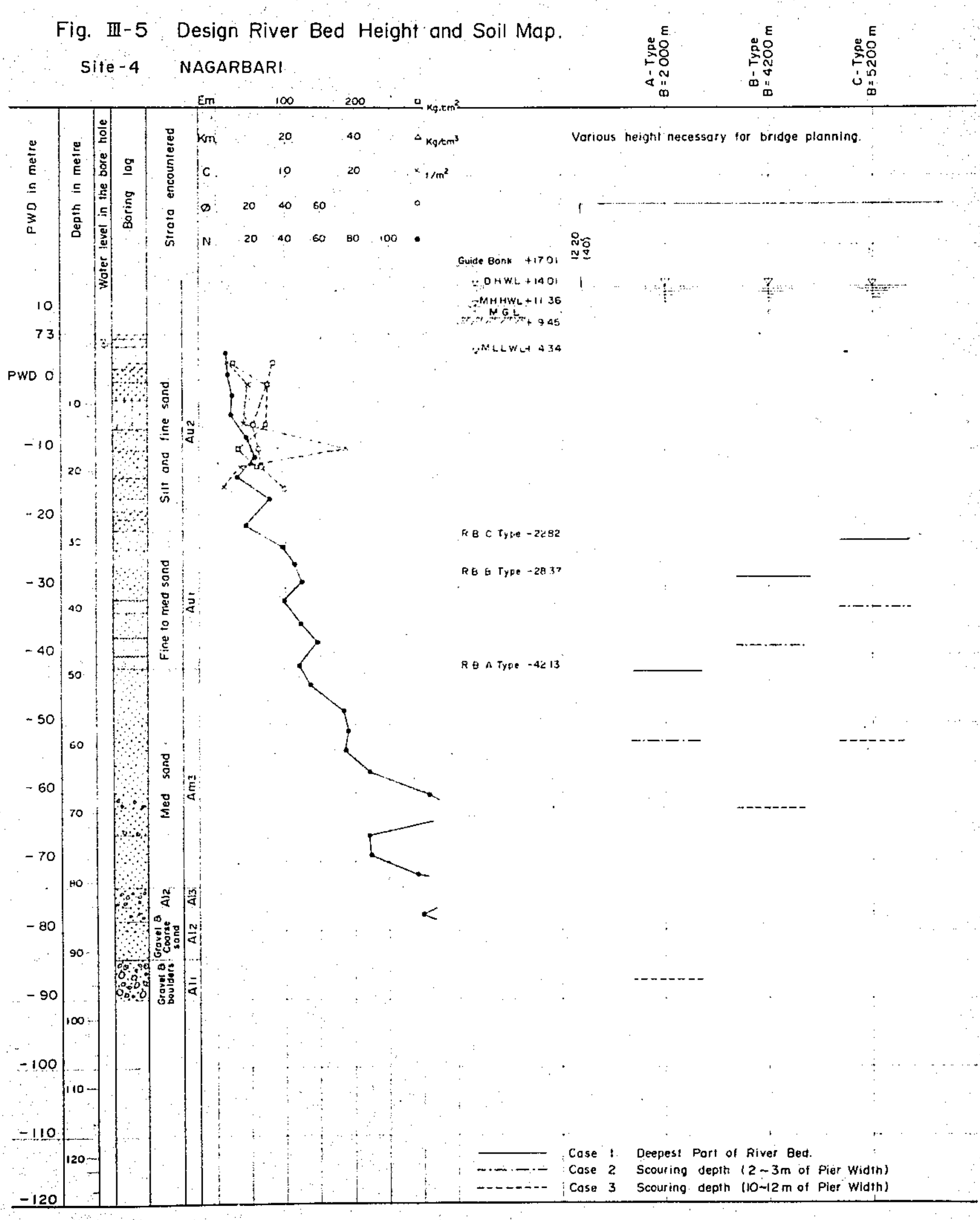


———	Case 1	Deepest Part of River Bed.
—·—·—	Case 2	Scouring depth (2~3m of Pier Width)
- - - -	Case 3	Scouring depth (10~12m of Pier Width)

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

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

Site-4 NAGARBARI



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

upper layer is silty and fine sand (Au_2) and in the lower layers, fine to medium sand (Au_1), med. sand (Am_3), dense fine to med. sand ($Am_{2,1}$) are found from top to bottom in turn.

The layers beneath Am_3 are over 60 of N-value by the standard penetration test and are considered as the reliable bearing layer. Under Am_3 layer at Nagarbari and Sirajganj, gravel and boulder layer (Al_1) of about 23-30 ft. in thickness is found out about 300 ft. and 240 ft. below ground level respectively.

At Gabargaon and Bahadurabad, coarse sand with small gravels (Du_2) is found out about 190 ft. and 180 ft. below ground level respectively.

The soil textures at the every four proposed sites are shown in Figs. III-2 ~ III-5 with proposed height of river bed.

6. Design river bed height and soil map.

Soil map, and design bed height, depth of local scouring around piers, design high water level, low water level and mean ground height are shown in Figs. III-2 ~ III-5 at the four proposed sites respectively in accordance with the A, B and C type. All height is shown referring to the bench mark of PWD.

7. Superstructures.

7-1. Railway bridge.

a. Loads. (ANNEX 2)

All loads to be used for design will be specified by Main Line Loading of Bridge Code for Indian Railways. (Fig. II-1)

b. Construction gage. (ANNEX 2)

The construction gage will be specified by the Bridge Code for Indian Railway keeping the provision of electrification in future.

c. Track gage. (ANNEX 3)

The track gage to be used for design shall be 5' 6". (Broad gage)

d. Structures. (ANNEX 3)

All structures will be designed by the Standard Specifications for Railway Bridges adopted by the Japan Society of Civil Engineers (authorized by the **Japan National Railway**), except the following matters which were determined by the Team considering local conditions of Bangladesh.

i. Wind velocity.

The wind velocity which makes the basis of calculation of wind pressure to be used for design is 35 m/sec. (115ft./sec)

ii. Range of temperature.

The range of atmospheric temperature to be used for design is from 0° to $40^{\circ}C$.

iii. Horizontal acceleration of earthquake.

The horizontal acceleration of earthquake which makes the basis of calculation of horizontal inertia force to be used for design is 0.1 G.

e. Materials. (ANNEX 3)

All materials to be used for design will be specified by the Japanese Industrial Standard.

7-2. Highway bridge.

a. Loads.

Live load to be used for design will be specified by the I.R.C. Standard Vehicle Class A. (Fig. II-2)

b. Construction gage.

The construction gage will be specified by I.R.C.

c. Structure.

All structures will be designed by the Standard Specifications for Highway Bridges adopted by the Japan Road Association (authorized by the Ministry of Construction of Japan), except the following matters which were determined by the Team considering local conditions of Bangladesh.

i. Wind velocity.

ii. Range of temperature.

iii. Horizontal acceleration of earthquake.

These are just same as railway bridge.

d. Materials.

Same as above.

8. Substructures.

According the result of meeting between both the parties, the following specifications will be applied for the design of substructures.

Standard Specifications for Reinforced Concrete adopted by the Japan Society of Civil Engineers (authorized by the Ministry of Construction of Japan).

9. Minimum navigation clearance. (ANNEX 4)

The minimum navigation clearance to be used for design is specified by the BIWTA as following.

Minimum Horizontal Clearance.

Between adjacent piers	250 feet.

Minimum Vertical Clearance.

Under soffit of the girders	40 feet.

CHAPTER IV

PROPERTIES OF MATERIALS

1. Structural steel.

Structural steel shown in the Table IV-1 were adopted as standard materials for the structure.

2. Allowable stresses of structural steel.

Allowable stresses of steel materials for structure are as shown in the Table IV-2.

3. Allowable stresses of concrete and reinforcement.

3-1. Superstructure.

Allowable stresses of concrete and reinforcement for superstructure are shown in Table IV-3-1.

3-2. Substructure.

Allowable stresses of concrete and reinforcement for sub-structure are shown in Table IV-3-2.

4. Allowable stresses for prestressed concrete structure.

In superstructure of bridges included to railway access and highway access, prestressed concrete bridges are designed and these allowable stresses are shown in Table IV-4.

Table.IV-1 Standard steel materials

Standard		Symbol of Steel Materials
JISG 3101	rolled steel for general structure	SS41
JISG3106	rolled steel for welded structure	SM41, SM50Y SM53, SM58

Table.IV-2 Allowable stresses of steel Materials for Structure (psi)

Stress \ Steel material	SS41, SM41	SM50Y, SM53	SM58
Axial tensile stresses	19912	29 868	36 980

Table. IV-3-1 Allowable Stress of Materials for Superstructure of Reinforced Concrete.

Design Strength of Concrete σ_{ck}					3 400
Allowable Stress (Psi)	Concrete	Bending Compressive Stress			1 140
		Compressive Stress by Normal Force			1 020
		Shearing Stress	in case of to be resisted by concrete only	Slab	130
				Beam	100
			in case of using web reinforcement		280
		Bond Stress			220
		Bearing Stress			1 020
	Reinforcing Bar	Tensile Stress		SD 30	25 600
		Yield Stress		SD 30	42 700

Table. IV-3-2 Allowable Stress of Materials for Substructure of Reinforced Concrete.

Design Strength of Concrete σ_{ck}					3 000
Allowable Stress (Psi)	Concrete	Bending Compressive Stress			1 000
		Compressive Stress by Nomal Force			900
		Shearing Stress	in case of to be resisted by concrete only	Slab	120
				Beam	92
			in case of using web reinforcement		260
		Bond Stress			210
		Bearing Stress			900
	Reinforcing Bar	Tensile Stress SD 30		Usually	25 600
				in Water	22 700
		Yield stress		SD30	42 700

Table.IV-4 Miscellaneous Values for Superstructure of Prestressed Concrete

Material	Descriptions		Values
Concrete	Design Strength σ'_{ck}		5 000 PSi
	Acting Design Load (Compressive Stress)		1 660 "
	" (Tensile Stress)		190 "
	Strength at Prestressing		4 300 "
	Maximum Size of Coarse Aggregate		1 inch
Prestressing Wire ø 7mm	Breaking Stress		220 KSi
	Yield Stress		192 "
	Allowable Tensile Stress	Design Load	132 "
		at Prestressing	173 "

CHAPTER V

PRELIMINARY DESIGN FOR COMPARISON

1. Outline.

The three distances of 2.0^{Km}, 4.2^{Km} and 5.2^{Km} or 5.6^{Km} between a pair of guide banks were investigated at each site of the four proposed sites in order to make preliminary design. The three distances were regarded as the bridge length itself at each site.

The preliminary design was made on the basis of this condition.

The following too kinds of bridge width were investigated for the design.

Case a

Railway part ; Single broad gage track (5'-6")

Highway part ; Two-lanes of total 24' width

Case b

Railway part ; Double broad gage tracks

Highway part ; Four-lanes of total 48' width

For the superstructure, steel truss type was applied. Four kinds of span length of 100^{m}, 150^{m}, 250^{m} and 350^{m} were investigated taking the minimum horizontal navigation clearance into consideration. For the substructure, well foundation and multi-pile foundation were considered as the adequate type. In the case of Jamuna River Bridge Project, the combined cases between these foundation types and superstructure types were considered to have the minimum construction cost.

2. Superstructure.

2-1. Structural type.

Planned span length of Jamuna River Bridge is from 100^m to 350^m as above-mentioned. Generally, the suitable bridge types to the range of these span length are as shown in Fig. V-1.

Bridge types to be applied, there are suspension bridge, cantilever truss bridge, continuous truss bridge, tied arch bridge and cable-stayed bridge. Based on data and informations related to these types of bridge various factors were considered from many points of view, such as the rationality in economical and structural, safety and comfortables for driving, and others. As this bridge is designed for a double purpose, rail-cum-highway bridge, such a type which has structural strength durable to the heavy railway loads. Moreover, from the view of width composition, such a type which is capable to have double deck type is desirable. As a result of these studies, it was judged that the truss type is the most desirable for this bridge. As to the transportion of steel materials by sea, truss bridge is cheaper than others according to the light weight of individual member. By this main reason, truss type is applied.

By the reason above mentioned and assuming of the dispersion of horizontal stress in the substructure, three-span continuous truss bridge for the spans 100^m and 150^m, and multi-span cantilever truss bridge for the spans 250^m and 350^m were considered. According to practical execution and trial calculation, the curved-chord truss is more reasonable than the parallel chord truss, in span of 250^m and 350^m. Therefore, frames of the truss is determined as illustrated in Fig. V-2.

2-2. Outline of structure.

Section of each member in the truss shall be box section, and for stringers and floorbeams, I-type section is applied. These members shall be fabricated by electric arc welding in the factory and splice and connection at the construction site shall be performed by high tention bolts.

As for floor slab type, reinforced concrete slab and orthoropic steel deck plate are considered.

Reinforced concrete slab is adequate for the span length shorter than 150^m and orthoropic steel deck plate is adequate for the spans longer than

Fig. Ⅴ - 1 Suitable Bridge Types by Different Span Length.

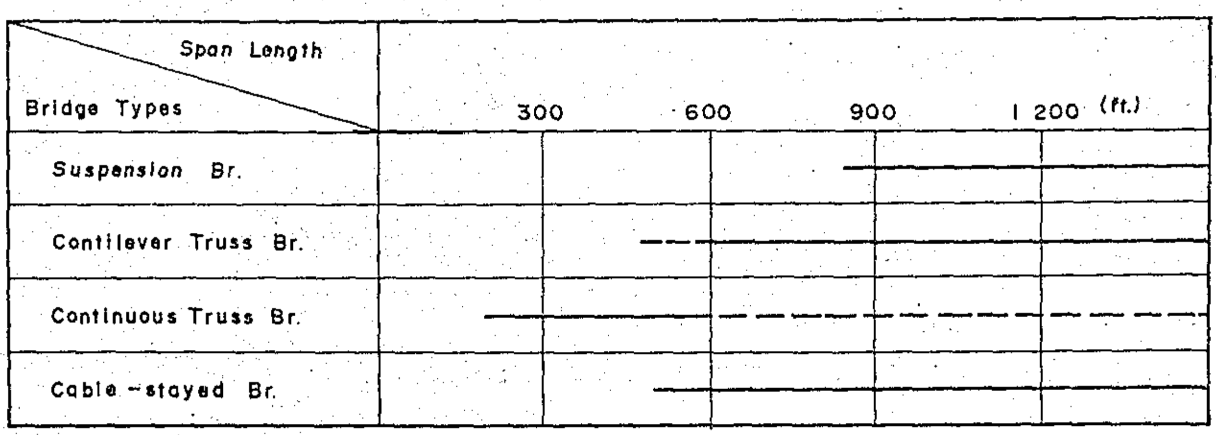
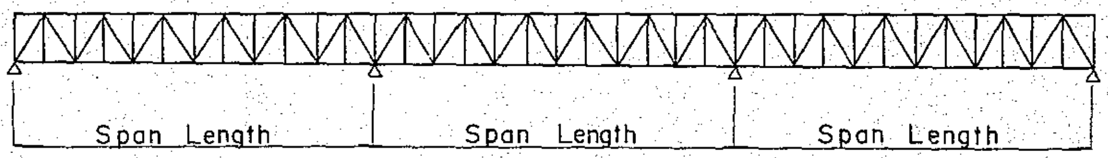
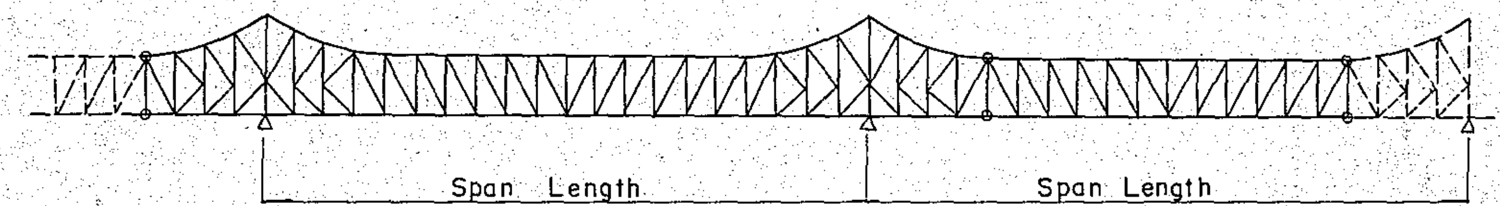


Fig. V-.2 Truss frame

3 Span continuous truss frame for span of 328' or 492'



Cantilever truss frame for span of 820' or 1148'



150^m. If reinforced concrete floor slab is used in a long span, dead loads will increase much to influence badly on superstructure and substructure. Railway bridge is designed with open floor type.

In the Case a, single track is arranged to one side. In the Case b, double tracks are planned to be placed close to the main truss respectively. Sections of each span in Case a and b are illustrated in Fig. V-3-1~3, V-4-1~3. These drawing also have truss height.

2-3. Calculation of design.

2-3-1. Design condition.

(1) Case a

i) Span $3 @ 100^m = 300^m$
$3 @ 150^m = 450^m$

Type Three-span continuous steel Warren truss bridge with parallel chords. (single deck type)
(rail-cum-highway bridge)

ii) Span 250^m
350^m

Type Cantilever steel truss bridge with curved chords.
(single deck type) (rail-cum-highway bridge)

iii) Load Car : I R C Standard Vehicle Class "A".
Train : Main Line Loading of Indian Railway Bridge Code.

iv) Width Road : 24' (two lane)
Railway : single track 5'~6" gage

v) Design wind velocity 30^m/sec (115 ft/sec)

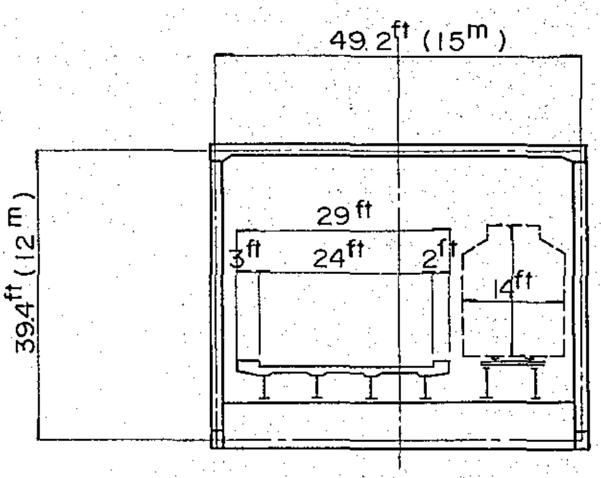
vi) Horizontal acceleration of earthquake $K_H = 0.1$ G
Quality of material : SS 41^{class}, $SM50Y^{class}$, SM58 and others specified by JIS.

(2) Case b

i) Span $3 @ 100^m = 300^m$
$3 @ 150^m = 450^m$

Fig. V-3-1 Typical cross sections in Case a

L = 100 m



L = 150 m

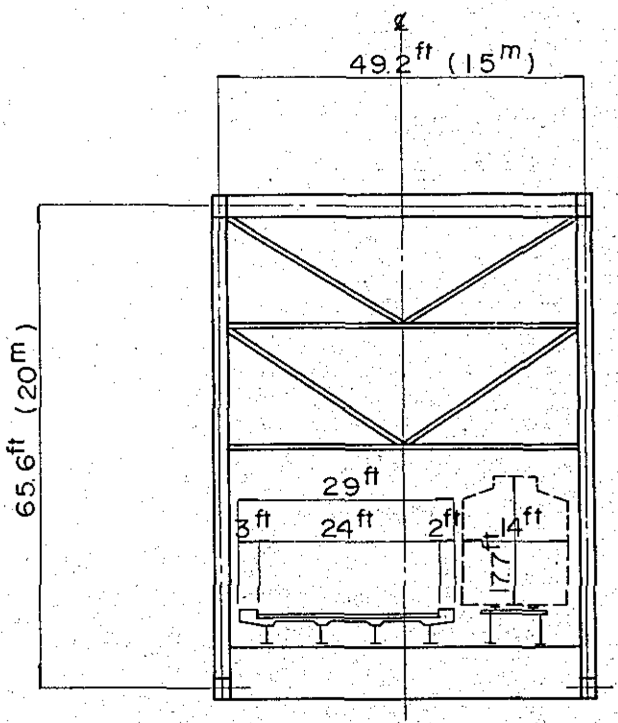


Fig. V-3-2 Typical cross section in Case a

L = 250 m

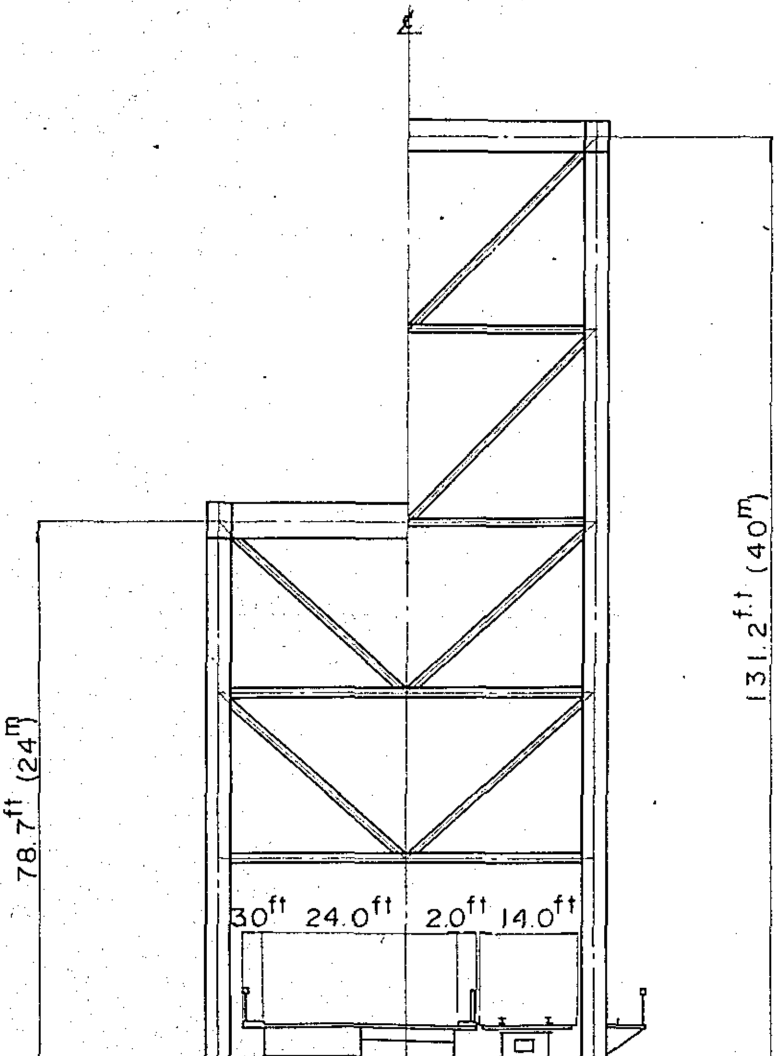


Fig. V-3-3 Typical cross section in Case a

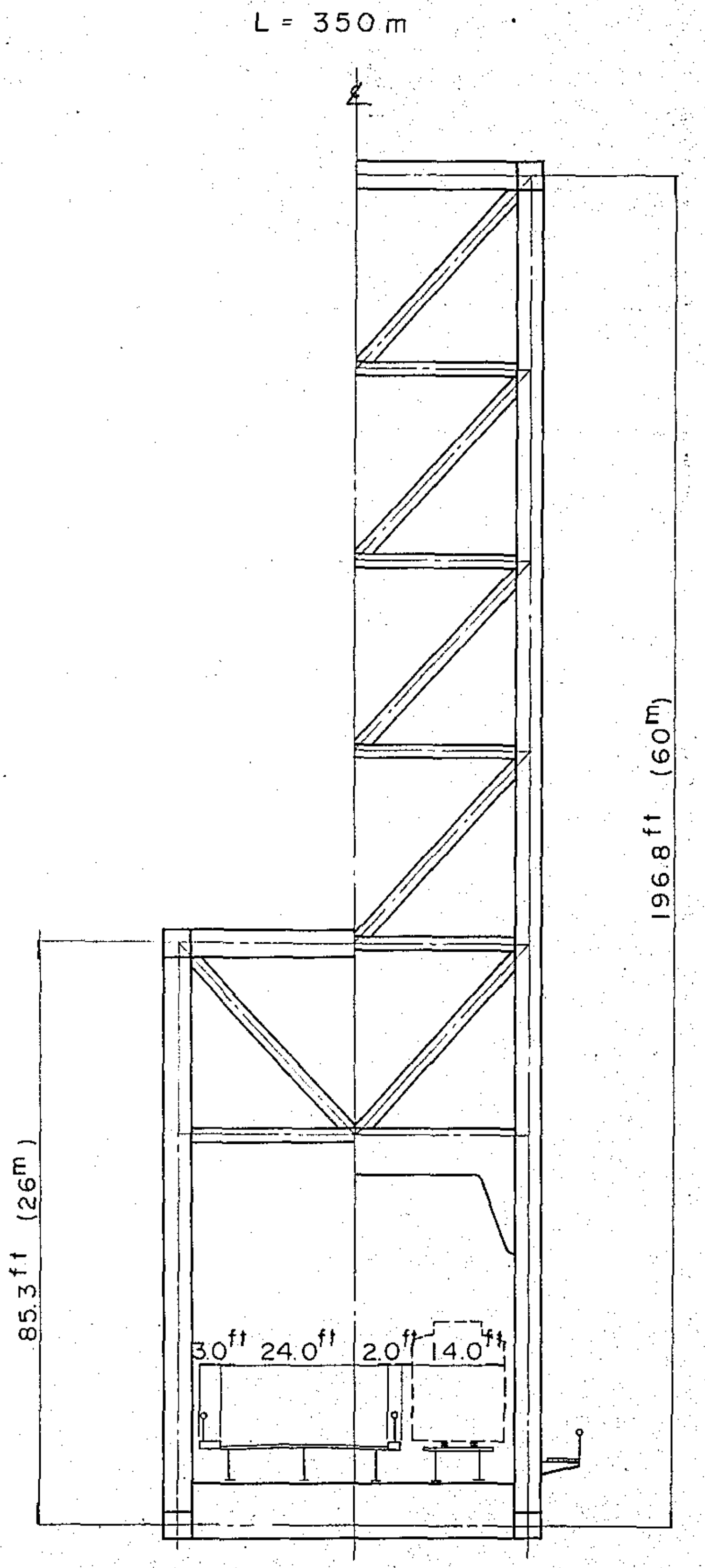
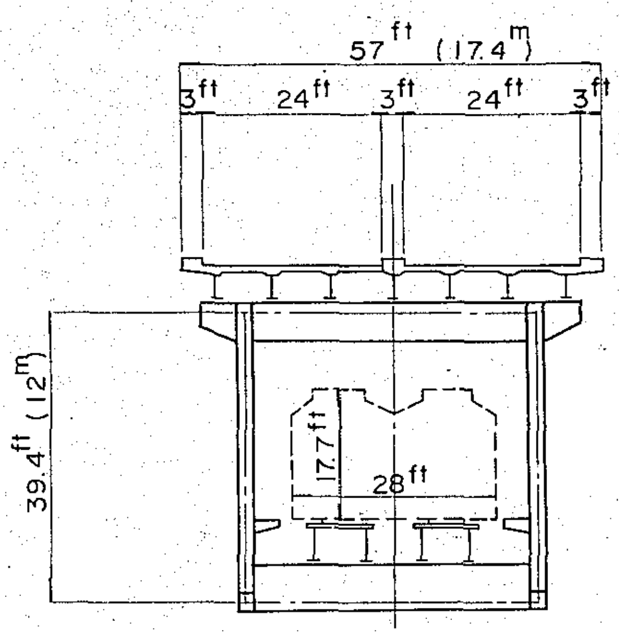


Fig. V-4-1 Typical cross sections in Case b

L = 100 m



L = 150 m

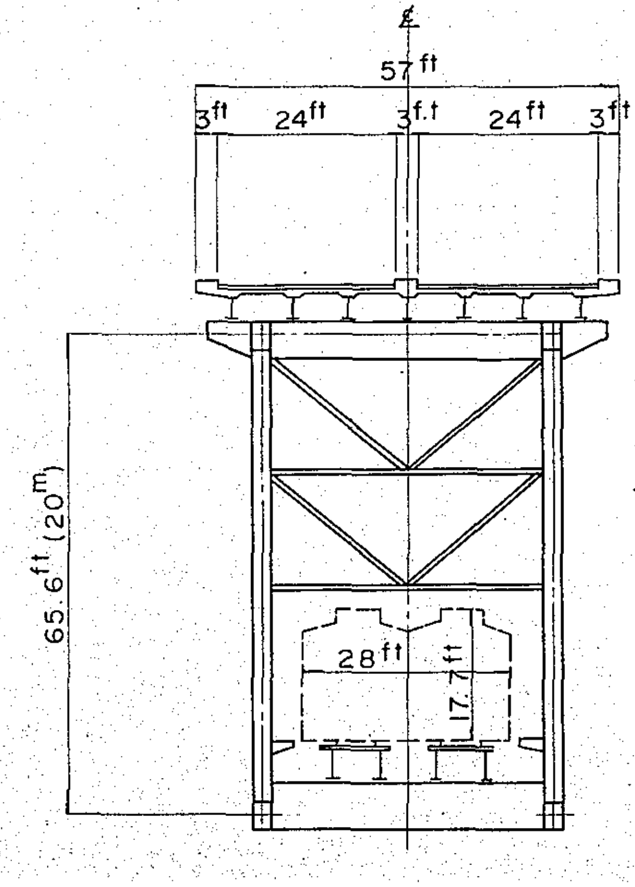


Fig. V-4-2 Typical cross section in Case b

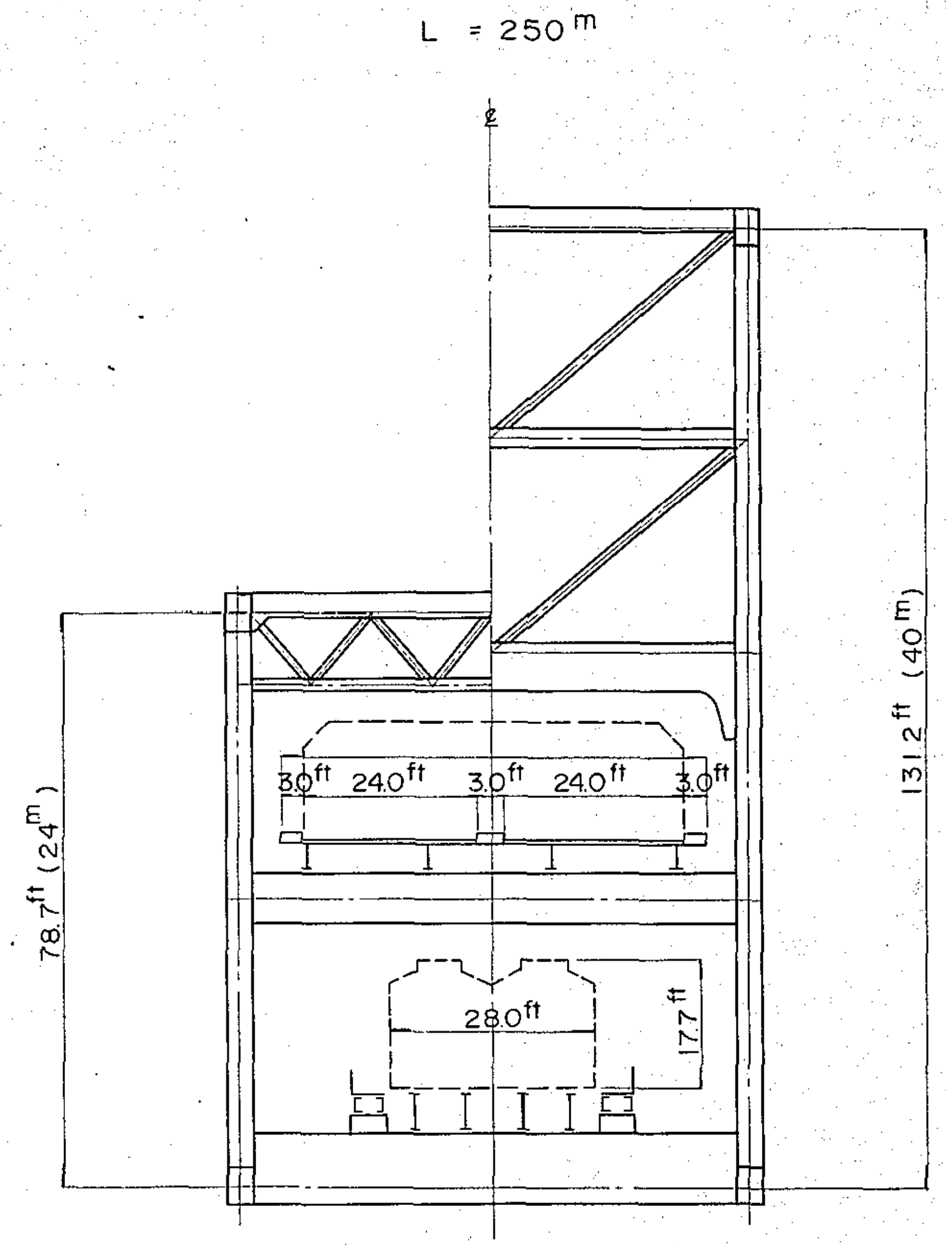
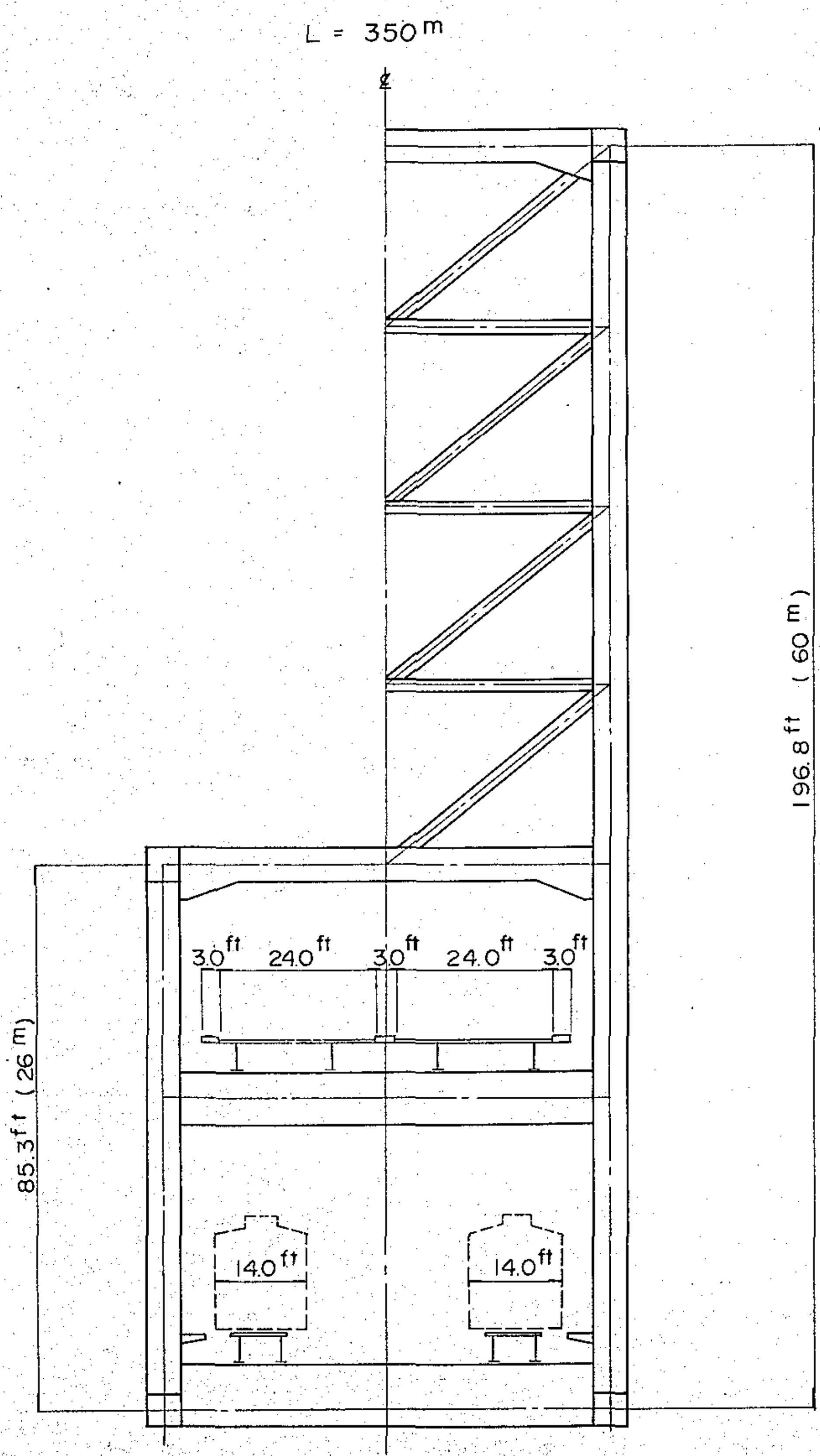


Fig. V-4-3 Typical cross section in Case b



Type Three-span continuous Warren truss bridge with parallel chords (double deck type)

(rail-cum-highway bridge)

ii) Span 250^m

350^m

Type Cantilever steel truss bridge with curved chords.

(double deck type) (rail-cum-highway bridge)

iii) Load Car : I R C Standard Vehicle Class "A"

Train : Main line Loading of Indian Railway Bridge Code.

iv) Width Road : 48' (four lane)

Railway : double track 5'～6" gage

v) Design Wind Velocity 30 m/sec (115 ft/sec)

vi) Horizontal acceleration of earthquake $K_H = 0.1$ G

Quality of Material : $SS41^{class}$, $SM50Y^{class}$, SM58 and others specified by JIS.

2-3-2. Result of Calculation.

Following factors were considered mainly at the calculation.

a) Span corresponding to impact coefficient.

A span corresponding to impact coefficient is specified in the Standard specifications for Highway Bridges, adopted by the Japan Road Association (authorized by the Ministry of Construction of Japan).

b) Maximum loaded length of train.

The maximum live load length is assummed to be 400^m. At the case of double track, running of same direction should be considered.

c) Secondary stress.

Eccentricity of member, stiffness of panel point, deflection of cross beam, deformation of floor construction by a change in a chord length, deflection of member of their dead load and others, such factors cause to produce secondary stress in truss members. Therefore, stress of 200 Kg/cm^2 was considered as a value of it.

d) Composition of stringer and cross beam.

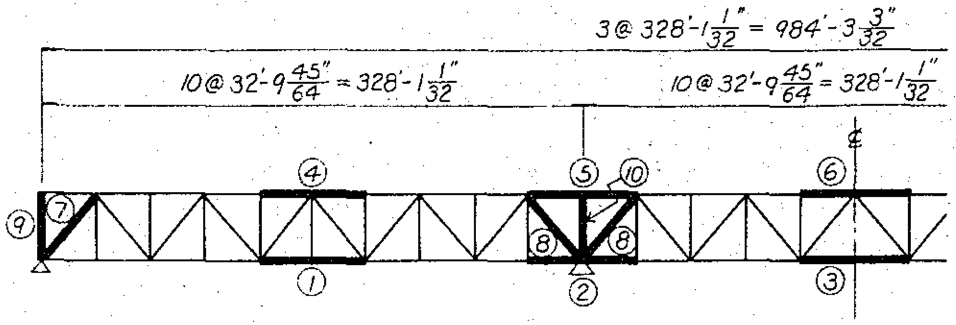
Considering of the execution, stringers were determined to be placed on cross beams instead of fixing to webs of cross beams.

e) Transverse stiffness.

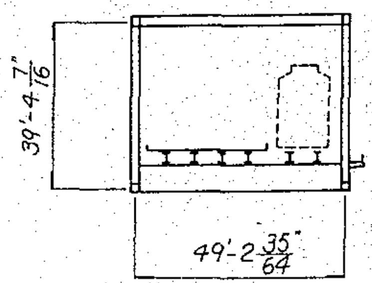
For the transverse stiffness to be bearable to wind forces and forces occurred in executing, upper cross beams are fixed to webs of upper chord members and lower cross beams are webs of lower chord members. At the same time, a suitable portal bracing was applied to such compositions

According to Case a and Case b by width composition, results of calculations in each of four spans are shown in Table V-1～4 at Case a and Tables V-5～8 at Case b. This Table conclusively showed axial forces of main members in main truss, sections, qualities of materials, allowable stress, stress intensity of sections and thickness of plate, sections of stringer and cross beam, and deflections by live loads.

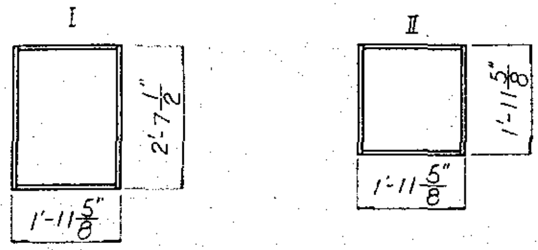
Table V-1 Span $328'-1\frac{1}{32}''$ 3-Span Continuous Truss Case-a



Case-a
(Single Deck)



Section

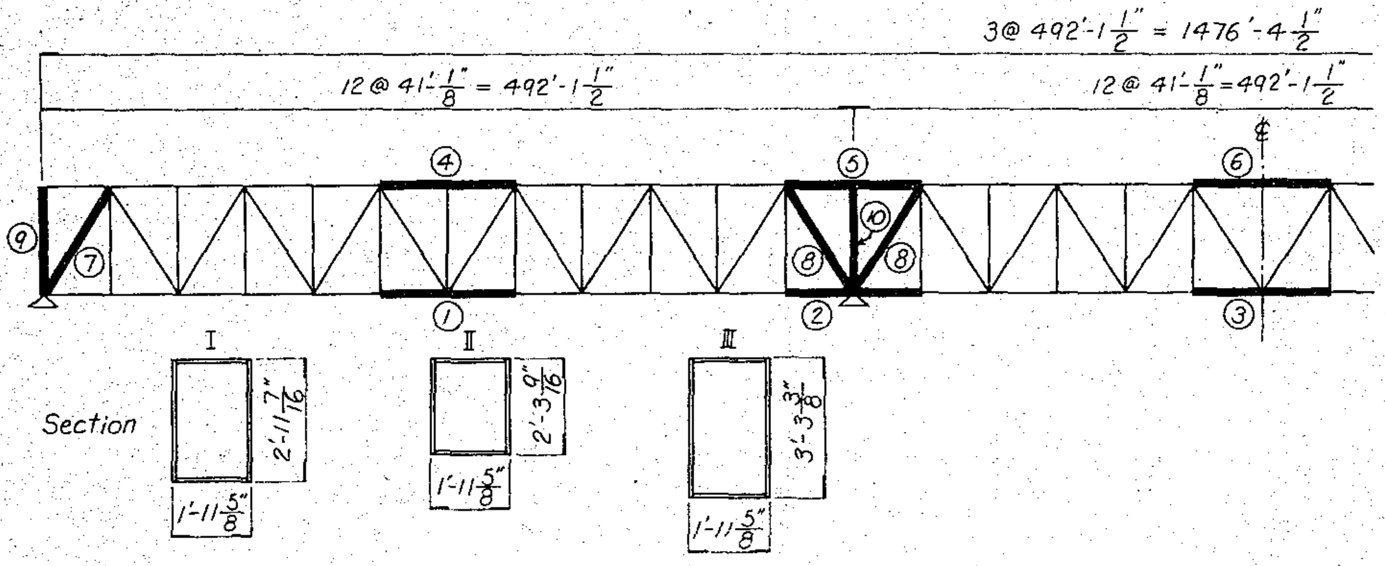


Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Member Force	t	1 085	−1 413	650	−1 085	1 413	−650	−1 172	−823	−632	−1 709
Type of Section	—	I	I	I	I	I	I	II	II	II	II
Material	—	SM 53	SM 53	SM 53	SM 53	SM 53	SM 53	SM 53	SM 53	SM 53	SM 58
Allowable Stress	psi	29 889	24 125	29 889	24 054	29 889	24 182	19 869	20 552	22 004	25 264
Stress	"	26 288	20 310	26 303	20 837	27 157	18 147	15 414	17 393	17 962	22 460
Plate Thickness	inch	$\frac{55}{64}$	$1\frac{1}{2}$	$\frac{33}{64}$	$1\frac{7}{64}$	$1\frac{7}{64}$	$\frac{3}{4}$	$1\frac{31}{32}$	$1\frac{3}{16}$	$\frac{55}{64}$	$1\frac{31}{32}$

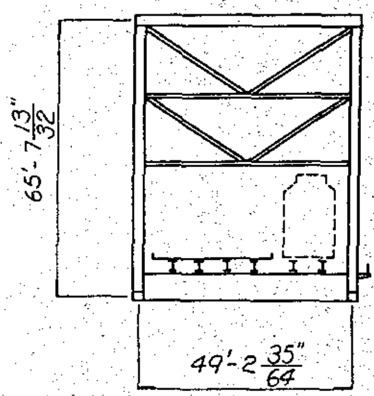
Maximum Deflection (Live-load)	
	Deflection
Railway (Single Truck)	$4\frac{27}{32}''$
Railway + Highway	$5\frac{35}{64}''$

		Section
Stringer	Highway	2-Pls $10\frac{15}{64}'' \times \frac{2}{3}''$
		1-Pl $3'-3\frac{3}{8}'' \times \frac{23}{64}''$
	Railway	2-Pls $1'-3\frac{3}{4}'' \times \frac{63}{64}''$
		1-Pl $4'-7\frac{1}{8}'' \times \frac{33}{64}''$
Floor Beam		2-Pls $1'-9\frac{17}{64}'' \times 1\frac{7}{64}''$
		1-PL $7'-2\frac{39}{64}'' \times \frac{7}{16}''$

Table V-2 Span 492'-1 1/2" 3-Span Continuous Truss Case-a



Case-a
(Single Deck)

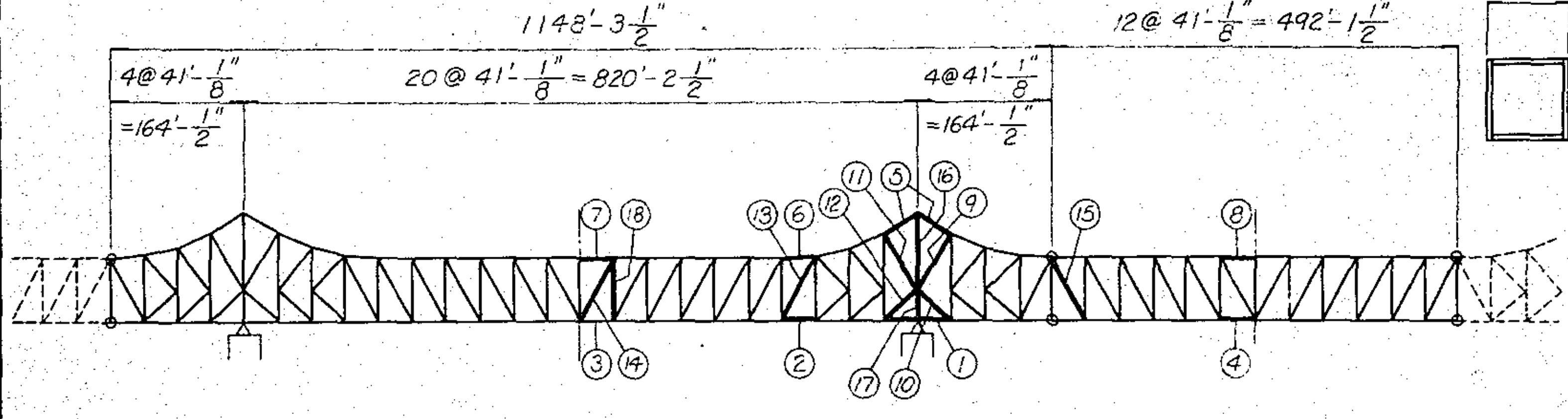


Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Member Force	t	1 573	-2 442	743	-1 573	1 659	-806	-1 257	-1 678	-1 085	-2 775
Type of Section	—	I	I	I	I	I	I	III	III	II	III
Material	—	SM53	SM58	SM53	SM58	SM58	SM53	SM58	SM58	SM58	SM58
Allowable Stress	psi	29 889	29 960	29 889	30 259	37 006	25 349	12 739	12 582	21 278	25 776
Stress	"	26 331	26 431	26 146	26 687	33 106	21 677	8 056	9 977	17 407	22 545
Plate Thickness	inch	1 3/16	1 31/32	2/3	1 17/64	63/64	55/64	2 23/64	2 9/16	1 37/64	1 31/32

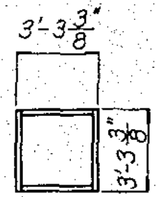
Maximum Deflection (Live-load)	Deflection
Railway (Single Truck)	6 27/64"
Railway + Highway	7 33/64"

		Section
Stringer	Highway	2-Pls 11 13/16" × 55/64"
		1-Pl 3'-3 3/8" × 23/64"
	Railway	2-Pls 1'-3 3/4" × 63/64"
		1-Pl 4'-7 1/8" × 33/64"
Floor Beam		2-Pls 1'-11 5/8" × 1 17/64"
		1-Pl 7'-2 39/64" × 15/32"

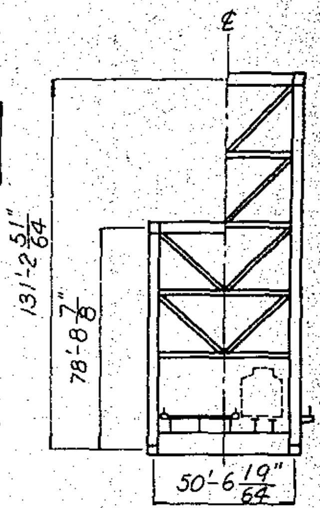
Table Ⅴ-3 Span $820'-2\frac{1}{2}''$ Cantilever Truss Case-a



Section (Chord, Diagonal)



Case-a (Single Deck)



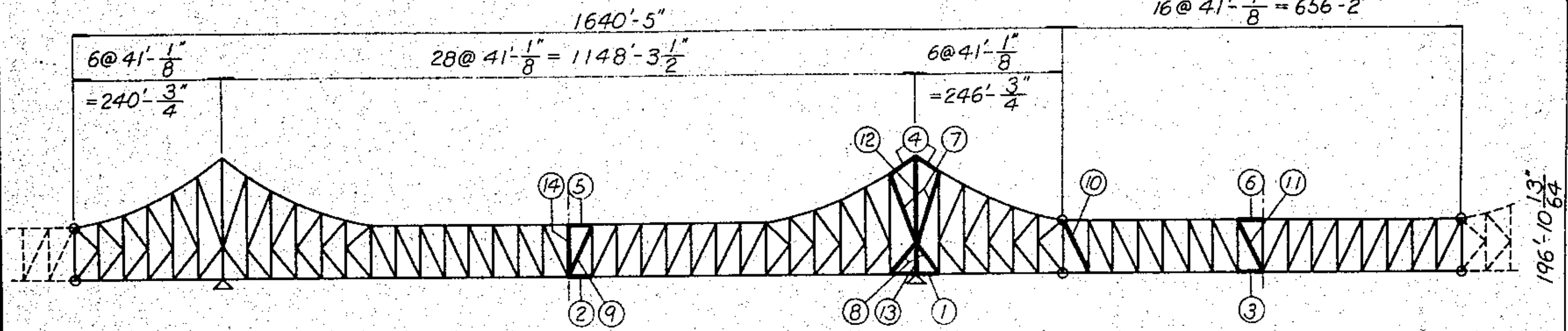
Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨
Member Force	t	−2 656	−1 971	4 570	2 080	2 644	−1 528	−4 720	−2 138	−531
Material	—	SM53	SM53	SM58	SM53	SM53	SM53	SM58	SM53	SS41
Allowable Stress	psi	26 146	26 189	37 006	29 889	29 889	26 203	31 611	26 174	15 258
Stress	"	24 011	23 769	30 046	26 843	26 559	23 029	28 438	22 730	12 013
Plate Thickness	inch	$1\frac{37}{64}$	$1\frac{3}{16}$	$2\frac{11}{64}$	$1\frac{7}{64}$	$1\frac{27}{64}$	$\frac{15}{16}$	$2\frac{23}{64}$	$1\frac{11}{32}$	$\frac{5}{8}$

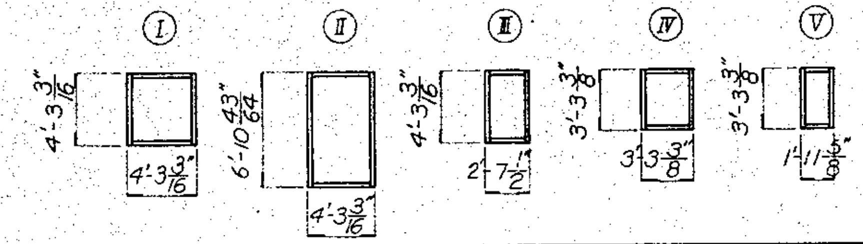
Member		⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱
Member Force	t	875	−1 026	1 214	2 159	586	1 414	−2 582	−4 883	−520
Material	—	SS41	SM41	SM41	SM53	SS41	SM41	SM58	SM58	SS41
Allowable Stress	psi	19 926	15 329	19 926	29 889	19 926	19 926	19 599	31 996	15 258
Stress	"	16 638	12 354	17 564	26 915	16 297	15 969	16 966	29 420	11 742
Plate Thickness	inch	$\frac{3}{4}$	$1\frac{3}{16}$	$\frac{63}{64}$	$1\frac{3}{16}$	$\frac{33}{64}$	$1\frac{17}{64}$	$2\frac{11}{64}$	$2\frac{23}{64}$	$\frac{5}{8}$

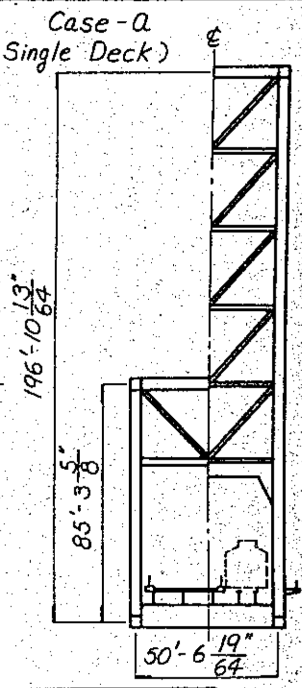
		Section
Stringer	Highway	1-Pl $7'-1\frac{3}{4}'' \times \frac{55}{64}''$
		1-Pl $4'-7\frac{1}{8}'' \times \frac{23}{64}''$
		1-Pl $11\frac{13}{16}'' \times \frac{15}{32}''$
	Railway	2-Pls $1'-3\frac{3}{4}'' \times \frac{63}{64}''$
		1-Pl $4'-7\frac{1}{8}'' \times \frac{33}{64}''$
Floor Beam		2-Pls $2'-3\frac{9}{16}'' \times 1\frac{17}{64}''$
		1-Pl $8'-2\frac{27}{64}'' \times \frac{15}{32}''$

Maximum Deflection (Live-load)	
Railway	$1'-6\frac{47}{64}''$
Railway + Highway	$1'-9\frac{49}{64}''$

Table V- 4   Span 1148'-3 1/2" Cantilever Truss   Case-a







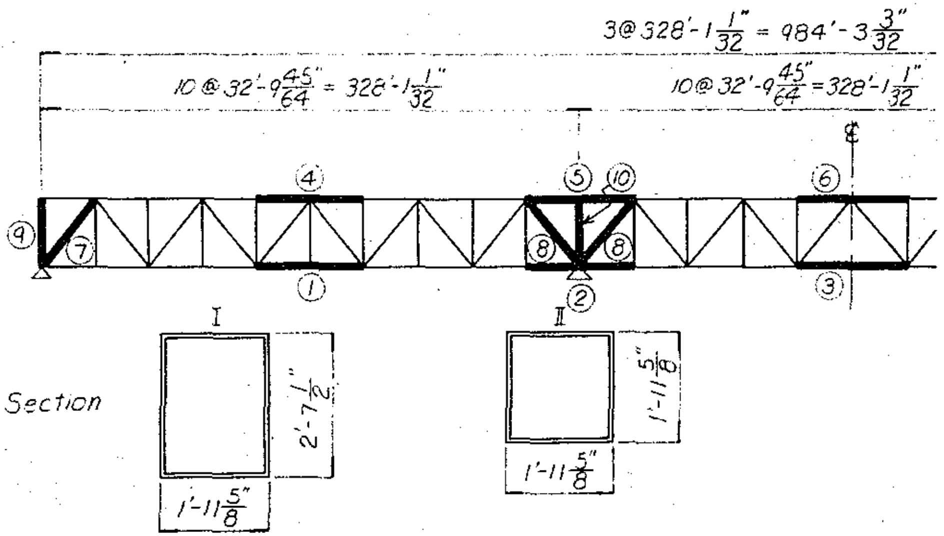
Member		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Member Force	t	-3 603	7 037	3 443	4 373	-7 130	-3 496	-1 654
Type of Section	—	I	I	IV	I	I	IV	I
Material	—	SM58	SM58	SM58	SM58	SM58	SM58	SM53
Allowable Stress	psi	33 519	37 006	37 006	37 006	33 305	31 611	15 486
Stress	"	30 928	29 590	34 045	33 561	29 989	29 405	12 696
Plate Thickness	inch	1 3/16	2 11/64	1 1/2	1 3/16	2 11/64	1 49/64	1 3/16

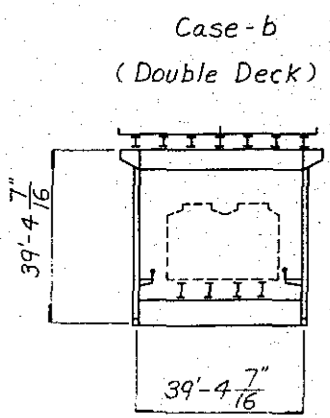
Member		(8)	(9)	(10)	(11)	(12)	(13)	(14)
Member Force	t	813	-326	1 892	-105	-4 501	-7 837	-450
Type of Section	—	I	III	IV	V	II	II	III
Material	—	SS41	SS41	SM41	SS41	SM58	SM58	SS41
Allowable Stress	psi	19 926	11 970	19 926	8 668	14 603	32 224	12 980
Stress	"	11 472	5 209	14 404	3 103	12 781	22 260	7 188
Plate Thickness	inch	5/6	5/6	1 31/32	19/32	2 23/64	2 23/64	5/6

		Section
Stringer	Highway	1-Pl 7'-1 3/4" × 55/64"
		1-Pl 4'-7 1/8" × 23/64"
		1-Pl 11 13/16" × 15/32"
	Railway	2-Pls 1'-3 3/4" × 63/64"
		1-Pl 4'-7 1/8" × 33/64"
Floor Beam		2-Pls 2'-3 9/16" × 1 17/64"
		1-Pl 8'-2 27/64" × 15/32"

Maximum Deflection (Live-load)	
Railway	1'-11 1/2"
Railway + Highway	2'-3 13/32"

Table V- 5 Span 328'-1 1/32" 3-Span Continuous Truss Case-b



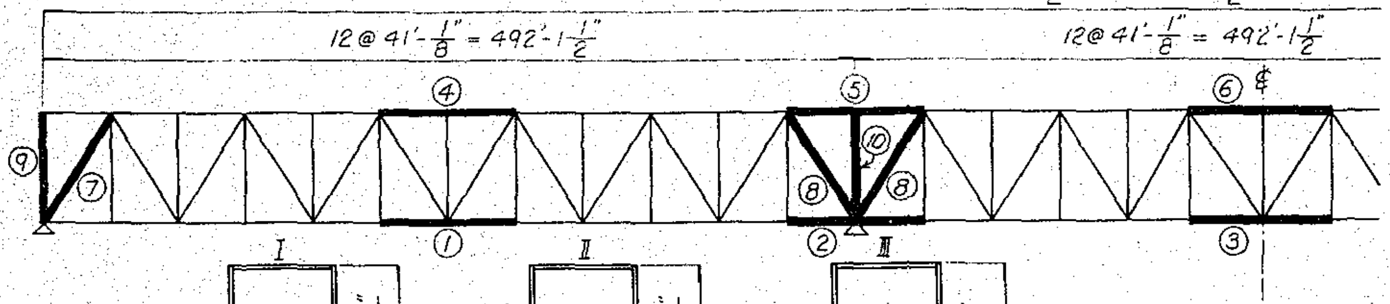


Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Member Force	t	1 631	-2 121	931	-1 631	2 121	-931	-1 232	-1 772	-947	-2 573
Type of Section	—	I	I	I	I	I	I	II	II	II	II
Material	—	SM58	SM58	SM58	SM58	SM58	SM58	SM58	SM58	SM53	SM58
Allowable Stress	psi	37 006	28 423	29 889	28 722	37 006	26 787	20 496	19 784	21 833	25 463
Stress	"	31 341	24 495	26 032	26 032	33 860	22 574	17 834	16 937	18 873	22 531
Plate Thickness	inch	1 7/64	1 57/64	3/4	1 11/32	1 11/32	55/64	1 49/64	2 9/16	1 17/64	2 9/16

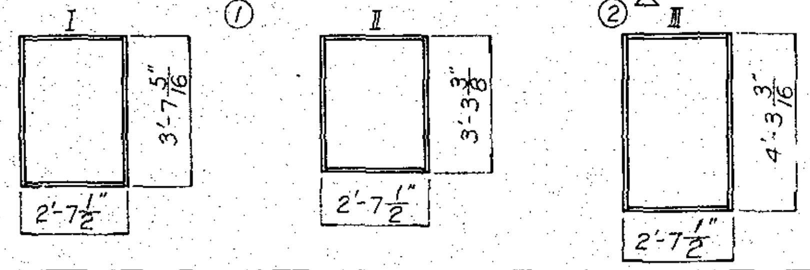
Maximum Deflection (Live-load)	
	Deflection
Railway (Single Truck)	4 27/32"
Railway + Highway	6 7/64"

		Section
Stringer	Highway	2-Pls 9 27/32" × 5/8"
		1-Pl 3'-7 5/16" × 23/64"
	Railway	2-Pls 1'-3 3/4" × 63/64"
		1-Pl 4'-7 1/8" × 33/64"
Floor Beam	Highway	2-Pls 1'-3 3/4" × 55/64"
		1-Pl 5'-2 63/64" × 23/64"
	Railway	2-Pls 1'-7 11/16" × 63/64"
		1-Pl 6'-6 47/64" × 25/64"

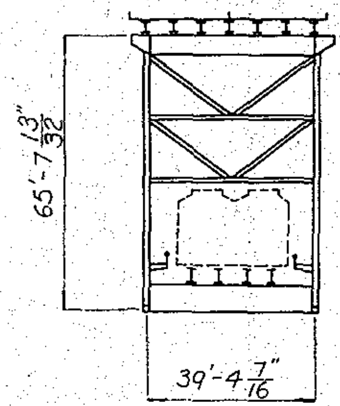
Table V-6 Span 492'-1 1/2" 3-Span Continuous Truss Case-b



Section



Case-b (Double Deck)

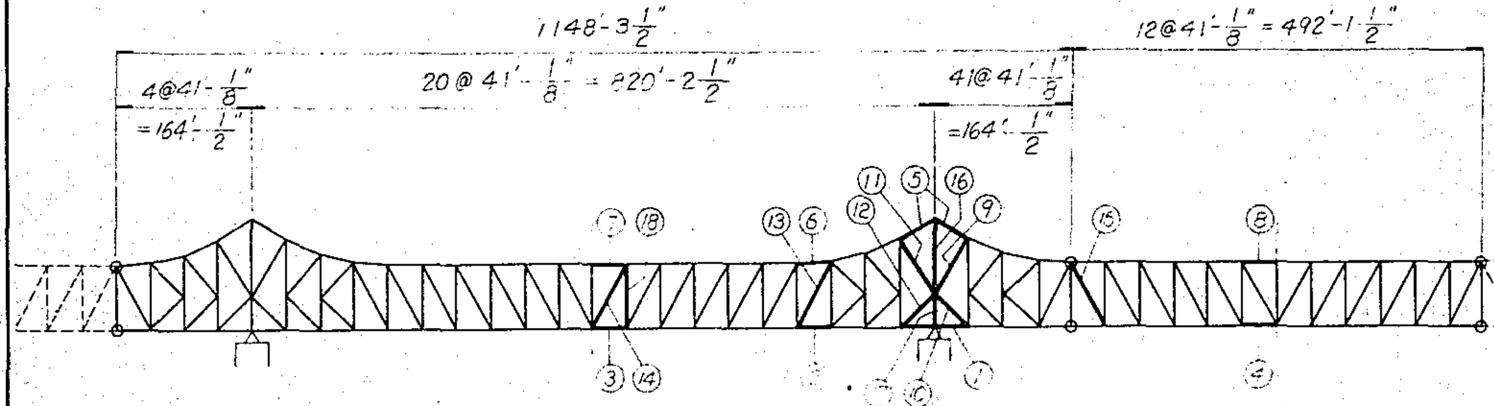


Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Member Force	t	2 473	-3 547	1 105	-2 473	2 364	-1 204	-1 893	-2 615	-1 753	4 458
Type of Section	—	I	I	I	I	I	I	III	III	II	III
Material	—	SM58	SM58	SM53	SM58	SM58	SM53	SM58	SM58	SM58	SM58
Allowable Stress	psi	37 006	32 181	29 889	32 366	37 006	26 573	19 570	19 001	28 011	29 334
Stress	"	34 344	29 477	26 730	28 993	34 287	23 399	16 923	15 912	25 363	26 317
Plate Thickness	inch	1 3/16	1 31/32	2/3	1 27/64	1 1/16	25/32	1 37/64	2 23/64	1 29/64	1 31/32

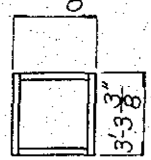
Maximum Deflection (Live-load)	Deflection
Railway (Single Truck)	3 45/64"
Railway + Highway	5 25/64"

		Section
Stringer	Highway	2-Pls 10 5/8" × 55/64"
		1-Pl 3'-7 5/16" × 23/64"
	Railway	2-Pls 1'-3 3/4" × 63/64"
		1-Pl 4'-7 1/8" × 33/64"
Floor Beam	Highway	2-Pls 1'-3 3/4" × 1 7/64"
		1-Pl 5'-2 63/64" × 23/64"
	Railway	2-Pls 1'-11 5/8" × 1 3/16"
		1-Pl 6'-6 47/64" × 25/64"

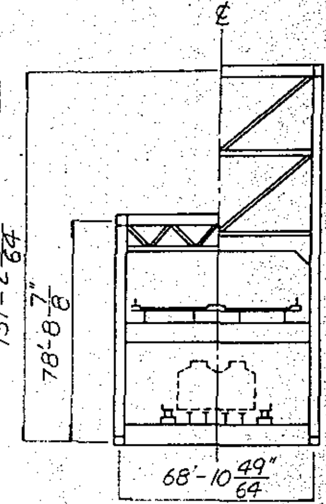
Table V-7 Span 820'-2 1/2" Cantilever Truss Case-b



Section (Chord, Diagonal)



Case-b (Double Deck)



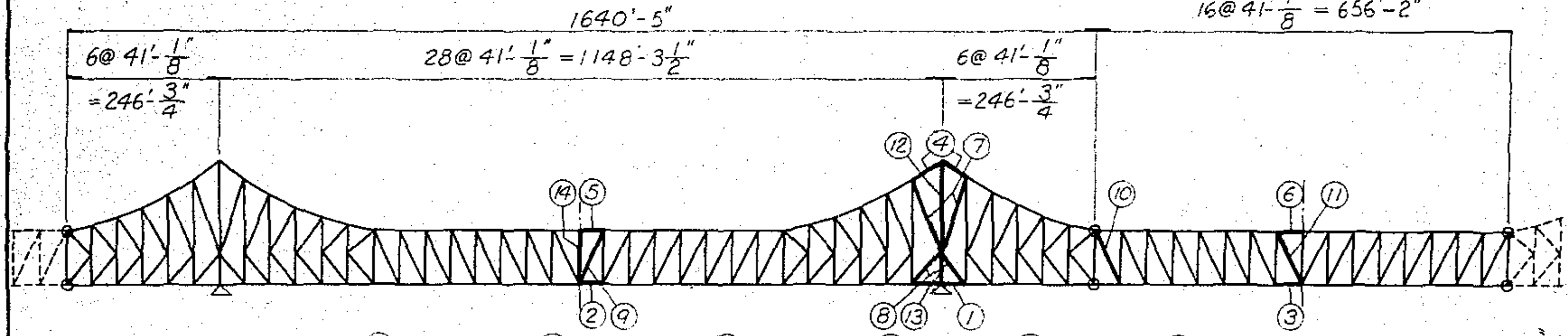
Member		①	②	③	④	⑤	⑥	⑦	⑧	⑨
Member Force	t	−3 993	−2 695	6 594	3 076	3 902	−2 076	−6 825	−3 162	−772
Material	—	SM58	SM53	SM58	SM53	SM58	SM53	SM58	SM53	SM41
Allowable Stress	psi	31 683	26 132	37 006	29 889	37 006	26 160	32 921	26 089	15 300
Stress	"	28 409	23 200	32 878	26 473	33 590	23 442	29 918	22 872	12 127
Plate Thickness	inch	$1\frac{31}{32}$	$1\frac{21}{32}$	$2\frac{9}{32}$	$1\frac{21}{32}$	$1\frac{21}{32}$	$1\frac{17}{64}$	$2\frac{19}{32}$	$1\frac{31}{32}$	$\frac{29}{32}$

Member		⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰	⑱
Member Force	t	1 290	−1 456	1 761	3 193	862	2 091	−3 810	−7 209	765
Material	—	SM41	SM53	SM53	SM53	SS41	SM41	SM58	SM58	SM41
Allowable Stress	psi	19 926	20 396	29 889	29 889	19 926	19 926	22 488	33 263	15 300
Stress	"	16 667	17 549	26 559	27 484	16 411	15 756	20 026	30 658	12 013
Plate Thickness	inch	$1\frac{7}{64}$	$1\frac{3}{16}$	$\frac{15}{16}$	$1\frac{21}{32}$	$\frac{3}{4}$	$1\frac{57}{64}$	$2\frac{11}{64}$	$2\frac{43}{64}$	$\frac{29}{32}$

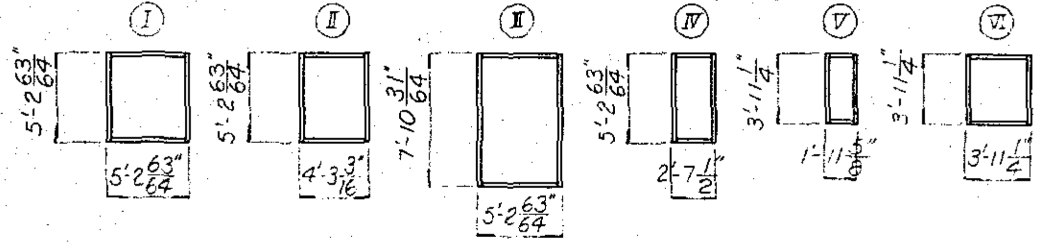
		Section
Stringer	Highway	1-Pl $7'\text{-}4\frac{37''}{64}\times\frac{55''}{64}$
		1-Pl $4'\text{-}7\frac{1''}{8}\times\frac{23''}{64}$
		1-Pl $11\frac{13''}{16}\times\frac{55''}{64}$
	Railway	2-Pls $1'\text{-}3\frac{3''}{4}\times\frac{63''}{64}$
		1-Pl $4'\text{-}7\frac{1''}{8}\times\frac{33''}{64}$
Floor Beam	Highway	2-Pls $2'\text{-}\frac{1''}{64}\times1\frac{7''}{64}$
		1-Pl $8'\text{-}2\frac{27''}{64}\times\frac{15''}{32}$
	Railway	2-Pls $2'\text{-}7\frac{1''}{2}\times1\frac{1''}{2}$
		1-Pl $9'\text{-}10\frac{7''}{64}\times\frac{25''}{32}$

Maximum Deflection (Live-load)	
Railway (Single Truck)	$1'\text{-}6\frac{11''}{32}$
Railway + Highway	$1'\text{-}11\frac{25''}{64}$

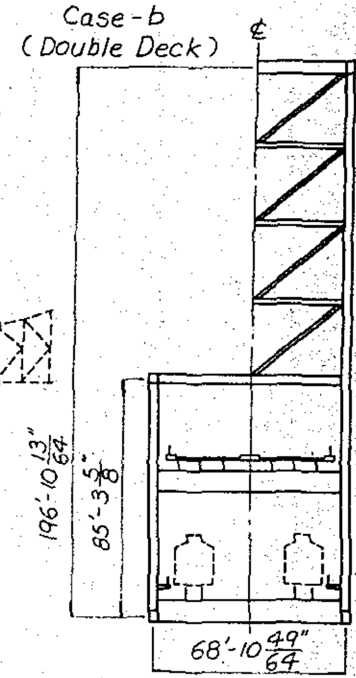
Table V-8 Span 1148'-3 1/2" Cantilever Truss Case-b



Section



Case-b
(Double Deck)



Member		①	②	③	④	⑤	⑥	⑦
Member Force	t	-5 409	9 721	5 052	6 316	-9 942	5 131	-2 214
Type of Section	—	I	I	VI	I	I	VI	II
Material	—	SM58	SM58	SM58	SM58	SM58	SM58	SM52
Allowable Stress	psi	35 099	37 006	37 006	37 006	34 942	32 949	17 521
Stress	"	32 722	33 746	31 768	34 017	33 946	30 416	16 069
Plate Thickness	inch	1 17/64	2 11/64	1 31/32	1 27/64	2 11/64	1 49/64	1 3/16

Member		⑧	⑨	⑩	⑪	⑫	⑬	⑭
Member Force	t	1 125	-384	2 775	-123	-6 440	-11 181	-633
Type of Section	—	II	IV	VI	V	III	III	IV
Material	—	SS41	SS41	SM41	SS41	SM58	SM58	SS41
Allowable Stress	psi	19 926	12 169	19 926	8 668	19 670	34 088	13 180
Stress	"	14 233	5 423	17 450	4 270	17 165	29 804	8 938
Plate Thickness	inch	5/6	5/6	1 31/32	25/64	2 23/64	2 23/64	5/6

		Section
Stringer	Highway	1-Pl 7'-4 37/64" × 55/64"
		1-Pl 4'-7 1/8" × 23/64"
		1-Pl 11 13/16" × 55/64"
	Railway	2-Pls 1'-3 3/4" × 63/64"
		1-Pl 4'-7 1/8" × 33/64"
Floor Beam	Highway	2-Pls 2'-1/64" × 7/64"
		1-Pl 8'-2 27/64" × 15/32"
	Railway	2-Pls 2'-7 1/2" × 1 1/2"
		1-Pl 9'-10 7/64" × 5/6"

Maximum Deflection (Live-load)	
Railway (Single Truck)	1'-7 17/32"
Railway + Highway	2'-1 5/8"

3. Substructure.

3-1. Structural type.

At the first stage, well foundation and multi-pile-foundation are applied as a type of the foundation, by considering necessary depth of foundations, importance and favourable executions. In Bangladesh, formerly well foundation was applied in Hardinge Bridge and King George IV Bridge, and recently also it was applied in foundations of road bridges between Dacca and Aricha. Advantages of this construction process are due to a massive body and good stability. Recently pile foundation process using large diameter size steel pipe was developed. Therefore, multi-pile-foundation using large steel pile of $2.0^m \sim 3.^m$ diameter should be investigated to be applied as a type of bridge foundation. Thus, two of these foundation process are studied.

In the case of multi-pile-foundation, the head of piles should be rigidly fixed to the base slab of the pier. This base slab will be constructed above DHWL. The base slab of this type of pier requires high rigidity because of the theoretical reason. As a pile has long portions of outstanding, a structure of this type is forced to be flexible and the center of gravity will be raised. Resulty, this is not desirable structurally and is apt to be bent by horizontal forces due to earthquake or current pressure.

Therefore, the well foundation was selected technically and economically as the foundation of Jamuna River Bridge. Local scouring around the pier is seemed to be more severe in the well foundation than in the multi-pile-foundation In future, it will be necessary to prevent the pier from scouring in order to secure the required grip of well in accordance with necessary.

3-2. Outline of structure.

The well foundation is most difficulty in settling, as well-known. The top of the well foundation is better to be lower for reducing of weight and pressure of water flow, and for outside views. If it is one meter higher than MLLWL, the settlement should be finished during a dry season from the view point of the execution process. Therefore, some difficulties should be anticipated. In order to carry out this purpose, we considered that the reverse circulation method is one of the most desirable execution method. In this case, some devices reducing resistances of frictions between curbshoe, body of well and surrounding earth should be considered. As the sinking velocity of well depends on the weight of itself, the thickness of wall of well should be as thick as practicable in order to accelerate the sinking velocity of well. Therefore, the thickness of wall was determined to $2.5^m \sim 3.5^m$.

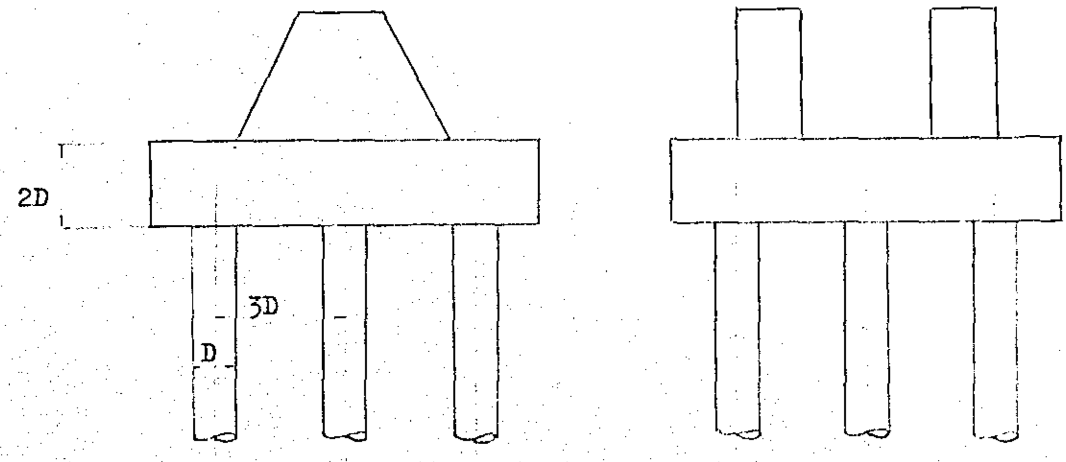
The definite length of grip of well must be needed to maintain a stability against lateral force. Therefore, some foot protection works around pier and their constant inspection and maintenance will be requested in future to secure the constant length of grip of well.

Sizes of pile to be used in the multi-pile-foundation are studied about two cases, such are the cases of 2.0^m and 3.0^m. As base slabs of piers are constructed above DHWL, piers will be able to be constructed in dry.

The shape of pier consists of reinforced concrete trapezoid and base slab. The reinforced concrete trapezoid is placed just below the main truss of the superstructure to have the wall thickness durable to support upper loads and the bearing shoes of the bridge at the top. In order to increase the stiffness of the base slab, the base of trapezoid is to be placed in parallel to the axis of the bridge, on the base slab to which pile heads are fixed rigidly. (Fig V-5)

In the case of multi-pile-foundation, though local scouring is a little, a method good for scouring should be applied to have a necessary length of grip as same as the case of well type.

Fig. V-5 Example diagram of multi-pile-foundation.



3-3. Calculation of Design.

3-3-1. Well foundation.

(1) Outline of design.

The most important problem in Jamuna River Bridge Construction Project is the subject of local scouring after construction of substructure. Hereinafter, the river bed scoured by water flows is abbreviated to "the river bed". Moreover, the depth caused by water scouring around the structure is defined as 1.8 times of water depth by investigations of the River Team. But in this case, the width right angled to the water flow direction are determined to approximate 12^{m}.

Depth of the foundation is adequate to have the depth of $80^{m} \sim 90^{m}$ which reaches to the layer of gravel or hard clay by considering the result of the boring test and the sinking ability of well. But sometimes, local scouring exceeds this depth. Such a time the foundation cannot be stabilized without foot protection. Therefore, in this design, such a construction method to compact the river bed by stoning artificially to protect the river bed was applied for the effective length of grip of the foundation. Thus, the calculation in this design is to require the elevation of the compacted river bed for the stabilization of the well, namely the requirement of necessary length of grip for the well foundation

(2) Design condition.

Type of foundation	Well foundation	
Shape	Circular section : $\phi 12^{m}$, Oval section $12^{m} \times 24^{m}$	
Flow velocity	Maximum $4.0^{m}/sec$	
Local scouring	1.8 times of a depth	
Acceleration of earthquake	Horizontal	kh = 0.1 G
	Vertical	kv = 0.0 G
Weight of unit volume	Concrete	$\gamma_c = 2.5\ t/m^3$
	Earth	$\gamma_s = 1.9$ "

Other items are based on following documents.

Concrete standard specifications : Japan Society of Civil Engineers

(Authorized by Ministry of Construction of Japan)

Standard specifications for Highway bridges : Japan Society of Civil Engineers (Authorized by Ministry of Construction of Japan)

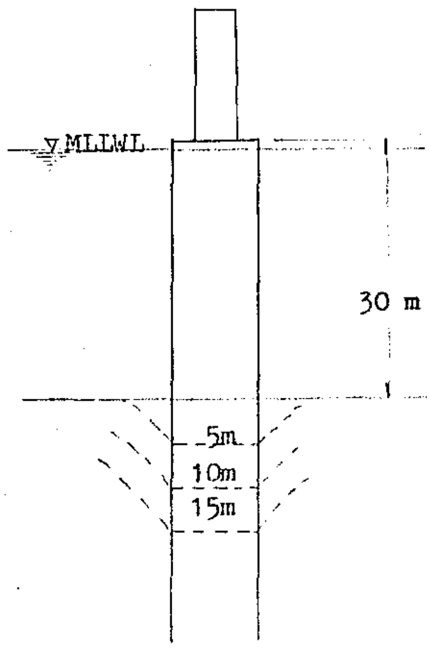
Design indicator for substructure of road bridge : Japan Road Association (Authorized by Ministry of Construction of Japan)

(3) Result of calculation.

1) Reaction of superstructre.

Reactions of superstructure are shown in Tables V-9~10.

2) Procedure of calculation.



A model of well foundation which has the dimension of 30^{m}, from the top of well to the river bed as shown on the drawing at right is considered. In this condition, the well stabilization is calculated by external forces which are assummed to act to local scouring at every 5^{m} unit from the river bed. When the result is spoted in the graph, necessary effective length of grip of well is required by stated conditions of the river bed in the graph. The result is shown in Figs. V-6~8. Calculating equation is all based on "Design indicator for substructure of highway bridges" editted by Japan Road Association (authorized by Ministry of Construction of Japan). The effective length of grip of well is calculated at two sites, Nagarbari and Sirajganj. According to the above calculation, other two sites will be assumed approximately without any calculations. This assumption does not object entirely to good ways in which calculations of material and

Table V-9 Reactions of Superstructure in Case a

(ton)

				N	Horizontal force			
					Longitudinal		Transverse	
					Fix.	Mov.	Fix.	Mov.
3 Span Cont. truss L=100m	Inter-mediate Support	Dead load		1614	440	81	161	161
		Live load	Railway	1018	285	51	102	102
			Highway	357				
		Total		2989	725	132	263	263
	End Support	Dead load		588		29	59	59
		Live load	Railway	410		21	41	41
			Highway	134				
		Total		1132		50	100	100
3 Span Cont. truss L=150m	Inter-mediate Support	Dead load		2916	795	146	292	292
		Live load	Railway	1485	414	74	149	149
			Highway	529				
		Total		4930	1209	220	441	441
	End Support	Dead load		1060		53	106	106
		Live load	Railway	586		29	59	59
			Highway	198				
		Total		1844		82	165	165
Cantiliver truss	L=250m	Dead load		5716	1143	286	572	572
		Live load	Railway	1781	356	89	178	178
			Highway	654				
		Total		8151	1499	375	750	750
	L=350m	Dead load		10316	2063	516	1032	1032
		Live load	Railway	2581	516	129	258	258
			Highway	1090				
		Total		13987	2579	645	1290	1290

Table V-10 Reactions of superstructure in Case b

(ton)

				N	Horizontal force			
					Longitudinal		Transverse	
					Fix.	Mov.	Fix.	Mov.
3 Span Cont. truss L=100m	Inter-mediate Support	Dead load		2734	746	137	273	273
		Live load	Railway	1988	555	99	199	199
			Highway	550				
		Total		5272	1301	236	472	472
	End Support	Dead load		994		50	99	99
		Live load	Railway	786		39	79	79
			Highway	206				
		Total		1986		89	178	178
3 Span Cont. truss L=150m	Inter-mediate Support	Dead load		4706	1484	235	471	471
		Live load	Railway	2922	812	146	292	292
			Highway	812				
		Total		8440	2296	381	763	763
	End Support	Dead load		1712		86	171	171
		Live load	Railway	1138		57	114	114
			Highway	304				
		Total		3154		143	285	285
Cantiliver truss	L=250m	Dead load		8970	1794	449	897	897
		Live load	Railway	3520	704	176	352	352
			Highway	1092				
		Total		13582	2498	625	1249	1249
	L=350m	Dead load		15720	3144	786	1572	1572
		Live load	Railway	5162	1032	258	516	516
			Highway	1452				
		Total		22334	4176	1044	2088	2088

Fig. V-6 Relations between safty factor and scouring depth of caissons

(AT SIRAJGANJ SITE)

Case a

(2-Lanes, single track)

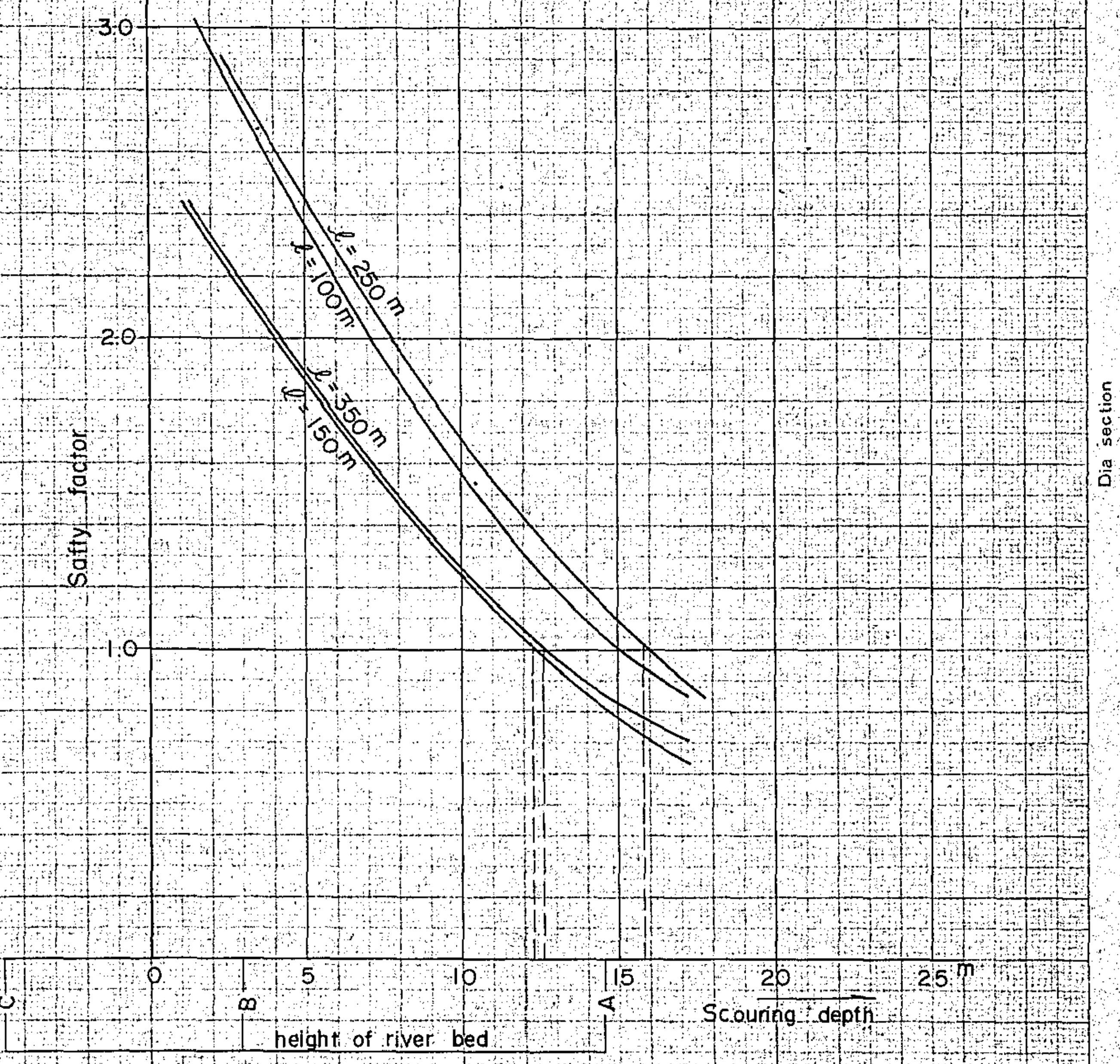


Fig. Ⅴ-7 Relations between safty factor and scouring depth of caissons

(AT NAGARBARI SITE)

Case a

(2 - Lanes, Single track)

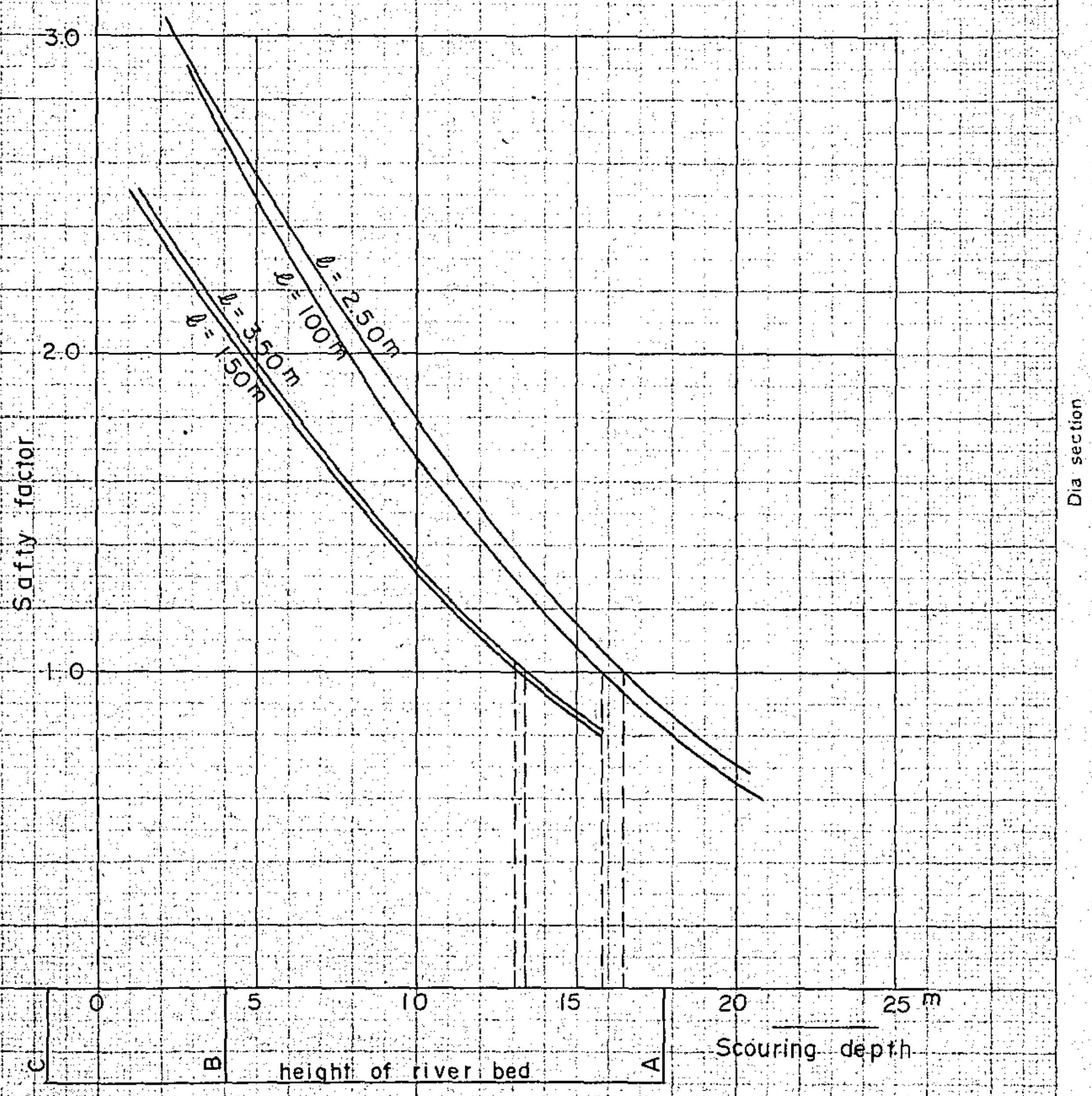
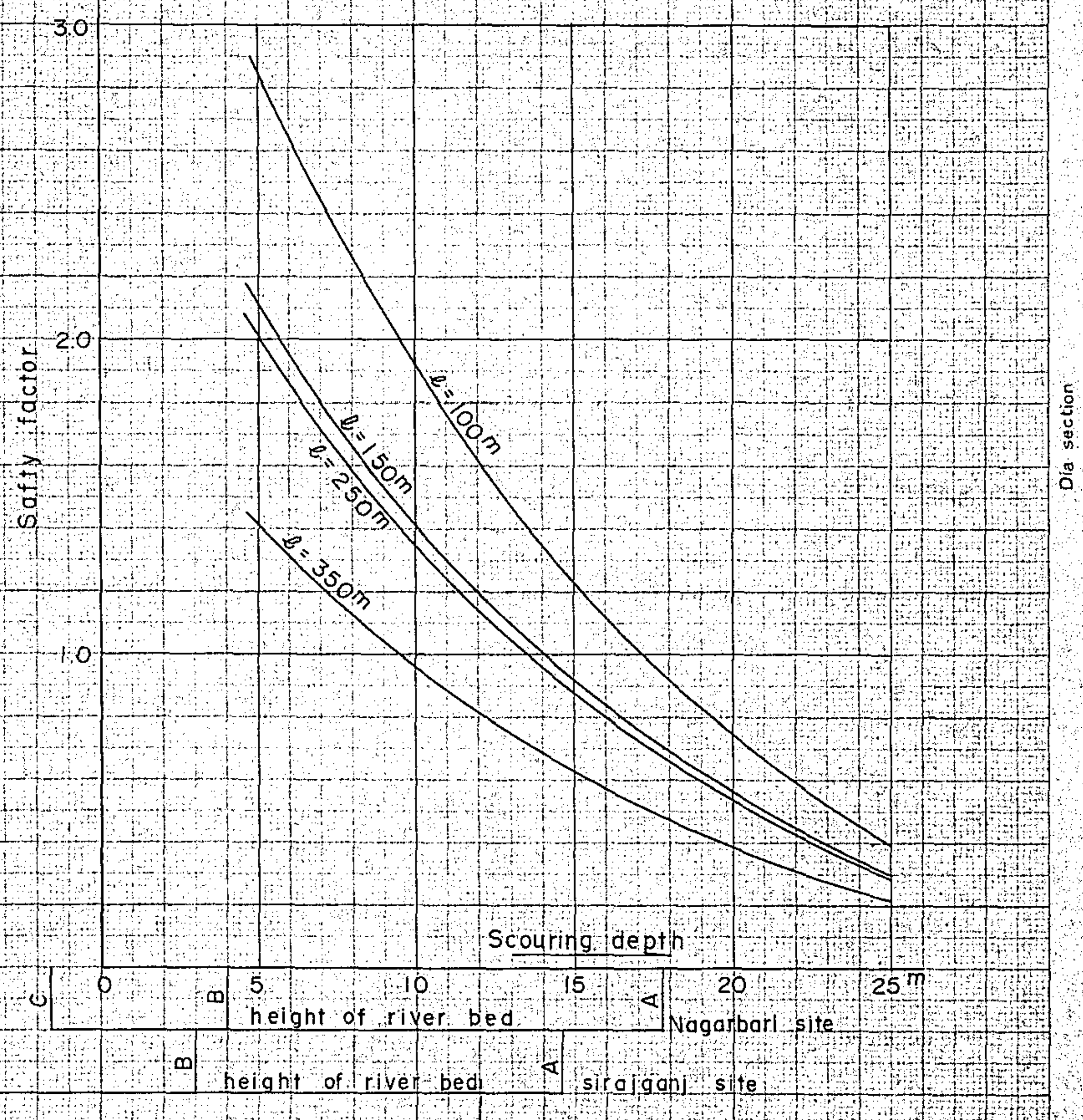


Fig V-8 Relations between safty factor and scouring depth of caissons

Case b

(4 - Lanes, double tracks)

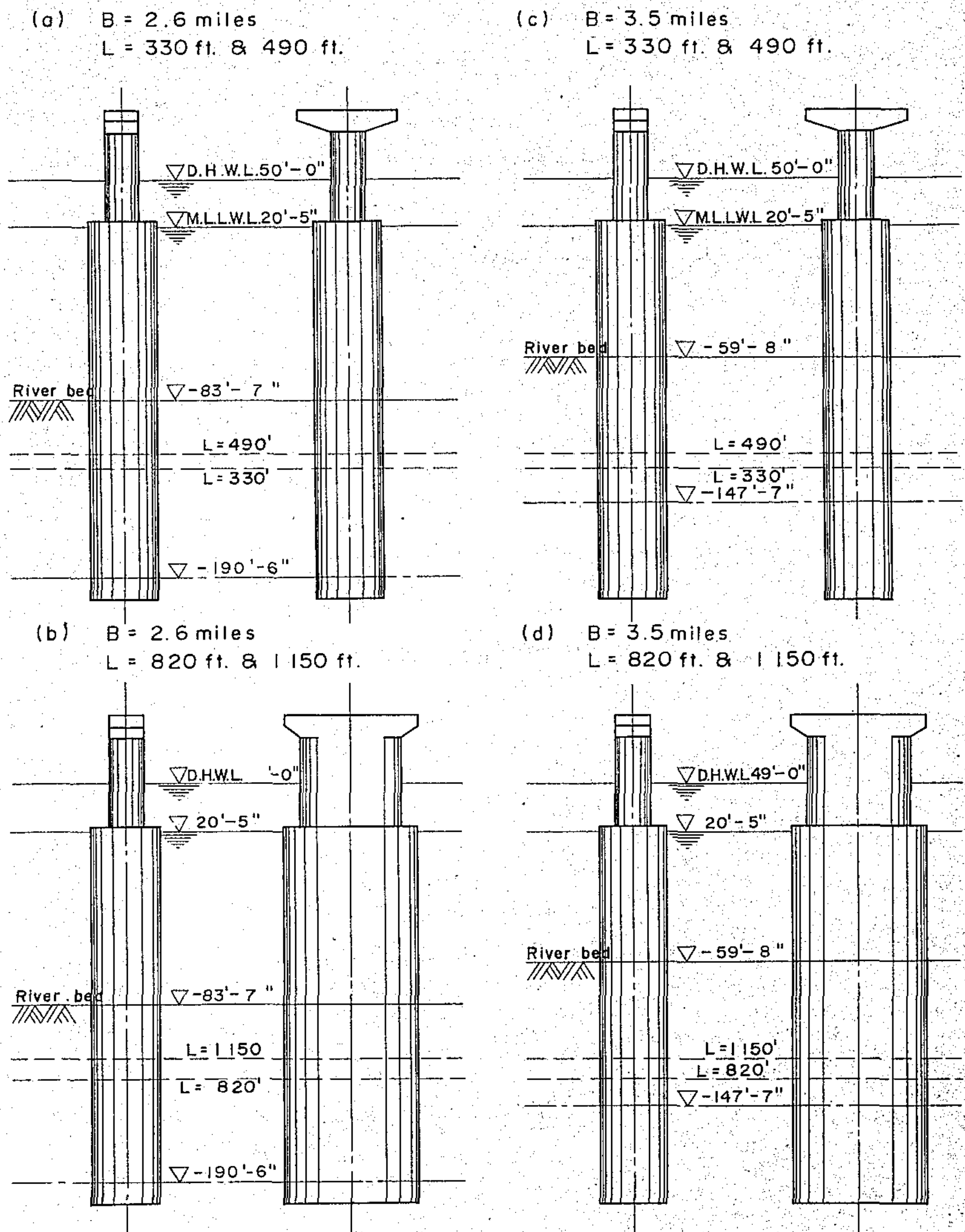


cost are included to decide the best site as the purpose of this project.

Moreover, the stabilization is calculated by a electronic computor. Plot graph by this result shows in Case a that lines for spans $\ell = 100^m$ and $\ell = 250^m$, and lines for spans $\ell = 150^m$ and $\ell = 350^m$ are approaching respectively in Figs. V-6, 7. These due to that the shap of well is $\phi\, 12^m$ at $\ell = 100^m$ and $\ell = 150^m$, and $12^m \times 24^m$ at $\ell = 250^m$ and $\ell = 350^m$, which cause the approximate similar increase in section and load. Also abovementioned lines show that sections at $\ell = 100^m$ and $\ell = 250^m$ are able to be lessened a little. In Case b, despite sections of well are same, $\ell = 150^m$ and $\ell = 250^m$ are approaching in Fig. V-8. This due to that $\ell = 150^m$ is the fixed base of three span continuous truss and $\ell = 250^m$ is that of a cantilever truss, and loads act to each fixed base are similar.

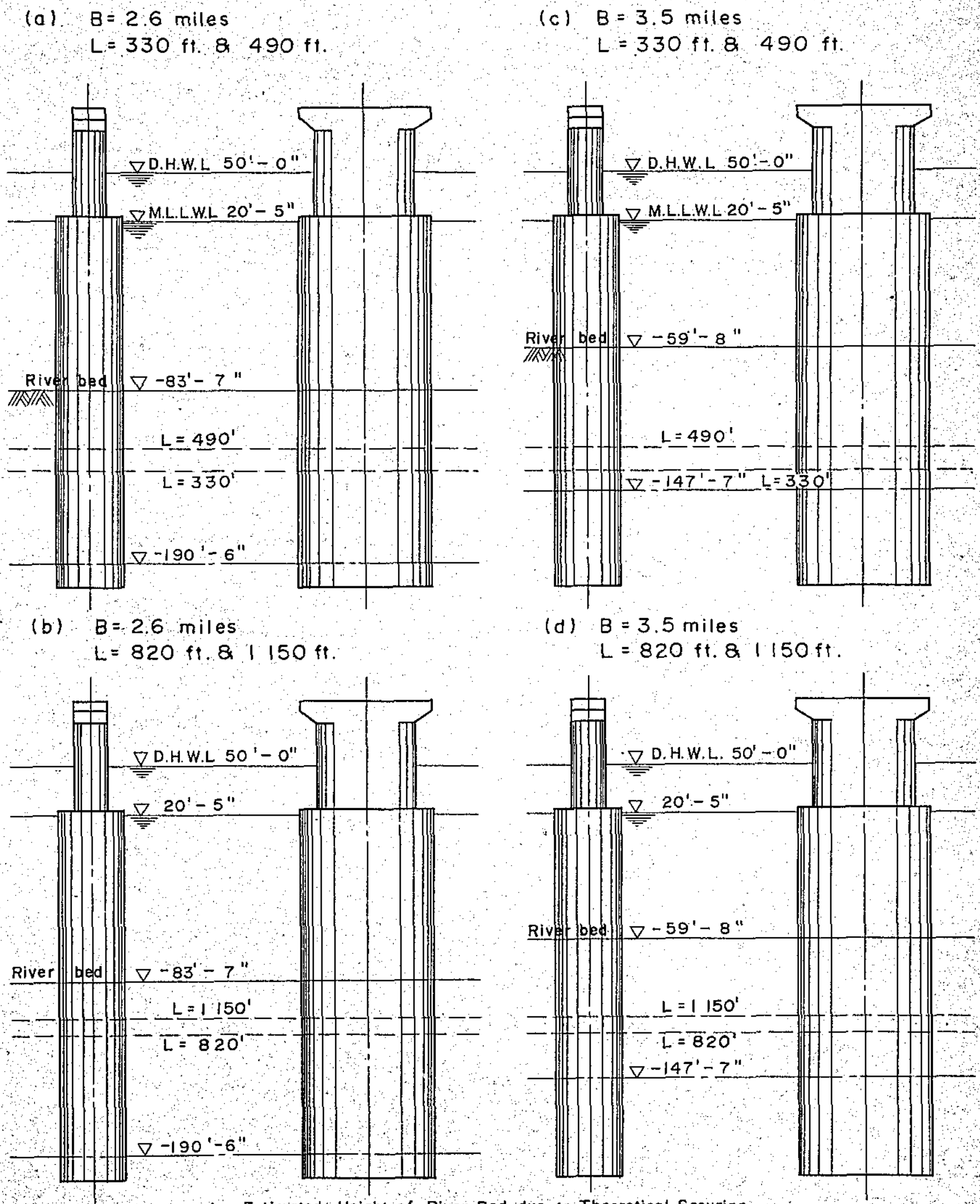
Effective length of grip assumed from this result showed in Fig. V-9 and Fig. V-10 as a example which covering the site of Sirajganj. These drawings show clearly that the longer in span, the longer grip is necessary.

Fig. Ⅴ-9 Necessary Length of Grip Required for Stability of Well (Case-a) at Sirajganj Site.



—— - —— : Estimated Height of River Bed due to Theoretical Scouring
— — — — : Height of River Bed required for Stability of Well.
B : Distance between Guide Banks.
L : Span Length of Bridge.

Fig. V-10 Necessary Length of Grip Required for Stability of Well (Case - b) at Sirajganj Site.



——— : Estimated Height of River Bed due to Theoretical Scouring.
— — — : Height of River Bed required for Stability of Well.
B : Distance between Guide Banks.
L : Span Length of Bridge.

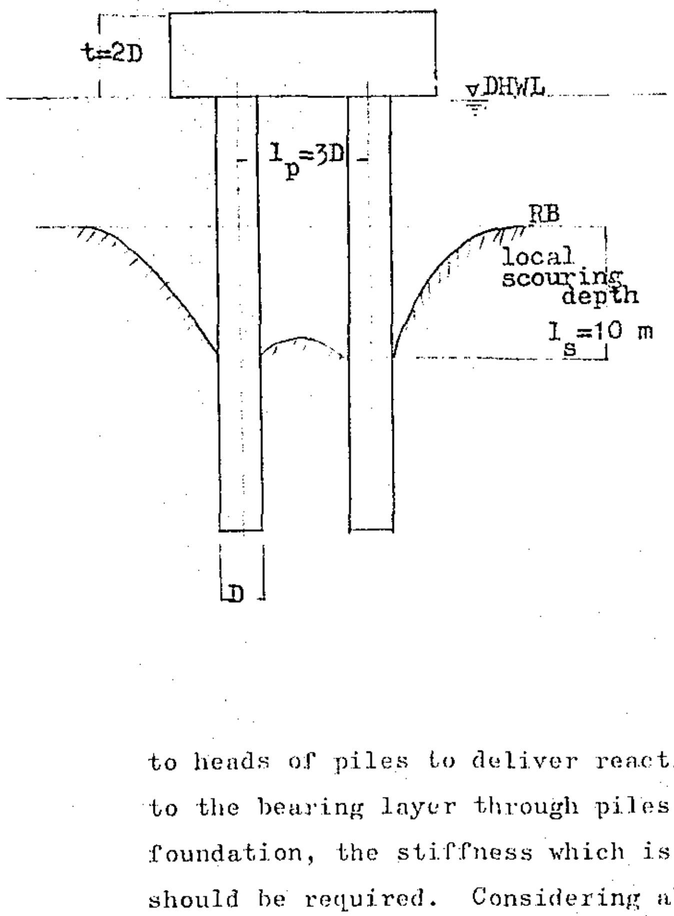
3-3-2. Multi-pile-foundation.

(1) Outline.

In the case of multi-pile-foundation, the river bed is lowered by influence of guide banks, piles are obstacles to water flows which cause the local scouring. Therefore, the multi-pile-foundation becomes the one consist of the piles with long unsupported part (free part).

The local scouring caused by a structure is very difficult to assume, at present.

Fig.V-11 Diagram of multi-pile foundation.



Of course, in this bridge this is one of the difficult problems. Therefore, in this bridge following results are obtained by the investigation of the River Team and experts in the association. Namely, in the case of the multi-pile foundation, when the diameter of pile is $2.0^m \sim 3.0^m$, the depth of the local scouring was defined to take $\ell = 10^m$ as one of considerations as shown in Fig. V-11. Though, the distance from center to center in piles is also related closely to the local scouring, it was determined to take three times of the pile diameter, namely $\ell_p = 3$ D by considerations of problems on execution and hydraulics.

The thickness is important for the base slab which is fixed rigidly to heads of piles to deliver reactions from the superstructure positively to the bearing layer through piles. At the calculation of the multi-pile-foundation, the stiffness which is able to be assumed as a rigid body should be required. Considering above-mentioned matters, the thickness of the base slab was determined to take twice the diameter of pile, after many calculations, namely

$$t = 2 \text{ D}.$$

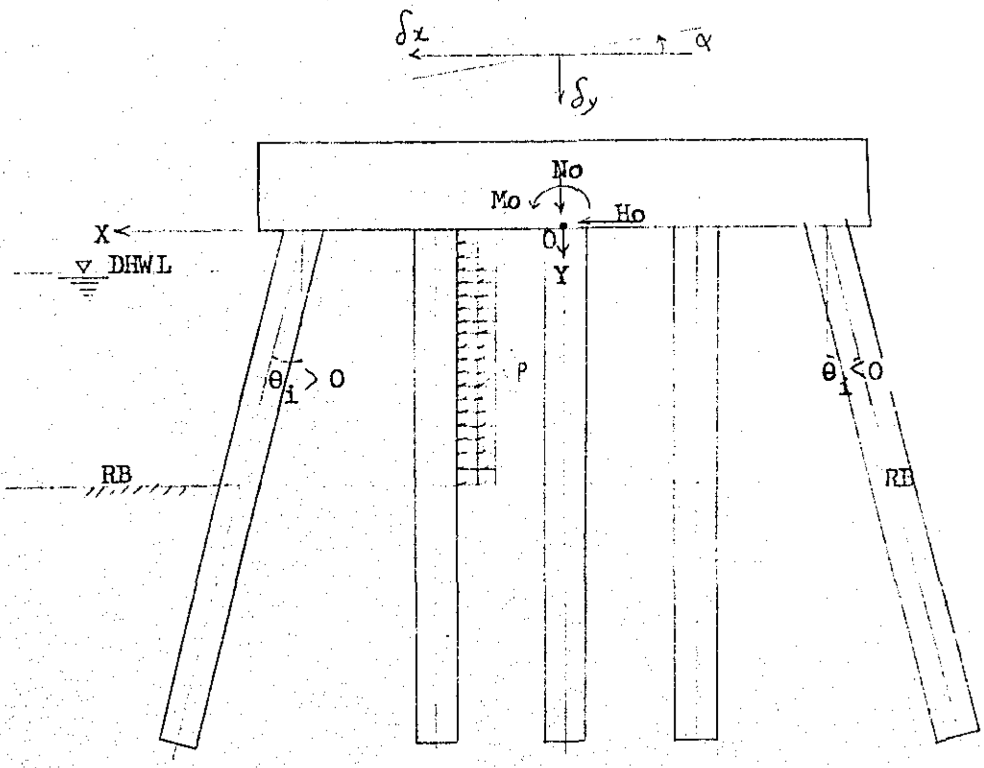
(2) Design Condition.

Diameter of pile	ϕ 2.0^m, ϕ 3.0^m
Thickness of plate of pile	$t = 40^{mm}$, $t = 60^{mm}$
Velocity current velocity	$v = 4.0^m/sec$
Depth of local scouring	10^m
Dist. center to center	3 D (D : Diameter of pile)
Thickness of base slab	2 D
Acceleration of earthquake	$k_h = 0.1$ G
	$k_V = 0$
Modulus of lateral foundation	$K_H = 3.6$ Kg/cm^3 (for D = 2.0^m)
	$K_H = 2.6$ " (for D = 3.0^m)
Weight per unit volume	Concrete $\gamma_c = 2.0t/m^3$ (Light-weight aggregates is used)
	Earth $\gamma_s = 1.9$ "
Thickness of corrosion	$t' = 2.0^{mm}$

(3) Calculation of stability.

1) Theoretical equation.

Fig. V-12 Diagram of theoretical system



One of arbitrary points on base slab is defined as original point O and the external force acting to point O is as shown in Fig. V-12. δx and δy are displacements in axes of co-ordinates, α is plus angle to X-axis, which are putted on the co-ordinate.

By assuming the base slab as a rigid body, displacement of the original point is shown in the following equation.

$$\begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} \delta_x \\ \delta_y \\ \alpha \end{bmatrix} = \begin{bmatrix} H_o + G_H \\ N_o + G_N \\ M_o + G_M \end{bmatrix}$$

with

$$A_{11} = \sum_i (K_{1i} \cos^2\theta_i + K_{vi}\sin^2\theta_i)$$

$$A_{12} = A_{21} = \sum_i \{(K_{vi} - K_{1i})\sin\theta_i\cos\theta_i\}$$

$$A_{13} = A_{31} = \sum_i \{(K_{vi} - K_{1i})x_i\sin\theta_i\cos\theta_i - (K_{1i}\cos^2\theta_i + K_{vi}\sin^2\theta_i)y_i - K_2\cos\theta_i\}$$

$$A_{22} = \sum_i (K_{vi}\cos^2\theta_i + K_{1i}\sin^2\theta_i)$$

$$A_{23} = A_{32} = \sum_i \{(K_{vi}\cos^2\theta_i + K_{1i}\sin^2\theta_i)x_i^2 - 2(K_{vi} - K_{1i})x_iy_i\sin\theta_i\cos\theta_i + (K_{1i}\cos^2\theta_i + K_{vi}\sin^2\theta_i)y_i^2 + (K_2 + K_3)(x_i\sin\theta_i + y_i\cos\theta_i) + K_{4i}\}$$

$$\begin{cases} G_H = \sum F_i\cos\theta_i \\ G_N = -\sum F_i\sin\theta_i \\ G_M = \sum (G_i - F_ix_i\sin\theta_i) \end{cases}$$

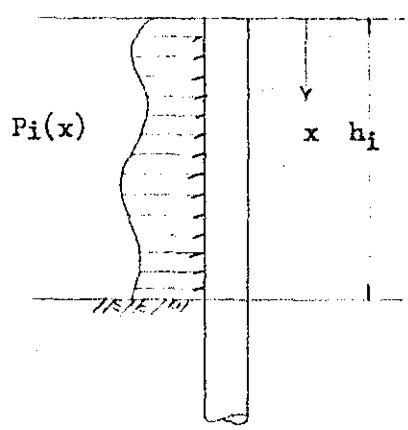
$$\begin{cases} F_i = K_{1i}\,\overline{\delta}x_i - K_{2i}\,\overline{\alpha}_i \\ G_i = -K_{3i}\,\overline{\delta}x_i + K_{4i}\,\overline{\alpha}_i \end{cases}$$

$$\begin{cases} \bar{\delta}_{ti} = \dfrac{1 + \beta_i(h_i + \bar{h}_{oi}) + 2\beta_i^2 h_i \bar{h}_{oi}}{2E_i I_i \beta_i^3} Q_{oi} + \dfrac{S_{oi}h_i - T_{oi}}{E_i I_i} \\ \bar{\alpha}_i = \dfrac{1 + 2\beta_i \bar{h}_{oi}}{2E_i I_i \beta_i^2} Q_{oi} \\ \bar{h}_{oi} = \dfrac{R_{oi}}{Q_{oi}} \end{cases}$$

$$\beta_i = \sqrt[4]{\frac{K_{Hi} D_i}{4E_i I_i}}$$

Fig. V-13 Diagram of thrust for pile

$$\begin{cases} Q_{oi} = \int^{h_i} P_i(x)dx \\ R_{oi} = \int^{h_i} P_i(x)(h_i - x)dx \\ S_{oi} = \frac{1}{2}\int^{h_i} P_i(x)(h_i - x)^2 dx \\ T_{oi} = \frac{1}{6}\int^{h_i} P_i(x)(h_i - x)^3 dx \end{cases}$$



But the pile should be based on the assumption of Y.L. Chang. And $P_i(x)$ is dispersed loads which act to a unit length at right angles with pile axis (t/m).

[Legend]

H_o : External force of horizontal, acts to original point O (t).

N_o : External force of Vertical, acts to original point O (t).

M_o : Moment due to external force acts to original point O (tm).

δ_x : Horizontal displacement of original point O (m).

δ_y : Vertical " " "

α : Rigidly rotating angle of base slab (rad).

K_{vi}: Axial spring constant (t/m).

K_{1i} : Force at right angles with pile axis, which produce a unit displacement at right angles with axis on pile head, when there is no rotation on pile head (t/m)

K_{2i} : Force at right angle with axis, which produce a unit rotation angles on pile head, when there is no displacement at right angles with axis on pile head (t/rad).

K_{3i} : Moment at pile head, which produce a unit displacement at right angles with axis on pile head, when there is no rotation on pile head (tm/m).

$K_{2i} = K_{3i}$ by reciprocal thorem.

K_{4i} : Moment at pile head, which produce a unit rotation angles on pile head, when there is no displacement at right angles with axis on pile head. (tm/rad)

x_i : Co-ordinate of Number i on x-axis (m).

y_i : " " on y-axis (m).

θ_i : Angles between Number i pile axis and y-axis (deg).

δ_x, δ_y and α can be acquired to solve three factors simultaneous equations above-mentioned. By which axial force P_{Ni}, a force at right angles with the axis P_{Hi} and restrained moment M_{ti} are calculated by following equations.

$$\begin{cases} P_{Ni} = K_{vi}\,\delta'_{yi} \\ P_{Hi} = K_{1i}\,\delta'_{xi} - K_{2i}\alpha - F_i \\ M_{ti} = -K_{3i}\,\delta'_{xi} + K_{4i}\alpha - G_i \end{cases}$$

with
$$\delta'_{xi} = \delta_x \text{Cos}\theta_i - (\delta y + \alpha x_i)\text{Sin}\theta_i$$

$$\delta'_{yi} = \delta_x \text{Sin}\theta_i + (\delta y + \alpha x_i)\text{Cos}\theta_i$$

Bending moment at outstanding of pile to which horizontal forces are acting directly, can be obtained from the theory of ordinary beam by acquiring P_{Hi} and M_{ti}, P_{Hi} is force at right angles with the axis on pile head, and M_{ti} is moment. At parts in the earth covering can be calculated by following equations.

Displacements on the ground surface

$$f = \frac{1 + \gamma + \beta (h + h_o + \gamma \overline{h}_o)}{2EI\beta^3} P_H$$

Bending moment at the point ℓm in the earth.

$$M_m = -\frac{P_H}{2\beta} \sqrt{\{1 + \gamma + 2\beta(h + h_o + \gamma\overline{h}_o)\}^2 + 1} \; \exp(-\beta\ell m)$$

$$\beta\ell m = \tan^{-1}\frac{1}{1 + \gamma + 2\beta(h + h_o + \gamma\overline{h}_o)}$$

with

$$\gamma = \frac{Q_o}{P_H} \;, \quad h_o = \frac{M_t}{P_H} \;, \quad \overline{h}_o = \frac{R_o}{Q_o}$$

Calculations of the stabilization will be made by the electronic computer based on the theory above-mentioned. Reactions of the superstructure are shown in Tables V-9, 10.

2) Result of calculation.

The unsupported length of the multi-pile-foundation (H_p) shall be the depth at D.H.W.L plus local scouring (10^m). The bottom end of footing shall be fitted to D.H.W.L.

The unsupported length each distance between guide banks on each site is shown in following table. (Table V-11)

Fig.V-14 Marks for Table V-11

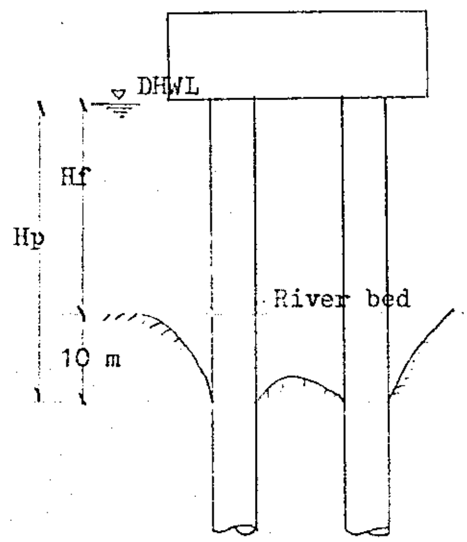


Table V-11 Outstanding length at each site

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

As the unsupported length $H_p = 60.5^m \sim 66.1^m$, at type A is very long, it is durable only to weights of it own and the body by the result of trial calculations. Which caused the design impracticable. Therefore, calculations of the stabilization in type A was not performed. And at cases of $H_p = 41^m$, 48^m and 52^m in type B, C will be calculated, as a typical example. Objects to be calculated is as follows.

Diameter of pile : $\phi = 2.0^m$ $t = 40^{mm}$
$\phi = 3.0^m$ $t = 60^{mm}$

Outstanding length: $H_p = 41^m$
$= 48^m$
$= 52^m$

Span : $L = 100^m$
150^m
250^m
350^m

Terms of support : Fixed
Movable

Width of superstructure : Case a (2 lanes, single track)
Case b (4 lanes, double track)

Results of calculations are shown in Tables V-12, 13.

Outlines of shapes in Case a, $\phi 3.0^m$ as a typical example are shown in Fig. V-15.

Table V-12-1 Case a

				Unit	41		48		52	
Span length				m	L = 100					
Diameter of pile				m	ϕ = 2.0					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	3		impossible		impossible	
			transverse	row	5					
			all piles	each	15					
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	$q_{v\ max}$	t/p	382	1048				
			$q_{v\ min}$	"	382	-330				
			q_H	"	0	87				
		Deflection of pile head		mm	0	312				
	Transverse	Reaction of pile	$q_{v\ max}$	t/p	474	715				
			$q_{v\ min}$	"	292	3				
			q_H	"	6	57				
		Deflection of pile head		mm	101	285				
	Bending moment			tm/p		1961				
	Max. stress of pile			Kg/cm^2		2195				
Movable pier	Number of piles		longitudinal	line	3		impossible		impossible	
			transverse	row	5					
			all piles	each	14					
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	$q_{v\ max}$	t/p	409	704				
			$q_{v\ min}$	"	409	14				
			q_H	"	0	47				
		Deflection of pile head		mm	0	183				
	Transverse	Reaction of pile	$q_{v\ max}$	t/p	508	715				
			$q_{v\ min}$	"	313	3				
			q_H	"	6	57				
		Deflection of pile head		mm	108	285				
	Bending moment			tm/p		1765				
	Max. stress of pile			Kg/cm^2		1878				

Table V-12-2 Case a

				Unit						
Span length				m	L = 150					
Diameter of pile				m	ϕ = 2.0					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	4		5		6	
		transverse		row	7		8		9	
		all piles		each	26		40		54	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	422	967	287	672	262	580
			q_V min	"	422	-164	287	-124	262	-78
			q_H	"	0	96	0	67	0	61
		Deflection of pile head		mm	0	329	0	364	0	421
	Transverse	Reaction of pile	q_V max	t/p	482	673	358	514	344	508
			q_V min	"	361	129	216	34	180	-5
			q_H	"	5	65	4	47	4	46
		Deflection of pile head		mm	97	307	161	409	218	527
	Bending moment			tm/p		2207		2117		2086
	Max. stress of pile			Kg/cm^2		2379		2105		2404
Movable pier	Number of piles	longitudinal		line	4		5		6	
		transverse		row	5		8		9	
		all piles		each	20		40		54	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	440	706	287	646	262	554
			q_V min	"	440	121	287	20	262	33
			q_H	"	0	49	0	47	0	43
		Deflection of pile head		mm	0	181	0	272	0	320
	Transverse	Reaction of pile	q_V max	t/p	532	806	358	514	344	508
			q_V min	"	348	20	216	34	180	-5
			q_H	"	6	64	4	47	4	46
		Deflection of pile head		mm	102	307	161	409	218	527
	Bending moment			tm/p		1921		2117		2086
	Max. stress of pile			Kg/cm^2		2056		2105		2404

Table V-12-3 Case a

				Unit						
Span length				m	L = 250					
Diameter of pile				m	$\phi = 2.0$					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	5		5		6	
			transverse	row	6		9		10	
			all piles	each	30		45		60	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	452	899	373	804	334	720
			q_V min	"	452	-39	373	-91	334	-81
			q_H	"	0	87	0	75	0	97
		Deflection of pile head		mm	0	294	0	400	0	660
	Transverse	Reaction of pile	q_V max	t/p	528	776	444	631	416	607
			q_V min	"	376	84	301	81	251	32
			q_H	"	5	65	4	56	4	53
		Deflection of pile head		mm	99	309	161	446	218	566
	Bending moment			tm/p		2008		2277		2511
	Max. stress of pile			Kg/cm^2		2173		2298		2532
Movable pier	Number of piles		longitudinal	line	5		5		6	
			transverse	row	5		9		10	
			all piles	each	25		45		60	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	516	752	373	661	334	686
			q_V min	"	516	227	373	188	334	-47
			q_H	"	0	51	0	52	0	67
		Deflection of pile head		mm	0	186	0	277	0	458
	Transverse	Reaction of pile	q_V max	t/p	608	933	444	631	416	607
			q_V min	"	423	46	301	81	251	32
			q_H	"	6	73	4	56	4	53
		Deflection of pile head		mm	102	334	161	446	218	566
	Bending moment			tm/p		2111		1961		2511
	Max. stress of pile			Kg/cm^2		2279		2049		2532

Table V-12-4 Case a

				Unit						
Span length				m	L = 350					
Diameter of pile				m	ϕ = 2.0					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	6		7		7	
		transverse		row	10		12		14	
		all piles		each	60		84		98	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	401	755	326	616	299	541
			q_V min	"	401	10	326	9	299	34
			q_H	"	0	81	0	69	0	66
		Deflection of pile head		mm	0	275	0	364	0	478
	Transverse	Reaction of pile	q_V max	t/p	444	582	372	489	345	447
			q_V min	"	357	183	278	137	253	128
			q_H	"	3	58	3	50	2	47
		Deflection of pile head		mm	92	283	155	420	207	530
	Bending moment			tm/p		1904		2170		2423
	Max. stress of pile			Kg/cm²		2019		2142		2349
Movable pier	Number of piles	longitudinal		line	5		7		7	
		transverse		row	9		12		14	
		all piles		each	43		84		98	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	511	755	326	544	299	494
			q_V min	"	511	216	326	152	299	81
			q_H	"	0	57	0	46	0	46
		Deflection of pile head		mm	0	202	0	261	0	333
	Transverse	Reaction of pile	q_V max	t/p	558	733	372	489	345	447
			q_V min	"	464	238	278	137	253	128
			q_H	"	4	69	3	50	2	47
		Deflection of pile head		mm	93	316	155	420	207	530
	Bending moment			tm/p		2040		2170		2120
	Max. stress of pile			Kg/cm²		2130		2142		2079

Table V-12-5 Case a

Span length				m	L = 100					
Diameter of pile				m	ϕ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	2		2		3	
		transverse		row	3		3		3	
		all piles		each	6		6		9	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1018	2556	1018	2763	823	1956
			q_v min	"	"	-585	"	-846	"	-390
			q_H	"	0	220	0	230	0	182
		Deflection of pile head		mm	0	192	0	299	0	266
	Transverse	Reaction of pile	q_v max	t/p	1290	2040	1253	2029	1094	1865
			q_v min	"	800	-69	783	-112	551	-299
			q_H	"	22	162	22	162	23	164
		Deflection of pile head		mm	50	171	68	236	92	292
	Bending moment			tm/p		4781		5852		5555
	Max. stress of pile			Kg/cm2		1717		2041		1788
Movable pier	Number of piles	longitudinal		line	2		3		3	
		transverse		row	2		3		3	
		all piles		each	4		5		9	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1365	2215	1223	2106	1018	1987
			q_v min	"	"	336	"	197	"	-69
			q_H	"	0	141	0	149	0	132
		Deflection of pile head		mm	0	127	0	184	0	226
	Transverse	Reaction of pile	q_v max	t/p	1666	2774	1550	2633	1283	2117
			q_v min	"	1064	-223	896	-330	754	-199
			q_H	"	32	206	33	207	22	162
		Deflection of pile head		mm	54	208	82	295	90	302
	Bending moment			tm/p		5040		6228		5755
	Max. stress of pile			Kg/cm2		1825		2106		1887

Table V-12-6 Case a

Pier	Direction	Item	Unit						
		Span length	m	L = 150					
		Diameter of pile	m	ϕ = 3.0					
		Thickness of pile	mm	t = 60					
		Outstanding length	m	41		48		52	
Fixed pier		Number of piles: longitudinal	line	3		3		3	
Fixed pier		Number of piles: transverse	row	3		3		3	
Fixed pier		Number of piles: all piles	each	8		9		9	
Fixed pier		Condition of load	–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Fixed pier	Longitudinal	Reaction of pile $q_{v\,max}$	t/p	1483	2857	1098	2537	1098	2631
Fixed pier	Longitudinal	Reaction of pile $q_{v\,min}$	"	1483	-23	1098	-126	1098	-552
Fixed pier	Longitudinal	Reaction of pile q_H	"	0	297	0	180	0	242
Fixed pier	Longitudinal	Deflection of pile head	mm	0	216	0	273	0	333
Fixed pier	Transverse	Reaction of pile $q_{v\,max}$	t/p	1670	2514	1340	2205	1371	2301
Fixed pier	Transverse	Reaction of pile $q_{v\,min}$	"	1296	320	857	-125	826	-222
Fixed pier	Transverse	Reaction of pile q_H	"	26	227	23	180	23	180
Fixed pier	Transverse	Deflection of pile head	mm	44	194	70	255	89	315
Fixed pier		Bending moment	tm/p		6700		6380		6949
Fixed pier		Max. stress of pile	Kg/cm^2		2271		2129		2215
Movable pier		Number of piles: longitudinal	line	2		2		3	
Movable pier		Number of piles: transverse	row	3		3		3	
Movable pier		Number of piles: all piles	each	6		6		8	
Movable pier		Condition of load	–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Movable pier	Longitudinal	Reaction of pile $q_{v\,max}$	t/p	1432	2362	1432	2493	1236	1976
Movable pier	Longitudinal	Reaction of pile $q_{v\,min}$	"	1432	325	1432	194	1236	363
Movable pier	Longitudinal	Reaction of pile q_H	"	0	155	0	155	0	149
Movable pier	Longitudinal	Deflection of pile head	mm	0	138	0	207	0	220
Movable pier	Transverse	Reaction of pile $q_{v\,max}$	t/p	1623	2508	1667	2666	1491	2405
Movable pier	Transverse	Reaction of pile $q_{v\,min}$	"	1240	179	1197	21	981	-66
Movable pier	Transverse	Reaction of pile q_H	"	22	201	22	201	26	202
Movable pier	Transverse	Deflection of pile head	mm	42	178	68	276	95	351
Movable pier		Bending moment	tm/p		6380		6949		6855
Movable pier		Max. stress of pile	Kg/cm^2		2095		2267		2226

Table V-12-7 Case a

Span length				m	L = 250					
Diameter of pile				m	φ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	3		3		3	
Fixed pier	Number of piles	transverse		row	4		4		4	
Fixed pier	Number of piles	all piles		each	10		12		12	
Fixed pier	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Fixed pier	Longitudinal	Reaction of pile	q_v max	t/p	1450	2689	1209	2607	1209	2803
Fixed pier	Longitudinal	Reaction of pile	q_v min	"	1450	81	1209	-299	1209	-394
Fixed pier	Longitudinal	Reaction of pile	q_H	"	0	285	0	238	0	259
Fixed pier	Longitudinal	Deflection of pile head		mm	0	206	0	268	0	364
Fixed pier	Transverse	Reaction of pile	q_v max	t/p	1582	2249	1383	2129	1406	2291
Fixed pier	Transverse	Reaction of pile	q_v min	"	1319	520	1035	179	1013	118
Fixed pier	Transverse	Reaction of pile	q_H	"	21	220	17	183	17	204
Fixed pier	Transverse	Deflection of pile head		mm	40	182	62	249	83	343
Fixed pier	Bending moment			tm/p		6463		6278		7381
Fixed pier	Max. stress of pile			Kg/cm²		2178		2114		2476
Movable pier	Number of piles	longitudinal		line	3		3		3	
Movable pier	Number of piles	transverse		row	3		3		4	
Movable pier	Number of piles	all piles		each	9		9		12	
Movable pier	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Movable pier	Longitudinal	Reaction of pile	q_v max	t/p	1467	2176	1467	2275	1209	2143
Movable pier	Longitudinal	Reaction of pile	q_v min	"	1467	613	1467	515	1209	166
Movable pier	Longitudinal	Reaction of pile	q_H	"	0	151	0	151	0	165
Movable pier	Longitudinal	Deflection of pile head		mm	0	117	0	178	0	243
Movable pier	Transverse	Reaction of pile	q_v max	t/p	1665	2632	1709	2797	1406	2291
Movable pier	Transverse	Reaction of pile	q_v min	"	1270	158	1226	-7	1013	118
Movable pier	Transverse	Reaction of pile	q_H	"	23	215	23	215	17	204
Movable pier	Transverse	Deflection of pile head		mm	43	189	70	291	83	343
Movable pier	Bending moment			tm/p		5543		6535		7381
Movable pier	Max. stress of pile			Kg/cm²		1929		2217		2476

Table V-12-8 Case a

				Unit						
Span length				m	L = 350					
Diameter of pile				m	ϕ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	4		4		4	
		transverse		row	4		4		4	
		all piles		each	16		16		16	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1596	2818	1596	2957	1596	3044
			q_v min	"	1596	238	1596	99	1596	12
			q_H	"	0	290	0	290	0	290
		Deflection of pile head		mm	0	203	0	307	0	386
	Transverse	Reaction of pile	q_v max	t/p	1738	2556	1772	2695	1795	2783
			q_v min	"	1454	500	1420	361	1397	273
			q_H	"	18	227	18	227	18	227
		Deflection of pile head		mm	38	188	63	291	83	371
	Bending moment			tm/p		6630		7674		8324
	Max. stress of pile			Kg/cm^2		2245		2542		2727
Movable pier	Number of piles	longitudinal		line	3		4		4	
		transverse		row	4		4		4	
		all piles		each	12		14		14	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1742	2476	1620	2216	1620	2263
			q_v min	"	1742	825	1620	869	1620	821
			q_H	"	0	161	0	163	0	163
		Deflection of pile head		mm	0	124	0	182	0	230
	Transverse	Reaction of pile	q_v max	t/p	1882	2644	1787	2563	1808	2640
			q_v min	"	1601	657	1453	521	1432	444
			q_H	"	17	211	20	220	20	220
		Deflection of pile head		mm	38	179	65	283	86	361
	Bending moment			tm/p		7098		6782		7429
	Max. stress of pile			Kg/cm^2		2303		2237		2419

Table V-13-1 Case b

				Unit						
Span length				m	L = 100					
Diameter of pile				m	$\phi = 2.0$					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	4		impossible		impossible	
Fixed pier	Number of piles		transverse	row	7					
Fixed pier	Number of piles		all piles	each	26					
Fixed pier	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Fixed pier	Longitudinal	Reaction of pile	q_v max	t/p						
Fixed pier	Longitudinal	Reaction of pile	q_v min	"						
Fixed pier	Longitudinal	Reaction of pile	q_H	"						
Fixed pier	Longitudinal	Deflection of pile head		mm						
Fixed pier	Transverse	Reaction of pile	q_v max	t/p						
Fixed pier	Transverse	Reaction of pile	q_v min	"						
Fixed pier	Transverse	Reaction of pile	q_H	"						
Fixed pier	Transverse	Deflection of pile head		mm						
Fixed pier	Bending moment			tm/p						
Fixed pier	Max. stress of pile			Kg/cm^2						
Movable pier	Number of piles		longitudinal	line	3		impossible		impossible	
Movable pier	Number of piles		transverse	row	6					
Movable pier	Number of piles		all piles	each	18					
Movable pier	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Movable pier	Longitudinal	Reaction of pile	q_v max	t/p	467	823				
Movable pier	Longitudinal	Reaction of pile	q_v min	"	467	50				
Movable pier	Longitudinal	Reaction of pile	q_H	"	0	52				
Movable pier	Longitudinal	Deflection of pile head		mm	0	200				
Movable pier	Transverse	Reaction of pile	q_v max	t/p	542	778				
Movable pier	Transverse	Reaction of pile	q_v min	"	392	95				
Movable pier	Transverse	Reaction of pile	q_H	"	5	63				
Movable pier	Transverse	Deflection of pile head		mm	98	303				
Movable pier	Bending moment			tm/p		2165				
Movable pier	Max. stress of pile			Kg/cm^2		2280				

Table V-13-2 Case b

				Unit						
Span length				m	L = 250					
Diameter of pile				m	ϕ = 2.0					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	6		6		7	
			transverse	row	8		10		12	
			all piles	each	48		60		84	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	447	834	385	771	321	641
			q_v min	"	447	14	385	-39	321	-18
			q_H	"	0	88	0	79	0	72
		Deflection of pile head		mm	0	296	0	413	0	479
	Transverse	Reaction of pile	q_v max	t/p	502	688	441	594	375	498
			q_v min	"	391	159	328	138	267	125
			q_H	"	4	63	3	56	3	50
		Deflection of pile head		mm	94	300	157	447	209	548
	Bending moment			tm/p		2050		2283		2491
	Max. stress of pile			Kg/cm^2		2182		2287		2431
Movable pier	Number of piles		longitudinal	line	5		6		7	
			transverse	row	8		9		12	
			all piles	each	40		54		84	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	508	751	412	628	321	525
			q_v min	"	508	212	412	156	321	98
			q_H	"	0	53	0	48	0	49
		Deflection of pile head		mm	0	193	0	273	0	350
	Transverse	Reaction of pile	q_v max	t/p	564	766	475	654	375	498
			q_v min	"	453	196	349	130	267	125
			q_H	"	4	68	4	59	3	50
		Deflection of pile head		mm	94	315	159	462	209	548
	Bending moment			tm/p		2024		2204		2491
	Max. stress of pile			Kg/cm^2		2130		2243		2431

Table V-13-3 Case b

			Unit						
Span length			m	L = 150					
Diameter of pile			m	ϕ = 2.0					
Thickness of pile			mm	t = 40					
Outstanding length			m	41		48		52	
Fixed pier	Number of piles	longitudinal	line	6		6		6	
Fixed pier	Number of piles	transverse	row	7		9		9	
Fixed pier	Number of piles	all piles	each	42		50		54	
Fixed pier	Condition of load		-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Fixed pier	Longitudinal	Reaction of pile $q_{v\ max}$	t/p	437	863	416	834	385	833
Fixed pier	Longitudinal	Reaction of pile $q_{v\ min}$	"	437	-28	416	-35	385	-93
Fixed pier	Longitudinal	Reaction of pile q_H	"	0	97	0	93	0	86
Fixed pier	Longitudinal	Deflection of pile head	mm	0	322	0	476	0	565
Fixed pier	Transverse	Reaction of pile $q_{v\ max}$	t/p	501	705	476	643	457	639
Fixed pier	Transverse	Reaction of pile $q_{v\ min}$	"	373	130	356	157	313	101
Fixed pier	Transverse	Reaction of pile q_H	"	5	64	4	62	4	57
Fixed pier	Transverse	Deflection of pile head	mm	96	302	160	472	215	589
Fixed pier	Bending moment		tm/p		1908		2391		2639
Fixed pier	Max. stress of pile		Kg/cm^2		2001		2405		2624
Movable pier	Number of piles	longitudinal	line	5		6		6	
Movable pier	Number of piles	transverse	row	7		9		9	
Movable pier	Number of piles	all piles	each	33		50		54	
Movable pier	Condition of load		-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Movable pier	Longitudinal	Reaction of pile $q_{v\ max}$	t/p	434	645	416	637	385	627
Movable pier	Longitudinal	Reaction of pile $q_{v\ min}$	"	434	174	416	163	385	114
Movable pier	Longitudinal	Reaction of pile q_H	"	0	50	0	55	0	51
Movable pier	Longitudinal	Deflection of pile head	mm	0	183	0	301	0	362
Movable pier	Transverse	Reaction of pile $q_{v\ max}$	t/p	496	690	476	643	457	639
Movable pier	Transverse	Reaction of pile $q_{v\ min}$	"	372	129	356	157	313	101
Movable pier	Transverse	Reaction of pile q_H	"	5	63	4	62	4	57
Movable pier	Transverse	Deflection of pile head	mm	97	301	160	472	215	589
Movable pier	Bending moment		tm/p		1949		2391		2639
Movable pier	Max. stress of pile		Kg/cm^2		2012		2404		2624

Table V-13-4 Case b

				Unit						
Span length				m	L = 350					
Diameter of pile				m	ϕ = 2.0					
Thickness of pile				mm	t = 40					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	7		8		8	
			transverse	row	12		12		15	
			all piles	each	84		96		120	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	425	762	389	696	287	539
			q_V min	"	425	53	389	53	287	23
			q_H	"	0	88	0	80	0	64
		Deflection of pile head		mm	0	293	0	415	0	435
	Transverse	Reaction of pile	q_V max	t/p	461	583	436	570	330	423
			q_V min	"	389	232	343	179	245	133
			q_H	"	3	60	3	57	2	46
		Deflection of pile head		mm	90	289	155	450	206	527
	Bending moment			tm/p		2047		2197		2411
	Max. stress of pile			Kg/cm²		2149		2254		2328
Movable pier	Number of piles		longitudinal	line	7		8		8	
			transverse	row	10		12		15	
			all piles	each	70		96		120	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	363	544	307	468	287	466
			q_V min	"	363	152	307	130	287	95
			q_H	"	0	46	0	47	0	48
		Deflection of pile head		mm	0	261	0	265	0	345
	Transverse	Reaction of pile	q_V max	t/p	420	570	354	466	330	423
			q_V min	"	307	125	261	132	245	138
			q_H	"	3	55	3	49	2	46
		Deflection of pile head		mm	158	442	155	417	206	527
	Bending moment			tm/p		2097		2154		2411
	Max. stress of pile			Kg/cm²		2111		2118		2328

Table V-13-5 Case b

Span length				m	L = 100					
Diameter of pile				m	$\phi = 3.0$					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	3		3		3	
			transverse	row	2		3		3	
			all piles	each	6		8		9	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	1042	2186	1067	2324	948	2301
			q_V min	"	1042	-221	1067	-327	948	-526
			q_H	"	0	228	0	243	0	216
		Deflection of pile head		mm	0	170	0	271	0	310
	Transverse	Reaction of pile	q_V max	t/p	1172	1618	1256	1921	1178	1911
			q_V min	"	912	347	878	75	719	-137
			q_H	"	23	174	17	157	15	139
		Deflection of pile head		mm	42	155	64	229	82	274
	Bending moment			tm/p		5206		6430		6242
	Max. stress of pile			Kg/cm^2		1758		2101		2048
Movable pier	Number of piles		longitudinal	line	3		3			
			transverse	row	3		3			
			all piles	each	5		5			
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_V max	t/p	1596	2486	1251	1881	1279	2138
			q_V min	"	1596	564	1251	478	1279	236
			q_H	"	0	260	0	155	0	118
		Deflection of pile head		mm	0	186	0	179	0	207
	Transverse	Reaction of pile	q_V max	t/p	1773	2674	1467	2237	1504	2380
			q_V min	"	1419	375	1035	121	1053	-6
			q_H	"	28	278	28	209	14	163
		Deflection of pile head		mm	45	226	74	279	81	304
	Bending moment			tm/p		6948		6427		5773
	Max. stress of pile			Kg/cm^2		2301		2084		1941

Table V-13-6 Case b

				Unit						
Span length				m	L = 150					
Diameter of pile				m	ϕ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles		longitudinal	line	4		4		4	
			transverse	row	3		3		4	
			all piles	each	12		12		14	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1203	2514	1203	2655	898	1832
			q_v min	"	1203	-201	1203	-342	898	-88
			q_H	"	0	294	0	294	0	218
		Deflection of pile head		mm	0	206	0	311	0	293
	Transverse	Reaction of pile	q_v max	t/p	1403	2281	1448	2438	1100	1811
			q_v min	"	1002	33	957	-1	700	-67
			q_H	"	24	199	24	199	18	167
		Deflection of pile head		mm	43	178	71	275	84	298
	Bending moment			tm/p		6718		2776		1439
	Max. stress of pile			Kg/cm^2		2211		2511		2012
Movable pier	Number of piles		longitudinal	line	2		2		3	
			transverse	row	4		4		4	
			all piles	each	8		8		10	
	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1581	2633	1581	2775	1443	2259
			q_v min	"	1581	391	1581	250	1443	518
			q_H	"	0	171	0	171	0	173
		Deflection of pile head		mm	0	150	0	226	0	249
	Transverse	Reaction of pile	q_v max	t/p	1718	2521	1751	2652	1625	2446
			q_v min	"	1444	503	1411	372	1261	330
			q_H	"	16	211	16	211	21	220
		Deflection of pile head		mm	37	178	61	276	86	360
	Bending moment			tm/p		6886		6718		7425
	Max. stress of pile			Kg/cm^2		2277		2260		2382

Table V-13-7 Case b

Item				Unit						
Span length				m	L = 250					
Diameter of pile				m	ϕ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	4		4		4	
Fixed pier	Number of piles	transverse		row	4		4		4	
Fixed pier	Number of piles	all piles		each	14		16		16	
Fixed pier	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Fixed pier	Longitudinal	Reaction of pile	q_V max	t/p	1551	2693	1357	2610	1357	2690
Fixed pier	Longitudinal	Reaction of pile	q_V min	"	1551	253	1357	-32	1357	-112
Fixed pier	Longitudinal	Reaction of pile	q_H	"	0	301	0	263	0	263
Fixed pier	Longitudinal	Deflection of pile head		mm	0	209	0	281	0	354
Fixed pier	Transverse	Reaction of pile	q_V max	t/p	1687	2426	1533	2361	1556	2443
Fixed pier	Transverse	Reaction of pile	q_V min	"	1416	520	1181	217	1159	135
Fixed pier	Transverse	Reaction of pile	q_H	"	20	232	18	203	18	203
Fixed pier	Transverse	Deflection of pile head		mm	40	191	63	268	83	342
Fixed pier	Bending moment			tm/p		6886		7014		7612
Fixed pier	Max. stress of pile			Kg/cm^2		2288		2306		2476
Movable pier	Number of piles	longitudinal		line	3		3		4	
Movable pier	Number of piles	transverse		row	4		4		4	
Movable pier	Number of piles	all piles		each	12		12		14	
Movable pier	Condition of load			-	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
Movable pier	Longitudinal	Reaction of pile	q_V max	t/p	1611	2427	1661	2533	1357	2021
Movable pier	Longitudinal	Reaction of pile	q_V min	"	1611	713	1661	607	1357	557
Movable pier	Longitudinal	Reaction of pile	q_H	"	0	165	0	165	0	146
Movable pier	Longitudinal	Deflection of pile head		mm	0	127	0	193	0	211
Movable pier	Transverse	Reaction of pile	q_V max	t/p	1802	2634	1835	2772	1556	2433
Movable pier	Transverse	Reaction of pile	q_V min	"	1521	506	1487	369	1159	135
Movable pier	Transverse	Reaction of pile	q_H	"	17	225	17	225	18	203
Movable pier	Transverse	Deflection of pile head		mm	38	187	62	289	83	342
Movable pier	Bending moment			tm/p		6886		7612		6944
Movable pier	Max. stress of pile			Kg/cm^2		2238		2446		2256

Table V-13-8 Case b

				Unit						
Span length				m	L = 350					
Diameter of pile				m	ϕ = 3.0					
Thickness of pile				mm	t = 60					
Outstanding length				m	41		48		52	
Fixed pier	Number of piles	longitudinal		line	4		4		4	
		transverse		row	6		6		6	
		all piles		each	22		22		24	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1746	2442	1746	2544	1541	2324
			q_v min	"	1746	670	1746	568	1541	411
			q_H	"	0	222	0	222	0	182
		Deflection of pile head		mm	0	158	0	239	0	255
	Transverse	Reaction of pile	q_v max	t/p	1830	2238	1851	2327	1667	2163
			q_v min	"	1660	875	1641	785	1415	570
			q_H	"	13	219	13	219	12	187
		Deflection of pile head		mm	34	178	57	275	75	315
	Bending moment			tm/p		5790		6809		6592
	Max. stress of pile			Kg/cm^2		1919		2200		2113
Movable pier	Number of piles	longitudinal		line	4		4		4	
		transverse		row	6		6		6	
		all piles		each	22		22		24	
	Condition of load			–	Usually	Earthquake	Usually	Earthquake	Usually	Earthquake
	Longitudinal	Reaction of pile	q_v max	t/p	1746	2220	1746	2362	1600	2218
			q_v min	"	1746	892	1746	750	1600	635
			q_H	"	0	174	0	174	0	160
		Deflection of pile head		mm	0	127	0	180	0	227
	Transverse	Reaction of pile	q_v max	t/p	1830	2238	1851	2327	1726	2260
			q_v min	"	1662	875	1641	785	1475	593
			q_H	"	13	219	13	219	12	201
		Deflection of pile head		mm	34	178	57	275	75	331
	Bending moment			tm/p		5790		6809		6956
	Max. stress of pile			Kg/cm^2		1919		2200		2225

Fig. Ⅴ - 15 - 1   Outline of structure of multi - pile foundation ø 3.0m

Case of bridge	Case a
Span Length	100m
Condition of support	Fix (Mov)
Outstanding length	35.5m, 42.0m (46.0m)

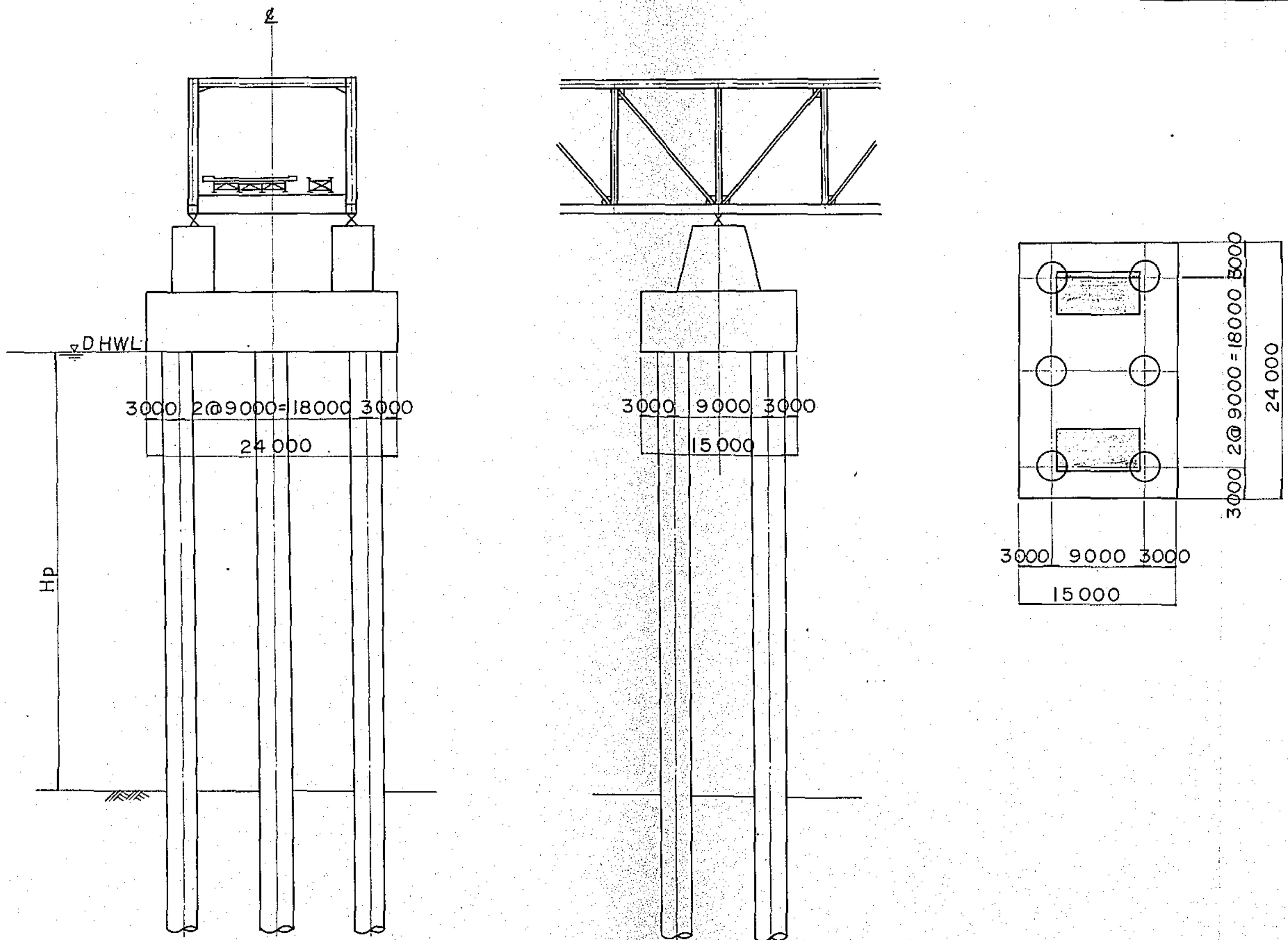


Fig. V-15-2 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	100m
Conditon of support	Fix
Outstanding length	46.0m

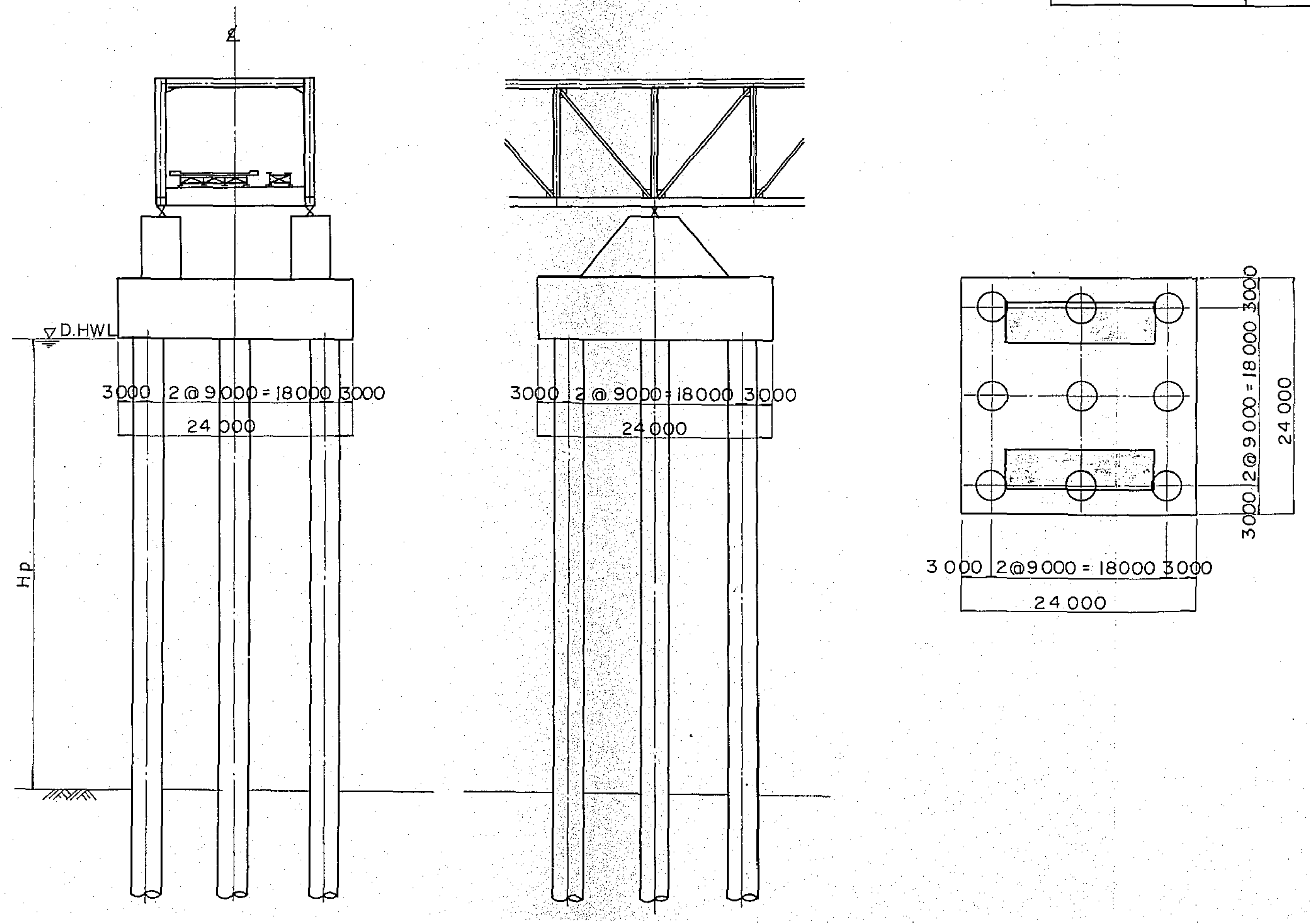


Fig. V - 15-3 Outline of structure of multi - pile foundation ø 3.0 m

Case of length	Case a
Span length	100 m
Condintion of support	Mov
Outstanding length	35.5 m

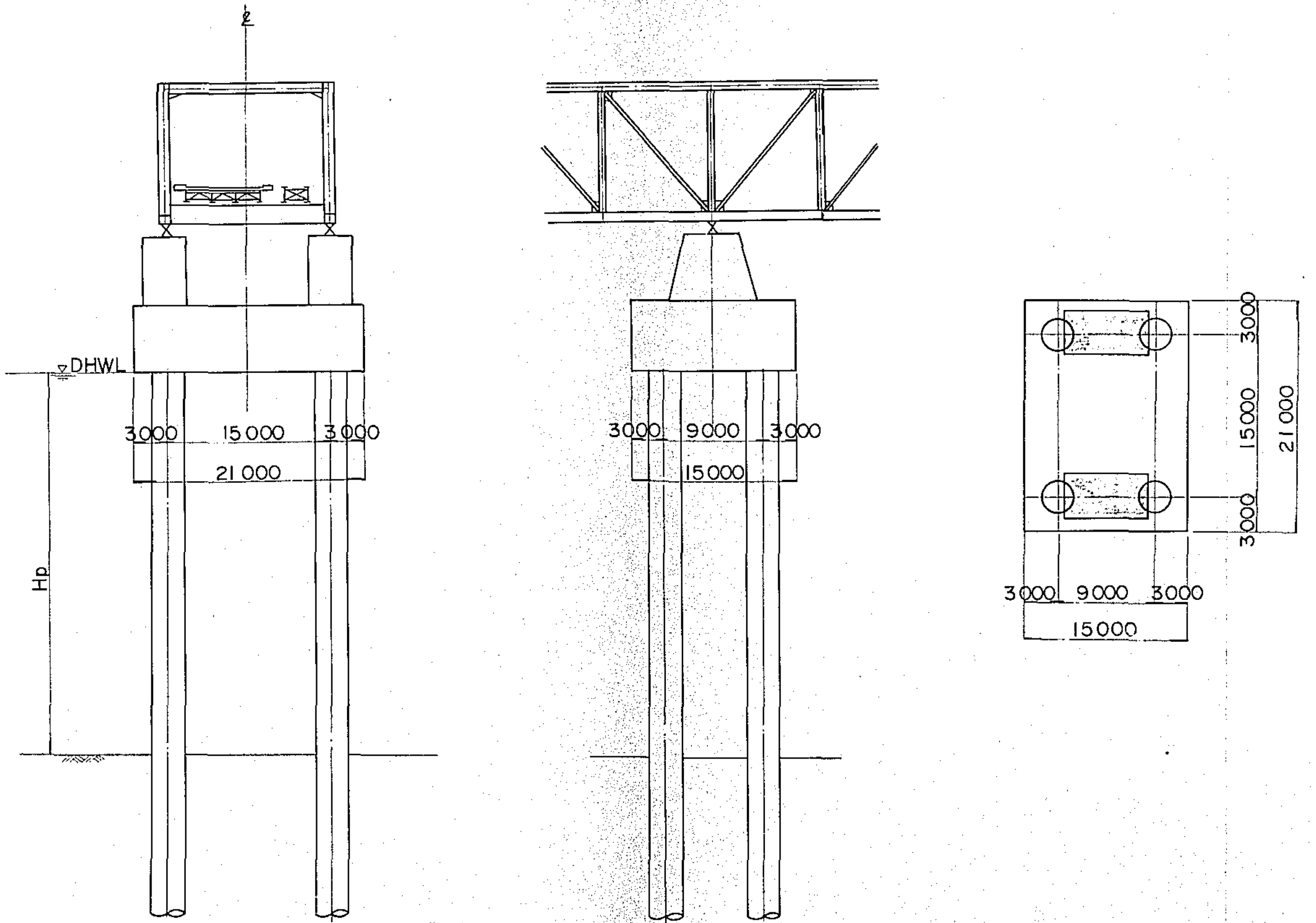


Fig. V - 15-4 Outline of structure of multi-pile foundation

ø 3.0m

Case of bridge	Case a
Span length	100m
Conditon of support	Mov
Outstanding length	42.0m

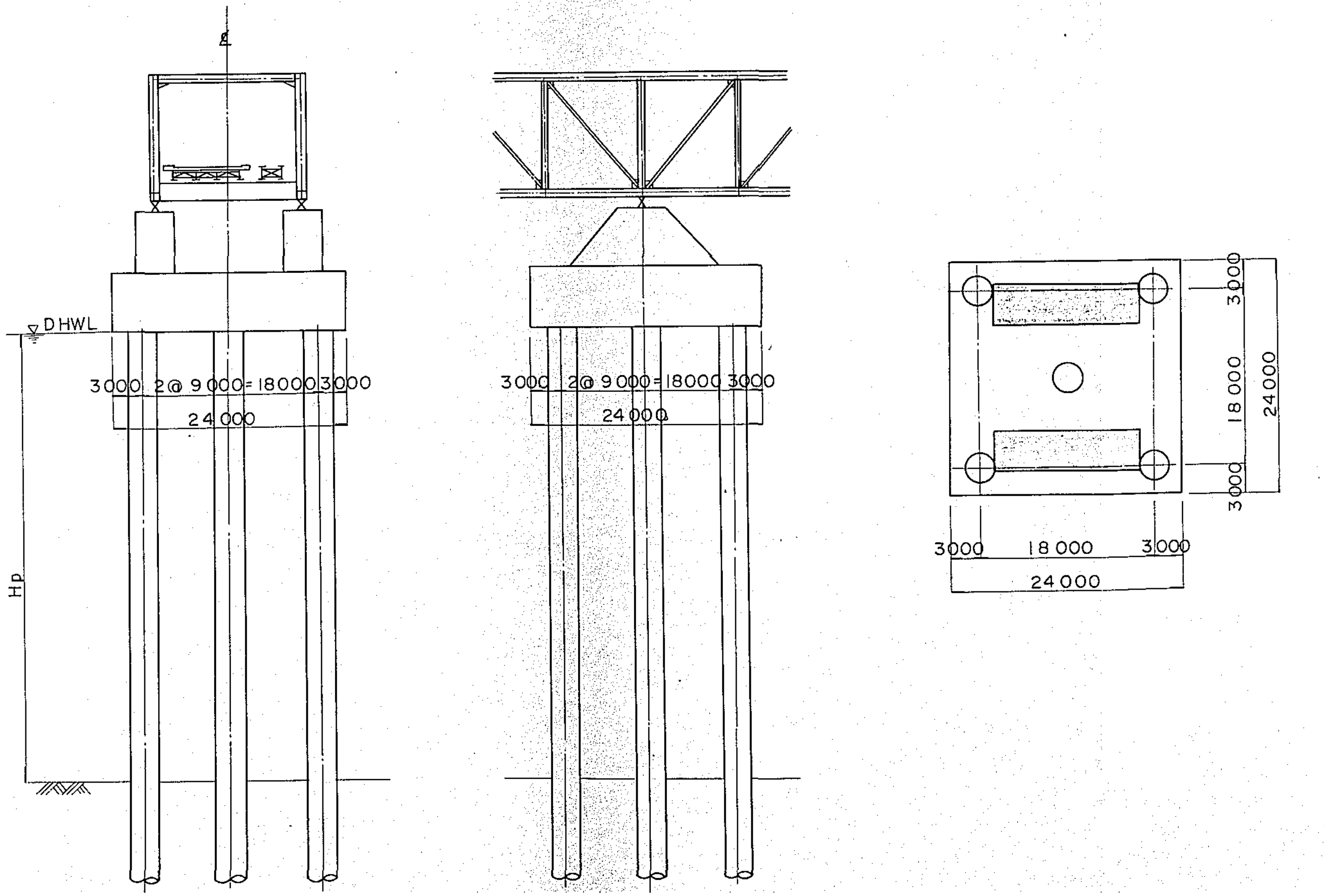


Fig. V-15-5 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	150 m
Conditon of spport	Fix
Outstandin length	42.0m, 460m

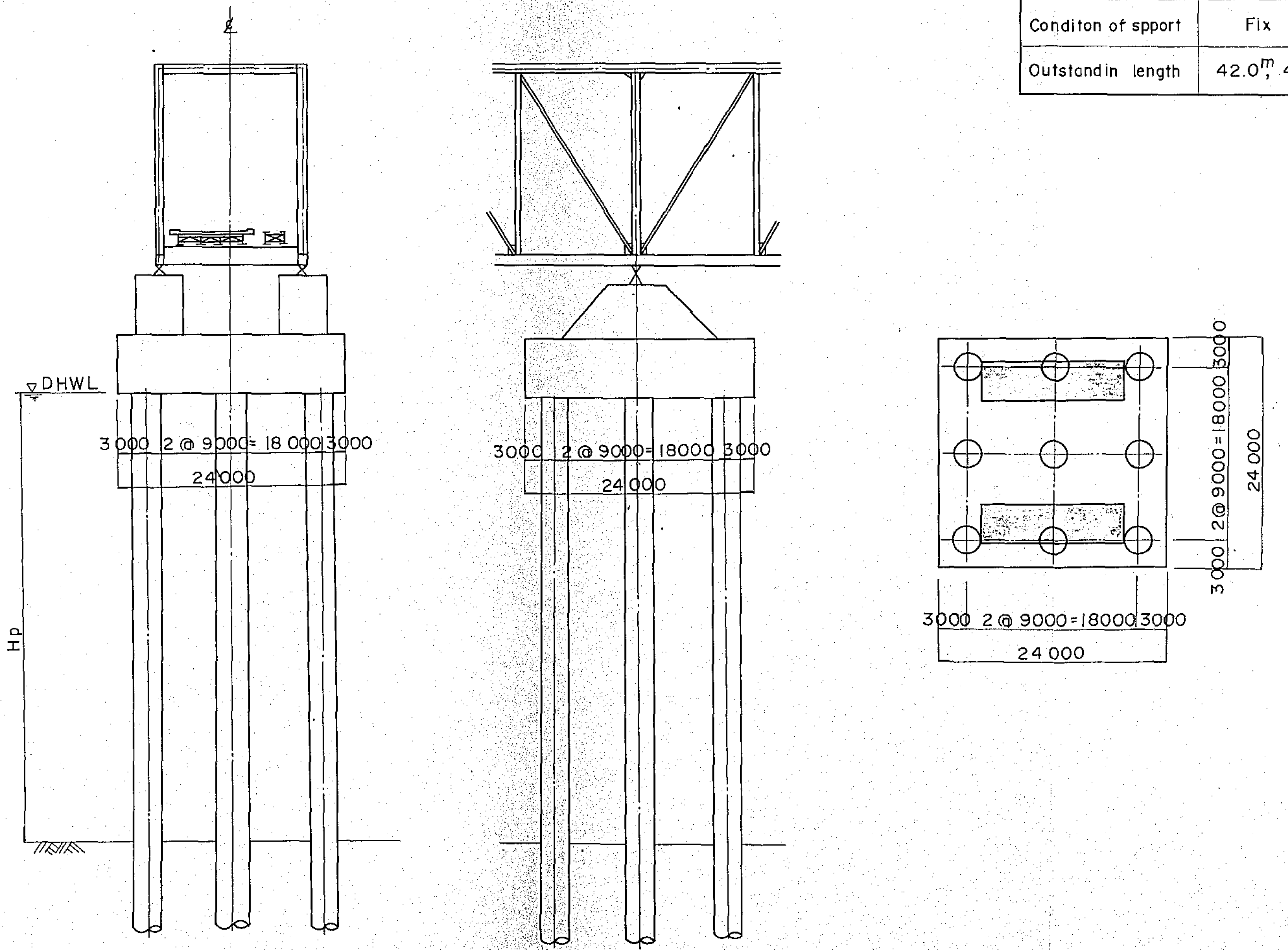


Fig. Ⅴ-15-6 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	150 m
Condition of support	Fix
Outstanding length	35.5 m

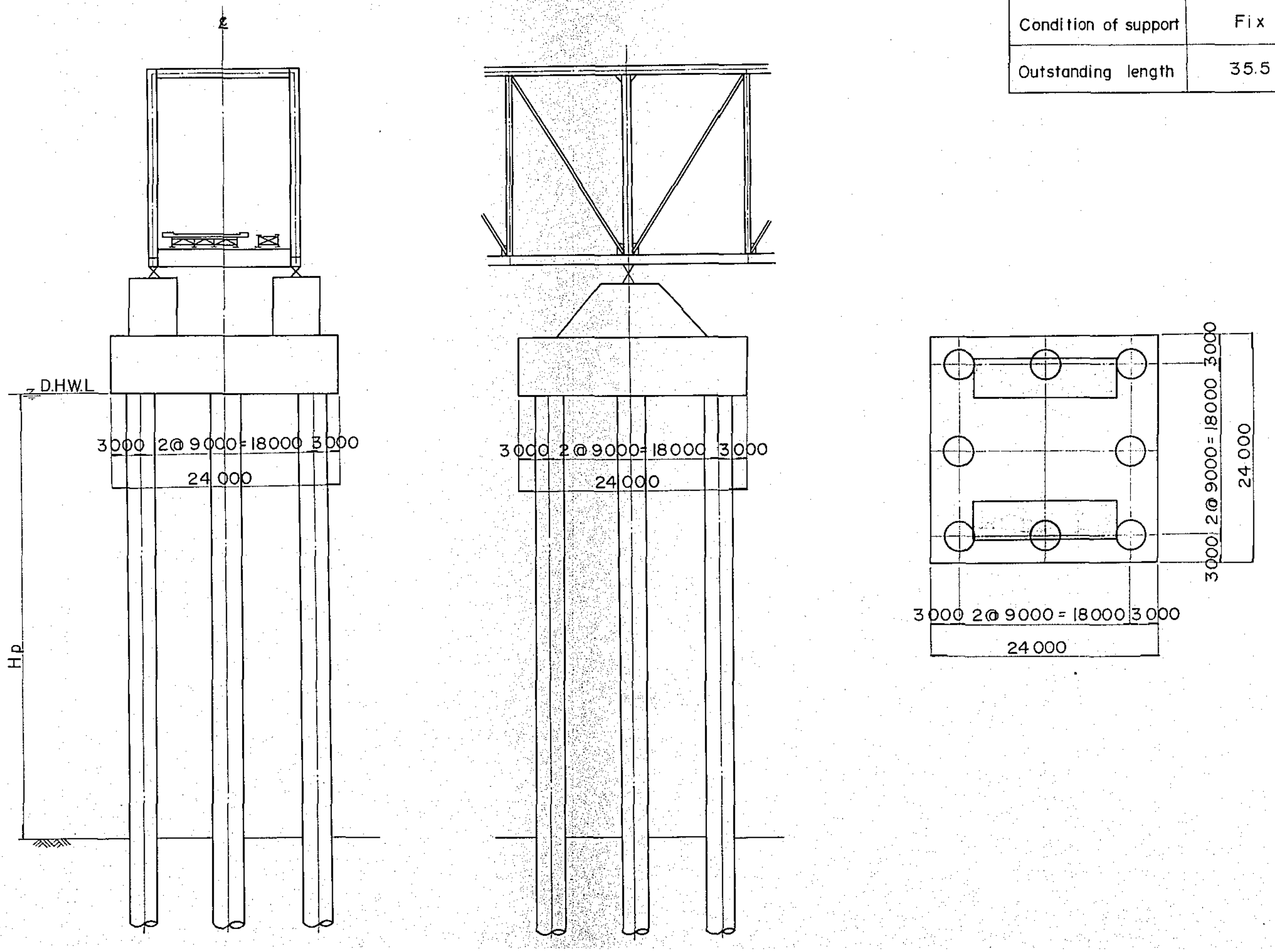


Fig. V - 15 - 7 Outline of structure of multi - pile foundation ø 3.0 m

Case of bridge	Case a
Span length	150 m
Condition of support	Mov
Outstanding length	35.5 m, 42.0 m

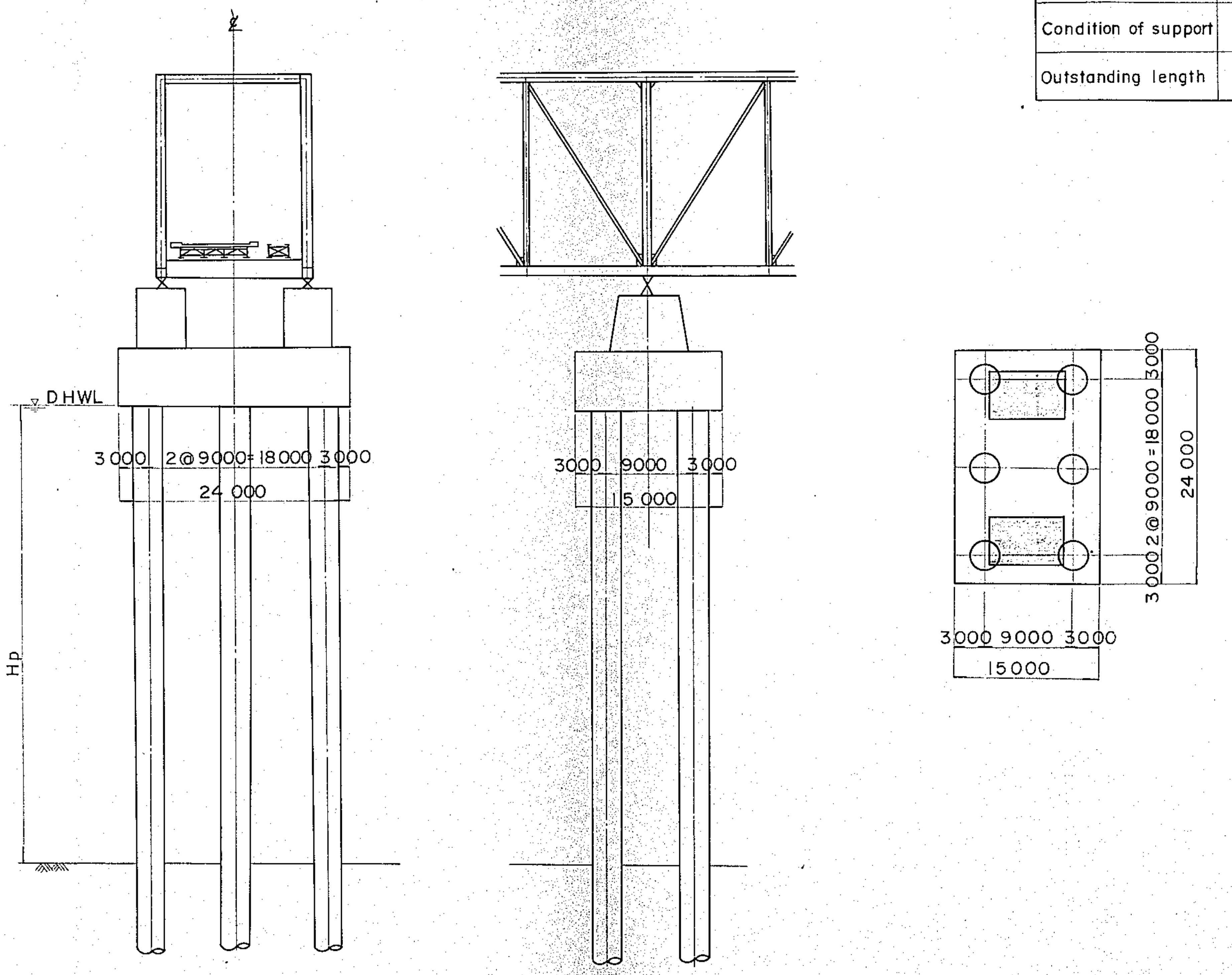
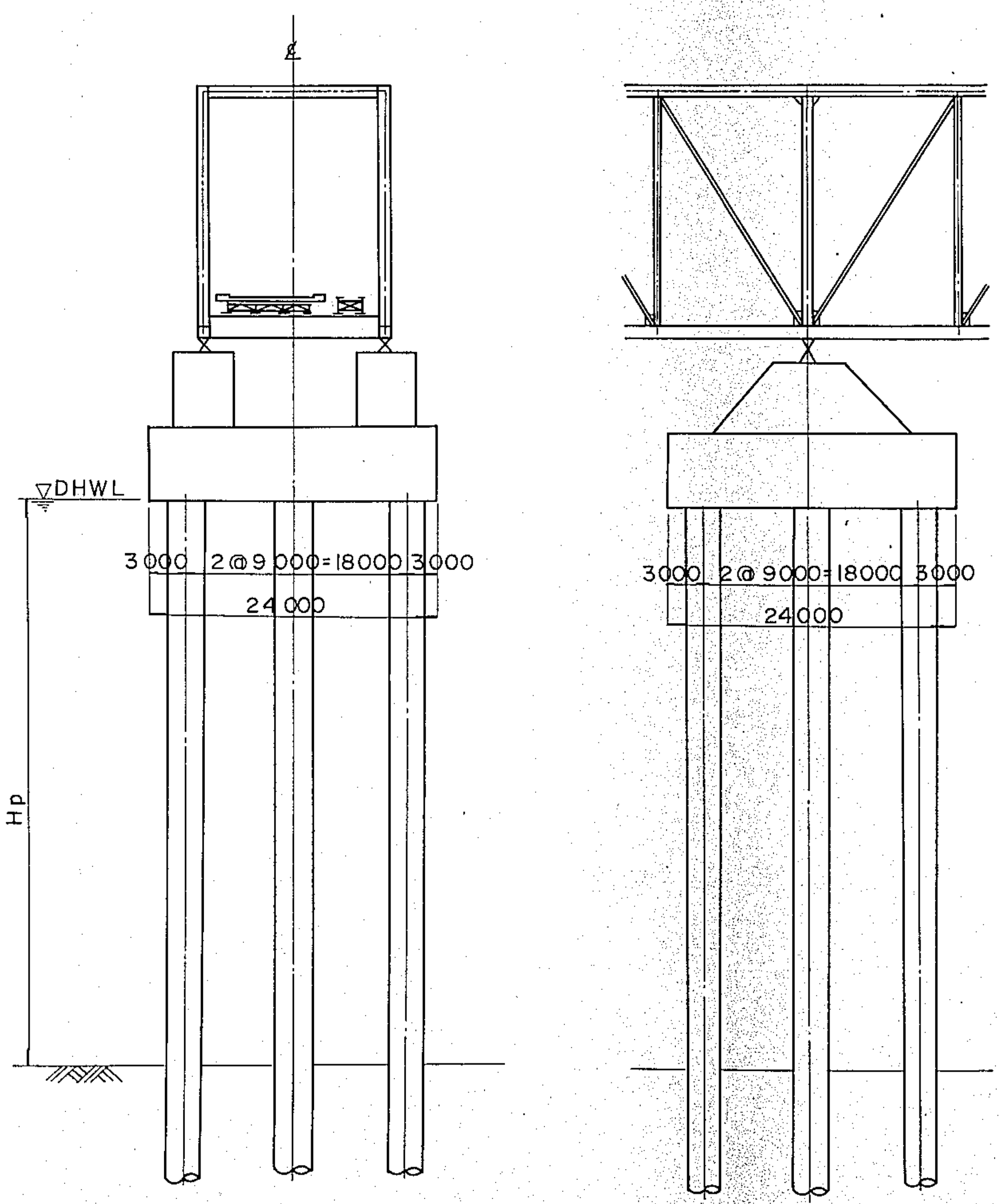


Fig. V-15-8 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	150m
Condition of support	Mov
Outstanding length	46.0m



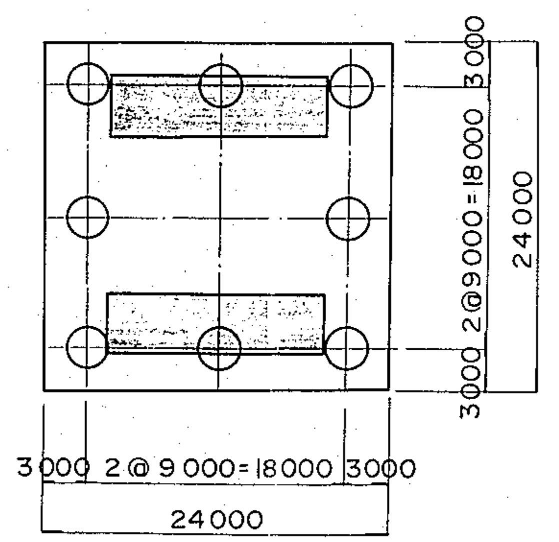
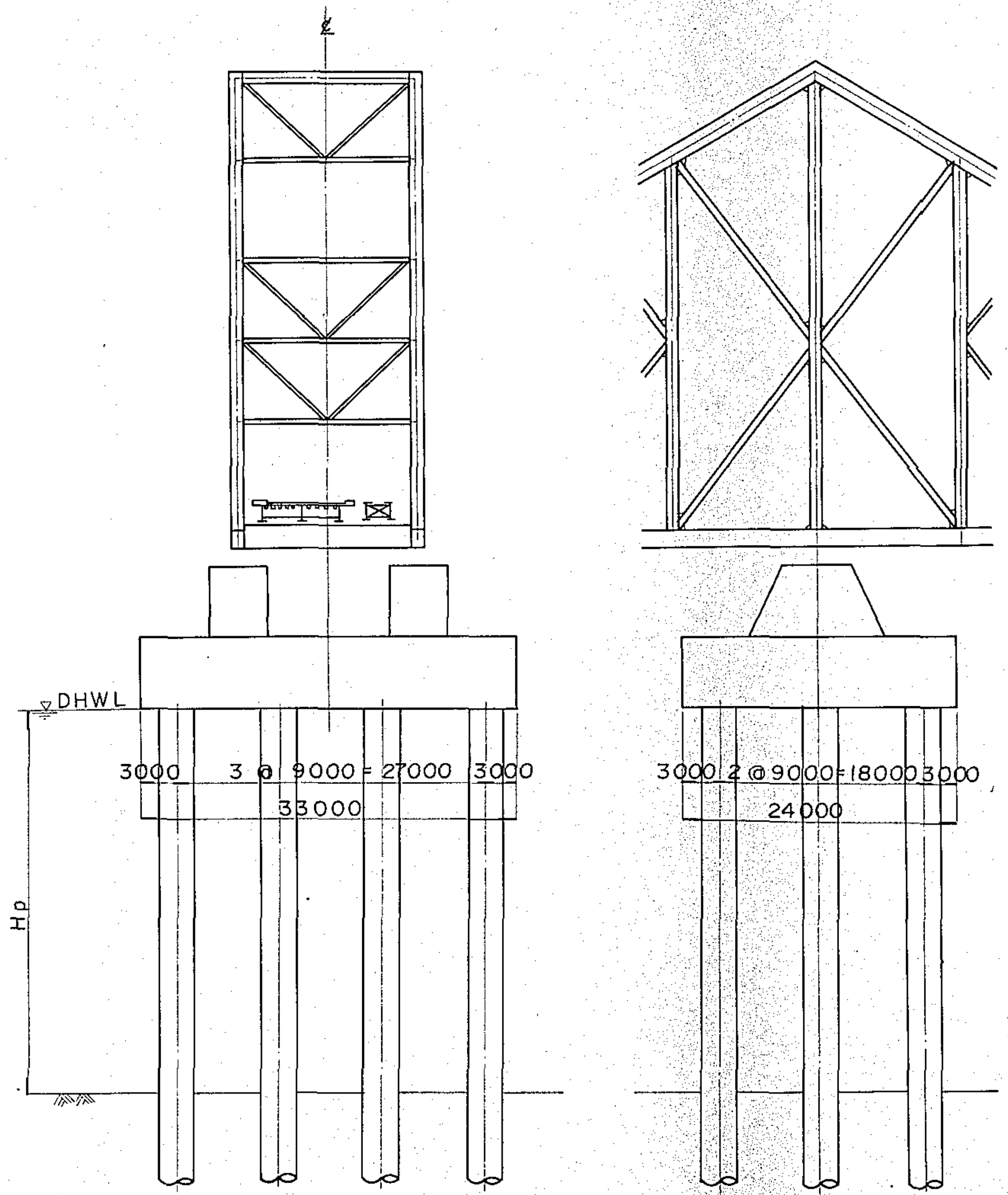


Fig. V-15-9 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	250m
Conditon of support	Fix (Mov)
Outstanding length	35.5m (46.0m)



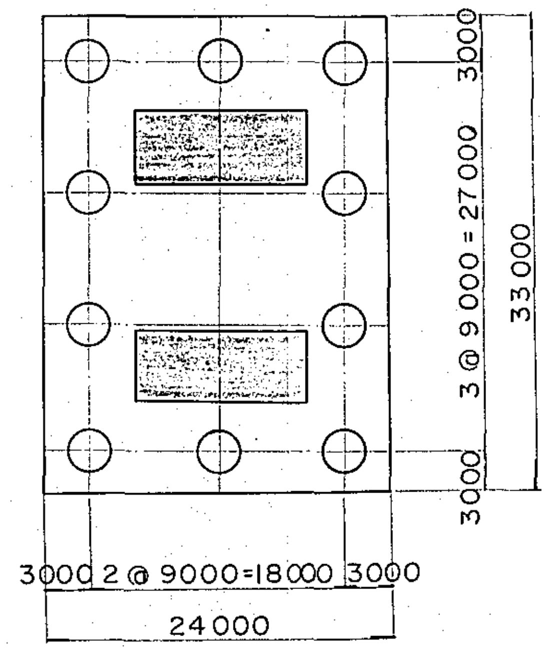


Fig. Ⅴ-15-10 Outline of structure of multi-pile foundation ø 3.0 m

Case of length	Case a
Span length	250 m
Condition of support	Fix
Outstanding length	42.0 m 46.0 m

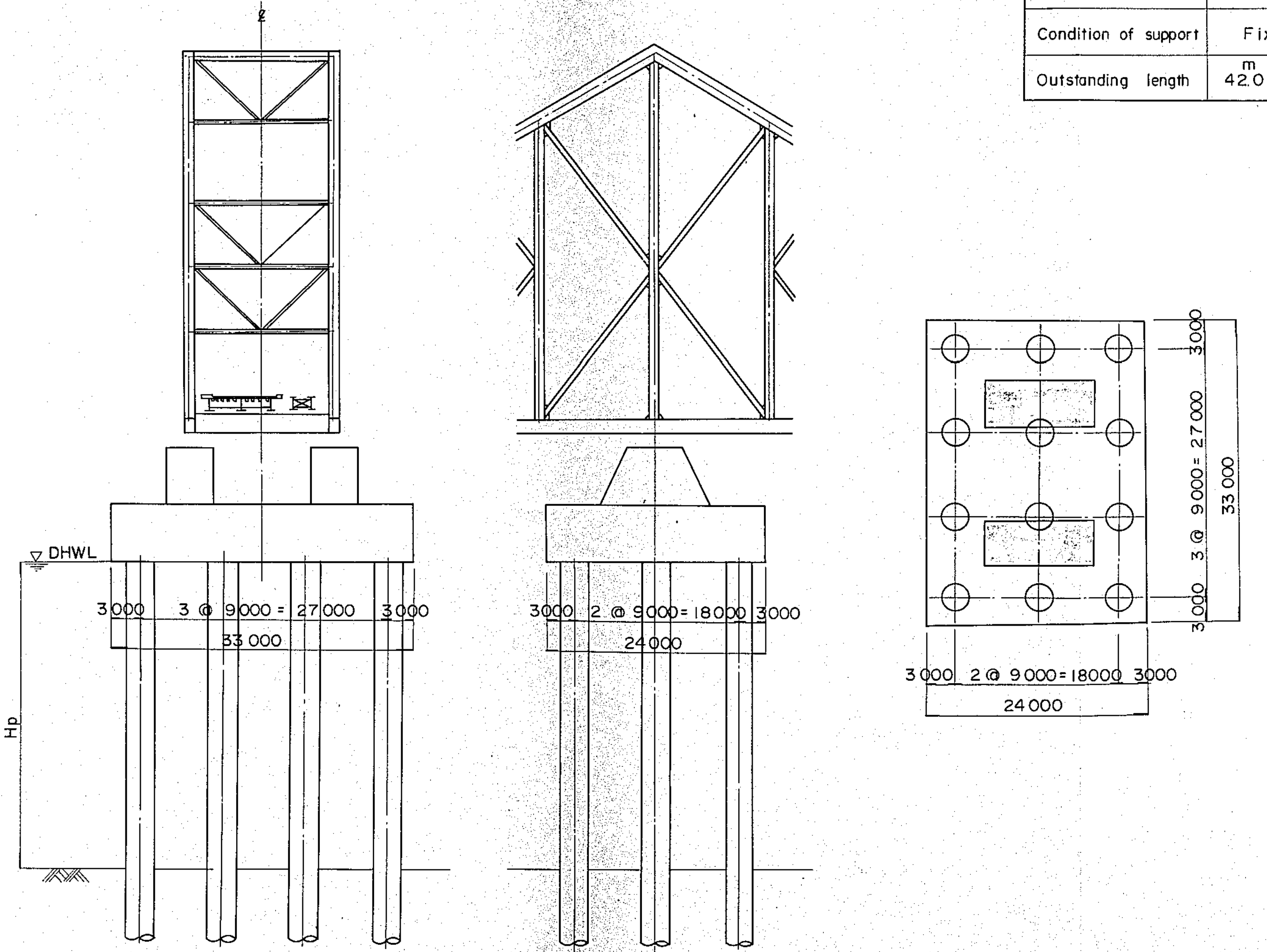


Fig. V-15-11 Outline of structure of multi-pile foundation ø 3.0m

Case of bridge	Case a
Span length	250 m
Condition of support	Mov
Outstanding length	35.5 m, 42.0 m

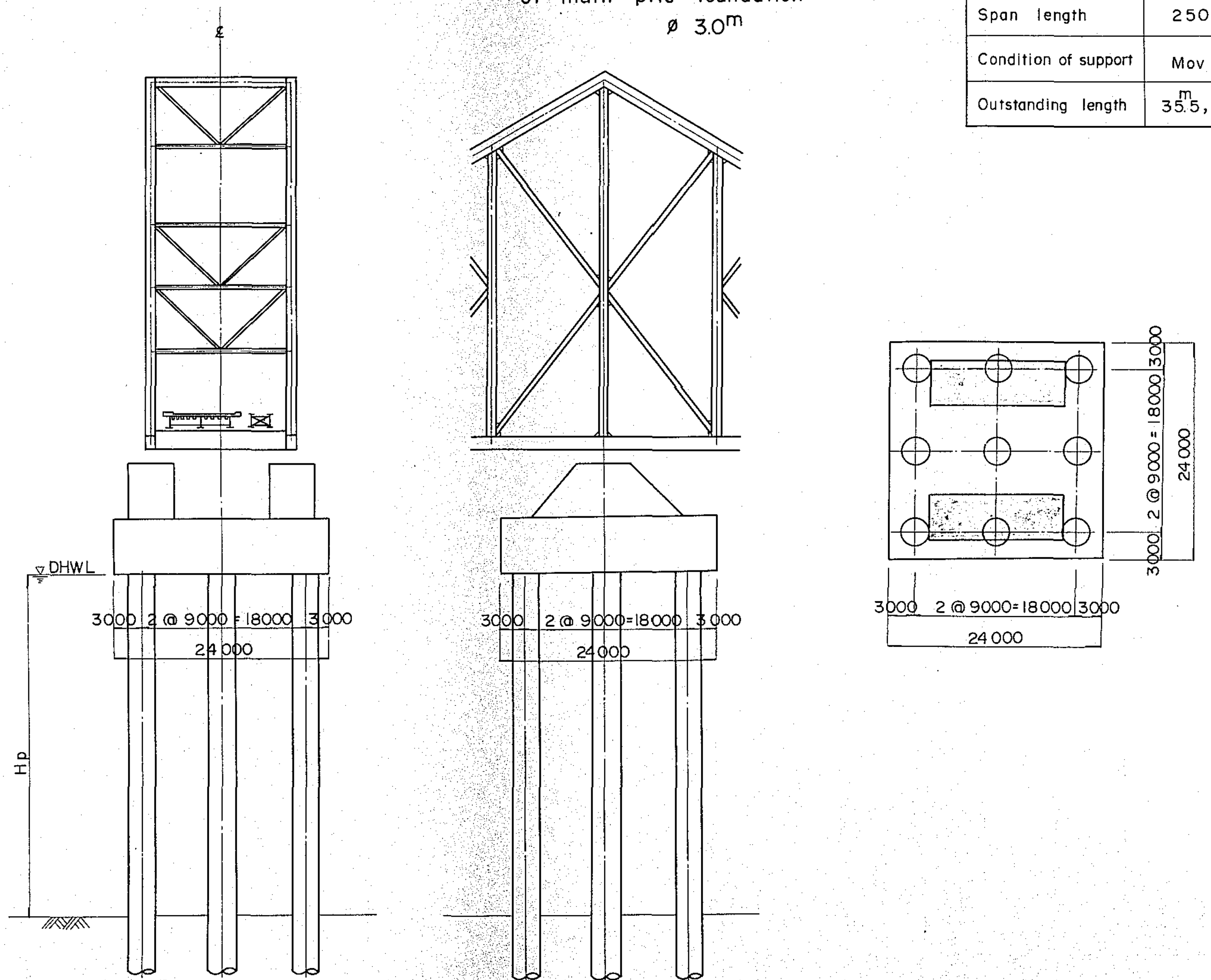
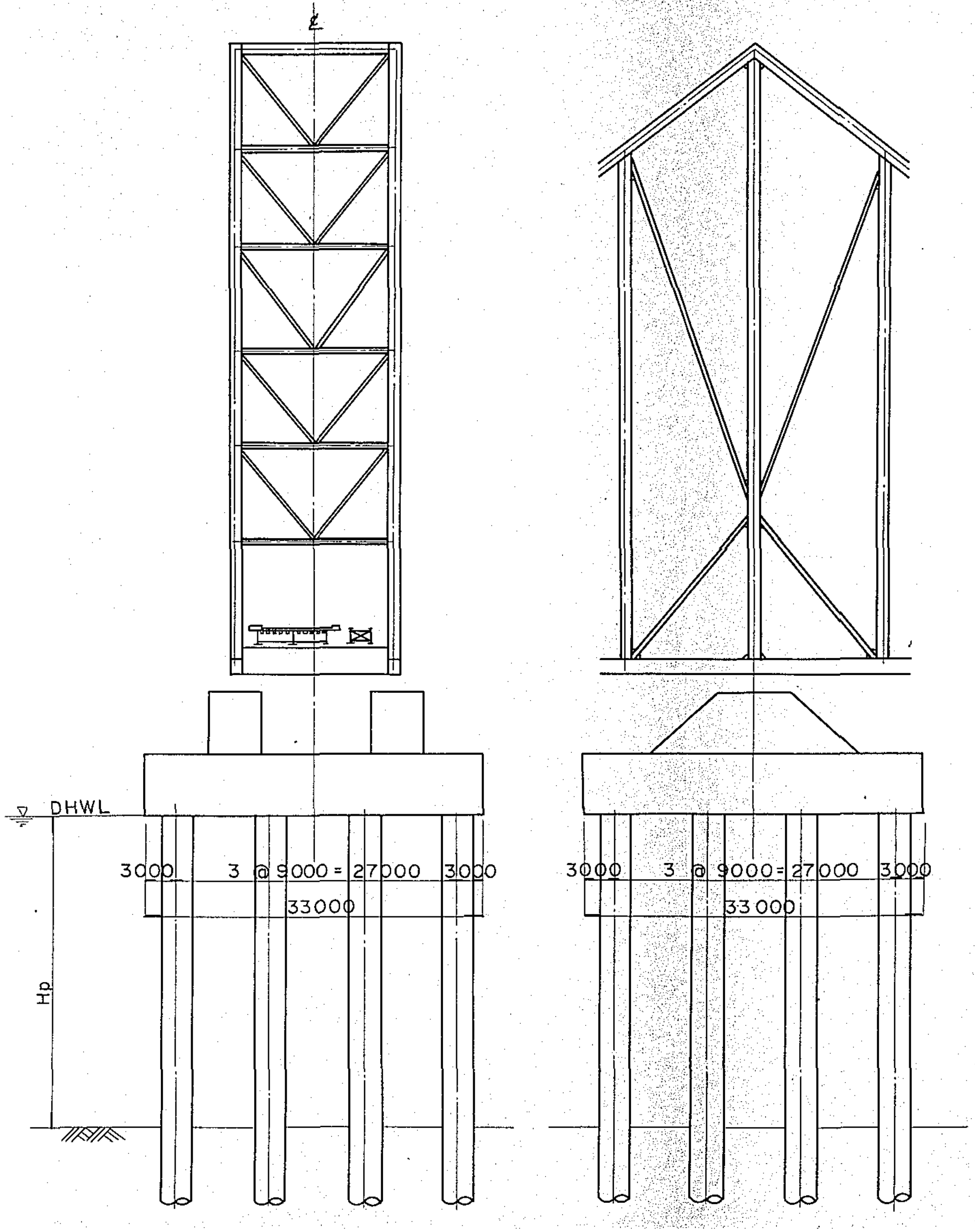


Fig V-15-12 Outline of structure of multi pile-foundation
ø 3.0^{m}

Case of bridge	Case a
Span length	350^{m}
Condition of support	Fix
Outstanding length	35.5^{m}, 42.0^{m}, 46.0^{m}



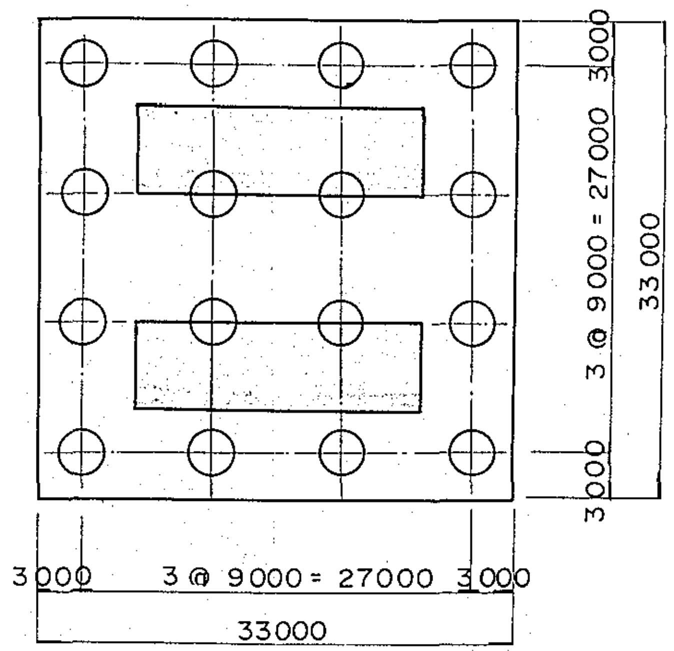
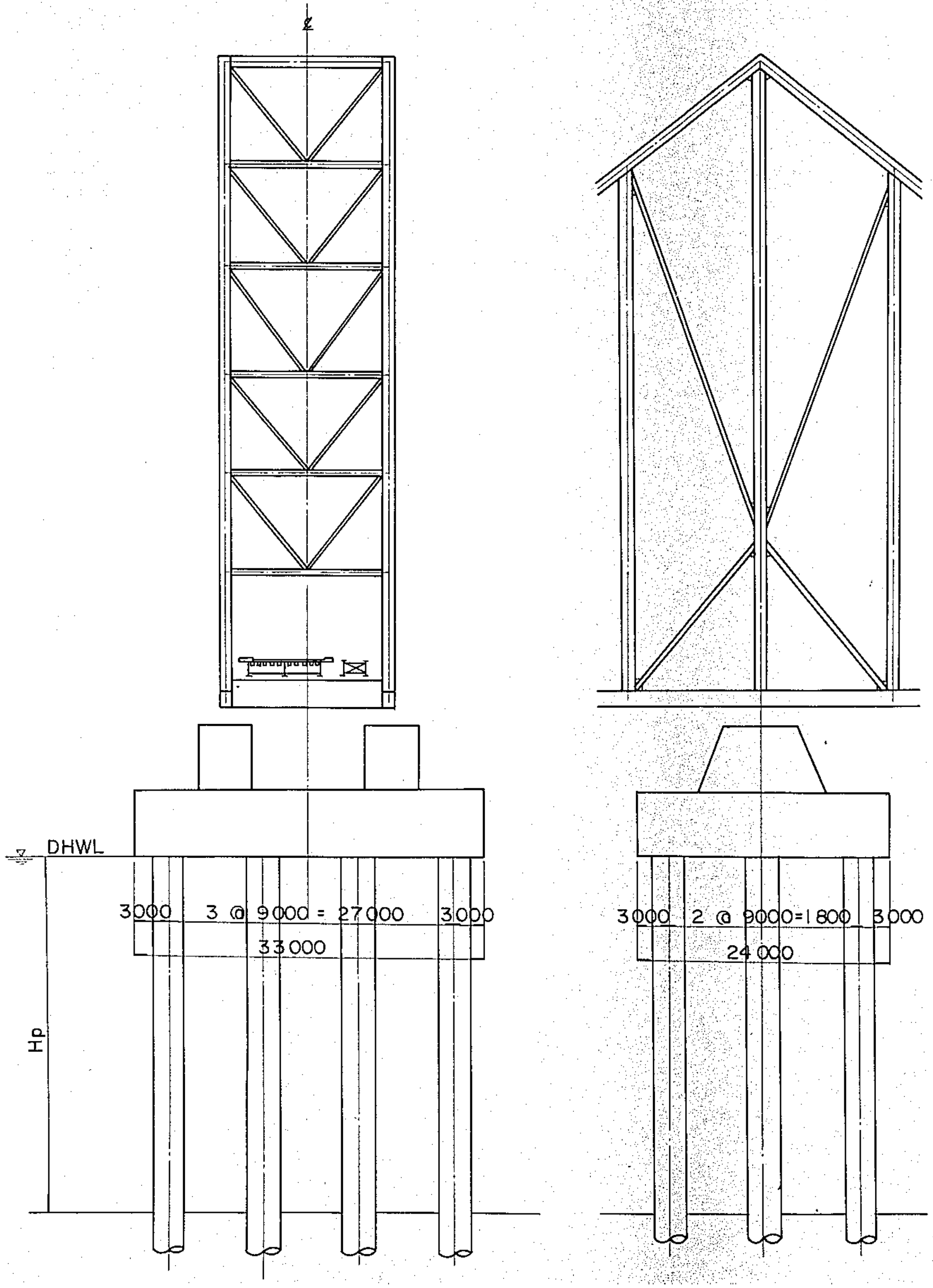


Fig. V-15-13 Outline of structure of multipile foundation ø 3.0m

Case of bridge	Case a
Span length	350 m
Condition of support	Mov
Outstanding length	35.5 m



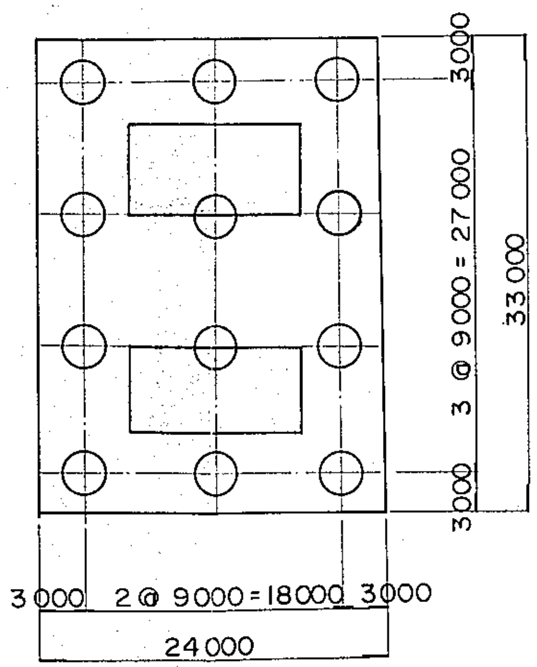
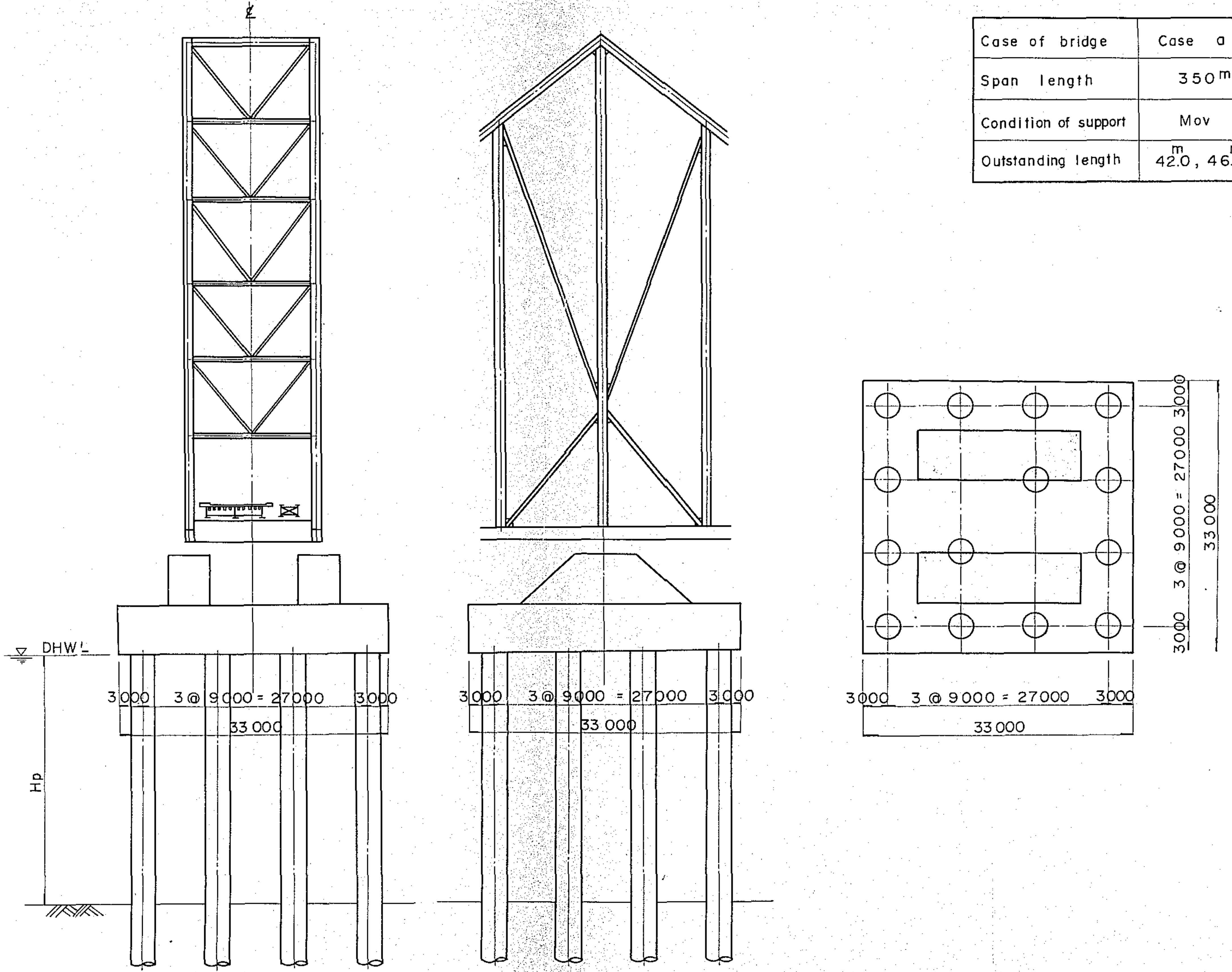


Fig. V-15-14 Outline of structure of multi-pile foundation

Case of bridge	Case a
Span length	350 m
Condition of support	Mov
Outstanding length	42.0 m, 46.0 m



4. Approaches.

4-1. Embankment.

The length of embankment in approaches is affected by the longitudinal slope of the railway. Because of the design height of formation level of railway for the Jamuna River Bridge is about 90 ft above the DHWL, embankment of about 2.2 miles of length will be required, provided that the longitudinal slope of railway is 1/200. In the Kadir part of embankment, closing dyke was constructed to dam up the river water as shown in the Report of River Training Works. In the land part of embankment, it was constructed from existing ground level to the DHWL by the same method as closing dyke.

The formation level of closing dyke is the same height of the DHWL and the banking embankment of approaches is constructed on the closing dyke. Good earth with satisfactory physical properties will be required for this embankment. Main values of them are as follows.

a. Unit weight (γ_e) : 1.9 t/m^3 (119 lbs/cft)

b. Angle of internal friction (ϕ) : 30°

c. Cohesion (c) : 0

With the consideration of the surcharge on embankment due to railway and highway, stability calculation by circular arc method was performed under the condition of slope gradient 1:2. The result of calculation showed the satisfactory stabilization for the slope. The result of calculations is shown in Fig. V-16. But at the present state, the slope gradient was designed to take 1:2.5, for the consideration of more safety.

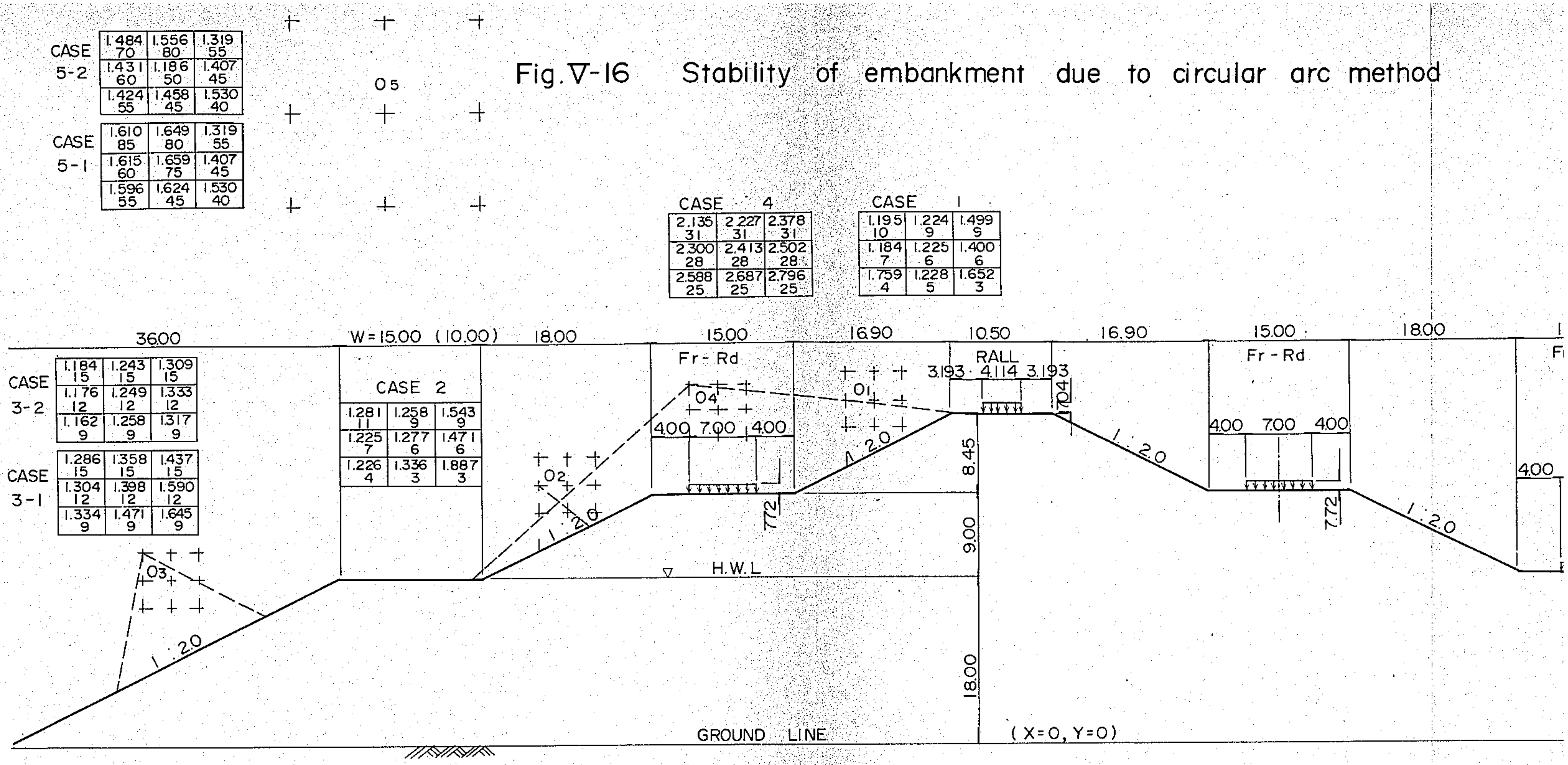
Though partly elevated bridge is considered instead of high embankment, embankment was applied to the approaches by the reason of more economical. By results of above-mentioned, the general earth work drawings were prepared to show Case a in Fig. V-17 and Case b in Fig. V-18.

4-2. Elevated part.

In Case b which is double tracks in railway part and four lanes carriageway in highway part, the Jamuna River Bridge has a double deck type and railway run through the lower part and vehicles run the upper part of the bridge. In highway running the upper part a elevated bridge is needed for leveling down to a level of embankment at approaches.

In this case, steel continuous box girder will be applied as a type of elevated bridge. As for a composition of standard spans at the elevated bridge, 3@ 60^m was assumed for the minimum construction cost and considerations of the deviation from center line of the railway. But at the highway part, steel piers of portal rigid frame type were applied where the highway part overlaps with railway part.

Fig.Ⅴ-16 Stability of embankment due to circular arc method



The same meterial were used for each larger of embankment, and their physical properties are as follows.

Unit weight	γ =	1.9 t/m³
Cohesion	c =	0
Internal friction angle	ϕ =	30°
Unit weight in water	γ' =	0.9 t/m³

The unit weight in water (γ') was used for soil under H.W.L.

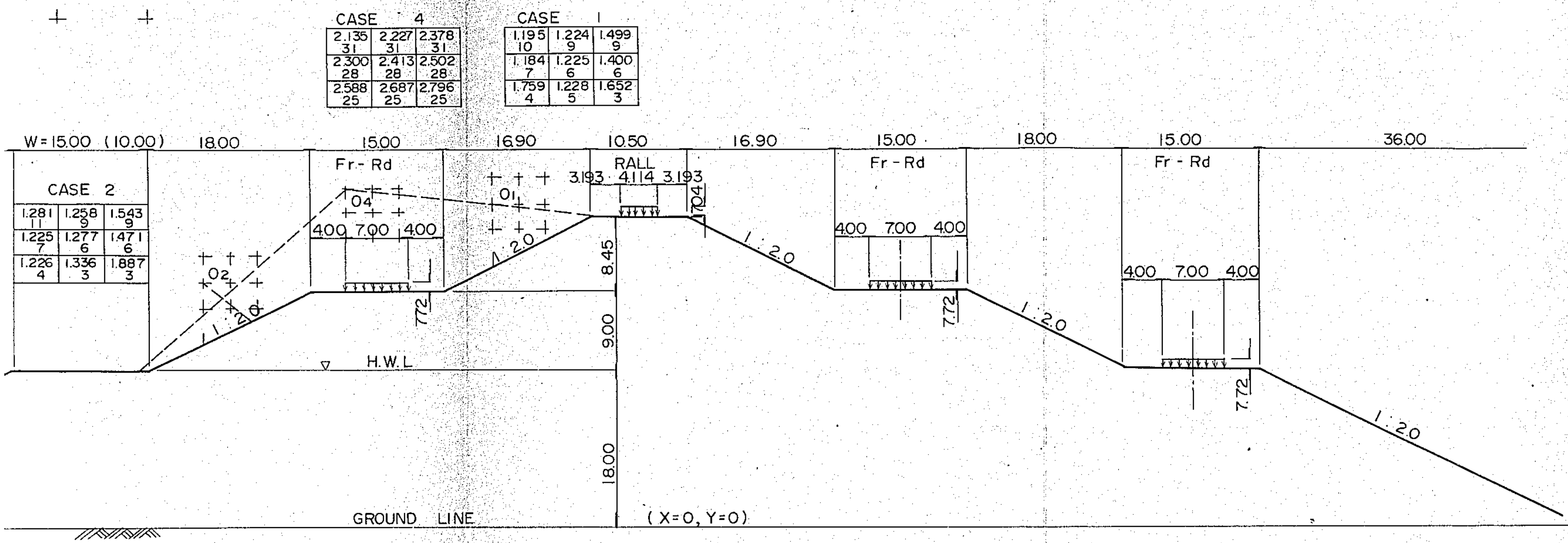
Surcharge

RAIL 2.041 t/m² ⟶ 1.074 m

ROAD 1.467 t/m² ⟶ 0.772 m

CASE	Cylindical surface			
	Co-Ordinate of centre of circle	Distance btw. centres	Height of bottom	Δ R
1	(X, Y) -14,37	3 m	+22	1 m
2	-46,28	3	+13	1
3 - 1	-88,18	3	-12	2
3 - 2				
4	-30,36	3	+8	2
5 - 1	-65,68	10 m	-12	5
5 - 2				

Fig. V-16 Stability of embankment due to circular arc method



The same meterial were used for each larger of embankment, and their physical properties are as follows.

γ = 1.9 t/m³
c = 0
on angle ϕ = 30°
water γ' = 0.9 t/m³

unit weight in water (γ') was used for soil under H.W.L

Surcharge
RAIL 2.041 t/m² ⟶ 1.074 m
ROAD 1.467 t/m² ⟶ 0.772 m

CASE	Cylindical surface				Remarks
	Co-Ordinate of centre of circle	Distance btw. centres	Height of bottom	Δ R	
1	(X, Y) -14,37	3 m	+22	1 m	
2	-46,28	3	+13	1	
3 - 1	-88,18	3	-12	2	W = 15
3 - 2					W = 10
4	-30,36	3	+8	2	No traffic load on high way
5 - 1	-65,68	10 m	-12	5	W = 15 Traffic load on rail and highway
5 - 2					W = 10

Fig. V-17-1 JAMUNA RIVER BRIDGE

PROFILE

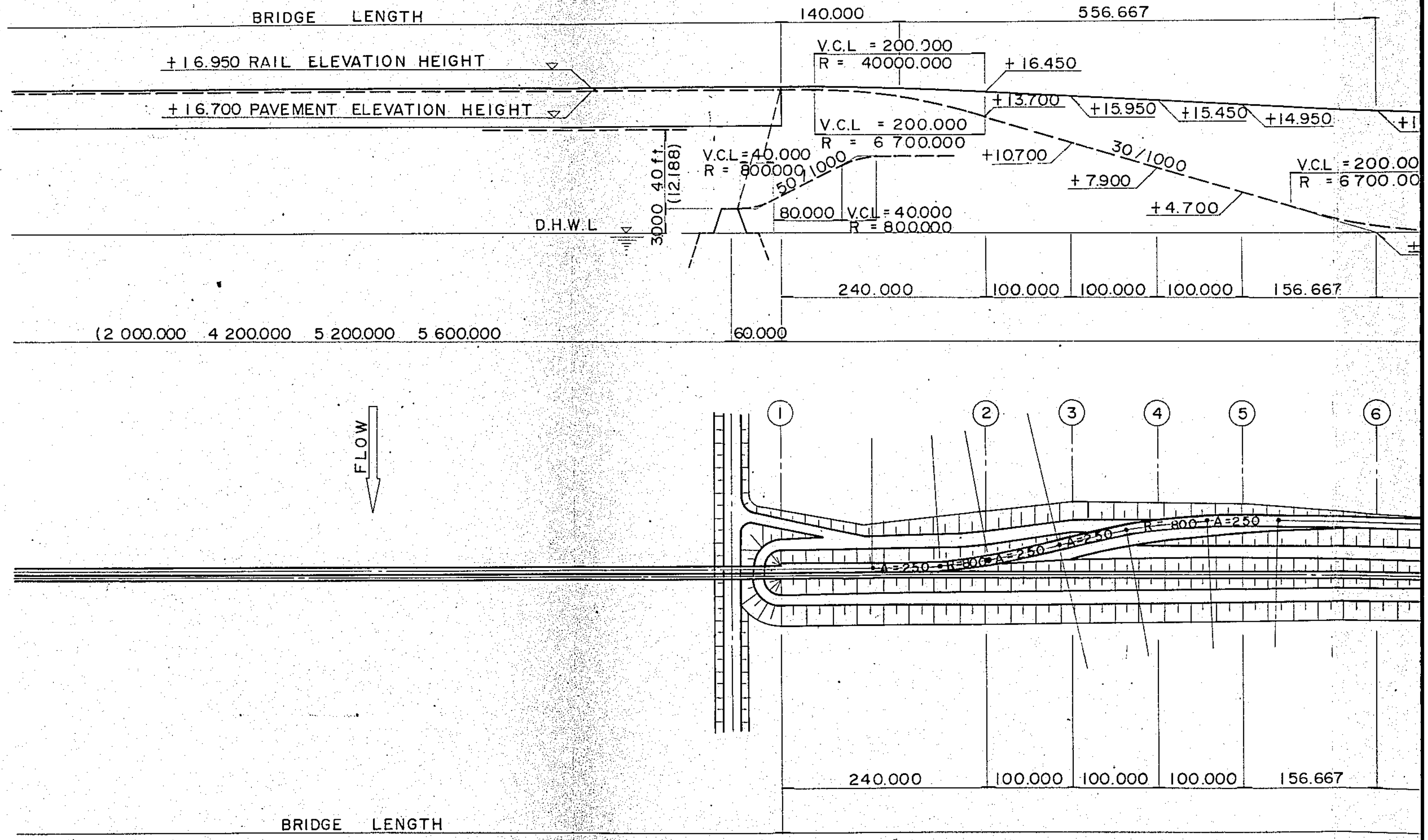
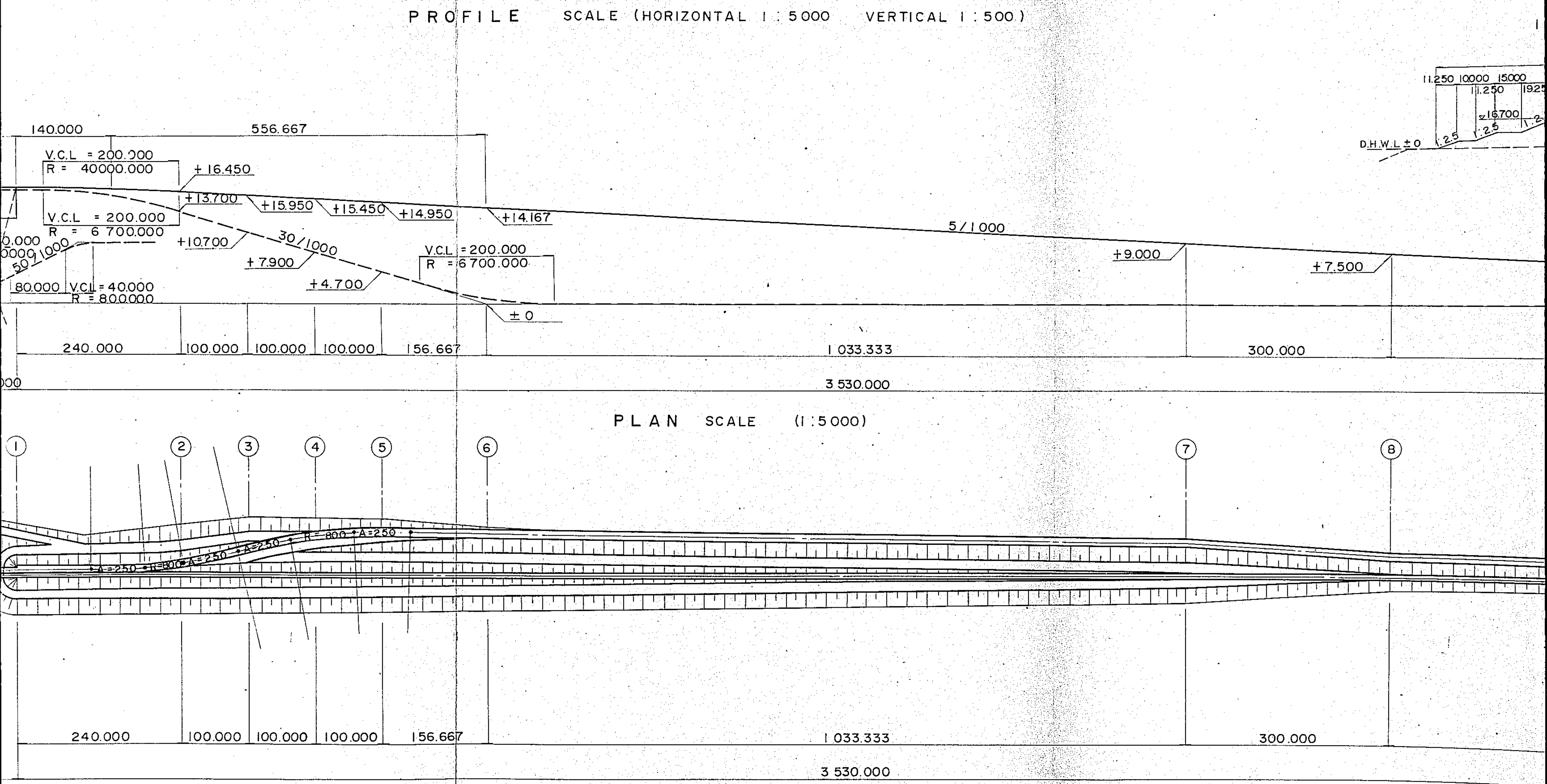


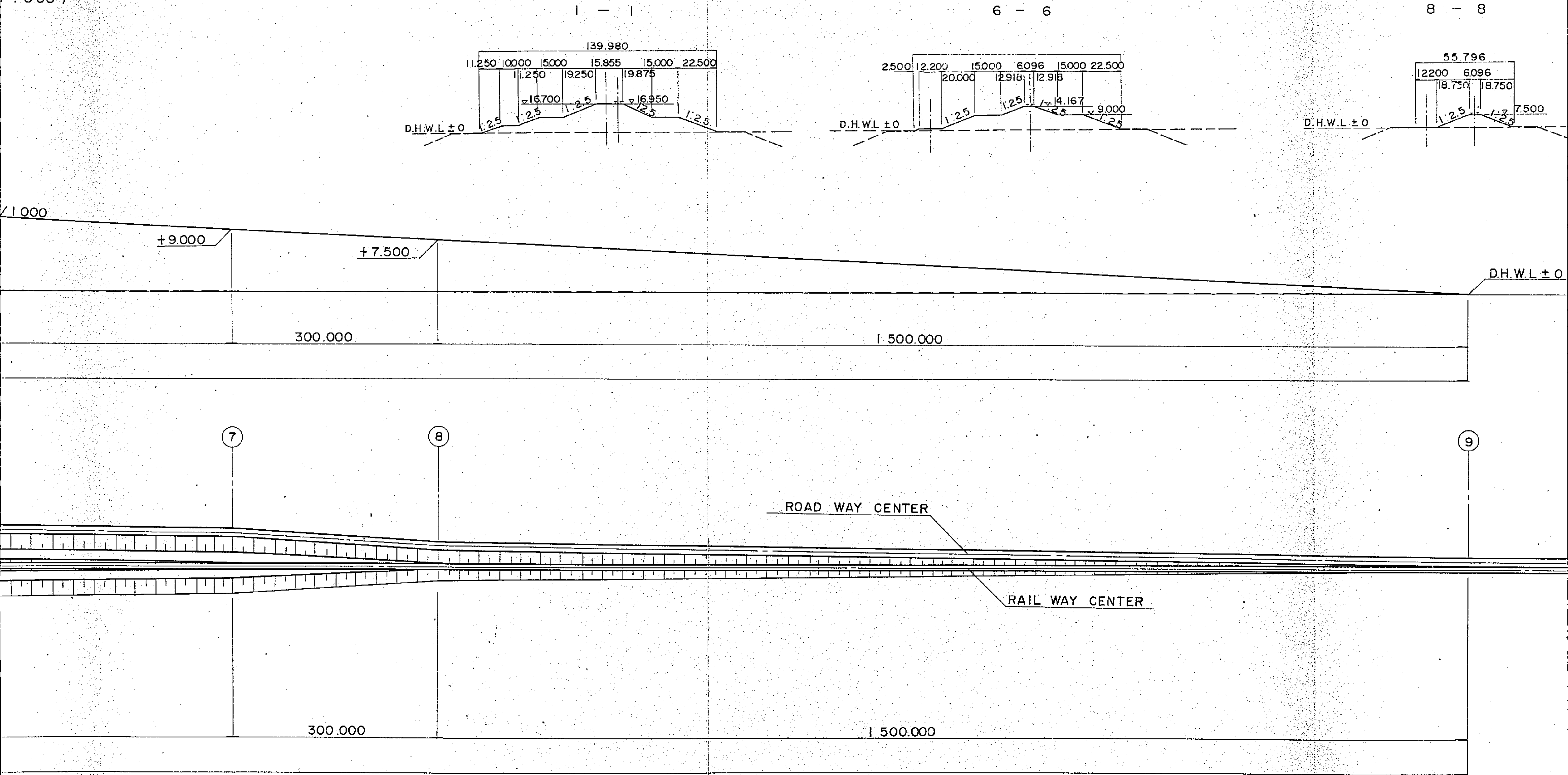
Fig.V-17-1 JAMUNA RIVER BRIDGE APPROACH (SINGLE TRACK RAILWAY & TWO LANE ROAD)



WAY & TWO LANE ROAD)

: 500)

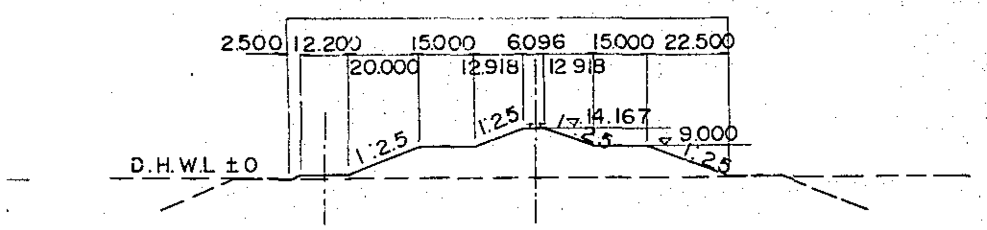
TYPICAL CROSS SECTION SCALE (1 : 2000)



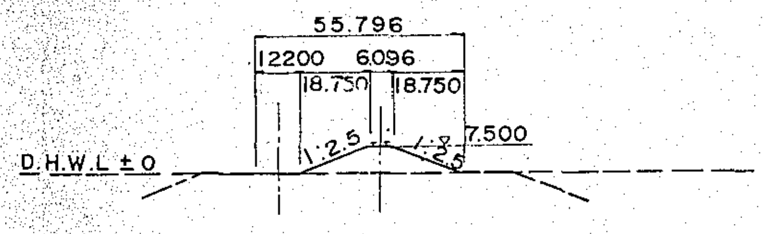
SHOWN LENGTH IS ME

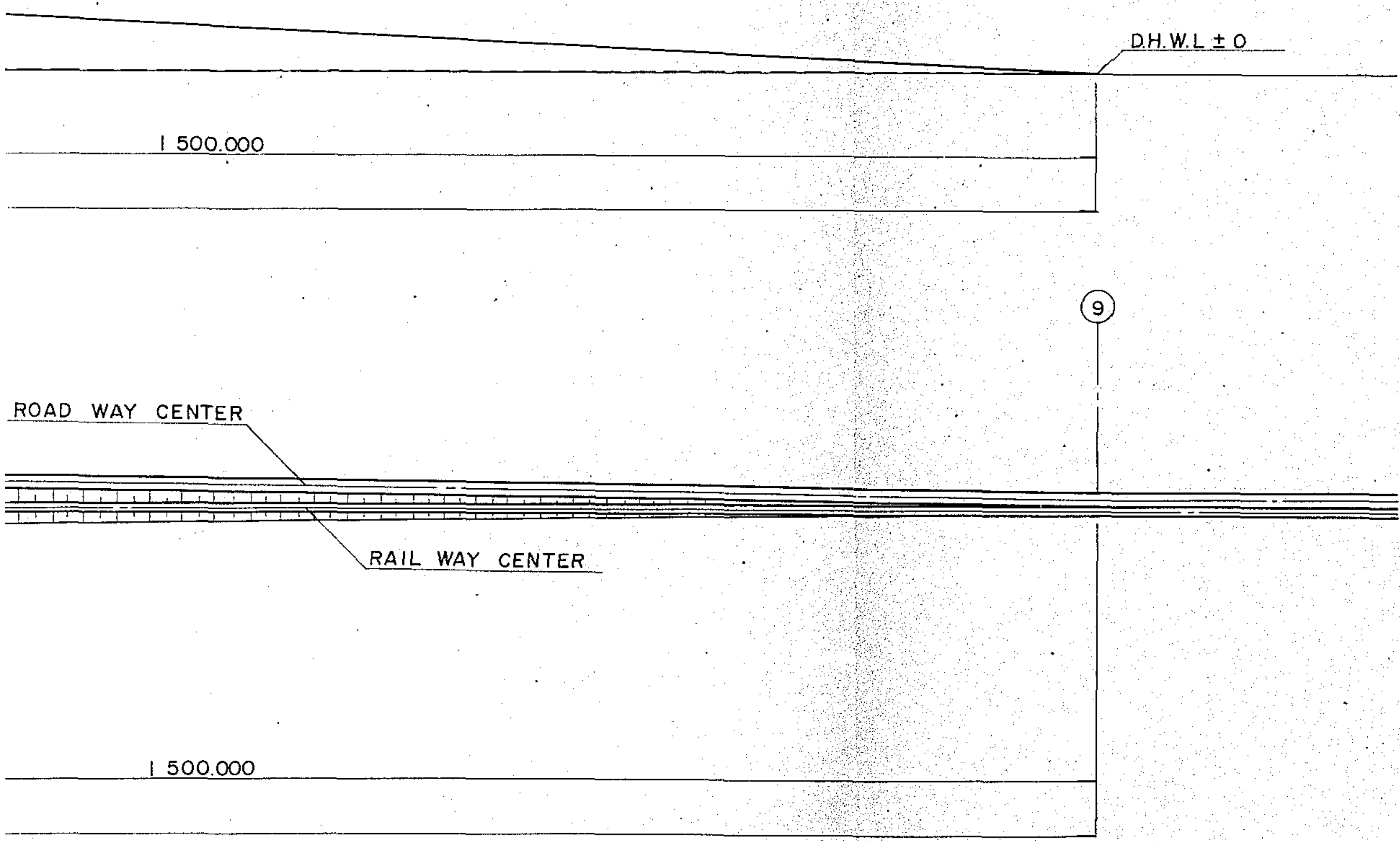
TYPICAL CROSS SECTION SCALE (1 : 2 000)

6 – 6



8 – 8





SHOWN LENGTH IS METER

JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE PROJECT APPROACH ROAD OF LEFT BANK (SINGLE TRACK & TWO LANES)
Drawn Date
Approved Date
NIKKEN CONSULTANTS INC.

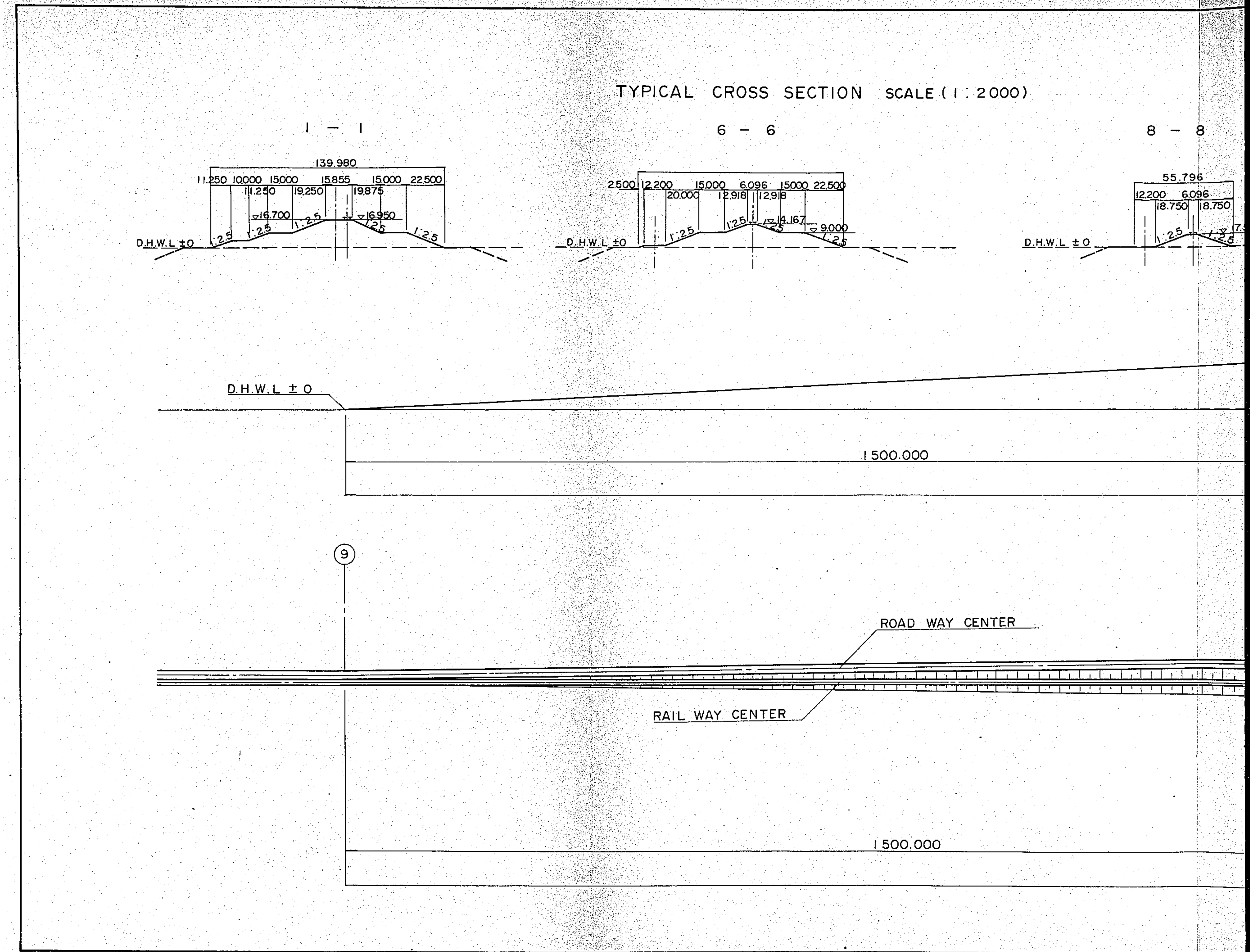
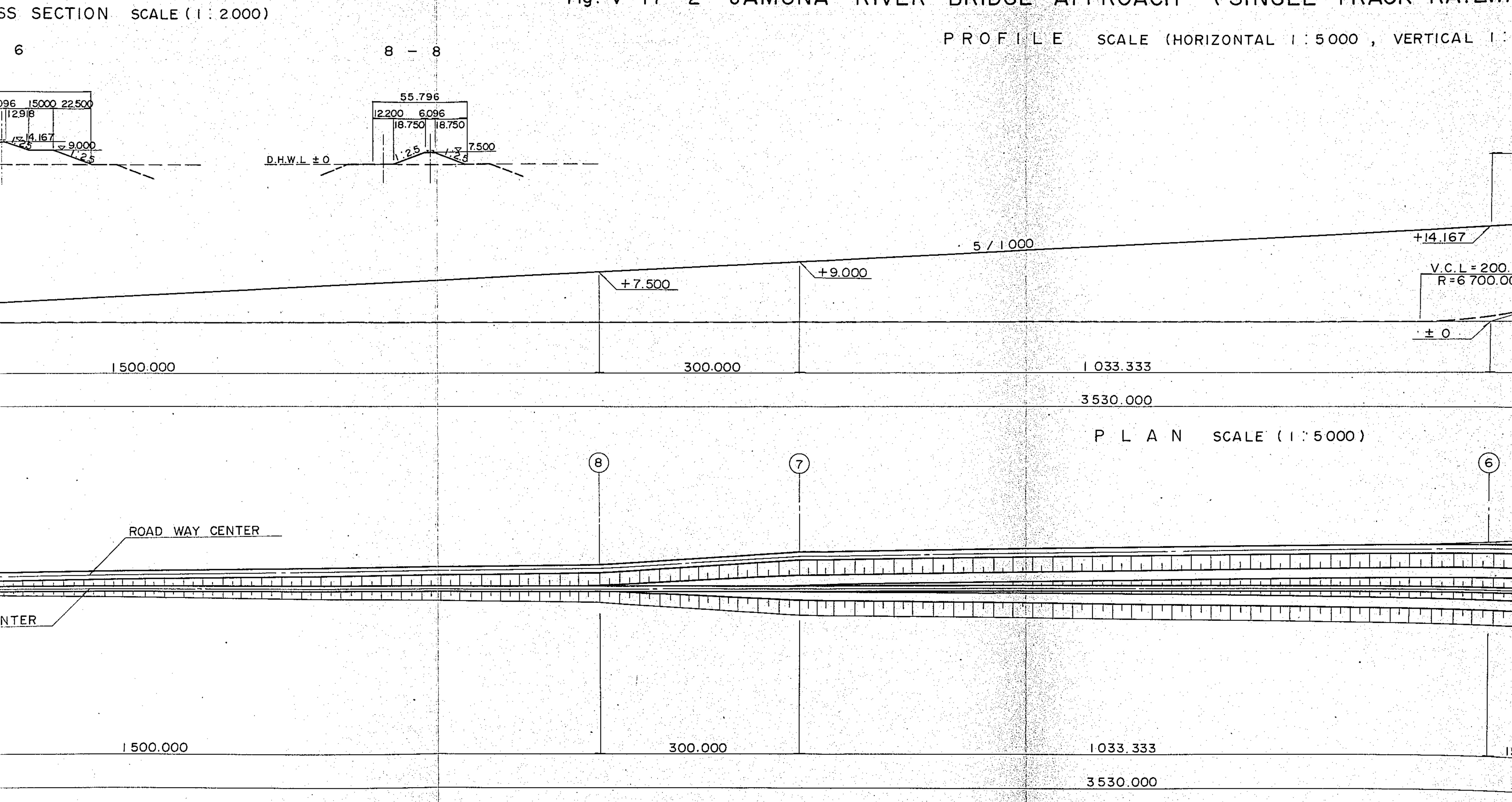
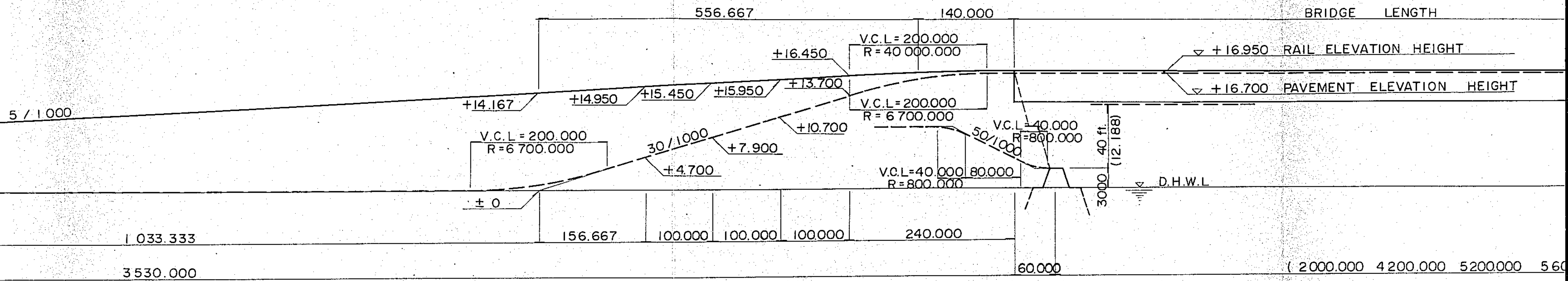

TYPICAL CROSS SECTION SCALE (1 : 2000)
1 - 1
6 - 6
8 - 8
139.980
11.250 10.000 15.000 15.855 15.000 22.500
11.250 19.250 19.875
16.700
16.950
D.H.W.L ±0
2.500 12.200 15.000 6.096 15000 22.500
20.000 12.918 12.918
14.167
9.000
55.796
12.200 6.096
18.750 18.750
D.H.W.L ± 0
1 500.000
ROAD WAY CENTER
RAIL WAY CENTER
1 500.000

Fig. Ⅴ-17-2 JAMUNA RIVER BRIDGE APPROACH (SINGLE TRACK RAILWA

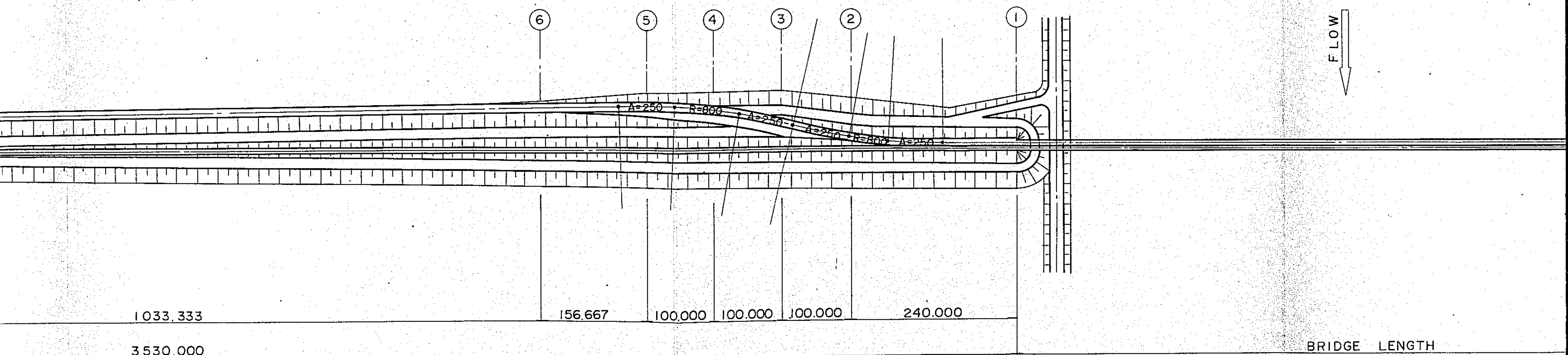


RIDGE APPROACH (SINGLE TRACK RAILWAY & TWO LANE ROAD)

ROFILE SCALE (HORIZONTAL 1 : 5000 , VERTICAL 1 : 500)

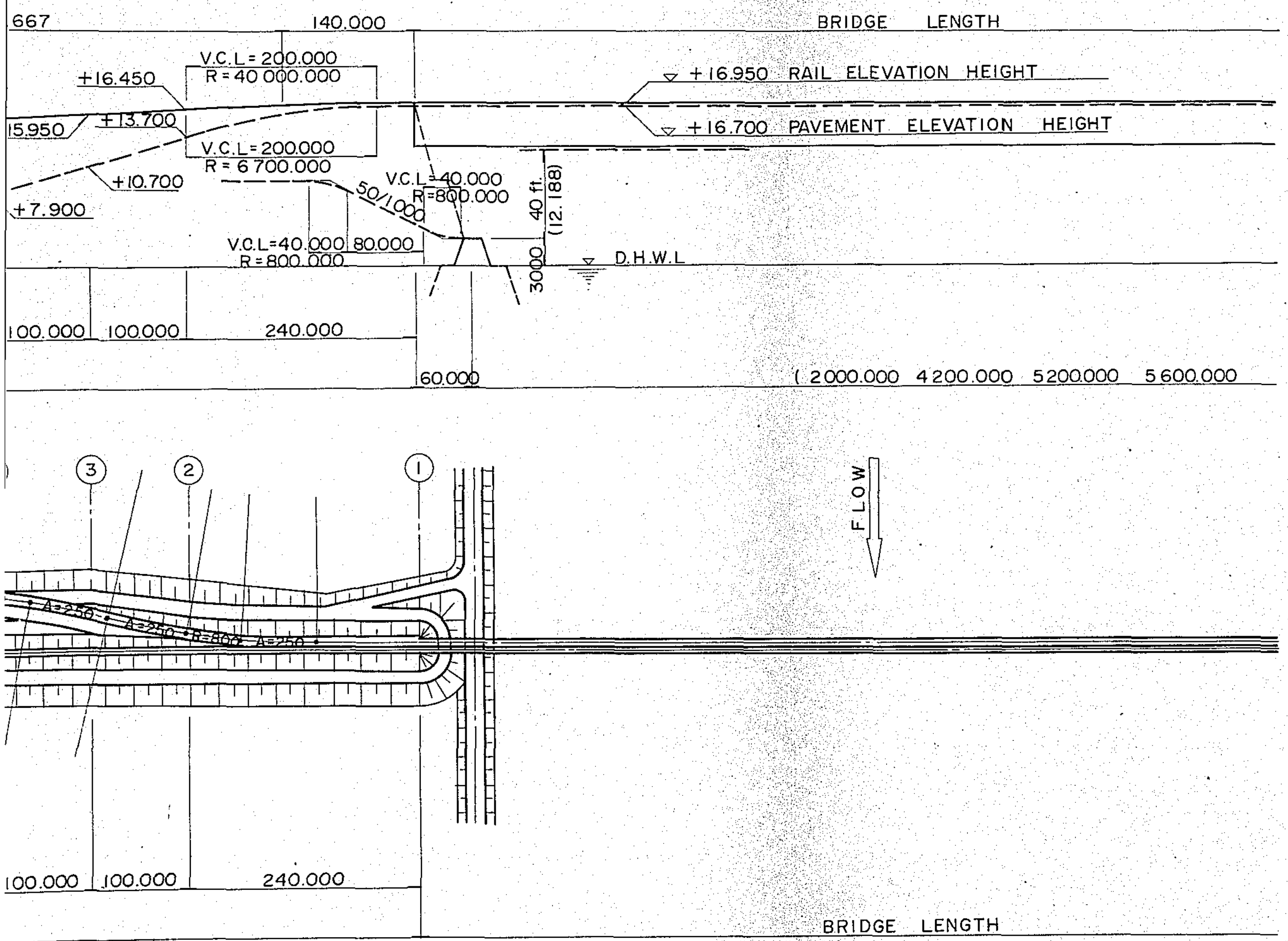


P L A N SCALE (1 : 5000)



SHOWN LENGTH IS METE

NE ROAD)



SHOWN LENGTH IS METER

JAPAN INTERNATIONAL COOPERATION AGENCY

PEOPLE'S REPUBLIC OF BANGLADESH

JAMUNA RIVER BRIDGE PROJECT

APPROACH ROAD OF RIGHT BANK
(SINGLE TRACK & TWO LANES)

Drawn	Date
Approved	Date

NIKKEN CONSULTANTS INC.

Fig. V-18-1

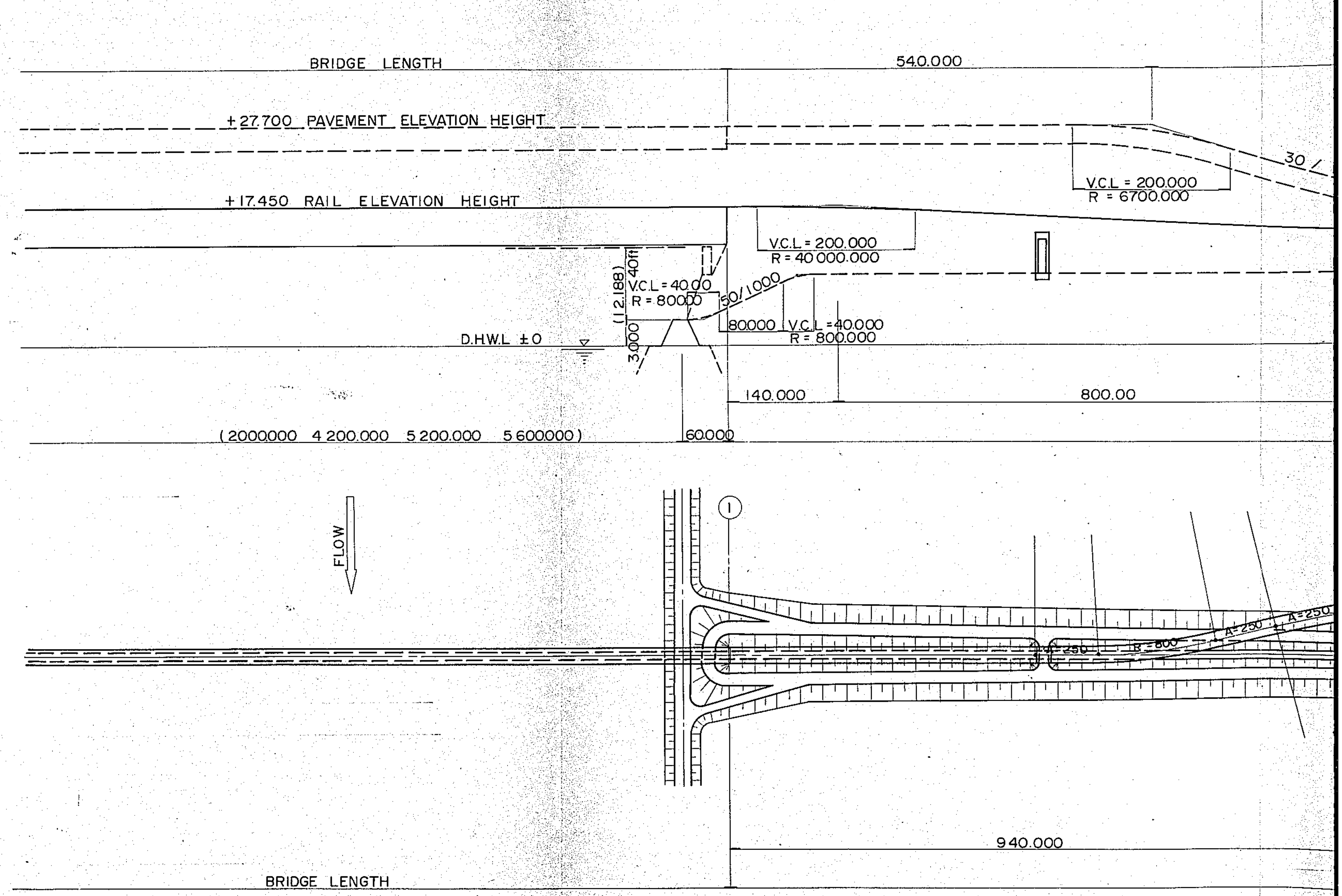
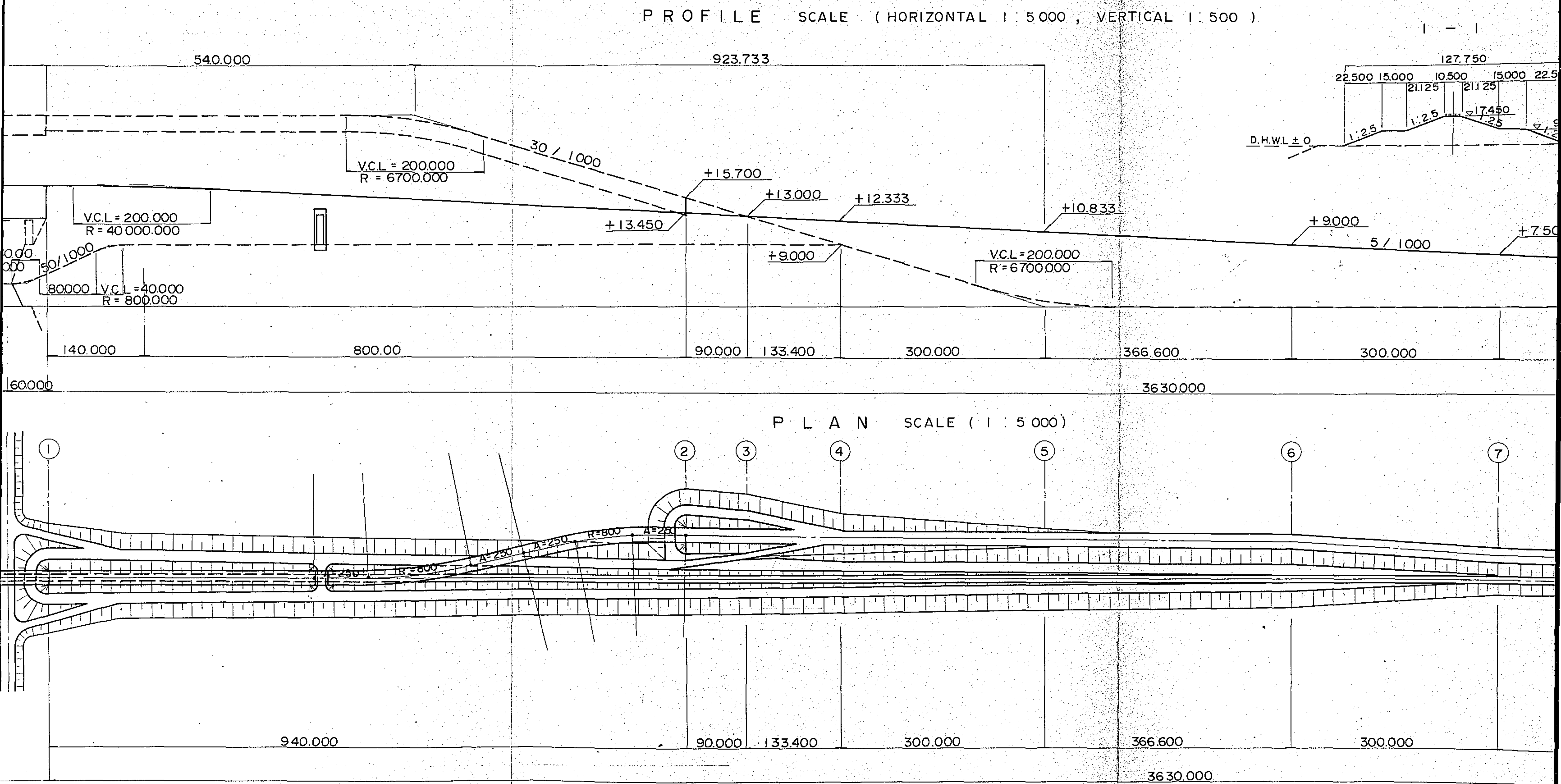
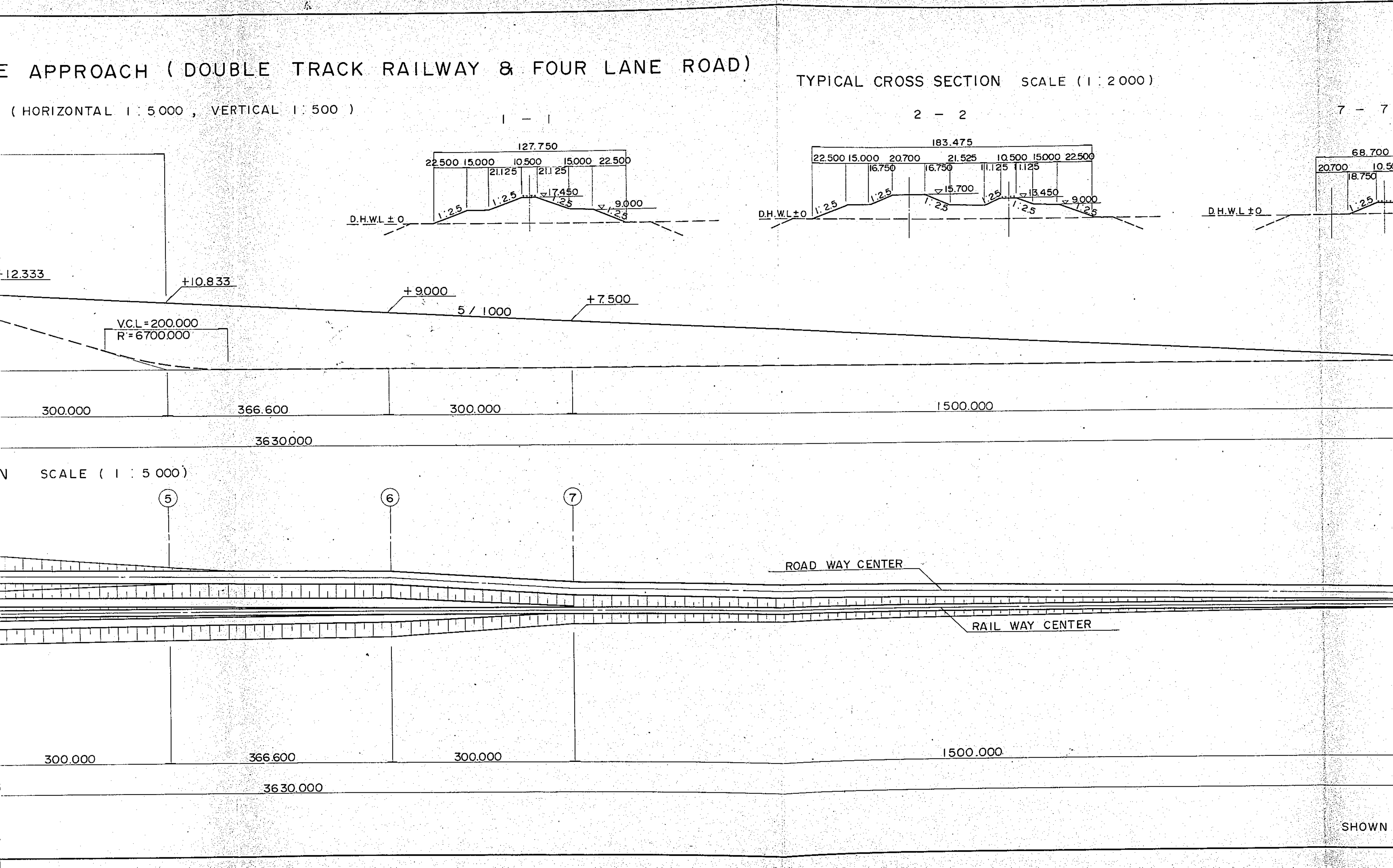
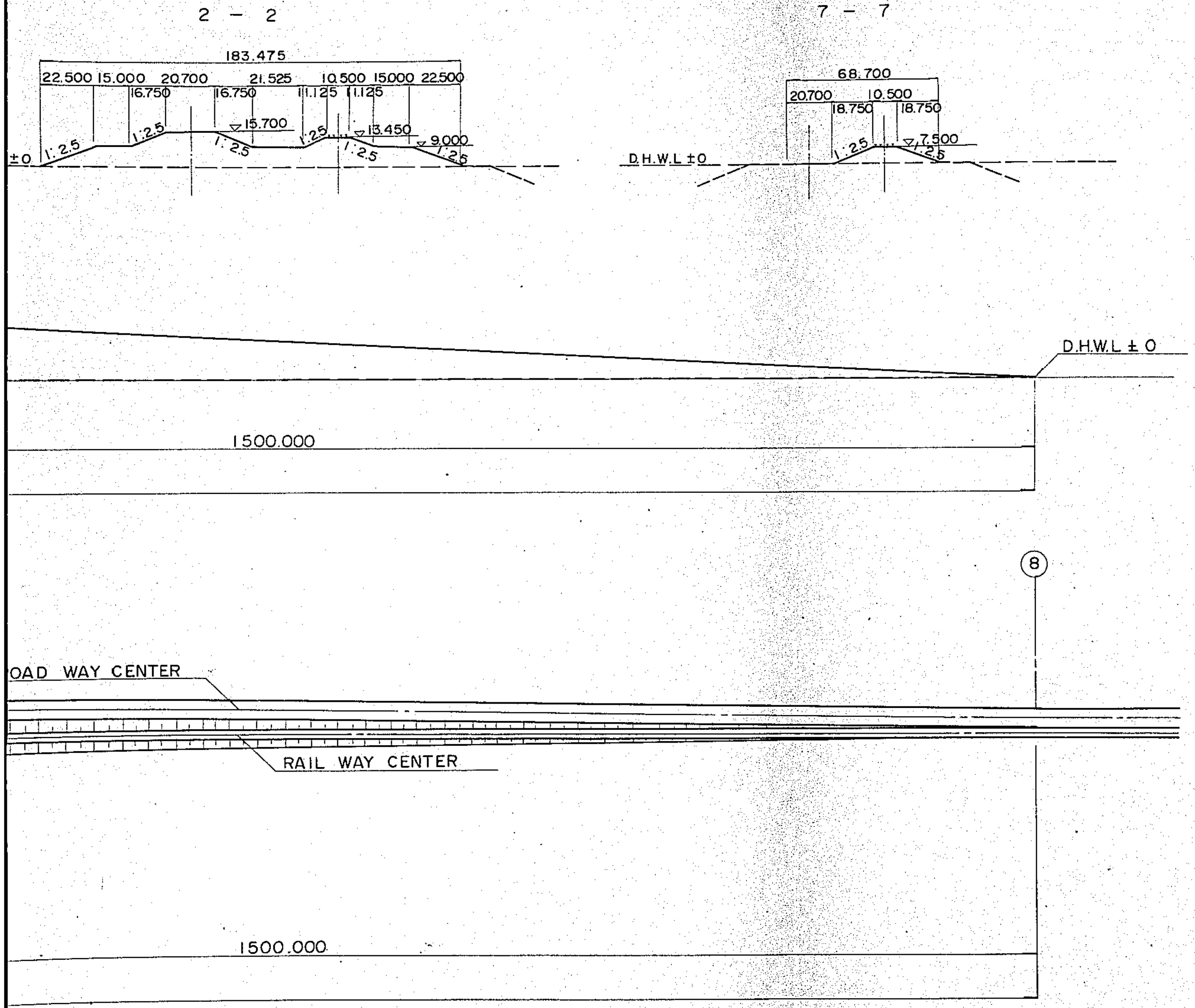

JA
BRIDGE LENGTH
540.000
+27.700 PAVEMENT ELEVATION HEIGHT
30/
V.C.L = 200.000
R = 6700.000
+17.450 RAIL ELEVATION HEIGHT
V.C.L = 200.000
R = 40 000.000
(12.188)
V.C.L = 40.00
R = 800.00
50/1000
80000
V.C.L = 40.000
R = 800.000
D.H.W.L ±0
3.000
140.000
800.00
(2000000 4 200.000 5 200.000 5 600000)
60.000
FLOW
1
A=250
R=800
940.000
BRIDGE LENGTH

Fig. Ⅴ-18-1 JAMUNA RIVER BRIDGE APPROACH (DOUBLE TRACK RAILWAY & FOUR L




E APPROACH (DOUBLE TRACK RAILWAY & FOUR LANE ROAD)
(HORIZONTAL 1 : 5 000 , VERTICAL 1 : 500)
TYPICAL CROSS SECTION SCALE (1 : 2 000)
1 - 1
127.750
22.500 15.000 10.500 15.000 22.500
21.125 21.125
17.450
9.000
D.H.W.L ± 0
2 - 2
183.475
22.500 15.000 20.700 21.525 10.500 15.000 22.500
16.750 16.750 11.125 11.125
15.700
13.450
9.000
D.H.W.L ± 0
7 - 7
68.700
20.700
18.750
D.H.W.L ± 0
12.333
+10.833
+9.000
+7.500
5 / 1000
V.C.L = 200.000
R = 6700.000
300.000
366.600
300.000
1500.000
3630.000
N SCALE (1 : 5 000)
5
6
7
ROAD WAY CENTER
RAIL WAY CENTER
300.000
366.600
300.000
1500.000
3630.000
SHOWN

TYPICAL CROSS SECTION SCALE (1 : 2000)



SHOWN LENGTH IS METER

JAPAN INTERNATIONAL COOPERATION AGENCY

PEOPLE'S REPUBLIC OF BANGLADESH

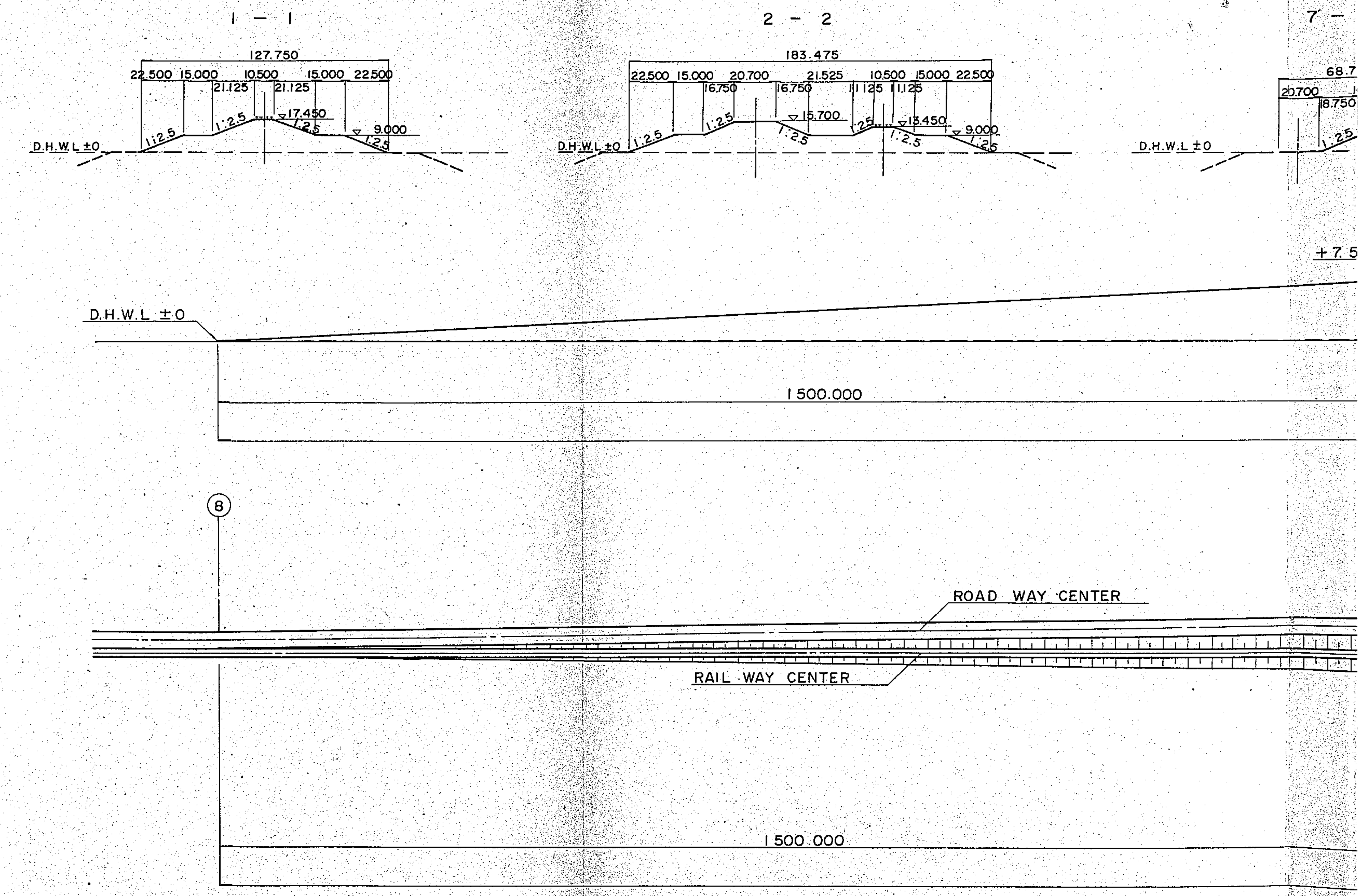
JAMUNA RIVER BRIDGE PROJECT

APPROACH ROAD OF LEFT BANK
(DOUBLE TRACK & FOUR LANES)

Drawn	Date
Approved	Date

NIKKEN CONSULTANTS INC.

TYPICAL CROSS SECTION SCALE (1 : 2000)



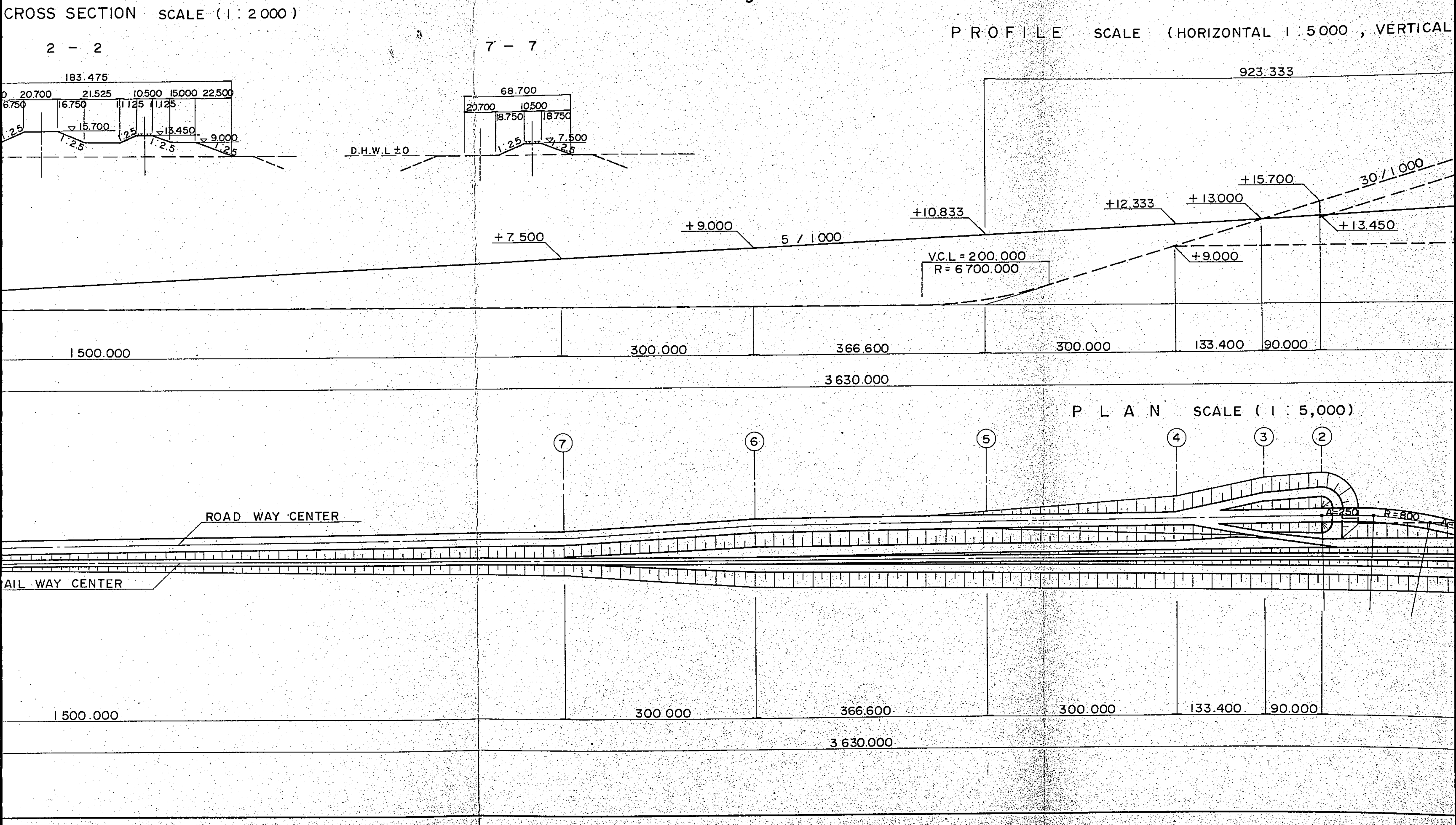
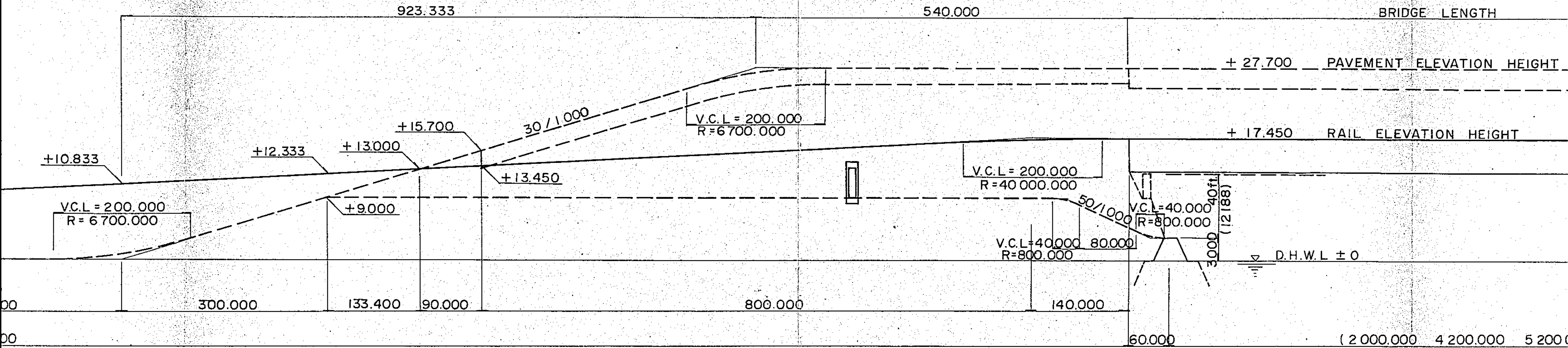


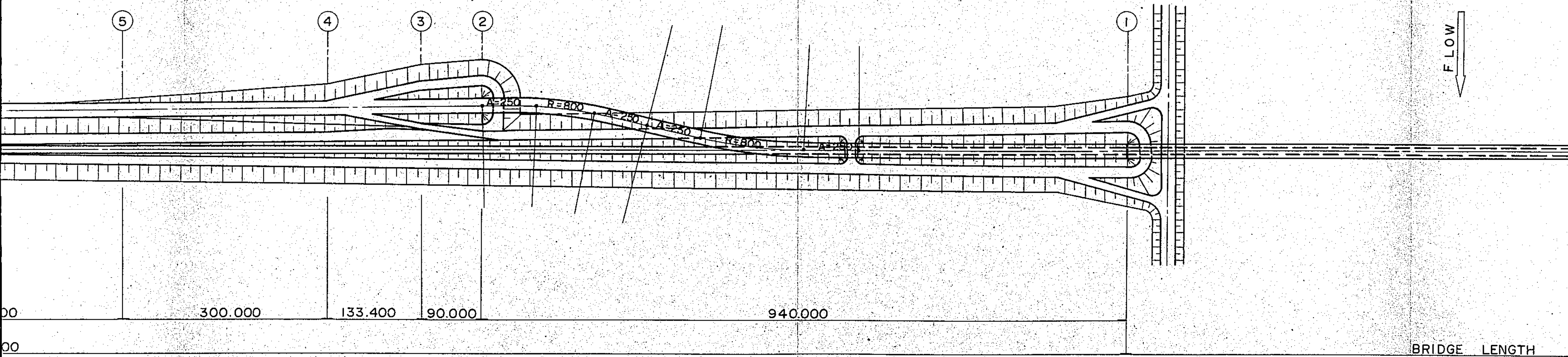
Fig. V-18-2 JAMUNA RIVER BRIDGE APPROACH (DOUBLE

AMUNA RIVER BRIDGE APPROACH (DOUBLE TRACK RAILWAY & FOUR LANE ROAD)

PROFILE SCALE (HORIZONTAL 1 : 5000 , VERTICAL 1 : 500)

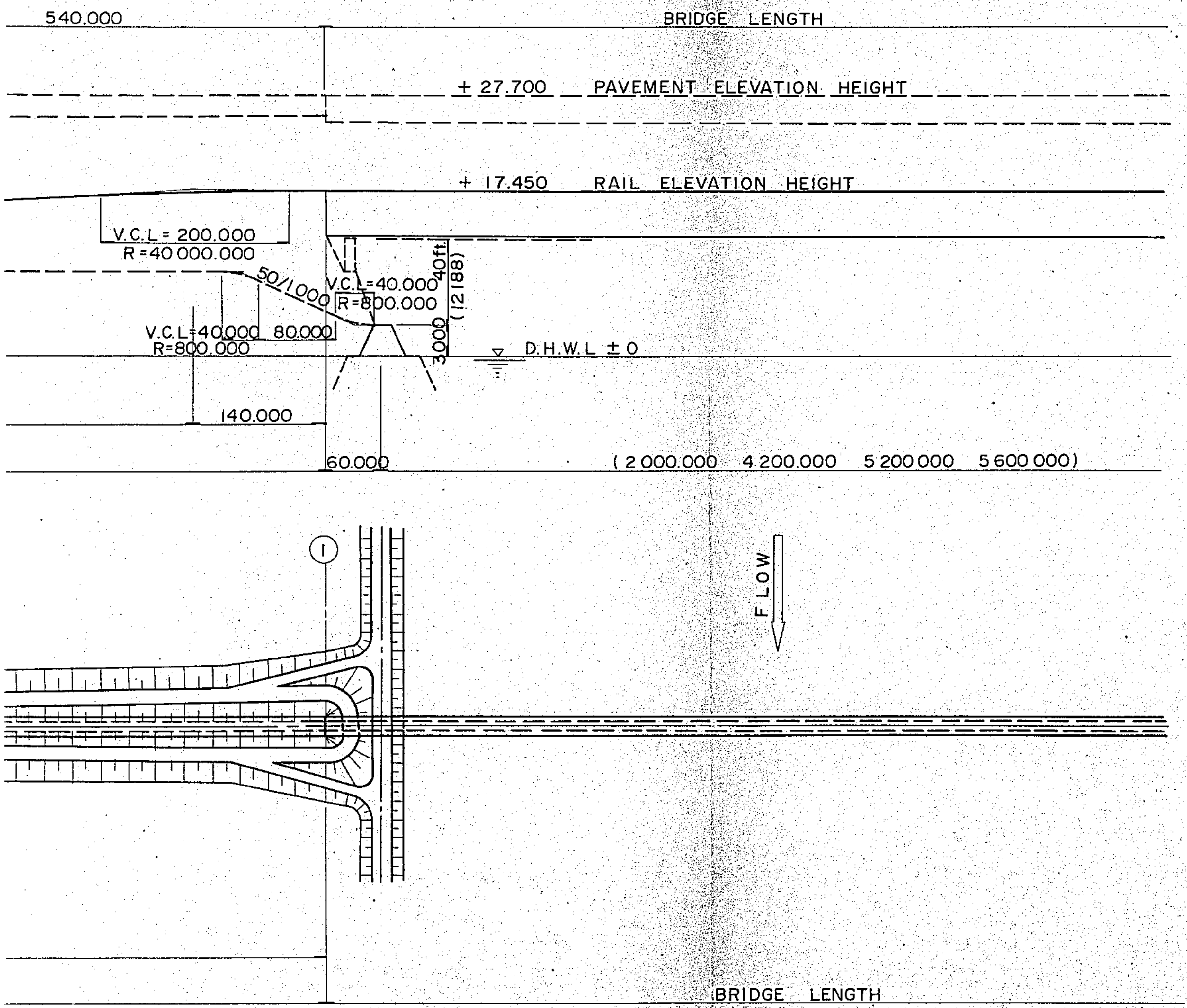


PLAN SCALE (1 : 5,000)



SHOWN LENG

FOUR LANE ROAD)



SHOWN LENGTH IS METER

JAPAN INTERNATIONAL COOPERATION AGENCY
PEOPLE'S REPUBLIC OF BANGLADESH
JAMUNA RIVER BRIDGE PROJECT APPROACH ROAD OF RIGHT BANK (DOUBLE TRACK & FOUR LANES)
Drawn Date
Approved Date
NIKKEN CONSULTANTS INC.