URBAN TRANSPORT STUDY
IN
GREATER METROPOLITAN AREAS
OF
GEORGETOWN, BUTTERWORTH AND BUKIT MERTAJAM

MALAYSIA

BRIDGE STUDY

OUTER RING ROAD PROJECT (PHASE II)

TECHNICAL REPORT-06

MARCH 1981

JAPAN INTERNATIONAL COOPERATION AGENCY

GOVERNMENT OF MALAYSIA

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GENERAL

In this report, of the proposed bridges, only three of them were studied. They were the bridges at stations 28, 90 and 105.

In the following page, the location of these three bridges are shown and they are named alphabetically, starting with the bridge with the lowest station number.

The format for this bridge study, topographic surveys and soil investigations were conducted earlier. Results of the topographic surveys and soil investigations are insufficient for determining the detail dimensions of the bridges. However it is sufficient to achieve the aim of this study.

To determine the type of bridges to be constructed the purpose as well as the required accuracy of the bridge will have to be considered. The decision is to select one that is simple and can be easily constructed.

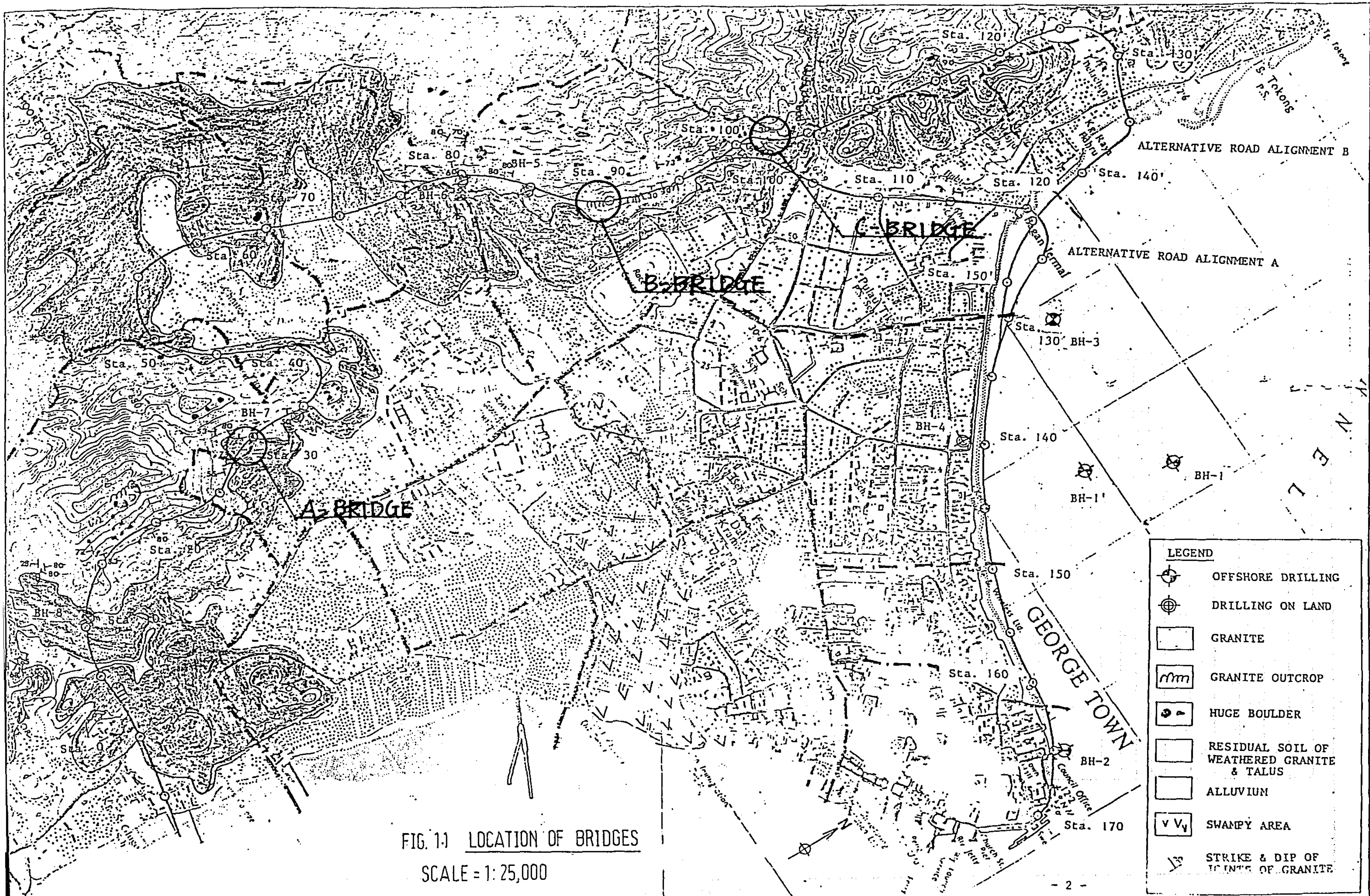


FIG. 1-1 LOCATION OF BRIDGES

SCALE = 1: 25,000

Chapter 1 BASIC DESIGN CRITERIA

1.1 Standard Specifications

The standard specifications for bridges shall be in accordance with the specifications of the British Standard Institution (BSI).

Specification for loads --- BS5400 : Part 2, BS648

Specification for steel girder bridges ---BS153

Specification for concrete bridges ---BS5400 : Part 4

Specification for materials --- BS153, BS5400 : Part 4, Part 6, Part 7

Specification for foundation --- CP2004

1.2 Loads

1.2.1 Dead Load

The dead load consists of the weight of the complete structure including the slabs, pavements, handrails and other public utility services.

The following weights shall be used in computing the dead load.

Table 1.1 DEAD LOAD OF MATERIALS

	Unit weight KN/m^3	Unit weight Kg/m^3
Steel, Cast steel and Forged steel	77.0	7850
Cast iron	71.1	7250
Aluminium alloys	27.5	2800
Reinforced concrete and Prestressed concrete	24.5	2500
Plain concrete	23.0	2350
Cement mortar	21.1	2150
Timber	7.8	800
Asphalt pavement	22.5	2300

1.2.2 <u>Live Load</u>

The structure and its elements shall be designed to withstand the more severe effects of the live load. The structure can be either of the following.

Design HA loading ----- Case A

Design HA loading combined with design HB loading ----- Case B

1.2.2.1 <u>Type HA Loading</u>

Type HA loading consists of a uniformly distributed load (UDL) combined with a knife edge load (KEL).

The UDL shall be taken as 30 KN per linear metre of notional lane for loaded lengths up to 30m, and for loaded lengths in excess of 30m, it is given in Table 1.2.

The KEL per notional lane shall be taken as 120 KN.

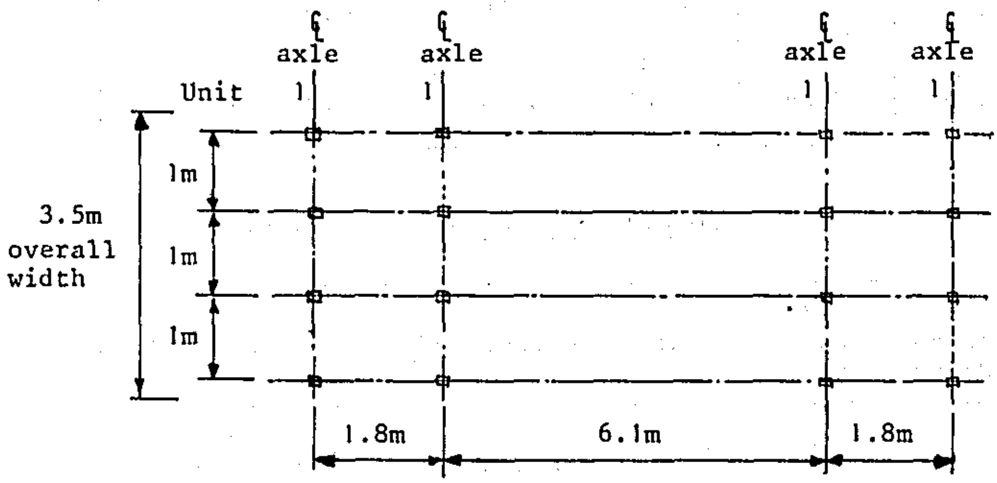
Table 1.2 TYPE HA UNIFORMLY DISTRIBUTED LOAD

Loaded length	Load	Loaded length	Load	Loaded length	Load
m	KN/m	m	KN/m	m	KN/m
Up to 30	30.0	73	19.7	160	13.6
32	29.1	76	19.3	170	13.2
34	28.3	79	18.9	180	12.8
36	27.5	82	18.6	190	12.5
38	26.8	85	18.3	200	12.2
40	26.2	90	17.8	210	11.9
42	25.6	95	17.4	220	11.7
44	25.0	100	16.9	230	11.4
46	24.5	105	16.6	240	11.2
49	23.8	110	16.2	255	10.9
52	23.1	115	15.9	270	10.6
55	22.5	120	15.5	285	10.3
58	21.9	125	15.2	300	10.1
61	21.4	130	15.0	320	9.8
64	20.9	135	14.7	340	9.5
67	20.5	140	14.4	360	9.2
70	20.1	145	14.2	380 and above	9.0
		150	14.0		

1.2.2.2 Type HB Loading

Figure 1.1 shows the plan and axle arrangement for one unit of nominal HB loading. One unit shall be taken as equal to 10 KN per axle. In this study, 45 units is used.

Fig. 1.2. PLAN AND AXLE ARRANGEMENT



1.2.3 Effects of Earthquakes

The effects of earthquakes need not be considered because earthquakes here are of small magnitudes and the possibility of a great earthquake occuring which could cause significant damage is very small during the life of the structure.

1.3 Materials

The grades and strengths of materials are shown as follows.

Table 1.3 STRENGTH OF REINFORCED CONCRETE

Grade	Character-istic strength	Cube strength at different ages				
		7 days	2 months	3 months	6 months	1 year
	N/mm^2					
20	20.0	13.5	22.0	23.0	24.0	25.0
25	25.0	16.5	27.5	29.0	30.0	31.0
30	30.0	20.0	33.0	35.0	36.0	37.0
40	40.0	28.0	44.0	45.5	47.5	50.0
50	50.0	36.0	54.0	55.5	57.5	60.0

Table 1.4 STRENGTH OF PRESTRESSED CONCRETE

Grade	Characteristic strength	Cube strength at different ages				
		7 days	2 months	3 months	6 months	1 year
	N/mm^2					
30	30.0	20.0	33.0	35.0	36.0	37.0
40	40.0	28.0	44.0	45.5	47.5	50.0
50	50.0	36.0	54.0	55.5	57.5	60.0
60	60.0	45.0	64.0	65.5	67.5	70.0

Table 1.5 STRENGTH OF REINFORCEMENT

Designation	Norminal Sizes(mm)	Specified Characteristic Strengths (N/mm^2)
Hot rolled mild steel (BS4449)	All sizes	250
Hot rolled high yield steel (BS4449)	All sizes	410
Cold worked high yield steel (BS4461)	Up to 16 above 16	460 425
Hard drawn steel wire (BS4482)	Up to 12	485

Table 1.6 SPECIFIED CHARACTERISTIC STRENGTHS OF PRESTRESSED WIRES

Nominal Size (mm)	Specified Characteristic Strength (KN)	Nominal Cross-sectional Area (mm^2)
2	6.34	3.14
2.65	10.3	5.5
3	12.2	7.1
3.25	14.3	8.3
4	21.7	12.6
4.5	25.7	15.5
5	30.8	19.6
7	60.4	38.5

Table 1.7 SPECIFIED CHARACTERISTIC STRENGTHS OF PRESTRESSED BARS

Nominal Size (mm)	Specified Characteristic Strength (KN)	Nominal Cross-sectional Area (mm^2)
20	325	314
25	500	491
32	800	804
40	1250	1257

Table 1.8 SPECIFIED CHARACTERISTIC STRENGTHS OF PRESTRESSED STRANDS

Number of Wires and Type of Strand	Nominal Size (mm)	Specified Characteristic Strength (KN)	Nominal Cross-sectional Area (mm^2)
7 Normal Strength Strand	6.4	44.5	24.5
	7.9	69.0	37.4
	9.3	93.5	52.3
	10.9	125.0	71.0
	12.5	165.0	94.2
	15.2	227.0	138.7
19 Normal Strength Strand	18.0	370.0	210.0
	25.4	659.0	423.0
	28.6	823.0	535.0
	31.8	979.0	660.0
7 High Strength Strand	9.6	102.5	55.0
	11.3	138.0	75.0
	12.9	184.0	100.0
	15.7	261.0	150.0

Table 1.9 SPECIFIED CHARACTERISTIC STRENGTHS OF COMPACTED STRANDS

Number of Wires	Normal Size (mm)	Specified Characteristic Strength (KN)
7	12.7	209
	15.2	300
	18.0	380

Chapter 2 SOIL CONDITIONS

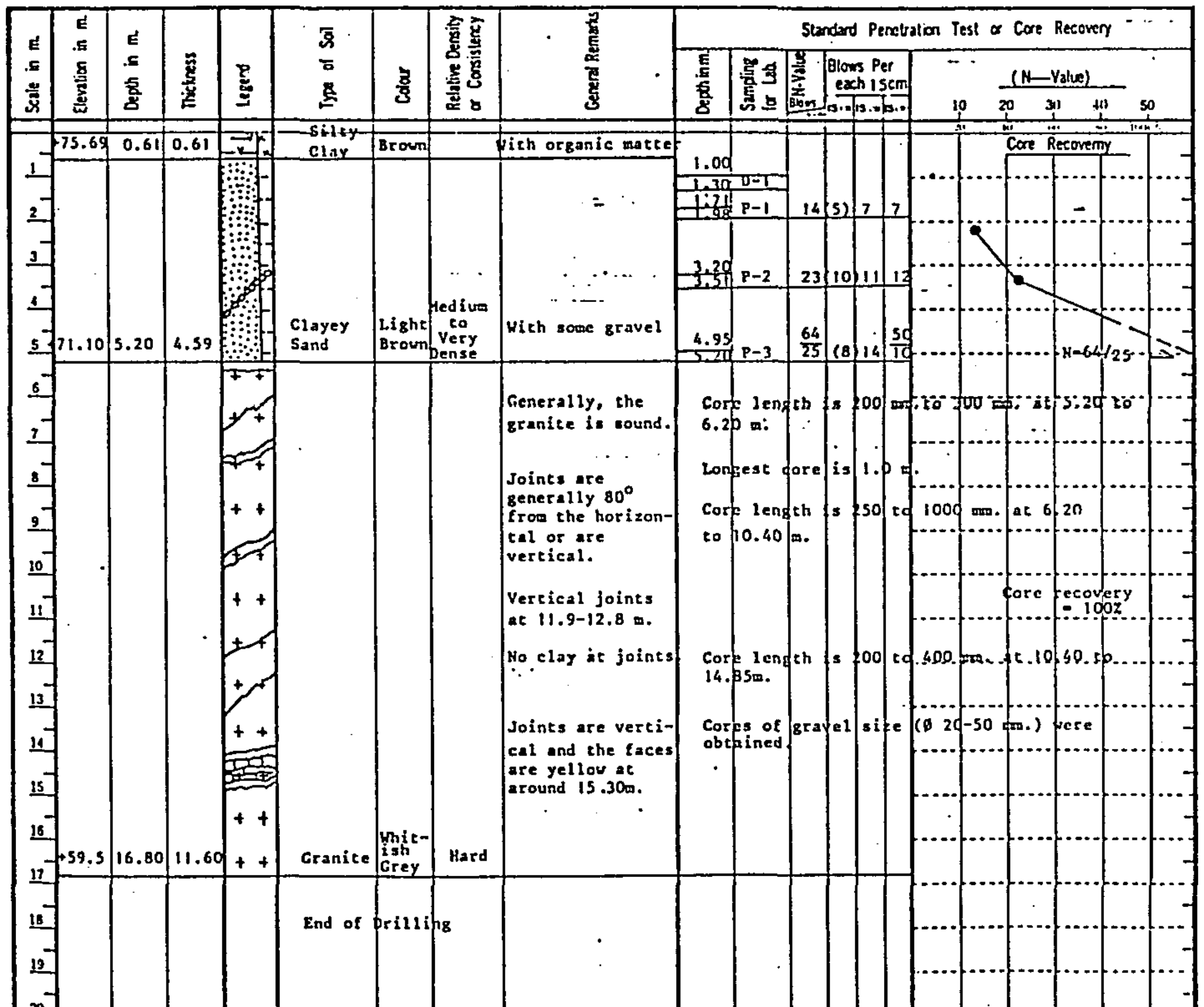
As stated in the Geotechnical Investigation Report regarding the bridge sites, sandy clay or clayey sand, with many submerged boulders of diameters from 1m to 5m, extends to a depth of from 5m to 10m before granite or weathered granite are encountered.

Fig. 2.1 shows the results of the drillings in BH-5 and BH-6.

According to Fig. 2.1, the granite or the weathered granite which are 5m to 10m below the ground level, is advantageous as the bedrock of the foundation.

Name of Project URBAN TRANSPORT STUDY
Hole Number No. BH-5 Elevation: + 76.30 m.
Water Table : - m.
Type of Drilling: ROTARY
Date: May 18 to 21, 1980.
Driller: GEOTECHNIQUE (MR. LEE)

Remarks



Name of Project URBAN TRANSPORT STUDY
Hole Number No. BH - 6 Elevation : + 65.70 m.
Water Table : - m.
Type of Drilling: ROTARY
Date : May 24 to 29, 1980.
Driller: GEOTECHNIQUE (MR. LEE)

Remarks

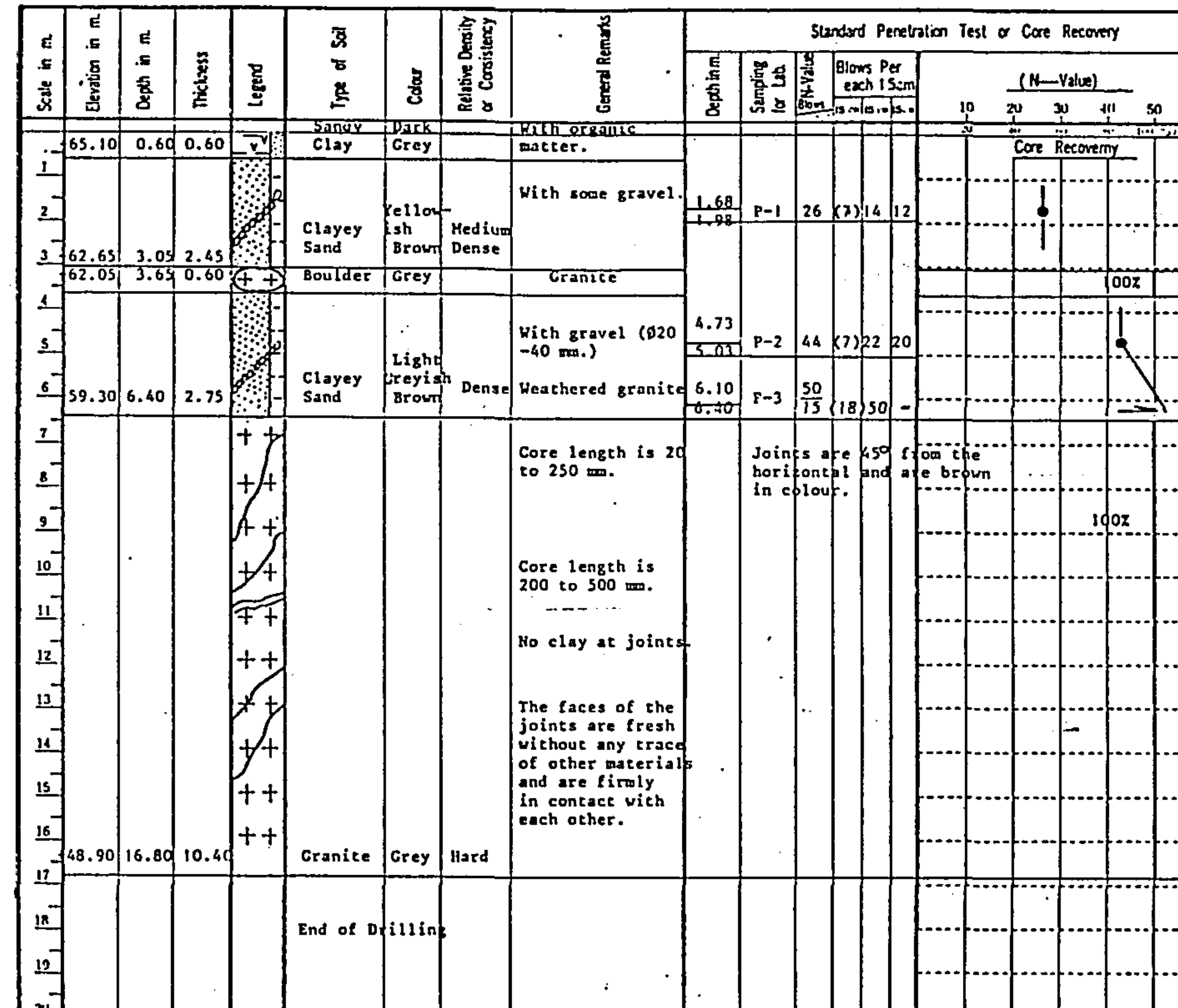


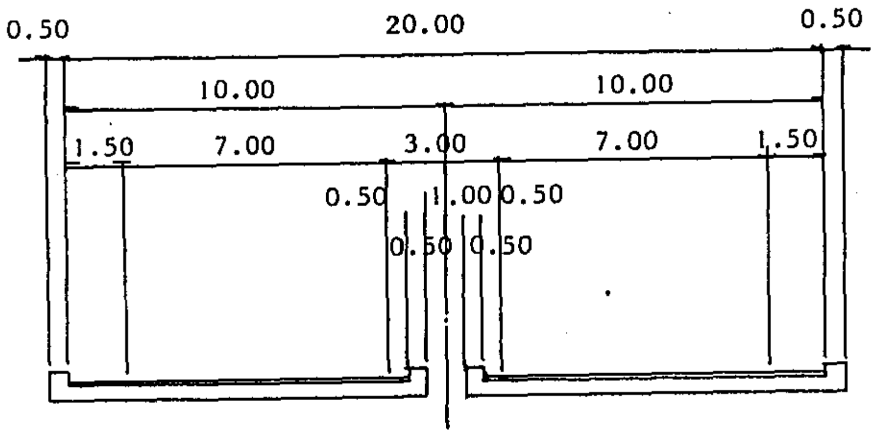
FIG. 2-1 RESULTS OF DRILLING IN BH-5 AND BH-6

Chapter 3 GENERAL PLANNING OF BRIDGES

3.1 Cross-section

The cross-section of the carriageways in the bridges is shown in Fig. 3.1.

Fig. 3.1 CROSS-SECTION OF CARRIAGEWAYS



3.2 Geographical Features at Sites of Bridges

The geographical features at the sites of bridges are shown in Figs. 3.2, 3.3 and 3.4.

The total length of each bridge should be as shown in the following table.

Table 3.1 TOTAL LENGTH OF EACH BRIDGE

	Total Bridge Length	Station
A - Bridge	270.0m	No.27+70 - No.30+40
B - Bridge	435.0m	No.88+35 - No.92+70
C - Bridge	310.0m	No.104+40 - No.107+50

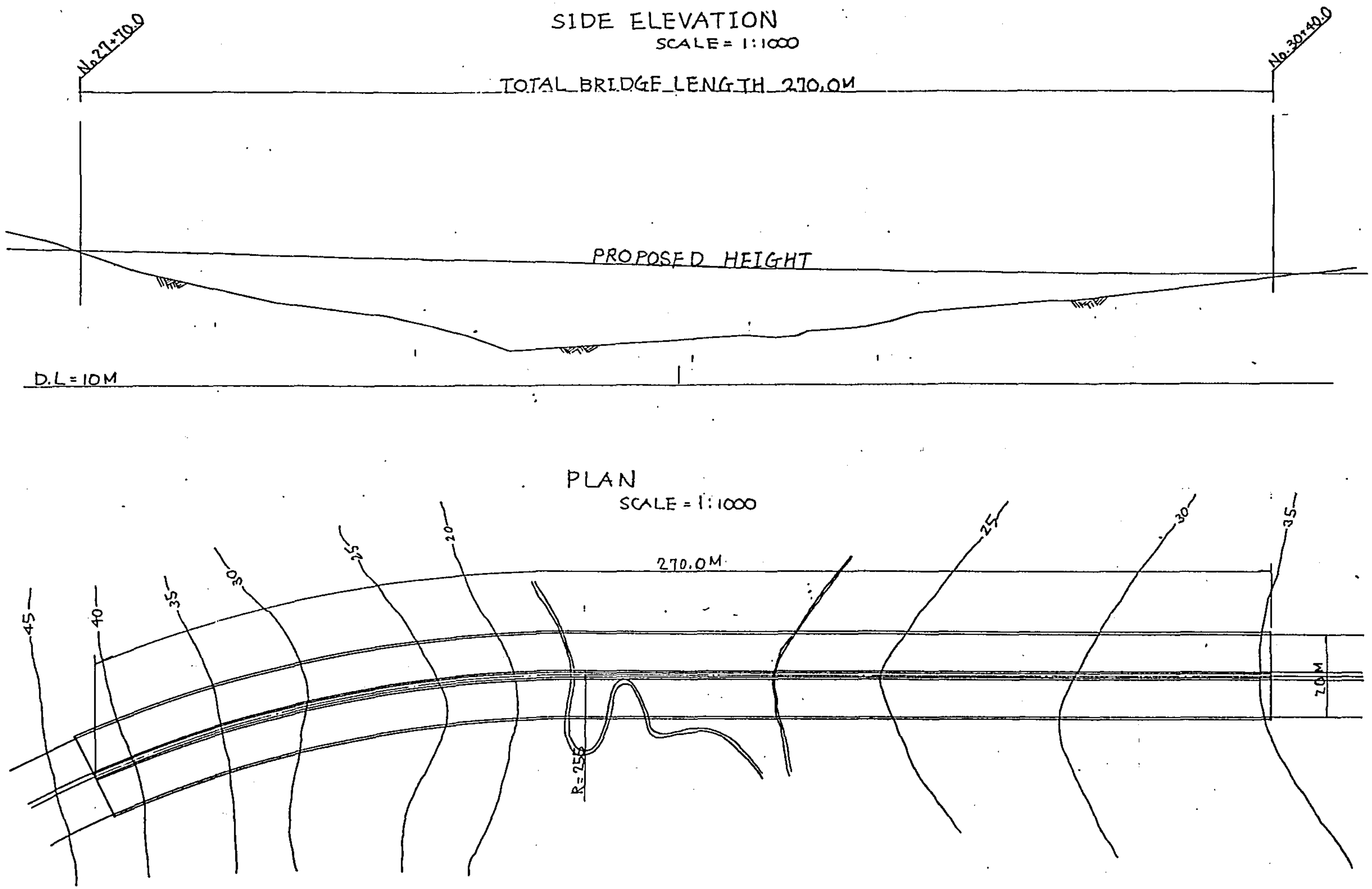


FIG. 3·2 SITE OF A-BRIDGE

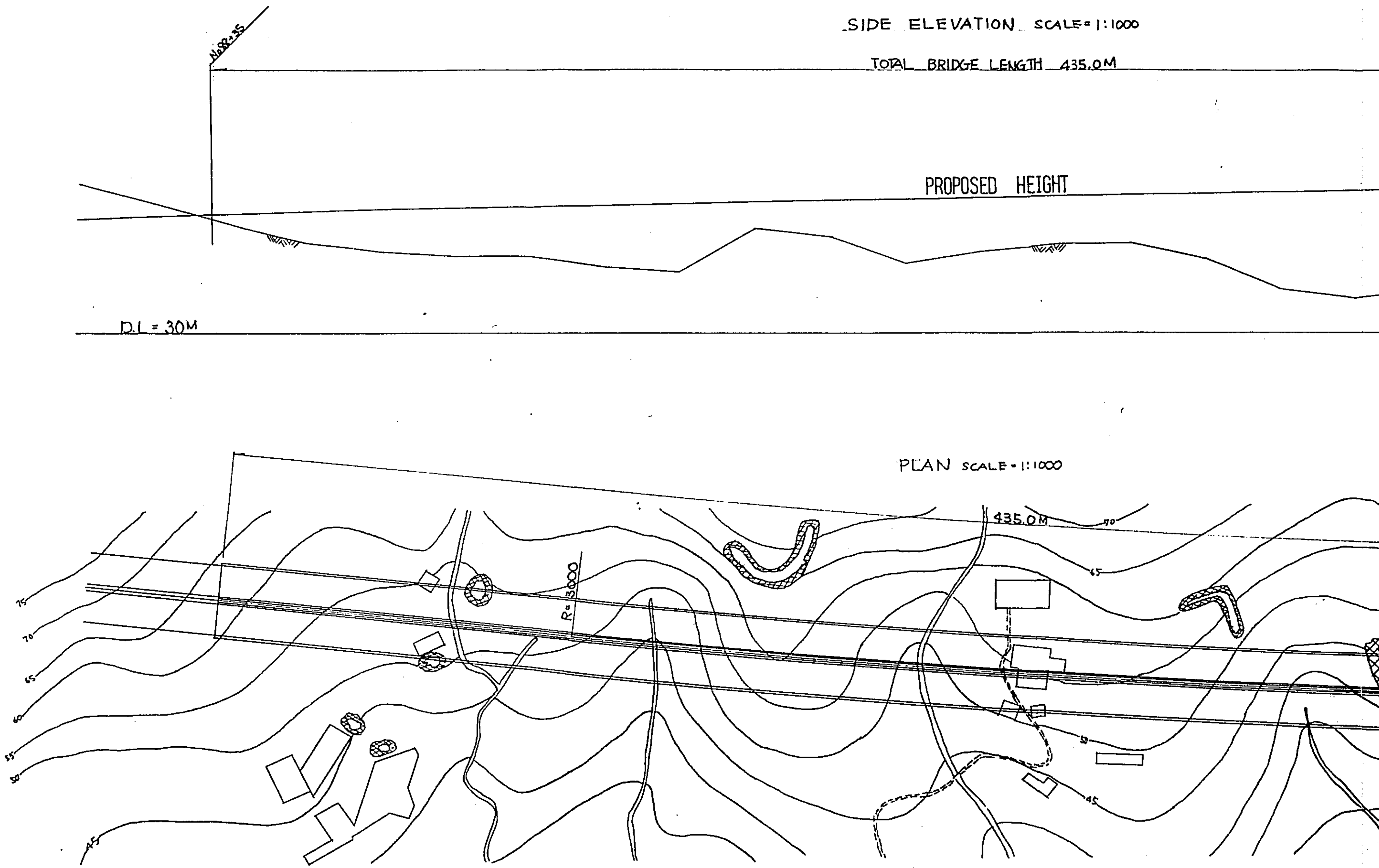
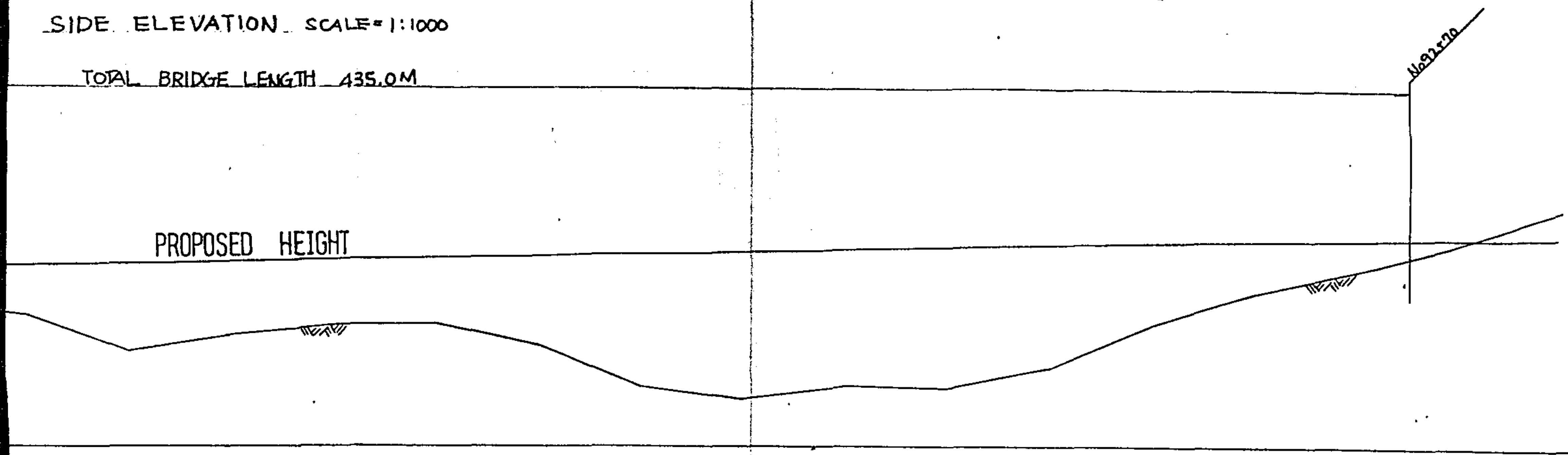


FIG. 3·3 SITE OF B-BRIDGE

SIDE ELEVATION SCALE=1:1000



PLAN SCALE=1:1000

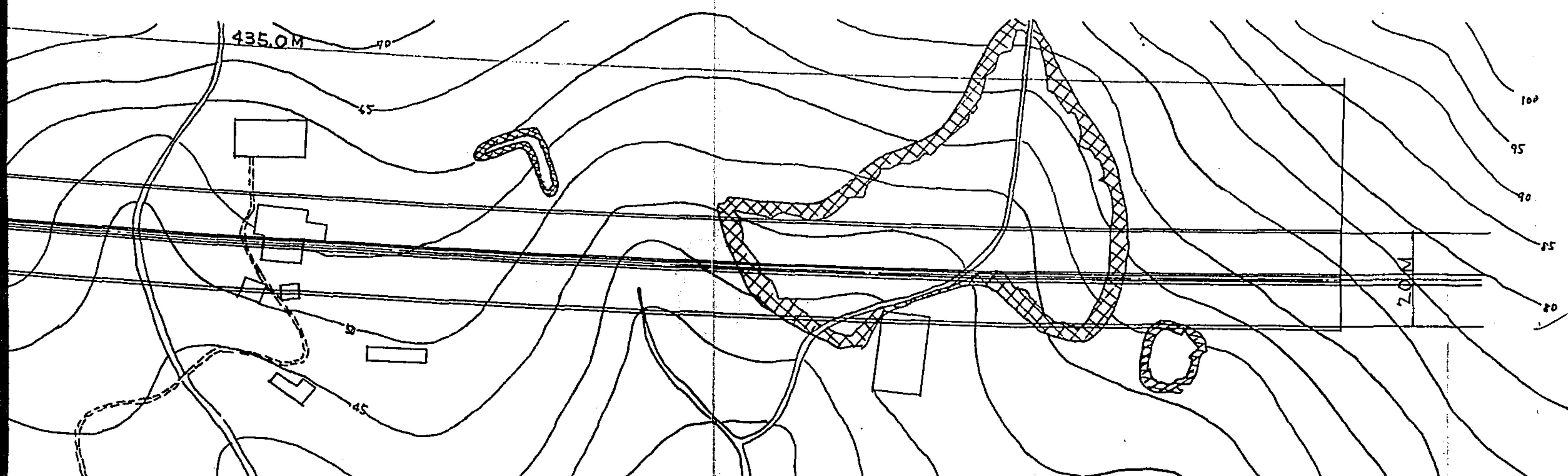


FIG. 3·3 SITE OF B-BRIDGE

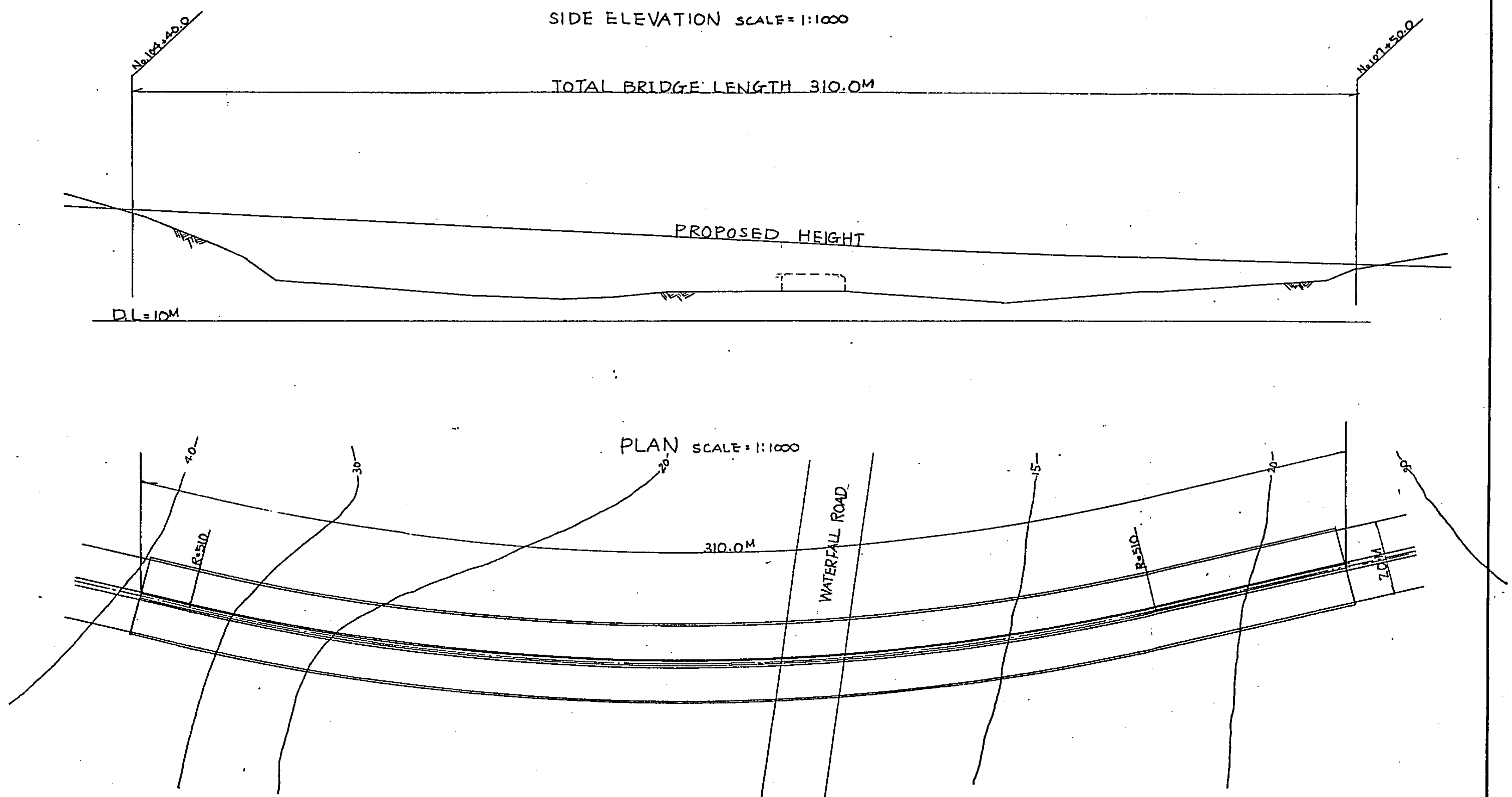


FIG. 3·4 SITE OF C-BRIDGE

3.3 Span Specifications

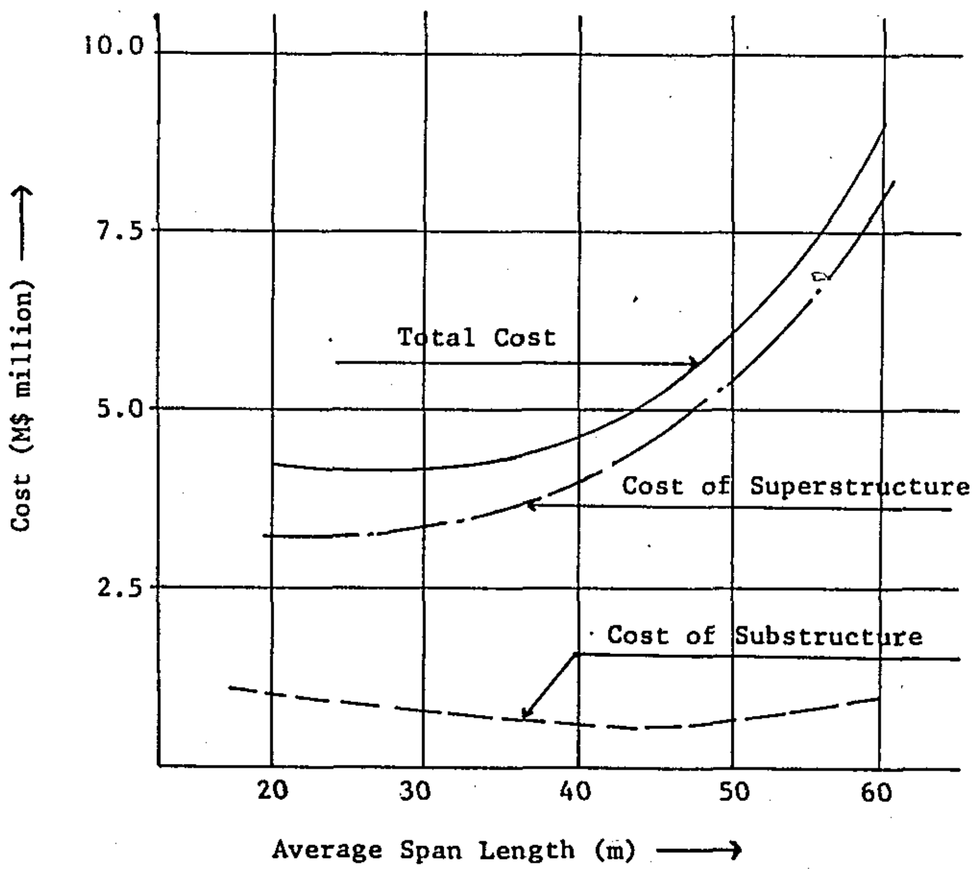
The span specifications should be based on the following basic considerations.

1) Economical span length

The graph in Fig. 3.5 shows a rough estimate of the cost of the bridge under the following conditions:

Total bridge length ---- 200m
Width of the bridge ---- 20m
Types of foundations ---- spread footing type
Average height of the substructure ---- 15m

Fig. 3.5 ROUGH ESTIMATE OF COST OF BRIDGE



The graph indicates that the economical span length is approximately 30m and that the total cost increases suddenly for span lengths above 40m.

Therefore, the basic span length should be approximately 30m.

2) Condition in construction of substructure.

As far as possible the piers should be located such that it avoids streams, roads and escarpments.

3) Structural desire of superstructure

In the case where the superstructure is the continuous girder type, the proportion of the length of the main span and the flanking span should be determined during structural designing.

Figs. 3.6, 3.7 and 3.8 show the spans of the three bridges.

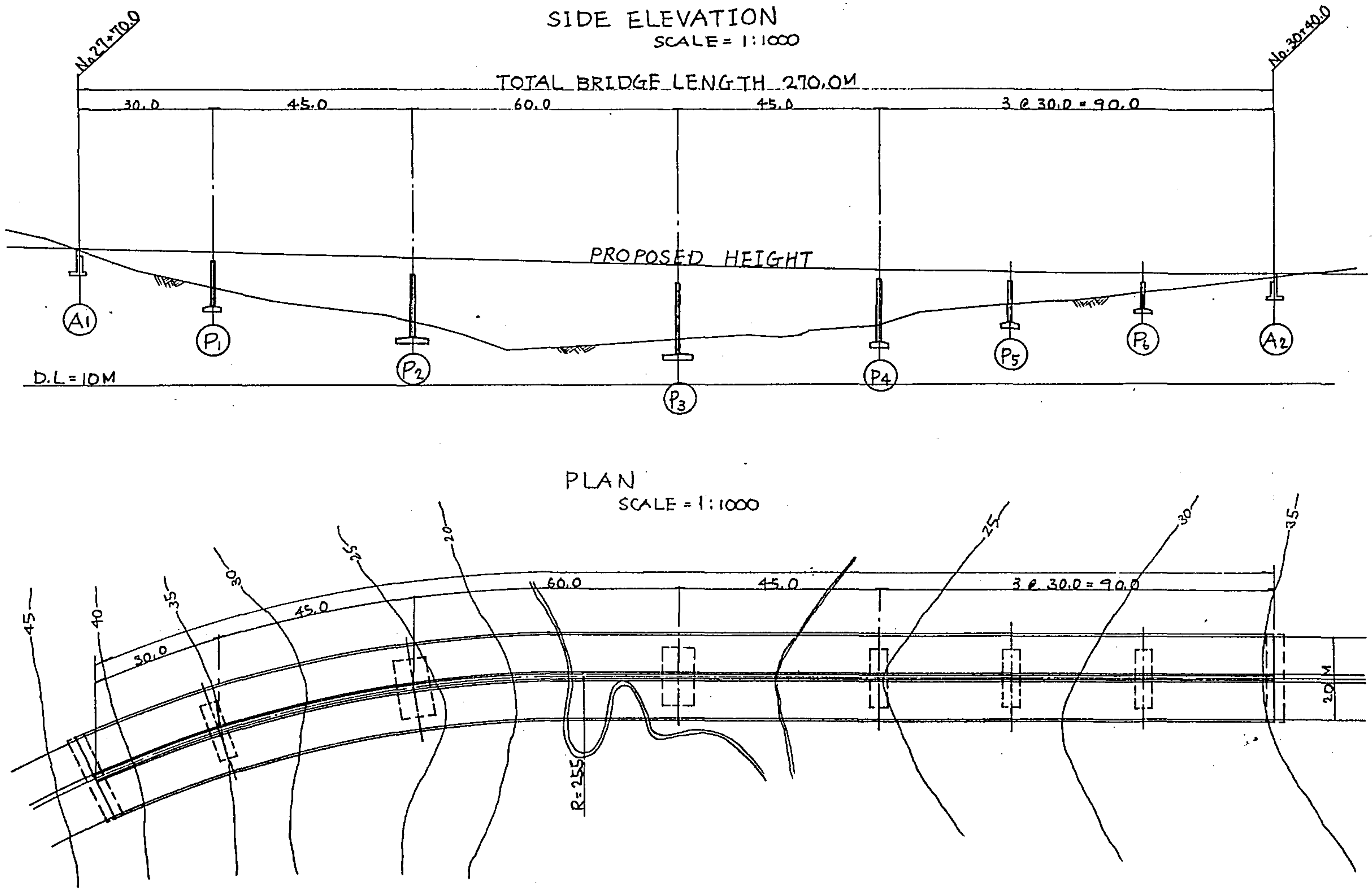


FIG. 3.6 GENERAL VIEW OF GREEN VILLAGE BRIDGE

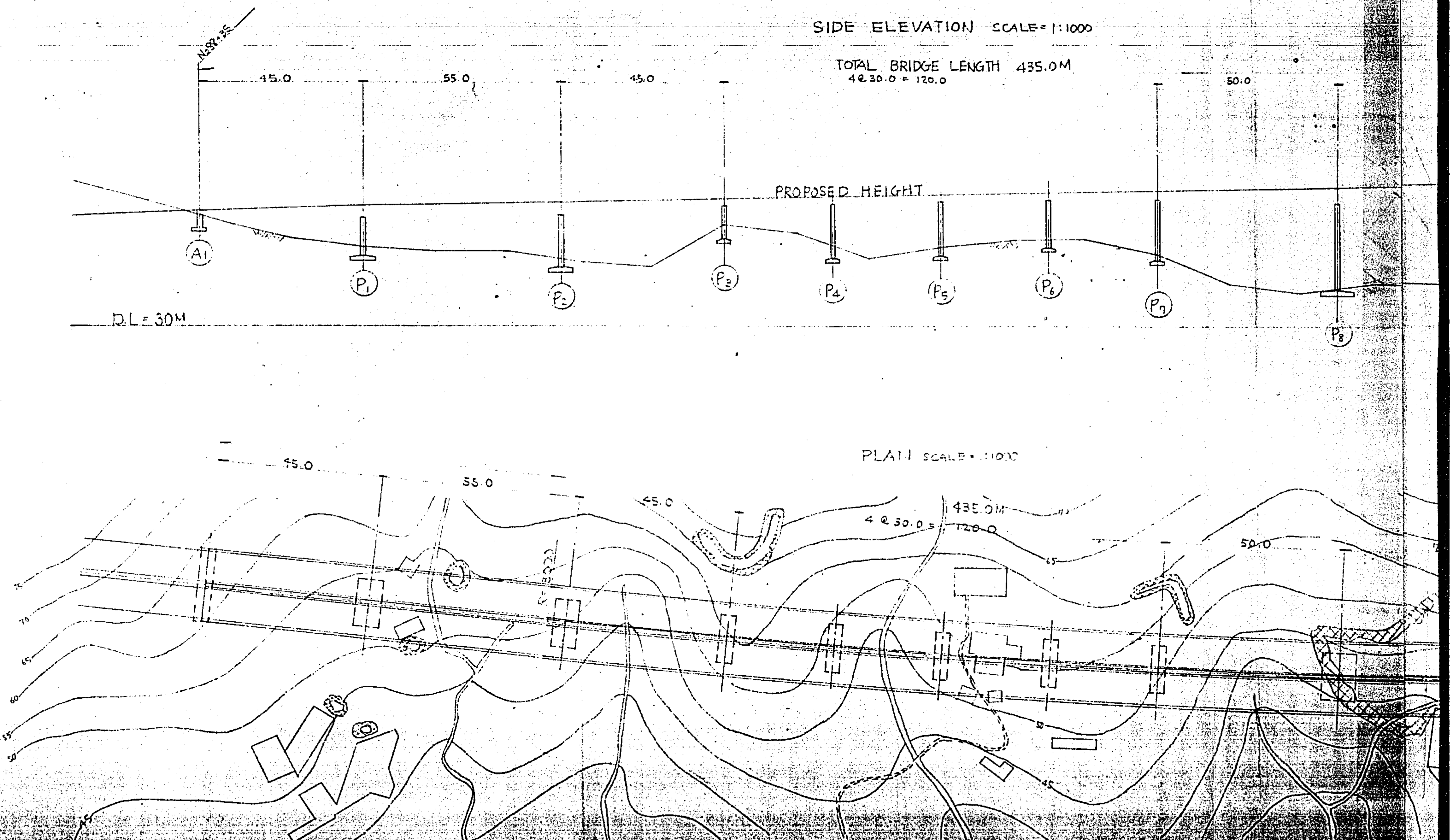


FIG. 3·7 GENERAL VIEW OF RIFLE RANGE BRI

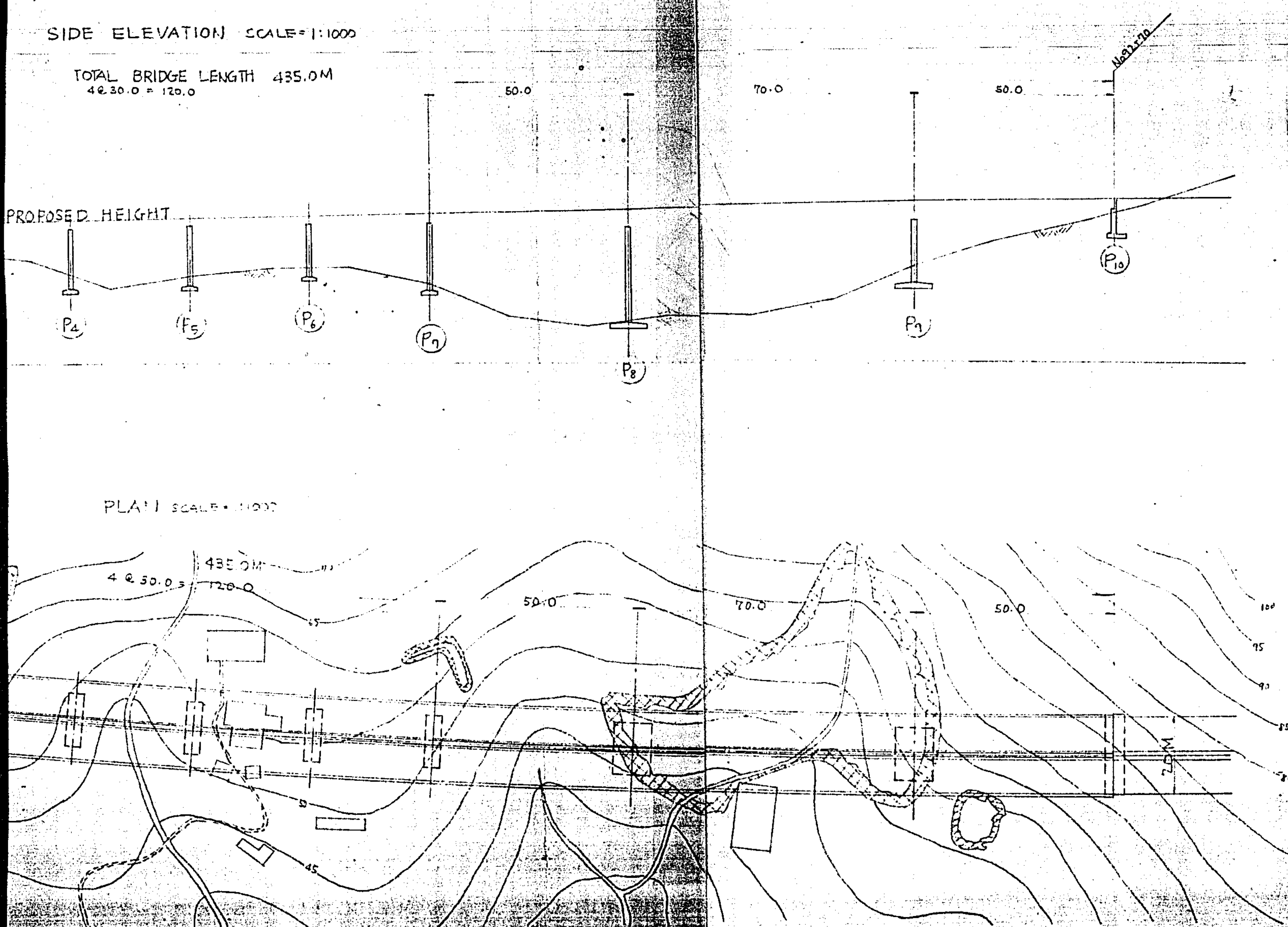


FIG. 3·7 GENERAL VIEW OF RIFLE RANGE BRIDGE

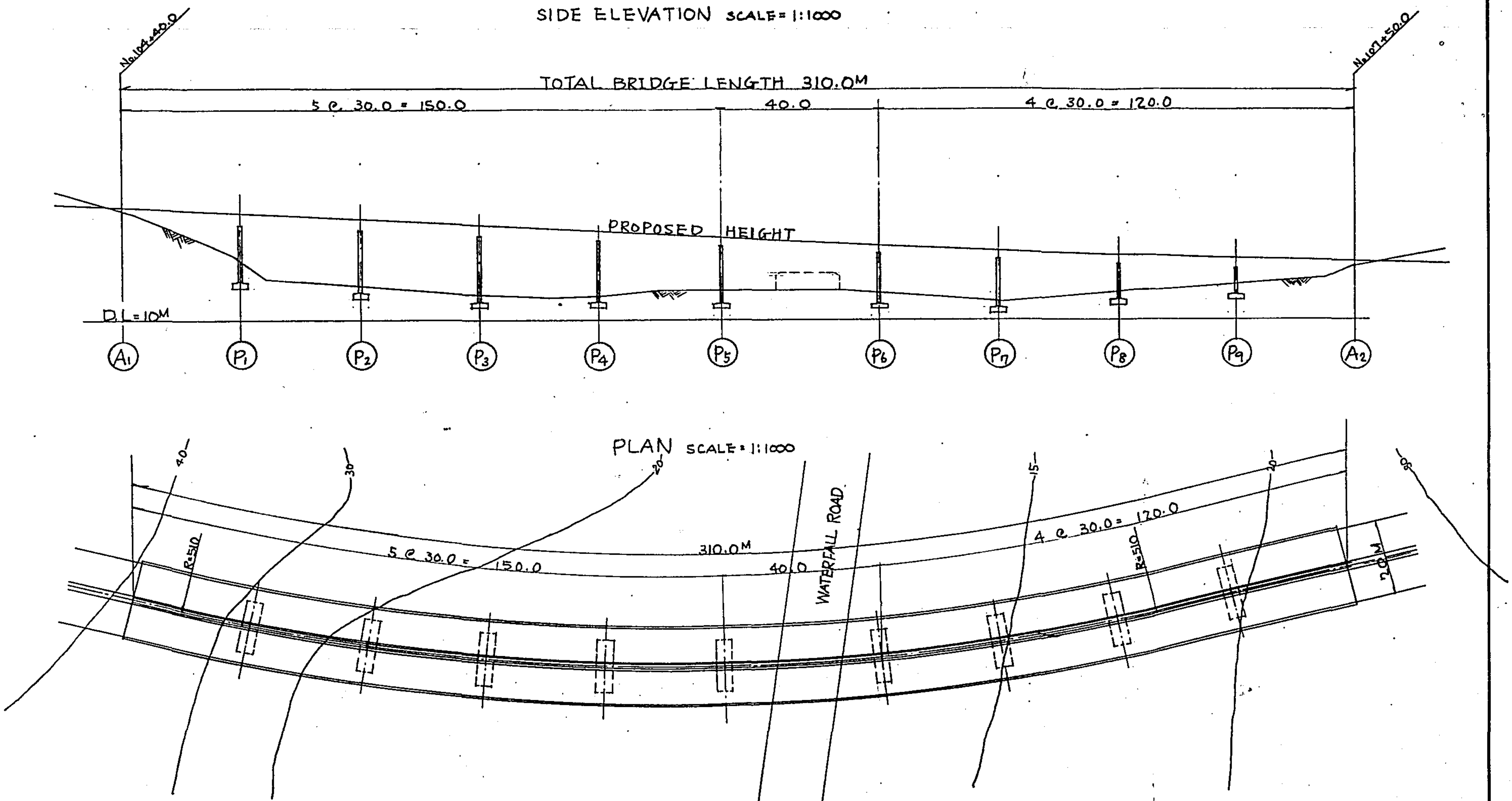
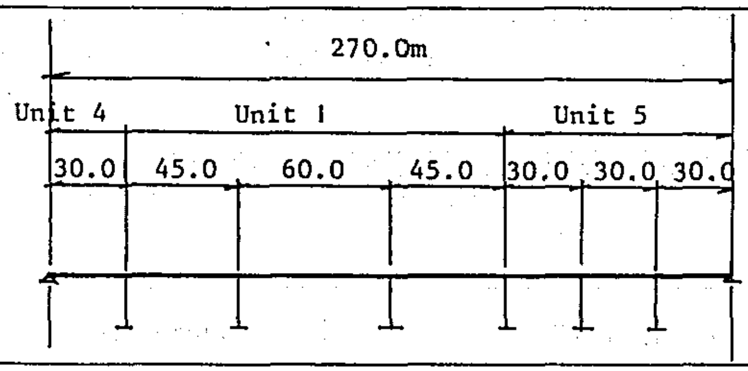
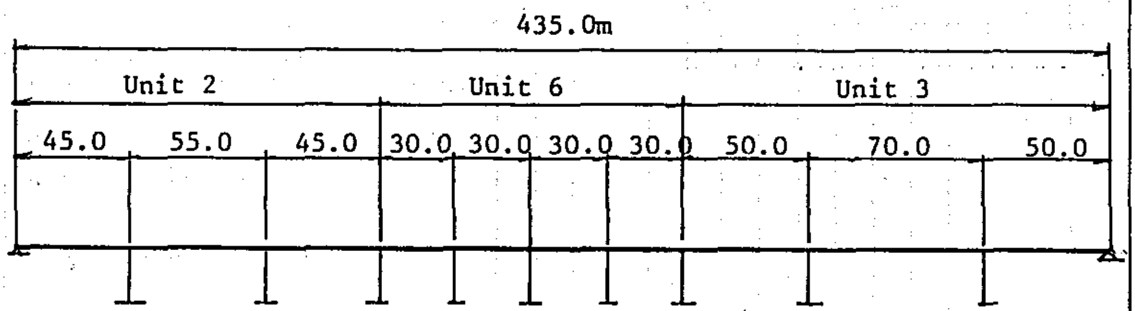
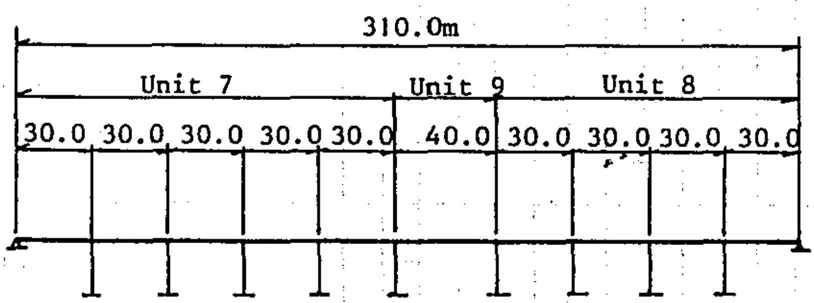


FIG. 3-8 GENERAL VIEW OF WATERFALL ROAD BRIDGE

3.4 Classification of Span Length

The total bridge length at each site should be considered as being divided into a few units. The units are classified as in the following table.

Fig. 3.2 CLASSIFICATION OF UNITS OF BRIDGES

Site	Side Profile	Curvature
A-Bridge		Unit 1,4 R=255.0m Unit 5 - - - Straight
B-Bridge		Unit 2,3,6 R=3000.0m
C-Bridge		Unit 7,8,9 R=510.0m

Each of units 1, 2 and 3 comprise of spans which are over 45.0 metres in length.

The span length for unit No.4 to No.8 is 30 metres. Unit 9 has a span length of 40 metres.

3.5 Bridge-Type Study — Superstructure

Concrete bridges should be adopted for the following reasons:

1) The use of reinforced concrete or prestressed concrete has the distinct advantage that the foreign component will be small.

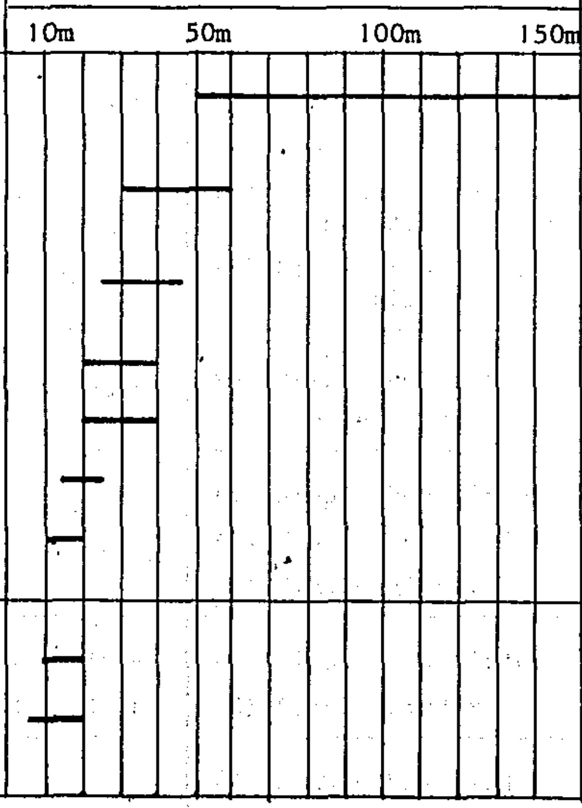
2) Concrete bridges are less expensive to maintain than steel ones.

3.5.1 Applicable Span Length in Concrete Bridge Types

The relationship between the type of superstructure and the span length and the suitability for the curvature of the roadway is as follows.

Table 3.3 RELATIONSHIP BETWEEN SUPERSTRUCTURES, SPAN LENGTH AND CURVATURE OF ROADWAY.

	Type & Structure	Span Length (10m, 50m, 100m, 150m)	Suitability for Curvature
Prestressed concrete bridge	Continuous box girder (cantilever girder erection)		○
	Continuous box girder (with timbering)		○
	Simple box girder		○
	Continuous girder		×
	Simple girder		△
	Hollow slab		○
	Pretensioned girder		△
Reinforced concrete bridge	Hollow slab		○
	Rigid frame		○



(Continued Overleaf)

(Continued) Key: Symbol "O" denotes suitable.

Symbol "X" denotes unsuitable.

Symbol " " denotes that the main structure of the bridge cannot be bent along the curves but only the road surface structure can be formed into the curves by using brackets or other means.

3.5.2 Study of Alternative Superstructures

According to Table 3.3, the following types of concrete superstructures are considered.

Table 3.4 ALTERNATIVES OF SUPERSTRUCTURES

	Unit	Span Length	Curvature	Alternative Types
Long Span	1 2 3	45.0 + 60.0 + 45.0 45.0 + 55.0 + 45.0 50.0 + 70.0 + 50.0	R = 255 m R =3000 m R =3000 m	(A) Continuous box girder (cantilever girder erection) (B) Continuous box girder (with timbering)
Short Span	4	30.0	R = 255 m	(C) Simple box girder (E) Simple girder
	5 6	3 x 30.0 4 x 30.0	R = ∞ R = 3000 m	(C) Simple box girder (D) Continuous girder (E) Simple girder
	7 8	5 x 30.0 4 x 30.0	R = 510 m R = 510 m	(C) Simple box girder (E) Simple girder
	9	40.0	R = 510 m	(C) Simple box girder (E) Simple girder

3.5.2.1 Long Span Bridge

(A) Continuous box girder type by cantilever girder erection

The erection method of this type is that the girder may be constructed by casting the elements which are from 2 meters to 5 meters in length in place with the travelling forms. In general, there are four steps to be followed.

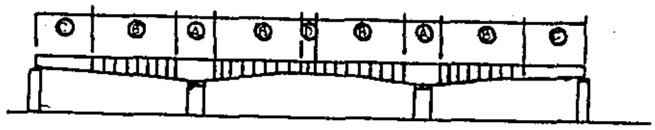


Fig. 3.9 ERECTION METHOD BY CANTILEVER GIRDER ERECTION

They are:

(1) First, section A (as shown in Fig. 3.9) will be constructed and supported by timbering.

(2) Then, the block next to section A will be constructed using the travelling form which is framed to the first block. The travelling form will then be moved onto the second block and thus the third block will be constructed using the travelling form on the second block. At the same time, another travelling form is also framed onto the other side of the first block and the same procedure is carried out simultaneously. Thus, both side will be balanced.

(3) After completing section B, section C will be constructed. In general, the timbering method is used for the construction of section C. Another method is that section C is constructed using the travelling form on a temperory stage.

(4) Finally, section D is constructed.

The major advantage of this method is that because scaffolding is not required, it is easy to erect over deep valleys, rivers with heavy flow and roads with heavy traffic.

The carriageway for each direction is supported by a single hollow box girder 6.0 m wide.
The girder depth varies from 1/17 L at each pier to 1/35 L at mid-span. (L means the main span length).
The riding surface of the bridge will be covered with an asphalt-wearing surface 6 cm thick.

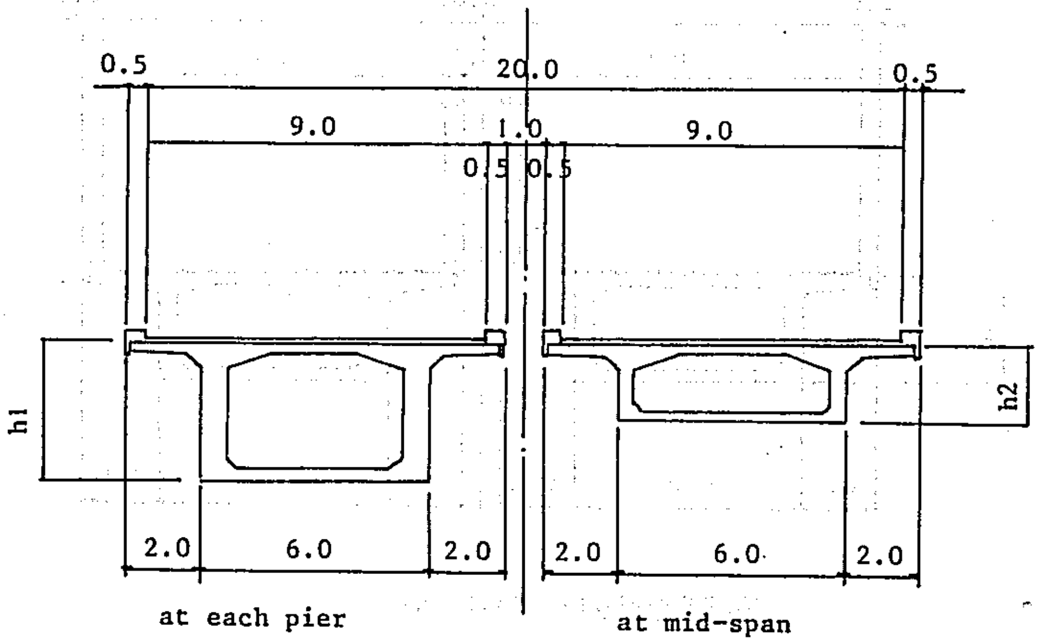


Fig. 3.10 CROSS-SECTION

(B) Continuous box girder type with timbering

This type should be constructed by casting timbering in place. This construction method will not be suitable in the following cases:

(i) In the case where the vertical spacing between the bottom of the girder and the base of the foundation of the timbering is over 10 meters.

(ii) In the case where the bridge is constructed over a road with heavy traffic or a river with heavy flow.

The carriageway for each direction should be supported by a single hollow box girder 6 meters wide.
The girder depth will be 1/22 of the average span length and does not vary through the bridge.

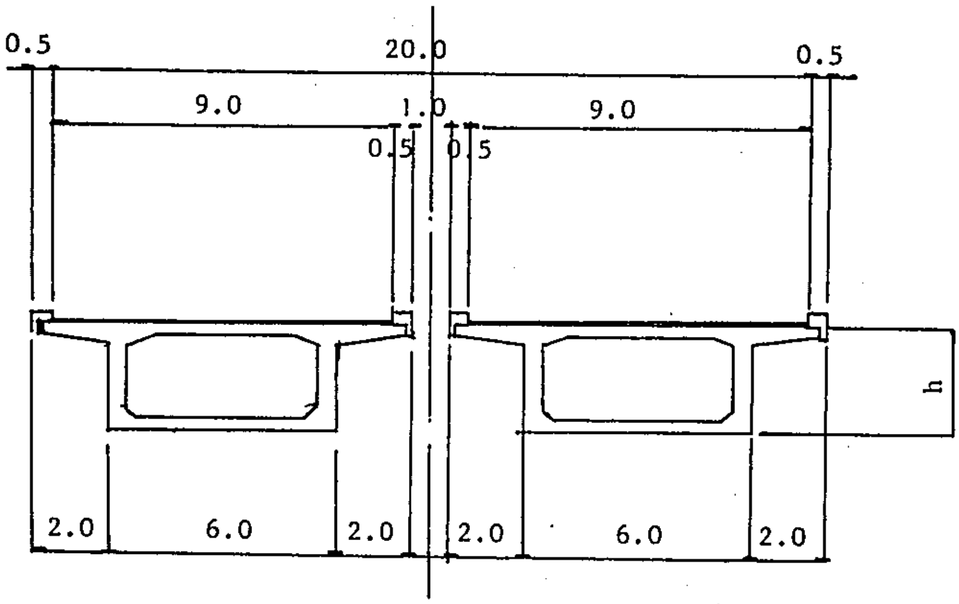


Fig. 3.11 CROSS-SECTION

This type has the advantage of not having a value below that of prestressed bars compared to the type constructed by cantilever girder erection.

3.5.2.2 Short Span Bridge

(C) Simple box girder type

This type will be constructed by casting timbering in place. It will not be suitable in cases where the bridges are constructed over deep valleys, roads with heavy traffic and rivers with heavy flow.

The carriageway for each direction should be supported by a single hollow box girder 6 meters wide. The girder depth will be 1/22 of the span length and is constant throughout.

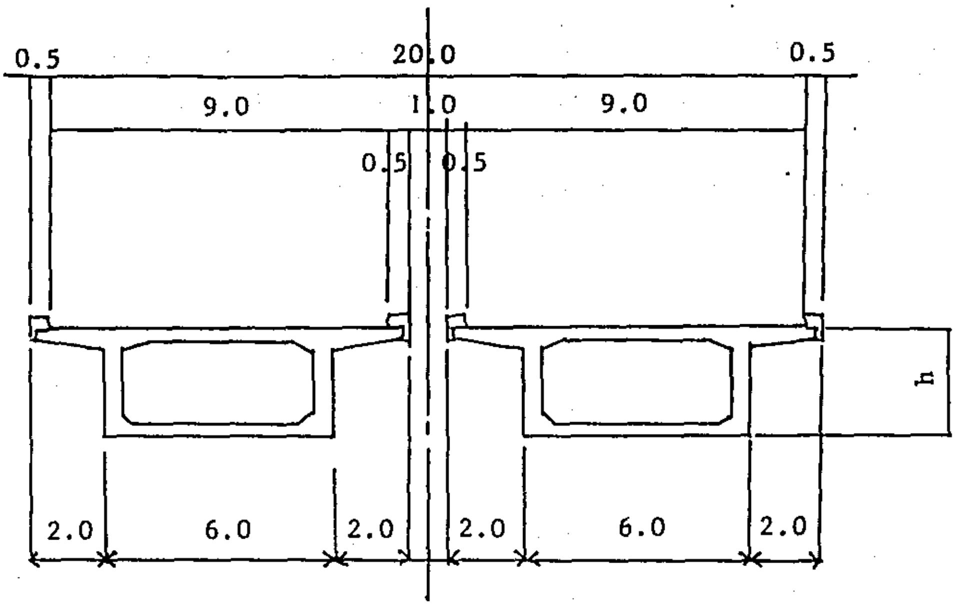


Fig. 3.12 CROSS-SECTION

This type has the advantage that in combination with the long span bridge it will present a neat view because this type has the same cross-section as that of the long span bridge.

The disadvantage of this type is that it is more expensive than the T-shaped girder bridge.

(D) Continuous composite girder type

Each I-shaped girder will initially be formed and erected as simple supported girders. Each girder will be erected by the erection girder.

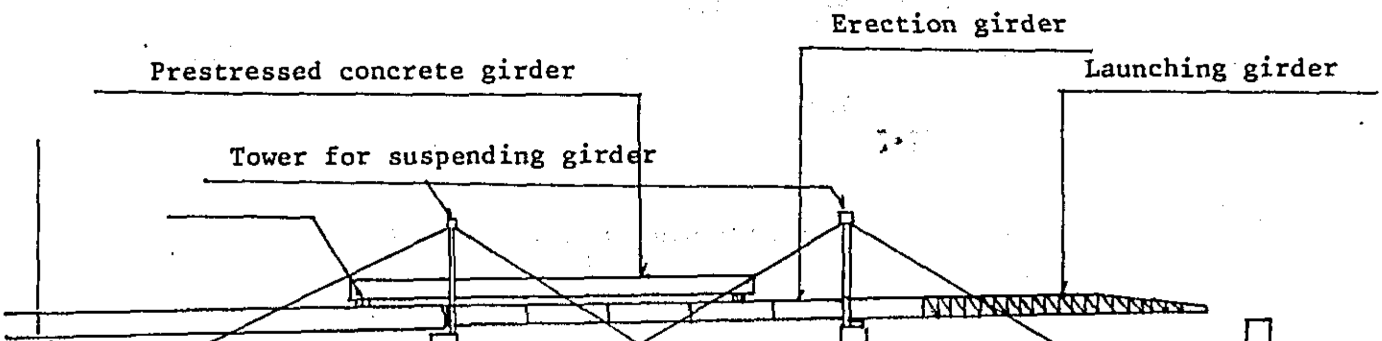
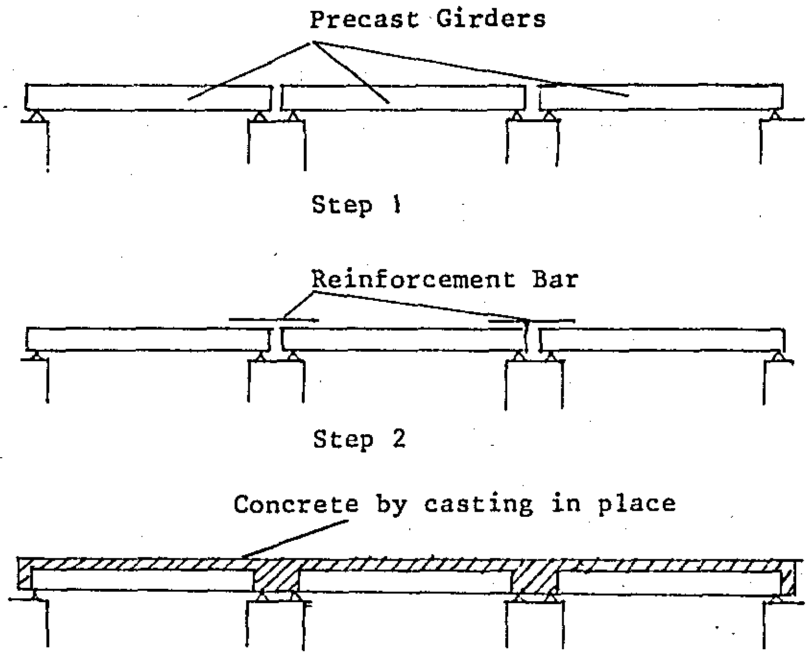


Fig. 3.13 ERECTION METHOD

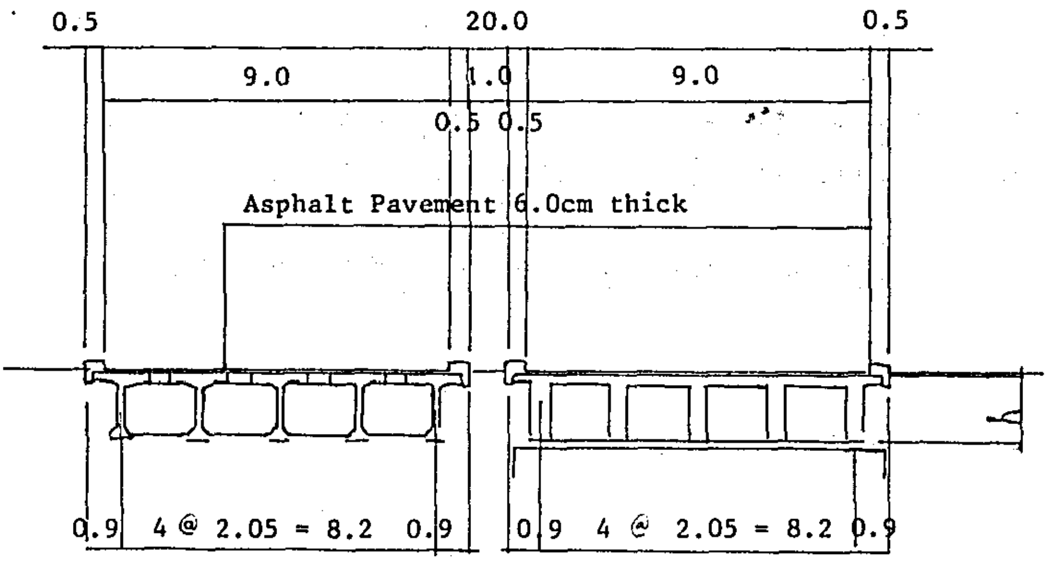
The sequence of completing each girder will be by casting in place according to the following steps.

Fig. 3.14 SEQUENCE FOR COMPLETING GIRDER



The carriageway for each direction should be supported by five girders. The depth of the girder with a span length of 30m is 1.7 meter.

Fig. 3.15 CROSS-SECTION



The advantages of this type are as follows:

- * The erection is easier than in the box girder type
- * The construction cost is also lower than in the box girder type.
- * Due to having less expansion joints than the simple supported type, it is comfortable to drive on it.

The disadvantages of this type are as follows:

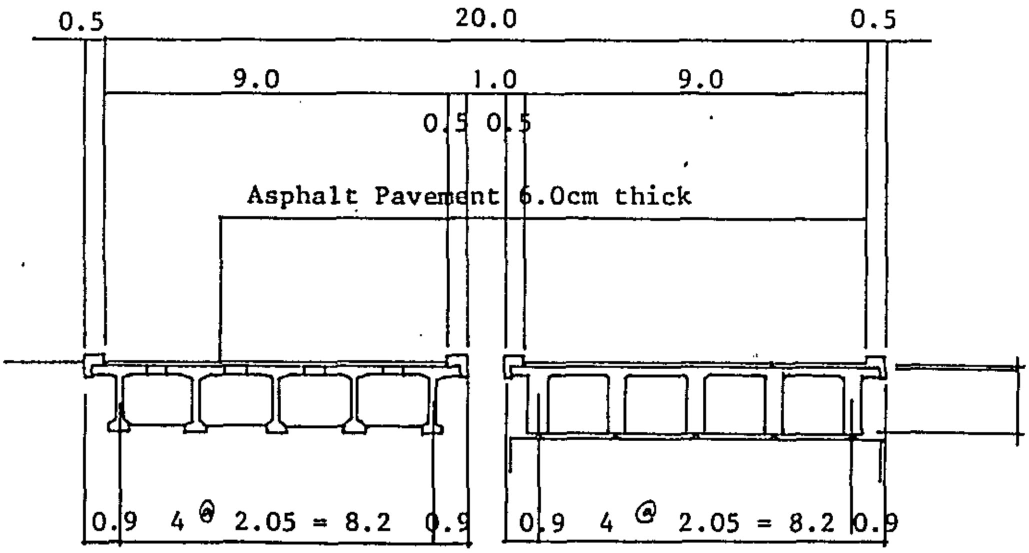
- * In combination with the long span bridge, the cross-section lacks unity.
- * It gives an inferior impression to the box girder when viewed from under the bridge.

(E) Simple T-shaped girder type (Post-tension)

Each T-shaped girder will be erected by the erection girder similar to the continuous composite girder type.

Each carriageway should be supported by five girders. The girder depth for a 30 meter span length is 1.4 meters. and for one with a 40 meter span length, it is 2.05 meters.

Fig. 3.16 CROSS-SECTION



3.5.2.3 Recommendations

Long Span Bridge

The erection of the timbering over a valley more than 15 meters deep is very difficult and if executed, expensive.

The box girder type, by the cantilever girder erection is considered slightly superior in terms of aesthetic value, to one by timbering.

Therefore, the recommended structure type is the continuous box girder bridge erected by the cantilever girder erection.

Short Span Bridge

The simple T-shaped girder bridge type is the easiest to construct and the most economical of all the alternatives.

The box girder type has the same cross-section as the long span bridge. Therefore, when combined with the long span bridge, it is expected to present a neat view. Compared to the other types of bridges, the simple composite girder type is mediocre.

Taking into consideration construction difficulties and construction costs, the type of structure recommended is the simple T-shaped girder bridge.

Table 3.5 RANKING OF SUPERSTRUCTURE TYPES

	Long Span Bridge		Short Span Bridge		
Bridge Type / Criteria	Continuous Box Girder (by canti -level girder erection)	Continuous Box Girder (by timbering)	Simple Box Girder	Continuous Composite Girder	Simple T-shaped Girder
Construction Difficulty	1	2	3	2	1
Economic Ranking	1	2	3	2	1
Aesthetic Ranking	1	2	1	2	3
Ease of Driving	1	1	2	1	2

3.5.3 Dimensions of Superstructures

The diamensions of the superstructures will be decided from rough calculations or from assumptions derived from actual results of other such studies.

Of the long span bridges, the Unit 3 bridge (L = 50m + 70m + 50m) will be roughly designed, while the dimensions for Unit 1 and 2 bridges should be decided by the assumptions from the results of Unit 3.

The dimensions for the simple T-shaped girder bridges with span lengths of 30m and 40m should be assumed from the actual results of other studies.

The dimension for each type is shown in Figures 3.17, 3.18, 3.19, 3.20 and 3.21.

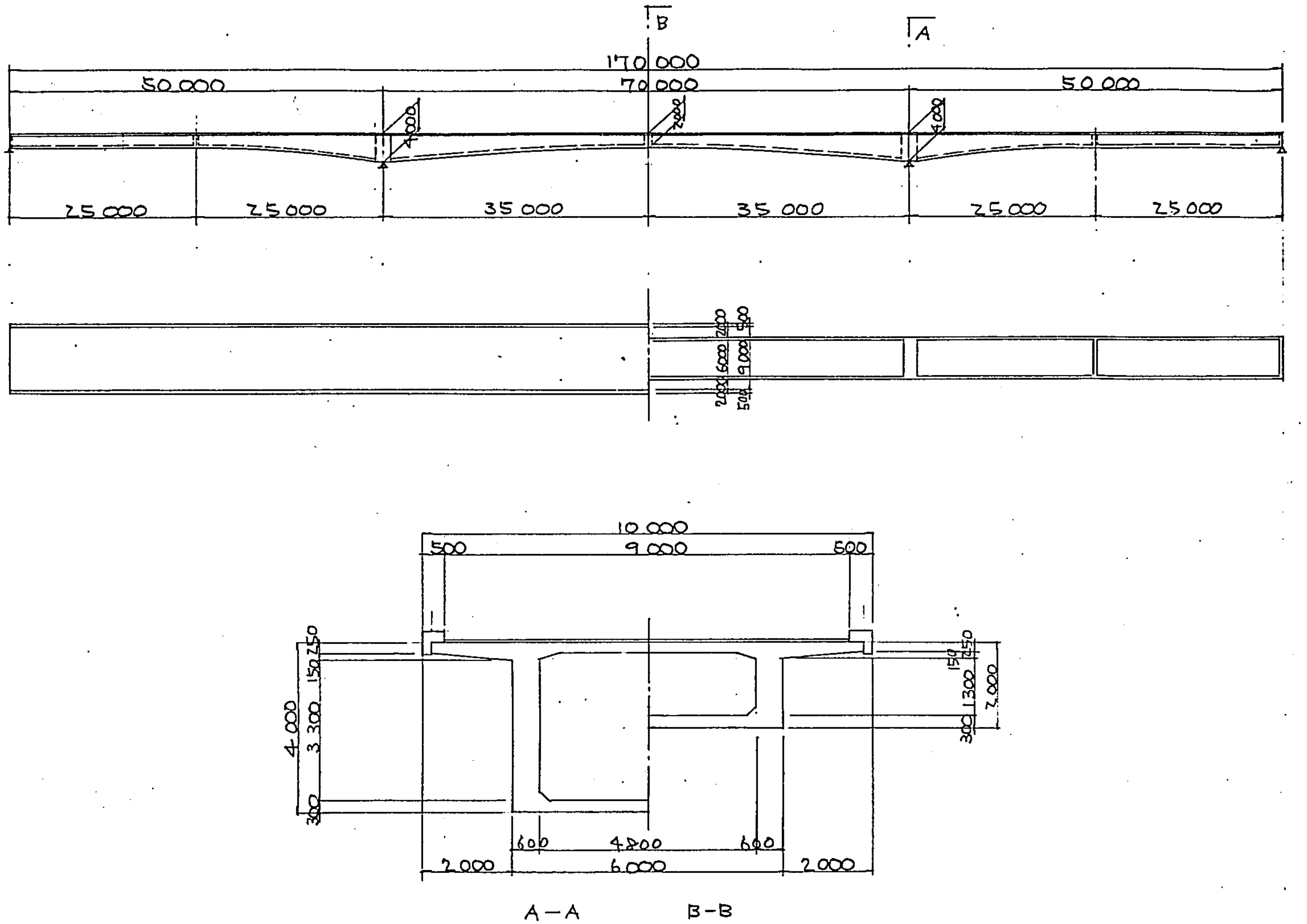


FIG. 3·17 DIMENSION OF SUPERSTRUCTURE OF CONTINUOUS 3-SPAN BRIDGE

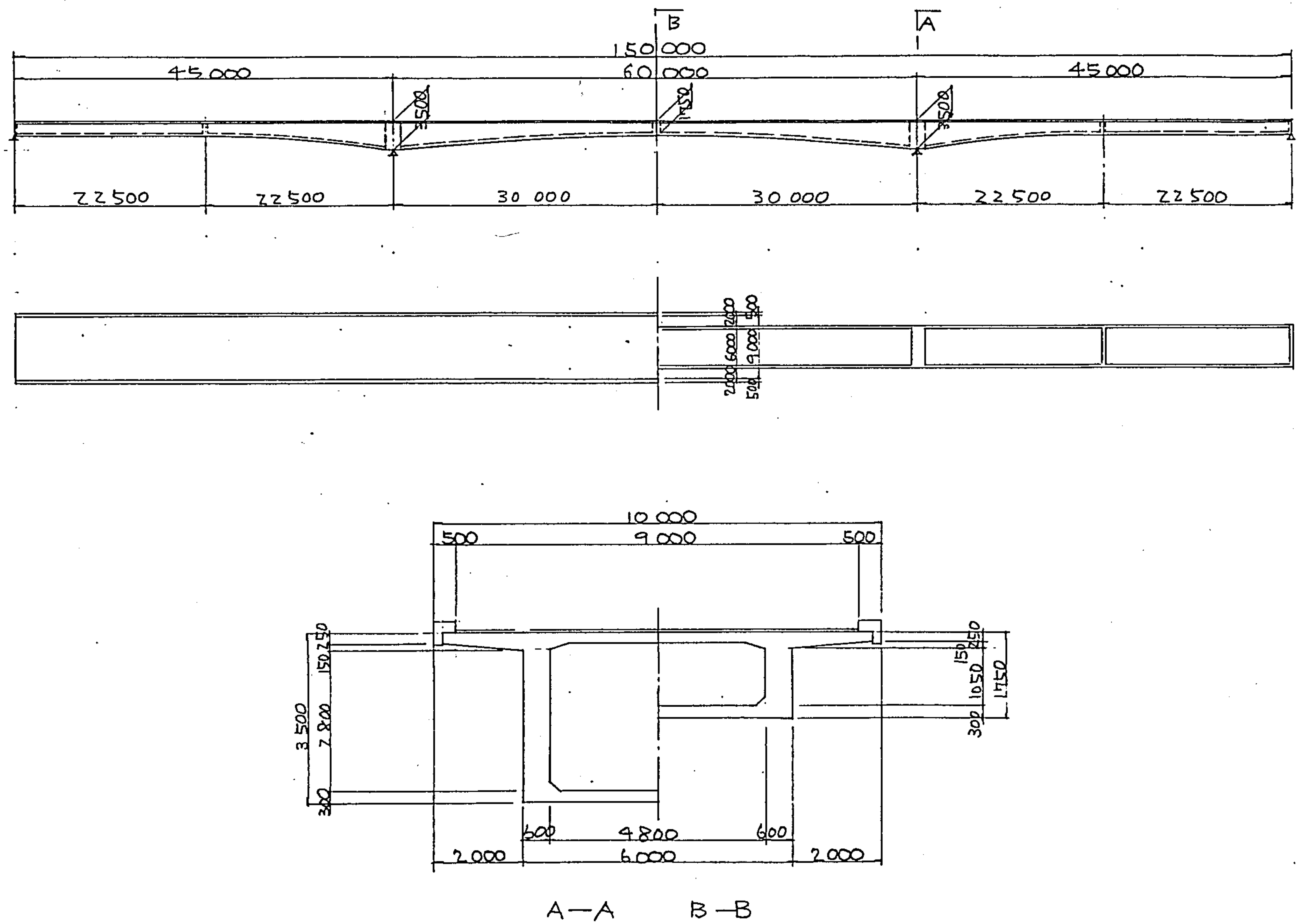


FIG. 3-18 DIMENSION OF SUPERSTRUCTURE OF CONTINUOUS 3-SPAN BRIDGE

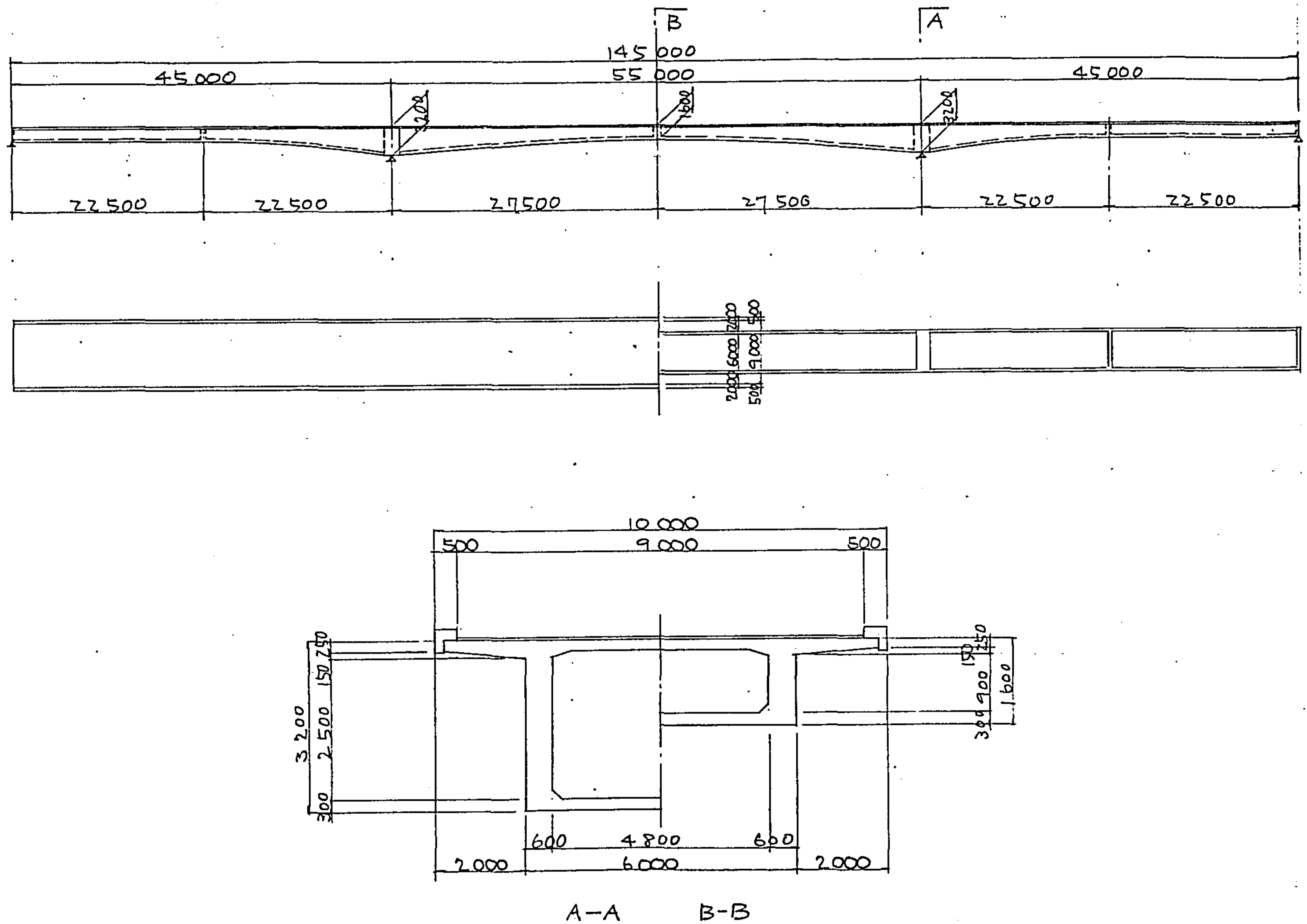
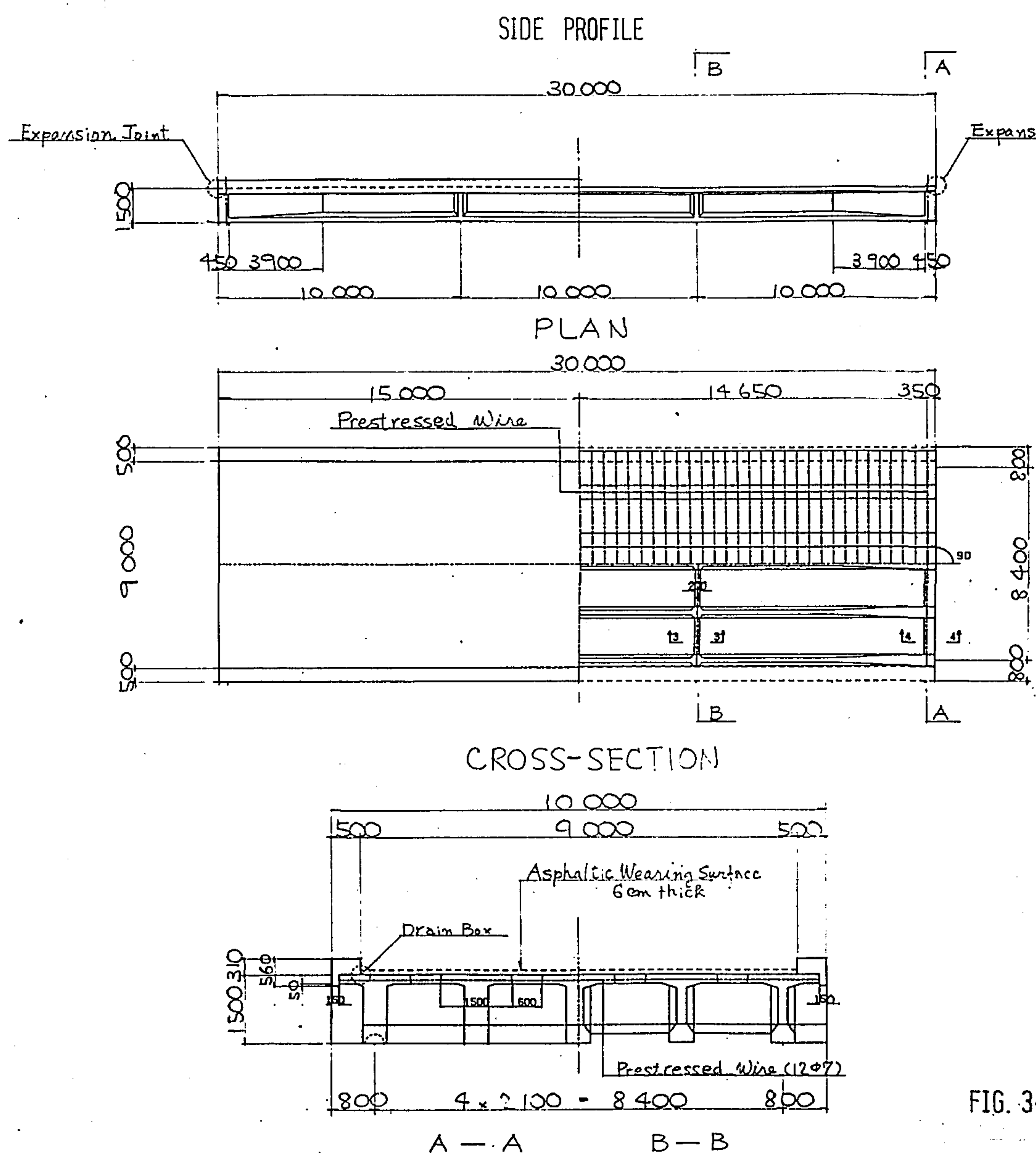


FIG. 3·19 DIMENSION OF SUPERSTRUCTURE OF CONTINUOUS 3-SPAN BRIDGE



REACTION PER 2-CARRIAGEWAY

With Load	Reaction (ton)
Dead Load	401
Live Load (UDL)	103
〃 〃 (KEL)	29
〃 〃 (HB)	184
Total	717

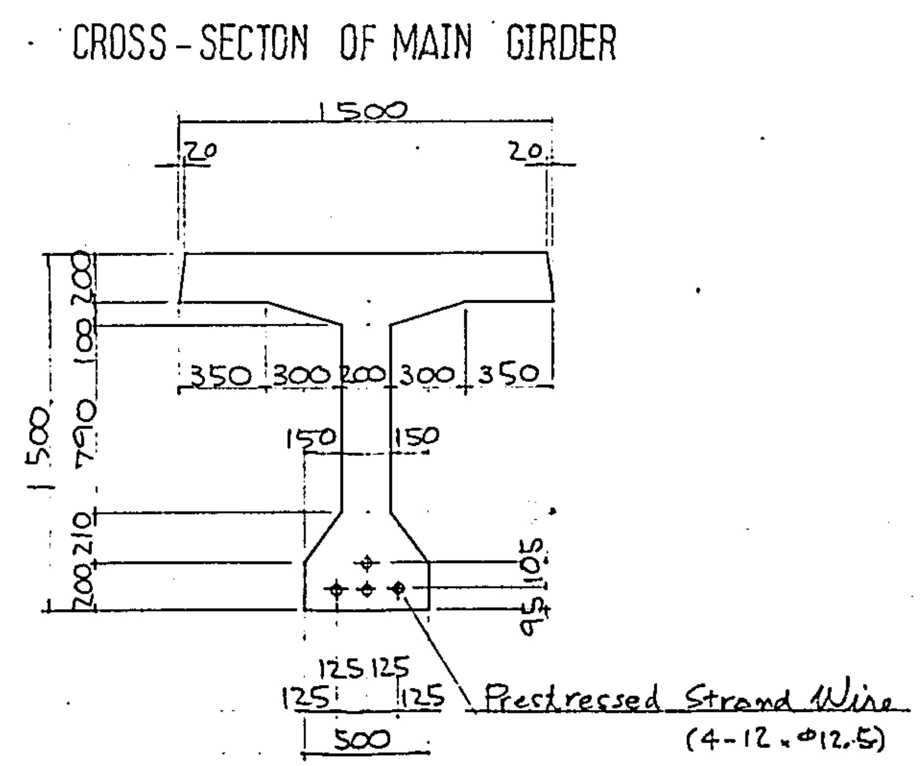
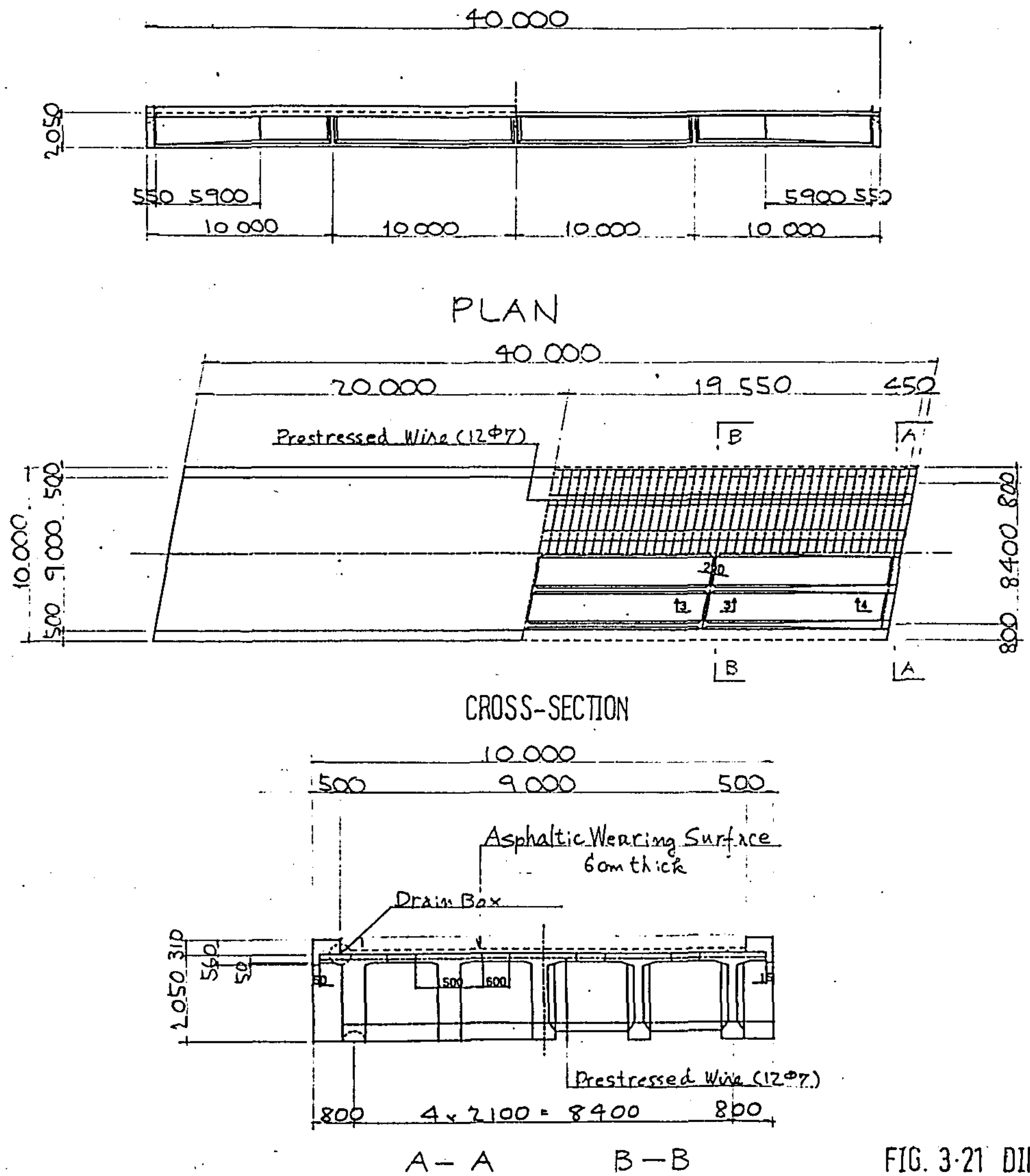


FIG. 3·20 DIMENSION OF SUPERSTRUCTURE FOR 30m SPAN

SIDE PROFILE

PLAN

CROSS-SECTION



REACTION PER 2-CARRIAGEWAY.

With Load	Reaction (ton)
Dead Load	623
Live Load (UDL)	122
〃 (KEL)	29
〃 (HB)	184
Total	958

CROSS-SECTION OF MAIN GIRDER

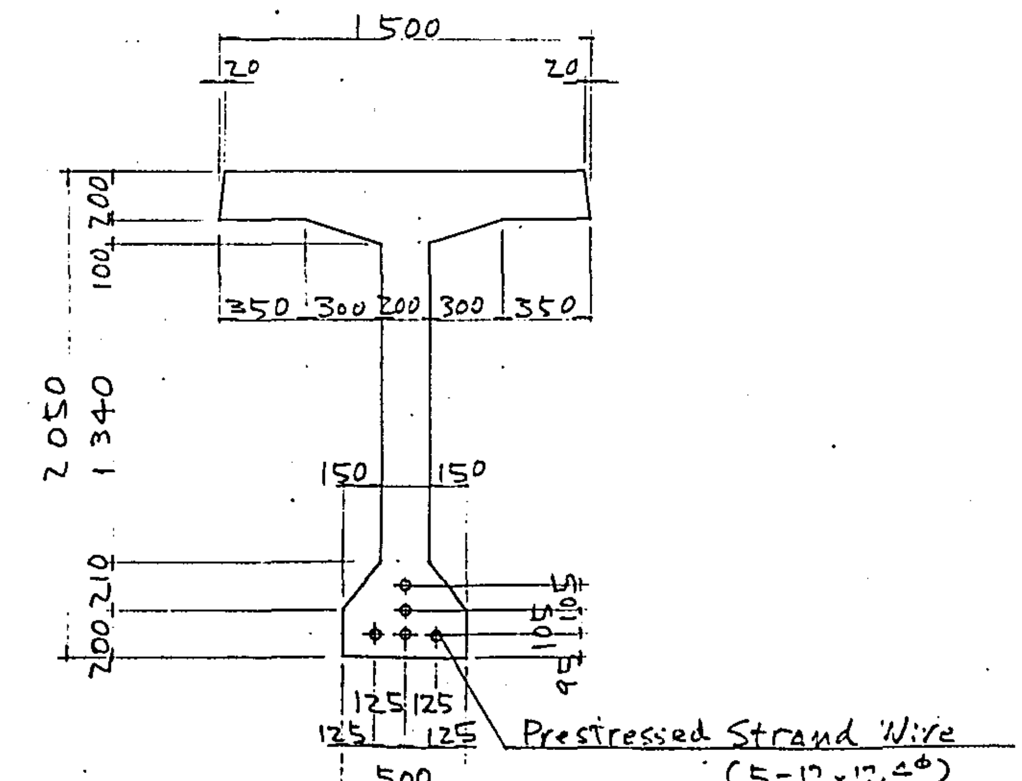
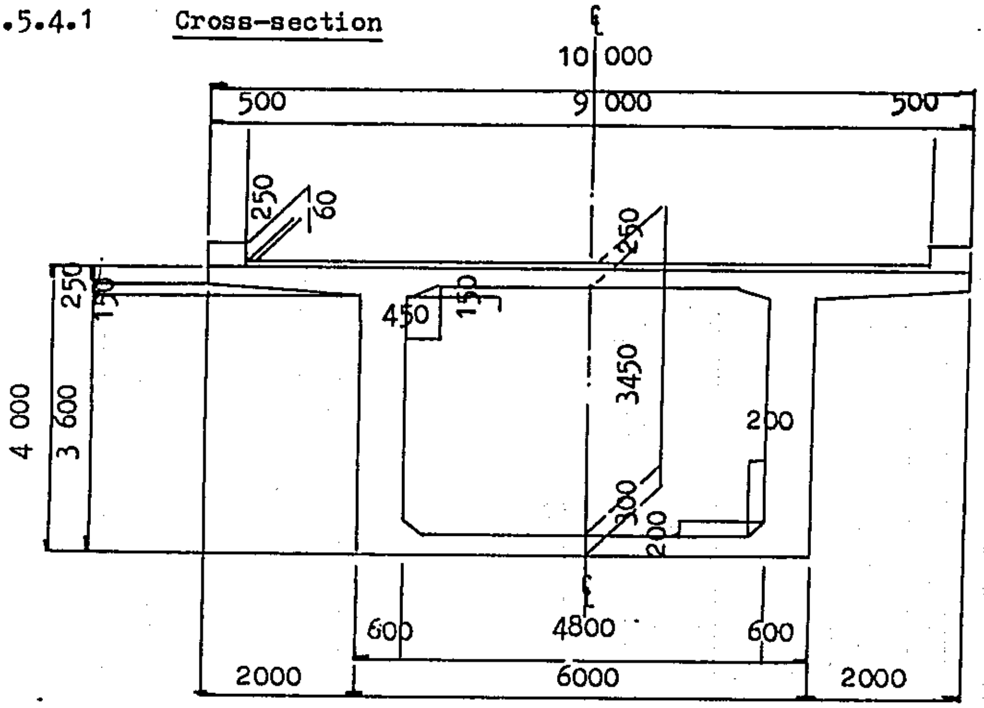


FIG. 3-21 DIMENSION OF SUPERSTRUCTURE OF 40m SPAN

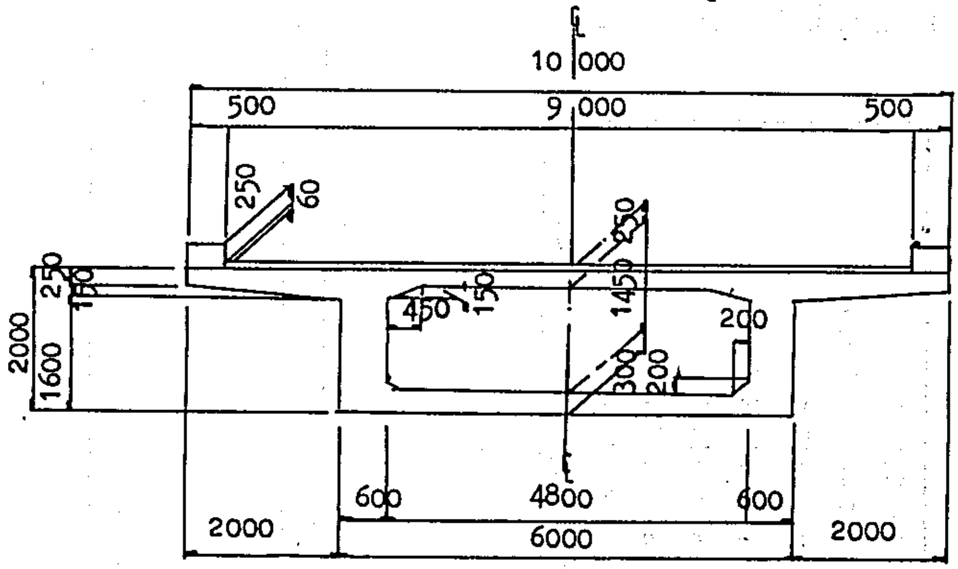
3.5.4 Rough calculation of long span bridges

(L = 50m + 70m + 50m)

3.5.4.1 Cross-section



Cross-Section at the main pier



Cross-section at mid-span

Figure 3.22 ROUGH CALCULATION OF LONG SPAN BRIDGES

3.5.4.2 Load conditions

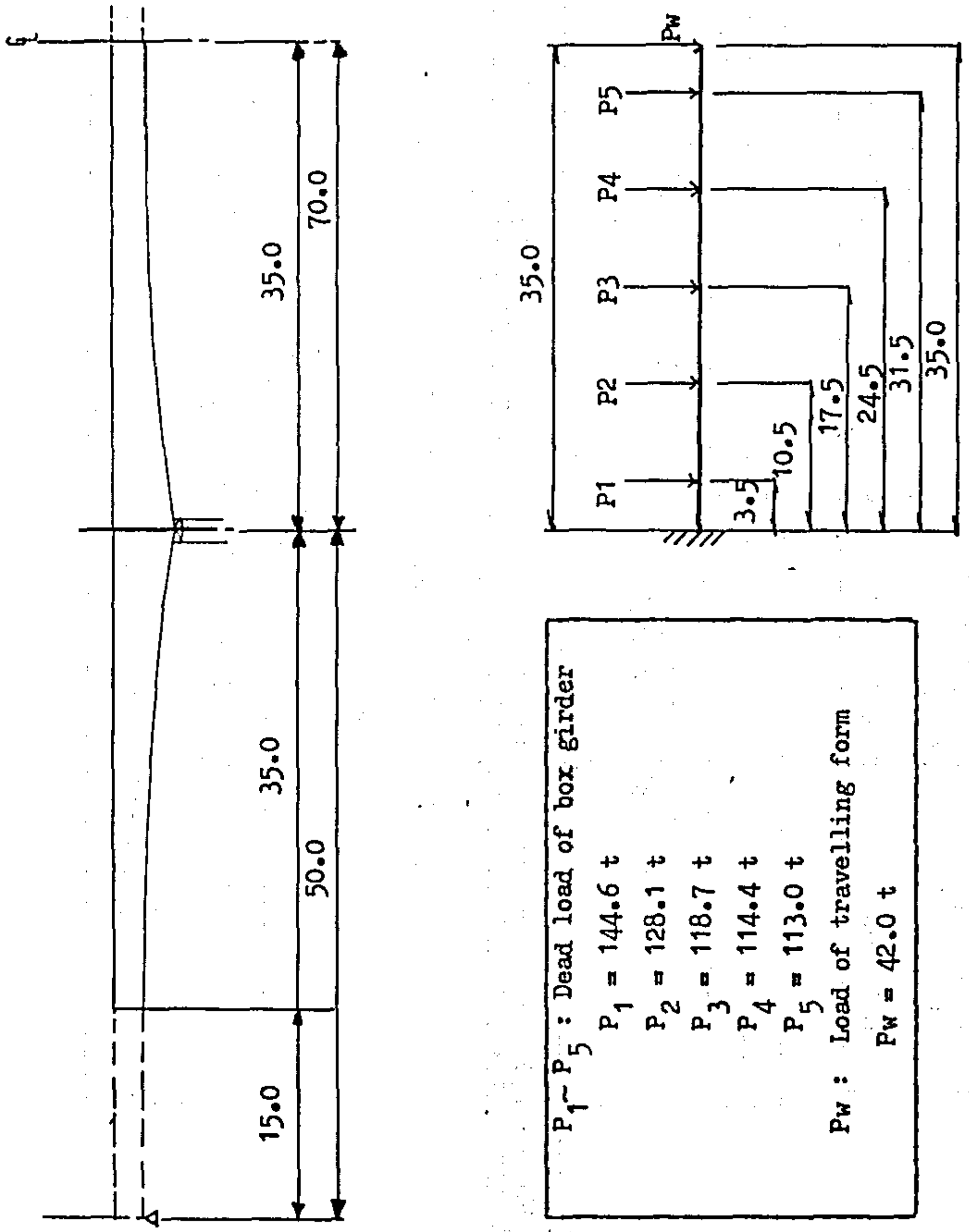
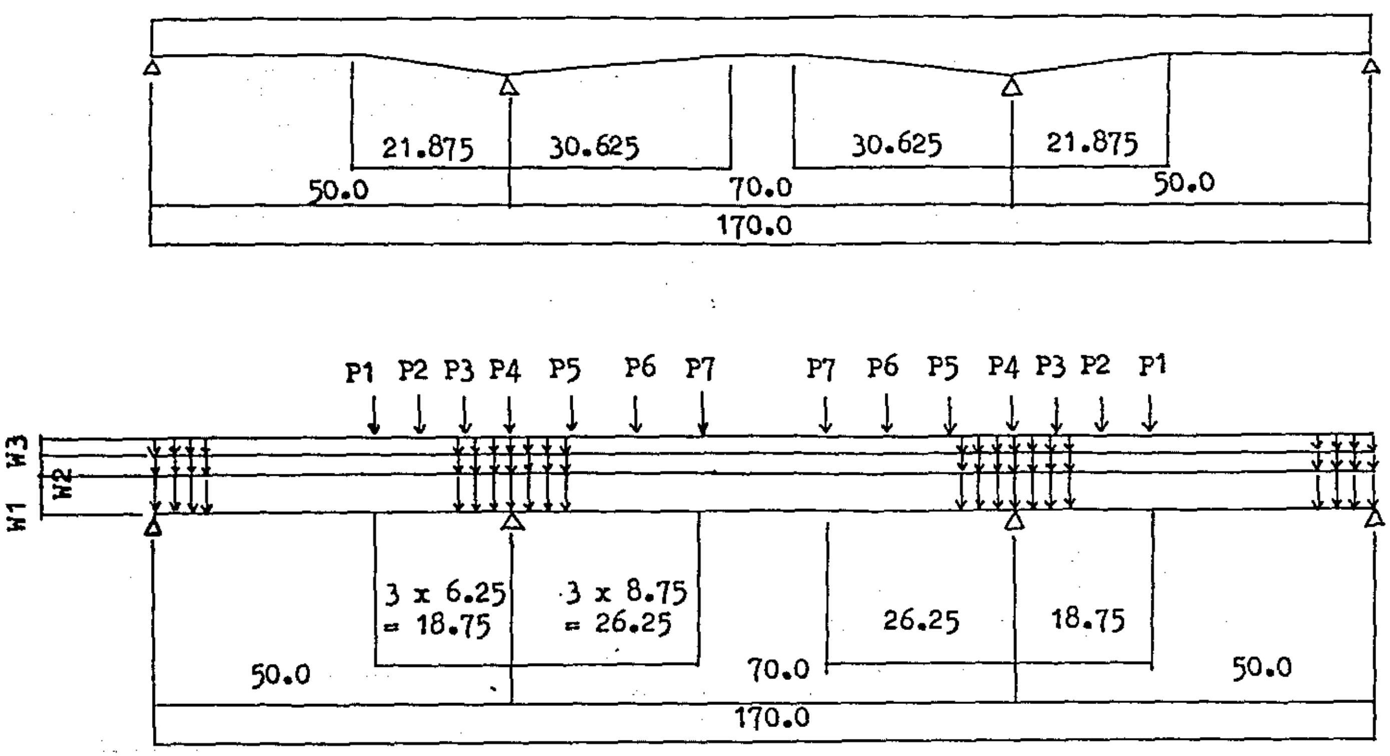
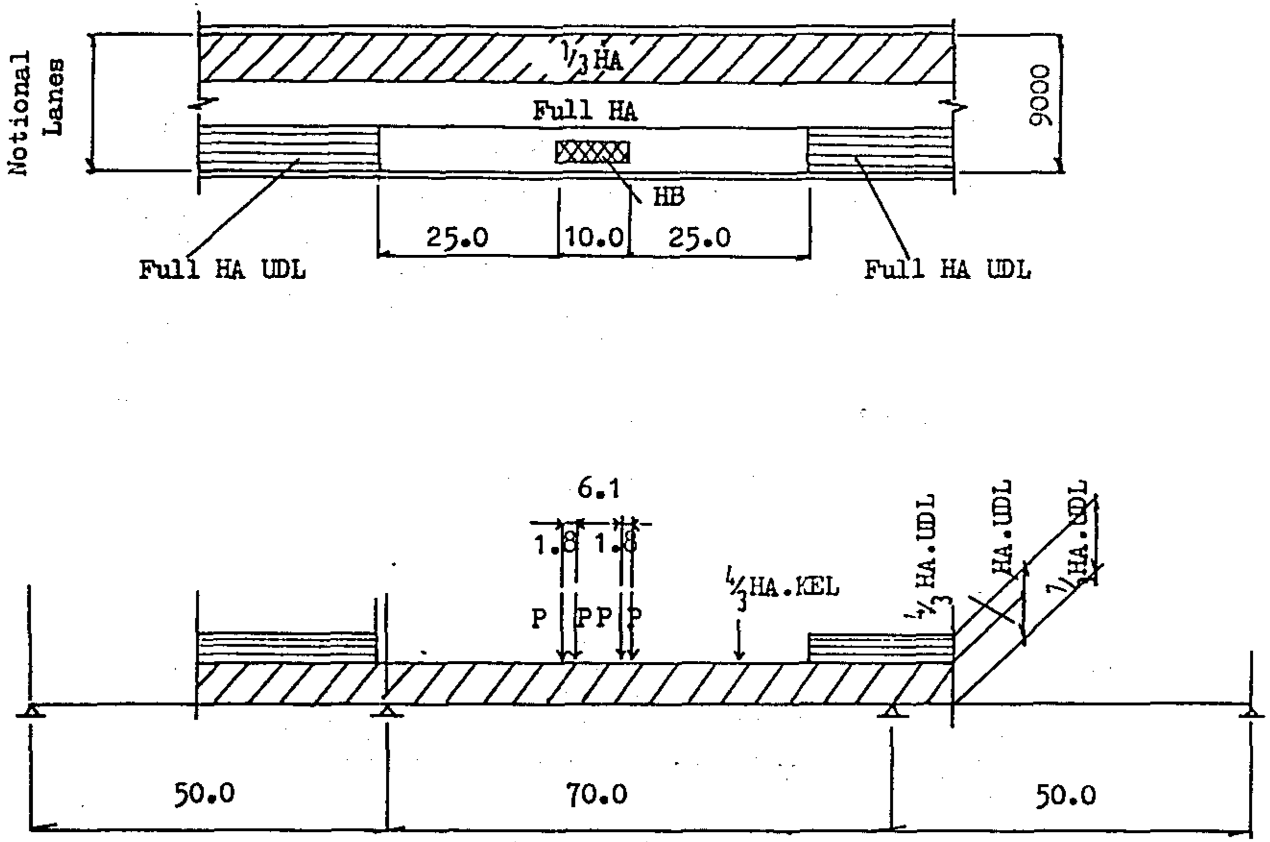


Figure 3.23 CASE 1: LOAD CONDITION DURING CONSTRUCTION



W_1, P_1~P_7 :	Load of main girder	W_2 : Load of wheel guard
W_1 = 16.12 t/m	P_3 = 26.79 t P_6 = 22.50 t	W_2 = 0.913 t/m
P_1 = 5.36 t	P_4 = 45.00 t P_7 = 7.50 t	W_3 : Load of pavement
P_2 = 16.07 t	P_5 = 37.50 t	W_3 = 1.242 t/m

Fig. 3.24 CASE 2.1 : DEAD LOAD



P = (45 units) = 450 KN

P = (45 units) = 450 KN

Figure 3.25 CASE 2.2: LIVE LOAD

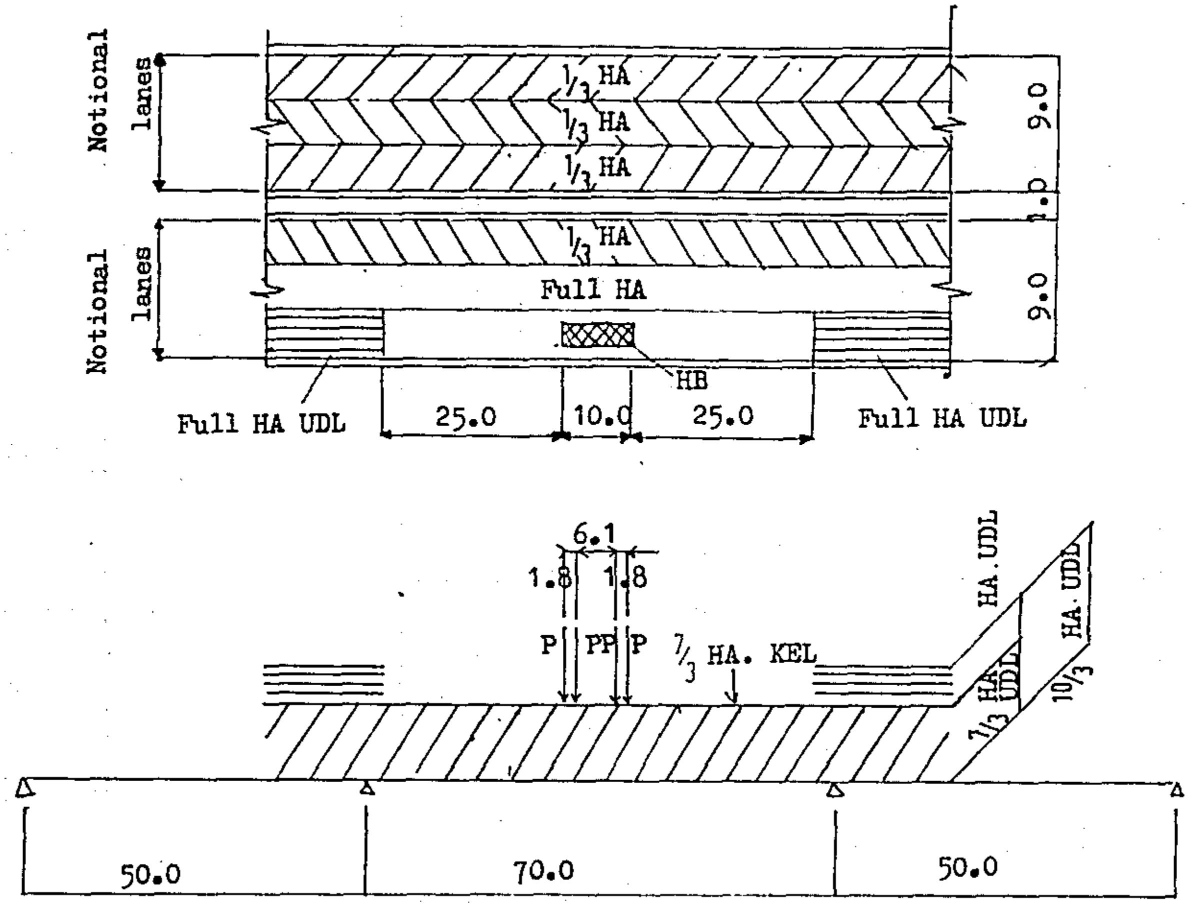


Figure 3.26 <u>CASE 3 : LIVE LOAD</u>

3.5.4.3 Bending moments

Table 3.6 BENDING MOMENTS

Point	With Load	Bending Moments (tm)
4	Case 2.1	2,206
	Case 2.2	2,888
	Total	5,094
8	Case 2.1	- 7,479
	Case 2.2	- 2,437
	Total	- 9,916
	Case 1	-11,760
	Case 1 + Case 2.2	-14,197
12	Case 2.1	4,634
	Case 2.2	3,182
	Total	7,816

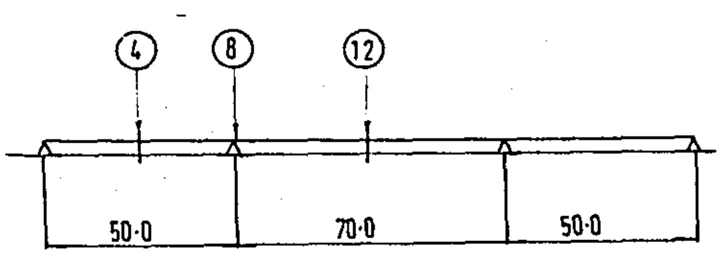


Fig. 3.27 LOCATION OF POINTS OF BENDING MOMENTS

Fig. 3.28 INFLUENCE LINE OF BENDING MOMENTS

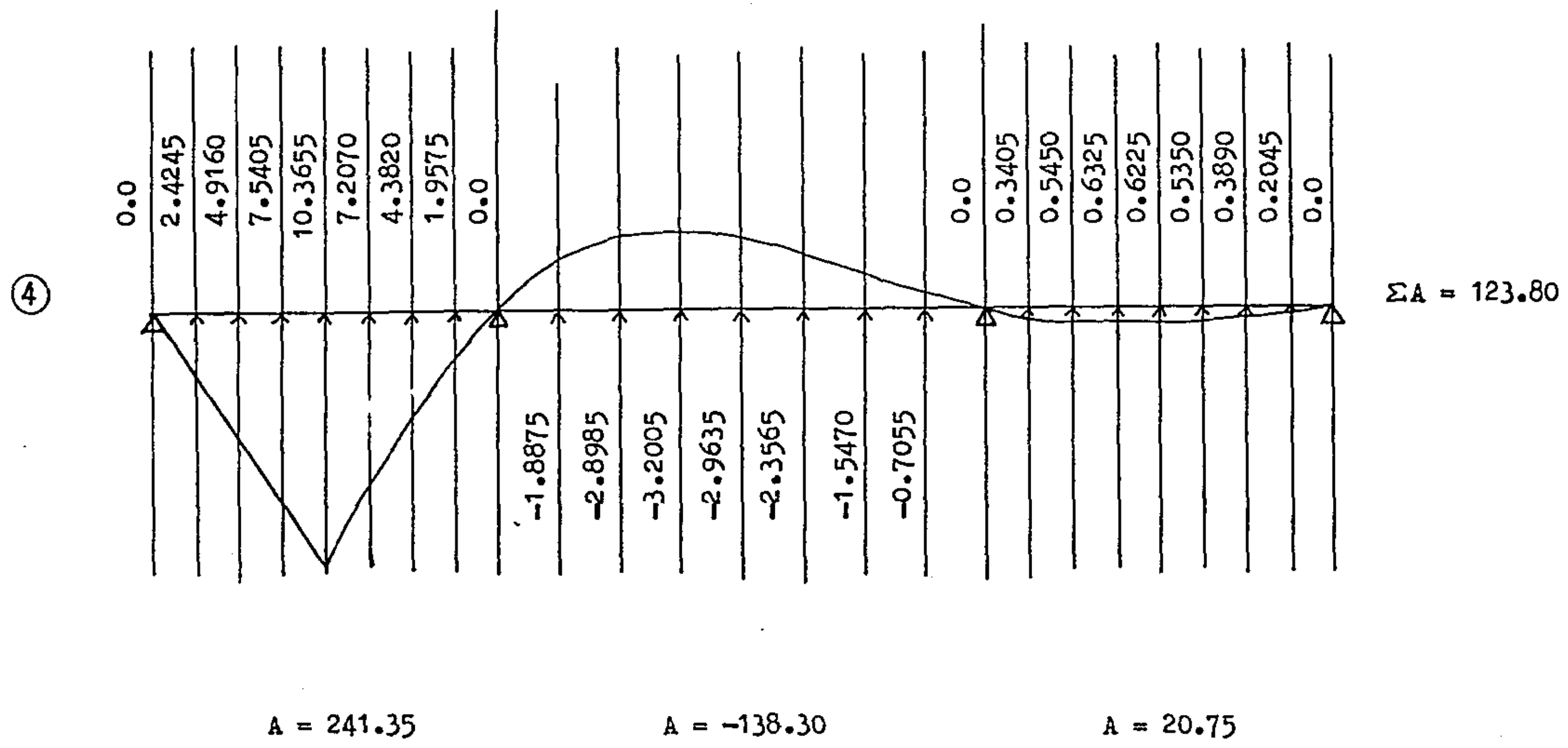


Fig. 3.29 INFLUENCE LINE OF BENDING MOMENTS

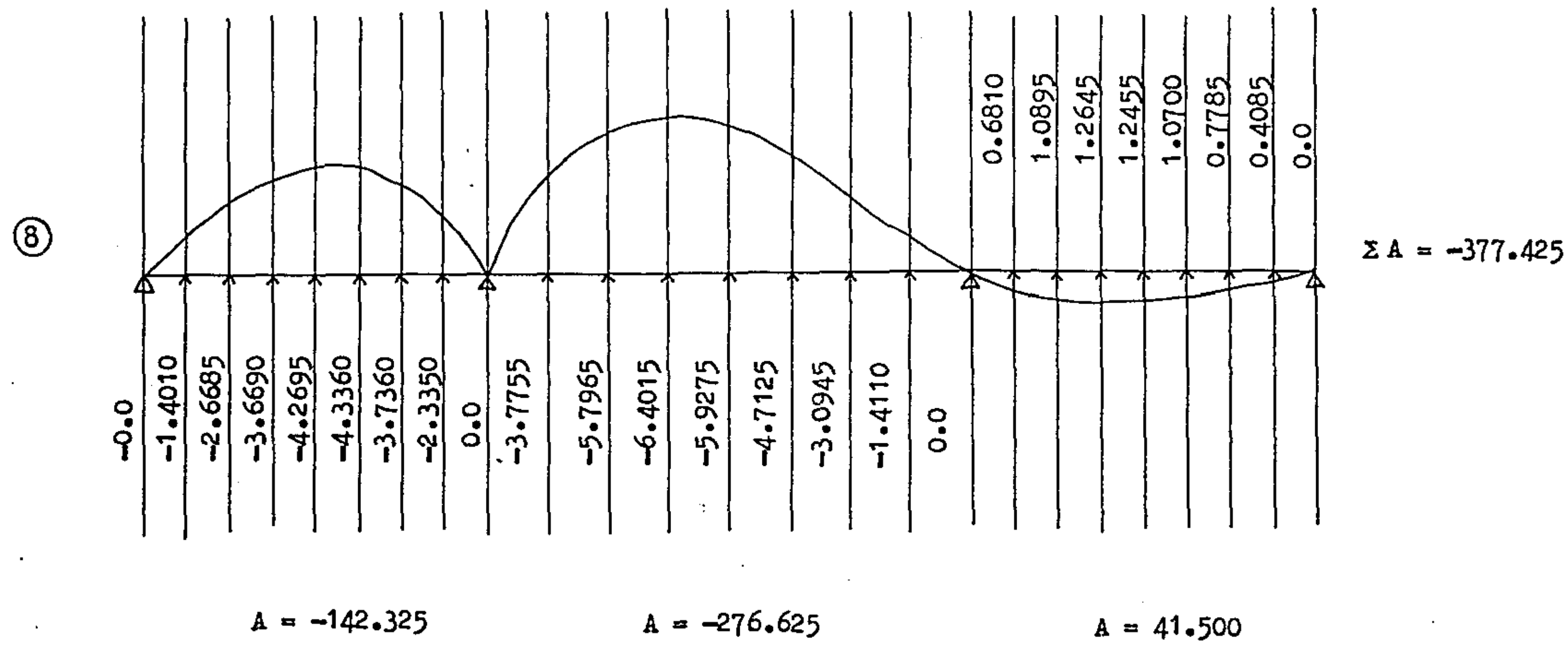
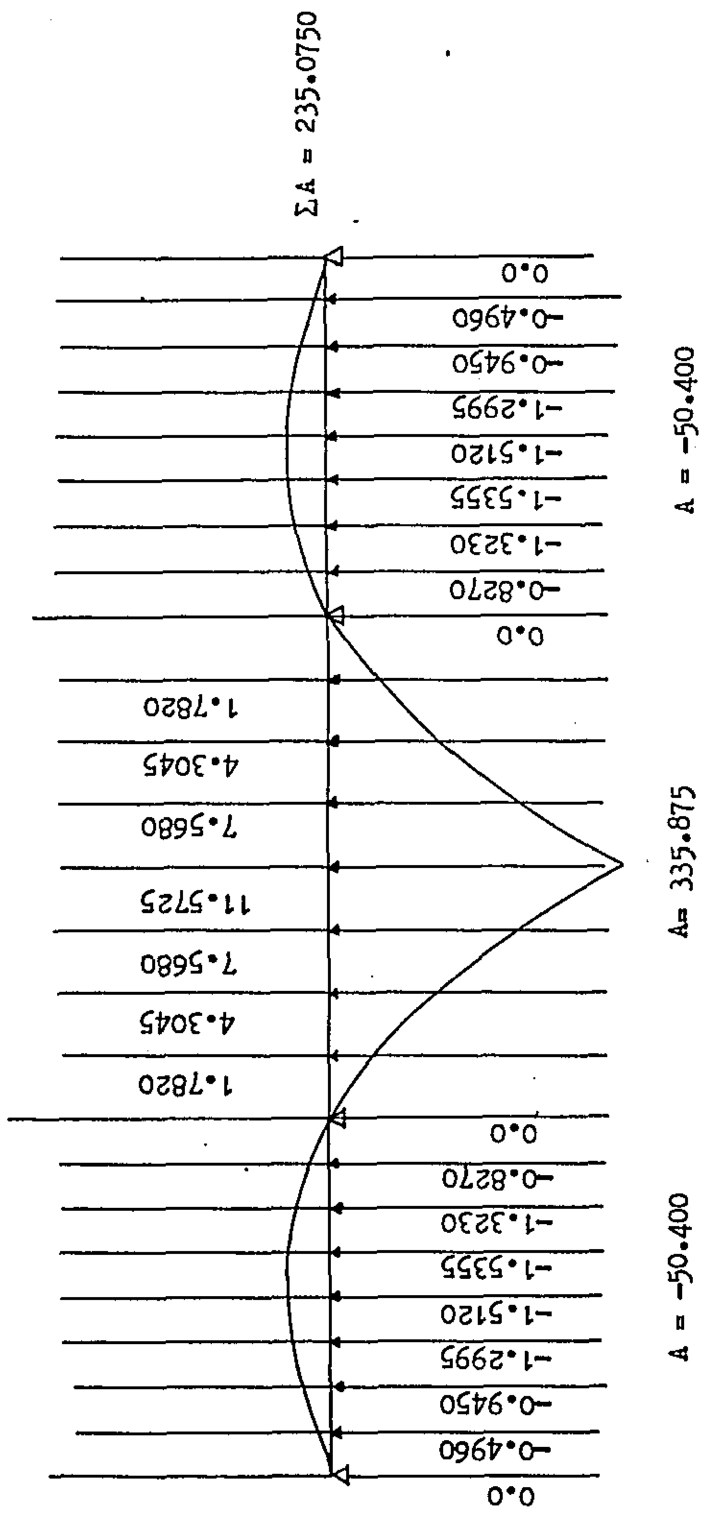
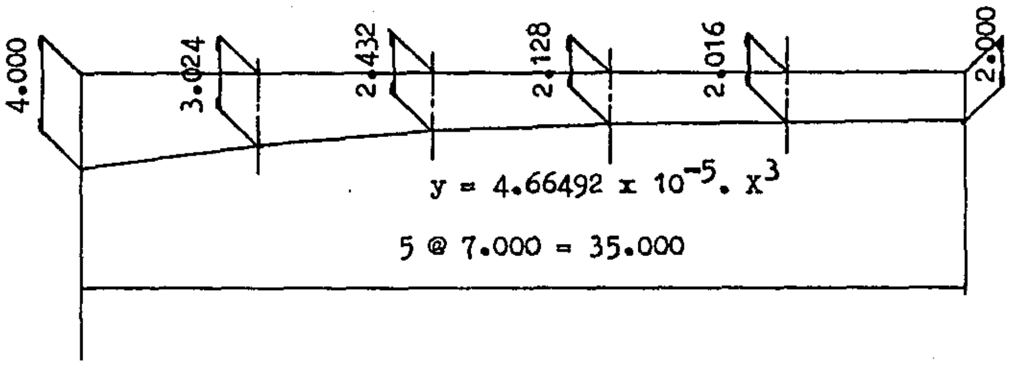


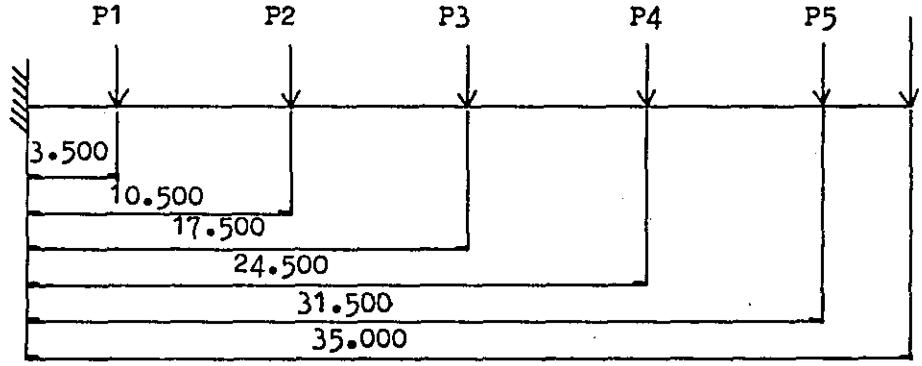
Fig. 3.30 <u>INFLUENCE LINE OF BENDING MOMENTS</u>



⑫

Bending Moments (8) —— Case 1





P_1 = 144.6 t
P_2 = 128.1 t
P_3 = 118.7 t
P_4 = 114.4 t
P_5 = 113.0 t

Bending Moments

$$M = 144.6 \times 3.50 + 128.1 \times 10.50 + 118.7 \times 17.50 + 114.4 \times 24.50 + 113.0 \times 31.50 + 42.0 \times 35.00 = (-11{,}760) \text{ tm}$$

Bending Moments (4) —— Case 2.1

Girder

M_{GC}	=	W_1 t/m	x	Area of influence diagram	
	=	16.120	x	123.80	= 1995.7
M_{GVi}	=	P_i t/m	x	Influence line	
M_{GV1}	=	5.36	x	7.2070	= 38.6
M_{GV2}	=	16.07	x	4.3820	= 70.4
M_{GV3}	=	26.79	x	1.9575	= 52.4
M_{GV4}	=	45.00	x	0	= 0
M_{GV5}	=	37.50	x	-1.8875	= -70.8
M_{GV6}	=	22.50	x	-2.8985	= -65.2
M_{GV7}	=	7.50	x	-3.2005	= -24.0
M_{GV8}	=	7.50	x	-2.3565	= -17.7
M_{GV9}	=	22.50	x	-1.5470	= -34.8
M_{GV10}	=	37.50	x	-0.7055	= -26.5
M_{GV11}	=	45.00	x	0	= 0
M_{GV12}	=	26.79	x	0.3405	= 9.1
M_{GV13}	=	16.07	x	0.5450	= 8.8
M_{GV14}	=	5.36	x	0.6325	= 3.4
M_{GV}	=	$\sum_{i=1}^{14} M_{GVi}$	= -56.3		
M_G	=	M_{GC}	+	M_{GV} = 1995.7 + (-56.3)	= 1939.5
Wheel guard M_W	=	W_2 t/m	x	Area of influence diagram	
	=	0.913	x	123.80	= 113.0
Pavement M_P	=	W_3 t/m	x	Area of influence diagram	
	=	1.242	x	123.80	= 153.8
				Total	= 2206 tm

Bending Moments (8) —— Case 2.1

Girder

M_{GC} = W_1 $^{t/m}$ x Area of influence diagram

= 16.120 x -377.425 = -6084.1

M_{GVi} = P_i $^{t/m}$ x Influence line

M_{GV1}	= 5.36	x	-4.3360	=	-23.2
M_{GV2}	= 16.07	x	-3.7360	=	-60.0
M_{GV3}	= 26.79	x	-2.3350	=	-62.5
M_{GV4}	= 45.00	x	0	=	0
M_{GV5}	= 37.50	x	-3.7755	=	-141.6
M_{GV6}	= 22.50	x	-5.7965	=	-130.4
M_{GV7}	= 7.50	x	-6.4015	=	-48.0
M_{GV8}	= 7.50	x	-4.7125	=	-35.3
M_{GV9}	= 22.50	x	-3.0945	=	-69.6
M_{GV10}	= 37.50	x	-1.4110	=	-52.9
M_{GV11}	= 45.00	x	0	=	0
M_{GV12}	= 26.79	x	0.6810	=	18.2
M_{GV13}	= 16.07	x	1.0895	=	17.5
M_{GV14}	= 5.36	x	1.2645	=	6.8

$M_{GV} = \sum_{i=1}^{14} M_{GVi} = -581.0$

$M_G = M_{GC} + M_{GV} = -6084.1 + (-581.0)$ = -6665.1

Wheel guard M_W = W_2 $^{t/m}$ x Area of influence diagram

= 0.913 x -377.425 = -344.6

Pavement M_P = W_3 $^{t/m}$ x Area of influence diagram

= 1.242 x -377.425 = -468.8

Total = -7479 tm

Bending Moments (12) —— Case 2.1

Girder

M_{GC}	=	W_1 t/m	x	Area of influence diagram	
	=	16.120	x	235.075	= 3789.4
M_{GVi}	=	P_i t/m	x	Influence line	
M_{GV1}	=	5.36	x	−1.5355	= −8.2
M_{GV2}	=	16.07	x	−1.3230	= −21.3
M_{GV3}	=	26.79	x	−0.8270	= −22.2
M_{GV4}	=	45.00	x	0	= 0
M_{GV5}	=	37.50	x	1.7820	= 66.8
M_{GV6}	=	22.50	x	4.3045	= 96.9
M_{GV7}	=	7.50	x	7.5680	= 56.8
M_{GV8}	=	7.50	x	7.5680	= 56.8
M_{GV9}	=	22.50	x	4.3045	= 96.9
M_{GV10}	=	37.50	x	1.7820	= 66.8
M_{GV11}	=	45.00	x	0	= 0
M_{GV12}	=	26.79	x	−0.8270	= −22.2
M_{GV13}	=	16.07	x	−1.3230	= −21.3
M_{GV14}	=	5.36	x	−1.5355	= −8.2
M_{GV}	=	$\sum_{i=1}^{14} M_{GVi}$	x	337.6	
M_G	=	M_{GC}	+	M_{GV} = 3789.4 + 337.6	= 4127.0
Wheel guard M_W	=	W_2 t/m	x	Area of influence diagram	
	=	0.913	x	235.075	= 214.6
Pavement M_P	=	W_3 t/m	x	Area of influence diagram	
	=	1.242	x	235.075	= 292.0
				Total	= 4634 tm

Bending Moments (4) —— Case 2.2

$M_{UDL} = \frac{4}{3} \times HA^{KN} \times 0.102^{t/KN} \times$ Area of influence diagram

$= \frac{4}{3} \times 22.9 \times 0.102 \times (241.35 + 20.75)$

$= 816$ tm

$M_{KEL} = \frac{4}{3} \times HA \times 0.102 \times$ Influence line

$= \frac{4}{3} \times 120 \times 0.102 \times 10.3655$

$= 169$ tm

$M_{HB} = 450^{KN} \times 4 \times 0.102 \times$ Influence line

$= 450 \times 4 \times 0.102 \times 10.3655$

$= 1903$ tm

$M_L = M_{UDL} + M_{KEL} + M_{HB} = 2888$ tm

Bending Moments (8) —— Case 2.2

$M_{UDL} = \frac{4}{3} \times 22.9 \times 0.102 \times (-142.325) + \frac{4}{3} \times 19.0 \times 0.102$

$\times (-276.625) = -1158$ tm

$M_{KEL} = \frac{4}{3} \times 120 \times 0.102 \times (-6.4015) = -104$ tm

$M_{HB} = 450 \times 4 \times 0.102 \times (-6.4015) = -1175$ tm

$M_L = M_{UDL} + M_{KEL} + M_{HB} = -2437$ tm

Bending Moments (12) —— Case 2.2

$M_{UDL} = \frac{4}{3} \times 19.0 \times 0.102 \times 335.875 = 868$ tm

$M_{KEL} = \frac{4}{3} \times 120 \times 0.102 \times 11.5725 = 189$ tm

$M_{HB} = 450 \times 4 \times 0.102 \times 11.5725 = 2125$ tm

$M_L = M_{UDL} + M_{KEL} + M_{HB} = 3182$ tm

3.5.4.4 Reactions

Table 3.7 REACTIONS

Point	With Load	Reaction	Remarks
RA	Case 2.1	634 t	2 x 317
	Case 3 UDL	125 t	–
	Case 3 KEL	29 t	–
	Case 3 HB	184 t	–
	Total	972 t	–
RB	Case 2.1	2,794 t	2 x 1397
	Case 3 UDL	349 t	–
	Case 3 KEL	29 t	–
	Case 3 HB	184 t	–
	Total	3,356 t	–

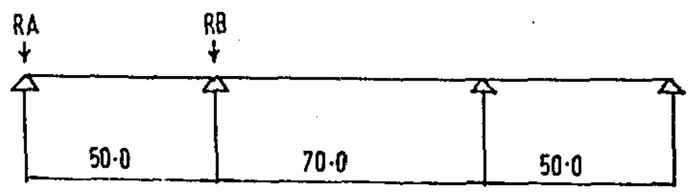


Fig. 3.31 LOCATION OF POINTS OF REACTIONS

Fig. 3.32 INFLUENCE LINE OF REACTION

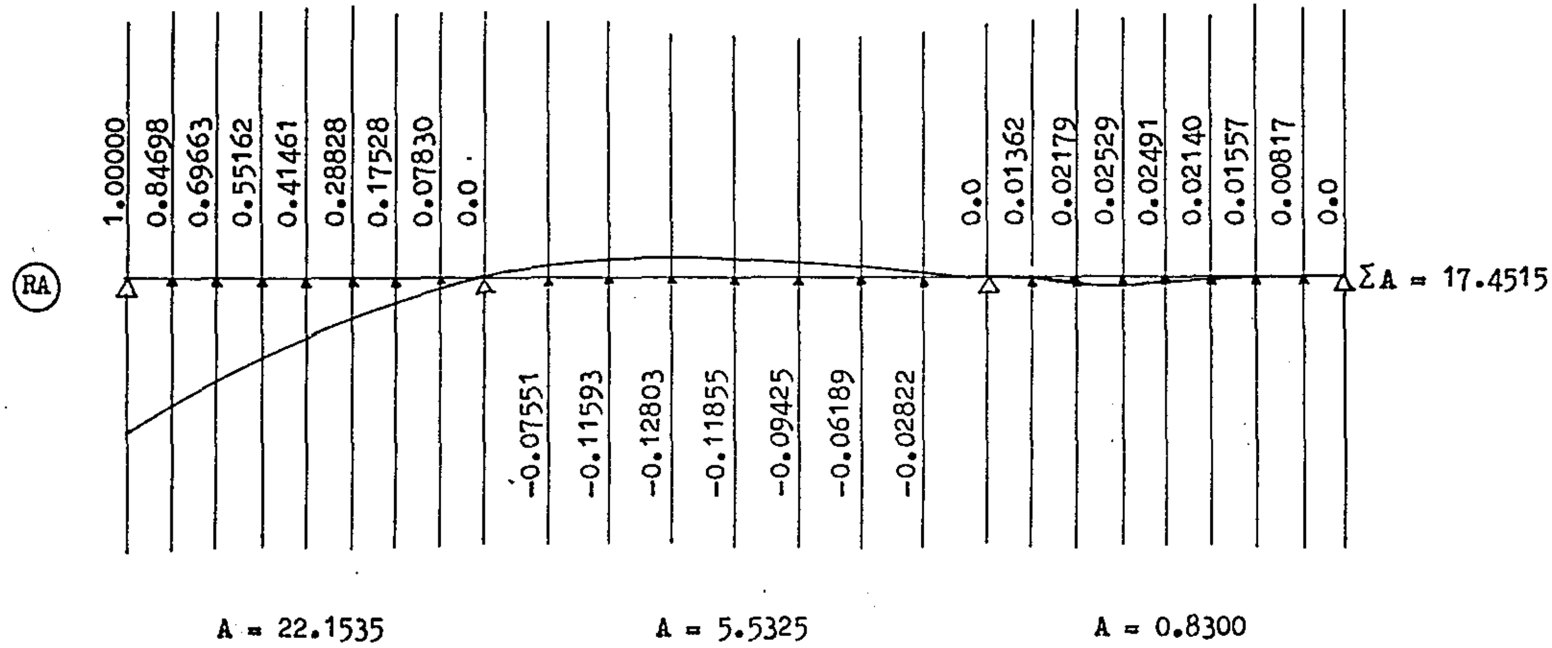
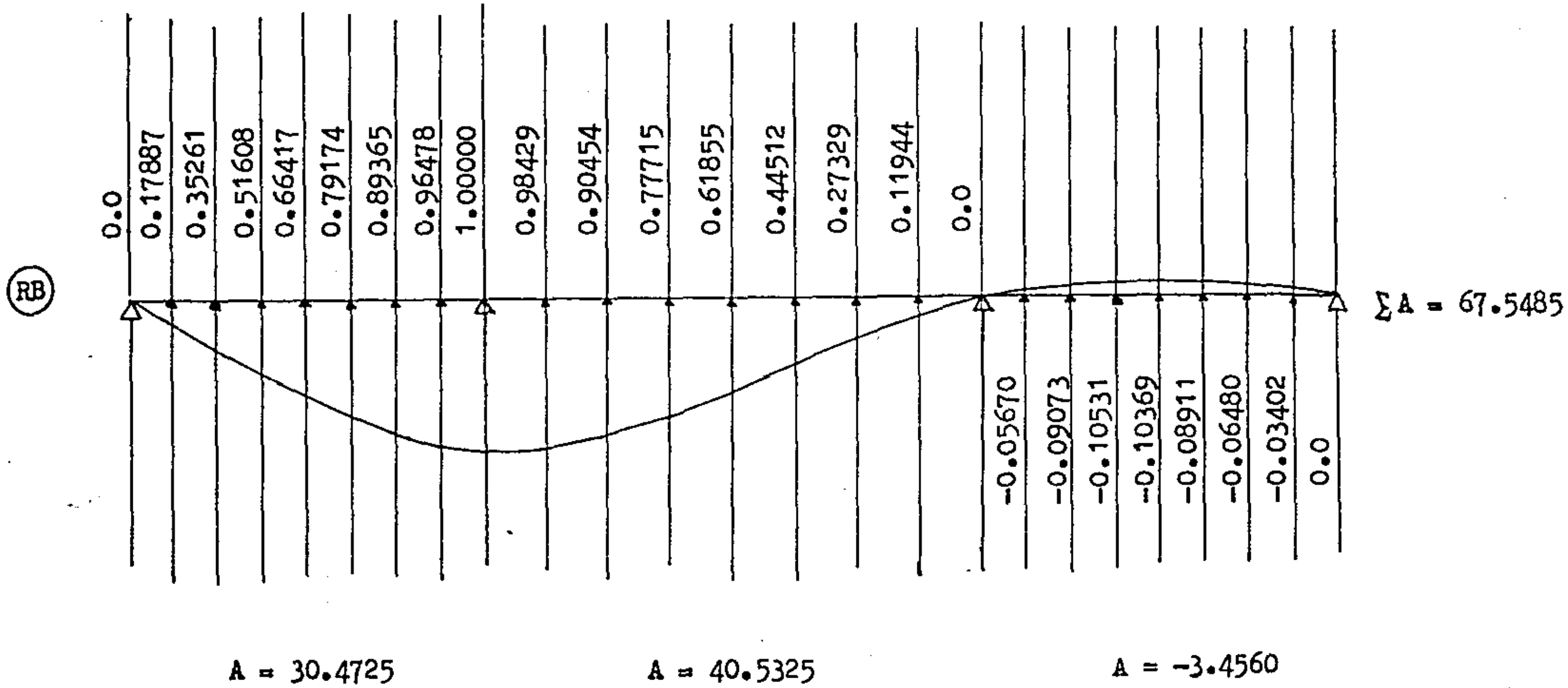


Fig. 3.33 INFLUENCE LINE OF REACTION



Reaction (RA) —— Case 2.1

Girder

R_{GC}	=	$W^{t/m}$ x Area of influence diagram		
	=	16.120 x 17.4515	=	281.3
R_{GVi}	=	$P_i^{t/m}$ x Influence line		
R_{GV1}	=	5.36 x 0.28828	=	1.5
R_{GV2}	=	16.07 x 0.17528	=	2.8
R_{GV3}	=	26.79 x 0.07830	=	2.1
R_{GV4}	=	45.00 x 0	=	0
R_{GV5}	=	37.50 x −0.07551	=	−2.8
R_{GV6}	=	22.50 x −0.11593	=	−2.6
R_{GV7}	=	7.50 x −0.12803	=	−1.0
R_{GV8}	=	7.50 x −0.09425	=	−0.7
R_{GV9}	=	22.50 x −0.06189	=	−1.4
R_{GV10}	=	37.50 x −0.02822	=	−1.1
R_{GV11}	=	45.00 x 0	=	0
R_{GV12}	=	26.79 x 0.01362	=	0.4
R_{GV13}	=	16.07 x 0.02179	=	0.4
R_{GV14}	=	5.36 x 0.02529	=	0.1
R_{GV}	=	$\sum_{i=1}^{14} R_{GVi}$ = −2.3		
R_G	=	R_{GC} + R_{GV} = 281.3 + (−2.3)	=	279.0
Wheel guard R_W	=	$W^{t/m}$ x Area of influence diagram		
	=	0.913 x 17.4515	=	15.9
Pavement R_P	=	$W^{t/m}$ x Area of influence diagram		
	=	1.242 x 17.4515	=	21.7
		Total	=	317 t

Reaction (RB) —— Case 2.1

Girder

R_{GC}	=	$W^{t/m}$	x	Area of influence diagram		
	=	16.120	x	67.5485	=	1088.9 t
R_{GVi}	=	$P_i^{t/m}$	x	Influence line		
R_{GV1}	=	5.36	x	0.79174	=	4.2
R_{GV2}	=	16.07	x	0.89365	=	14.4
R_{GV3}	=	26.79	x	0.96478	=	25.8
R_{GV4}	=	45.00	x	1.00000	=	45.0
R_{GV5}	=	37.50	x	0.98429	=	36.9
R_{GV6}	=	22.50	x	0.90454	=	20.4
R_{GV7}	=	7.50	x	0.77715	=	5.8
R_{GV8}	=	7.50	x	0.44512	=	3.3
R_{GV9}	=	22.50	x	0.27329	=	6.1
R_{GV10}	=	37.50	x	0.11944	=	4.5
R_{GV11}	=	45.00	x	0	=	0
R_{GV12}	=	26.79	x	−0.05670	=	−1.5
R_{GV13}	=	16.07	x	−0.09073	=	−1.5
R_{GV14}	=	5.36	x	−0.10531	=	−0.6

$R_{GV} = \sum_{i=1}^{14} R_{GVi} = 162.8$

$R_G = R_{GC} + R_{GV} = 1088.9 + 162.8 = 1251.7$ t

Wheel guard $R_W = W^{t/m} \times$ Area of influence diagram

$= 0.913 \times 67.5485 = 61.7$

Pavement $R_P = W^{t/m} \times$ Area of influence diagram

$= 1.242 \times 67.5485 = 83.9$

Total = 1397 t

Reaction (RA) —— Case 3

$R_{UDL} = \frac{7}{3} \times HA^{KN} \times 0.102^{t/KN} \times$ Area of Influence diagram

$= \frac{7}{3} \times 22.9 \times 0.102 \times (22.1535 + 0.8300)$

$= 125.3$ t

$R_{KEL} = \frac{7}{3} \times 120^{KN} \times 0.102^{t/KN} \times$ Influence line

$= \frac{7}{3} \times 120 \times 0.102 \times 1.000$

$= 28.6$ t

$R_{HB} = 450^{KN} \times 4 \times 0.102^{t/KN} \times$ Influence line

$= 450 \times 4 \times 0.102 \times 1.000$

$= 183.6$ t

$R_L = R_{UDL} + R_{KEL} + R_{HB} = 338$ t/2-carriageway

Reaction (RB) —— Case 3

$R_{UDL} = \frac{7}{3} \times 22.9 \times 0.102 \times 30.4725 + \frac{7}{3} \times 19.0$

$\times 0.102 \times 40.5325$

$= 349.4$ t

$R_{KEL} = \frac{7}{3} \times 120 \times 0.102 \times 1.000$

$= 28.6$ t

$R_{HB} = 450 \times 4 \times 0.102 \times 1.000$

$= 183.6$ t

$R_L = R_{UDL} + R_{KEL} + R_{HB} = 562$ t/2-carriageway

3.5.4.5 Required quantity of prestressed bars.

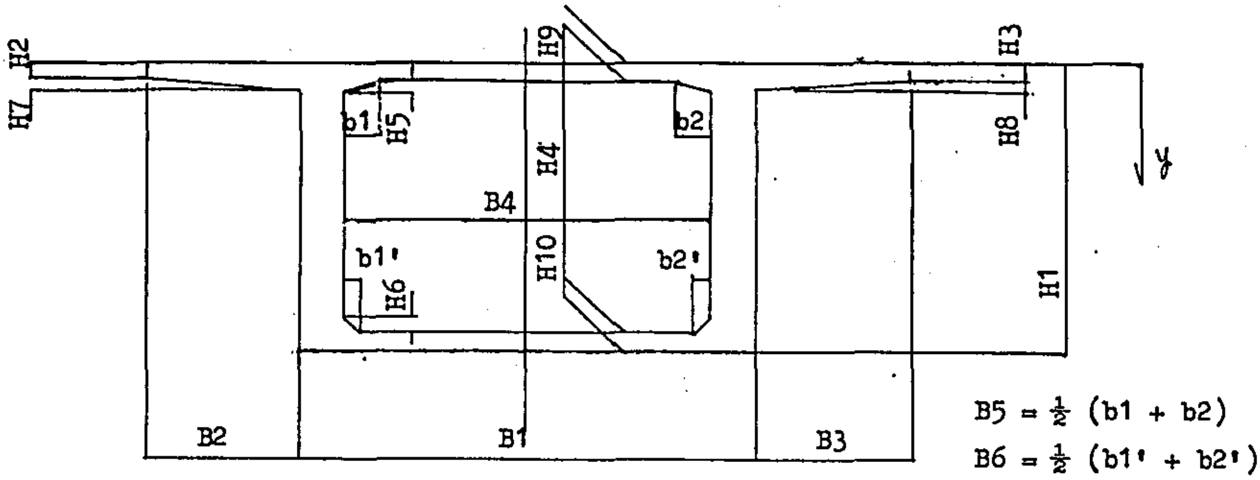


Fig. 3.34 CROSS-SECTION OF BEAMS

unit : cm

	H = 2.00 m	H = 4.00 m
H1	200	400
H2	25	25
H3	25	25
H4	145	345
H5	15	15
H6	20	20
H7	15	15
H8	15	15
H9	25	25
H10	30	30
B1	600	600
B2	200	200
B3	200	200
B4	480	480
B5	45	45
B6	20	20

Table 3.8 DIMENSIONS OF BEAMS

H = 2.00 m

H1	200.0	B1	600.0
H2	25.0	B2	200.0
H3	25.0	B3	200.0
H4	145.0	B4	480.0
H5	15.0	B5	45.0
H6	20.0	B6	20.0
H7	15.0		
H8	15.0		
H9	25.0		
H10	30.0		

	A	Y	AY
	120000.0	100.0	12000000
	5000.0	12.5	62500
	5000.0	12.5	62500
	-69600.0	97.5	-6786000
	675.0	30.0	20250
	400.0	163.3	65320
	1500.0	30.0	45000
	1500.0	30.0	45000
TOTAL	64475.0		5514570

	AY**2	IO
	1200000000	400000000
	781250	260417
	781250	260417
	-661635000	-121945000
	607500	8438
	10666756	8889
	1350000	18750
	1350000	18750
TOTAL	5.53901E+08	2.78630E+08

N	AC	AP	NO
0	0.000	0.0000	0.000
Y,	Y	EP	A
85.53	-114.47	0.00	64475.0
I	WC,	WC	WP
3.6087E+08	4219260	-3152560	0
R**2			
5597			

H = 4.00 m

H1	400.0	B1	600.0
H2	25.0	B2	200.0
H3	25.0	B3	200.0
H4	345.0	B4	480.0
H5	15.0	B5	45.0
H6	20.0	B6	20.0
H7	15.0		
H8	15.0		
H9	25.0		
H10	30.0		

	A	Y	AY
	240000.0	200.0	48000000
	5000.0	12.5	62500
	5000.0	12.5	62500
	-165600.0	197.5	-32706000
	675.0	30.0	20250
	400.0	363.3	145320
	1500.0	30.0	45000
	1500.0	30.0	45000
TOTAL	88475.0		15674570

	AY**2	IO
	9600000000	3200000000
	781250	260417
	781250	260417
	-6459435000	-1642545000
	607500	8438
	52794756	8889
	1350000	18750
	1350000	18750
TOTAL	3.19822E+00	1.55803E+09

N	AC	AP	NO
0	0.000	0.0000	0.000

Y,	Y	EP	A
177.16	-222.84	0.00	88475.0

I	WC,	WC	WP
1.9794E+09	11173030	-8882670	0

R**2

22373

$$N = \frac{M}{Pe\left(\frac{Z}{A} + e\right)}$$

M : Bending moments

N : Required number of prestressed bars

Pe : Tensile force prestressing = 41.0 ton/one

(ϕ 32 mm Ap = 804.2 mm^2)

A : Cross-section area of girder

Z : Section modulus

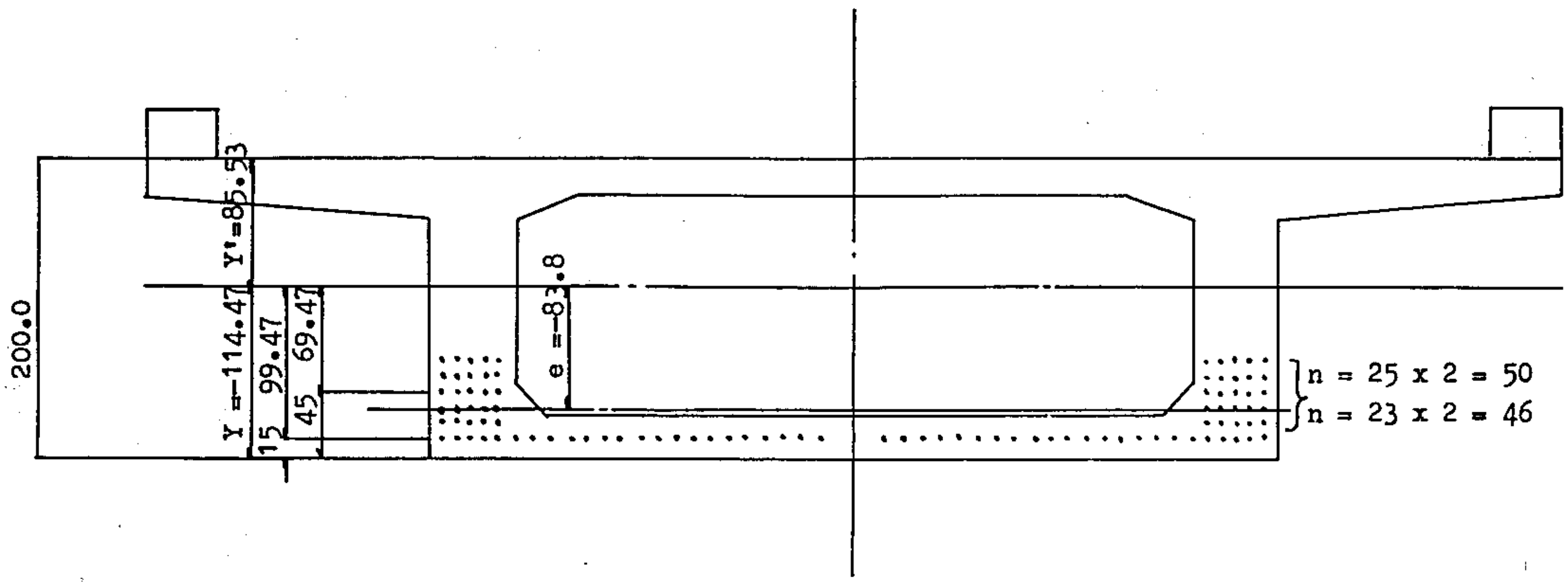
e : Eccentricity

④ $N = \dfrac{5094 \times 10^5}{41.0 \times 10^3 \times \left(\dfrac{3152560}{64475} + 80\right)} \doteqdot 96$

⑧ $N = \dfrac{14197 \times 10^5}{41.0 \times 10^3 \times \left(\dfrac{11173030}{88475} + 145\right)} \doteqdot 130$

⑫ $N = \dfrac{7816 \times 10^5}{41.0 \times 10^3 \times \left(\dfrac{3152560}{64475} + 80\right)} \doteqdot 146$

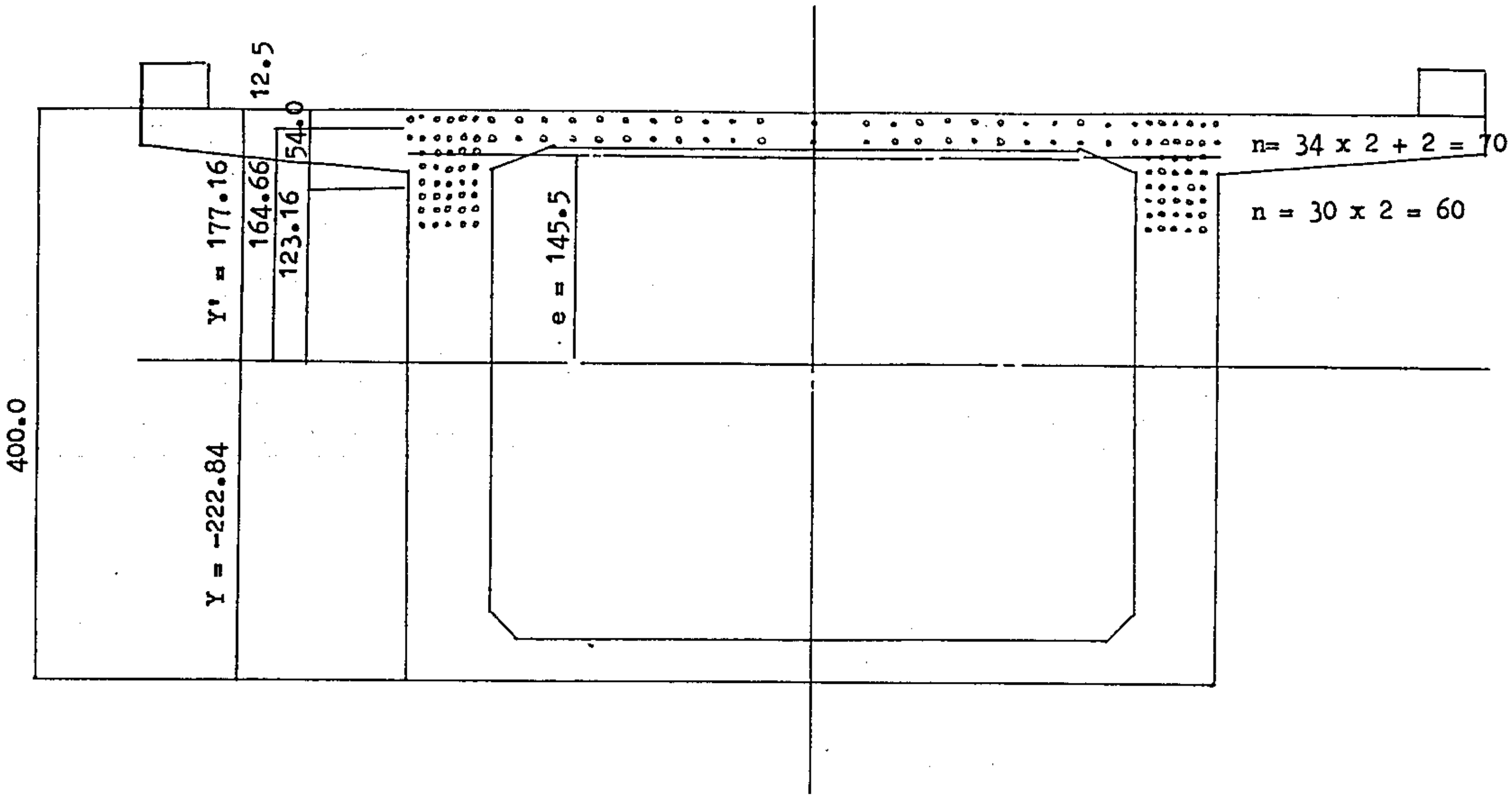
④ N = 96



$$e = \frac{50 \times 69.47 + 46 \times 99.47}{96} = 83.8$$

Fig. 3.35 LOCATION OF PRESTRESSED BARS

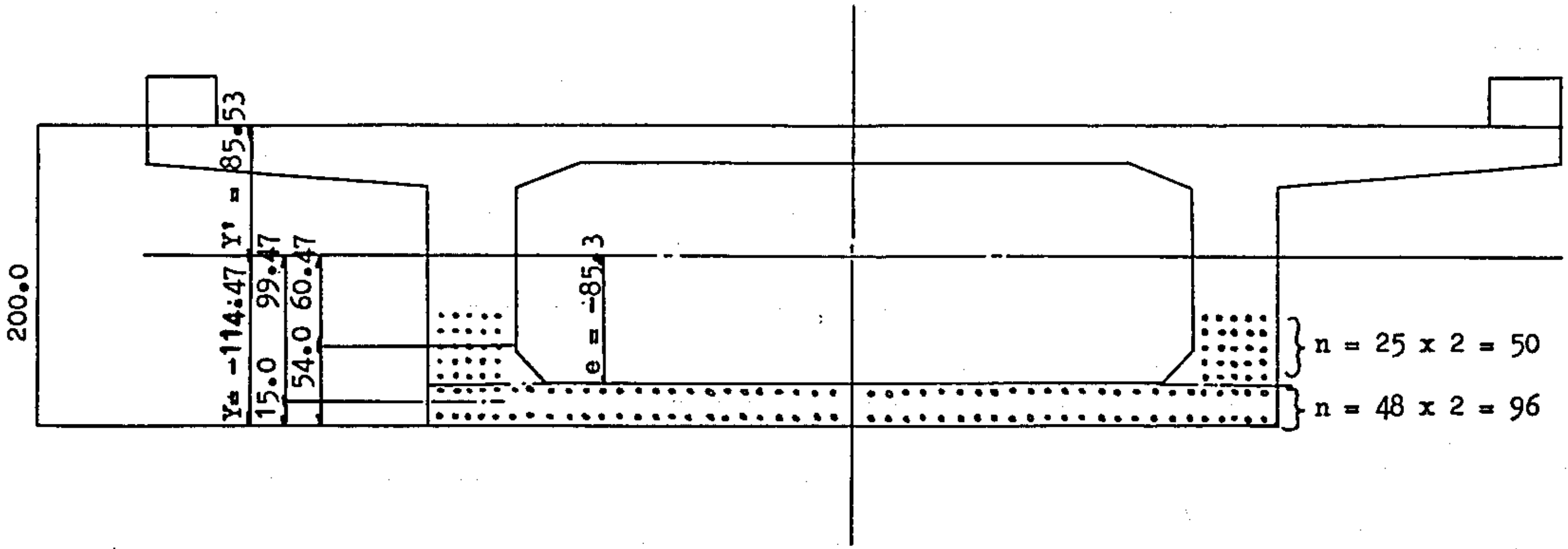
⑧ $N = 130$



$$e = \frac{70 \times 164.66 + 60 \times 123.16}{130} = 145.5$$

Fig. 3.36 <u>LOCATION OF PRESTRESSED BARS</u>

⑫ N = 146



$$e = \frac{88 \times 99.47 + 50 \times 60.47}{138} = 85.3$$

Fig. 3.37 LOCATION OF PRESTRESSED BARS

Table 3.9 REACTIONS

Point	Load Case	Unit 1	Unit 2		Unit 3	
		Reaction	α	Reaction	α	Reaction
RA	Case 2.1	634 t	0.9206	584 t	0.9747	618 t
	Case 3 U D L	125	0.8981	112	0.8914	111
	Case 3 K E L	29	1.0000	29	1.0000	29
	Case 3 H B	184	1.0000	184	1.0000	184
	Total	972		909		942
RB	Case 2.1	2,794	0.8780	2,453	0.8139	2,274
	Case 3 U D L	349	0.8809	307	0.8262	288
	Case 3 K E L	29	1.0000	29	1.0000	29
	Case 3 H B	184	1.0000	184	1.0000	184
	Total	3,356		2,973		2,775

3.6 Study of Substructures

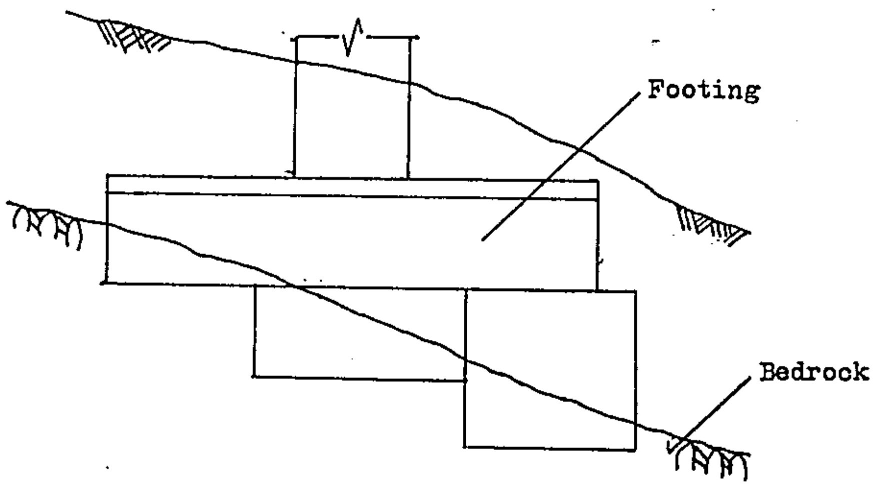
3.6.1 Foundation

As stated in Chaper 2, at the sites of the bridges, sandy clay or clayer sand with many imbedded boulders with diameters of 1 m to 5 m extends to a depth of from 5 m to 10 m before the bedrock of granite or weathered granite is encountered.

For such soil conditions, the pile foundation cannot be adopted. The spread footing foundation is the only type suitable.

Excavation of the boulders will be done by open-cut smashing with dynamite.

In the case where the foundation is constructed on the escarpment of the bedrock, the concrete by casting in place should level the bed for the foundation as shown in the figure below.

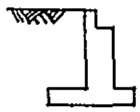
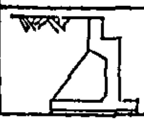


3.6.2 Abutment

The following types of abutments are generally used, and the appropriate height for each type is shown in Table 3.9

Gravity Type
Inverse T-shaped Type
Buttressed Type

Table 3.10 TYPES AND HEIGHTS OF ABUTMENTS

Type	Height (m)			
	10	20	30	
Gravity Type	5			
Inverse T-shaped Type		13		
Buttressed Type			20	

Since all the abutments in the three sites are from 6 meters to 10 meters in height, the inverse T-shaped type should be adopted.

3.6.3 Pier

Carriageways for both directions of traffic should be supported by two piers and one foundation. The pier should be T-shaped.

3.6.4 Dimensions of Substructures

3.6.4.1 Abutment

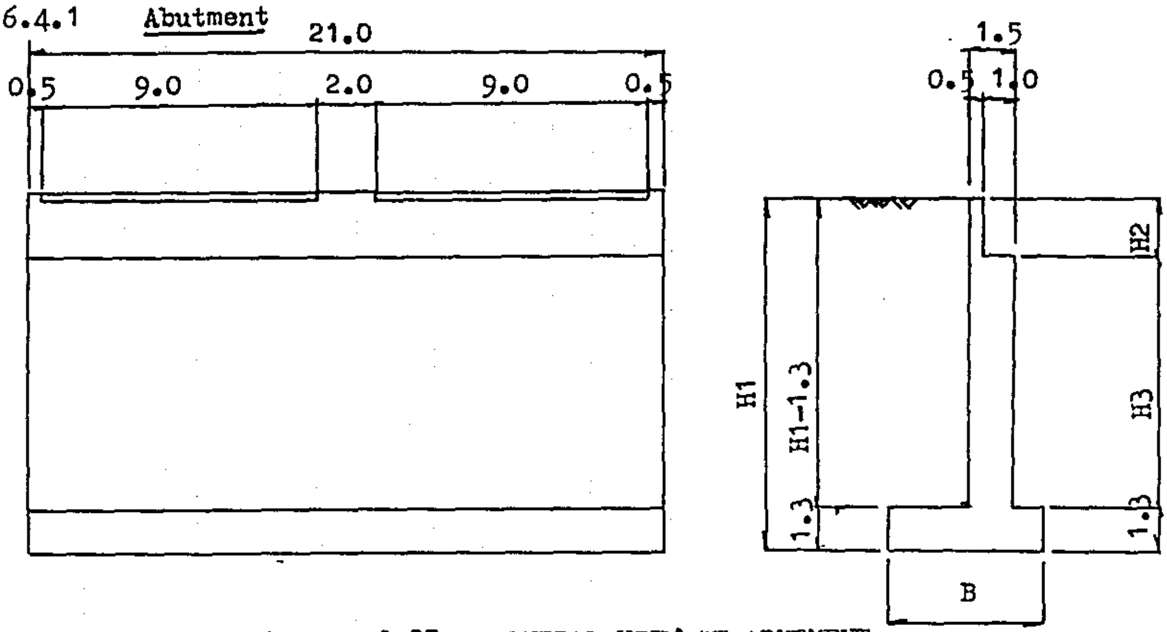


Figure 3.27 GENERAL VIEW OF ABUTMENT

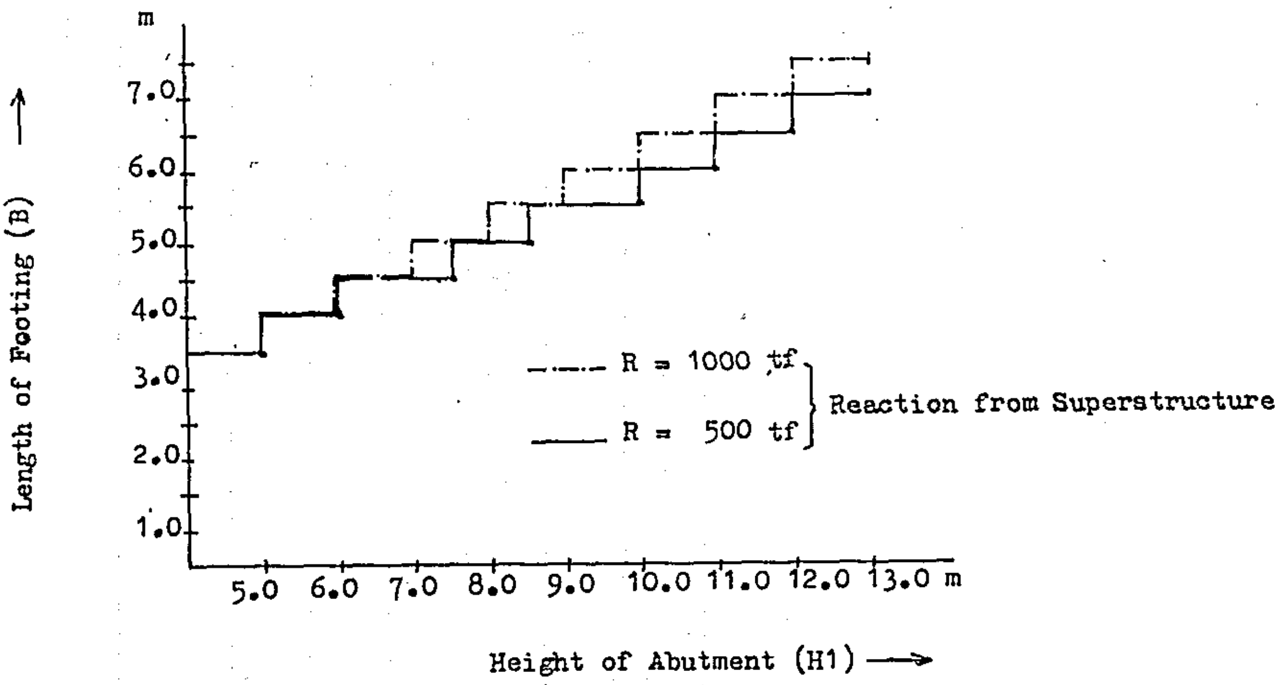


Figure 3.28 GRAPH OF LENGTH OF FOOTING

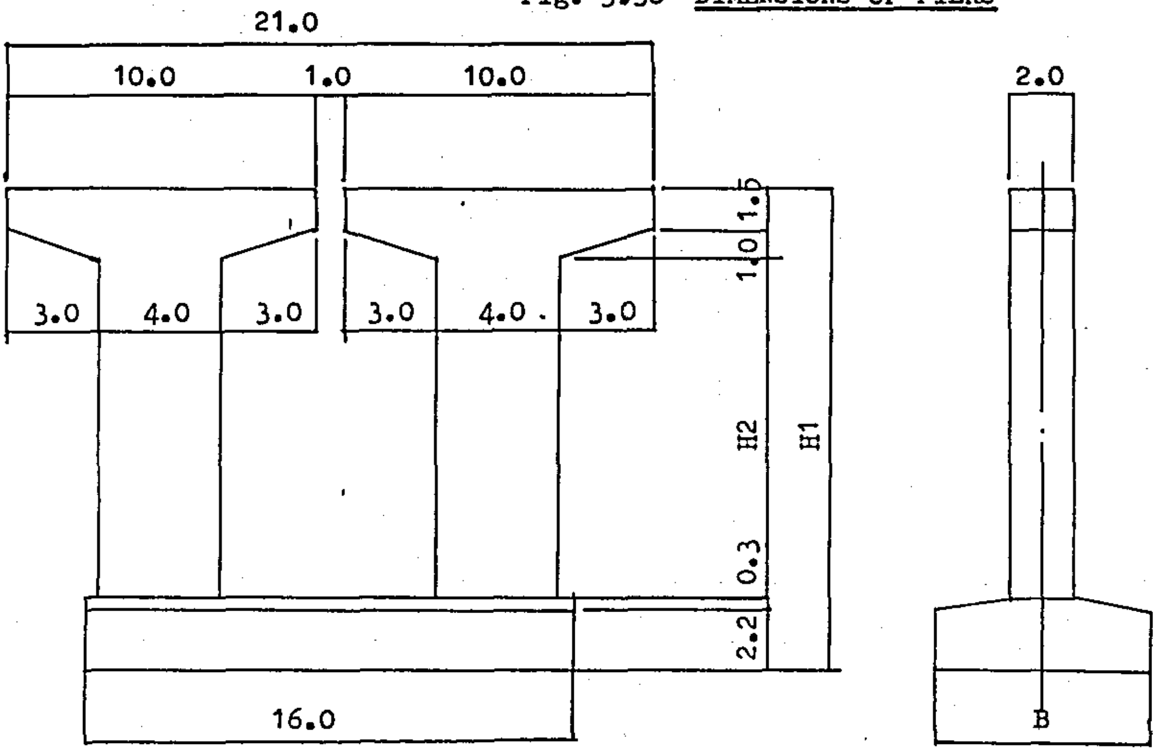
Table 3.11 DIMENSIONS OF ABUTMENTS

		H_1 (m)	H_2 (m)	H_3 (m)	Rd (t)	Rl (t)	R = Rd + Rl (t)	B (m)
A-Bridge.	Start Point	6.0	1.6	3.1	401	316	717	4.0
	End Point	6.0	1.6	3.1	401	316	717	4.0
B-Bridge	Start Point	7.0	1.9	3.8	618	324	942	4.5
	End Point	10.0	2.2	6.8	634	338	972	6.0
C-Bridge	Start Point	7.0	1.6	4.1	401	316	717	4.5
	End Point	7.0	1.6	4.1	401	316	717	4.5

3.6.4.2 <u>Pier</u>

Fig. 3.38 <u>DIMENSIONS OF PIERS</u>

A - TYPE



B - TYPE

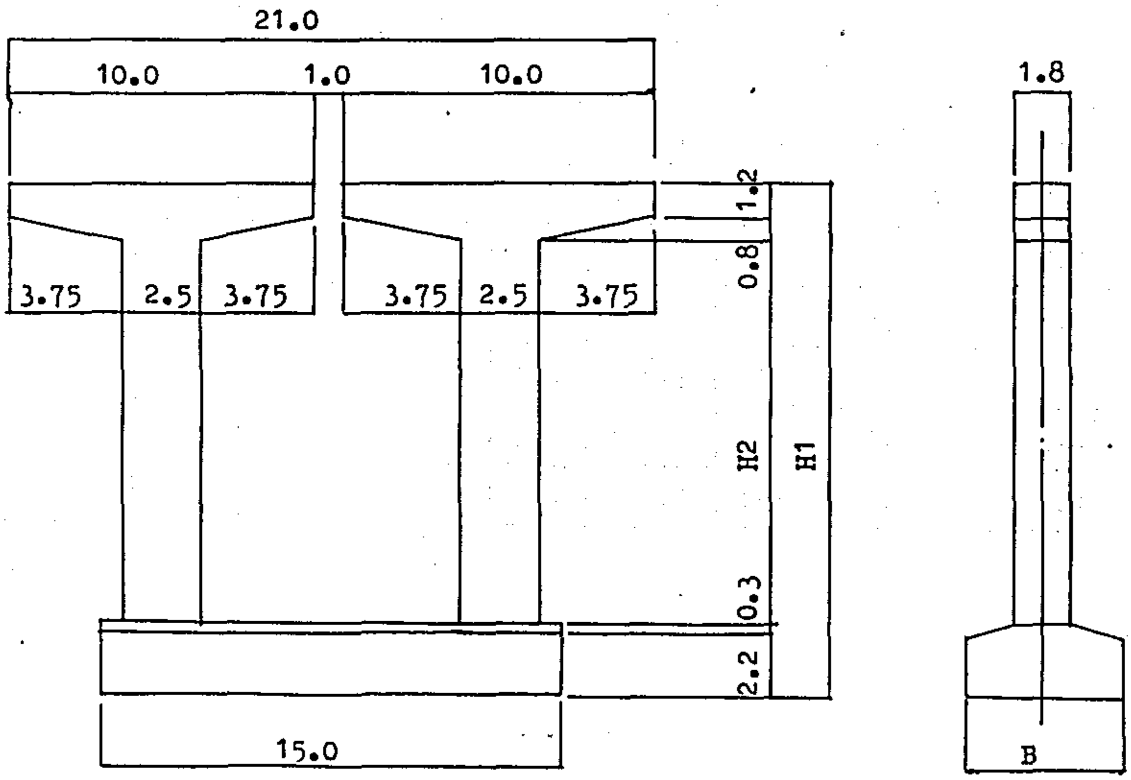


Table 3.12 **SUMMARY OF REACTIONS OF EACH BRIDGE**

		Type	H_1 (m)	H_2 (m)	Rd (t)	R1 (t)	$R=R_1+R_2$ (t)	B (m)
A-Bridge	P1	B-Type	12.0	7.5	1,772	428	2,200	4.0
	P2	A "	16.5	11.5	3,850	520	4,370	7.5
	P3	A "	19.0	14.0	3,950	520	4,470	7.5
	P4	B "	16.5	12.0	1,771	428	2,199	4.0
	P5	B "	11.0	6.5	1,464	419	1,883	4.0
	P6	B "	8.0	3.5	1,397	419	1,816	4.0
B-Bridge	P1	A "	13.0	8.0	3,484	501	3,985	7.0
	P2	A "	17.0	12.0	3,644	501	4,145	7.0
	P3	B "	11.0	6.5	1,681	427	2,108	4.0
	P4	B "	17.0	12.5	1,599	419	2,018	4.0
	P5	B "	17.0	12.5	1,599	419	2,018	4.0
	P6	B "	15.0	10.5	1,554	419	1,973	4.0
	P7	B "	19.0	14.5	1,877	441	2,318	4.0
	P8	A "	27.0	22.0	4,799	562	5,361	9.5
	P9	A "	18.5	13.5	4,459	562	5,021	9.5
C-Bridge	P1	B "	19.0	14.5	1,644	419	2,063	4.0
	P2	B "	20.0	15.5	1,667	419	2,086	4.0
	P3	B "	20.0	15.5	1,667	419	2,086	4.0
	P4	B "	18.0	13.5	1,622	419	2,041	4.0
	P5	B "	17.0	12.5	1,821	438	2,259	4.0
	P6	B "	15.0	10.5	1,776	438	2,214	4.0
	P7	B "	16.0	11.5	1,577	419	1,996	4.0
	P8	B "	12.0	7.5	1,487	419	1,906	4.0
	P9	B "	9.0	4.5	1,419	419	1,838	4.0

Chapter 4 MATERIALS

4.1 Superstructures

Table 4.1 MATERIALS OF A-BRIDGE

Materials		Grade	Unit	P.C Continuous Box Girder Bridge		P.C Simple T-Shaped Girder Bridge		Total
		Bridge Type		P.C Continuous Box Girder Bridge		P.C Simple T-Shaped Girder Bridge		Total
		Span Length (m)		45 + 60 + 45		30		—
		Grade	Unit \ Quantity	2		8		—
Concrete	Main Girder	40	m^3	(980)	1,960	(110)	880	2,840
	Diaphragm	25	m^3	(42)	84	(19)	152	236
Form	Main Girder	–	m^2	(3,526)	7,052	(637)	5,096	12,148
	Diaphragm	–	m^2	(164)	328	(108)	864	1,192
	Total	–	m^2	(3,690)	7,380	(745)	5,960	13,340
Steel Reinforcement		410	t	(123)	246	(17)	136	382
Prestressed Bar		32	t	(101.3)	203	(–)	–	203
Prestressed Strand		12 x 12.5	t	(–)	–	(6.7)	54	54
Asphalt Wearing Surface		6cm thick	m^2	(1,350)	2,700	(270)	2,160	4,860
Guard		–	m	(300)	600	(60)	480	1,080
Kerb		–	m	(300)	600	(60)	480	1,080
Expansion Joint		Rubber	m	(10)	20	(10)	80	100
Steel Bearings		–	t	(37)	74	(–)	–	74
Rubber Bearings		–	Each	(–)	–	(10)	80	80

Table 4.2 MATERIALS OF B-BRIDGE

Materials		Grade	Unit	P.C Continuous Box Girder Bridge				P.C Simple T-Shaped Girder Bridge		Total
		Bridge Type		P.C Continuous Box Girder Bridge				P.C Simple T-Shaped Girder Bridge		Total
		Span Length (m)		45 + 55 + 45		50 + 70 + 50		30		–
		Grade	Unit \ Quantity	2		2		8		–
Concrete	Main Girder	40	m^3	(923)	1,846	(1,192)	2,384	(110)	880	5,110
	Diaphragm	25	m^3	(39)	78	(52)	104	(19)	152	334
Form	Main Girder	–	m^2	(3,329)	6,658	(4,266)	8,532	(637)	5,096	20,286
	Diaphragm	–	m^2	(150)	300	(203)	406	(108)	864	1,570
	Total	–	m^2	(3,479)	6,958	(4,469)	8,938	(745)	5,960	21,856
Steel Reinforcement		410	t	(115)	230	(149)	298	(17)	136	664
Prestressed Bar		32	t	(96.9)	194	(126.9)	254	(-)	-	448
Prestressed Strand		12 x 12.5	t	(-)	-	(-)	-	(6.7)	54	54
Asphalt Wearing Surface		6cm thick	m^2	(1,305)	2,610	(1,530)	3,060	(270)	2,160	7,830
Guard		–	m	(290)	580	(340)	680	(60)	480	1,740
Kerb		–	m	(290)	580	(340)	680	(60)	480	1,740
Expansion Joint		Rubber	m	(10)	20	(10)	20	(10)	80	120
Steel Bearings		–	t	(36)	72	(42)	84	(-)	-	156
Rubber Bearings		–	Each	(-)	-	(-)	-	(10)	80	80

Table 4.3 MATERIALS OF C-BRIDGE

Materials		Grade	Unit	P.C Simple T-Shaped Girder Bridge		P.C Simple T-Shaped Girder Bridge		Total
		Span Length (m)		30		40		–
			Quantity	18		2		–
Concrete	Main Girder	40	m^3	(110)	1,980	(171)	342	2,322
	Diaphragm	25	m^3	(19)	342	(39)	78	420
Form	Main Girder	–	m^2	(637)	11,466	(1,030)	2,060	13,526
	Diaphragm	–	m^2	(108)	1,944	(216)	432	2,376
	Total	–	m^2	(745)	13,410	(1,246)	2,492	15,902
Steel Reinforcement		410	t	(17)	306	(23)	46	352
Prestressed Bar		32	t	(–)	–	(–)		–
Prestressed Strand		12 x 12.5	t	(6.7)	121	(11.0)	22	143
Asphalt Wearing Surface		6cm thick	m^2	(270)	4,860	(360)	720	5,580
Guard		–	m	(60)	1,080	(80)	160	1,240
Kerb		–	m	(60)	1,080	(80)	160	1,240
Expansion Joint		Rubber	m	(10)	180	(10)	20	200
Steel Bearings		–	t	(–)	–	(–)	–	–
Rubber Bearings		–	Each	(10)	180	(10)	20	200

4.2 Substructure

Table 4.4 MATERIALS OF A-BRIDGE

Materials	Grade	Unit	Abutment	Pier	Retaining Wall	Total
Concrete	25	m^3	458	2,289	-	2,747
	20	m^3	-	-	-	-
Form	-	m^2	595	2,189	-	2,784
Steel Reinforcement	-	t	46	229	-	275
Scaffolding	-	m^3	329	4,039	-	4,368

Table 4.5 MATERIALS OF B-BRIDGE

Materials	Grade	Unit	Abutment	Pier	Retaining Wall	Total
Concrete	25	m^3	702	4,040	307	5,049
	20	m^3	796	3,759	-	4,555
Form	-	m^2	1,200	5,521	535	7,256
Steel Reinforcement	-	t	70	404	31	505
Scaffolding	-	m^3	562	8,202	-	8,764

Table 4.6 MATERIALS OF C-BRIDGE

Materials	Grade	Unit	Abutment	Pier	Retaining Wall	Total
Concrete	25	m^3	524	2,806	—	3,330
	20	m^3	—	—	—	—
Form	—	m^2	681	2,683	—	3,364
Steel Reinforcement	—	t	52	281	—	333
Scaffolding	—	m^3	435	7,385	—	7,820