NO. 51

THE KINGDOM OF THAILAND

The Feasibility Study on

THE RAMA VI BRIDGE CONSTRUCTION PROJECT

SUPPLEMENTARY REPORT
Strengthening and Rehabilitation for Krung Thon and Krung Thep Bridges

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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CONTENTS

SUMMARY

The KRUNG THON Bridge and the KRUNG THEP Bridge were constructed in 1958 and 1959, respectively. Due to the rapid increase of traffic and also of the vehicle weight, in recent years, these bridges have been suffering from remarkable deterioration, and both the bridges are already considered to be very dangerous operationally.

The study comprises general investigations of the two bridges, the surveys of the available data on obtained from the recent examinations and repairing works, the related surveying and stress analysis. It aims at estimating the strength and the durability of the bridges, in addition to the feasibility study of their Rehabilitation and Strengthening.

The deterioration has been particularily severe with regard to the damage and deformation of the carriage way, rusting on the lower chords and on the floor frames, discrepancy of the bascule mechanism and scouring of the river bed.

The Rehabilitation and Strengthening measures proposed in this report have been classified into the three categories listed below.

(1) Emergency measures

(2) Temporary measures

(3) Long-term measures

The emergency and temporary measures aim at eliminating, at least temporarily, the danger of the bridge members which are actually in critical situation. Particularly the emergency measures aim at removing the causes of deterioration occurring in daily use.

The long-term measures aim at providing more durability for both the bridges, in order to attain prolonged use under normal conditions.

A list of all categories of Rehabilitation and Strengthening measures proposed in this report is summarized below.

(1) Emergency Measures

- Painting of the main truss, cross beam, and stringer, etc., in the vicinity of the supports of the trussed beams and expansion joints of both bridges.
- Painting of the web plate of the main beam near the machine room of the KRUNG THEP Bascule Bridge.
- Painting of the cross beam and stringer in the vicinity of the Reinforced Concrete (hereinafter referred to as RC) slab construction joint.
- Adjustment of the height and improvement of the expansion joints of both bridges and also of drainage.
- Patching at the damaged parts of the asphalt pavement in the trussed girder of both bridges.

(2) Temporary Measures

- Repairing of the irreguralities in the surface of RC slab of the KRUNG THEP Bascule Bridge and over-laying of bituminous wearing layers.
- Improvement of the construction joints at the RC slabs of both the bridges
- Replacing of the RC slab on the Prestressed Concrete (hereinafter referred to as PC) composite beams of the approach bridges.
- Improvement or replacement of the 6-span continuous RC T-shaped rigid beams in the approach section of the KRUNG THON Bridge.
- Restoration of the locally damaged parts and twisted parts of the main truss members of both bridges and enforcement of measures for preventing

CHAPTER 1

OUTLINE OF THE KRUNG THON BRIDGE AND KRUNG THEP BRIDGE

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The Greater Bangkok City is divided in two major areas, namely, the Bangkok side and the Thonburi side of the main stream of the Chao Phraya River (river width of approximately 300 m) flowing through the center of the city. The transportation between the two major areas mentioned above is ensured by means of the 6 bridges existing presently, ranging from the NONTHABURI Bridge located at the upstream extremity to the KRUNG THEP Bridge located at the downstream extremity, and includes the KRUNG THON Bridge.

Aiming at making possible the smooth flow of vehicular traffic which was increased rapidly in the recent years, PWD and other authorities of the Kingdom of Thailand are planning the construction of the following bridges, in addition to the 6 bridges existing presently:

- The SATHON Bridge (presently under construction) between the KRUNG THEP Bridge and the MEMORIAL Bridge.
- The NEW MEMORIAL BRIDGE located immediately downstream of the MEMORIAL Bridge.
- WAT SAI Bridge to be used by the expressway, approximately 8 km downstream of the KRUNG THEP Bridge.
- The NEW NONTHABURI BRIDGE and the PATHUMTHANI Bridge, located respectively 5 km and 11 km upstream of the NONTHABURI Bridge.

Data such as actually measured volume of traffic (obtained in 1981), number of lanes, etc., regarding the presently existing bridges are listed in Table 1-1 and Table 1-2.

Table 1-1 Screen Line (Chao Phraya River)
Present Traffic Volume

Vehicle Type / Bridge	Motor-cycle	Car	Bus	Truck	Total (Excluding motorcycles)
Nonthaburi	610	1780	1400	4100	7280
RAMA VI	3260	14580	3440	4240	22260
Krung Thon	7350	30250	4470	6420	41140
Phra Pin Klao	14550	52580	6560	7750	72890
Memorial	48580	45680	10680	12210	68570
Krung Thep	16080	26490	3360	17920	47770
Total	90430	177360	29910	52640	259910

Table 1-2 One-Lane Volume and Motorcycle Rate

Bridge	No. of Lanes	One-Lane Volume	Motorcycle Rate
Nonthaburi	2	3,910	7.7%
RAMA VI	2	11,130	12.8%
Krung Thon	4	10,285	15.2%
Phra Pin Klao	6	12,150	16.6%
Memorial	4	17,140	41.5%
Krung Thep	4	11,940	25.2%
Average (Total)	3.7 (22)	11,815	25.8%

Note : Rate of Motorcycle is number of Motorcycles/ Traffic volume + Motorcycles.

The superstructure of the main span of the KRUNG THON Bridge and KRUNG THEP Bridge, which are the subject of the present Strengthening and Rehabilitation study is steel structure in both cases. The bridges were designed and constructed in 1958 and 1959, respectively, under the responsibility of the Fuji Sharyo Co., Ltd. of Japan. In the bridges, the superstructures and the substructures of the approach span were designed by another consultant at the same time, and the superstructure is composed of the combination of PC and RC structures.

With regard to the substructure, the open caisson is adopted in the foundation of the main span located in the river, while the precast concrete pile foundation system is adopted in the approach section.

More than 20 years have already elapsed after the construction, and very pronounced damage can be observed in the asphalt pavement, the RC slab and in various parts of the bridge.

Particularly the KRUNG THEP Bridge is expected to become part of the future Middle Ring Road, and it is therefore required to be able to withstand the traffic of heavy vehicles which will necessarily take place in future as a consequence of the increase of traffic volume in general.

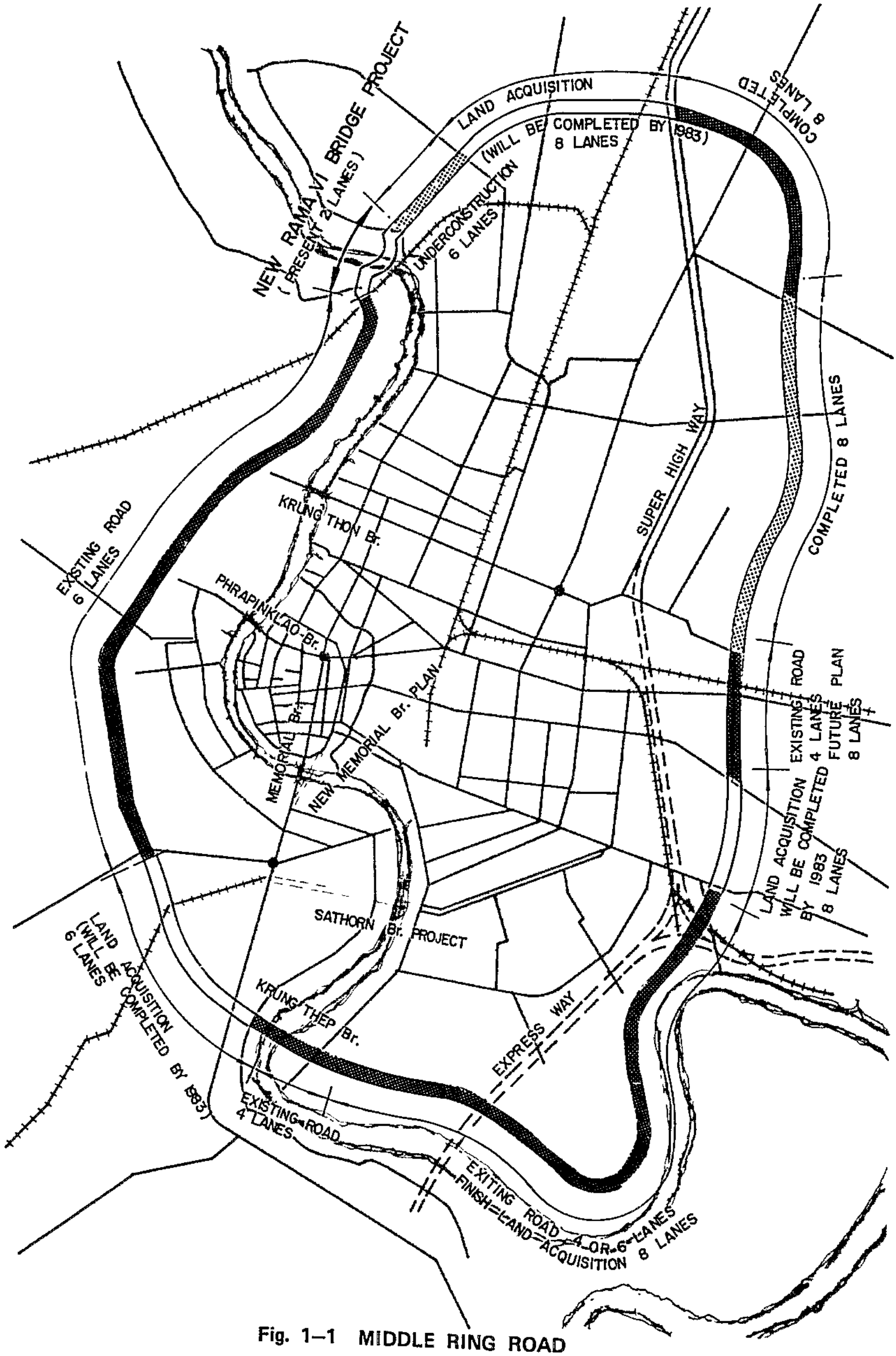

Fig. 1–1 MIDDLE RING ROAD

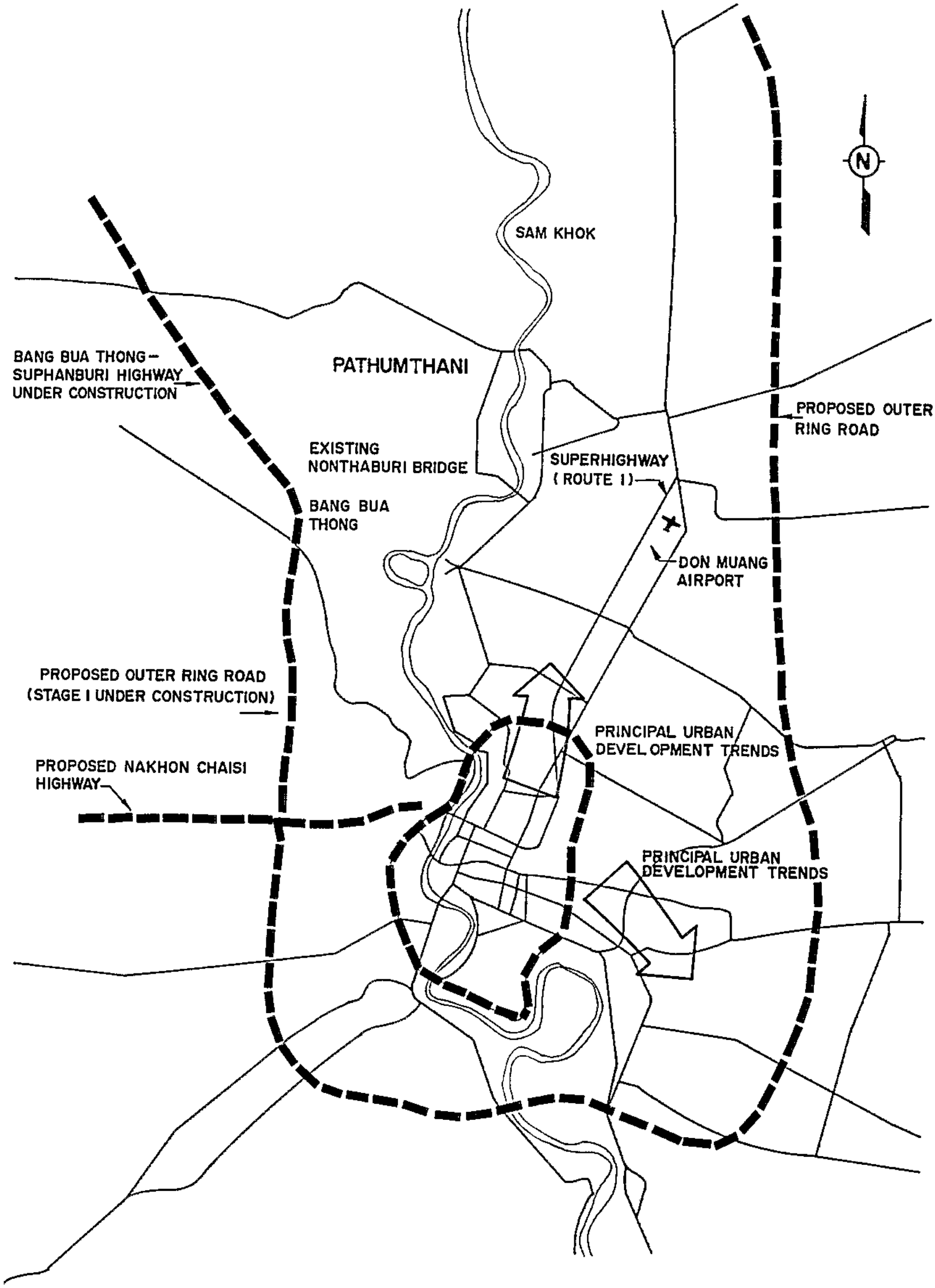

Fig. 1–2 DEVELOPMENT FEATURES

KRUNG THON BRIDGE
GENERAL VIEW

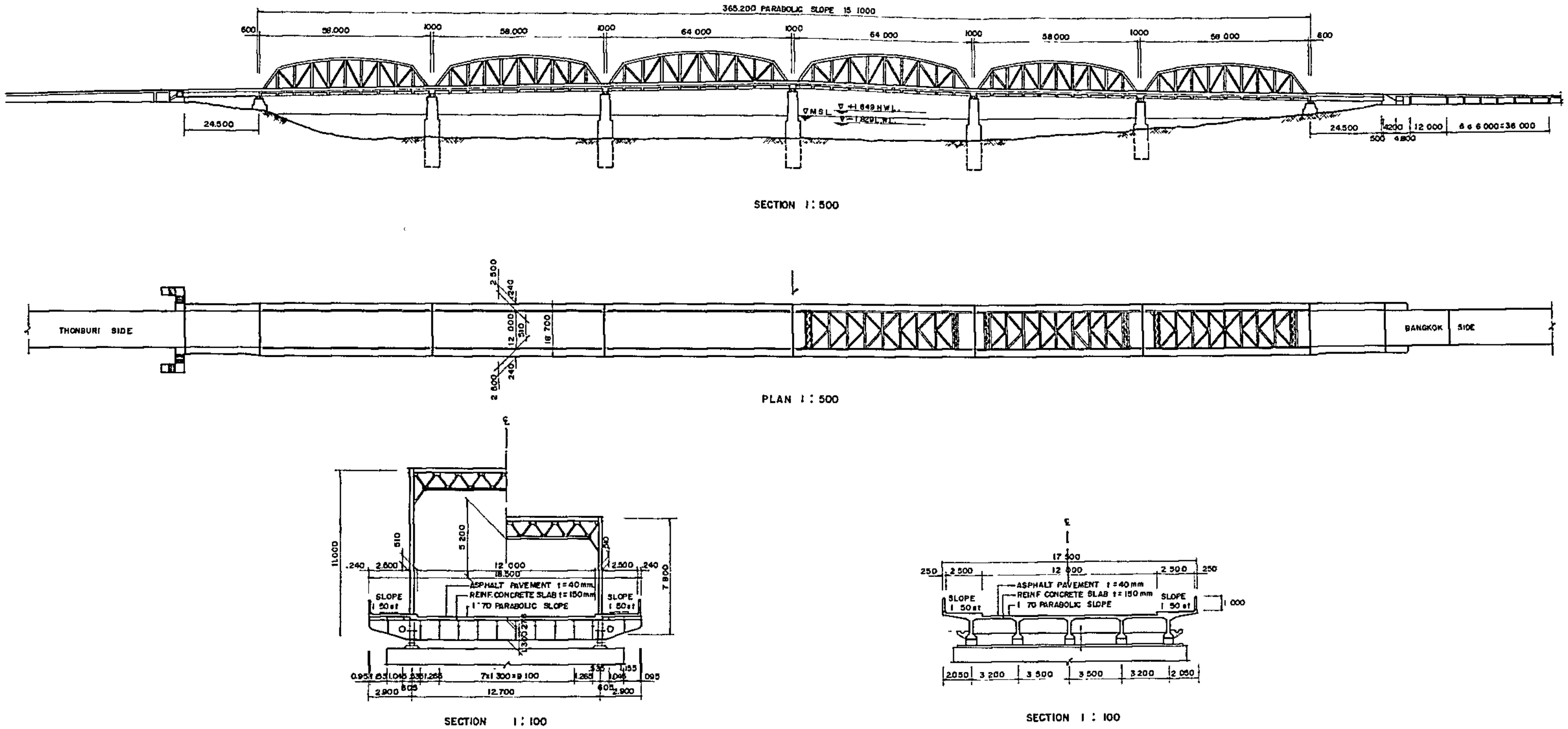

Fig. 1–3

KRUNG THEP BRIDGE
GENERAL VIEW

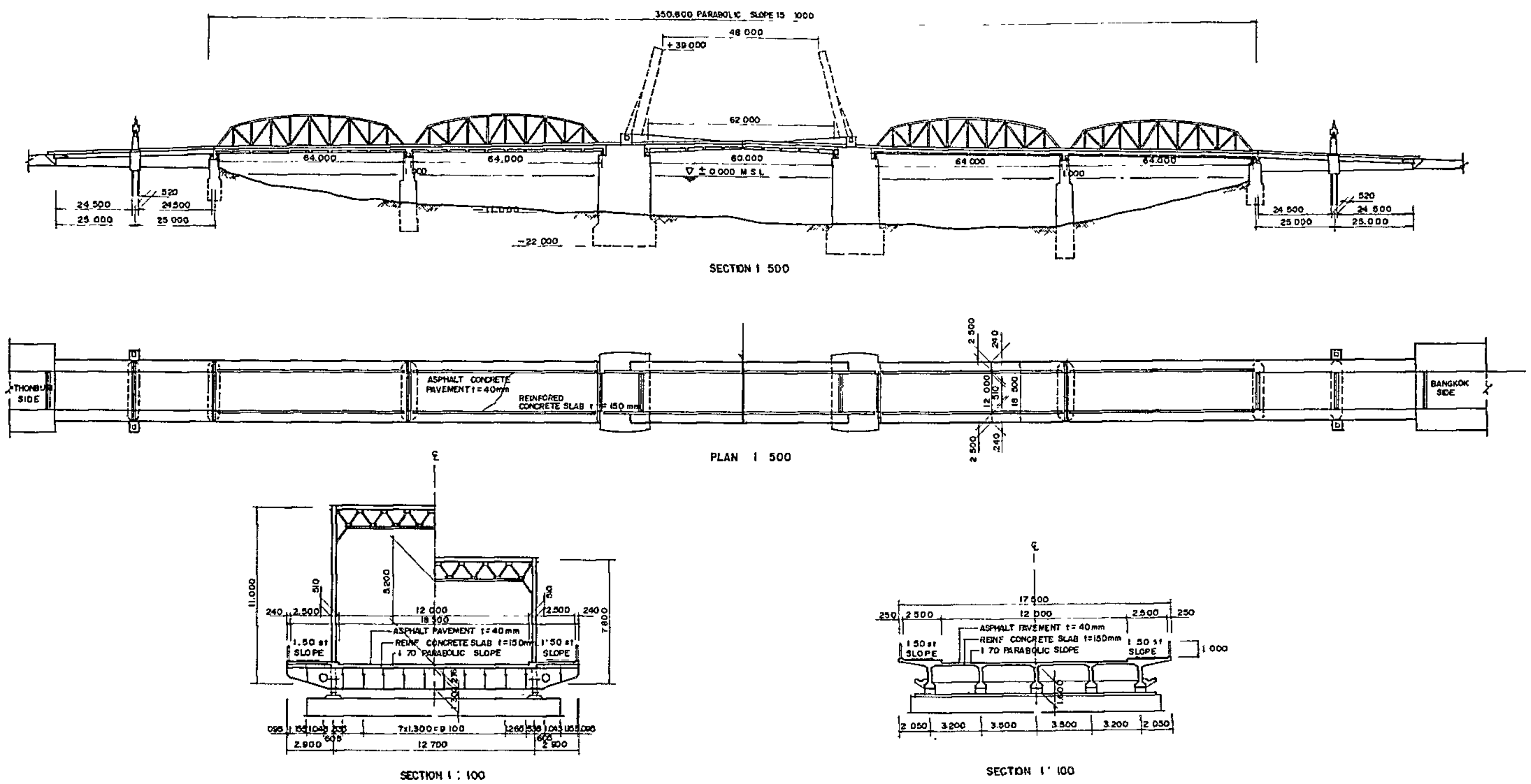

Fig. 1–4

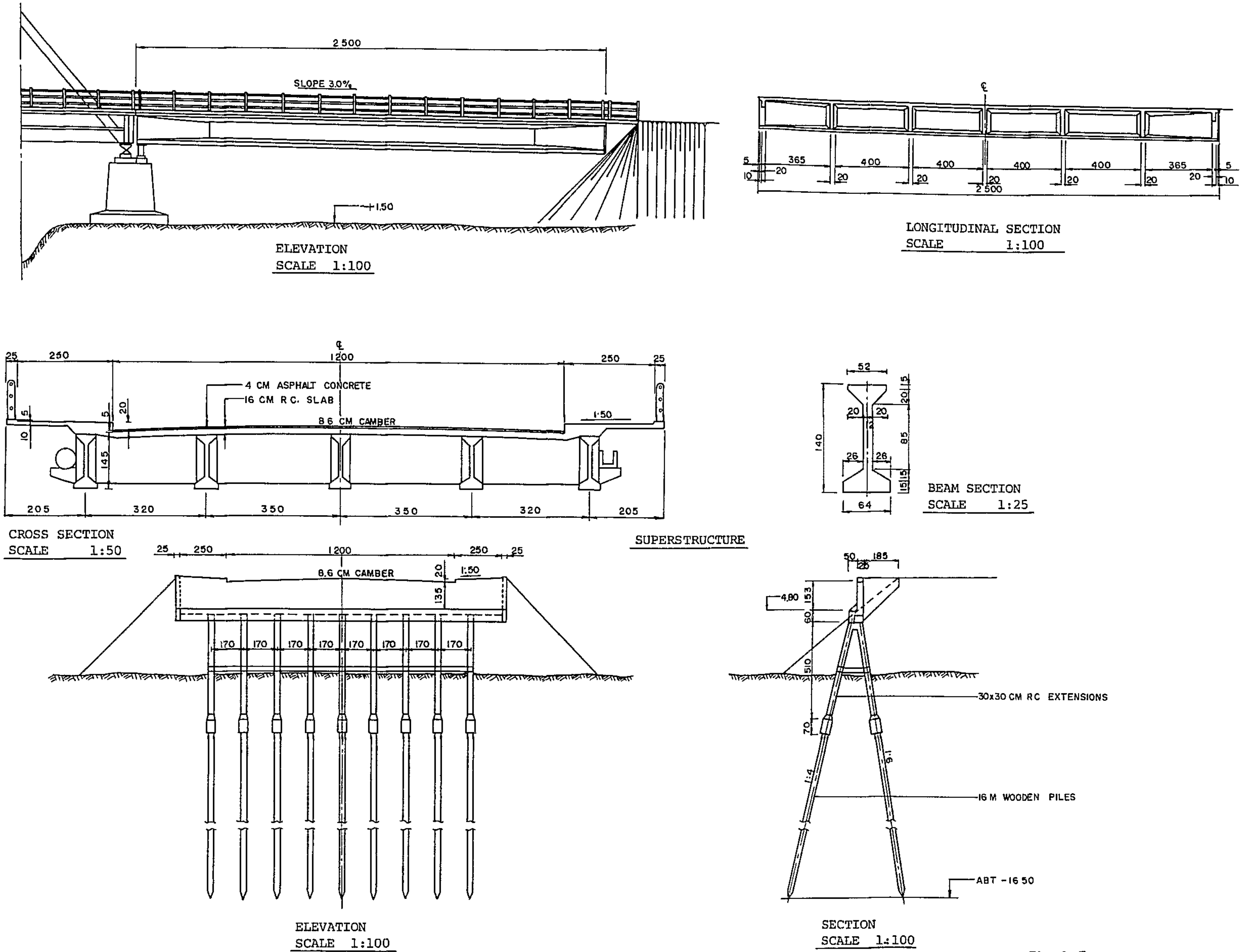
2 500
SLOPE 3.0%
+1.50
ELEVATION
SCALE 1:100
LONGITUDINAL SECTION
SCALE 1:100
365
400
400
400
400
365
2 500
4 CM ASPHALT CONCRETE
16 CM R.C. SLAB
8.6 CM CAMBER
1200
250
25
205
320
350
350
320
205
CROSS SECTION
SCALE 1:50
SUPERSTRUCTURE
BEAM SECTION
SCALE 1:25
52
64
140
85
8.6 CM CAMBER
170
ELEVATION
SCALE 1:100
ABUTMENT
30x30 CM R.C. EXTENSIONS
16 M WOODEN PILES
ABT -16.50
SECTION
SCALE 1:100

Fig. 1–5

CHAPTER 2

PURPOSES AND CONTENTS OF THE STRENGTHENING AND REHABILITATION STUDY

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PURPOSES AND CONTENTS OF THE STRENGTHENING AND REHABILITATION STUDY

2—1 Purpose of the Strengthening and Rehabilitation Study

Once constructed, the periodic inspection of bridges was prone to be neglected, due to the difficulties of access inherent to the places where this kind of structure is constructed. Particularly in bridges constructed over large rivers and over the sea, the tendency of negligence is more pronounced.

Both the KRUNG THON Bridge and the KRUNG THEP Bridge are designed in accordance with the specification of the Government of the Kingdom of Thailand regarding live loads specified approximately 25 years ago (refer to Figure 4-1.1), and partially in accordance with the Japanese Specifications related to steel road bridges and the Japanese Industrial Standards.

However, as a consequence of the changes in the traffic situation occurring thereafter, particularly increase in the use of large-size vehicles including trailers, etc., excessive stresses have taken place in the floor, slab, stringer, etc., resulting into deterioration of the pavement, occurrence of cracks in the RC floor slabs, etc.

If these cracks remain as they are, rust will take place not only in the reinforcement bars in the floor slab but also in the stringers, cross beams, etc., resulting in a considerable impoverishment in its capacity to withstand loads, durability and other parameters determining the overall capacity of the bridge.

Experts dispatched to Thailand in 1970 by JICA carried out studies related to the cracks taking place in the floor slabs in addition to the maintenance and inspection of the electromechanical system for opening and closing of the Bascule Bridge and proposed measures required to cope with the situation prevailing at the time.

After that, a primary repair in the pavement and in the cracks of the floor slab of the KRUNG THON Bridge were carried out based upon the recommendations by the experts mentioned above, but the KRUNG THEP Bridge remained untreated.

The present study on Strengthening and Rehabilitation aims at checking the condition of the pavement and the floor slabs of these bridges after repairing them and at carrying out a preliminary investigation of the whole substructures and superstructures of the bridges. It includes also an examination regarding the capacity of the various members for the increased live load, and also a proposal for their Strengthening and Rehabilitation.

2–2 Contents of the Study

2-2-1 Investigation on the Actual State

The state of the damage taking place in the major members, having harmful effects on the load carrying capacity and durability of the bridge was visually inspected for the following features:

1) Superstructure

   a) State of the pavement and the expansion joints of the bridge.

   b) Cracks and their distributions in the PC beams RC slabs and RC beams of the approach sections and in the deck slabs on the steel beams in the main spans.

   c) State of rusting of the main steel members in the main spans, particularly at the spliced sections, panel points and rivets.

   d) Operating condition of the electromechanical system at the opening and closing of the Bascule span.

   e) State of operation of the bearing shoes of the main beams.

2) Substructure

a) Settlement of the each pier compared with the state prevailing at the time of completion of the bridges.

b) Progress of the scouring of the river bed near each pier.

c) Cracks taking place in the bodies of the each pier.

2-2-2 Study of the New Live Loads

1) Actual state of the live loads.

2) Comparative study of the loads.

2-2-3 Proposal to the Future Surveying, Rehabilitation and Strengthening

1) Examination of the stress of the various members corresponding to the future increase of the live load.

2) Method of strengthening the members with overstress.

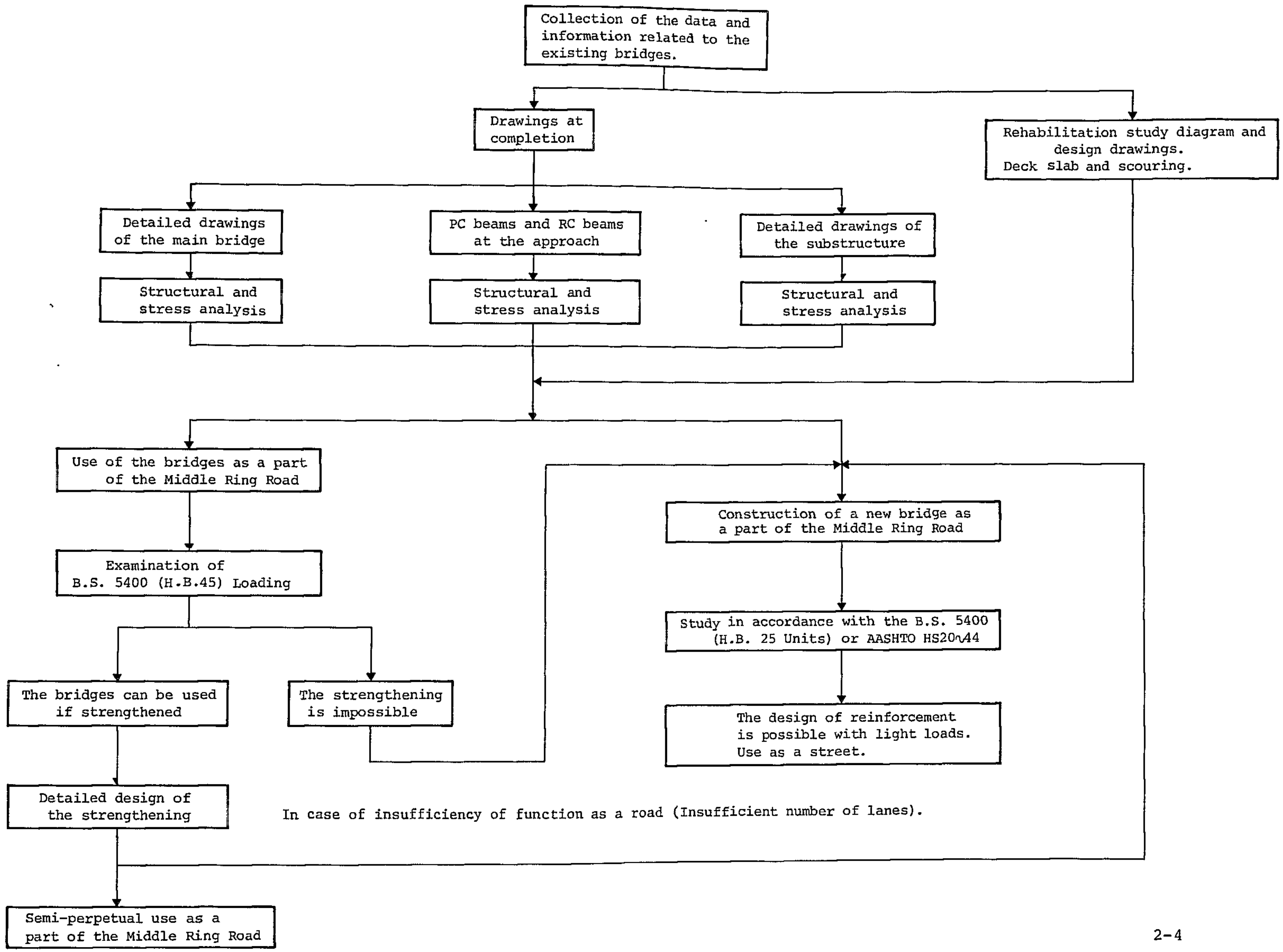
3) Repairing methods of the pavement, the floor slab and expansion joints and measures to cope with the traffic load.

4) Measures preventing the piers located in the river from scouring.

5) Measures to cope with the rusting of the steel members.

6) Other measures related to the durability of the bridges.

2-2-4 Flowchart of the Strengthening and Rehabilitation Study



CHAPTER 3
INVESTIGATION OF THE ACTUAL SITUATION

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3–1 Pavement of the Bridges (Truss Section)

Based upon the recommendations made by the experts dispatched in 1970 to the Kingdom of Thailand by the JICA, carriageways of the KRUNG THON Bridge were submitted to a complete replacement of the pavement in 1972, by means of the overlay method (See Appendix 3-1.1).

Generally speaking, the said repair brought satisfactory results, but as can be seen in the photographs, the covering overlaid on the expansion joint and the coverings on the construction joints of the RC slabs located at the span center of some trussed beam swelled out or resulted in cracks. In addition, parts of the concrete pavement replaced (6 cm thickness) together with the covering near the expansion joints have been recently causing cracks, resulting in the exposure of the reinforcement bars of the pavement. That situation contributes to impoverishing further the comfortable passage of vehicles through the bridges. (Refer to Photo 3-1.1 and Photo 3-1.2).

Partial repairs have been made in the KRUNG THEP Bridge, but generally speaking, it is uneven because the pavement has not undergone a complete repair so far.

As shown in Figure 3-3.2 through Figure 3-3.5, the concrete block pavements on the footpath of the KRUNG THON Bridge and KRUNG THEP Bridge present cracks everywhere, but they do not cause hindrances to the pedestrian flow. (Refer to Photo 3-1.3 through Photo 3-1.6).

3–2 Expansion Joints

It is not possible to know the present state of the expansion joints of the carriageway of the KRUNG THON Bridge because they are overlaid with asphalt. However, as for the

footpath, there are 3 or 4 deteriorated portions where the face plates are torn off.
(Refer to Photo 3-2.1 and Photo 3-2.2).

In the KRUNG THEP Bridge, some expansion joints located at the cantilever end of the Bascule Bridge are loose, but in general they are in satisfactory condition, both in the footpaths and in the carriageways.
(Refer to Photo 3-2.3 through Photo 3-2.6).

3-3 Floor Slabs

As shown in Figure 3-3.1, in the Trussed Beam Section, a 15 cm thick RC floor slab is continuously supported with stringers arranged at intervals of 1.3 m.

Based upon the recommendations presented in 1970, the KRUNG THON Bridge was submitted to a strengthening aimed at preventing the extension of the cracks and the rusting of the reinforcement bars. The said strengthening was carried out in 1971 by injecting epoxy resin into the cracks taking place at that occasion (maximum width of 0.2 mm).

Based upon the crack investigation drawings prepared at that time, follow-up investigations were carried out at this time, by selecting the most typical parts. However, these investigations did not reveal evidence of the subsequent progressive extension of the cracks existing at that time nor the occurrence of new cracks.
(Refer to Figures 3-1.2, 3 and 4 and Photo 3-3.1 through Photo 3-3.4).

3-4 Stringers and Cross Beams

Generally speaking, both stringers and cross beams are in satisfactory condition. However, the cross beams under the construction joints of the RC floor slabs and the neighbouring stringers related to them present some rust in the upper flange. As a result, the floor slabs located on the cross beams are floating off the upper flanges.

The rivets of the stringer and cross beams presents little rust. However, some rust can be observed in the intermediate beams supporting the construction joints of the floor slab and in the end cross beams near the expansion joints.
(Refer to Photo 3-4.1 through Photo 3-4.6).

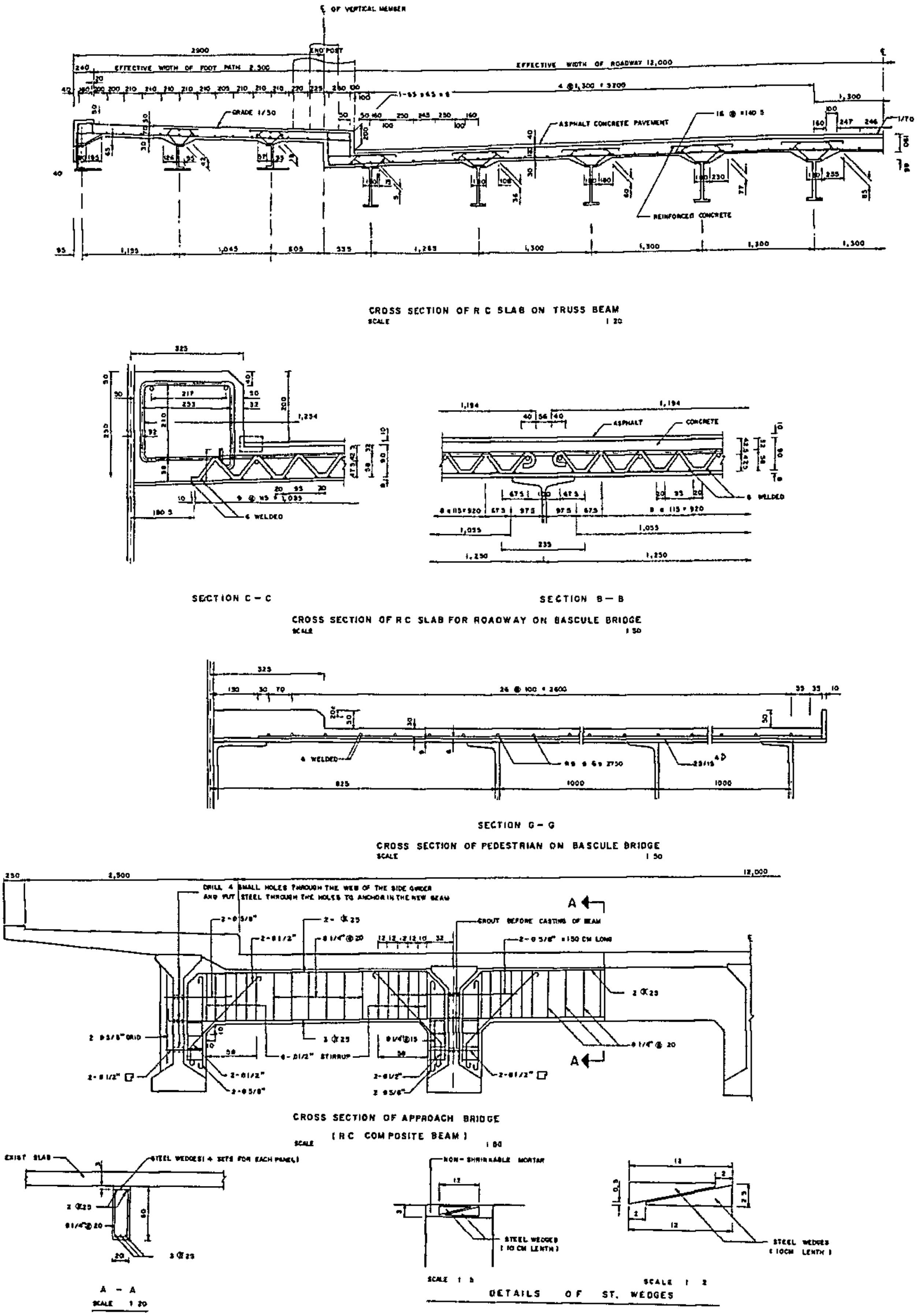


Fig. 3–3.1 EXISTING FLOOR SLABS ON THE TRUSSED BEAM, BASCULE BRIDGE AND PC COMPOSITE BEAM OF THE APPROACH BRIDGE

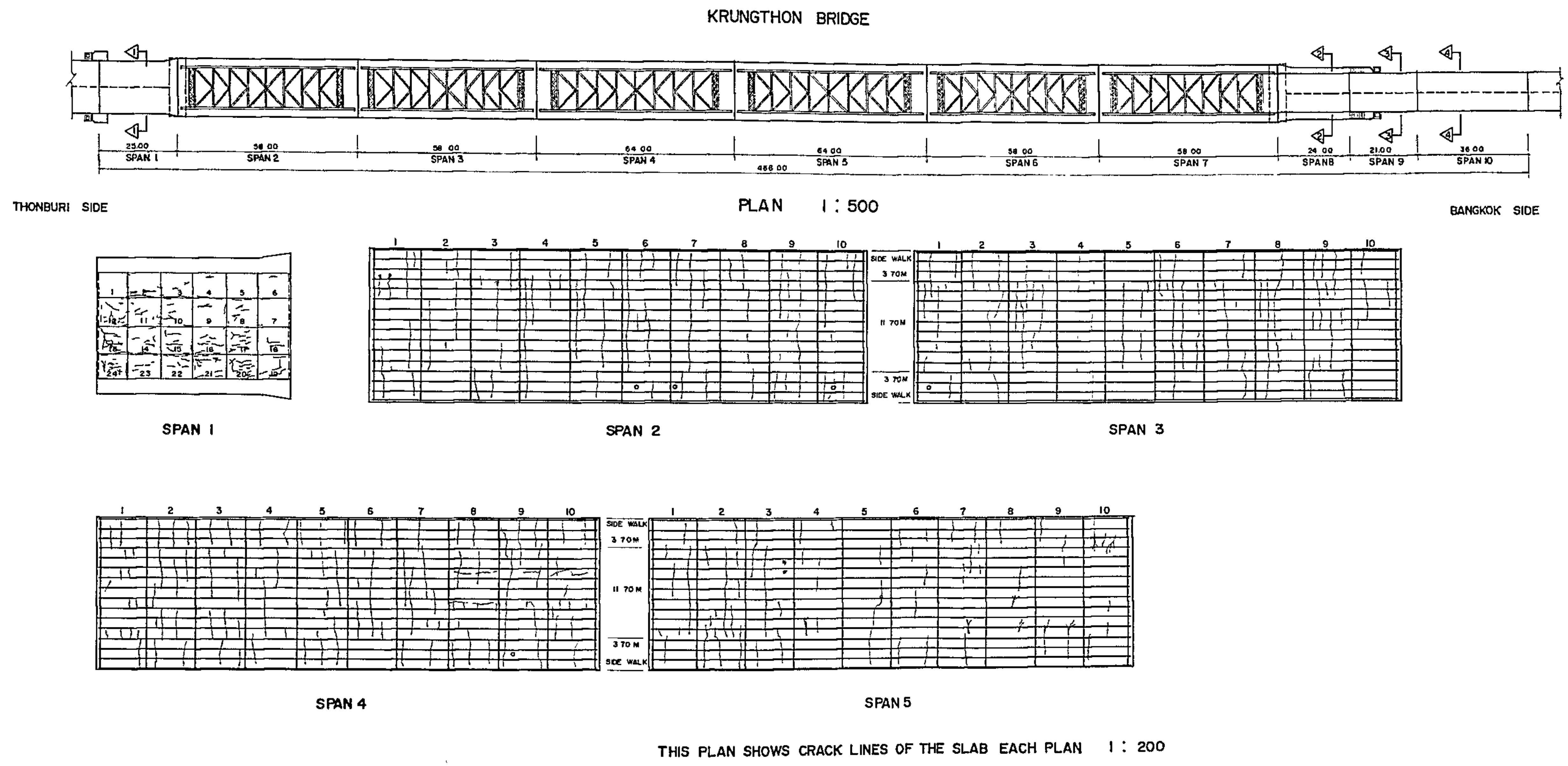


Fig. 3–3.2 CRACKS DEVELOPED ON THE CONCRETE FLOOR SLABS OF THE MAIN AND APPROACH BRIDGE – KRUNG THON BRIDGE

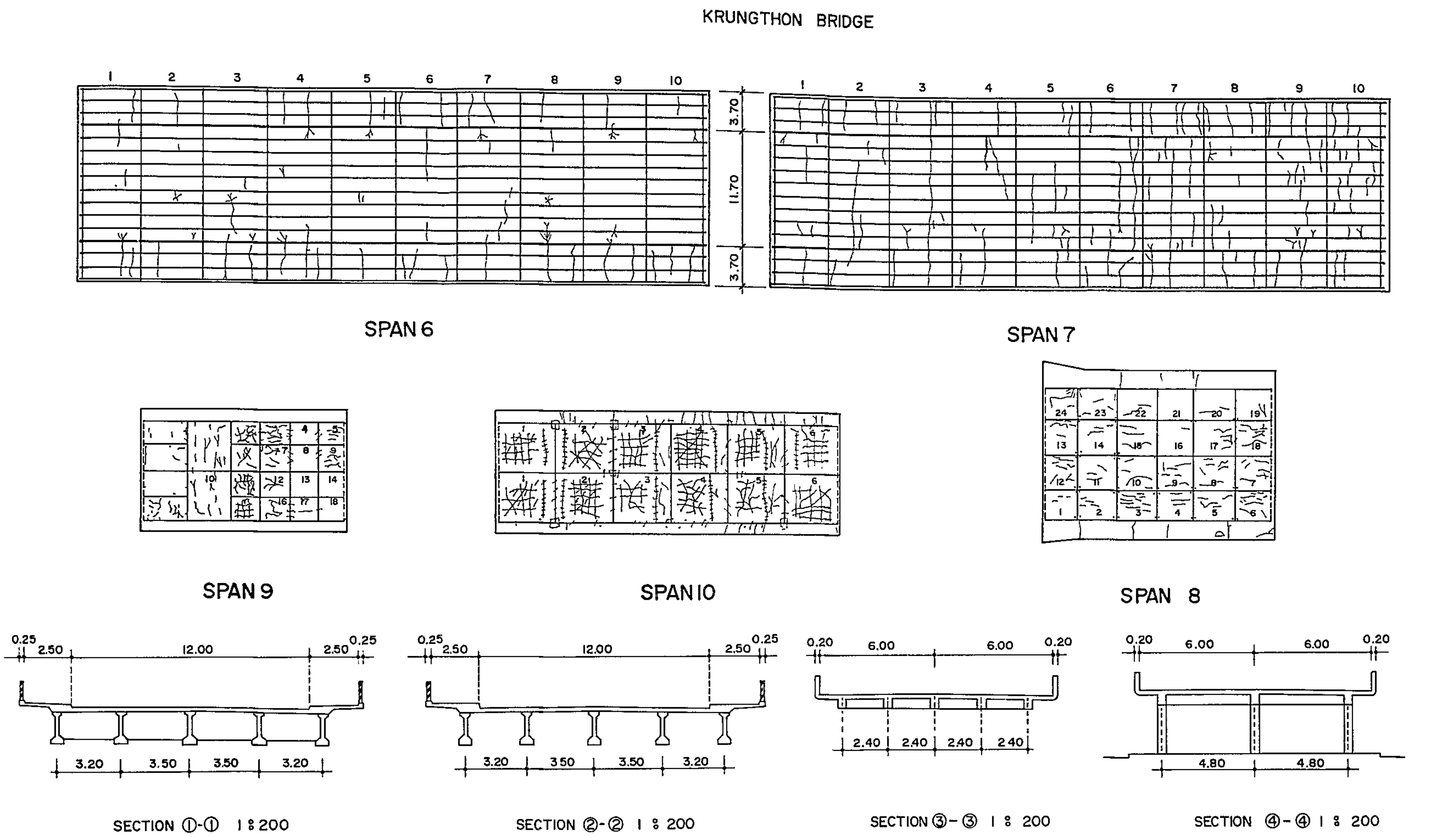


Fig. 3-3.3 CRACKS DEVELOPED ON THE CONCRETE FLOOR SLABS OF THE MAIN AND APPROACH BRIDGE – KRUNG THON BRIDGE

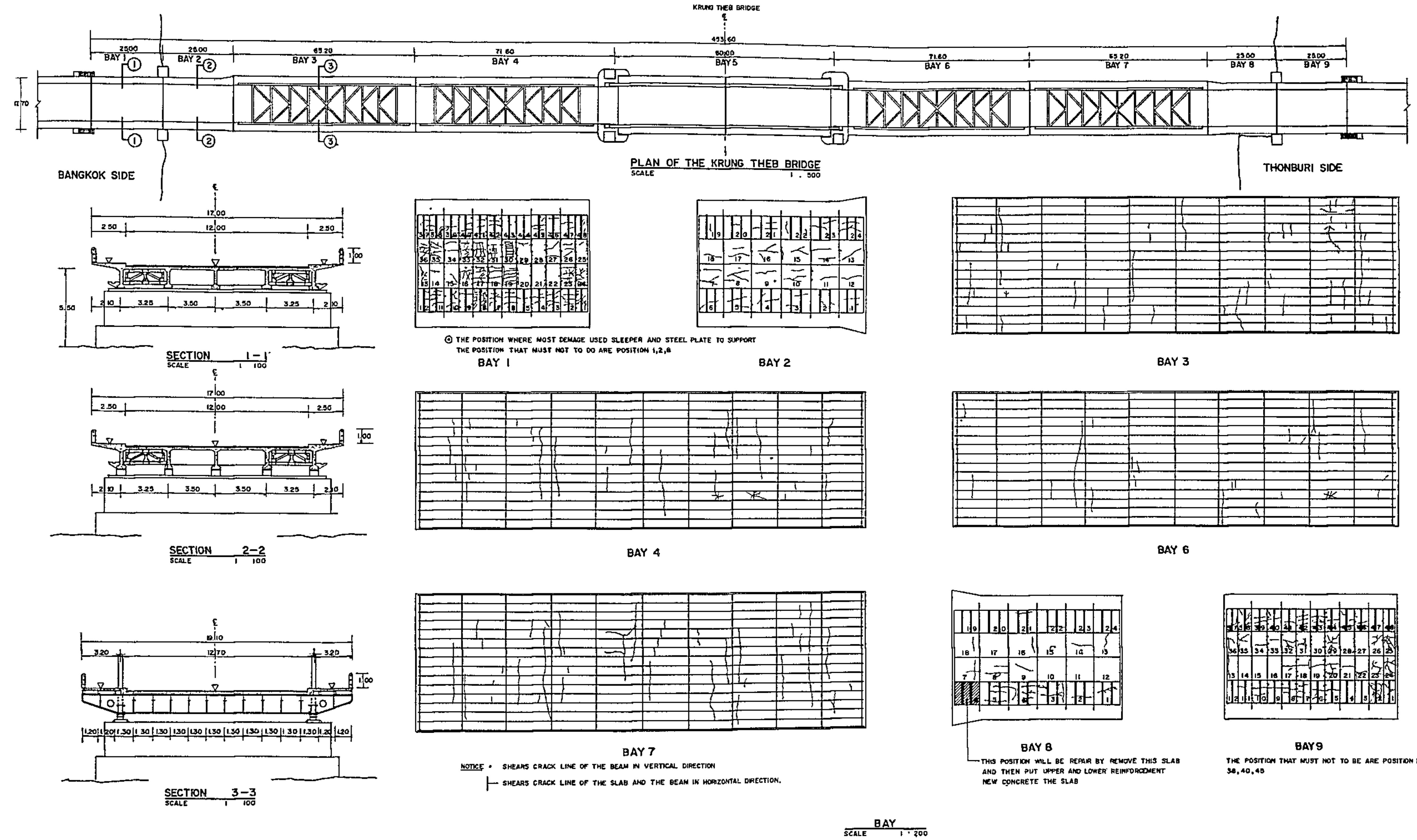


Fig. 3–3.4 CRACKS DEVELOPED ON THE CONCRETE FLOOR SLABS OF THE MAIN AND APPROACH BRIDGE – KRUNG THEP BRIDGE

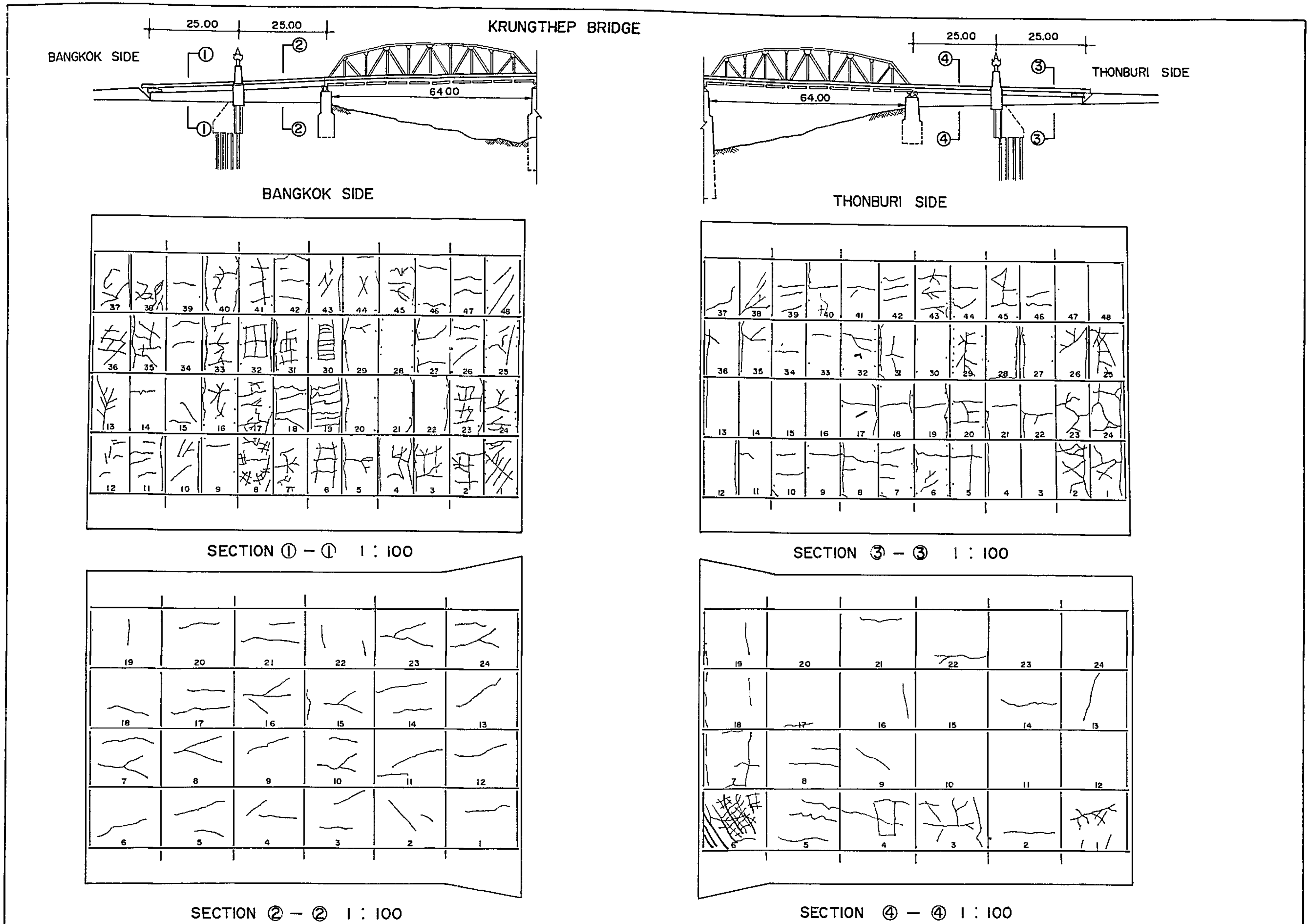


Fig. 3–3.5 CRACKS DEVELOPED ON THE CONCRETE FLOOR SLABS OF THE APPROACH BRIDGE – KRUNG THEP BRIDGE

3-5 Main Structure, Sway Bracing and Upper and Lower Lateral Bracing

The members such as main structure, sway bracing, upper lateral bracings, etc., located above the carriageway were visually inspected with binoculars. Problems such as deterioration of the painting, rusting of the steel structures, etc., were not observed in this visual inspection.

Partially damaged sections caused by collisions of large trucks or trailers were observed in part of the cover plates of the end post of the trusses with large member width in a few places, particularly in the KRUNG THON Bridge.
(Refer to Photo 3-5.1 through Photo 3-5.6).

Also in the KRUNG THEP Bridge, a pronounced twisting of the vertical member caused by a vehicle collision was observed at the Thonburi Side.
(Refer to Photo 3-5.1)

In the main member located under the floor slab, particularly near the supporting points exposed to the rainwater, a serious formation of rust was observed.

At the other lower lateral bracings, gusset plates, etc., considerable progress of local rusting was also observed.
(Refer to Photo 3-5.8 through Photo 3-5.10).

3-6 Bascule Bridge

3-6-1 Pavement and Floor Slabs

The pavement and the floor slabs of the bascule bridge are as shown in Photo 3-6.1. The asphalt covering (10 mm thick) is almost completely worn out, resulting in the exposure of the RC floor slab under it.

There are holes everywhere in the RC slab, and it is presumed that rainwater is infiltrating into the steel plates under the said slabs. It is not possible to know the actual state of the upper face of the steel plates because they are covered by the RC slabs, but the lower face was not rusted, except near the expansion joints. (Refer to Photo 3-6.1).

3-6-2 Stringer, Cross Beams and Lower Lateral Bracings

The whole upper face of the stringers are covered with steel plates, and they are in satisfactory condition, with no rust at all, because there is no infiltration of rain-water.
(Refer to Photo 3-6.2 through Photo 3-6.4).

3-6-3 Main Beams

The main beams are not rusted either above or below the floor slab. However, near the machine room and at the side faces near the splice part, formation of rust was observed, and in some cases 30% to 50% of the rivet head was lost.
(Refer to Photo 3-6.7 and Photo 3-6.8).

3-6-4 Opening and Closing Operation System and Shear Key

The opening and closing operation of the Bascule Bridge is carried out every day at 6 a.m. In addition, it can be opened at 10 a.m. or 2 p.m. at request by ships in advance.

Presently, the machinery is operating without trouble, and each opening and closing operation required approximately 3 minutes respectively.

However, the shear key located at the span center presents the eccentricity as shown in Figure 3-6.1.

In addition, the clearances between rear key and bascule beam end is 15 mm and 45 mm at upstream and downstream sides in both machine rooms on the Bangkok side and on the Thonburi side.

In addition, a big crack opened 4 years ago at the lower side of the RC cantilever floor slab where the rear key is located, in the Thonburi side machine room.

There is the strengthening with an H-beam aimed at coping with the said crack.
(Refer to Photo 3-6.9 through Photo 3-6.12).

3–7 Bearing Shoes

Bearing shoes at the fixed support of the trussed beam and the Bascule Bridge do not present any damage, rust, etc. Also the bearing shoes at movable support do not present any apparent damage and rust. The rollers and other parts located in the interior of the covering are presumed to be producing rust.
(Refer to Photo 3-7.1 and Photo 3-7.2).

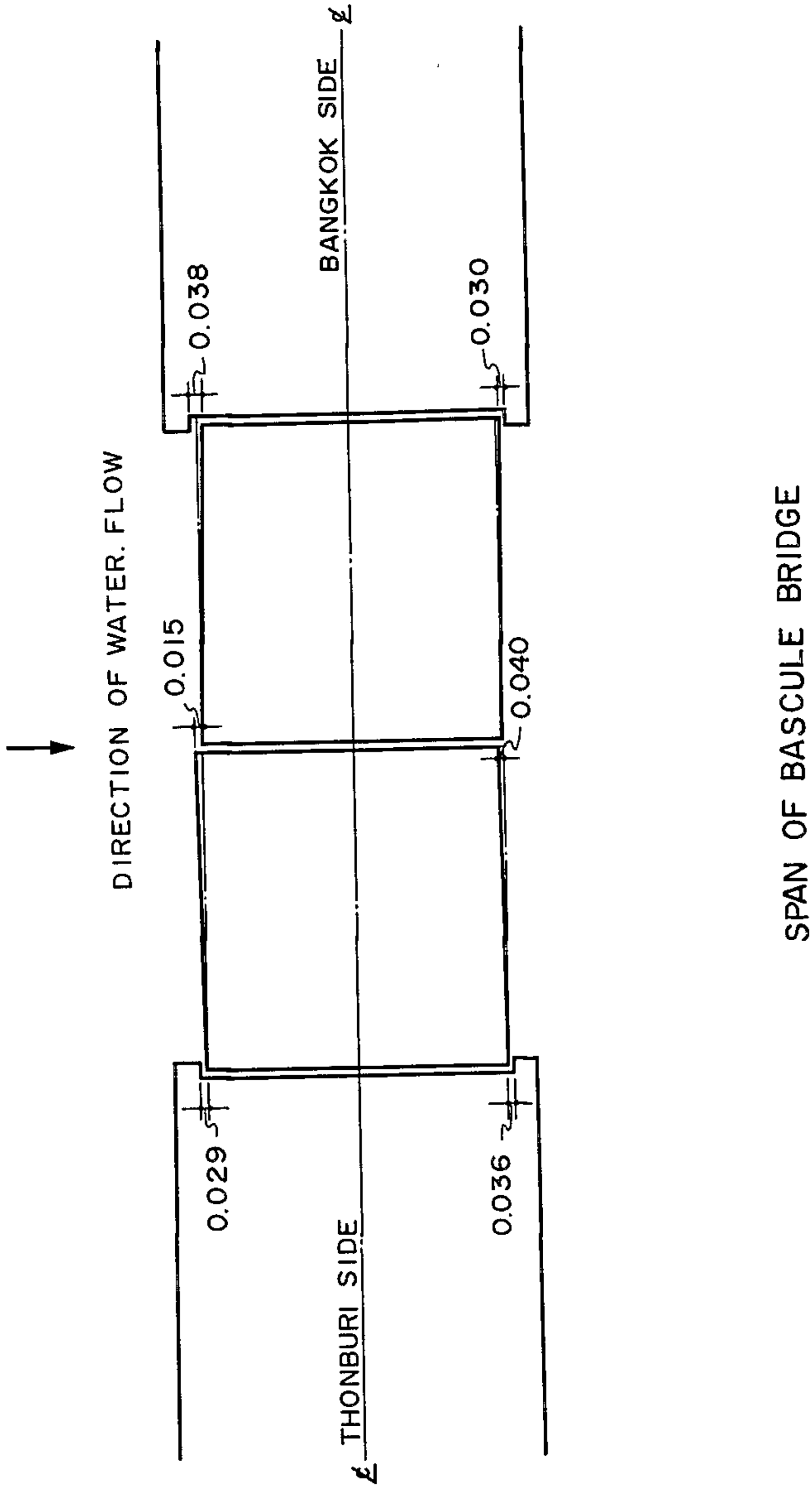


Fig. 3–6.1 PLANE SHIFT VALUES AT THE EACH POINT WHEN THE BRIDGE IS CLOSED

3-8 Approach Bridge

3-8-1 KRUNG THON Bridge

As can be seen in Figure 1-3 and Figure 3-5.5, the Bangkok side of the KRUNG THON Bridge is a combination of simple PC composite beams (span 24.500 M) and 2 continuous spans of RC-T-shaped beam rigid-frame bridges (spans 4.300 M + 12.000 M), in addition to 6 continuous spans of RC-T-shaped beam rigid-frame bridges (span 6 x 6.000 M). On the other hand, the approach on Thonburi side is composed of a single span of simply supported PC composite beams (span 24.500 M) and the bankings.

The results of examination of the cracks taking place in these RC slabs are shown in Figure 3-3.2 and Figure 3-3.3.

Particularly the RC-T-rigid-frame beams extending over 6 continuous spans have a slab thickness of only 20 cm which is very slender compared with the spacing of 4.800 M between the main beams as shown in Fig. 3-8.1. The cracks taking place in that section are quite serious, forming a fine "net" of cracks. The said part of the bridge is in a dangerous state, and at the end of August, 1981, supports were provided temporarily as shown in Fig. 3-8.2, aiming at preventing peeling off. (Photo 3-8.1 through Photo 3-8.6)

3-8-2 KRUNG THEP Bridge

As shown in Figure 1-4, both the Bangkok side and the Thonburi side are composed of 2 spans of simply supported PC composite beams (span of 24.500 M respectively while the remaining parts are bankings.)

The results of the examination of the cracks taking place in these RC slabs are shown in Figure 3-3.4. The fine "net" of cracks has developed particularly at the 1st span at both sides for about 13 years. Accordingly, as shown in Figure 3-3.1 and Figure 3-3.4, cross beams have been provided between the originally existing cross beams, in order to support the floor slab. In addition, temporary supports have been constructed everywhere, aiming at preventing the floor slab peeling off and falling off as shown in Fig. 3-8.3. (Refer to Photo 3-8.7 through Photo 3-8.10)

3–9 Pier and Foundation

The results of the visual inspection of the piers located both in the river and on the land, of both KRUNG THON Bridge and KRUNG THEP Bridge, do not evidence any cracks or other defects.

As for the river bed scouring at the foundations, the results of the examination carried out approximately 2 years ago are shown in Figure 3-9.3 through Figure 3-9.12. (Refer to Photo 3-9.1 through Photo 3-9.4).

Longitudinal cross section surveying was carried out aiming at investigating the unequal settlement of the foundations, but the obtained results shows that no remarkable unequal settlement of piers is taking place. (Refer to Figure 3-9.13 and Figure 3-9.14).

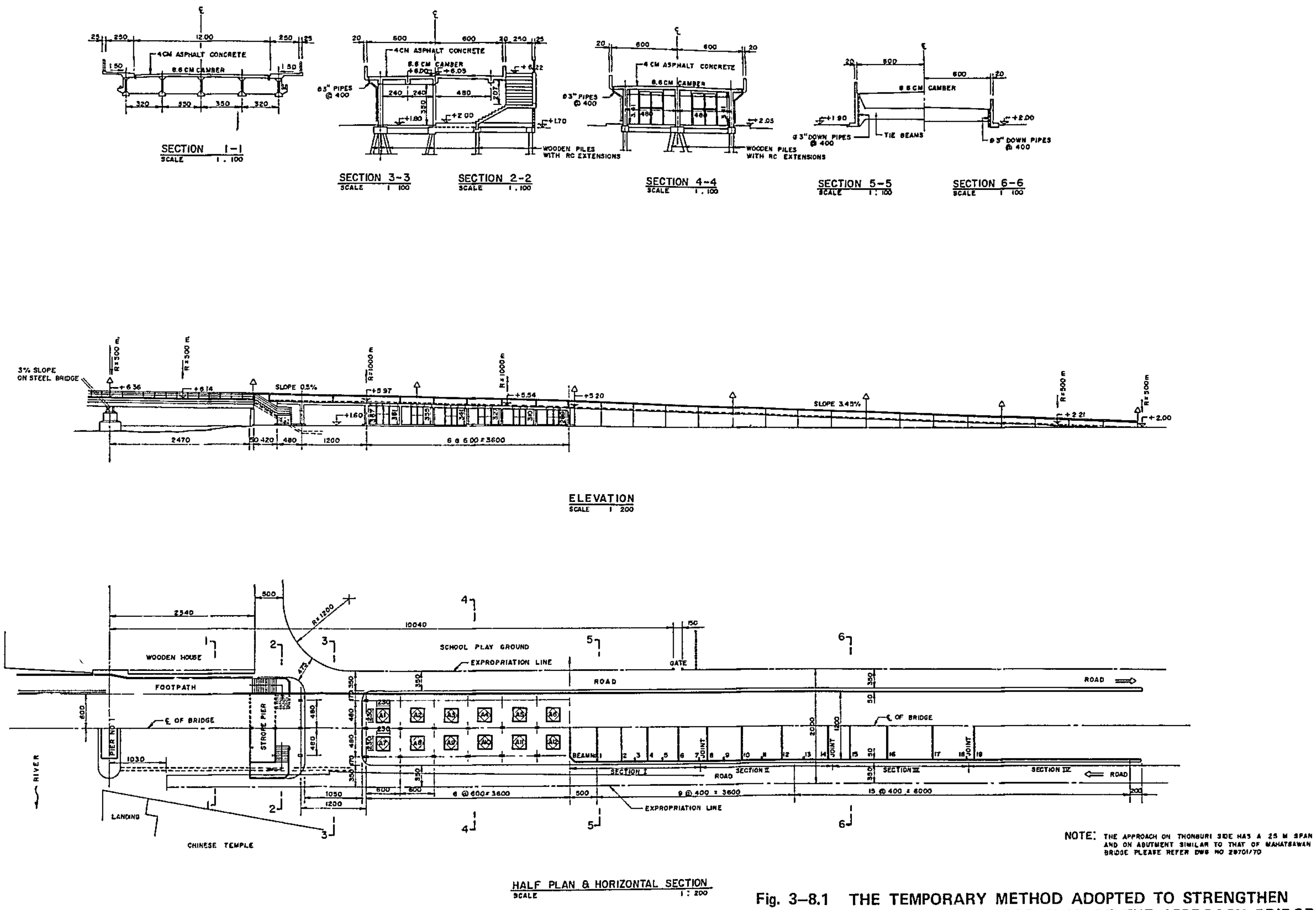


Fig. 3–8.1 THE TEMPORARY METHOD ADOPTED TO STRENGTHEN THE CONCRETE FLOOR SLAB OF THE APPROACH BRIDGE – KRUNG THON BRIDGE

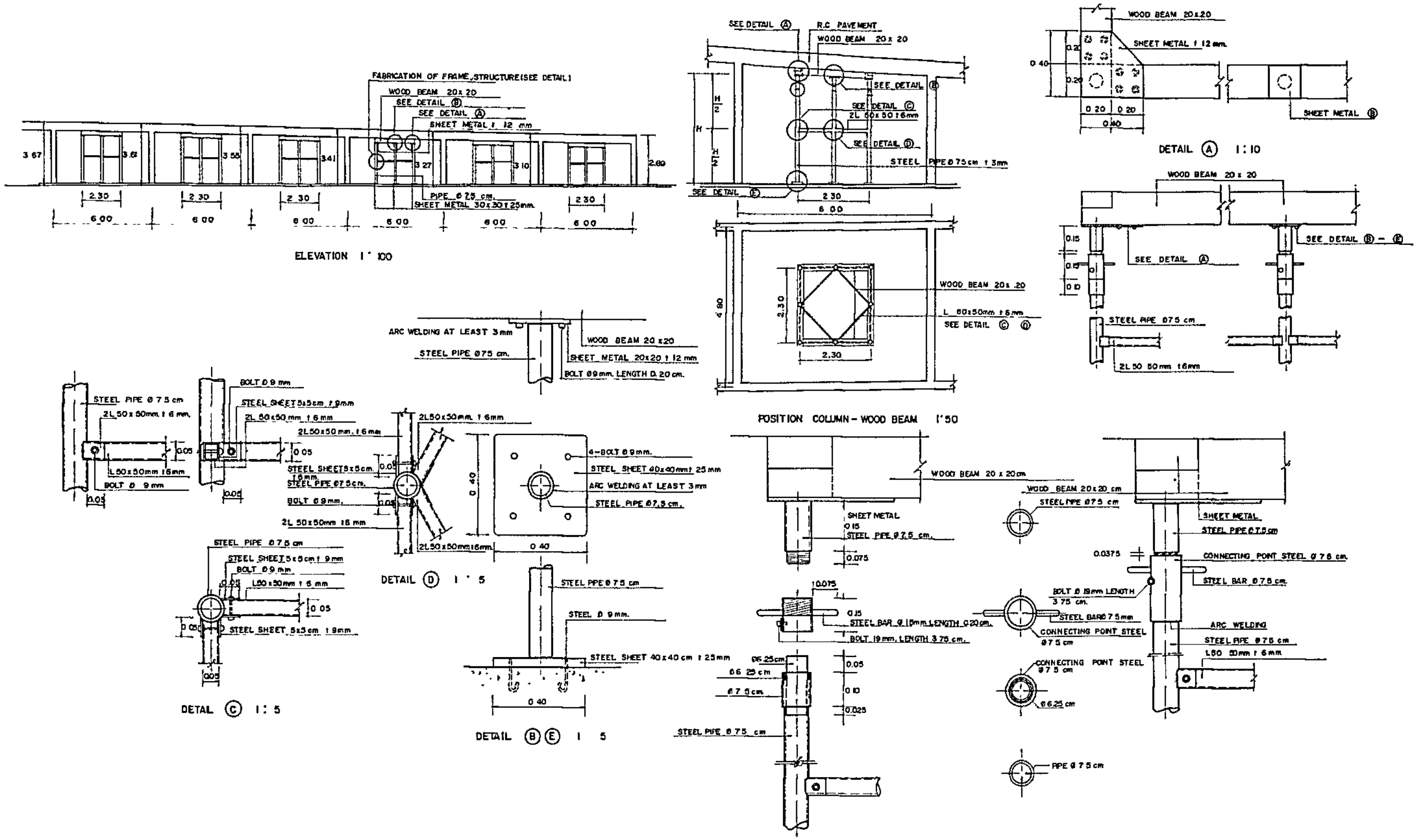
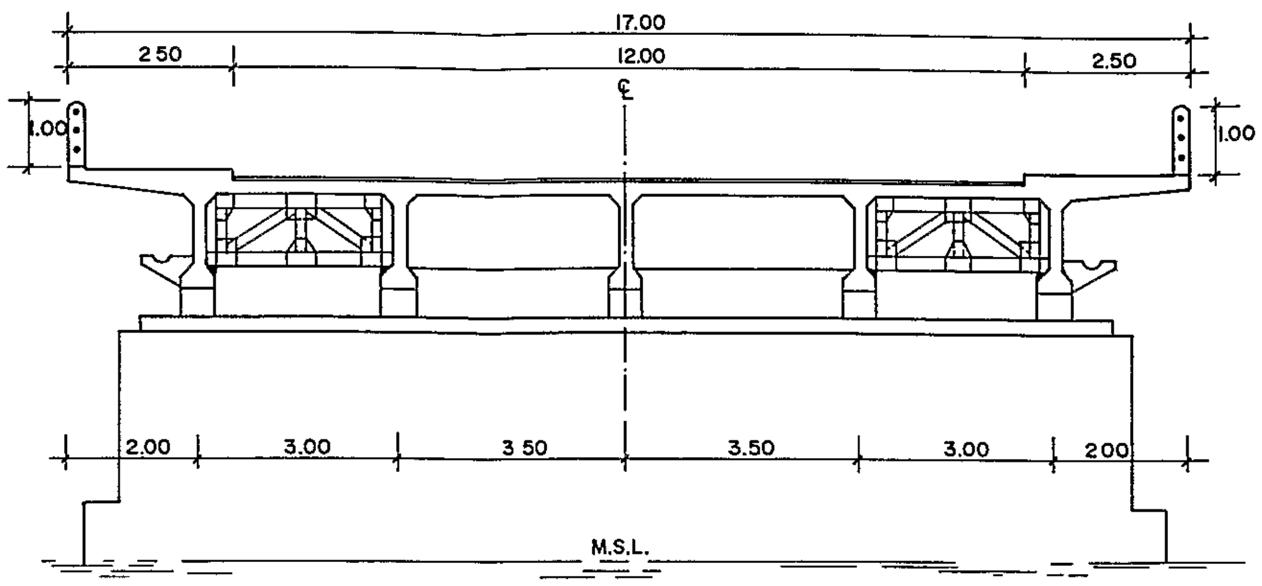
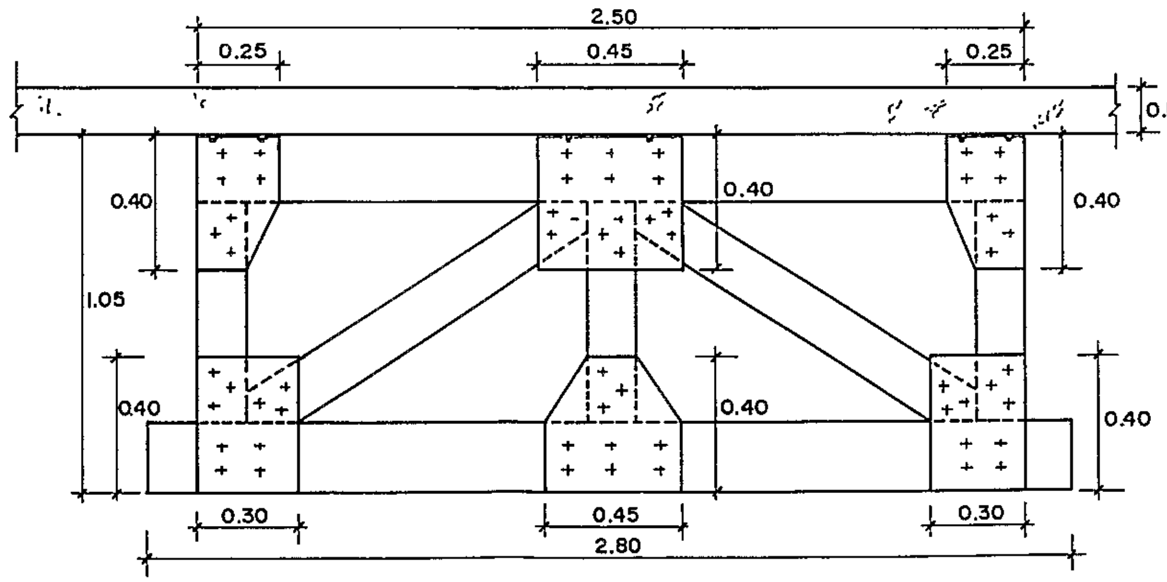


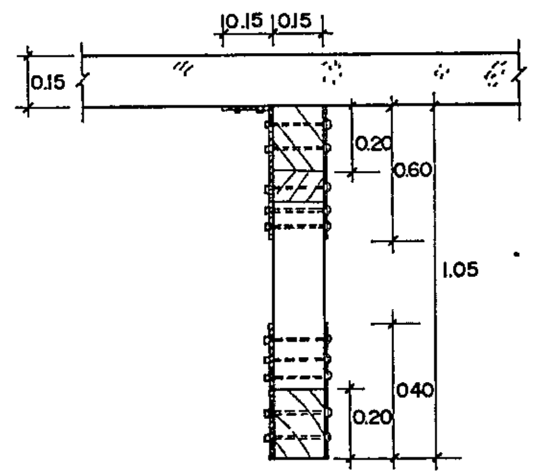
Fig. 3–8.2 THE TEMPORARY METHOD ADOPTED TO STRENGTHEN THE CONCRETE FLOOR SLAB OF THE APPROACH BRIDGE – KRUNG THON BRIDGE



TRANSVERSE CROSS—SECTION OF BRIDGE 1 : 50



SIDE VIEW OF CRACKS ON TIMBER SUPPORT 1 : 10



DETAIL OF SUPPORT 1 : 10

Fig. 3–8.3 THE TIMBERING ADOPTED TO STRENGTHEN THE CONCRETE FLOOR SLABS OF THE APPROACH BRIDGE – KRUNG THON BRIDGE AND KRUNG THEP BRIDGE

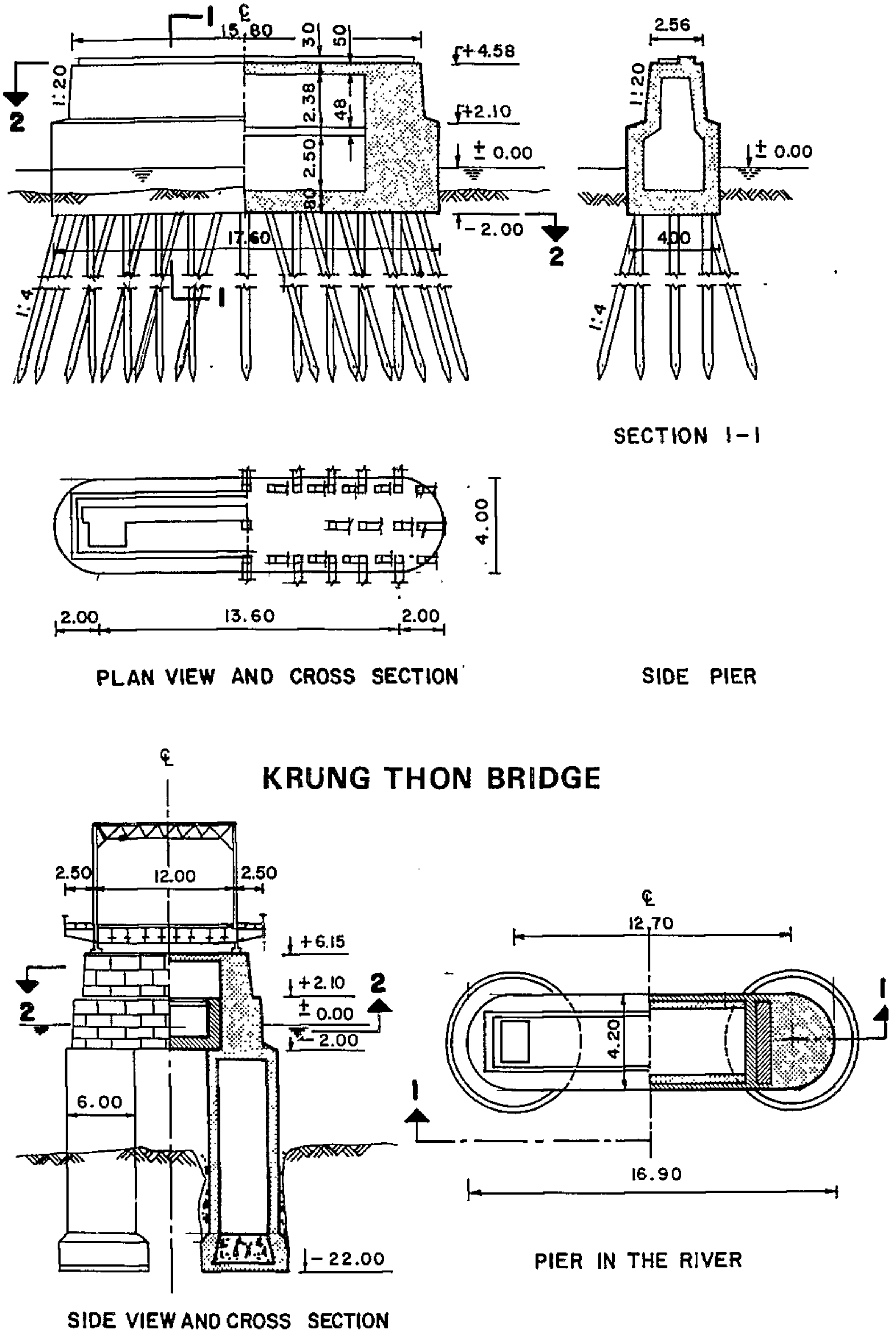
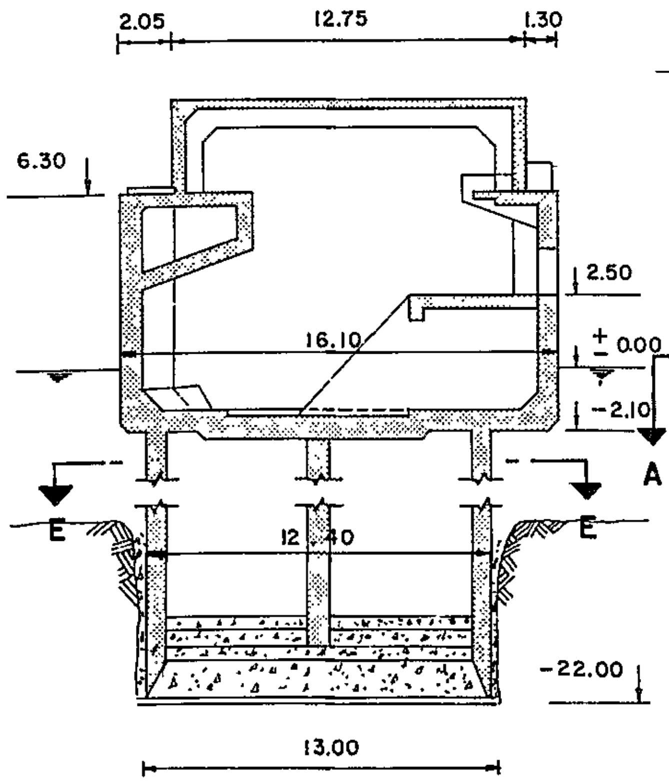
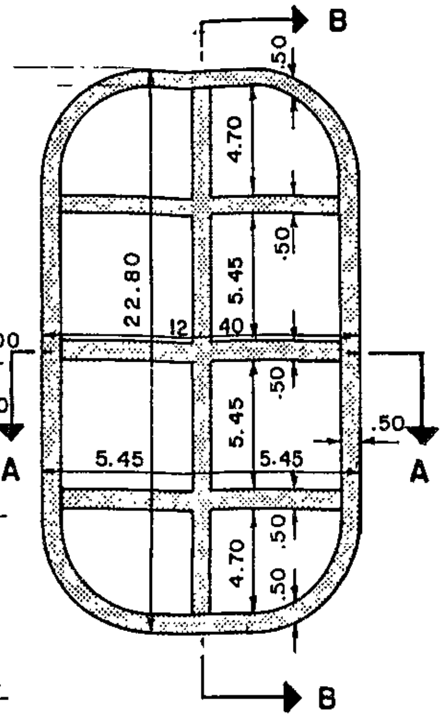


Fig. 3–9.1 THE EXISTING SUBSTRUCTURE OF THE MAIN BRIDGE – KRUNG THON BRIDGE

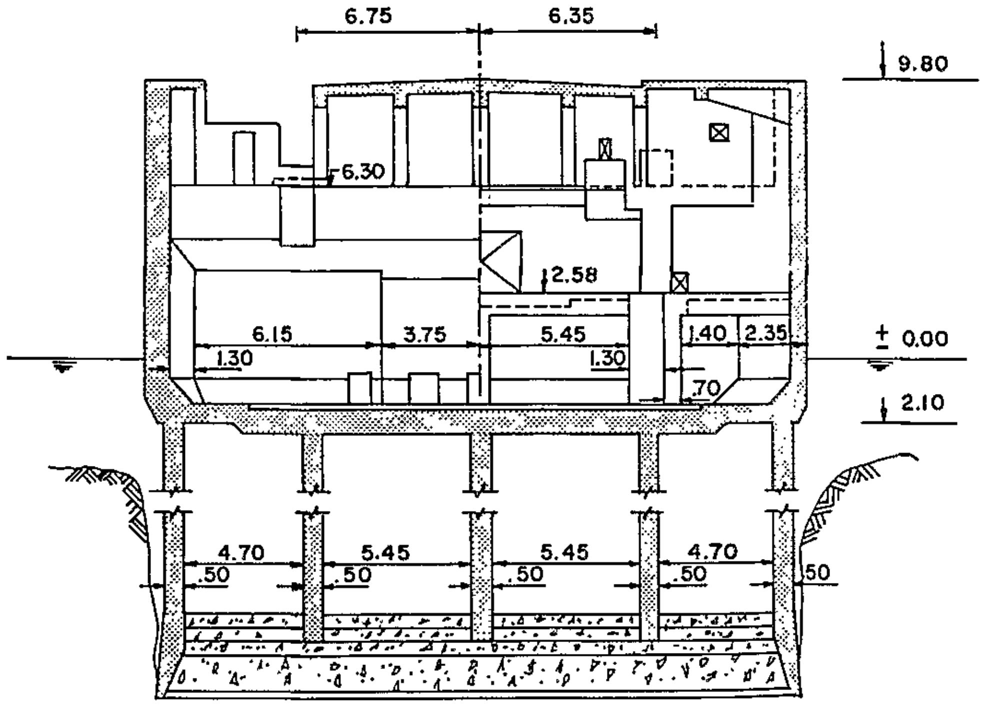
KRUNG THEP BRIDGE





SECTION E-E

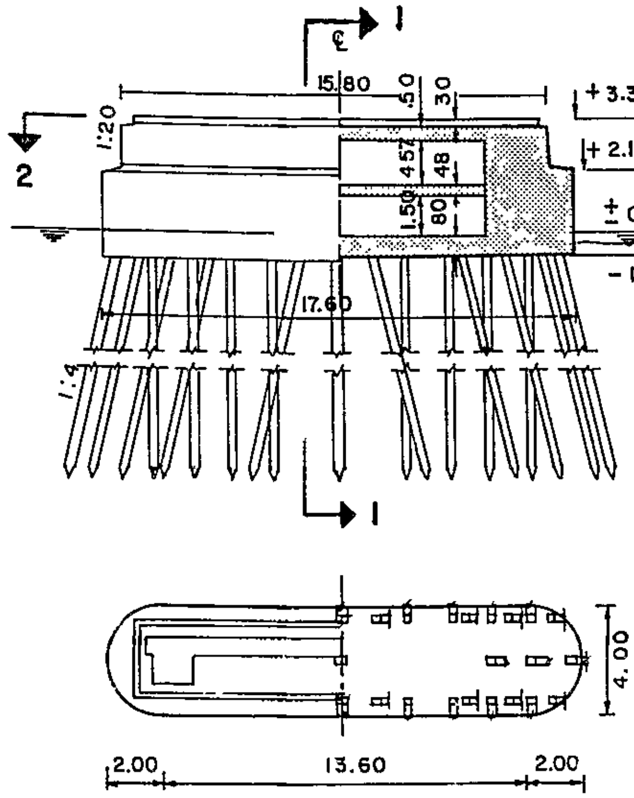
CROSS SECTION OF THE PIER

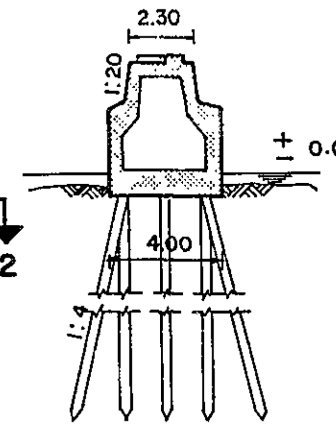


SECTION B – B

CROSS SECTION OF THE PIER

KRUNG THEP BRIDGE

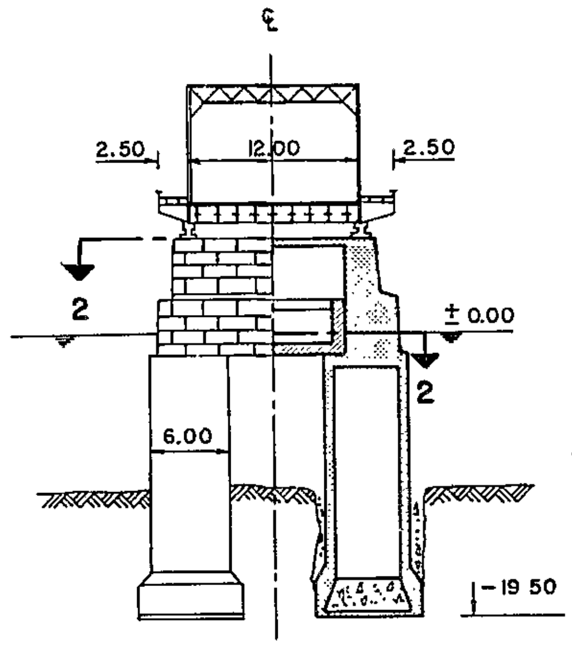


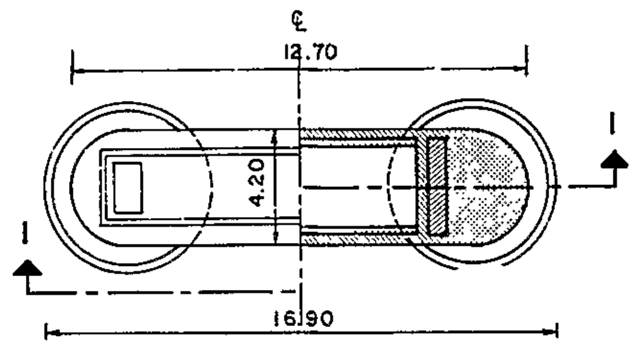


SECTION I-I

SIDE PIER

PLAN VIEW AND CROSS SECTION



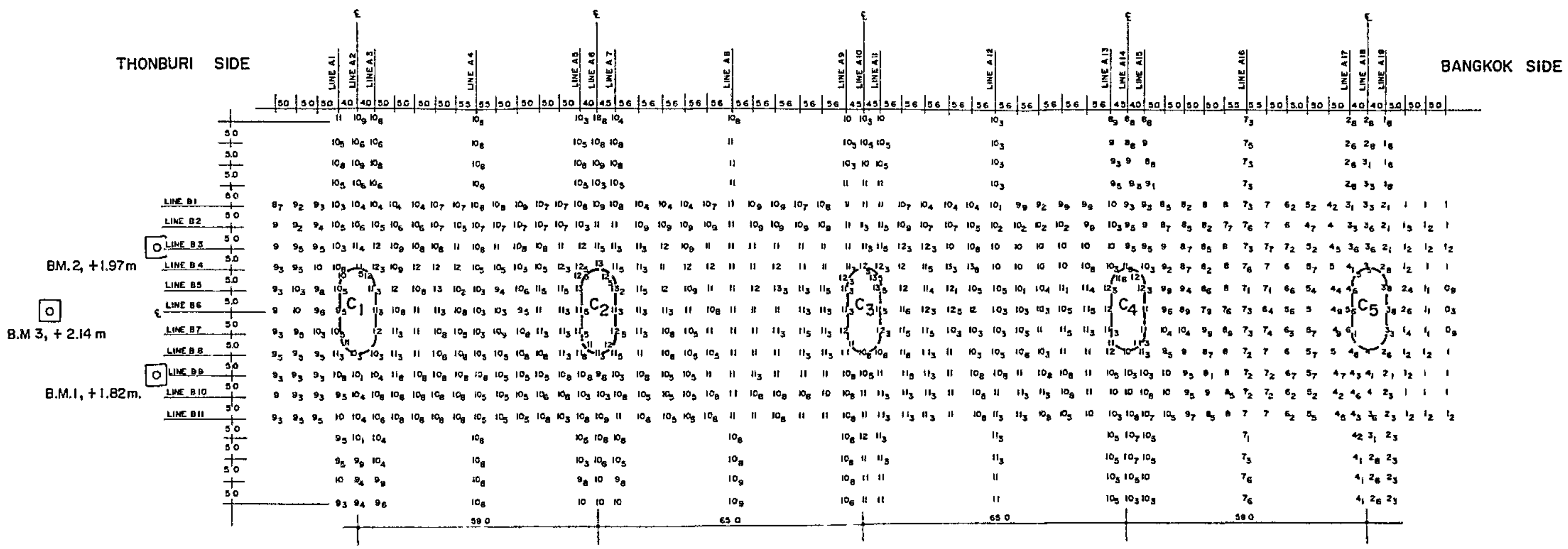


PIER IN THE RIVER

SECTION I-I

SIDE VIEW AND CROSS SECTION

Fig. 3–9.2 THE EXISTING SUBSTRUCTURE OF THE MAIN BRIDGE – KRUNG THEP BRIDGE



SOUNDING IN METERS
REDUCES TO MEAN SEA LEVEL

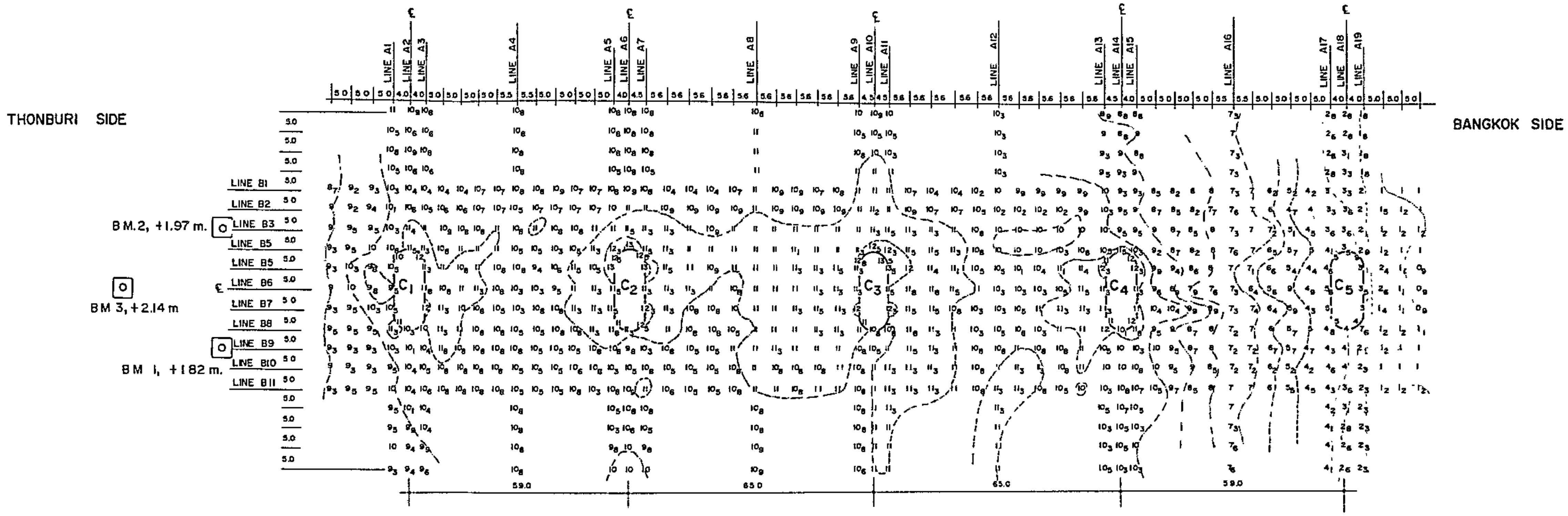
SCALE 1 : 500

10 5 0 1 2 3 40 m

TIDAL DATA HYDROGRAPHIC DEPARTMENT

HIGHEST HIGH WATER	+ 2.42	m
MEAN HIGH WATER	+ 0.92	m
MEAN SEA WATER	+ 0.00	m
MEAN LOW WATER	− 0.25	m
LOWEST LOW WATER	− 1.74	m

Fig. 3–9.3 SPOT ELEVATION ON CHAOPHRAYA RIVER UNDER THE KRUNG THON BRIDGE



CONTOUR DEPTH

- 1 m
- 2 m
- 3 m
- 4 m
- 5 m
- 6 m
- 7 m
- 8 m
- 9 m
- 10 m
- 11 m
- 12 m
- 13 m

SOUNDING IN METERS
REDUCES MEAN SEA LEVEL

TIDAL DATA HYDROGRAPHIC DEPARTMENT

HIGHEST HIGH WATER	+2.42	m
MEAN HIGH WATER	+0.92	m
MEAN SEA LEVEL	±0.00	m
MEAN LOW WATER	−0.25	m
LOWEST LOW WATER	−1.74	m

SCALE 1 : 500

10 5 0 1 2 3 40m

Fig. 3–9.4 CONTOURS CHAOPRAYA RIVER UNDER THE KRUNG THON BRIDGE

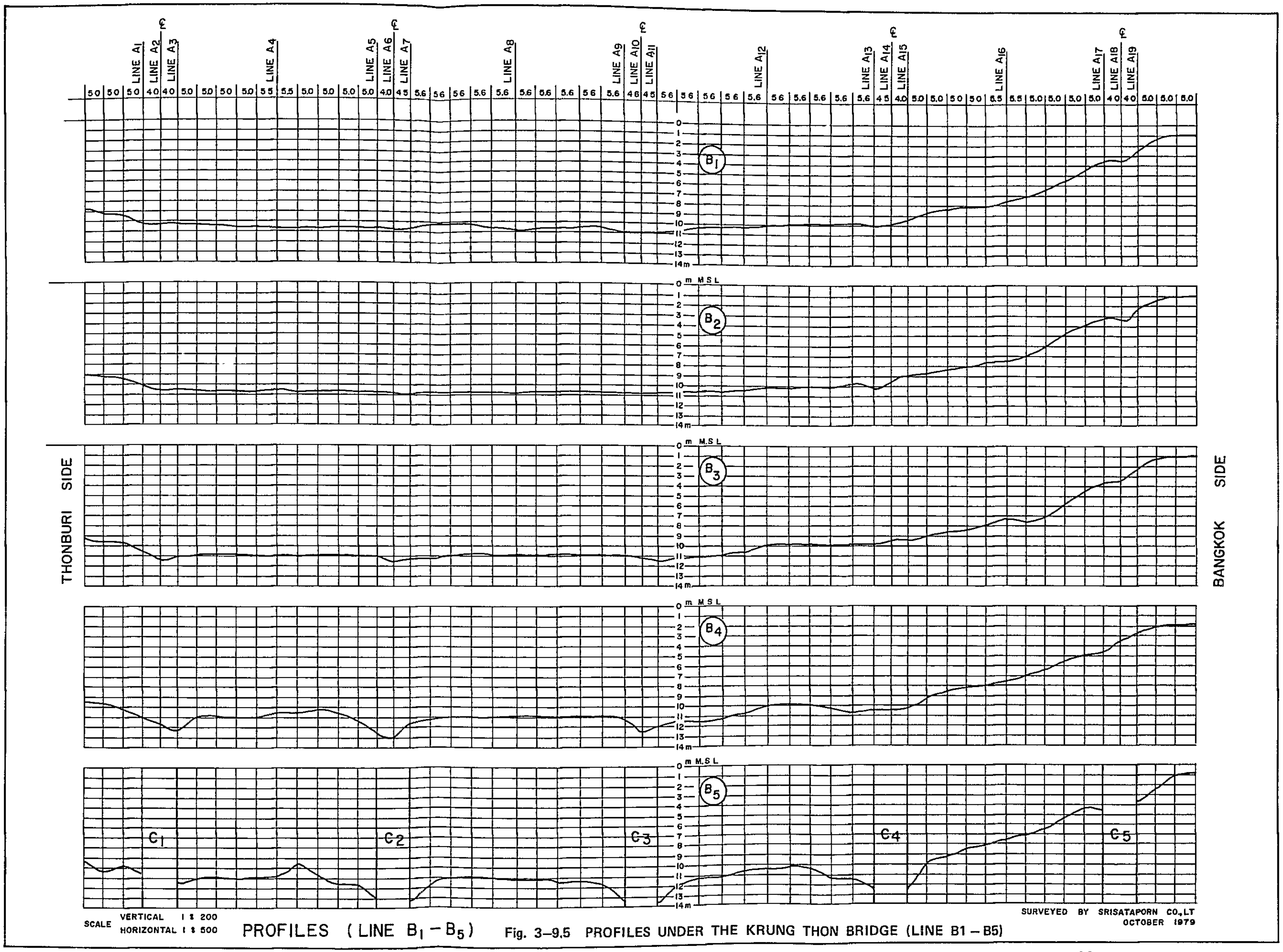
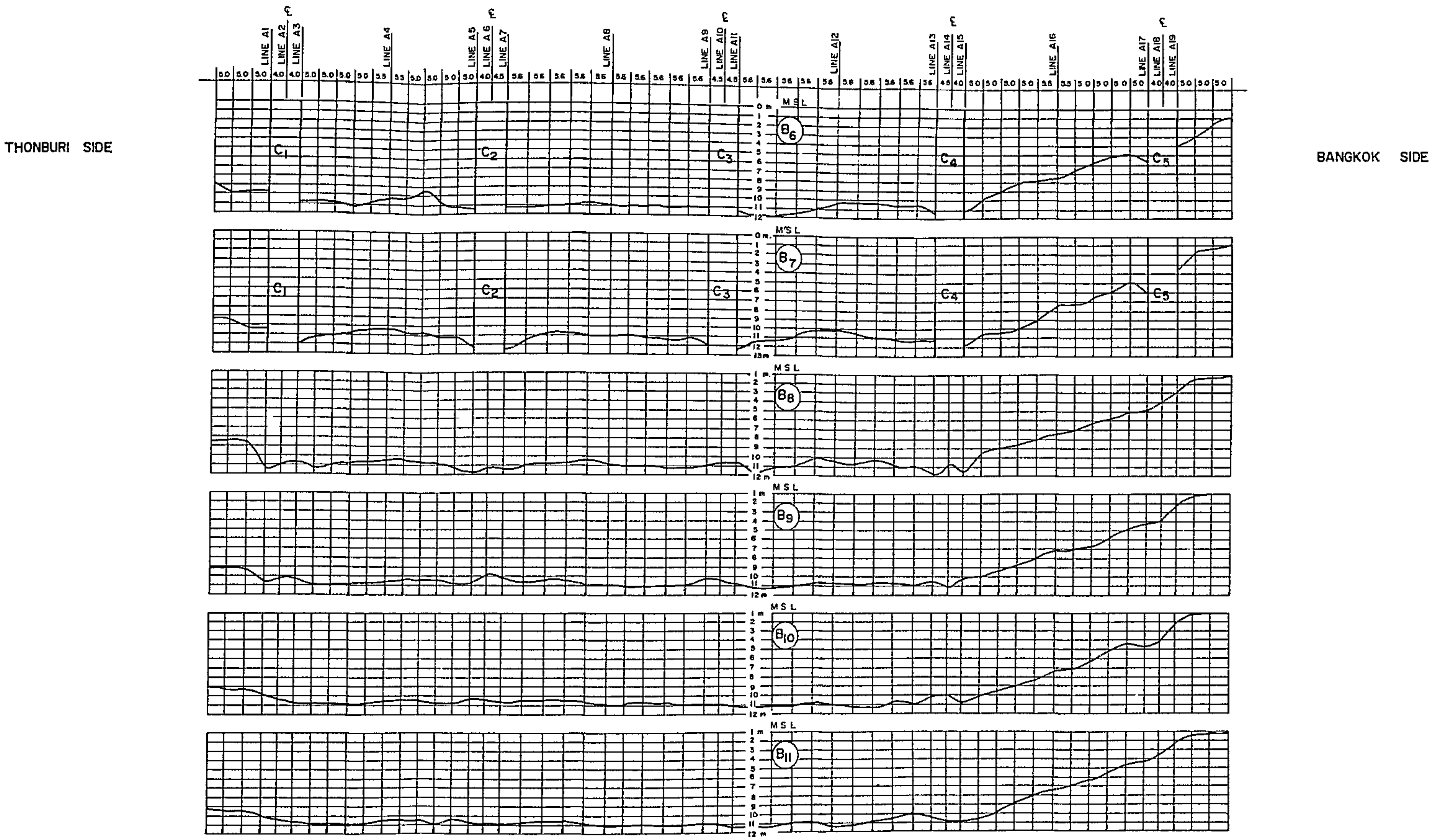


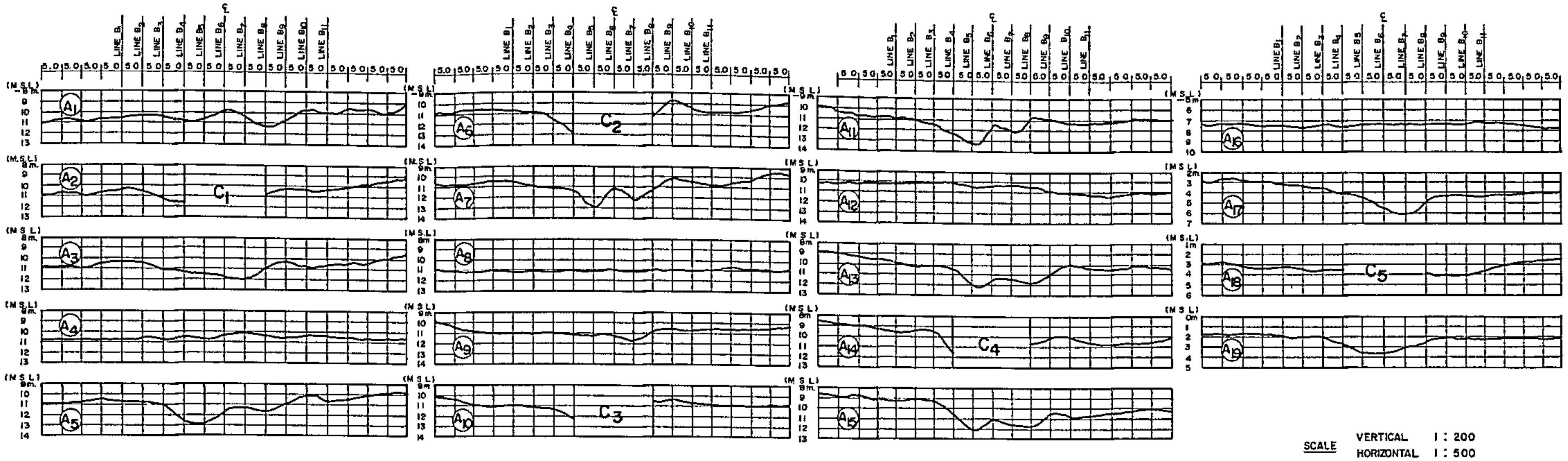
Fig. 3–9.5 PROFILES UNDER THE KRUNG THON BRIDGE (LINE B1 – B5)



SCALE VERTICAL 1 : 200
HORIZONTAL 1 : 500

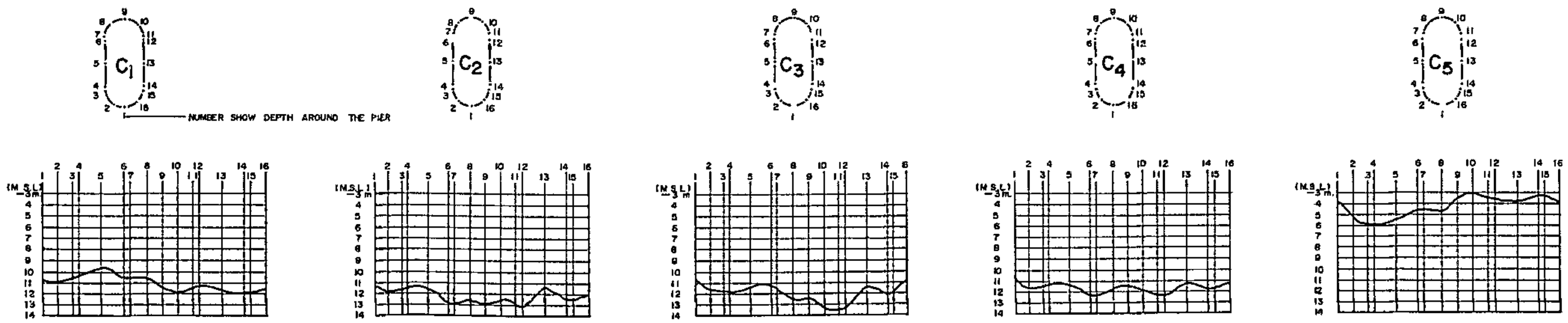
PROFILES LINE B6 – B11
KRUNG THON BRIDGE

Fig. 3–9.6 PROFILES UNDER THE KRUNG THON BRIDGE (LINE B6 – B11)



SCALE VERTICAL 1 : 200
HORIZONTAL 1 : 500

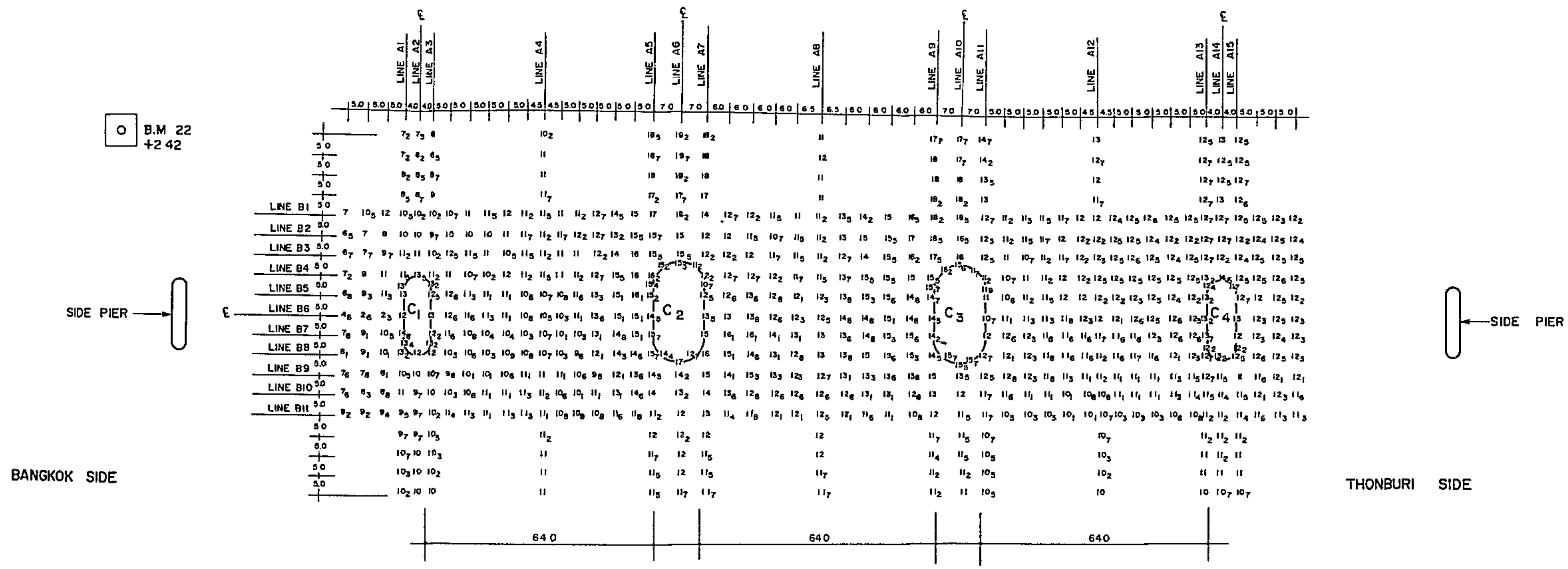
LONGITUDINAL PROFILES (LINE A_1 – A_{19})



PROFILES AROUND THE PIER C_1 – C_5

SURVEYED BY SRISATAPORN CO.,LT
OCTOBER 1979

Fig. 3–9.7 PROFILES UNDER THE KRUNG THON BRIDGE



SOUNDING IN METERS
REDUCES TO MEAN SEA LEVEL

TIDAL DATA SATHUPRADIT STATION

HIGHEST HIGH WATER	+2.17	m
MEAN HIGH WATER	+0.90	m.
MEAN SEA LEVEL	±0.00	m
MEAN LOW WATER	-0.36	m
LOWEST LOW WATER	-1.72	m.

SCALE 1 : 500

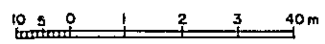


Fig. 3-9.8 SPOT ELEVATIOM ON CHAO PHRAYA RIVER UNDER THE KRUNG THEP BRIDGE

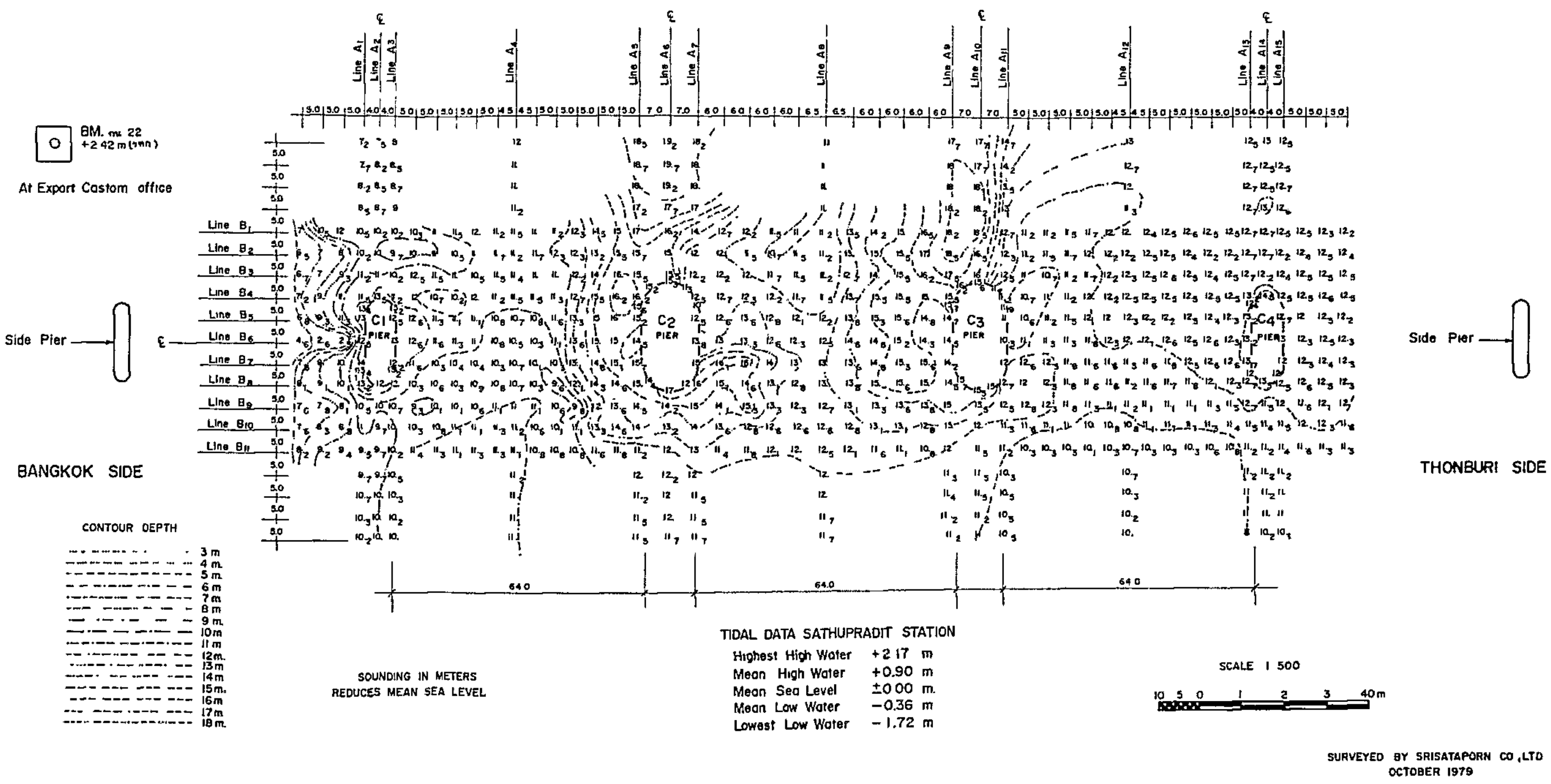
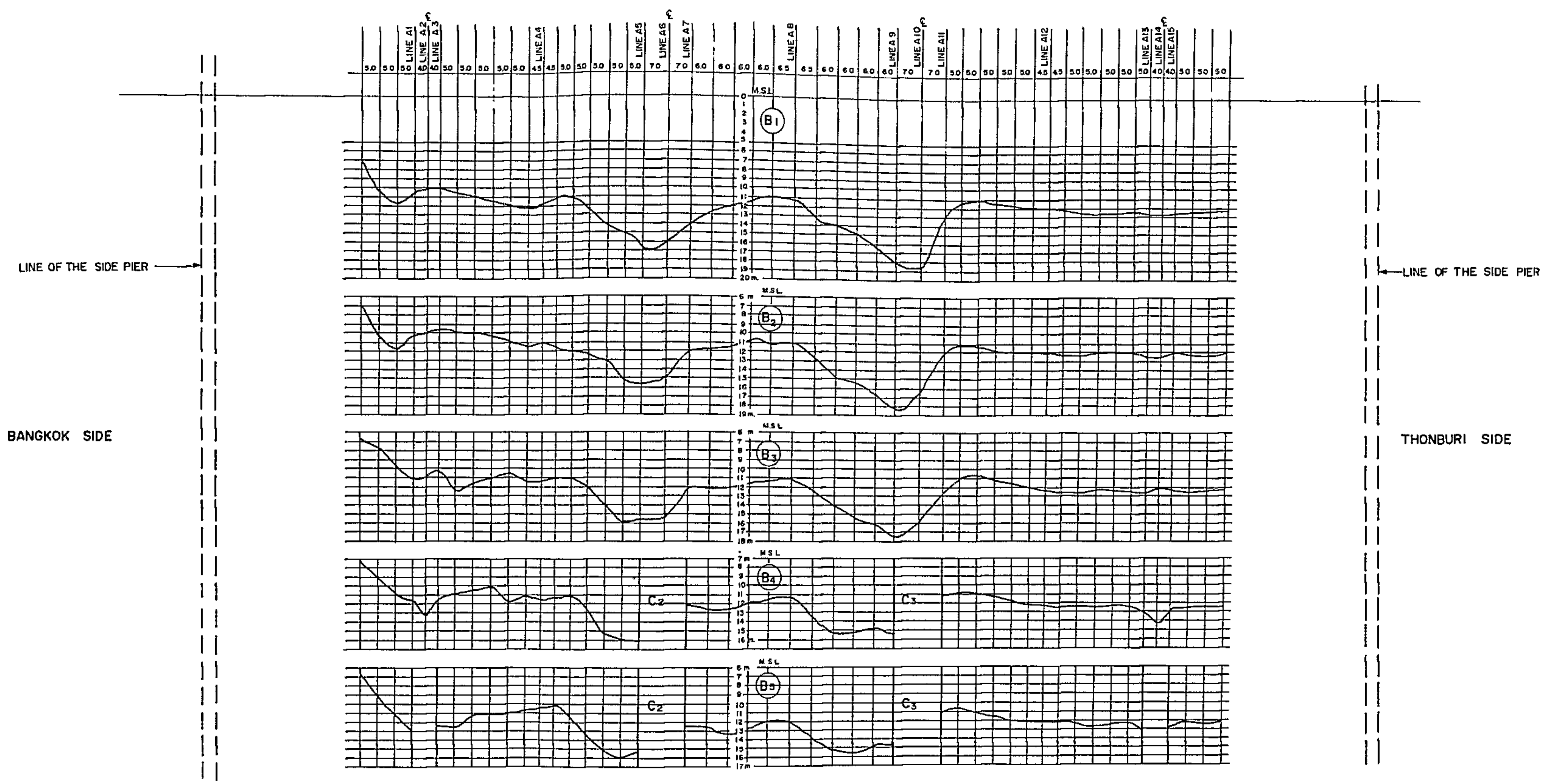


Fig. 3–9.9 CONTOURS CHAO PHRAYA RIVER UNDER THE KRUNG THEP BRIDGE



PROFILES LINE B1—B5

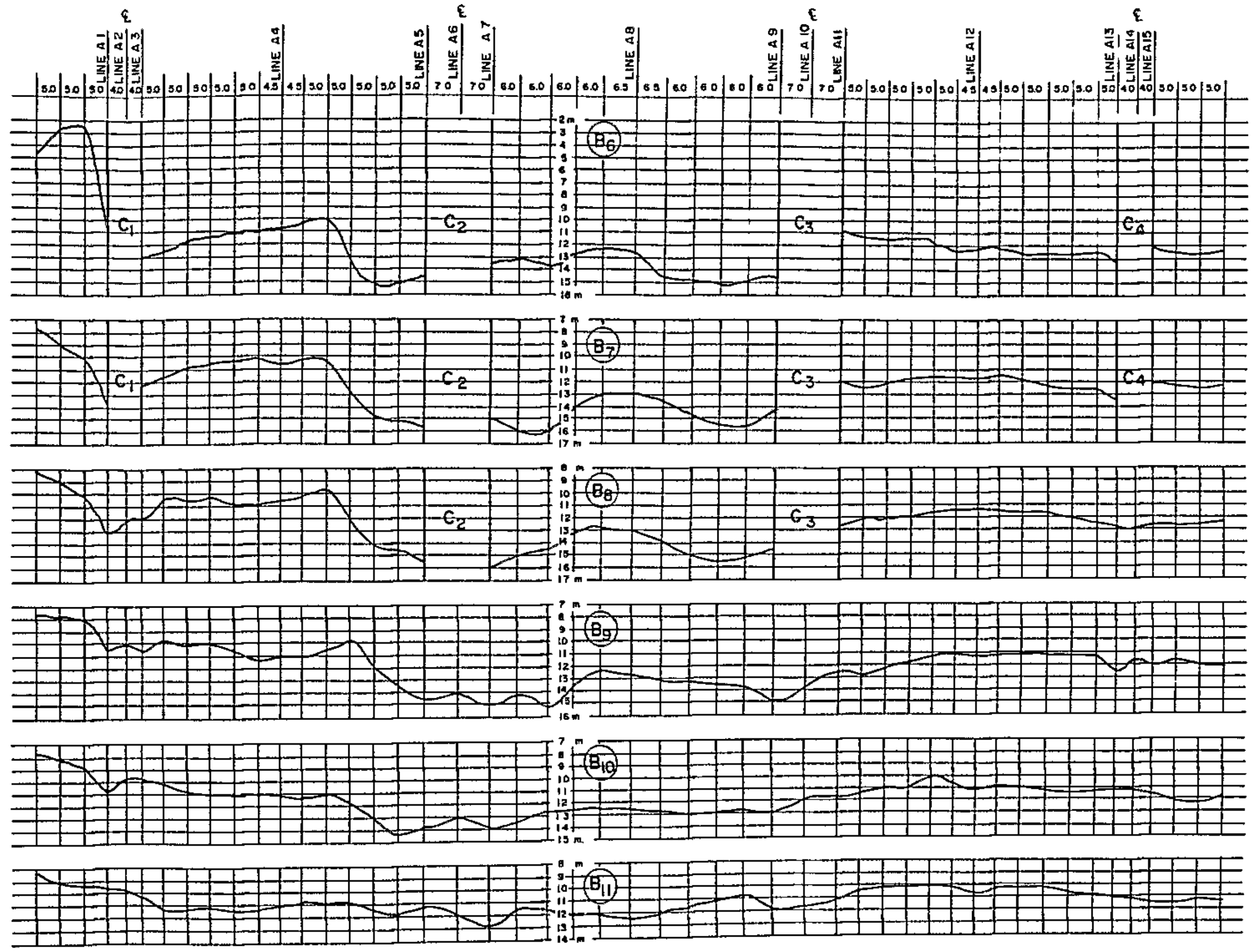
SCALE VERTICAL 1 : 200

HORIZONTAL 1 : 500

Fig. 3–9.10 PROFILES UNDER THE KRUNG THEP BRIDGE (LINE B1 – B5)

LINE OF SIDE PIER

BANGKOK SIDE



LINE OF SIDE PIER

THONBURI SIDE

PROFILES LINE B6–B11

SCALE VERTICAL 1 : 200

HORIZNTAL 1 : 500

Fig. 3–9.11 PROFILES UNDER THE KRUNG THEP BRIDGE (LINE B6 – B11)

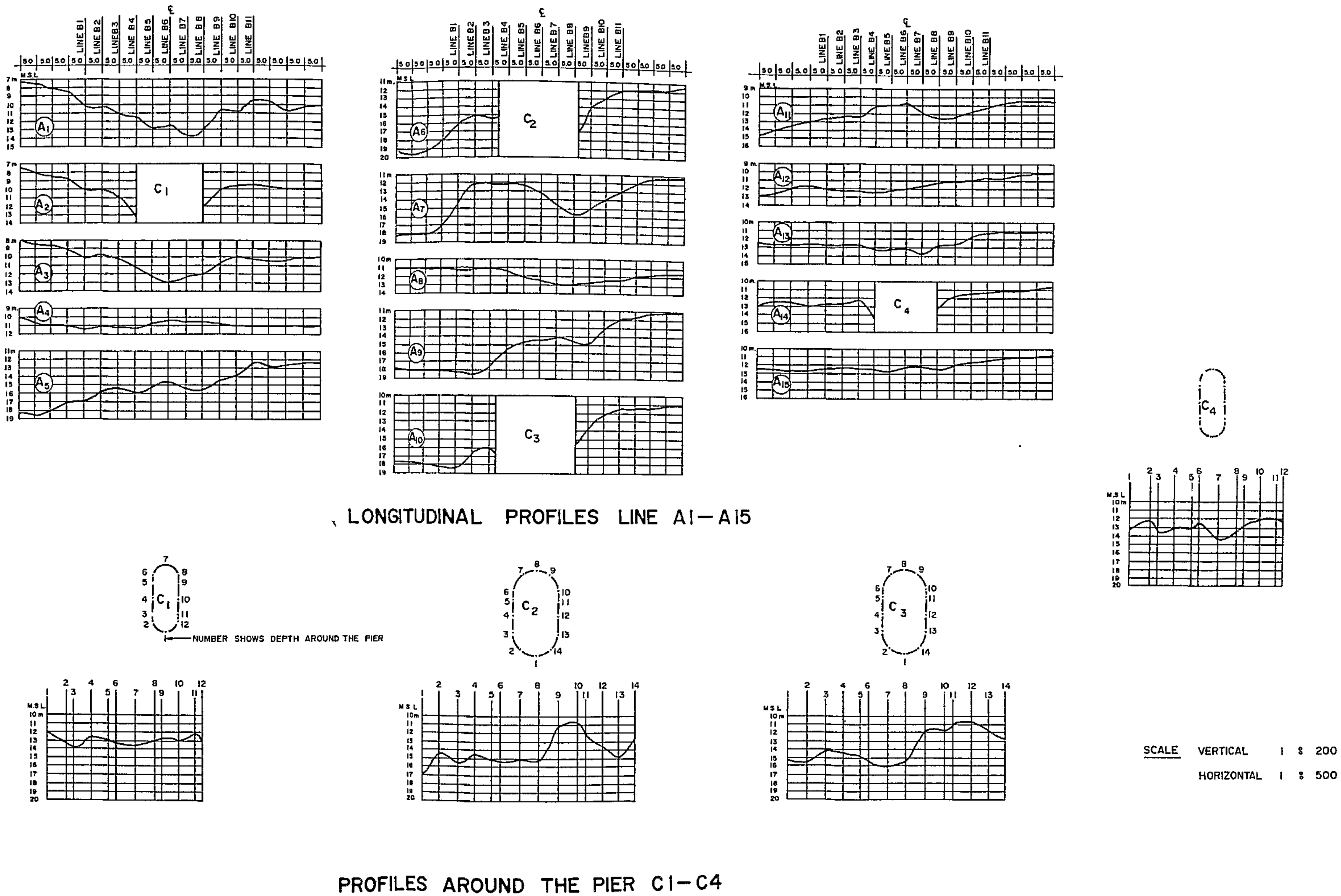


Fig. 3–9.12 PROFILES AROUND THE PIER C1 – C4 OF THE KRUNG THEP BRIDGE

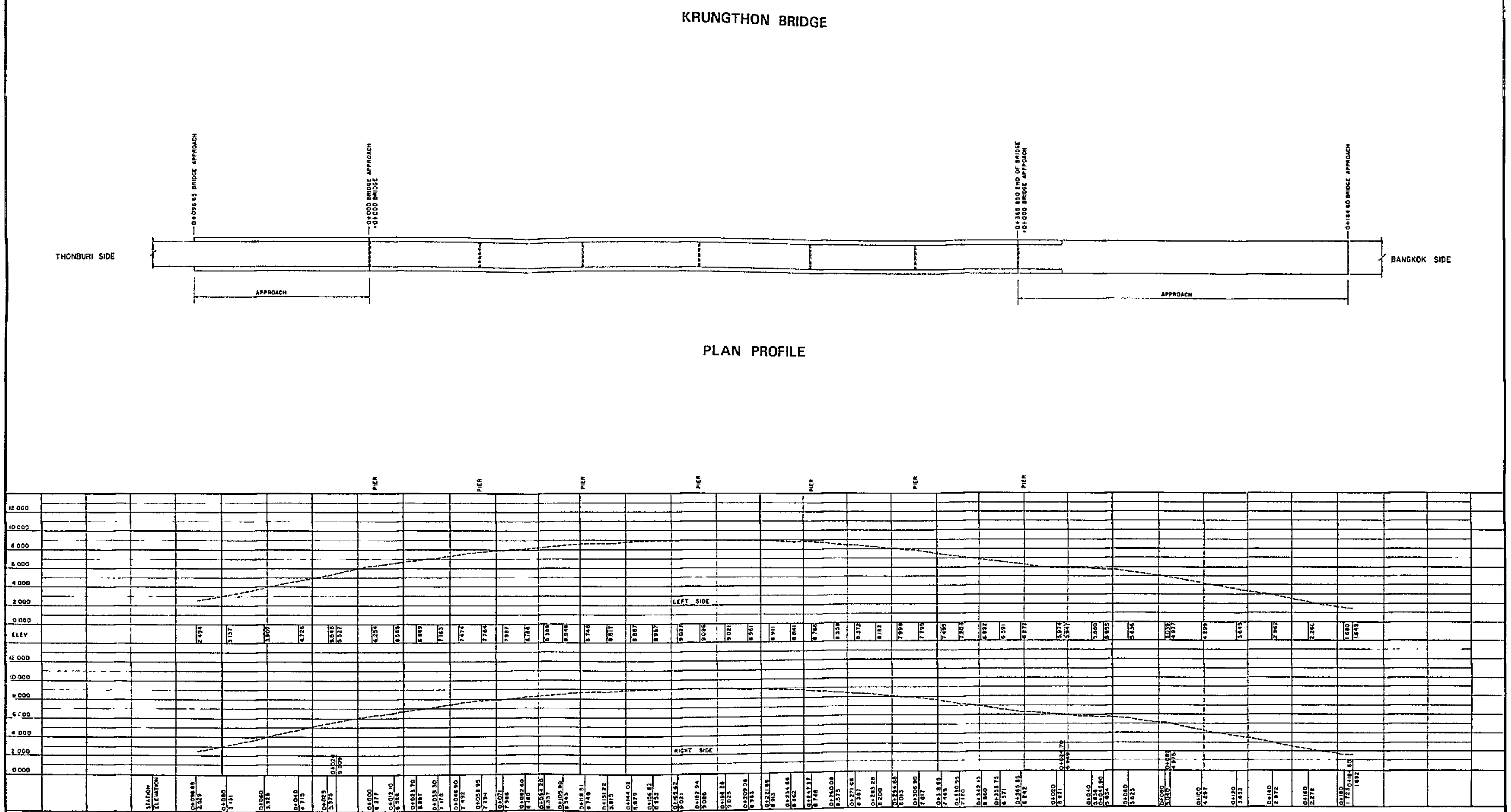


Fig. 3–9.13 LONGITUDINAL ELEVATIONS ON THE CURBSTONE OF THE ROAD SURFACE – KRUNG THON BRIDGE

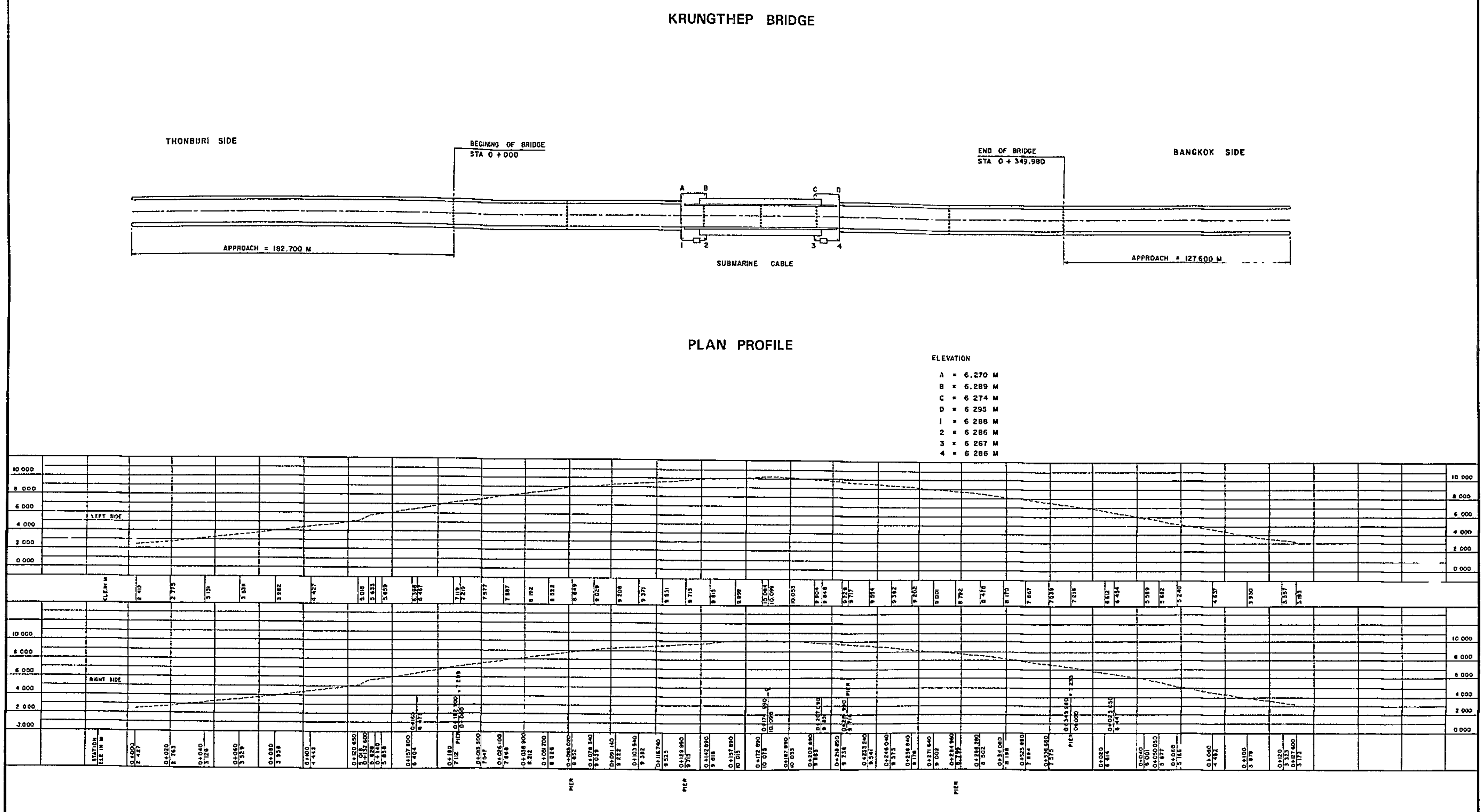
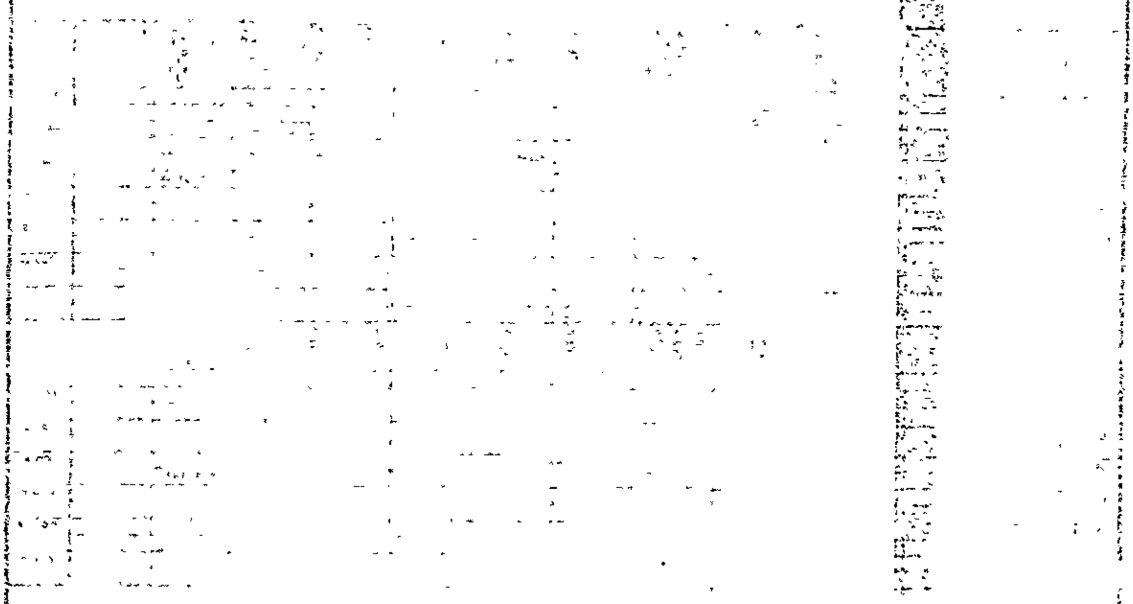


Fig. 3–9.14 LONGITUDINAL ELEVATIONS ON THE CURBSTONE OF THE ROAD SURFACE – KRUNG THEP BRIDGE



CHAPTER 4
DISCUSSION OF THE LIVE LOAD

CHAPTER 4:
DISCUSSION OF THE LIVE LOAD

4–1 Original Design Load and Conditions

1) One traffic lane shall be reckoned as 3 meters wide.

2) In one traffic lane of each span only two 16-ton standard trucks shall be considered in the design.

3) One heavy 29.25-ton tractor truck with semi-trailer shall be considered on each span, and the space left on the road way shall be considered as full of pedestrians. Uniformly distributed load of 400 kg/m^2 on the road way.

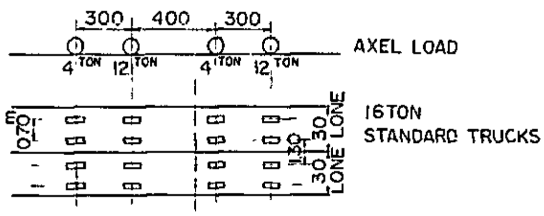
4) Uniformly distributed load of 300 kg/m^2 on the foot-paths.

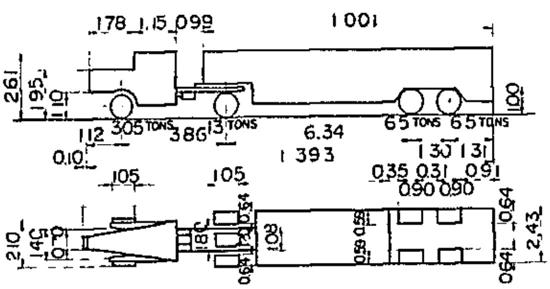
Impact live load stresses, except those due to pedestrians shall be increased by an impact factor.

$$i = \frac{25}{L + 60}$$

where i = impact factor

L = loaded length in meters





29. 25 TONS TRACTOR TRUCK

Fig. 4–1.1 29.25 –TON TRACTOR TRUCK

4–2 Actual Live Load

The maximum weight of the trucks allowed to pass across the bridges is restricted to 21 tons. However, the effective control of the maximum load limit mentioned above is very difficult, in view of the requirement of installation of facilities such as automatic axle weight scale, bypass road, etc.

The vehicle load which is actually causing the most severe influence upon the bridges is composed of heavy trucks with 10 wheels, which are presumed to have gross weights of the order of 30 tons.

According to the observations of PWD of the Kingdom of Thailand, the maximum loading conditions caused by vehicles loaded on one span of the bridge is composed of 6 heavy trucks of the 30 t type in a row in the outer lanes, and lightweight trucks and other types of vehicles in a row in the other 2 lanes.

The typical axle loads of the heavy truck are estimated as shown in Figure 4-2.1.

3-axle vehicle
Estimated gross weight
27.8 t (max. 39.9 t)

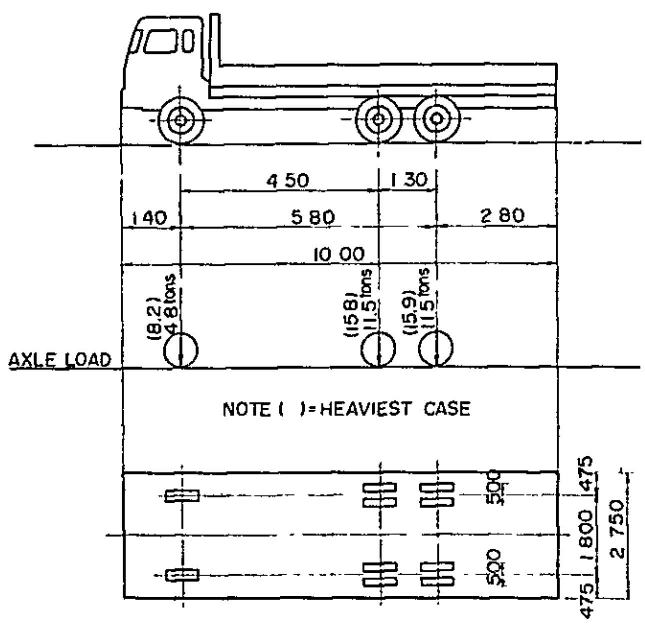


Fig. 4–2.1

4–3 Comparative Study of the Load

Of the various bridges crossing the Chao Phraya River, the SATHORN Bridge which is under construction and the NEW MEMORIAL Bridge which is expected to start its construction work soon, are designed in accordance with the loading of the BS 5400 : Part 2 : 1978 "Specification for Loads HB 45" (British Standards Institution). The KRUNG THEP Bridge is expected to be a part of the Middle Ring Road. Accordingly, it is desirable to adopt the same loading for strengthening as at other new bridges. This can be said also for Krung Thon Bridge.

4-3-1 HA and HB Loading

The HA loading is the load related to the ordinary traffic of vehicles in England, and is composed either of the combination of the uniformly distributed load (UDL) and the knife edge load (KEL) or the individual wheel loads.

The HB loading indicates the unit load related to special vehicles for public road bridges in England. HB25 is taken into consideration in ordinary cases, but it is possible to increase it up to HB45 in special cases.

The bridge is to be designed in accordance with the HA loading or the combination of the HA and HB loadings mentioned above. These loads also include an impact factor.

1) HA uniformly distributed load

The intensity of UDL of the carriageway varies in accordance with the loaded length, as shown in the table below.

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		

Note 1 : The loaded length for the member under consideration shall be the base length of the adverse area (see 3.2.5). Where there is more than one adverse area, as for continuous construction, the maximum effect should be determined by consideration of any adverse area or combination of adverse areas using the loading appropriate to the base length of the total combined base lengths.

Note 2 : This Table and Note used from the part 2 of BS 5400, 1978.

2) HA nominal KEL

KEL = 120kN x 0.098 = 11.76 t/lane = 3.92 t/m

3) Footpath and cycle track live load

Elements supporting footpath and cycle tracks only shall be taken as follows:

(a) for loaded lengths of 30 m and under, a uniformly distributed live load of 5.0 kN/m^2.

(b) for loaded lengths in excess of 30 m, k x 5.0 kV/m^2,

where k is the

$$\frac{\text{nominal HA UDL for appropriate loaded length (in kN/m)}}{30 \text{ kN/m}}$$

Special consideration shall be given to the intensity of the live load to be adopted on loaded lengths in excess of 30 m where exceptional crowds may be expected (as, for example, where a footbridge serves a sports stadium).*

Intensity of uniform load on footway p

loaded length $\ell \leqq 30$ m
$p = 5.0 \times 0.098 = 0.49 \ t/m^2$
loaded length $\ell > 30$ m
$p = 5.0 \times 0.998 \ K = 0.49 \ Kt/m^2$

K value is calculated by the formula shown above.

Note * This Sentence used from the BS 5400 : Part 2 : 1978.

4) Dimensions of HB vehicle and axle loads

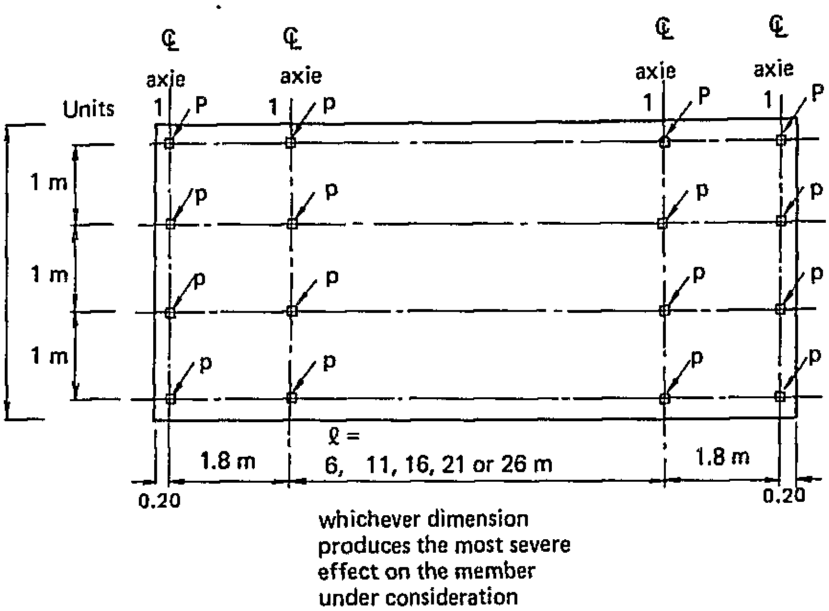


Fig. 4–3.1

HB45 loading : P = 2.5 x 45 x 0.089 = 11.025 t

Axle load 4P = 44.1 t Gross weight W45 = 176.4 t

HB25 loading : P = 2.5 x 25 x 0.098 = 6.125 t

Axle load 4P = 24.5 t Gross weight W25 = 98.0 t

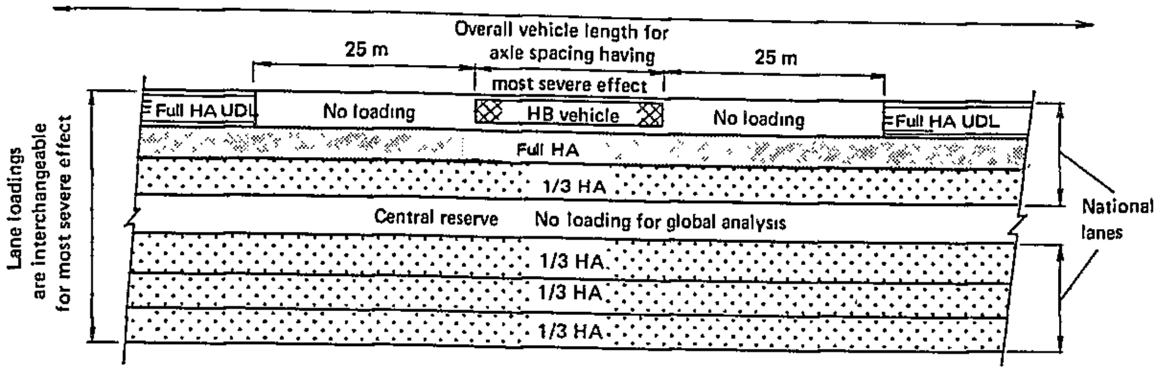
Assuming the spacing between the 2nd axle and the 3rd axle is 6.00 m, which produces the most severe effect on the member, the overall length of the vehicle is 10.00 m. In this case, the load intensity on the area occupied by the vehicle is as follows.

HB45 loading $$P_{45} = \frac{176.4}{3.5 \times 10} = 5.04 \text{ t/m}^2$$

HB25 loading $$P_{25} = \frac{98.0}{3.5 \times 10} = 2.8 \text{ t/m}^2$$

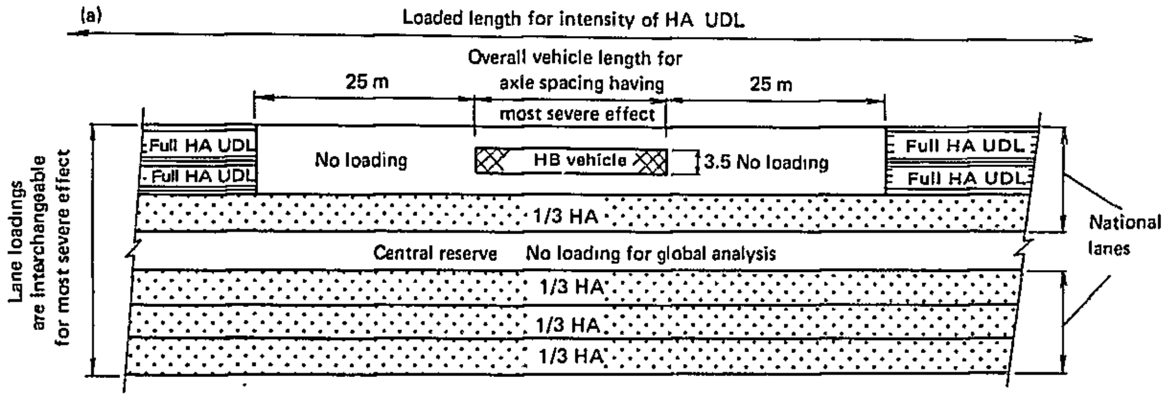
5) Combination of the HB loading and HA loading

(1) HB vehicle within one notional lane

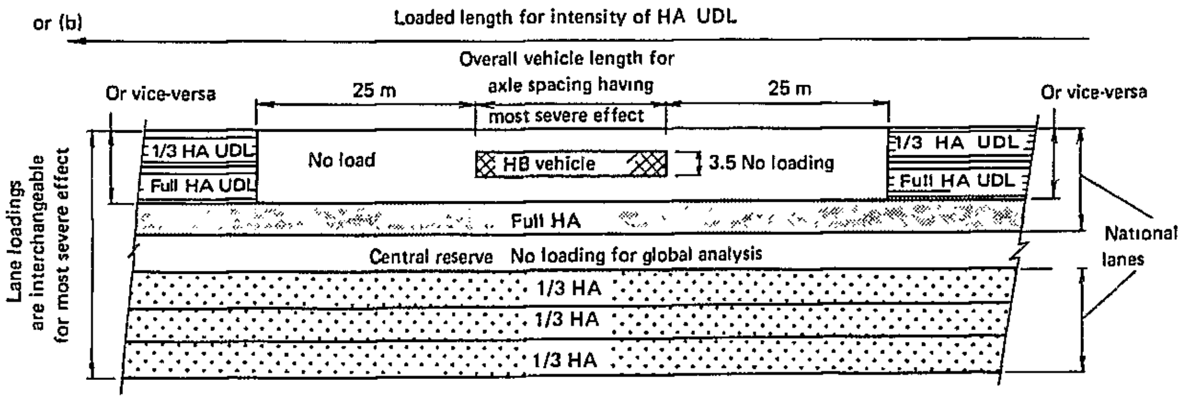


(2) HB vehicle stradding two notional lanes

(a)



or (b)



NOTE 1. The overall length and width of the HB vehicle shall be as specified in 6.3.1.

NOTE 2. Unless otherwise stated, type HA loading includes both uniformly distributed loading (UDL) and knife edge loading (KEL).

Fig. 4–3.2 TYPE HA AND HB HIGHWAY LOADING IN COMBINATION

CHAPTER 5

STUDY ON STRESS IN THE SUPER-STRUCTURES

CHAPTER 5
STUDY ON STRESS IN THE SUPERSTRUCTURES

5–1 Live Load

In this chapter, investigations will be made to determine the conditions of overstresses caused by live loads checked in the previous chapter 4, and also to identify the locations necessary to be rehabilitated together with strengthening methods to be applied.

Basically HB25 loadings of BS will be used in calculation, supplemented by HB45 loadings for references.

BS 5400; Part 2. 1978

The calculations are carried out in accordance with the HB loading (45 Unit and 25 Unit).

5–2 Allowable Stress of the Steel Materials

The quality of steel used in both KRUNG THON Bridge and KRUNG THEP Bridge is in accordance with JIS (Japanese Industrial Standards).

Recently, problems related to the load carrying capacity, strengthening, and the vehicle load restriction of bridges constructed in the past in accordance with old standards, are arising also in Japan as a consequence of the increase of vehicle weights.

The Ministry of Construction of Japan picked up the said problems as a special theme, and loading tests and analysis of many bridges were carried out since 1965, mainly under the responsibility of the institute of the Construction Ministry.

In the said studies, theoretically values were calculated in correspondence between the values of the actual loads and the results of the measurement of the stresses, compared by dividing the bridges into its various members, i.e., the floor slab, the floor frames (stringer and cross beams) and main beam (plate girder and trussed beam). (Refer to Appendix 5-2.1).

Since the necessity of the strengthening of the members in both the bridges is studied based upon the data and information mentioned above, the permissible stresses of the steel materials is adopted in accordance with the "Highway Bridge Specification" published in 1980 by the Road Association of Japan.

1) Allowable stress of steel plates (SS41)

a) Normal tensile stress and bending tensile stress

$$\sigma_{ca} = 1400 \text{ kg/cm}^2$$

b) Normal compressive stress

$$\frac{\ell}{r} \leqq 20 \qquad \sigma_{ca} = 1400 \text{ kg/cm}^2$$

$$20 < \frac{\ell}{r} \leqq 93 \qquad \sigma_{ca} = 1400 - 8.4\ (\frac{\ell}{r} - 20)$$

$$\frac{\ell}{r} > 93 \qquad \sigma_{ca} = \frac{12.0 \times 10^6}{6{,}700 + (\frac{\ell}{r})^2}$$

where ℓ: Effective backling length of the member (cm).
r: Radius of gyration of area of the gross section of the member (cm)

c) Bending compressive stress

When the compressive flange is directly fixed with the concrete floor slab and other parts of the bridges.

$$\sigma_{ca} = 1400 \text{ kg/cm}^2$$

In all cases except those ones mentioned above.

$$\frac{A_W}{A_C} \leqq 2\ ;\ \frac{\ell}{b} \leqq 4.5 \qquad \sigma_{ca} = 1400 \text{ kg/cm}^2$$

$$4.5 < \frac{\ell}{b} \leqq 30 \qquad \sigma_{ca} = 1400-24(\frac{\ell}{b} - 4.5)$$

$$\frac{A_W}{A_C} > 2\ ;\ \frac{\ell}{b} \leqq \frac{9}{K} : \qquad \sigma_{ca} = 1400 \quad \text{"}$$

$$\frac{9}{K} < \frac{\ell}{b} \leqq 30 \qquad \sigma_{ca} = 1400-12(K\frac{\ell}{b} - 9)$$

where A_w : Gross area of the web plate (cm^2)

A_c : Gross area of compressive flange (cm^2)

ℓ : Distance between the fined point to next fixed point of the compressive flange plate (cm)

b : Width of the compressive flange plate (cm)

$$K = \sqrt{3 + \frac{A_w}{2A_c}}$$

d) Shearing stress

$\tau_a = 800$ kg/cm^2

2) Allowable stress of rivets

SV 34

Shearing stress τ_a

Shop rivet	1100 kg/cm^2
Field "	1100 kg/cm^2

3) Allowable stress of anchor bolt and pin

Shearing stress	SS41	S35C
Anchor bolt	600 kg/cm^2	800 kg/cm^2
Pin	1000 kg/cm^2	1400 kg/cm^2
Fine bolt	900 kg/cm^2	1200 kg/cm^2

5–3 Stress of Trussed Beams

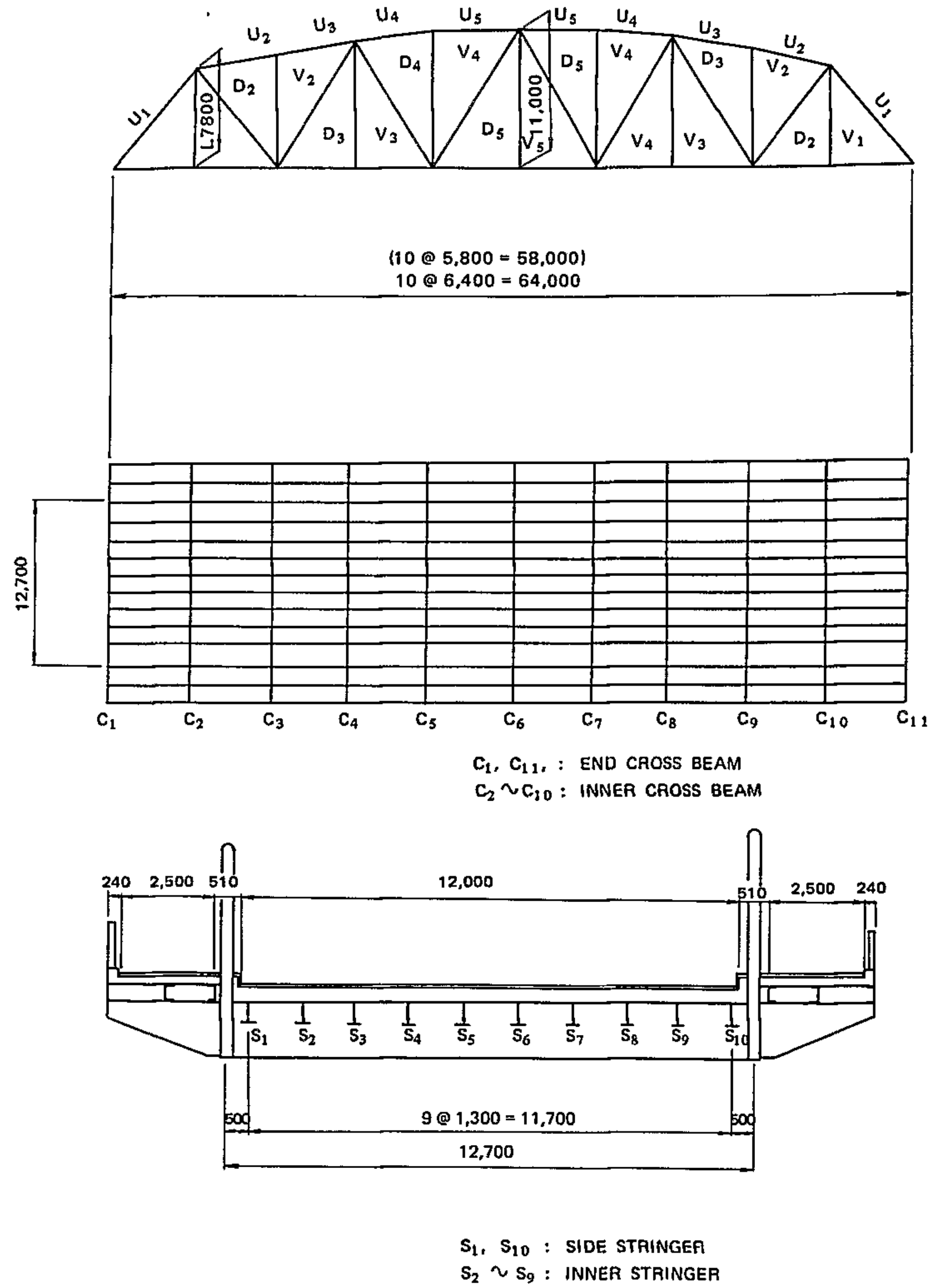


Fig. 5–3.1

1) Member stress of the Trussed Beam (span length 64.00 M)

Table 5-3.1

Unit kg/cm²
( ) shown for HB-45 loading

Member		Dead Load Stress	Live Load Stress	Total Stress	Allowable Stress	Over Stress %	Remarks
Inner stringer		288	(2131) 1184	(2419) 1472	1400	(72.8) 5.1	
Side stringer		288	(1667) 950	(1955) 1238	"	(39.6) -	
Inner Cross Beam	σ_c	393	(1187) 826	(1580) 1219	"	(12.9) -	
	σ_t	452	(1365) 950	(1817) 1402	"	(29.8) 0.1	
End Cross Beam	σ_c	265	(1287) 858	(1552) 1123	"	(10.9) -	
	σ_t	304	(1475) 983	(1779) 1287	"	(27.1) -	
Main Truss Upper Chord	U_1	621	(552) 396	(1173) 1017	1139	(3.0) -	
	U_2	723	(537) 365	(1260) 1088	1309	(-) -	
	U_3	719	(533) 363	(1252) 1082	1313	(-) -	
	U_4	756	(544) 382	(1300) 1138	1295	(0.4) -	
	U_5	754	(544) 380	(1998) 1134	1296	(0.2) -	
Main Truss Lower Chord	L_1, L_2	700	(519) 373	(1219) 1073	1400	(-) -	
	L_3, L_4	821	(601) 424	(1422) 1245	"	(1.6) -	
	L_5	908	(646) 454	(1554) 1362	"	(11.0) -	
Main Truss Diagonal Member	D_2	837	(710) 504	(1547) 1341	"	(10.5) -	
	D_3	516	(569) 402	(1085) 918	931	(16.5) -	
	D_4	433	(751) 525	(1184) 958	1400	(-) -	
	D_5	125	(620) 425	(745) 550	876	(-) -	
Main Truss Vertical Member	V_1, V_3, V_5	584	(944) 622	(1528) 1206	1400	(9.1) -	
	V_2	202	(150) 102	(352) 304	"	(-) -	
	V_4	258	(186) 130	(444) 388	"	(-) -	

2) Member stress of the Trussed Beam (span length 58.00 M)

Table 5-3.2

Unit kg/cm^2
( ) shown for HB-45 loading

Member	Stress	Dead Load Stress	Live Load Stress	Total Stress	Allowable Stress	Over Stress %	Remarks
Inner stringer		200	(1853) 1029	(2053) 1229	1400	(46.6) -	
Side stringer		200	(1441) 824	(1647) 1024	"	(17.6) -	
Inner Cross Beam	σ_c	793	(1255) 873	(1648) 1266	"	(17.7) -	
	σ_t	451	(1441) 1002	(1892) 1453	"	(35.1) 3.8	
End Cross Beam	σ_c	212	(1138) 756	(1350) 968	"	(-) -	
	σ_t	243	(1306) 868	(1549) 1111	"	(10.6) -	
Main Truss Upper Chord	U_1	618	(511) 363	(1129) 981	1108	(1.9) -	
	U_2	650	(564) 396	(1214) 1046	1305	(-) -	
	U_3	642	(558) 391	(1200) 1033	1308	(-) -	
	U_4	684	(579) 405	(1263) 1089	1292	(-) -	
	U_5	679	(576) 403	(1255) 1082	1293	(-) -	
Main Truss Lower Chord	L_1, L_2	740	(608) 434	(1348) 1174	1400	(-) -	
	L_3, L_4	842	(779) 506	(1621) 1348	"	(15.8) -	
	L_5	829	(694) 487	(1523) 1316	"	(8.8) -	
Main Truss Diagonal Member	D_2	845	(735) - 519	(1580) 1364	"	(12.9) -	
	D_3	492	(624) 438	(1116) 930	948	(17.7) -	
	D_4	315	(639) 444	(954) 759	1400	(-) -	
	D_5	102	(584) 404	(686) 506	892	(-) -	
Main Truss Vertical Member	V_1, V_3, V_5	522	(959) 638	(1481) 1160)	1400	(5.8) -	
	V_2	136	(118) 83	(254) 219	"	(-) -	
	V_4	140	(118) 83	(258) 223	"	(-) -	

5–4 Stress in the Bascule Bridge

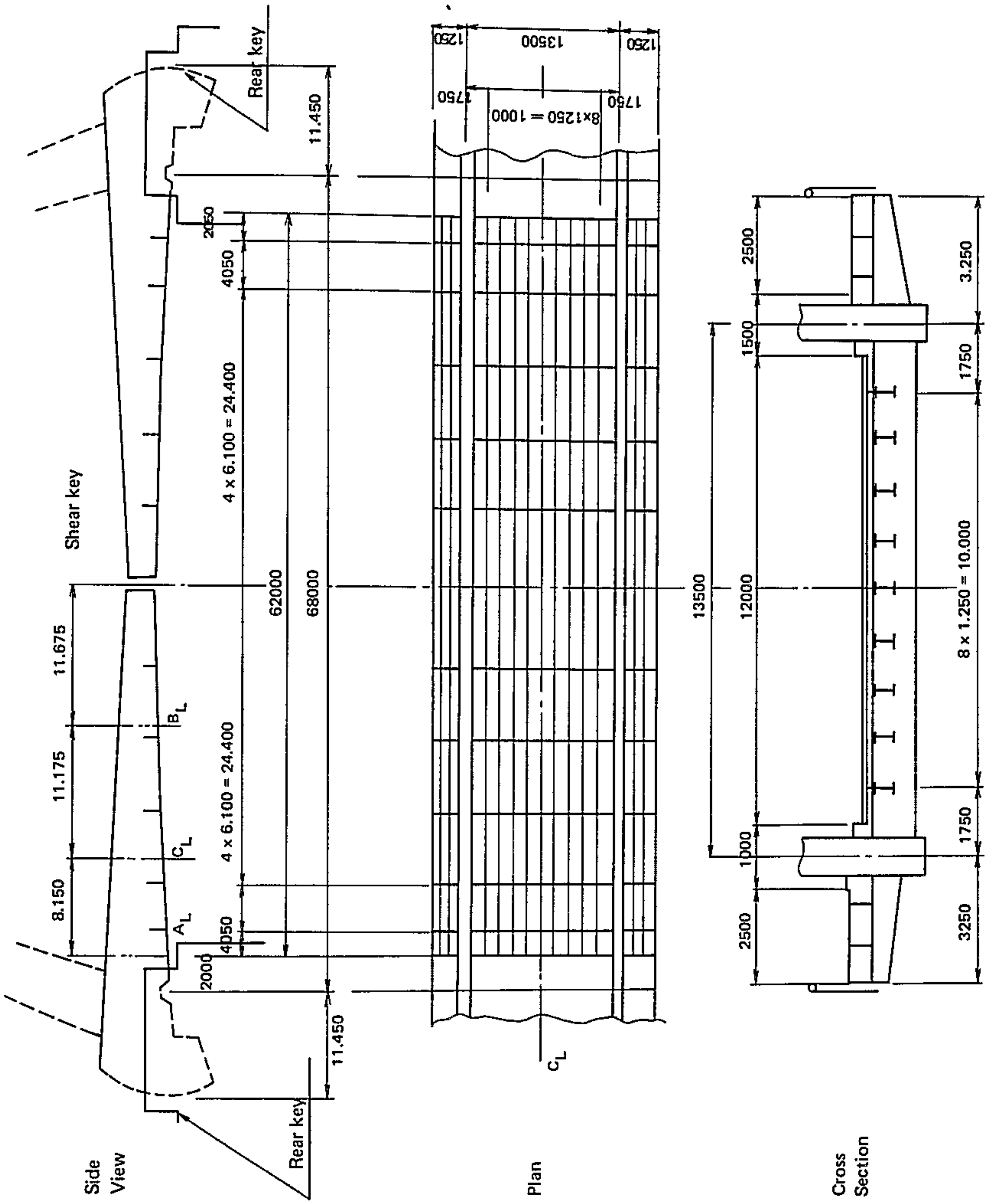


Fig. 5–4.1

1) Member stress of the Bascule Bridge

Table 5-4.1 Unit kg/cm^2

( ) shown for HB-45 loading

Member			Dead Load Stress	Live Load Stress	Total Stress	Allowable Stress	Over Stress %	Remarks
R.C. Slab Span Center	Concrete		2	(73) 41	(75) 43	70	(7.1) -	
	Reinforcement Bar		11	(397) 220	(408) 231	1400	(-) -	
Stringer	Upper Flange σ_c		126	(1905) 1056	(2031) 1182	1400	(45.1) -	
	Lower Flange σ_t		126	(1905) 1056	(2031) 1182	"	(45.1) -	
Cross Beam	Upper Flange σ_c		262	(1243) 870	(1505) 1132	"	(7.5) -	
	Lower Flange σ_t		322	(1529) 1065	(1851) 1387	"	(32.2) -	
Main Girder	Section B_L	Up Flange σ_t	364	(824) 561	(1188) 925	"	(-) -	
		Lo Flange σ_σ	366	(826) 563	(1192) 929	1142	(4.4) -	
		τ_w	83	(172) 116	(255) 199	800	(-) -	
	Section C_L	Up Flange σ_t	530	(745) 517	(1275) 1047	1400	(-) -	
		Lo Flange σ_c	536	(753) 23	(1289) 1059	1162	(10.9) -	
		τ_w	118	(172) 119	(290) 237	800	(-) -	
	Section A_L	Up Flange σ_t	640	(734) 517	(1374) 1157	1400	(-) -	
		Lo Flange σ_c	646	(741) 522	(1387) 1168	1132	(22.5) 3.2	
		τ_w	89	(108) 76	(187) 165	800	(-) -	

2) RC slab of the trussed beam

		HB-45	HB-25	σ_a
Concrete	σ_t kg/cm²	88	51	70
Overstress	%	25.7	-	
Reinforcement	σ_t kg/cm²	1349	778	1400
Overstress	%	-	-	

5–5 Stress in the Approach PC Composite Beam

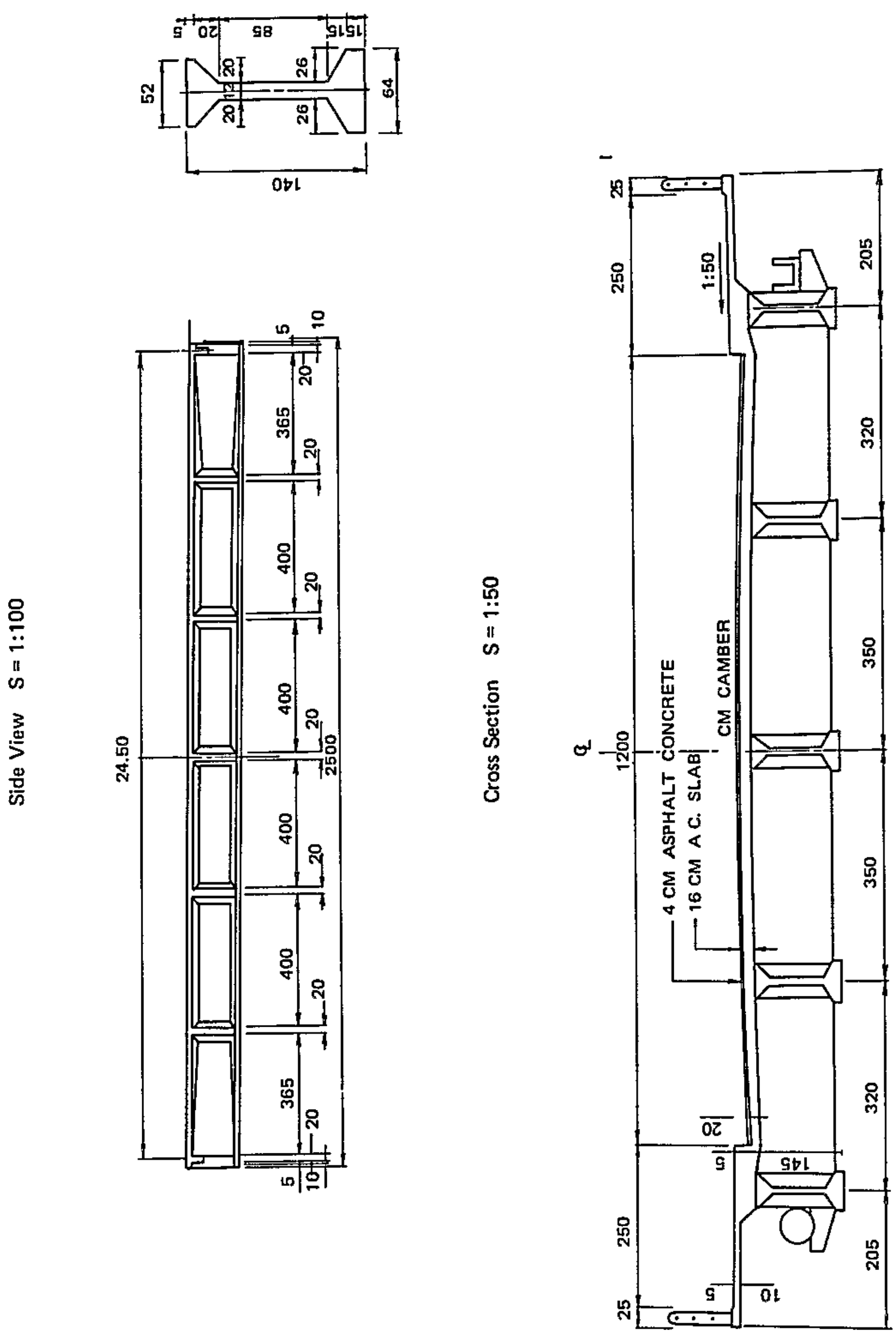


Fig. 5–5.1

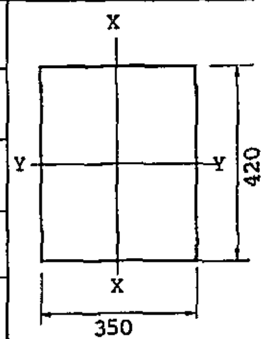
1) Sum of each stress of slab

Table 5-5.1

Unit kg/cm^2
( ) shown for HB-45 loading

Member		Dead Load Stress	Live Load Stress	Total Stress	Over Stress %
Slab Type IV	At middle of slab (Y-direction)				
	Concrete σ_c	5	(62) 34	(67) 39	(-) -
	Reinforcement σ_s	170	(2217) 1229	(2387) 1339	(70.6) -
	At middle of slab (X-direction)				
	Concrete σ_c	7	(81) 45	(88) 52	(25.7) -
	Reinforcement σ_s	246	(2913) 1617	(3159) 1863	(125.6) 33.1
	At edge of slab (Y-direction)				
	Concrete σ_c	10	(238) 132	(248) 142	(254.3) 102.9
	Reinforcement σ_s	457	(11402) 6337	(11859) 6794	(747.1) 385.3
Slab Type III	At middle of slab (Y-direction)				
	Concrete σ_c	9	(66) 36	(75) 45	(7.1) -
	Reinforcement σ_s	394	(2736) 1516	(3130) 1910	(123.6) 36.4
	At middle of slab (X-direction)				
	Concrete σ_c	7	(103) 57	(110) 64	(57.1) -
	Reinforcement σ_s	275	(4276) 2366	(4551) 2641	(225.1) 88.6
	At edge of slab (Y-direction)				
	Concrete σ_c	17	(259) 144	(276) 161	(294.3) 130
	Reinforcement σ_s	1008	(15511) 8664	(16519) 9652	(1079.9) 589.4
	At edge of slab (X-direction)				
	Concrete σ_c	13	(189) 105	(202) 118	(188.6) 68.6
	Reinforcement σ_s	794	(11294) 6275	(12088) 7069	(763.4) 404.9

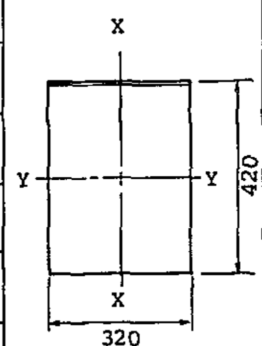
Remarks:



σ_{ca} = 70 kg/cm^2
σ_{sa} =1400 "

Note:

This measurement is based on the original specifications and the lateral lines later added are not taken into consideration.



σ_{ca} = 70 kg/cm^2
σ_{sa} = 1400 "

2) Sum of stresses in PC beam

Table 5-5.2 At Center of Girder

		Bending Moment	Prestress Force	Stress at Point	
				Top Fiber	Bottom Fiber
1	Prestress (9 cables)	t.m 124.5	t 220	kg/cm^2 -46.4	kg/cm^2 +149.3
2	Own weight of girder	72.6		+63.9	-50.2
3	Cross beam	27.0		+23.8	-18.7
4	Prestress (7 cables)	84.8	164.5	-27.4	+106.0
5	Roadway slab	80.7		+71.0	-56.0
6	Wearing surface	17.3		+2.7	-8.0
7	(HB-45) HB-25	(526) 292.2		(+83.0) 46.1	(-244) -135.7
	Total			(170.6) 133.7	(-121.6) -13.3
				Compres-sion	Tension

CHAPTER 6

RECOMMENDATIONS RELATED TO THE STRENGTHENING AND REPAIR

CHAPTER 6
RECOMMENDATIONS RELATED TO THE STRENGTHENING AND REPAIR

6–1 General

The superstructures of the main spans of both KRUNG THON Bridge and KRUNG THEP Bridge, (steel trussed bridge with curved chord and steel bascule bridge) were designed, constructed approximately 30 years ago by the Fuji Sharyo Co., Ltd. of Japan.

As mentioned in the paragraph 4-1 "Original Design Load and Conditions", the design load conditions adopted at the time are considerably smaller compared with the traffic loads prevailing presently. Accordingly, the execution of the strengthening and repairs in these structures, aiming at making them able to cope with the huge live loads taking place presently or expected to take place in future, is very difficult.

When the PC composite beam and the RC rigid T-beam of the approach section, constructed at the same time, are also taken into consideration, the limits imposed on the effectiveness of the repair and strengthening jobs mentioned above is determined by factors such as the material durability, degree of deterioration and difficulty or ease of strengthening of the steel and concrete composing the said structures.

With regard to the steel bridge, the part located above the bridge surface is in satisfactory condition, with negligible rust, and with exception of some local cuts in part of the main structure caused by the collision of vehicles.

On the other hand, with regard to the members located under the floor slab, there is serious formation of rust caused by rainwater, etc., near the expansion joints and construction joints of the RC slab. The said rust is so serious that it could damage the durability of the steel bridge.

On the other hand, as for the RC slabs of the trussed beam section of the main span, cracks are negligible in spite of the small thickness of the slab and the small quantity of the reinforcement bars, thanks to the spacing of only 1.3 m between supports, which is a very small value due to the technical standards prevailing at the time.

The PC composite beams, RC rigid beams and other parts of the approach bridges have slabs and are poorly reinforced compared with the relatively large spacing between the main girders. Accordingly, the said structures do not have any margin at all to cope with the increases of the live load.

The cracks taking place in the RC slabs of the approach bridges present considerably differences in each span, but generally speaking, they are in very advanced state, presenting a fine "mesh" pattern. As a matter of fact, the status quo is ensured by supporting temporarily the various parts by means of temporary supports constructed everywhere.

Having in mind the considerations presented above, the overstress taking place in the various members as a result of increase of live loads, etc., it is considered impossible to carry out the strengthening up to the level of the HB 45 loading. It is necessary to have in mind that the HB 45 loading (total weight of 176.4 t and load of 5.0 t/m^2 on the area occupied by the axles) is a very special load, more than 2 times as large as the TT-43 (total weight of 86 t corresponding to 2 vehicles and load of 0.97 t/m^2 for the area occupied by the axles) which is the special load in the trunk roads of Japan. The TT-43 load is the design load to be adopted in bridges expected to be submitted to the traffic of high intensity of trailer trucks of the ultra-large size type recently produced in Japan. The TT-43 load was enacted in Japan by taking into consideration the actual weight of the said ultra-large trailer trucks. On the other hand, the HB 25 loading (total weight of 98 t and load of 2.8 t/m^2 in the area occupied by the axles) is almost equivalent to the TT-43. The HB 25 loading has the necessary and sufficient capacity as target of the final strengthening measures to be adopted in the bridges in question.

As for the strengthening and repair jobs to be carried out in the various parts of the bridges, they can be classified in various types, ranging from the emergency measures to the long-term measures, in accordance with their degree of urgency. The various repair and strengthening measures are described below.

6–2 Strengthening and Repair of the Various Parts of the Bridges

6-2-1 Emergency Measures

1) Execution of the painting of the main truss, cross beam, stringer, etc., near the expansion joints and shoes of the trussed beam.

2) Execution of the painting of the main beam web plate near the open/shut machine room of the KRUNG THEP Bascule Bridge.

3) Execution of the painting of the cross beam and stringer near the RC slab construction joint.

4) Execution of the adjustment of the elevation of the expansion joints, improvement of the structure and the method of drainage of rainwater of both bridges.

5) Execution of the patching in the holes of existing asphalt pavement in the carriageways of both bridges.

6-2-2 Temporary Measures

1) Execution of the repair of the unevenness of the RC slab of the KRUNG THEP Bascule Bridge and execution of the asphalt covering as wearing course.

2) Execution of the improvement of the construction joints in the RC slabs of both bridges.

3) Replacement of the RC slab located on the PC composite beams of the approach sections.

4) Improvement or replacement of the 6 spans, Continuous RC-T-rigid beam of the approach section of the KRUNG THON Bridge.

5) Repair of the local breaking and twisting of the main truss members of both bridges and execution of measures to prevent the future collisions of vehicles.

6) Execution of detailed investigations by mechanical engineers for adjustment of the "discrepancy" taking place in the open/shut mechanism of the KRUNG THEP Bascule Bridge and execution of measures to cope with the uplift pressure of the Thonburi side rear rock key.

7) Execution of measures to cope with the scouring of the pier foundation of the substructure located in the river.

6-2-3 Long-term Measures

1) Execution of the complete replacement of the RC slabs and pavement location of the trussed beams section at both bridges.

2) Execution of the complete replacement of the approach bridges of the two bridges.

3) Execution of the strengthening measures for increase of stability regarding the scouring of the piers of both bridges located in the river.

4) Study of the traffic capacity of the KRUNG THEP Bridge as part of the Middle Ring Road.

6-2-4 General Measures

The general measures listed below are not necessarily indispensable in the specific case of the two bridges but they are recommendable for the sake of maintenance and administration of bridges in general.

1) Installation of automatic balances for weighing of the axle loads of vehicles and the restriction of the weight

of the vehicles.

2) Construction of inspection paths and other facilities for the purpose of maintenance and repair of bridges.

6–3 Rough Description of the Methods of Execution of the Various Measures

<table>
<tr><th colspan="2" rowspan="2">Type of Work</th><th colspan="2">Emergency Measures and Temporary Measures</th></tr>
<tr><th>KRUNG THON Bridge</th><th>KRUNG THEP Bridge</th></tr>
<tr><td>Superstructure</td><td>Repair of the pavement RC slabs and expansion joints</td><td>1) Patching of holes existing in the pavement.
a) A quadrilateral perpendicular to the road surface should be cut with a cutter around the damaged part. Remove the damaged part of the pavement taking care not to damage the floor slab and clean the removed place.
b) If the place is wet, heat up and dry it by using a burner or another similar apparatus.
c) Carry out a tack coat, aiming at improving the sticking of the asphalt mixture on the floor slab. The tack coat is required not only on the floor slab surface, but also on the side surfaces of the quadrilateral cut as described above.
d) Fill the quadrilateral to be patched with the hot mixture (or ambient temperature mixture), spread it evenly and then carry out the compaction with a roller. The maximum size of the aggregates should be of the order of 5 mm through 10 mm, and the patch should be finished approximately 3 mm higher than the surrounding level, by taking into consideration the settlement due to consolidation.
e) Scatter either stone powder or sand on the patch surface.
f) The road can be opened to the traffic when the surface of the patch cools down to a temperature which can be touched with the hand.
g) The patching of the construction joint of the RC slab should be carried out in accordance with the illustration presented in Figure 6-2.2.</td><td>1) Take the same measures described at left with holes on the pavement of the trussed beam floor slab.
2) With regard to the bascule span, fill the holes on the RC floor slab with resin mortar in small cracks after removing dust, mud, etc. and cleaning them perfectly.
3) Remove and clean perfectly the asphalt covering existing on the floor slab.
4) Apply the tack coat on the RC floor slab and then carry out the covering with new asphalt mortar.</td></tr>
</table>

Type of Work		Emergency Measures and Temporary Measures	
		KRUNG THON Bridge	KRUNG THEP Bridge
Superstructure		2) Carry out the sealing in the cracks taking place in the pavement. a) Clean carefully the cracks in order to remove dust, mud, etc., contained therein.	
	Adjustment of the height of the expansion joint	1) Level up the expansion joint, by eliminating the overlay on it. a) Remove the pavement and part of the RC floor slab near the existing expansion joint. b) Carry out the adjustment of the height and set the new expansion joint taking into consideration the drainage system and its maintenance. (Refer to Figure 6-2.1)	1) Take the measures required so the rainwater does not flow into the main structure near the supports from the expansion joint.
	Measures to cope with the formation of rust in the steel trussed beams and bascule bridge	1) Rust of the lower chord near by the truss beam support is not as advanced as the KRUNG THEP Bridge, but painting is required as soon as possible at least at some parts where rusting is more serious. a) Completely remove the rust and then carry out the painting. b) Improve the expansion joints and the construction joints of the floor slab in order to prevent floor rainwater from infiltrating into the steel structure.	1) There are serious formations of rust at some parts of the main girder near by the 6 supports of the trussed beam and bascule bridge. Painting is urgently required at least partially, because the said formations of rust present a serious risk to the durability of the bridge. a) Remove completely the rust then carry out the painting. b) Improve of the expansion joint of rainwater into the drainage system, in order to prevent rainwater flowing into the sea located under the bridge surface, particularly the lower chord of the truss located near the supports. c) Rusting is taking place on the cross beam and stringer, due to the infiltration of rainwater from the RC slab construction joint. Make the improvements required to prevent flow of rainwater.

<table>
<tr><th colspan="2" rowspan="2">Type of Work</th><th colspan="2">Emergency Measures and Temporary Measures</th></tr>
<tr><th>KRUNG THON Bridge</th><th>KRUNG THEP Bridge</th></tr>
<tr><td></td><td></td><td></td><td>d) There are serious formations of rust at the splicings of the main girder near the machine room of the bascule bridge. Carry out painting and take measures to prevent flow of rain water.</td></tr>
<tr><td>Superstructure</td><td>PC and RC bridges of the approach section</td><td>1) The cracks taking place in the RC slab of the PC composite beam are not as serious as those taking place in the KRUNG THEP Bridge. However, there are some places where timbering is needed to provide some adequate supports to the slab.

2) In the 6 spans continuous RC rigid girder, the floor slab thickness of 20 cm is very thin in comparison with the spacing of 4.80 m between the main girders. Cracks can be observed everywhere, and in addition, they are still progressing. Presently they are supported by wooden timbering, but this method should be continued until carrying out a radical remodelling or a complete replacement of the bridge.

3) The considerations related to the application of restrictions regarding the load of the vehicles passing through the bridge are identical to those of the KRUNG THEP Bridge. It is also recommended to control the weights of passing vehicles, the same as for the KRUNG THEP Bridge.</td><td>1) There are differences according to the place, but generally speaking, cracks are progressing at present in the RC slab of the PC composite beam and there some places with serious risks of depressions.

As can be seen in Figure 3-3, the RC slabs are supported by timbering from the main girder. However, it is better to remove the existing slabs and to replace them with new ones, with larger thickness and larger quantity of reinforcing bars.

2) Stress analysis in the existing bridge was carried out in accordance with the HB 25 loading. The results indicate that excessive compressive and tensile stresses take place in the upper and lower flanges of the main girder, as shown in the attached table. Accordingly, the restriction of passing especially large vehicles is required even after the replacement of the floor plates.</td></tr>
</table>

<table>
<tr><th colspan="2" rowspan="2">Type of Work</th><th colspan="2">Emergency Measures and Temporary Measures</th></tr>
<tr><th>KRUNG THON Bridge</th><th>KRUNG THEP Bridge</th></tr>
<tr><td>Superstructure</td><td>Restoration of the truss members damaged by the collision of vehicles and measures to prevent the occurrence of collisions in the future</td><td>1) There are 3 or 4 places at the trussed beam where either the cover plate or the lower flange plate are locally cut due to the collision of vehicles.

The end post is a compression member, and it is expected that no serious problems will take place even when it is left unrepaired in an over-stressed state at the time of application of the design load (HB 25 loading). However, it is eventually recommendable to make the following repairs.

a) To remove some of the rivets located near where the cutting took place. The number of rivets to be removed should be that required for the splicing.

b) The bent parts should be straightened by heating up the affected members.

c) Apply the splice plate and carry out the splicing by tightening it with rivets or H.T. bolts.

2) Measures to prevent the occurrence of collision of vehicles.

Actually, the distance from the boundary of the footpath to the edge of the end post is approximately 22 cm, and it is supposed that at least 25 m is required for that purpose. Remove the curbstone once, fill the space of the curbstone with cement mortar and then re-install the curbstone once again. The driveway will become somewhat narrower, but the curbstone should be installed with a margin on the order of 30 cm.</td><td>1) There is a very pronounced twisting in the vertical member V_2 of the trussed beam, due to the collision of a vehicle. Refer to Photo 3-5.7.

Fortunately, stress taking place in V_2 is very small, and the said deformation does not have serious effects upon the whole structure. However, eventually it is recommendable to make the repairs described below.

a) Install temporarily suspension members (2 s or 4Ls) at the lower and upper points where the deformation caused by the twisting disappears.

b) Cut the vertical member at the upper and lower points where the deformation caused by the twisting disappears.

c) Introduce a newly constructed vertical member at the central part and connect its web plates with the web plates of the remaining parts of the vertical member web plates by splice plates.

d) Remove the temporarily suspended member, one side at a time and connect the flange plates by splice plates to finish the restoration.

2) Measures to prevent the occurrence of collisions of vehicles.

The same measures explained for the KRUNG THON Bridge are also applicable to this bridge.</td></tr>
</table>

Type of Work		Emergency Measures and Temporary Measures	
		KRUNG THON Bridge	KRUNG THEP Bridge
Superstructure	Open/Shut system of the bascule bridge and and shear key		1) Actually the opening/closing operation of the bascule bridge is carried out every day at 6 a.m. and the operation system does not present any trouble. However, the shear key of the center of the span and the rear rock key of the rear extremity present the horizontal transversal eccentricity and the horizontal longitudinal eccentricity shown in Figure 3-6.2, Photo 3-6.9 and Photo 3-6.10. These eccentricities tend to increase gradually, and there is the possibility of future trouble in the operation of the bascule bridge opening/closing operation. It is presumed that the eccentricity mentioned above is caused by the deformations due to the scouring of the bridge pier of the substructure. However, it is indispensable to make detailed investigations (to be carried out by mechanical engineers) of the wearing and other troubles in the operation system, particularly in the rotation shaft of the tranion. 2) A crack opened approximately 4 years ago at the lower side of the seat concrete slab of the rear rock key of the Thonburi side, and it is strengthened with H-Beam members, as shown in Photo 5-5.2. According to the original design, no uplift pressure should take place in the rear rock key, but there is possibility of occurrence of uplift pressure as a consequence of the increase in the live load. Therefore, similar measures are also presumed to be required at the Bangkok side.

Type of Work		Long-term Measures: KRUNG THON Bridge	Long-term Measures: KRUNG THEP Bridge
Superstructure	RC slab, pavement and expansion joint	1) The actually existing RC slabs should be completely removed and replaced with new RC slabs, taking in consideration the following modifications. a) The thickness of the slab should be increased to some extent. b) The main reinforcement of the slab should be composed of double bars, and the quantity of distribution bars should be increased. c) The RC slabs should be made without construction joints through each span. 2) In case of making the repair of the pavement, it is recommendable to adopt the asphalt concrete pavement, in view making possible an easy maintenance and repair. However, in case of adopting the concrete pavement, it is recommendable to construct it together with the RC slab. In addition, a wearing course composed of a covering (10 mm thick) of asphalt + mortar should also be constructed.	1) With exception of the bascule bridge, the RC slab and the pavement should be completely replaced, as in the KRUNG THON Bridge. 2) The expansion joints should be steel finger-type ones, having a construction making easy maintenance and repair possible, and should be furthermore equipped with water drainage facilities. (Refer to Fig. 6-2.1)
Superstructure	Reinforcement of the stringers	1) The time of complete replacement of the RC slabs is the best time for strengthening of the stringers, cross beams, etc. Accordingly, it is indispensable to investigate in advance the places requiring strengthening, the strengthening method and other related details. The strengthening method and other details are presented in Figure 6-2.3.	1) With regard to the strengthening of the trussed beam and floor system, the same measures adopted in the KRUNG THON Bridge are also applicable in the case.

<table>
<tr><th colspan="2" rowspan="2">Type of Work</th><th colspan="2">Long-term Measures</th></tr>
<tr><th>KRUNG THON Bridge</th><th>KRUNG THEP Bridge</th></tr>
<tr><td>Superstructure and Substructure</td><td>With regard to approach bridge</td><td>1) The overstressed state of the lower edge of the main girder cannot be changed even after completely replacing the RC slab of the PC composite beam, by increasing the thickness and the quantity of reinforcement bars of the slab. Eventually, it is recommendable to shorten the spacing between the main girders and to completely replace the bridge itself.
2) With regard to the RC rigid frame T-girder bridge extending continuously over 6 spans, the spacing between the floor plates is 4.800 m, which is a large value compared with the spacing between the stringers of the truss. The thickness of 20 cm of the floor slab is also small, as shown in the Figure 3-5. The strengthening method utilizing the actually existing floor slab, like that one illustrated in Figure 6-2.5 may be taken into consideration. However, special methods are required for the sake of driving the foundation piles, because the space available under the girders is restricted.

The complete replacement of the bridge should be taken into consideration if the actually existing floor slab cannot be utilized or when the said method is not feasible in view of the restrictions imposed by budgeting.</td><td>1) With regard to the PC composite beam, the same measures adopted in the KRUNG THON Bridge are also applicable in this case.</td></tr>
</table>

Type of Work		Long-term Measures	
		KRUNG THON Bridge	KRUNG THEP Bridge
Substructures	Increase of stability regarding the scouring of the piers of bridges located in the river	As for the river-bed scouring at the foundations, the scouring of 2 or 3 meters has developed around each pier as the result of investigation of PWD. And the piers seem to be unstable considering the depth of Caisson. As the temporary measures, there is execution of method of crush-rock and cement mortar, as shown Fig. 6-2.6. It is, however, better to change the bearing system such as driving steel or concrete piles into the bearing stratum.	The same measures adopted in the KRUNG THON Bridge.

<table>
<tr><th colspan="2" rowspan="2">Type of Work</th><th>General Measures</th></tr>
<tr><th>Measures Common to Both Bridges</th></tr>
<tr><td rowspan="3">Superstructure and Substructure</td><td>Installation of equipment for automatic weighing of the axle load of the vehicles</td><td>Recently the traffic of large-size vehicles exceeding the weight limits fixed by law is increasing (also in Japan) and is becoming problem because it causes the cracking of RC slabs, wearing and damage of pavements.

Japan Highway Public Corporation, Tokyo Expressway Public Corporation and other related organizations are installing facilities like automatic axle load scales, interlocked recorders, cameras, etc., near toll gates in order to check in advance the traffic of such vehicles. There are two types of axle load scales, namely, the fixed type one shown in Photo 6-2.1 through Photo 6-2.4 and the movable type one shown in Photo 6-2.5.

Also in the Kingdom of Thailand, it is recommendable to construct these facilities (including the bypass roads for vehicles with overload and facilities for removal of overloaded vehicles), in order to gradually put the weight limit into practice.</td></tr>
<tr><td>Construction of roads of access for inspection of the bridge</td><td>Generally speaking, bridges are not provided with access roads for inspection and as a result, the periodic inspections are neglected in view of the difficulties of access. As a consequence, serious formations of rust and cracks are prone to be overlooked, resulting in the occurrence of accidents and shortening of the durability of the structure itself. Particularly in the case of steel bridges, these inspection roads are effective for the sake of painting, and accordingly it is recommendable to take them into consideration at the design stage. Refer to Figure 6-2.7 and Figure 6-2.8.</td></tr>
<tr><td>Investigations for the next stage</td><td>(1) Boring for geological investigation near both bridges.
(2) Study of the stability for the substructure foundation.
(3) Non-destructive strength test for the concrete of the approach bridges.
(4) Detailed inspection of the bascule bridge operating machinery for the KRUNG THEP Bridge. The causes of the horizontal discrepancy of the shear rock keys located at the center span and at the rear end of main girder should be inspected with particular care.
(5) Study of the volume of traffic at the KRUNG THEP Bridge as a part of the Middle Ring Road.</td></tr>
</table>

EEL FINGER JOINT

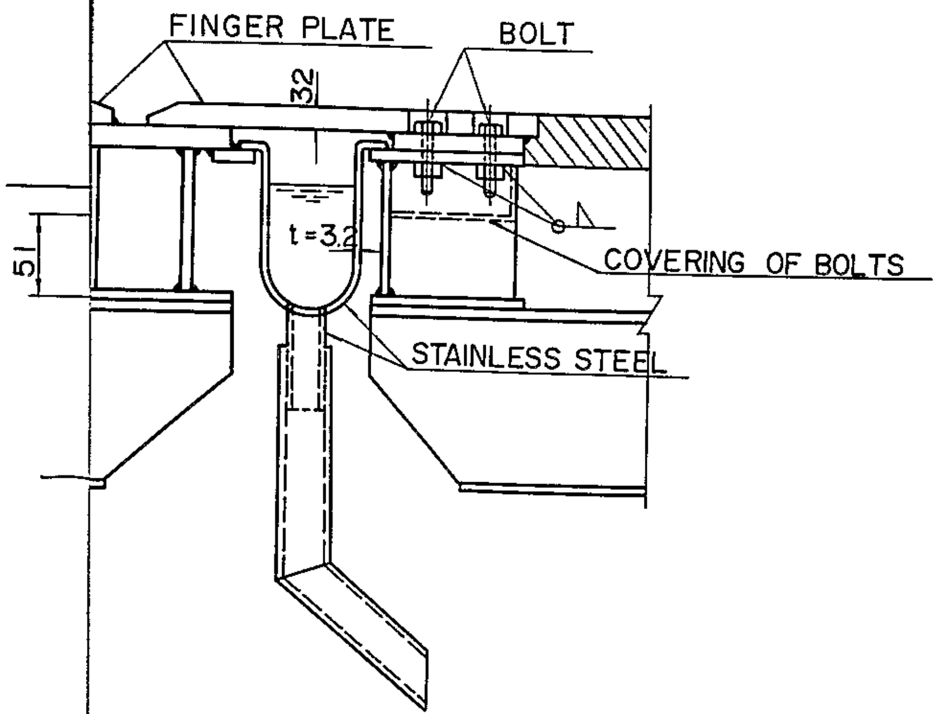
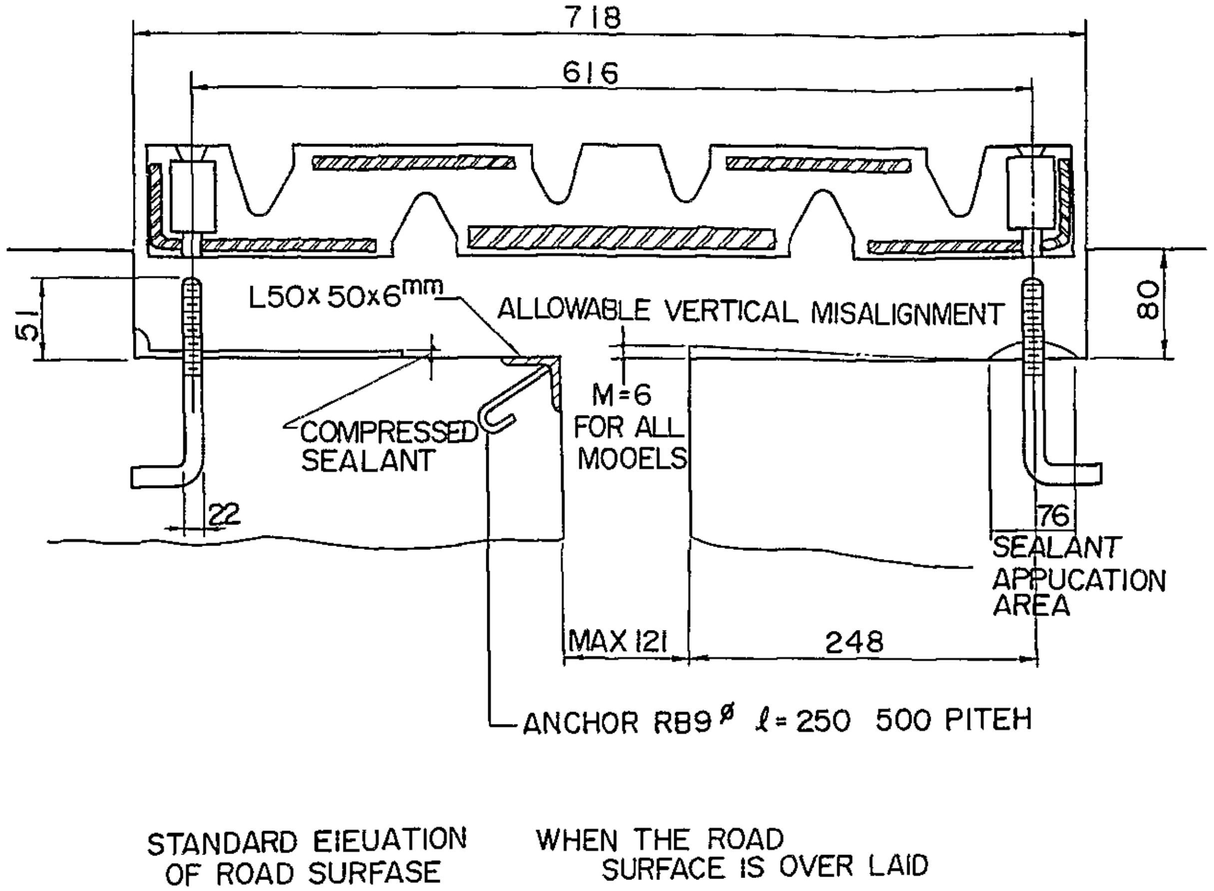


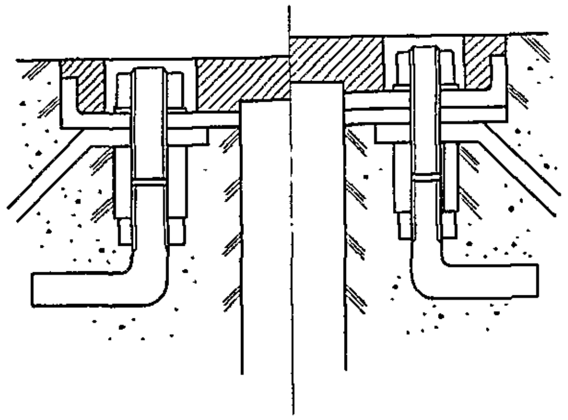
PLATE IS BOLTED WITH LOWER
E AS POSSIBULE TO CLEAR, IF
GUTTER IS STOPPED WITH SOILS
S BETTER TO UISE THE STAINLESS STEEL
ES AS GUTTER WHICH IS DIFFICULT TO CHANGE
WATTER IS LEAD IN PLACE NO TROUBLE

OC

1) F
2) F
(9

Fig. 6–2.1 IMPROVEMENT OF EXPANSION JOINT



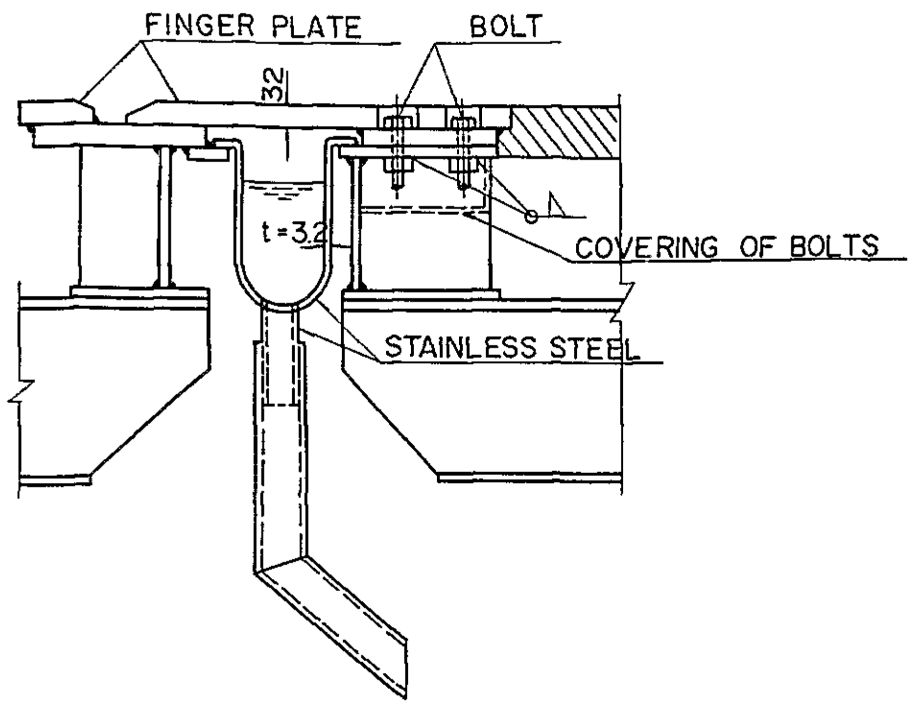


	NAMES OF MATERIALS
①	LONG BOLT
②	NUT
③	WASHER
④	ANCHOR BAR
⑤	ANCHOR BOLT
⑥	ROCK NUT
⑦	SHORT BOLT
⑧	LONG NUT
⑨	SPACER

OCCASION OF RISING THE EXPANSION JOINT

1) REMOVE THE SHORT BOLT ⑦ AND CHANGE TO THE LONG BOLT ①
2) PUT THE SPACER (MADE OF STEEL, HARD RUBBER, OR EPOXIDE RESIN) ⑨ UNDER THE EXPANSION JOINT

STEEL FINGER JOINT



1) FACE PLATE IS BOLTED WITH LOWER PLATE AS POSSIBULE TO CLEAR, IF THE GUTTER IS STOPPED WITH SOILS
2) IT IS BETTER TO UISE THE STAINLESS STEEL PLATES AS GUTTER WHICH IS DIFFICULT TO CHANGE
3) RAIN WATTER IS LEAD IN PLACE NO TROUBLE

Fig. 6–2.1 IMPROVEMENT OF EXPANSION JOINT

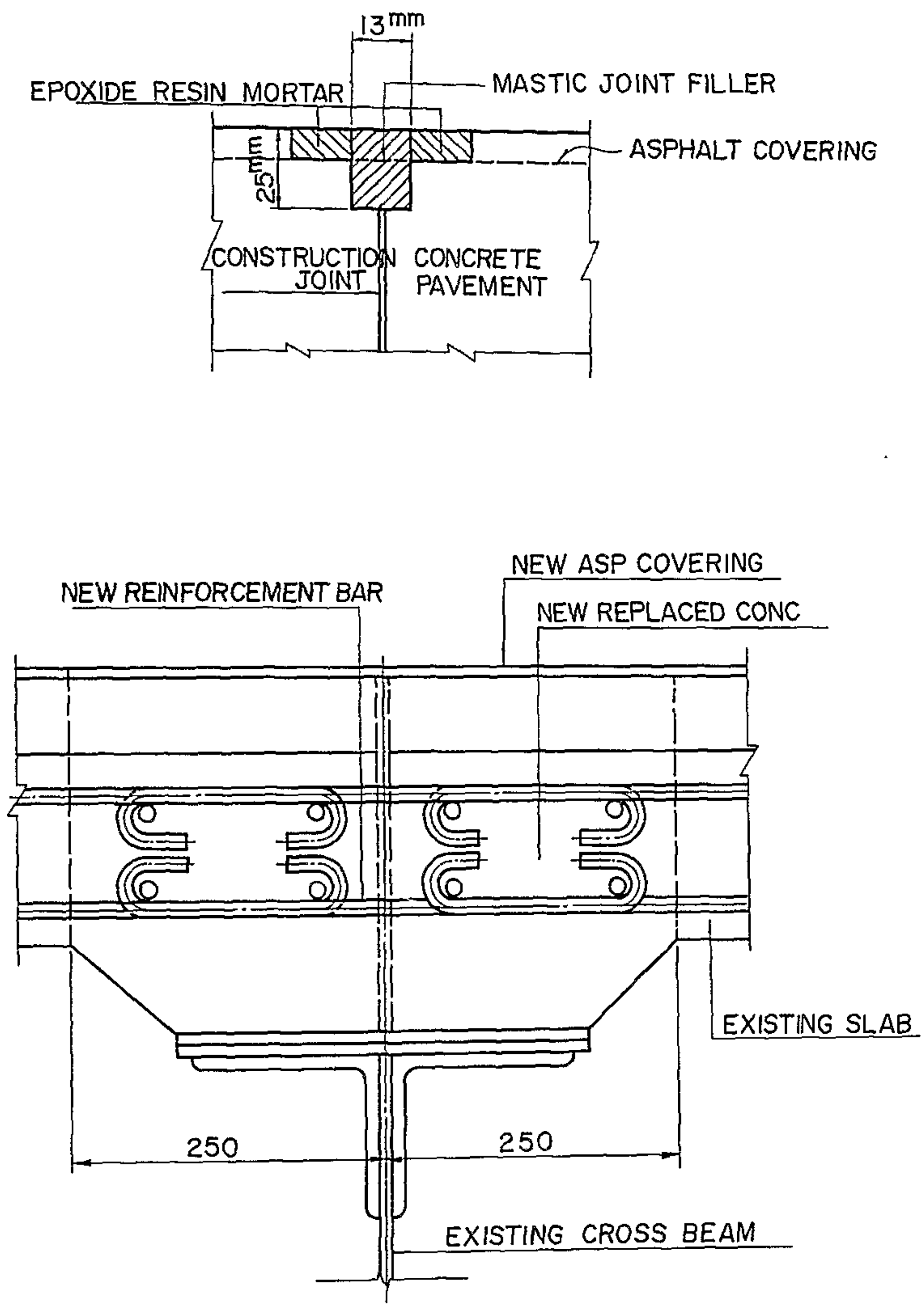


Fig. 6–2.2 IMPROVEMENT AND DISSOLUTION OF CONSTRUCTION JOINT

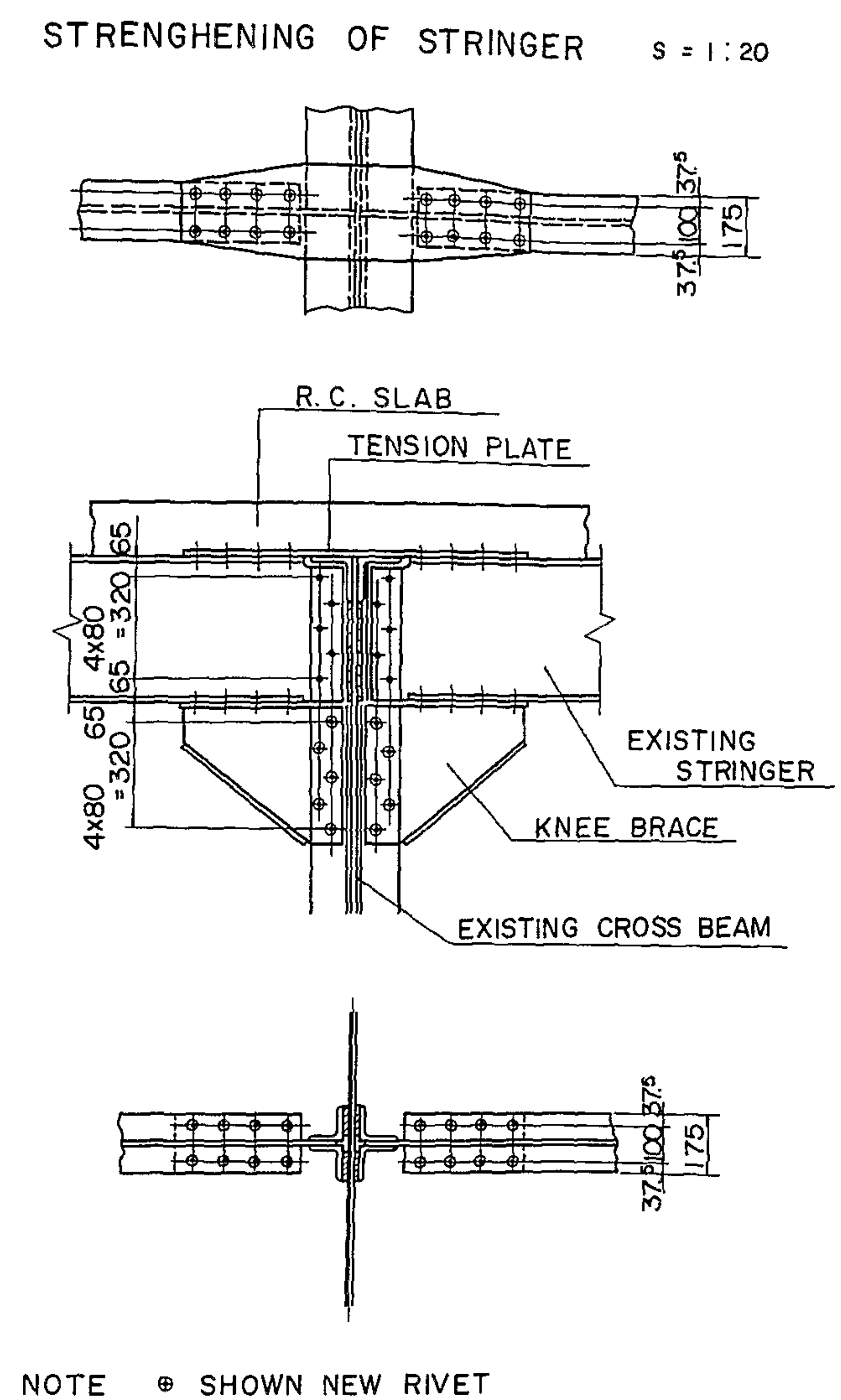


Fig. 6-2.3 STRENGTHENING OF STRINGER

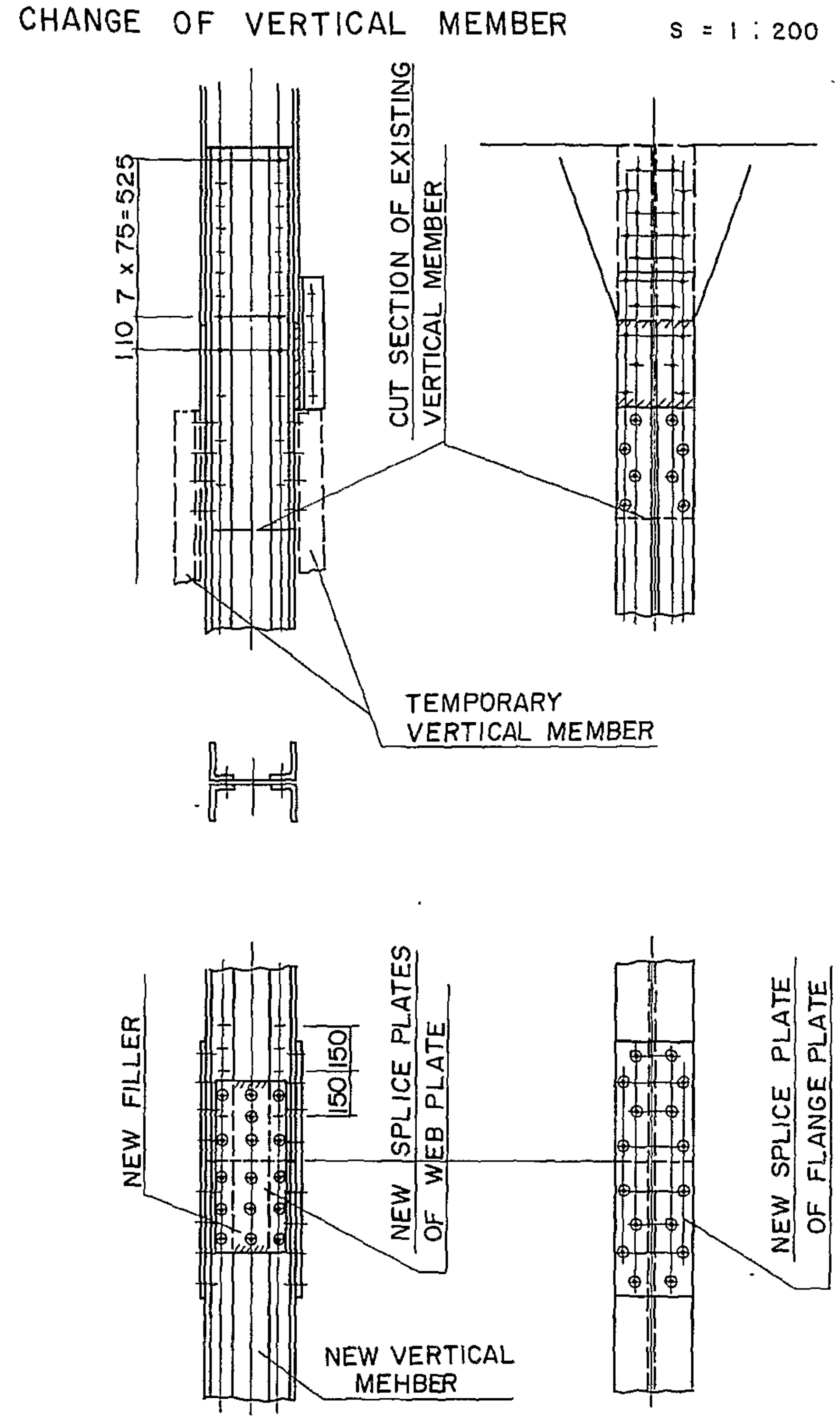


Fig. 6-2.4 CHANGE OF VERTICAL MEMBER

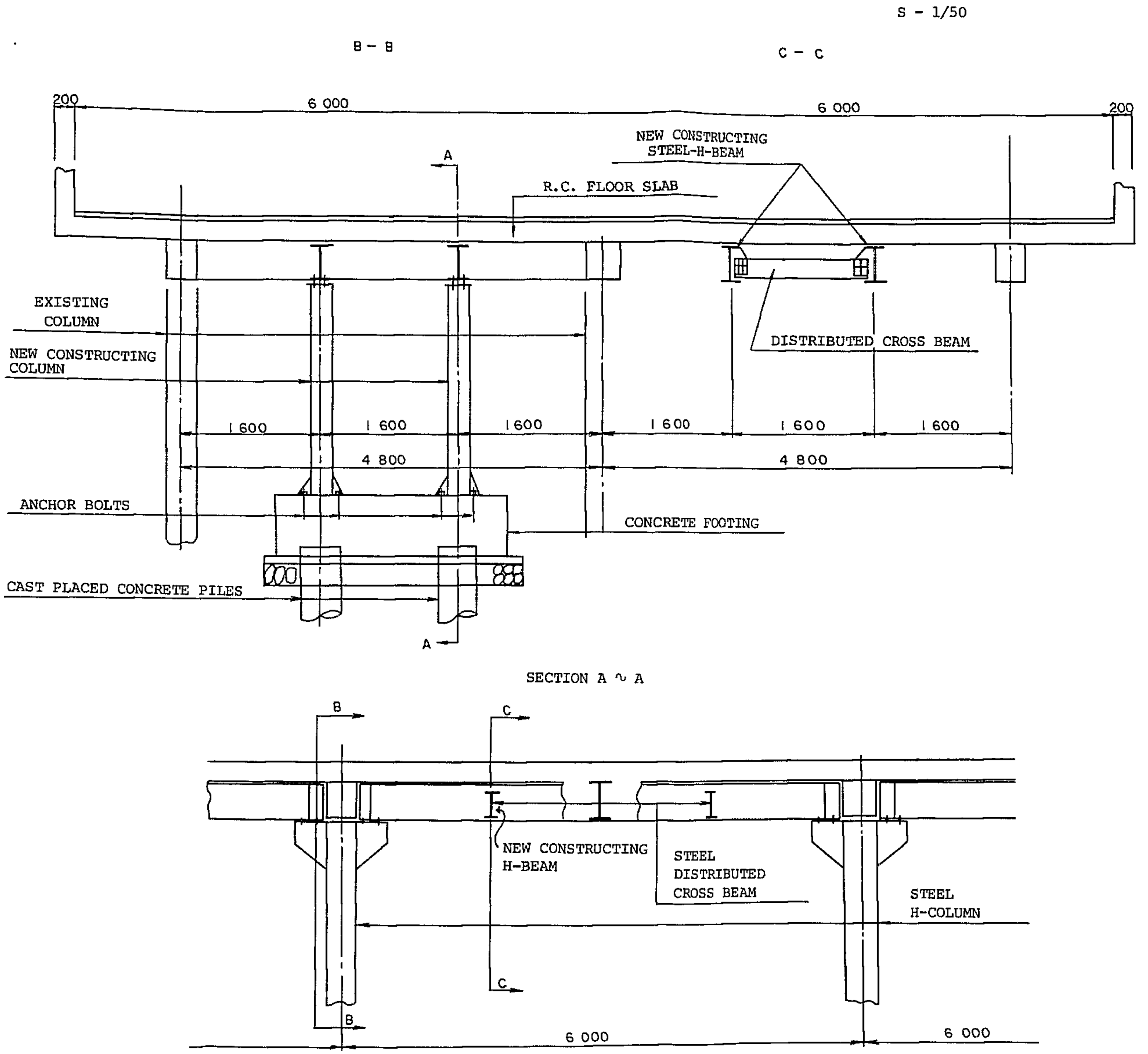
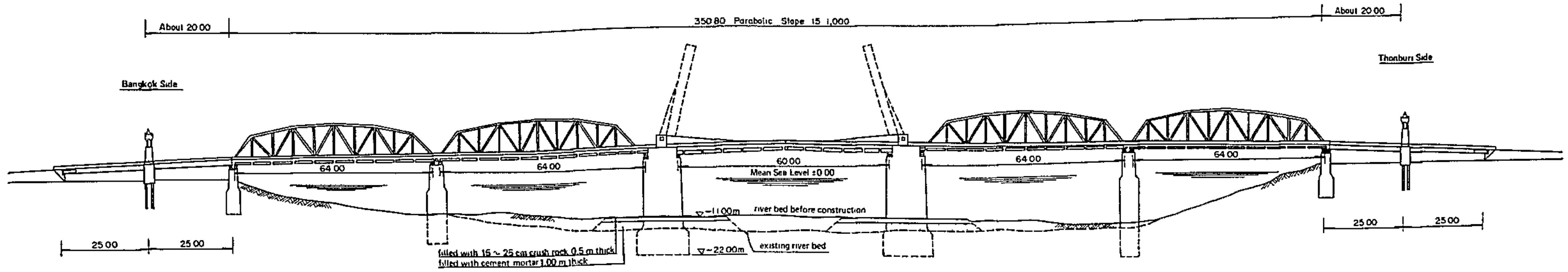
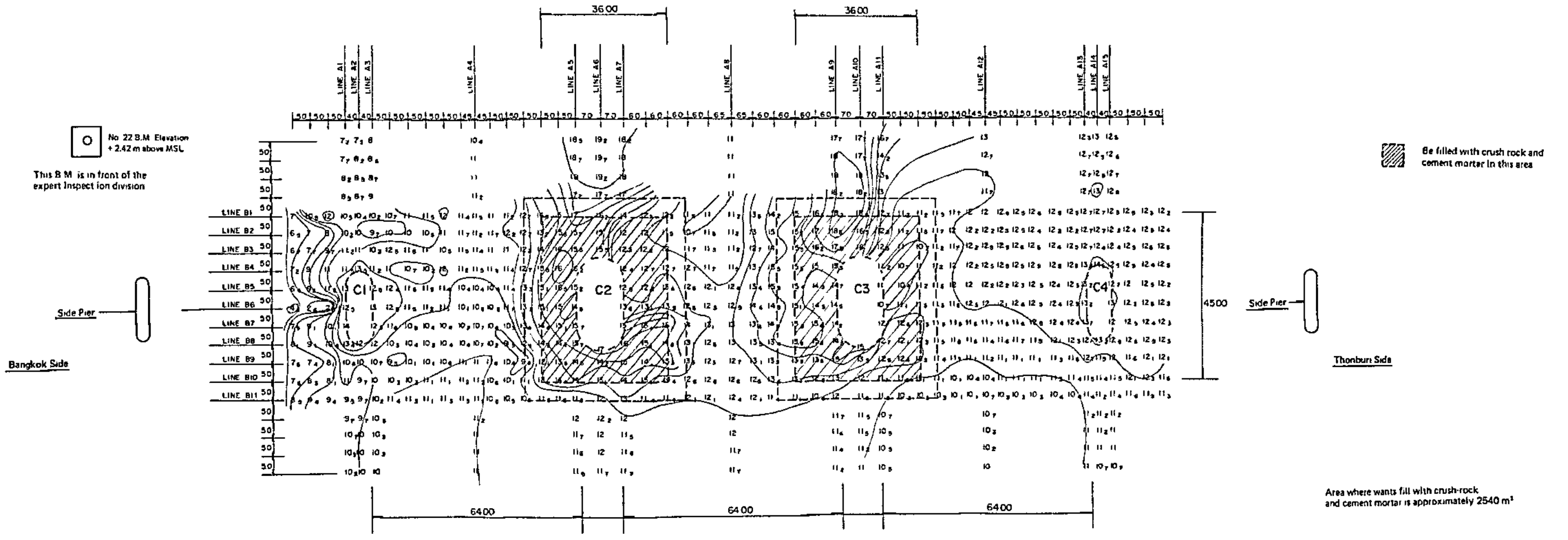


Fig. 6–2.5 TEMPORARY STRENGTHENING METHOD FOR 6 SPAN CONTINUOUS RC–T–RIGID BEAM

SIDE VIEW OF THE KRUNG THEP BRIDGE





TIDAL DATA SATHUPRADIT STATION

HIGHEST HIGH WATER	+ 2.17m
MEAN HIGH WATER	+ 0.90m
MEAN SEA LEVEL	± 0.00m
MEAN LOW WATER	− 0.36m
LOWEST LOW WATER	− 1.72m

PLAN SHOWS CONTOURS OF CHAO PHRAYA RIVER BED

Fig. 6–2.6 COUNTER MEASURE TO SCOURING OF THE RIVER BED AROUND THE PIERS

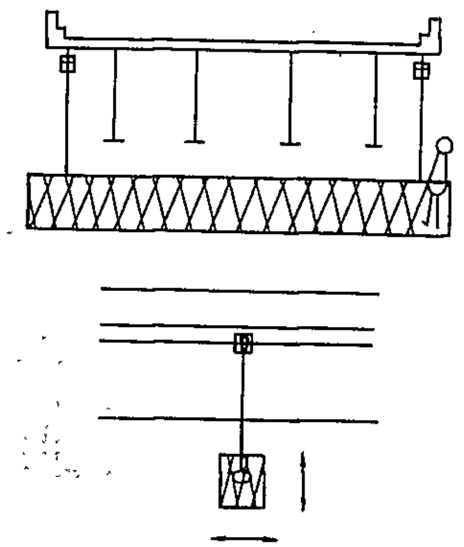
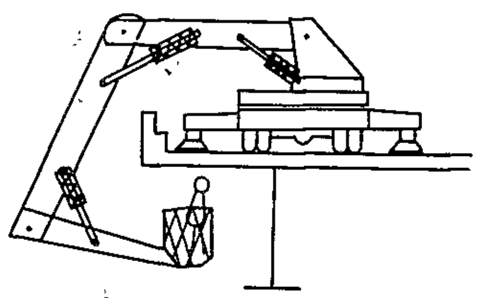


Illustration shows a movable gondola



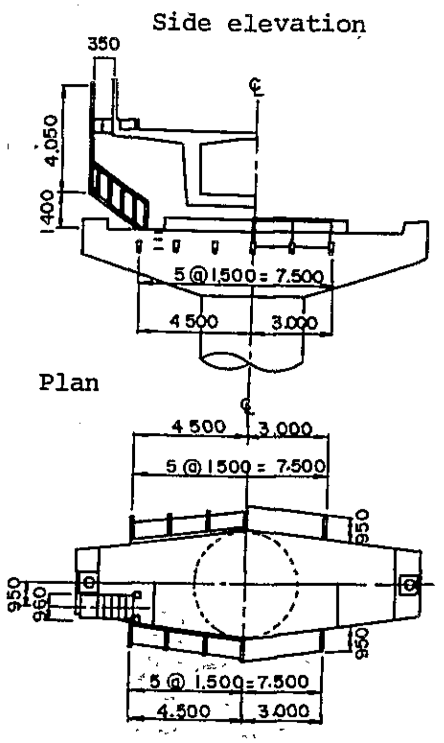


Figure shows an example of inspection scaffold for a pier

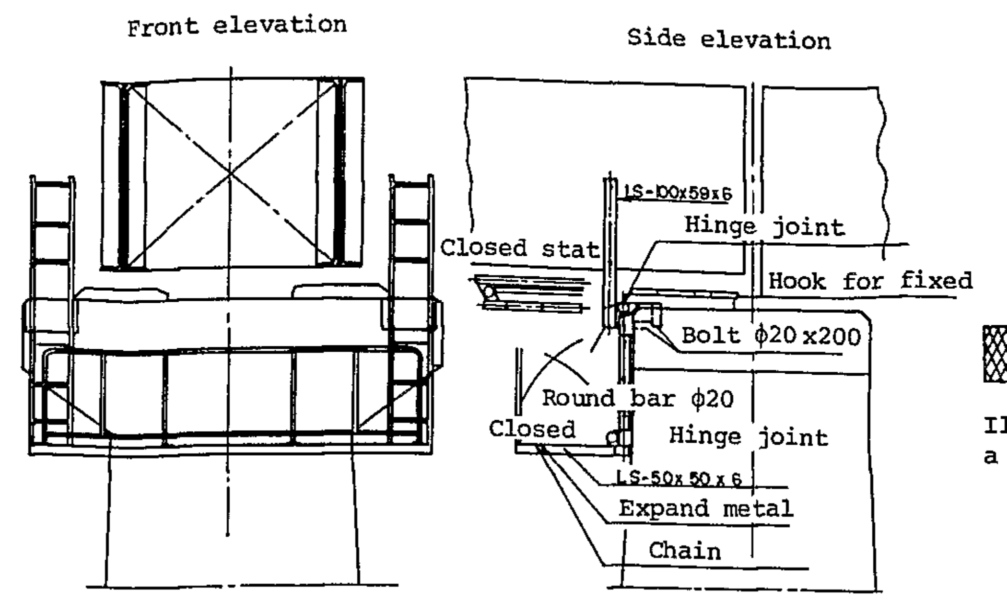


Figure shows a inspection path able to opening and closing

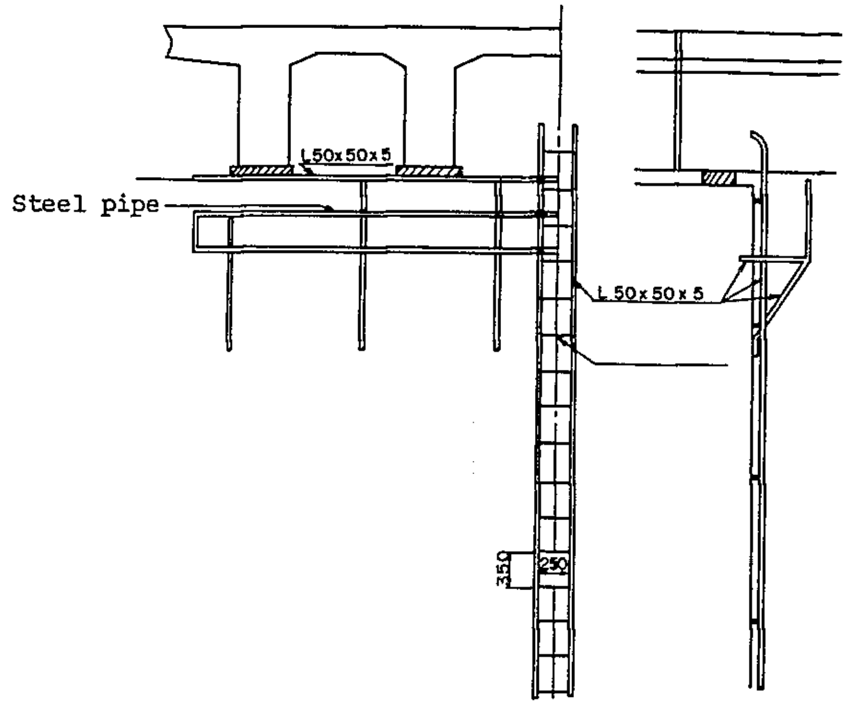


Figure shows a ladder for inspection

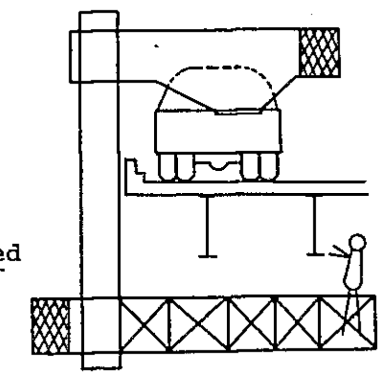


Illustration shows a vehicle with scaffolding

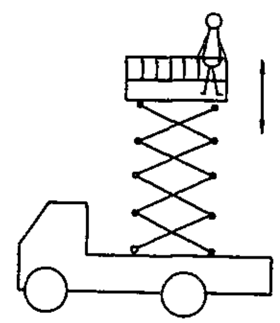


Illustration shows a with scaffolding vehicle

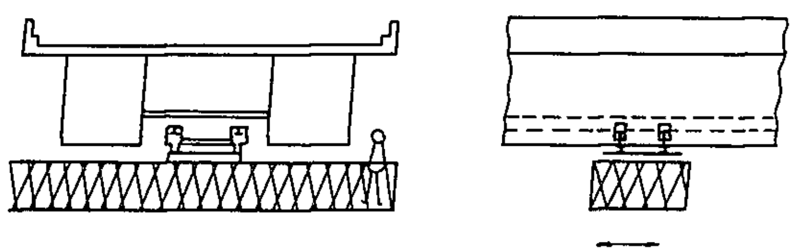


Illustration shows a movable gondola

Figure shows an example of a steel Box Girder

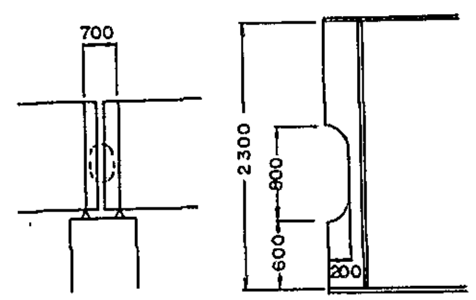


Figure shows a steel Plate Girder

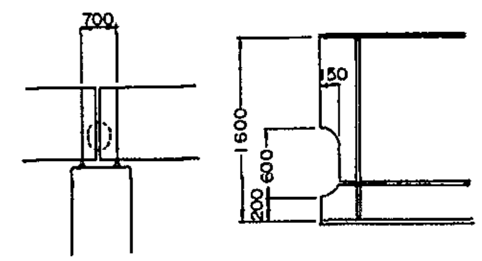


Figure shows a cutting of a steel Girder End

Fig. 6–2.7

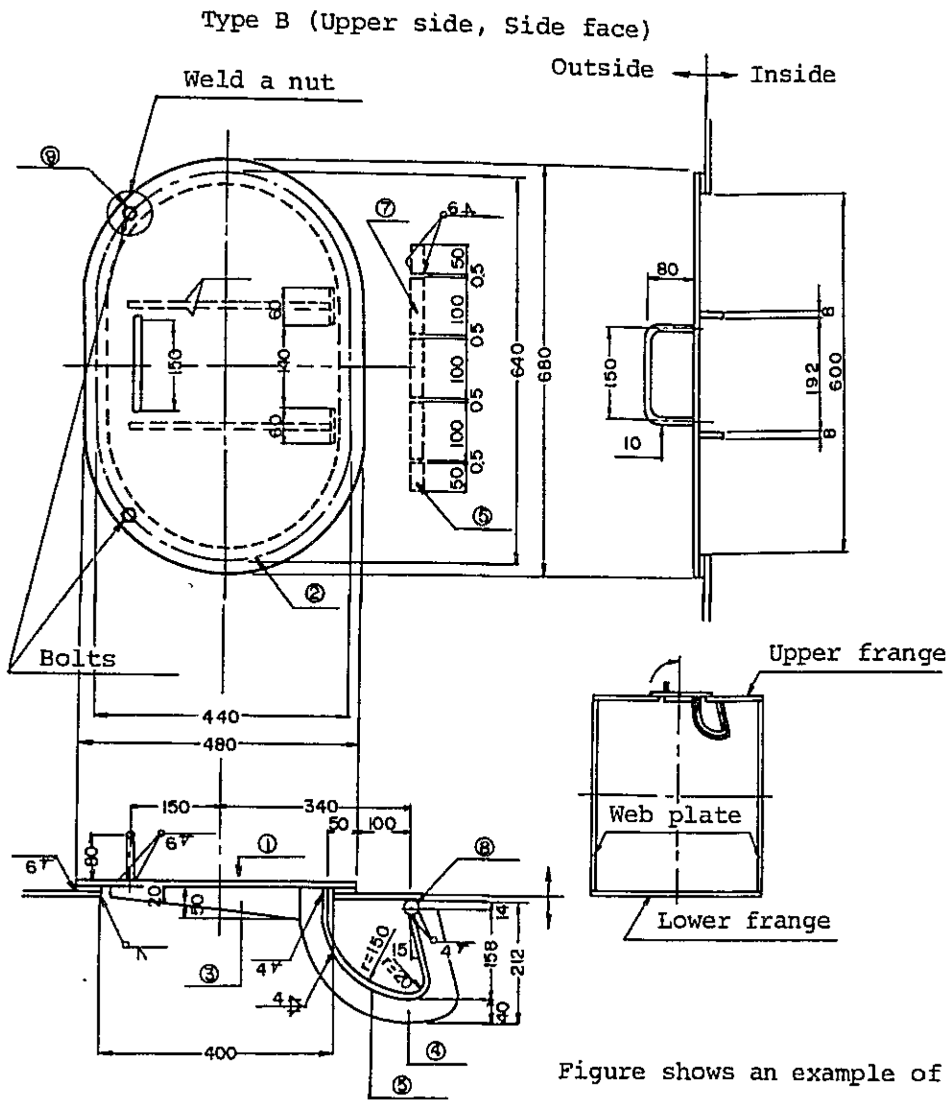


Figure shows an example of Manhole

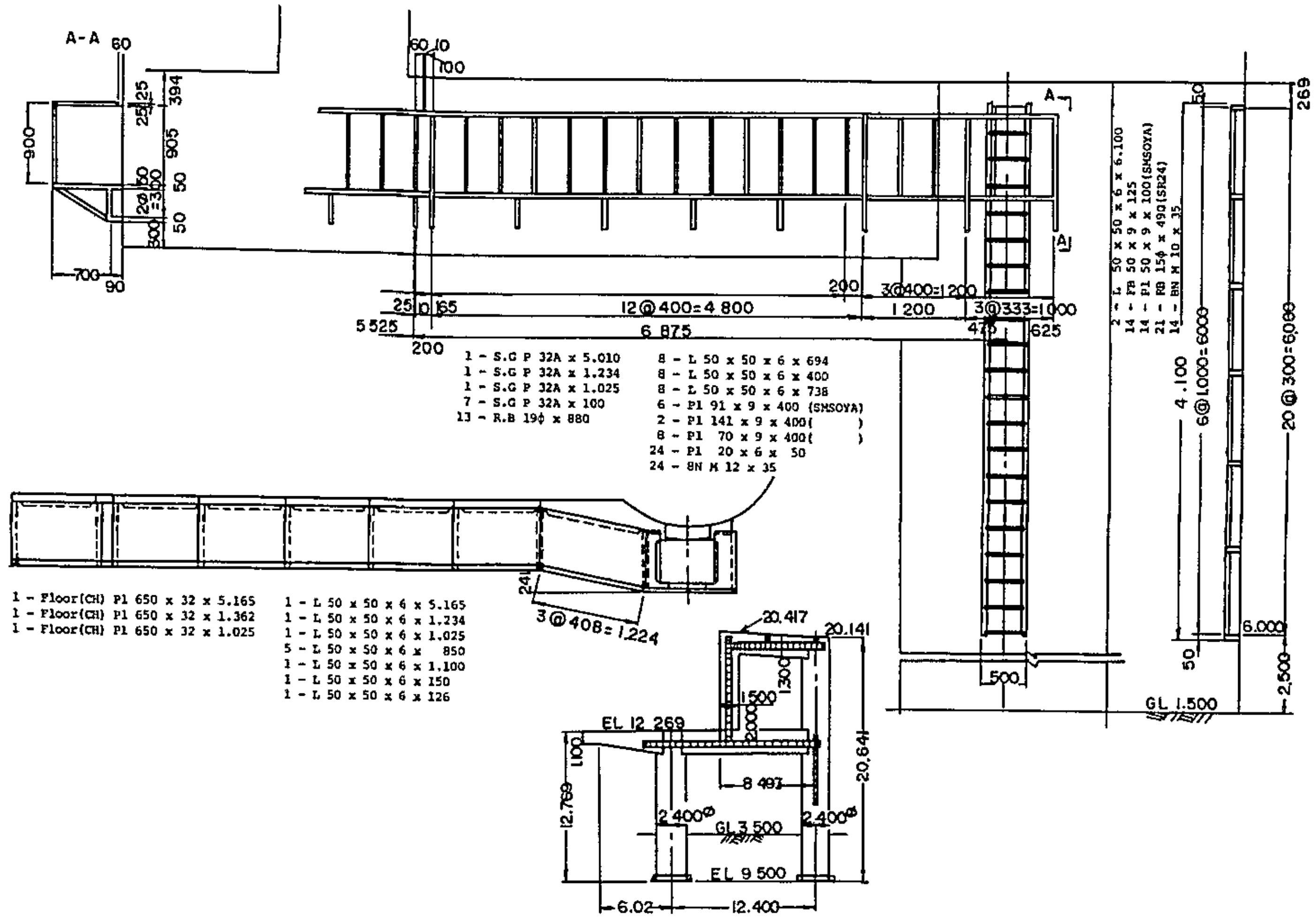


Figure shows an example of inspection path for a substructure

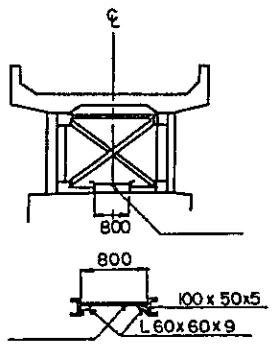


Figure shows an inspection path
for steel composite Girder

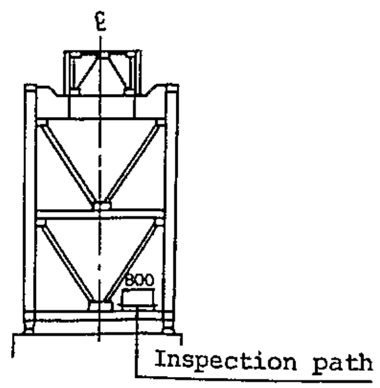


Figure shows an inspection path
for Steel Deck Trussed Beam

Fig. 6–2.8

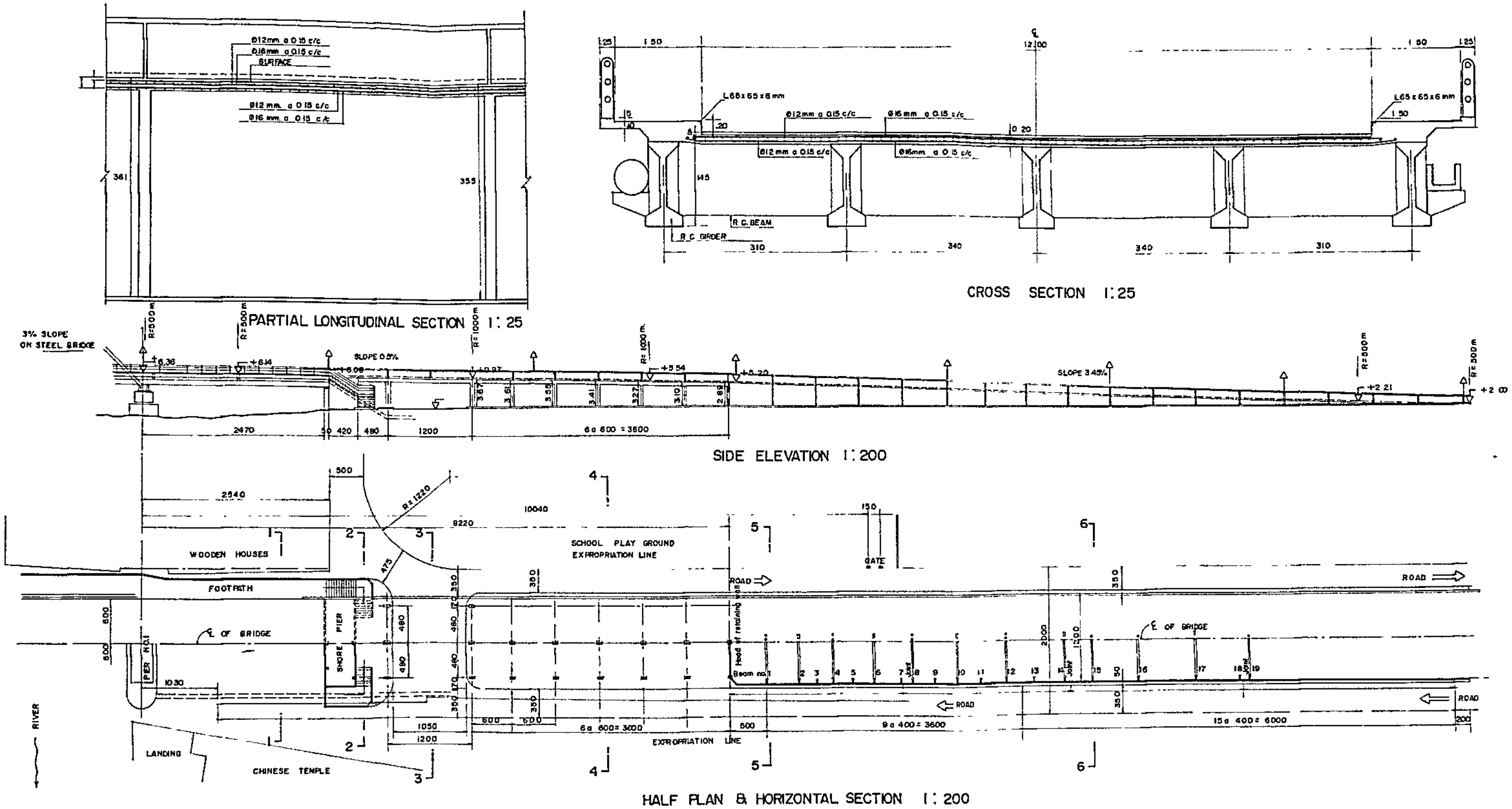


Fig. 6–2.9 REPLACEMENT OF THE RC FLOOR SLAB ON THE RC COMPOSITE GIRDER

APPENDICES

APPENDIX 3-1.1

OVERLAY METHOD

1) Removal of the actually existing asphalt pavement.

2) Clean perfectly the asphalt floor plate surface.

3) Take measures to improve the adherence of the concrete to be placed on the old concrete layer of the actually existing floor plate (e.g. roughening of the surface with application of wire brush on the actually existing floor plate).

4) Place a layer of approximately 6cm thickness of concrete having a small contraction on the actually existing floor plate.

5) Place a mesh of reinforcement bars in the new concrete mentioned above. (The reinforcement bars should be approximately 6mm diameter.)

6) Provide joints at the positions corresponding to the cross beams, in order to prevent the occurrence of contraction cracks in the new concrete layer.

   (The width of these joints should be on the order of 10mm.)

   Water stopping joint filler should be filled in the joints mentioned above.

7) Large cracks should be filled with epoxy resin.

   (Generally speaking, cracks 0.3mm or more are the objects of this treatment. In case of places with easy deterioration of the concrete, cracks of 0.2mm should be filled, and at places where the concrete is immersed in sea water, cracks of 0.1mm should be filled.)

   This method brings satisfactory results when correctly executed, and in addition the required cost is relatively small. However, partial stopping of the traffic is indispensable, at least temporarily. In order to shorten the stoppage of the traffic, it is recommendable to use types of concrete which harden more quickly up to the required strength. (A type of cement which hardens more rapidly than the conventional quick hardening cement was developed in Japan. In Japan this new kind of cement can be purchased at prices on the order of 11,000 Yen/ton near Tokyo.)

The effectiveness of the overlay method is determined by the strength of adherence of the new and old concrete layers. It is possible to check the effectiveness of adherence of these concrete layers by carrying out a static load test, wearing test, etc., with a model, but the most recommendable method is to apply this method "in loco" at some parts of the bridges in question and to test it with the actual traffic of vehicles.