3-3-2 Plan of Operation

The Ministry of Communication, Transport and Post (MCTP) has overall responsibility for the entire transportation network. The MCTP has several self-supporting companies under their jurisdiction. The MCTP had 2,185 staff in 1991 and some 12,000 staff including personnel working in self-supporting companies. As shown in Fig. 3-2, The Road and Bridge Department has the following six self-supporting companies:

1) Road Construction Company
2) Bridge Construction Company
3) Crushing Stone Company
4) Saw Mill Unit
5) Ferry Operation Companies
6) Road Repair and Maintenance Units

The Road Repair and Maintenance Units are divided into following eight units.

1) Routes No. 1 and No. 15
2) Route No. 5 Section A (Phnom Penh - Pursat 186 km)
3) Route No. 5 Section B (Pursat - Battambang 105 km)
4) Routes No. 2, No. 3 and No. 17
5) Routes No. 6 and No. 12
6) Routes No. 4 and No. 18
7) Route No. 7
8) Route No. 13

Due to twenty-year abandonment of Route 6A, Route 6A including the Chroy Changwar Bridge is not included in any road repair and maintenance units. It is very sure that the Project will be implemented under the RBD and will be maintained under the Road Repair and Maintenance Unit.

3-3-3 Location and Condition of Project Site

a. Location of Project Site

The Project Site for Restoration of Chroy Changwar Bridge is on the existing partially collapsed 709 m long Chroy Changwar Bridge plus the lengths of the approach sections.

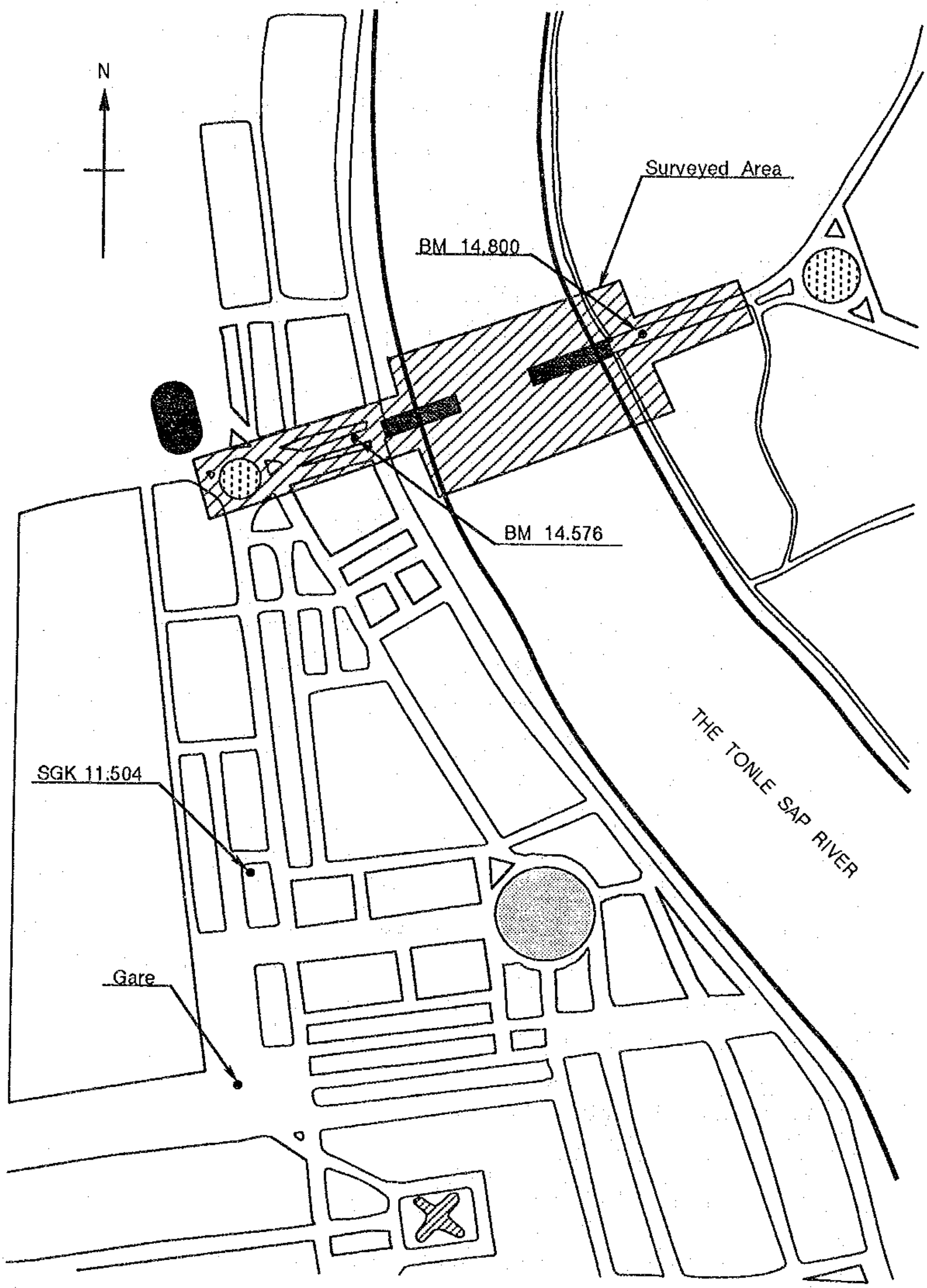


Fig. 3-3 Location of Project Site

b. Present Condition of Chroy Changwar Bridge

The structural soundness investigation was carried out about the following items:

1) Visual inspection of structural steel plate and deck
2) Visual inspection of structural concrete in the air
3) Visual inspection of structural concrete in the water
4) In-situ compression strength test by Schmidt Hammer
5) Laboratory compression strength test using core samples
6) Deformation/Aberration investigation of bridge structure by survey equipment
7) Visual inspection of pavement

The results of the investigation are summarized as follows:

1) The surface of slope is eroded in some portion. Consolidation settlement is observed in the embankment of Chroy Changwar side and due to the settlement traffic railings are seriously damaged. (Photo 3-1)

2) The grouted riprup located in front of abutment is deteriorated and piles were exposed as shown in Photos. (Photo 3-2, Photo 3-3)

3) The bearing layer of P8 abutment is scored in part and should be repaired. (Photo 3-4)

4) Although local cracks and/or local separation of concrete were observed at the bottom of some columns of concrete pier, these deterioration are not significant and these concrete were judged to be sound. (Photo 3-5)

5) Some minor cracks were appeared on the surface of piers P1-P3 and P6-P8, but these are not significant. No settlement and no deterioration of concrete were found.

6) No. 4 pier and No. 5 pier are seriously damaged and almost collapsed because of the destruction due to the explosion.

7) Some connection bolts of the existing 2 spans continuous box girder bridge were stolen and disappeared. Local rust was observed at the end of the girder and blacket. A part of hand rail, bearings are corroded. But these are not serious from the structural viewpoint. (Photo 3-6, Photo 3-7, Photo 3-8)

8) Expansion joints were corroded but no serious deterioration was observed. (Photo 3-9, Photo 3-10)

9) Pavement is hardly deteriorated due to thirty years leaving without maintenance. (Photo 3-11)

10) Almost all drainage pipe are stuffed by soil or gravel.

11) Some posts of handrailings are deteriorated hardly. (Photo 3-12)

12) The bearing of P1 abutment located in the upstream side is corroded partially. The bearings of P8 abutment are in a good condition than P1 abutment. (Photo 3-13)

13) The slant of rocker bearing would not be occurred by collapse of center span but it would be due to an execution error during installation. (Photo 3-15)

14) The deck plate was sound judging from the condition observed in the site after removing the pavement.

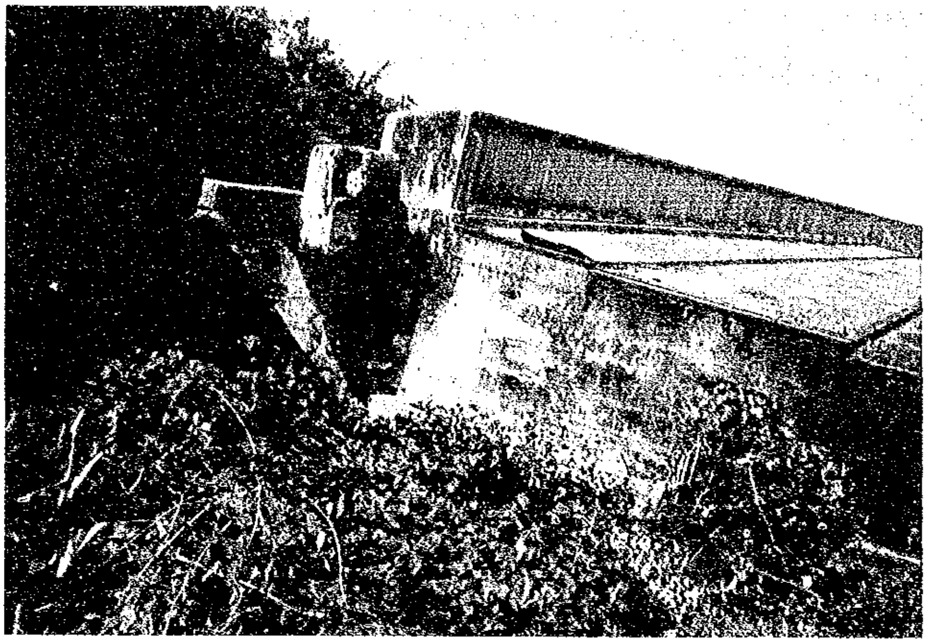


Photo 3-1 Consolidation settlement of embankment Chroy Changwar side

Photo 3-2 Deterioration of grouted riprup Phnom Penh side

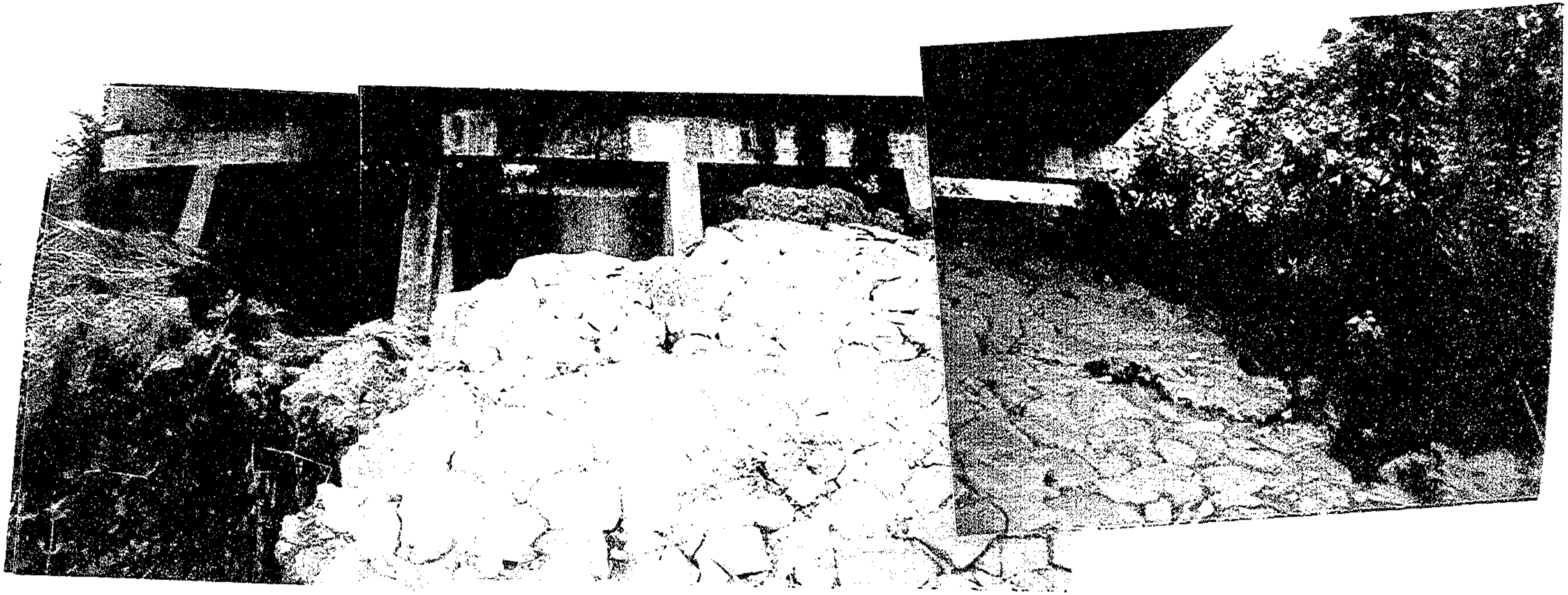


Photo 3-3 Deterioration of grouted riprup Chroy Changwar side

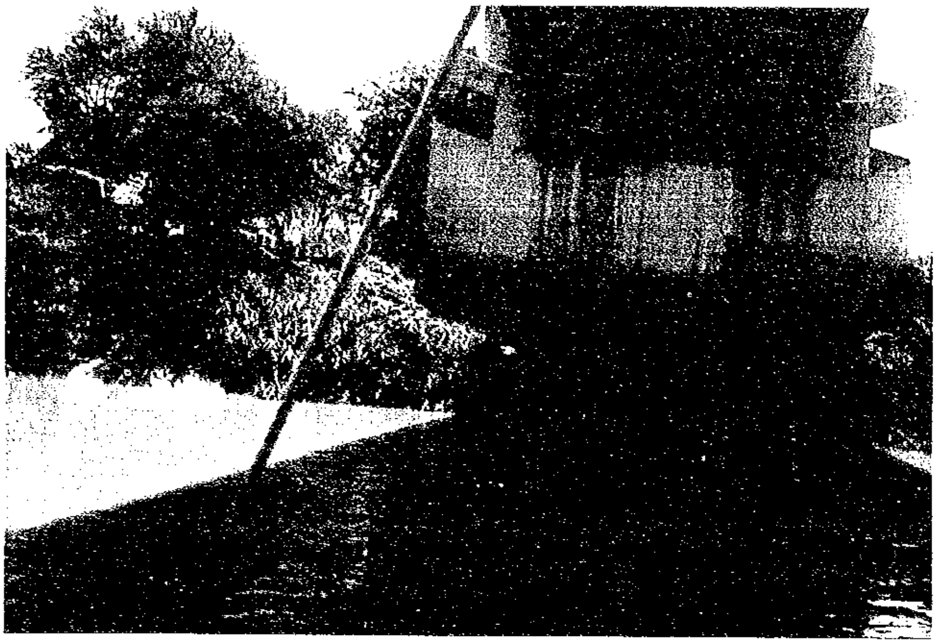


Photo 3-4 Erosion of foundation layer of P8 abutment

Photo 3-5 Concrete cracks at the bottom of column of pier

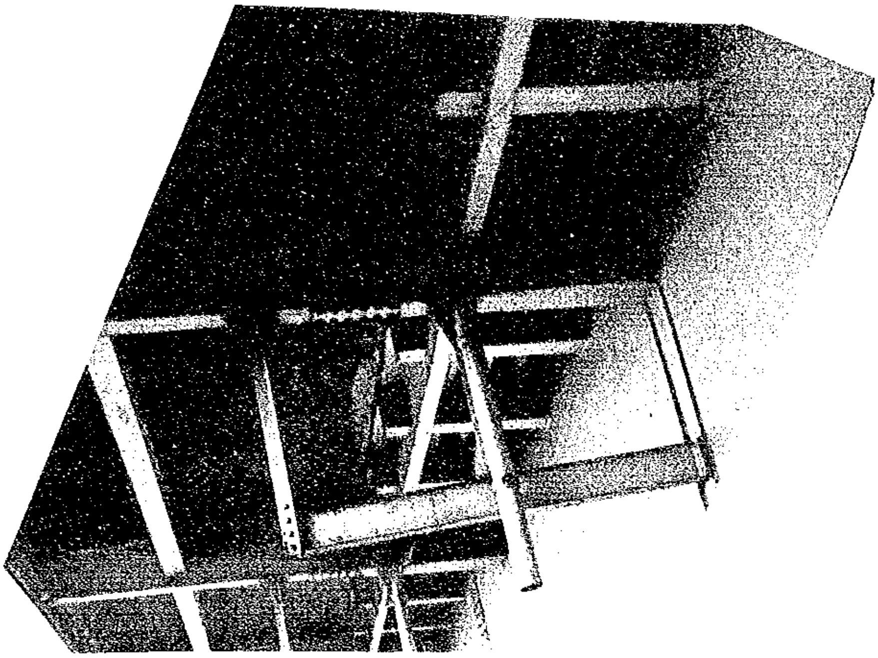


Photo 3-6　　Condition of rusted blacket

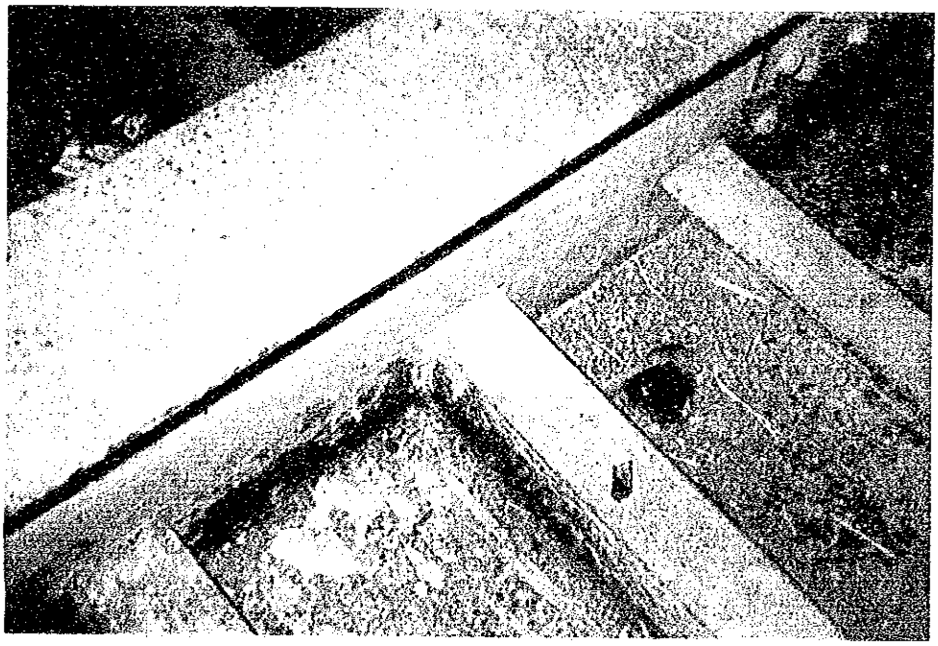


Photo 3-7　　Condition of rusted rib and flange plate

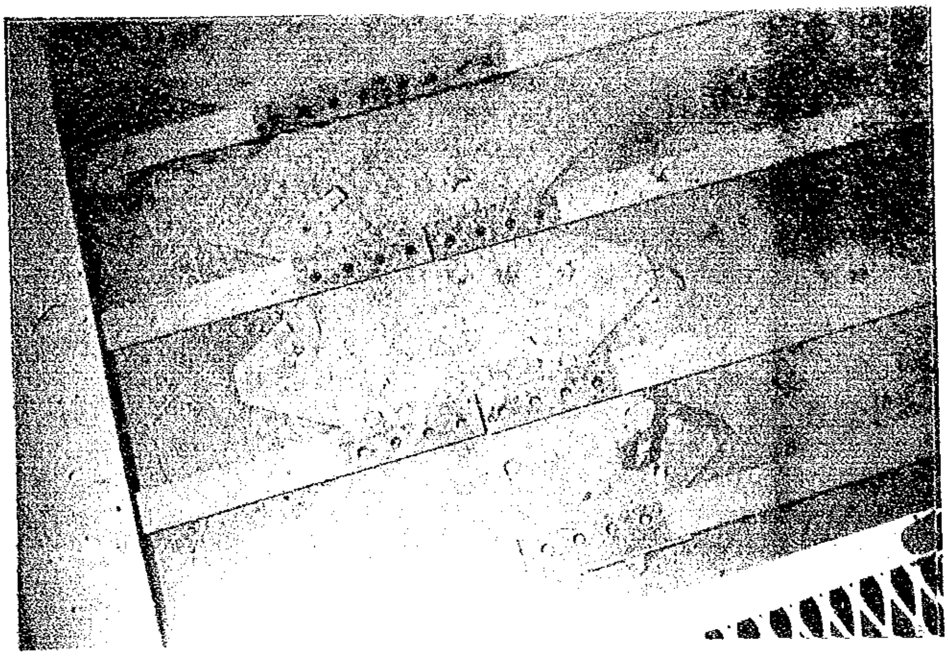


Photo 3-8 Condition of connection bolts

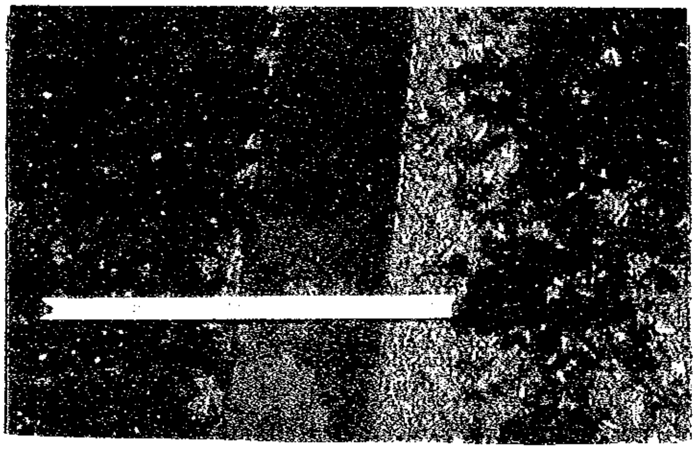


Photo 3-9 Expansion joint of Concrete bridge

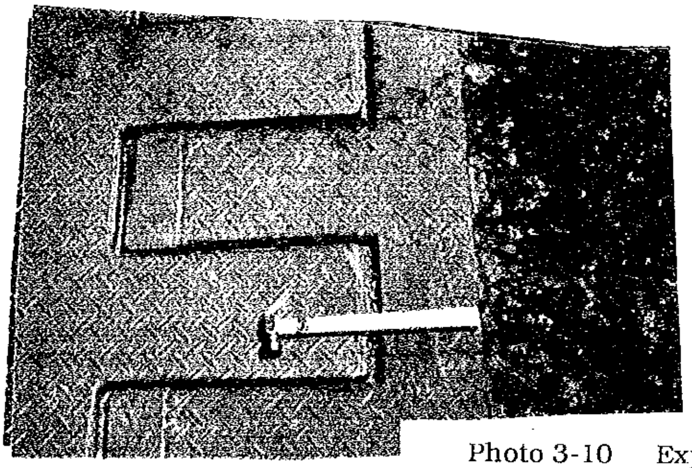


Photo 3-10 Expansion joint of steel bridge

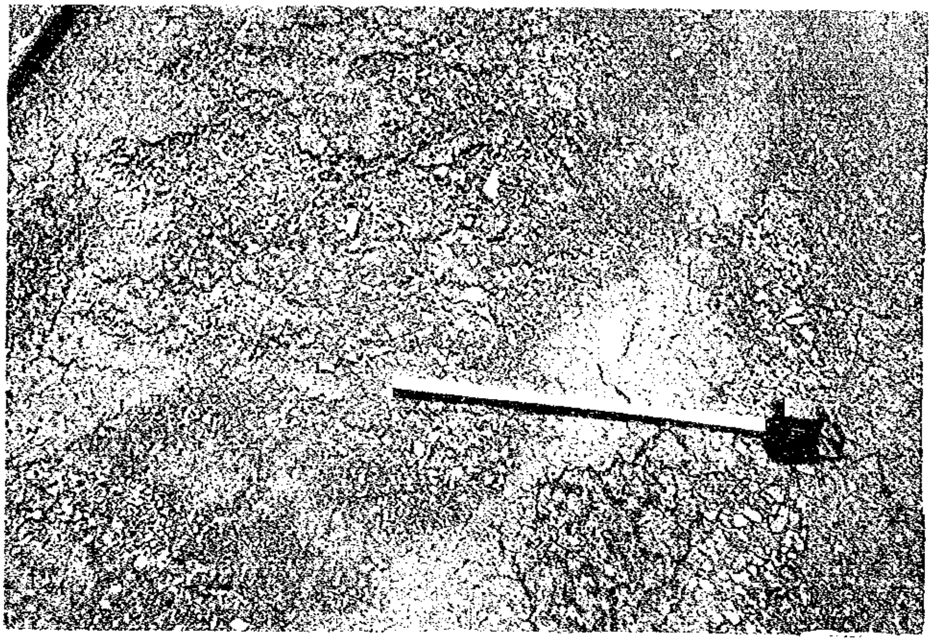


Photo 3-11 Deteriorated pavement

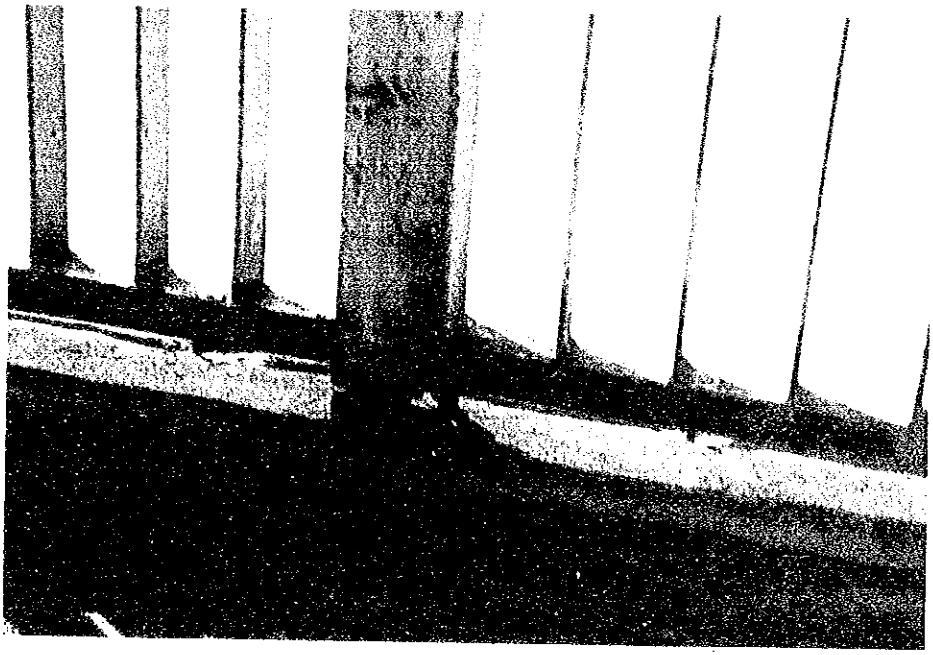


Photo 3-12 Corroded post of hand rail

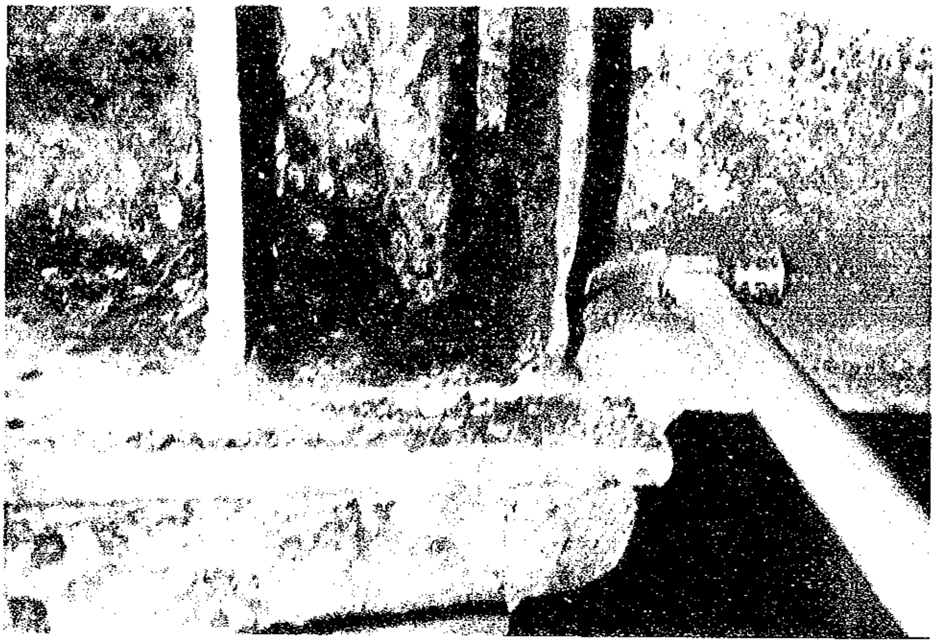


Photo 3-13 Bearing of P1 abutment

Photo 3-14 Bearing of P8 abutment

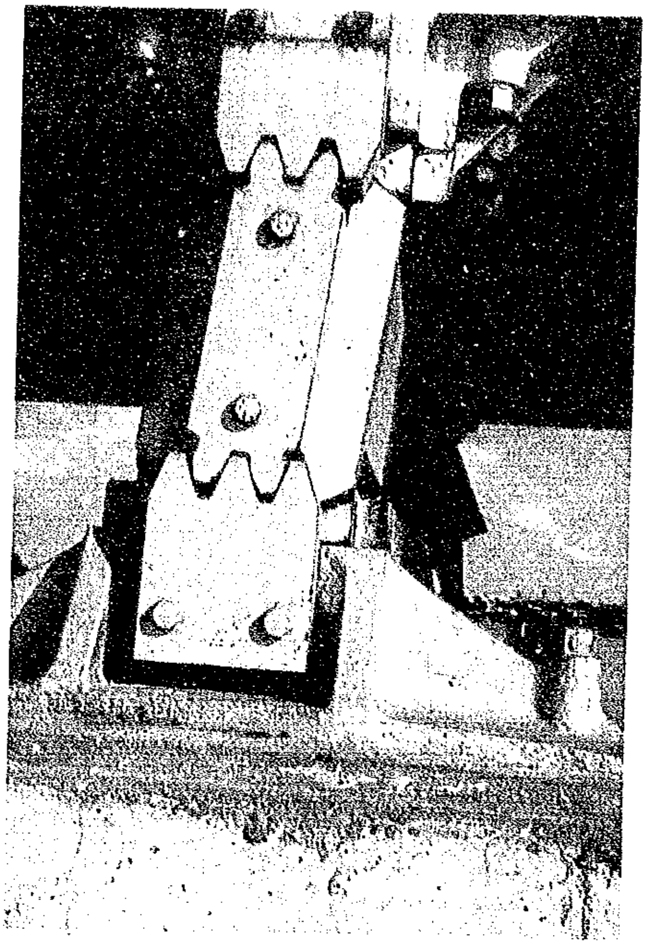


Photo 3-15 Bearing of P7 abutment

C. Geological Condition

(1) General

The objective of the soil survey is to provide information and data for structural and other designs for the Project.

Field investigation (machine boring, standard penetration test, sampling, etc.) and laboratory soil tests were carried out for the bridge project from April 1992 to May 1992 .

Machine boring survey was performed by R-100 type boring machine of made in China on the river and R-type to C-type boring machine of made in old name U. S. S. R on the land.

Machine boring was conducted for a total of 7 holes (140.29 m) with standard penetration test carried out at 120 each. Concrete core boring was Conducted for a total of 10 holes (10 m) with weathering test of in-situ for concrete.

The samples taken from those survey were tested by the company at their laboratory in Ho Chi Min. Those are shown in below.

1.	Machine boring on the river	4 locations	64.09 m
	Machine boring on the land	3 locations	76.20 m
	Total	7 locations	140.29 m
2.	Standard penetration test		120 each
3.	Sampling		35 samples
4.	Concrete core boring	10 locations	10 m
5.	Weathering test of in-situ for concrete		10 each
6.	Soil laboratory test		35 samples
7.	Compression test of concrete		18 samples

(2) Geological Condition

- Geological background

The project area is located at Tonle Sap River of north part of Phnom Penh and consist of generally flat plain with an altitude 12 meters of Phnom Penh side. The river bed level is form -8 meters to -11 meters. On the Chroy Changwar head land between the Tonle Sap and Mekong river small dykes is 8 meters.

- Stratigraphy

(a) General

The geological strata of project region are composed of the Paleozoic and Mesozoic sedimentary rocks. On the flat plain of Phnom Penh, the sedimentary rocks is overlain by sediments of quaternary age of more than 20 meters thick. Those are illustrated in geological cross section and are tabulated below.

Geological Formation of Project Area

Geological Time		Formation	Symbols	Description
Quaternary	Holocene	Alluvium	Ac	Clay, silt, organic soil
			As	Fine to coarse sand
	Pleistocene	Diluvium	Ds	Fine to medium sand
			Mc	Stiff to hard clay
Mesozoic		Sandstone	Ss	Weak weathered sandstone Including shale

- Characteristics of the formation

<u>Alluvium deposit</u>

Alluvium deposits are composed of cohesive soil (Ac) and sandy soil (As).

- Cohesive soils consist of brown, green, and grey silty clay, sandy clay, silt, sandy silt, and organic clay.

The thickness of cohesive soil ranges from 12 meters to 17 meters at the Phnom Penh side, from 1 meter to 4 meters at river bed and is 20 meters at the Chroy Changwar side.
The N-value ranges from 3 to 10 and natural water content ranges from 21.7 to 39.5 %.

- Loose to medium sandy soil (As) consists of green and grey fine to coarse sand with lens condition in the Ac deposit.
  The N-value ranges from 9 to 17 and thickness of As deposit ranges from 1.5 meters to 2.3 meters.

<u>Diluvium deposit</u>
Diluvium deposit consist of dark green fine to coarse sand at the Phnom Penh side.

The thickness of stratum is more than 6 meters and the N-value ranges from 43 to 84.

The deposit is situated at a depth 15 meters to 22 meters under.

<u>Base rock</u>

- Weathered clay (Mc)
  Base rock (sandstone with shale) in the project area is turned by highly weathered into clayey soils and they are composed of yellow ~ yellowish brown, stiff to hard clay with white kaoline clay.
  This is located at an altitude from -9 meters to -13 meters under (thickness of soil layer is maximum 17 meters).
  The N-value ranges from 10 to 45 and natural water content from 19.9 % to 28.9 %.

- Sandstone (Ss)
  The formation is extensively distributed in this area and composed of yellow to yellowish brown fine sandstone with shale. This is weak weathered. The N-value ranges from 63/30 to 50/1.5 at a part of dominant standstone and from 39 to 43 at a part of dominant shale.
  The formation is located at an altitude from -9 meters to -27 meters under.
  From the fact, it is assumed that the bed strikes northeast-southwest and dips northwest.

(3) Soil Laboratory Test

1) General

The soils subjected to analysis for the earth work design are alluvium deposit (Ac, As deposit), diluvium deposit (Ds deposit) and weathered soil of bed rock (Mc) of which a total of 35 samples were taken, mainly by S.P.T and other sampling and analyzed for the following soil laboratory tests.

Samples of each stratum

Alluvium deposit	Ac-deposit	--------------------	10 samples
	As-deposit	--------------------	2 samples
Diluvium deposit	Ds-deposit	--------------------	3 samples
Weathered Clay	Mc-deposit	--------------------	20 samples
	Total		35 samples

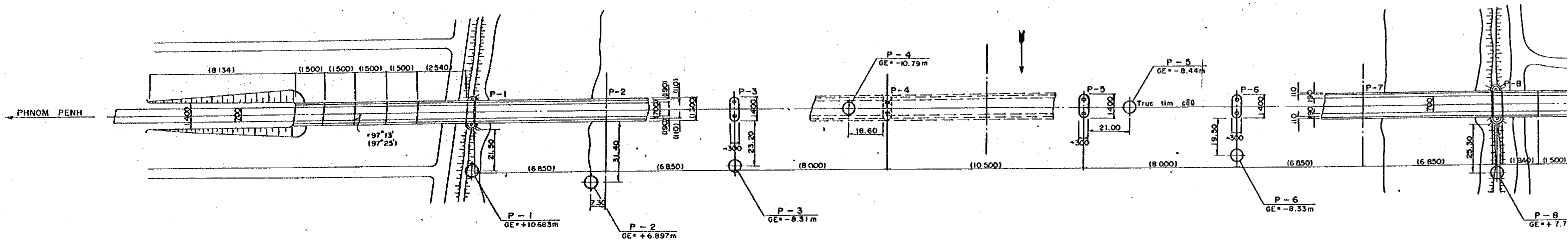
Contents of laboratory test

Item of test	Standard	Unit	Quantity
Specific gravity	ASTM-D-854	test	35
Natural water content	ASTM-D-2216	test	35
Particle size analysis	ASTM-D-422	test	35
Liquid limit	ASTM-D-423	test	27
Plastic limit & index	ASTM-D-424	test	27
Wet weight	calipers method	test	6

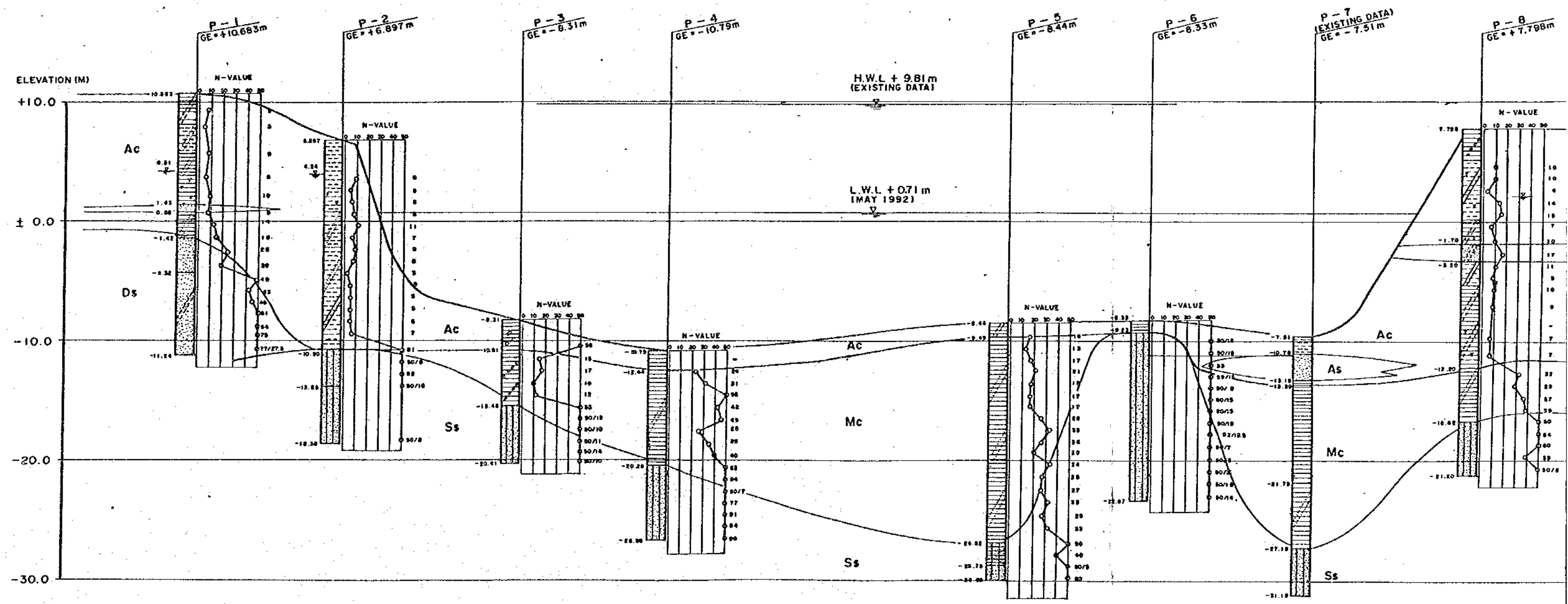
2) Soil laboratory test result

- Particle size gradation
  The gradation of four soil categories is shown in Table 3-1 and Figure 3-6 Deposit Ac and Mc contain fine particles of clay and silt more than 82 % and 69 % by total weight.

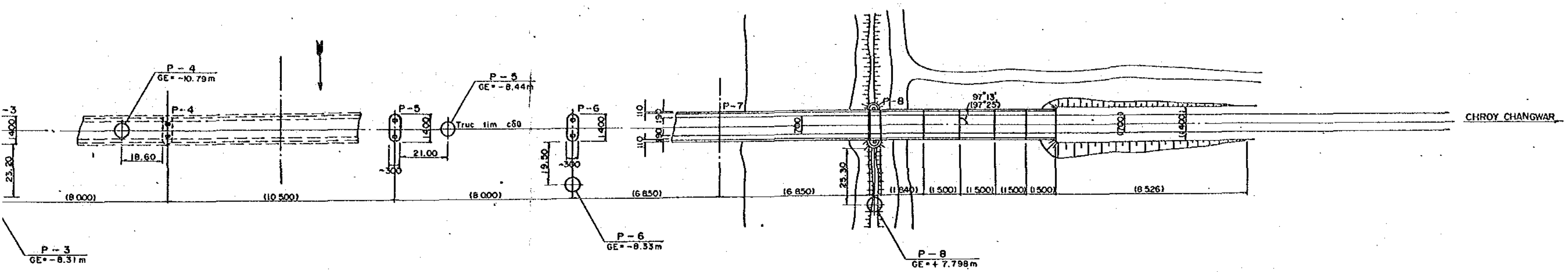
PLANE MAP OF CHROY CHANGWAR BRIDGE SCALE 1 : 1,000



GEOLOGICAL CROSS SECTION (H = 1/1,000 V = 1/200)



PLANE MAP OF CHROY CHANGWAR BRIDGE SCALE 1 : 1,000



GEOLOGICAL CROSS SECTION (H = 1/1,000 V = 1/200)

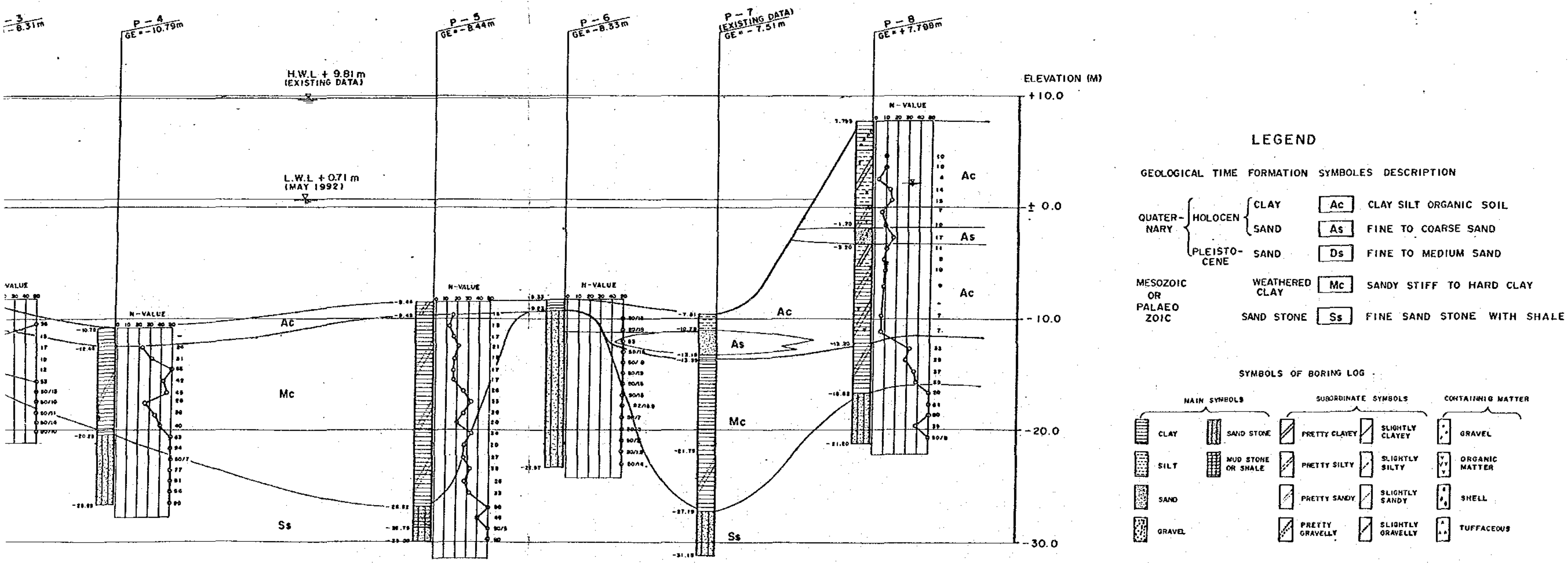


Fig. 3-4 Geological Cross Section

Table 3-1 Result of Particle Size Gradation

Items of gradation and Average / Deposit	Gravel (%)	Sand (%)	Silt - Clay (%)	No. 10 (2.00 mm) (%)	No. 40 (0.425 mm) (%)	No. 200 (0.075 mm) (%)
	Average Value	Average Value	Average Value	Average Value	Average Value	Average Value
	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range
Ac-Deposit	-	16.6	83.4	100	98.9	83.4
(Cohesive soil)	-	7.2 ~ 26.0	74.0 ~ 92.8	-	97.1 ~ 100	74.0 ~ 92.8
As-Deposit	12.5	71.5	16.0	88.0	66.0	16.0
(Sandy soil)	6 ~ 19	68 ~ 75	6 ~ 26	81 ~ 95	54 ~ 78	6 ~ 26
Ds-Deposit	7.8	76.5	10.2	87.1	56.3	10.2
(Sandy soil)	4.2 ~ 12.0	59.4 ~ 91.4	4.6 ~ 21.6	78.8 ~ 95.4	50.0 ~ 62.6	4.6 ~ 21.6
Mc-Deposit	3.7	27.2	69.1	96.4	92.4	69.1
(Cohesive soil)	0 ~ 20.0	17.1 ~ 37.3	57.7 ~ 80.5	90.4 ~ 100	84.5 ~ 100	57.7 ~ 80.5

- Character of consistency

  The objective of the test is to classify of soil with particle size gradation.

  The character of consistency is summarized in Table 3-2 and is shown Figure 3-4 and 3-5.

  - No change of consistency is observed with increasing depth below ground
  - According to the consistency chart, Ac and Mc-deposit are to be classified into CL
  - Colloidal activity

    80 % of Ac-deposit and 73 % of Mc-deposit are to be classified as non activity clay (mainly Kaolinite) and ordinary clay (mainly illite)
  - Ac-deposit is classified as being in a unstable

    Condition as $WL \geq Wn > Wp$ and $Ic = -0.24 \sim 0.74$
  - Mc-deposit is classified as being in a stable condition as $Wn \leq Wp$ and $Ic = 0.8 \sim 1.2$

Table 3-2 Result of Consistency

Items of Consistency / Deposit	Wn (%)	Wl (%)	Ip	If	It	Ic	Activity Ratio
	Average Value	Average Value	Average Value	Average Value	Average Value	Average Value	Average Value
	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range	Representa -tive Range
Ac-Deposit	30.6	36.5	15.6	17.8	1.24	0.37	0.98
(Cohesive soil)	21.7 ~ 39.5	31.8 ~ 41.2	11.3 ~ 15.6	8.6 ~27.0	0.36 ~ 2.12	-0.24 ~ 0.74	0.63 ~ 1.39
Mc-Deposit	24.4	43.3	19.7	15.3	1.55	0.93	1.07
(Cohesive soil)	19.9 ~ 28.9	37.6 ~ 49.0	15.4 ~ 24.0	10.0 ~ 22.9	0.95 ~ 2.15	0.75 ~ 1.19	0.73 ~ 1.14

Note: CH: High plasticity and cohesive clay with non organic

OH: Organic clay with medium plasticity

MH: Non-organic silt, Mica or diatomaceous fine sand/silt and elastic silt

CL: Low to medium plasticity silt, clay with sand or gravel, and low cohesive clay

Wn: Natural water content

WL: Liquid limit

Ip: Plasticity index

If: Flow index

It: Toughness index (It = Ip/If)

A degree of shear strength at plastic limit

Ic: Consistency index (Toughness and stability of cohesive soil)

$Ic = WL - Wn/Ip$

$Ic \geq 1$ Stable condition

$Ic = 0$ Unstable Condition: Liquidize by disturbance

Colloidal activity: Colloidal activity is defined by Skempton that clay mineral and geological condition of sediment had deep ties.
clay is classified by tour group from non activity clay to high activity clay as more than 2.
It is shown as following formula

$$\text{Colloidal activity} = \frac{\text{Plasticity index Ip}}{\text{Soil particle (\%) of less than } 2\mu}$$

Table 3-3 Classification by Colloidal Activity

Activity Ratio	Kind of Cohesional Soil by Activity Ratio	Main Clay Mineral	Deposit Condition
A < 0.75	Non activity clay	Kaolinite	• Clay of aqueous and fresh water sediment • Clay of marine deposit which have been leaching
A = 0.75 ~ 1.20	Ordinary clay	Illite	Clay of marine and estuarine deposit
A > 1.25	Activity clay	• Including organic colloid • A=2 is including Montmorillonite	-

- Specific gravity, Wet density and Void ratio

Those are summarized in Table 3-4 and shown in Figure 3-6.

Table 3-4 Result of Gs, γt and e

Items of Soil Properties / Deposit		Specific gravity Gs	Wet Density γ_t.(t/m³)	Void Ratio e
		Average Value	Average Value	Average Value
		Representa -tive Range	Representa -tive Range	Representa -tive Range
Ac-Deposit (Cohesive soil)	Average Value	2.696	-	-
	Representative Range	2.686 ~ 2.706	-	-
As-Deposit (Sandy soil)	Average Value	2.663	-	-
	Representative Range	2.660 ~ 2.666	-	-
Ds-Deposit (Sandy soil)	Average Value	2.673	-	-
	Representative Range	2.666 ~ 2.680	-	-
Mc-Deposit (Cohesive soil)	Average Value	2.702	1.93	0.794
	Representative Range	2.690 ~ 2.714	1.89 ~ 1.97	0.722 ~ 0.866

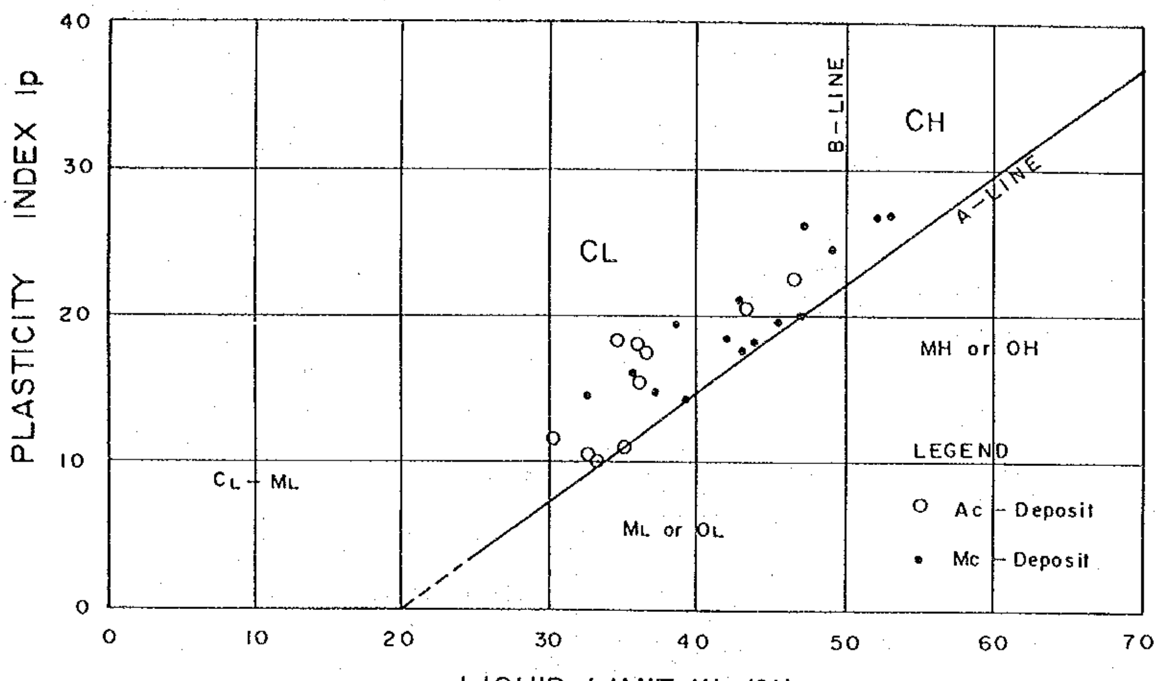
- Specific gravity

  The test results yield reasonable value with a standard deviation of less than 0.012.

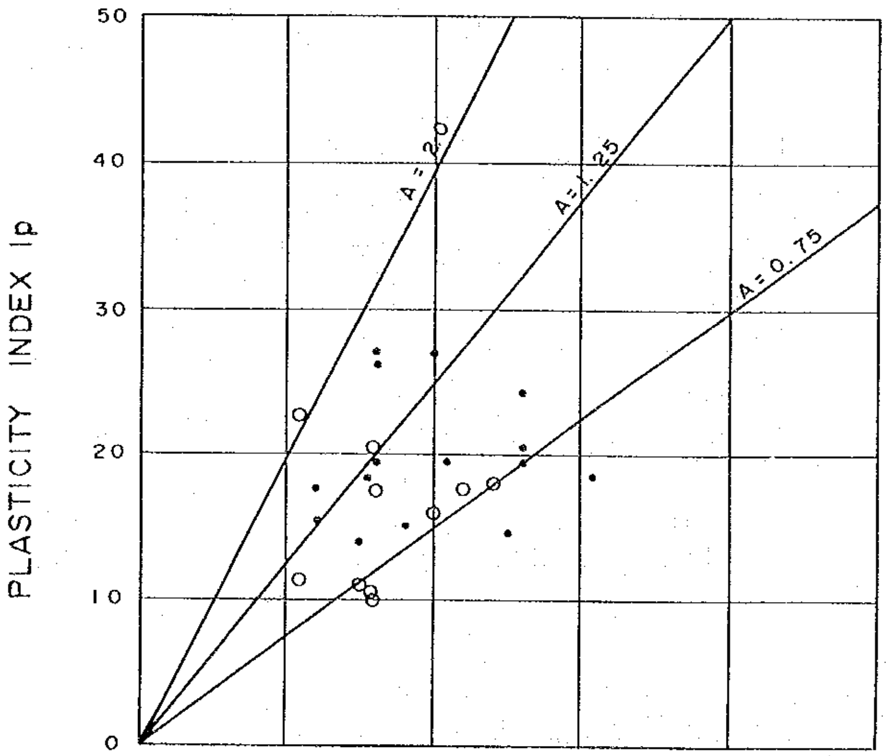
- Wet density and Void ratio

  Sampling of MC-deposit is not undisturbed sample by denison-type sampler. Those test results are some suggestions for reference.

FIG. 3-5 CONSISTENCY CHART



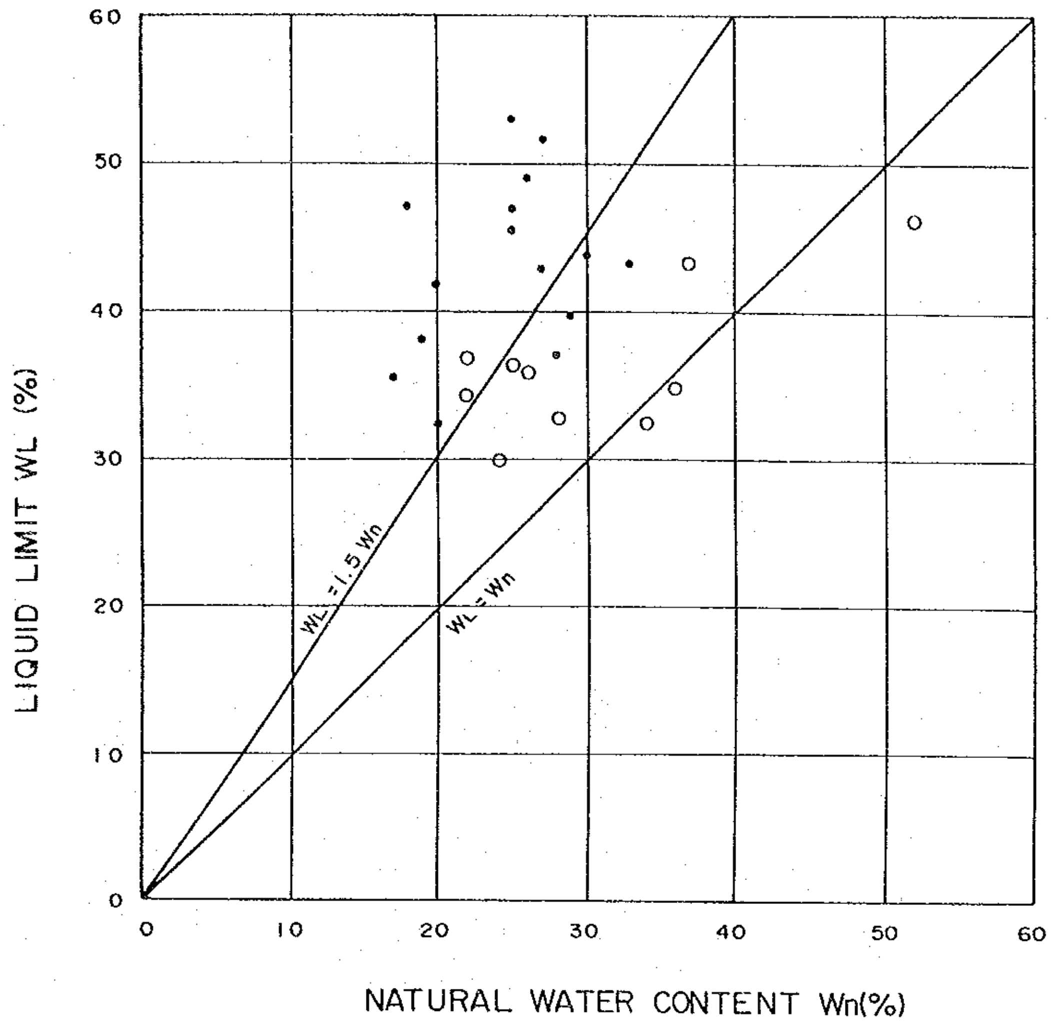
PLASTICITY CHART



SOIL PARTICLE CONTET OF 2u UNDER

COLLOIDAL ACTIVITY

FIG. 3-6 RELATIVE CHART OF (Wn) AND (WL), (Gs)



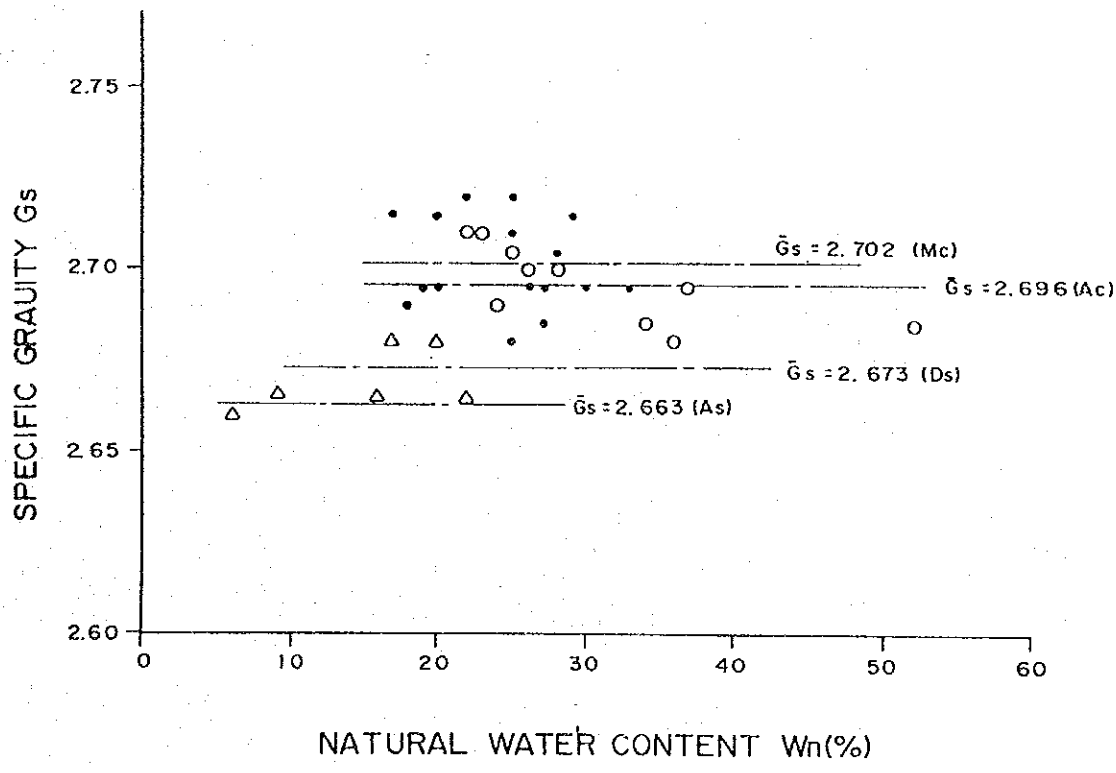
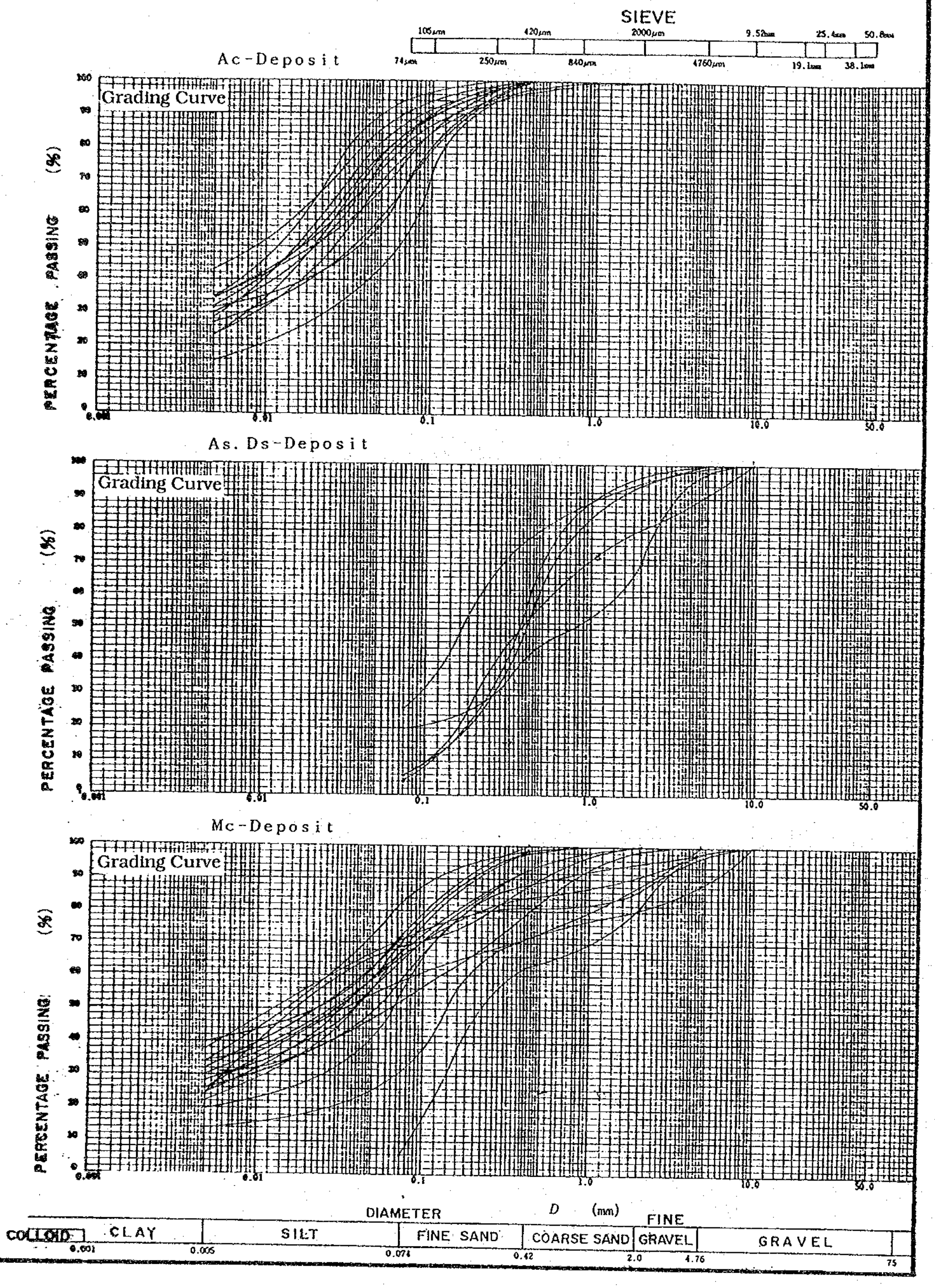


Fig. 3-7 Grain Size Distribution Curve



(4) Concrete Core Boring and Tests

1) General

The objective of the tests are to provide information of the existing concrete pier (P-1, P-2, P-4). Concrete core samples were taken by concrete core boring machine. Weathering test of in-situ for concrete and laboratory test (compressive test) were undertaken.

- Machine

• Boring machine HONDA GX 140
  Engine HONDA G200 5.5 Hp

• Pump YAMAHA YD30GN
  Engine HONDA G200 5.5 Hp

- Location and boring depth

Location		Boring Depth	Coring Condition
P-1	No. 1	1.0	Poor
	No. 2	1.0	Poor
	No. 3	1.0	Medium
P-2	No. 1	1.0	Good
	No. 2	1.0	Good
P-4	No. 1	1.0	Good
	No. 2	1.0	Medium
	No. 3	1.0	Good
	No. 4	1.0	Good
	No. 5	1.0	Poor
Total		10.0	

2) Test result

- Compressive test for concrete

  Concrete core samples have retained natural and wet condition with arrangement 50mm diameter and 100mm length.

  The unconfined compressive strength is compiled in the following below and table 3-6.

  Natural condition 111.8 ± 75.2 kgf/cm^2

  Wet condition 358.2 ± 69.9 kg/cm^2

Table 3-5 Compressive Test Result

Location			Natural Condition		Wet Condition		
Pier No.	Boring No.	Test No.	Practical Value kgf/cm^2	Average Value kgf/cm^2	Practical Value kgf/cm^2	Average Value kgf/cm^2	$\frac{Wet}{Natural}$
P-1	3	1	549	535.1	39.3	181.8	0.53
		2	521.2		282.3		
P-2	1	1	409	429	303	321	0.75
		2	504		393.8		
		3	374		266.6		
	2	1	510	451	280.3	341.5	0.76
		2	392		402.6		
P-4	1	1	553	481	447	412	0.85
		2	473		443		
		3	417		346		
	2	1	359	404	416.5	394.5	0.97
		2	448		372.5		
	3	1	306	379	407	349	0.92
		2	366		291.7		
		3	466		—		
	4	1	383	453	260	384.3	0.85
		2	405		438.5		
		3	572		454.5		
Total (Average)	7	18	x = 444.8 σ = 75.2 n = 18		x = 358.2 σ = 69.9 n = 17		0.81

- Weathering test of in-situ for concrete

  The test is carried out by measuring a distance from surface of concrete to red reaction where a part of fresh concrete is blown by spray at alcohol solution of 1% phenolphthalein.

Red reaction	Alkaline
Non reaction	Weathering

Test result is compiled in the following below and in table.

P-1 ranges from 0 to 0.5 cm
P-2 ranges from 2.5 to 3.0 cm
P-4 ranges from 0.0 to 4.0 cm

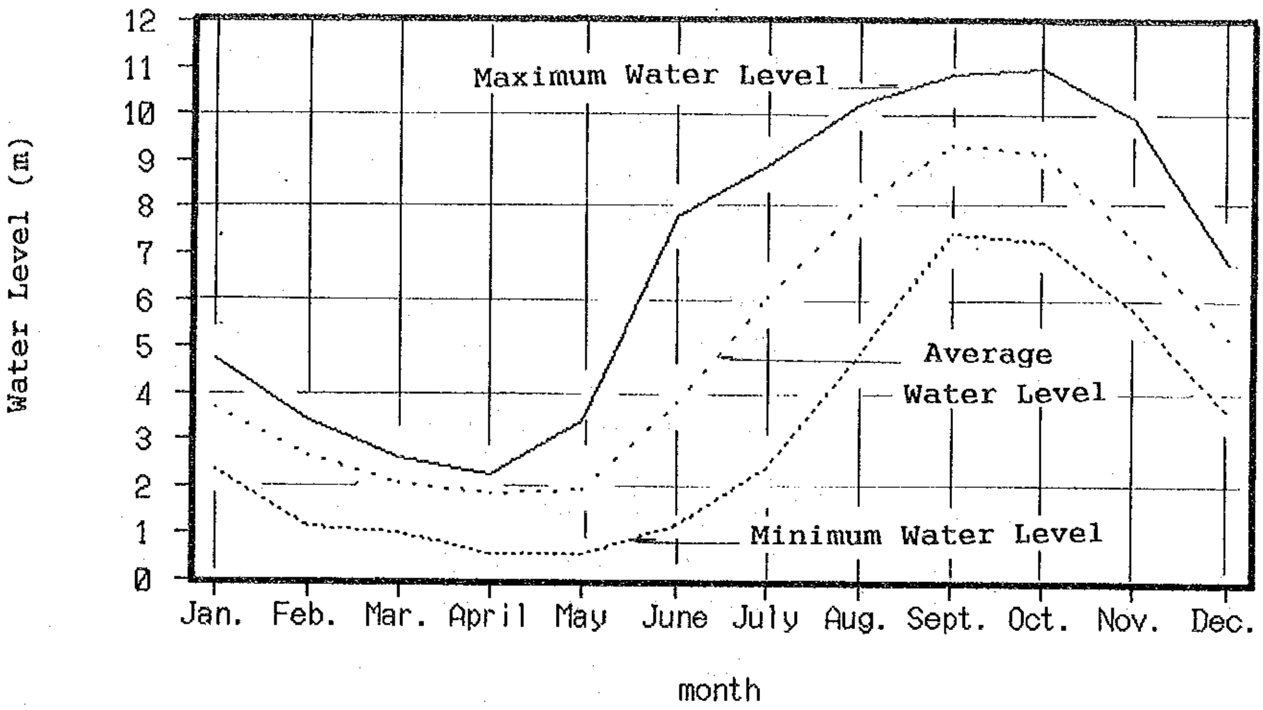
Location		Weathering Distance	Location		Weathering Distance
Pier No.	Test No.		Pier No.	Test No.	
P-1	No. 1	0.5 cm	P-4	No. 1	2.0 cm
	No. 2	0		No. 2	2.0 cm
	No. 3	0.5 cm		No. 3	4.0 cm
	No. 3'	0.5 cm		No. 4	3.0 cm
	No. 3"	0		No. 5	3.0 cm
P-2	No. 1	2.5 cm			
	No. 2	2.5 cm			
	No. 2'	3.0 cm			

(5) Hydrological Condition

The water stage of the Tonle Sap River measured by bubble gage in Phnom Penh is summarized in Fig. 3.7.

Velocity of flow is also given in Fig. 3.7.

These data shall be considered in the planning of construction.



	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Max	4.730	3.410	2.600	2.240	3.400	7.800	8.920	10.250	10.840	10.980	9.900	6.800
Min	2.330	1.160	1.040	0.580	0.560	1.210	2.440	4.870	7.420	7.250	5.800	3.640
Ave'	3.681	2.672	2.075	1.858	1.958	3.818	6.064	8.073	9.337	9.161	7.297	5.211

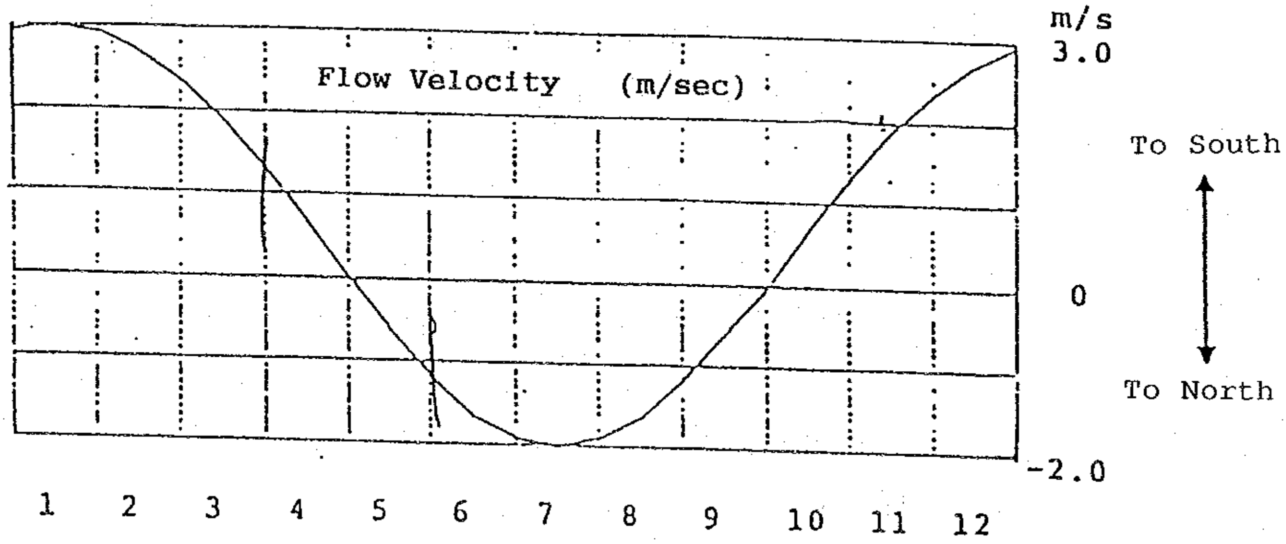


Fig. 3-8 Water Level at Phnom Penh Port (1961 ~ 1974)

3-3-4 Outline of Repair of Chroy Changwar Bridge

As mentioned in 3.3.3 b), all piers except piers No. 4 and No. 5 and the remaining portions of the superstructures are sound from the structural viewpoint. The repair of Chroy Changwar Bridge is to be planned taking the utilization of the remaining portion of the bridge into consideration. Therefore, both horizontal and vertical alignments, length of bridge, elevation and width coincide with the original bridge in principle. The subject of study focuses on the content of repair works of collapsed 265 m long center spans. Following three alternative schemes are examined;

Scheme - A : Utilization of remaining piers No. 4 and No. 5
- B : Reinforcement of remaining piers No. 4 and No. 5
- C : New construction of piers No. 4 and No. 5

Scheme-A

The Scheme-A is to construct substructure on the existing pier No. 4 and pier No. 5.

This scheme is unlikely practical because the damage of pier No. 4 and pier No. 5 investigated by the team is more serious than expected.

Scheme-B

The Scheme-B is that the damaged portion of piers No. 4 and No. 5 will be either removed or reinforced and steel superstructure will be erected on them. In this case due to increase of vertical load caused by additional weight of concrete, the examination of bearing capacity of stratum becomes necessary. Technical uncertainty such as design and construction method still remain.

Scheme-C

The Scheme-C is to construct new piers instead of the existing piers. There are two options, the same location and aside. The former has disadvantages that it will require higher cost and longer construction period to demolish and remove all or part of footing of the existing piers before the construction of new pier. The latter will require different span arrangement from the original.

However, the latter has advantage that it will shorten construction period because of limited demolition of piers.

Based on the result of basic design study conducted in Japan, Scheme-C was evaluated to be the most suitable one to meet the requirements of construction period and construction economy. The detailed procedure to select the proposed components of the Project is described in Chapter 4.

3-4 Technical Cooperation

The Project is for the construction of a large-scale bridge structure, and its detailed design and construction planning and supervision are thought as a rare case in Cambodia which has not been experienced in terms of the magnitude.

Local engineers desire to have a chance to learn the methods of design and construction supervision of the structure. However, full consideration and support by the Consultants and the Contractors will be necessary for RBD staff engineers to obtain the techniques about the structures.

The existing supper structure is of steel which will require periodical maintenance. Such maintenance is not familiar for RBD management who therefore would be required to secure technical know-how for the steel bridge maintenance such as painting, bolt refastening, etc. which are deemed necessary after the completion.

Chapter 4: Basic Design

CHAPTER 4: BASIC DESIGN

4-1 Design Policy

The considerations made in developing the design are as summarized below:

(1) Careful examination of the proposed schemes and methods of execution in respect of project time and costs implications,

(2) Horizontal force is applied to maintain safety of newly constructed piers by considering seismic coefficient of kh=0.05,

(3) The alignment, the longitudinal slope, and the width of the bridge to be newly constructed are to be agreed with that of old destructed bridge,

(4) Due attention is paid to the water stage of the Tonle Sap River to maintain safety during temporary works of substructure,

(5) The superstructure is fabricated divided in three blocks, the weight of each block is around 500 to 600 tons, and each block is erected by a floating crane.

(6) Execution yard, office, and stock yard are to be provided in the official land close to the site.

Based on the above principles, the basic design have been developed with following policies:

To reduce the term of works for early provision of services,

To select the most adequate structure type for superstructure and substructure in the site,

To design the structures that have safety, easiness of construction and maintenance, economy and adequacy to environment.

4-2 Study and Examination on Design Criteria

4-2-1 Design Criteria of Structure

(1) Substructure

1. Design Ground Level

	River Bed	Design Ground Level
P4 Pier	-10.67m	-12.32m
P5 pier	-8.32m	-9.82m

2. Velocity of Flow and Water Stage

Velocity of flow and water stage of the Tonle Sap River are given in Fig. 3.7.

3. Wind Loads

Wind load $w = 250\ kg/m^2$

4. Seismic Load

There is no observation record of earthquake in Cambodia but to maintain safety of structure, 5% of the self weight of the structure is applied horizontally by equivalent static force method.

5. Soil Conditions

Soil condition is shown in Fig. 3.3.

The maximum frictional resistance of pile is calculated by the following equations.

P4 pier $f = 0.5*c$ or $0.5*N <= 10.0\ tf/m^2$ average $N = 27$

P5 pier $f = 0.5*c$ or $0.5*N <= 10.0\ tf/m^2$ average $N = 15$

Bearing layer of pile foundation is to be lower than following elevation.

P4 pier	-20.2 m
P5 pier	-26.7 m

6. Material and Allowable Stress

Material	Type	Allowable Tensile or Compressive Stress
Reinforcing Bars	SD295	1,800 kg/cm^2
Steel Pipe Pile	SKY400 SKY490	1,400 kg/cm^2 1,900 kg/cm^2
Steel material for structure	SS400 SM490	1,400 kg/cm^2 1,900 kg/cm^2

7. Corrosion Margin

$t = 2.0$ mm

8. Allowable Horizontal Displacement

At the top of steel pipe sheet pile	4.0 cm - 5.0 cm
At the design ground level	1.5 cm

9. Load and Load Combinations

Kinds of Load

- Dead load
- Live load
- Impact load
- Earth pressure
- Hydraulic pressure
- Buoyancy or uplift

Wind load
Effect of temperature change
Effect of earth pressure
Wave pressure
Braking force
Temporary load and force during erection
Collision force

Loading Combinations
Principal load
Principal load + Earthquake force
Principal load + Earthquake force + Thermal force
Temporary load and force during erection

(2) Superstructure

1.	Class of bridge	First class bridge
2.	Type of bridge	3 spans continuous steel box girder with steel plate deck
3.	Span length	65.0m + 135.0m + 65.0m
4.	Dead Load	

The unit weights as given in Table 4.1 are used for calculation of the dead load.

Table 4.1 Unit weights of Materials

Material	Unit Weight (kg/m^3)
Steel, cast steel and forged steel	7,850
Cast iron	7,250
Aluminum alloys	2,800
Reinforced concrete	2,500
Prestressed concrete	2,500
Concrete	2,350
Cement mortar	2,150
Timber	800
Bituminous material (for water-proofing)	1,100
Asphalt pavement	2,300

5. Design live load

TL-20 and TT-43 are adopted in the design of the bridge, the details are described as below:

1) Live load for slab and floor system

On the road way, the T-loading shown in Fig. 4.1 and Table 4.2 or TT-43 as shown in Fig. 4.3 whichever produce the greater stress shall be placed.

In designing the roadway with the T-20 and TT-43 loadings applied, one unit of the TT-43 loading in the longitudinal direction and up to two units in the transverse direction shall be placed per bridge, and for the remainder of the transverse direction, the T-20 loading shall be placed.

In the designing stringers and slab bridge with particularly long span, the truck train loading shown in Fig. 4.2 or the L-loading whichever produces the greater stress, shall be used instead of the T-loading.

On sidewalk, an uniform live load of 500 kg per square meter of sidewalk area shall be applied.

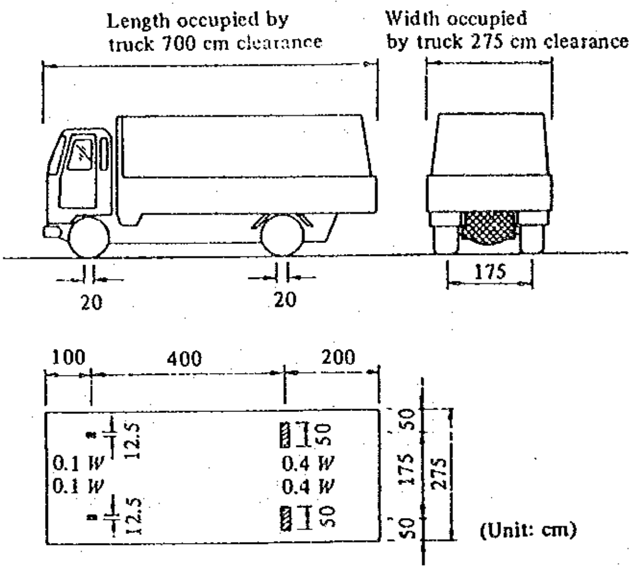


Fig. 4.1 T-Loadings

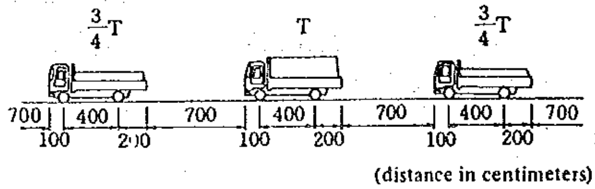


Fig. 4.2 Truck Train Loadings

Table 4,2 T-Loadings

Class of bridge	Loading	Gross weight W(ton)	Weight of a front wheel 0.1W(kg)	Weight of a rear wheel 0.4W(kg)	Width of a front wheel b_1 (cm)	Width of a rear wheel b_2 (cm)	Length of contact area of a wheel on the road-surface a(cm)
1st	T-20	20	2000	8000	12.5	50	20

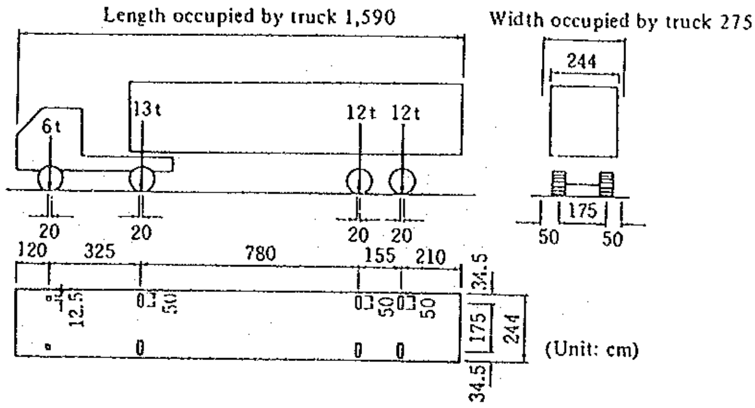


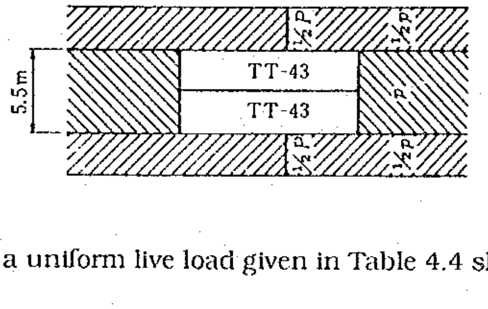
Fig. 4.3 TT-43 Loadings

2) Live load for main girder

A main girder shall be designed for the following live loads:

On the roadway, the L-20 loading specified in the Fig. 4.4 and Table 4.3 or the L-20 and TT-43 loadings, whichever produce the maximum stress shall be placed.

In designing a main girder with the L-20 and TT-43 loadings applied, one unit of the TT-43 loading in the longitudinal direction and up to two units in the transverse direction shall be applied per bridge, and for the portion front and rear of the TT-43 loading, uniform loads p and L-20 (main loads) loading shall be applied and for the remainder one half of uniform load p (sub-loads) shall be applied respectively as shown below.



On sidewalk a uniform live load given in Table 4.4 shall be applied.

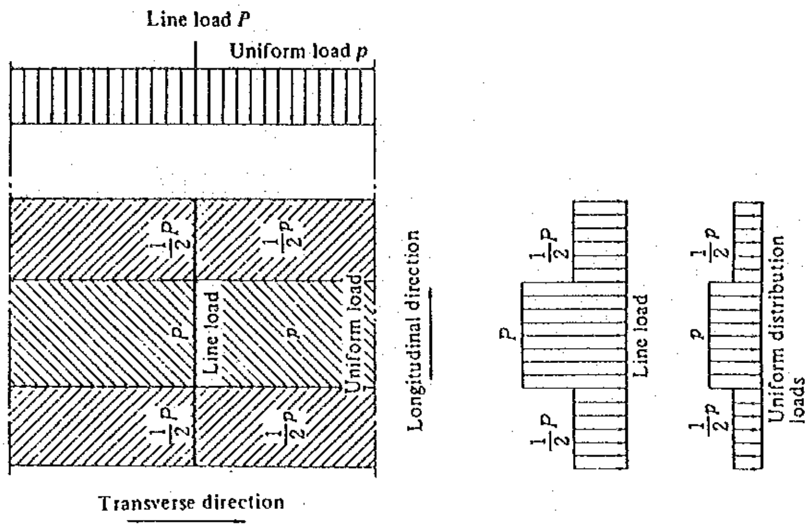


Fig. 4.4 L-Loadings

Table 4.3 L-Loadings

Class of bridge	Loading	Main loads (up to 5.5 meters in width)				Sub-loads
		Line load P (kg/m)	Uniform load, p (kg/m^2)			50% of main loads
			$L \leq 80$	$80 < L \leq 130$	$L > 130$	
1st	L-20	5,000	350	430-L	300	

where,

L = Span length in meters.

For the suspended span and the cantilever span in a cantilever

Table 4.4 Uniform Load for Sidewalks

Span length, L (m)	$L \leqq 80$	$80 < L \leqq 130$	$L > 130$
Uniform load (kg/m^2)	350	430-L	300

6. Width — Carriageway 7.0m; Cycle Track 1.9m; Sidewalk 1.1m

6. Width	Carriageway	7.0m
	Cycle Track	1.9m
	Sidewalk	1.1m

7. Alignment — Straight line

8. Longitudinal slope — Refer to Fig. 4.10

9. Crossfall

Carriageway	1.5%
Cycle Track and sidewalk	2.0%

10. Structure of pavement

Carriageway	asphalt pavement	t=8.0cm
Cycle Track	asphalt pavement	t=3.0cm
Sidewalk	asphalt pavement	t=3.0cm

11. Coefficient of seismic — kh = 0.05

12. Hand rail — Height from the surface of pavement is; h = 1.10 m

13. Change of temperature — from 10 degree to 60 degree Centigrade

14. Wind loads — $w = 250.0\ kg/m^2$

15. Difference of temperature — t=15.0 degree Centigrade

16. Material and allowable stress

Allowable axial tensile stress

Kind of Steel	SS400, SM400, SMA400W	SM490	SM490Y, SM520, SMA490W	SM570, SMA570W
Axial tensile stress	1,400	1,900	2,100	2,600

Allowable axial compressive stress

$\sigma_{ca} = \sigma_{cag} \bullet \sigma_{cal}/\sigma_{cao}$

where,

σ_{ca} : Allowable axial compressive stress (kgf/cm^2)

σ_{cag} : Allowable compressive stress without considering buckling given in the following table (kgf/cm^2)

σ_{cal} : Allowable stress for local buckling (kgf/cm^2)

σ_{cao} : Maximum value of allowable compressive stress without considering buckling given in the following table (kgf/cm^2)

Kind of Steel	SS41, SM41, SMA41W	SM50	SM50Y, SM53, SMA50W	SM58, SMA58W
Axial Compressive Stress	$\frac{l}{\gamma} \leq 20$: 1,400	$\frac{l}{\gamma} \leq 15$: 1,900	$\frac{l}{\gamma} \leq 14$: 2,100	$\frac{l}{\gamma} \leq 18$: 2,600
	$20 < \frac{l}{\gamma} \leq 93$: $1{,}400 - 8.4\left(\frac{l}{\gamma} - 20\right)$	$15 < \frac{l}{\gamma} \leq 80$: $1{,}900 - 13\left(\frac{l}{\gamma} - 15\right)$	$14 < \frac{l}{\gamma} \leq 76$: $2{,}100 - 15\left(\frac{l}{\gamma} - 14\right)$	$18 < \frac{l}{\gamma} \leq 67$: $2{,}600 - 22\left(\frac{l}{\gamma} - 18\right)$
	$93 < \frac{l}{\gamma}$: $\frac{12{,}000{,}000}{6{,}700 + \left(\frac{l}{\gamma}\right)^2}$	$80 < \frac{l}{\gamma}$: $\frac{12{,}000{,}000}{5{,}000 + \left(\frac{l}{\gamma}\right)^2}$	$76 < \frac{l}{\gamma}$: $\frac{12{,}000{,}000}{4{,}500 + \left(\frac{l}{\gamma}\right)^2}$	$67 < \frac{l}{\gamma}$: $\frac{12{,}000{,}000}{3{,}500 + \left(\frac{l}{\gamma}\right)^2}$
Remarks	l : Effective buckling length of member (cm) γ : Radius of gyration (cm)			

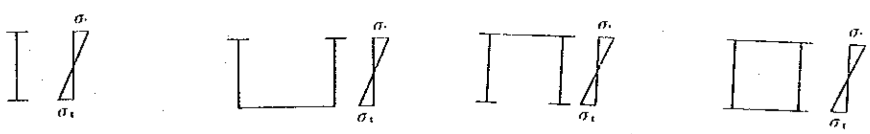
Allowable Flexural Compressive Stress

Kind of Section	Kind of Steel			
	SS400, SM400, SMA400W	SM490	SM490Y, SM520, SMA490W	SM570, SMA570W
Compressive flange plate is supported by concrete slab directly Box, π section	1,400	1,900	2,100	2,600

Others	$\frac{A_w}{A_c} \le 2$	$\frac{l}{b} \le 4.5$: 1,400 $4.5 < \frac{l}{b} \le 30$: 1,400 $-24\left(\frac{l}{b}-4.5\right)$	$\frac{l}{b} \le 4.0$: 1,900 $4.0 < \frac{l}{b} \le 30$: 1,900 $-38\left(\frac{l}{b}-4.0\right)$	$\frac{l}{b} \le 3.5$: 2,100 $3.5 < \frac{l}{b} \le 27$: 2,100 $-44\left(\frac{l}{b}-3.5\right)$	$\frac{l}{b} \le 5.0$: 2,600 $5.0 < \frac{l}{b} \le 25$: 2,600 $-66\left(\frac{l}{b}-5.0\right)$
	$\frac{A_w}{A_c} > 2$	$\frac{l}{b} \le \frac{9}{K}$: 1,400 $\frac{9}{K} < \frac{l}{b} \le 30$: 1,400 $-12\left(K\frac{l}{b}-9\right)$	$\frac{l}{b} \le \frac{8}{K}$: 1,900 $\frac{8}{K} < \frac{l}{b} \le 30$: 1,900 $-19\left(K\frac{l}{b}-8\right)$	$\frac{l}{b} \le \frac{7}{K}$: 2,100 $\frac{7}{K} < \frac{l}{b} \le 27$: 2,100 $-22\left(K\frac{l}{b}-7\right)$	$\frac{l}{b} \le \frac{10}{K}$: 2,600 $\frac{10}{K} < \frac{l}{b} \le 25$: 2,600 $-33\left(K\frac{l}{b}-10\right)$

A_w : Area of web
A_c : Area of compressive flange
l : Space between support of compressive flange
b : Width of compressive flange

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



I Section U Section π section Box

Allowable shearing stress

<table>
<tr><th colspan="2" rowspan="2">Kind of Stress</th><th colspan="4">Kind of Steel</th></tr>
<tr><th>SS400, SM400, SMA400W</th><th>SM490</th><th>SM490Y, SM520, SMA490W</th><th>SM570, SMA570W</th></tr>
<tr><td colspan="2">Shearing stress</td><td>800</td><td>1,100</td><td>1,200</td><td>1,500</td></tr>
<tr><td rowspan="2">Bearing stress</td><td>Calculated by Hertz Formular</td><td>6,000</td><td>7,000</td><td>—</td><td>—</td></tr>
<tr><td>Bearing stress between steel plate and steel plate</td><td>2,100</td><td>2,800</td><td>3,100</td><td>3,900</td></tr>
</table>

4-2-2 Design Criteria of Road

Design Standards adopted for the road design in this project are as follows:

Design Speed	60 km/hr
Horizontal Curves	
Minimum Radius	120 m
Maximum Crossfall	6%
Translation Curve Length	50 m
Vertical Curves	
Minimum Radius of Sag Curve	1,000 m
Minimum Radius of Crest Curve	1,400 m
Maximum Gradient	5%
Crossfall of Carriageway in Normal Crown	1.5%
Minimum Stopping Sight Distance	75 m
Minimum Passing Distance	250 m
Lane Width	3.5 m
Cycle Track Width	1.9 m
Side Walk Width	1.1 m

4-3 Basic Design

4-3-1 Comparative Study

(1) Superstructure

Newly constructed piers shall be constructed outside of existing piers to reduce the construction schedule as shown in Fig. 4.5. In this case, demolition and construction can be executed simultaneously. Then the span length of the new Chroy Changwar Bridge is: 65.0m + 130.0m + 65.0m.

Considering the length of center span, following two alternatives are to be considered in the design of this project,

Alt. 1 3 spans continuous steel box girder bridge
Alt. 2 3 spans continuous prestressed concrete box girder bridge

According to results of preliminary study, it was concluded that the block construction method shall be adopted to construct prestressed concrete box girder bridge in this project within the term of works.

In accordance with the results of preliminary design, approximate quantities, approximate construction cost, construction schedule, and ease of construction were examined. The results of comparison are given in Table 4.5.

Alt. 1 is superior to Alt. 2 as shown in the table.

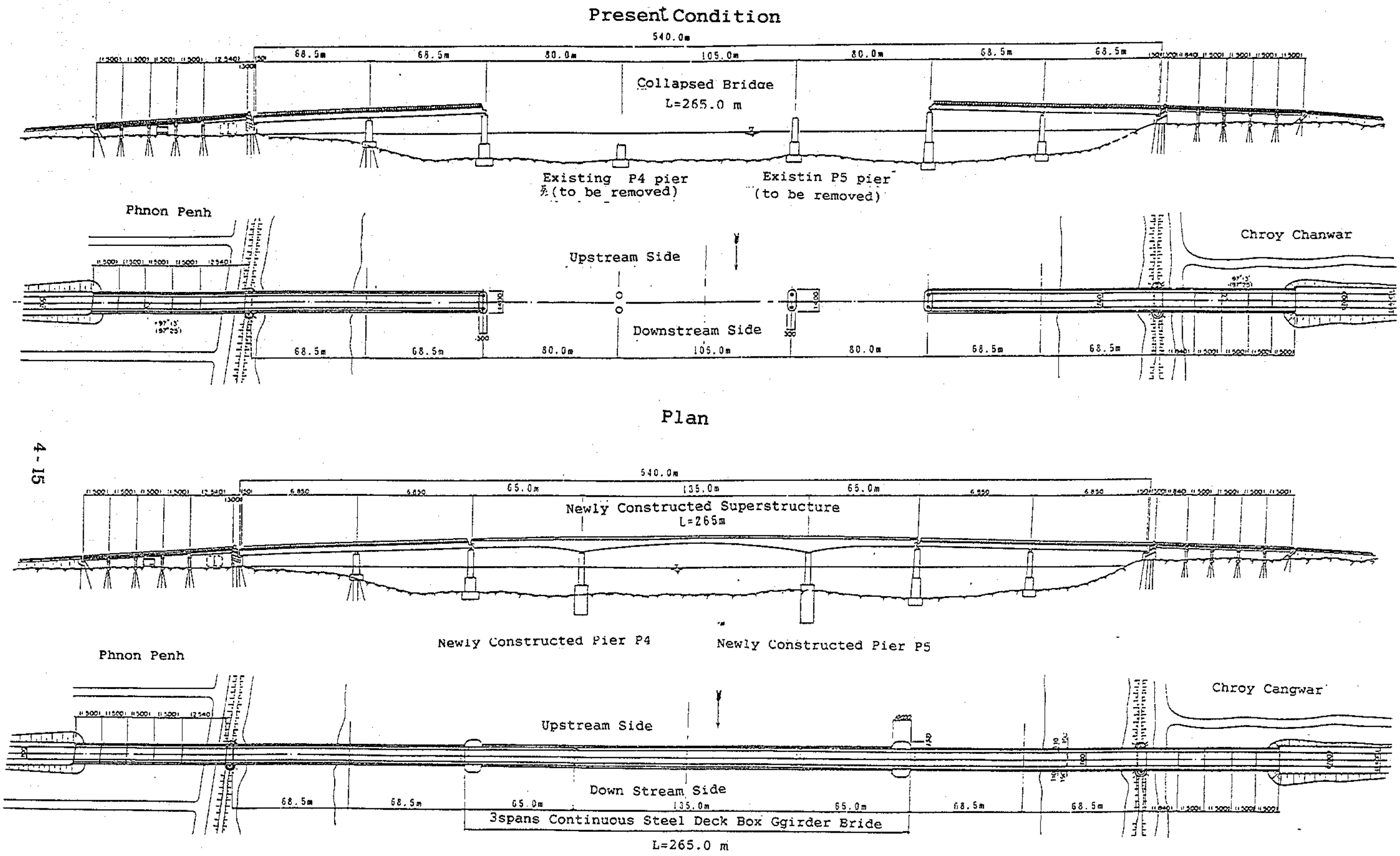
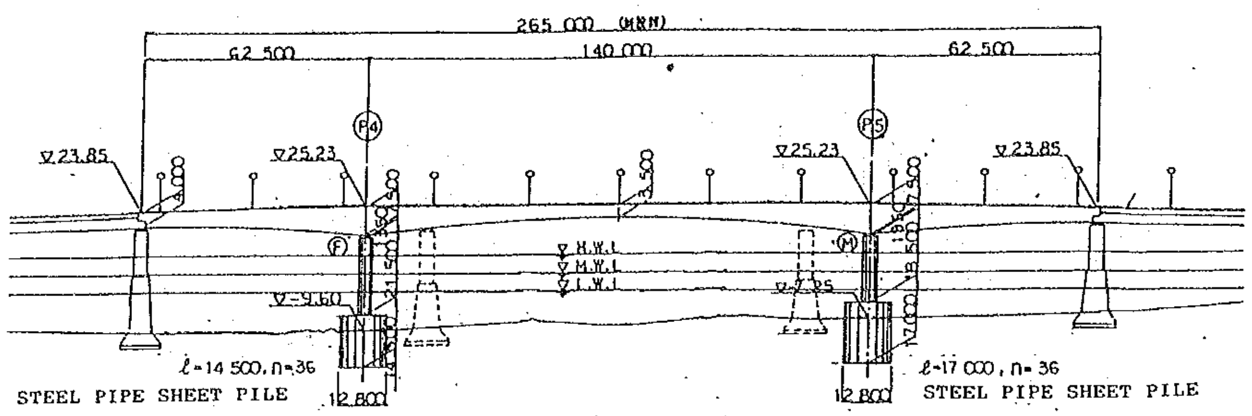
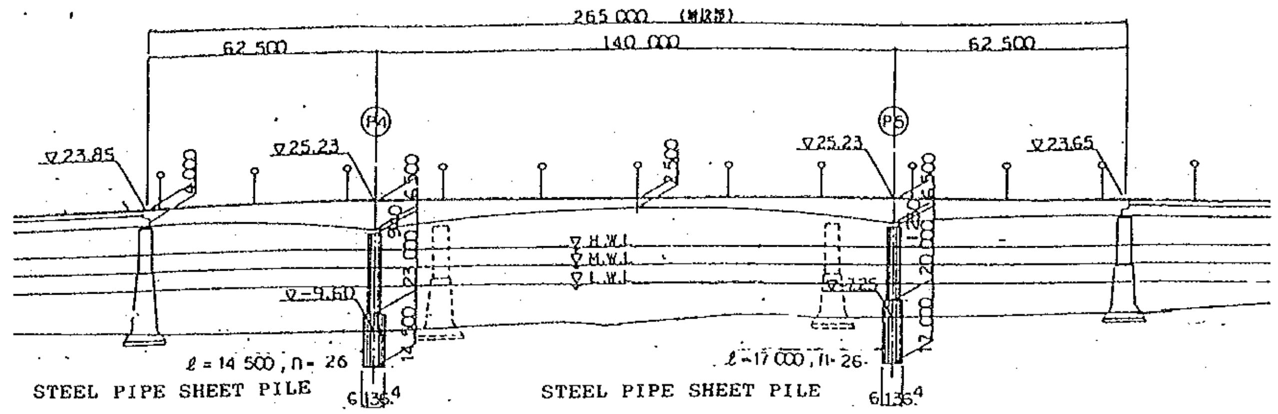
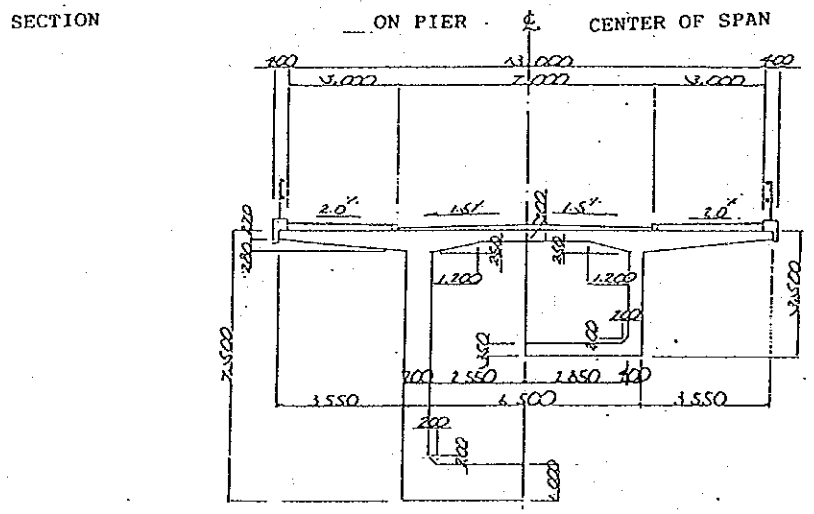
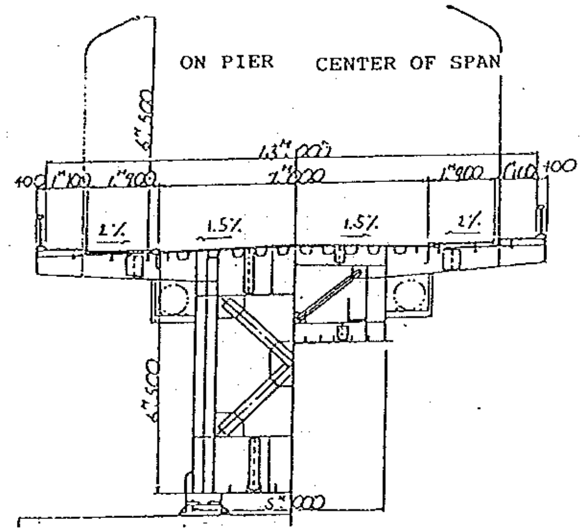


Fig. 4-5 Span Arrangement of the Chroy Changwar Bridge

Table 4-5 COMPARISON TABLE OF SUPERSUTRUCTURE TYPE

	3SPANS CONTINUOUS PC BOX GIRDER BRIDGE	3SPANS CONTINUOUS STEEL BOX GIRDER BRIDGE
SIDE VIEW		
CROSS SECTION		
APPROXIMATE QUANTITY	Superstructure Concrete Volume 3640 cu.m Area of bridge 3445 sq.m Substructure Alt. 1 Multicolumn foundation Concrete Volume 933 cu.m Steel Pipe Pile Sheet Pile (1500mm) 251 t Steel 79 t Alt. 2 Steel Pipe Sheet Pile Foundation Concrete Volume 956 cu.m Concrete casting in steel pipe pile 156 cu.m Steel Pipe Sheet Pile(800mm) 368 t	Superstructure Steel 1430 t Area of bridge 3445 sq.m Substructure Alt. 1 Multicolumn foundation Concrete Volume 536 cu.m Steel Pipe Pile Sheet Pile (1500 mm) 131 t Steel 32 t Alt. 2 Steel Pipe Sheet Pile Foundation Concrete Volume 769 cu.m Concrete casting in steel pipe pile 119 cu.m Steel Pipe Sheet Pile(800mm) 281 t
COST	In case of Alt. 1 Multicolumn Foundation : Cost Index = 1.0 In case of Alt. 2 Steel Pipe Pile Foundation : Cost Index = 1.0	In case of Alt. 1 Multicolumn Foundation : Cost Index = 1.002 In case of Alt. 2 Steel Pipe Pile Foundation : Cost Index = 1.02
REMARKS	*Construction cost and term of works are almost same as Alt.2. *Regarding to maintenance ,a concrete bridge is superior to a steel bridge in general. *The scale of substructure is larger than Alt.2 due to the large reaction from superstructure.	*Construction cost and term of works are almost same as Alt.1. *Alt.2 is superior than Alt.1 from a view point of uniformity of external appearance to the existing piers. There is less uncertainty in this Alt. ,as most of processing and fabrication of the steel bridge members are carried out in Japan. The amonunt of construction works in the site is less than that of the cocrete bridge.
Evaluation	○	◎

(2) Substructure

Following substructure types are studied in the comparative study of this bridge.

Alt. 1	Spread footing	Double wall cofferdam
		Steel caisson
Alt. 2	Caisson foundation	Steel caisson
		Pneumatic caisson
Alt. 3	Pile foundation	Multicolumn foundation
		Pile foundation

Alt. 4 Steel pipe pile sheet pile foundation

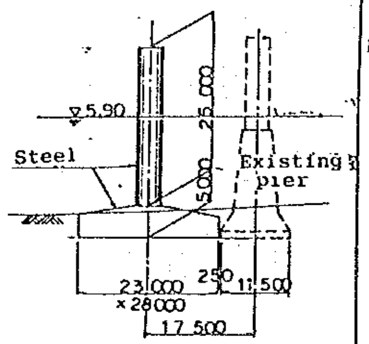
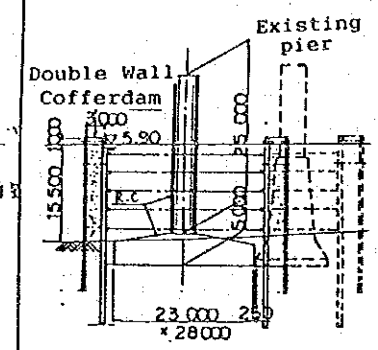
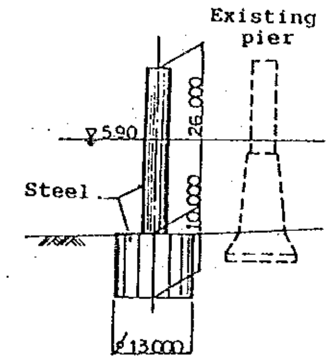
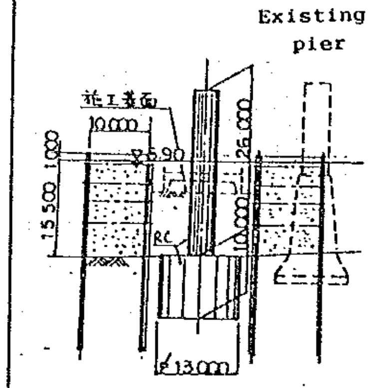
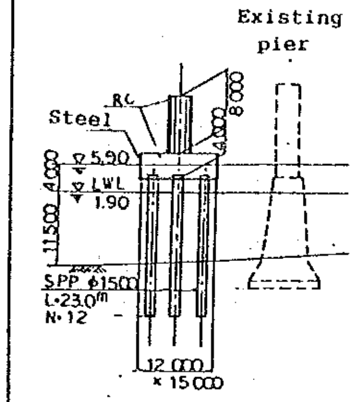
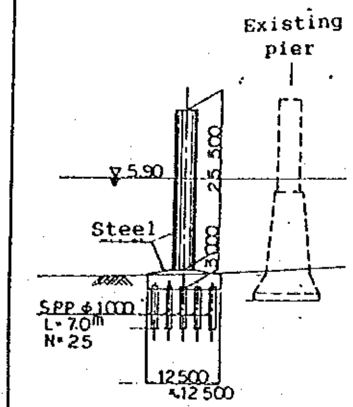
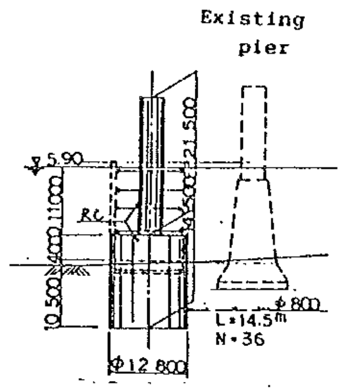
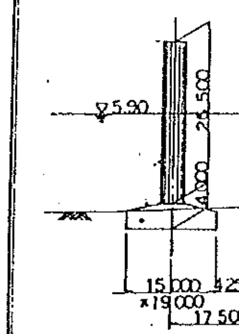
Comparative table that is derived from results of preliminary design is given in the Table 4.6.

Steel pipe pile sheetpile foundation is selected considering follows:

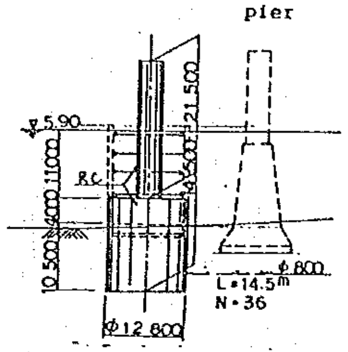
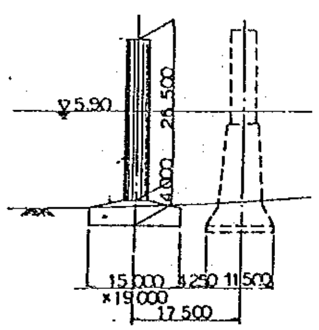
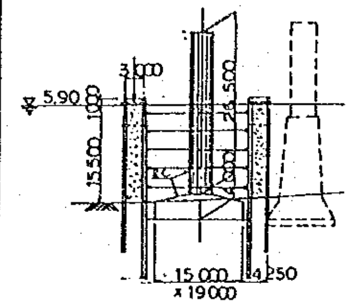
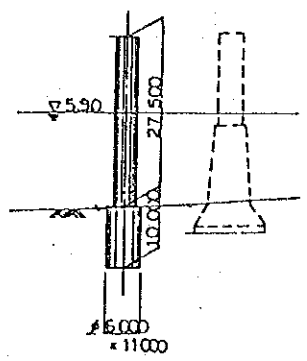
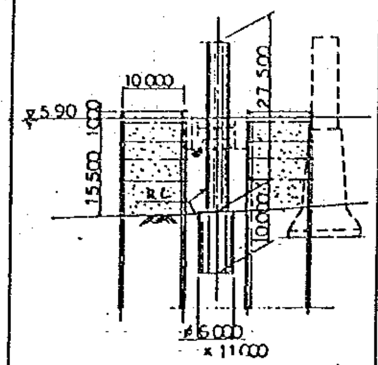
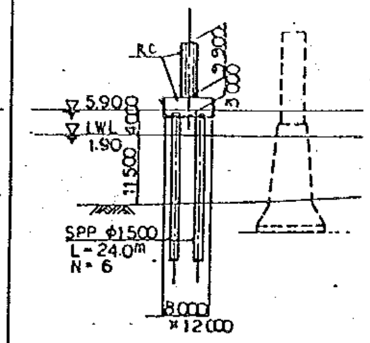
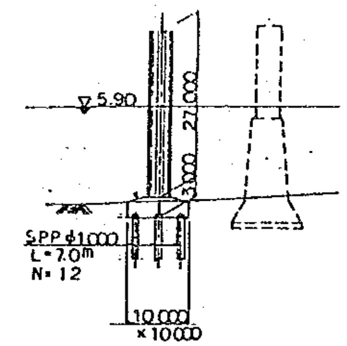
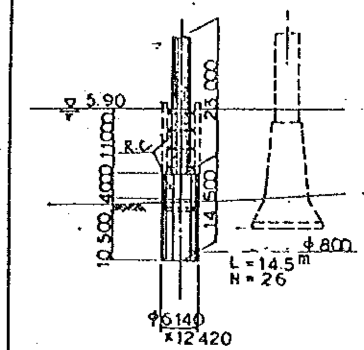
1) Although the construction cost of the steel pipe sheet pile foundation is expensive than that of the multicolumn foundation, the former is more suitable than the latter in this location, considering the uniformity of appearance to the existing piers.

2) The steel pipe sheet pile foundation is desirable than the multicolumn foundation from a view point of the navigation clearance. Because in case of the multicolumn foundation, the navigation clearance becomes small due to the existence of the footing located above the water level.

Tab.4.6 Comparison of Alternative Types

Type of superstructue	3 Spans Continuous Prestressed Concrete Box Girder Bridge							
Type of substructure	Spread Footing		Caisson		Multicolumn Foundation		Steel Pipe Pile Sheet Pile Fondation	
	Steel Footing	Double Wall Cofferdam	Steel caisson	Double Wall Cofferdam	Multicolumn Foundation	Steel Pipe Pile Foundation		Steel Foot
Side View								
1st Selection: Construction Method	• Demolition of existing concrete pier and clearing of debris. • Pier and footing made by steel plate designed as form is towed by tag boats. •Concrete placing in water. •Construction of pier.	•A footing and a pier are constructed after dried up inside of the cofferdam •Demolition and clearing of existing pier shall be carried out prior to the construction of a new pier.	• A steel caisson made by steel plate ,that is functional as forms ,is towed by tug boats. •The pier is constructed as a pneumatic caisson	·Inside of the cofferdam is filled by soil. •A pier is constructed as a pneumatic caisson. • scale of cofferdam becomes verry large to demolish the existing pier inside of the cofferdam.	Cofferdam is not necessary. ·This alternative is inferior to other foundation types in aesthetic quality because a footing appears above the water level.	Steel pipe piles are driven Special tecnnques are necessary in the execution of connection between footing and pile underwater.	Steel pipe sheet piles are used both as members of temporary cofferdam and permanent bearing piles. •Ease of work of this foundation type is inferior to multicolumn foundation.	
1st Selection: Evaluation	×	Term of works is long ×	△	Term of works is long ×	Superior to other alternatives in ease of execution ○	△	○	
2nd Selection: Approximate Quantity	———	———	Concrete Volume 653 m³ Caisson 1 725 m³ Steel Pier (SM490Y) 153 t Footing (SS400) 86 t	———	Conccrete Volume 933 m³ Steel Pipe Pile (1500mm, n=12) 251 t Steel (SS400) 79 t	Concrete Volume 1 083 m³ Steel Pipe Pile (1000mm, n=25) 81 t Steel Pier (SM490Y) 150 t Footing (SS400) 66 t	Concrete Volume 956 m³ Concrete Volume Casting in piles 156 m³ Steel pipe 133 m³ sheet pile 800mm n=36 388 t	Concrete Volume Steel Pier (SM490Y Footing SS400
2nd Selection: Cost Index	Expensive	———	2.19	———	1.0	1.59	1.21	3
2nd Selection: Ease of Execution	———	———	Several problems arise along the fablication of steel caissons and its transportation	———	·Execution is easy Ther is no underwater works	Many underwater works		
2nd Selection: Overall Evaluation	——— ×	——— ×	△	——— ×	The diameter of steel pipe becomes large ○	△	○	△

6 Comparison of Alternative Types of Foundation

		3 Spans Continuous Steel Box Girder Bridge with Steel Deck						
	Steel Pipe Pile Sheet Pile Fondation	Spread Footing		Caisson		Multicolumn Foundation		Steel Pipe Pile Sheet Pile Fondation
tion		Steel Footing	Double Wall Cofferdam	Steel caisson	Double wall cofferdam	Multicolumn Foundation	Steel Pipe Pile Foundation	
ng								
ven ion e .	Steel pipe sheet piles are used both as members of temporary cofferdam and permanent bearing piles. ・Ease of work of this foundation type is inferior to multicolumn foundation.	Regarding to the construction method,reffer to the descriptions about 3 Spans Continuous PC Box Girder Bridge.						
△	○	△	×	△	×	○	△	○
m³ t t t	Concrete Volume 956 m³ Concrete Volume Casting in piles 156 m³ Steel pipe 133 m³ sheet pile 388 t 800mm n=36	Concrete Volume 1 682 m³ Steel Pier (SM490Y) 156 t Footing SS400) 102 t	—	Concrete ﾌｰﾄ 690 m³ Caisson 760 m³ Steel Pier (SM490Y) 162 t Footing (SS400) 58 t	—	Concrete ﾌｰﾄ 536 m³ Steel pipe pile 131 t 1500mm,n=6 Steel (SS400) 32 t	Concrete ﾌｰﾄ 964 m³ Steel pipe pile 39 t 1000mm,n=12 Steel Pier (SM490Y) 159 t Footing (SS400) 42 t	Concrete ﾌｰﾄ 769 m³ 72 m³ Concrete Volume Casting in piles 24 m³ Steel pipe sheet pile 119 m³ 800mm,n=26 281 t
	1.21	3	—	2.86	—	1.0	2.55	1.30
			—		—			
			—		—			
	○	△	×	△	×	○	△	○

4-3-2 Design of Substructure

A steel pipe sheet pile foundation is analysed as a infinite beam supported on elastic foundation as its flexural behaviour is prominent when its ratio of L/Bv is larger than 1.0, in where L means the length of steel pipe sheet pile and Bv means the effective loading width respectively.

But if L/Bv is smaller than 1.0, shearing deformation is prominent and the stress condition of the foundation is similar to a group pile foundation due to the combined efficiency of junctions are not enough.

It is specified that if the ratio L/Bv is equal or smaller than 1.0, the steel pipe sheet pile foundation shall be designed by three dimensional structural analysis in the "SPECIFICATIONS FOR HIGHWAY BRIDGES" published by JAPAN ROAD ASSOCIATION.

Three dimensional structural analysis is adopted in the design of this project.

The steel pipe sheet piles shall be used as not only foundation piles but also as a wall of cofferdam. Stress condition of temporary stage as a cofferdam and that of completed stage supporting the superstructure are to be combined.

The stress of each condition is computed by following equations:

1. Above balancing point of earth pressure and bottom slab

$$Es*I*\frac{d4y}{d4x} - P(X) = 0$$

2. Below balancing point of earth pressure and bottom slab

$$Es*I*\frac{d4y}{d4x} + Kh*d'*y - p(x) = 0$$

where,

Es	:	Yong's modulus of steel pipe sheet pile
I	:	Polar moment of inertia of area
y	:	Displacement at depth x
x	:	Distance from the top of steel pipe sheet pile
p(x)	:	Lateral pressure, water pressure
Kh	:	Coefficient of lateral subgrade reaction
d'	:	Unit width of steel pipe sheet pile

4-3-3 Design of Superstructure

(1) General View of Superstructure

The drawings of general view of deck, typical cross-section, and layout of longitudinal ribs are given in Fig. 4.6 ~ Fig. 4.8.

(2) Design of Deck Plate

Floor construction is assumed to be composed by following members:

Longitudinal ribs

Lateral ribs

The space of lateral ribs are assumed to be 3.0m.

Bracket

Outside girder

Deck plate

The thickness of deck plate is 12mm.

Each member is designed by following design method.

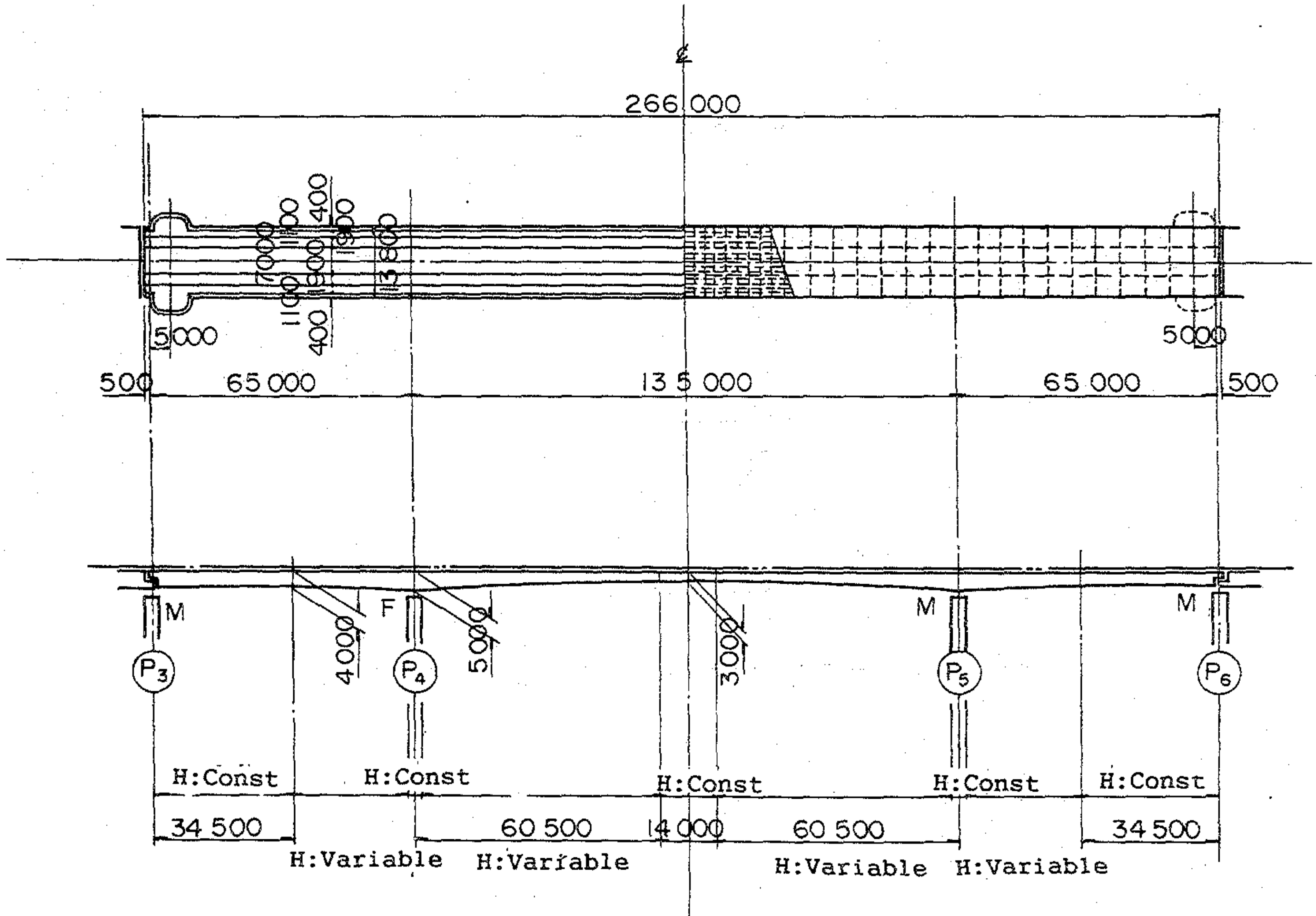
A computer program named "Automatic Design Program of Steel Plate Deck" by JIP is adopted in the design of the bridge, which is based on "Finite Strip Method" and considering longitudinal ribs and orthoropy deck plate.

Deck plate is analyzed by FSM considering longitudinal ribs as infinite continuous plate supported by two sides in box girder-portion and as infinite continuous plate supported by one side in cantilever portion.

A lateral rib are analyzed by FSM as simple beam that is supported by girder.

A bracket is designed by FSM as a cantilever.

An outside girder is designed by conventional method as a infinite continuous beam supported by bracket.



H:Web Height

Fig. 4.6 General View of Superstructure

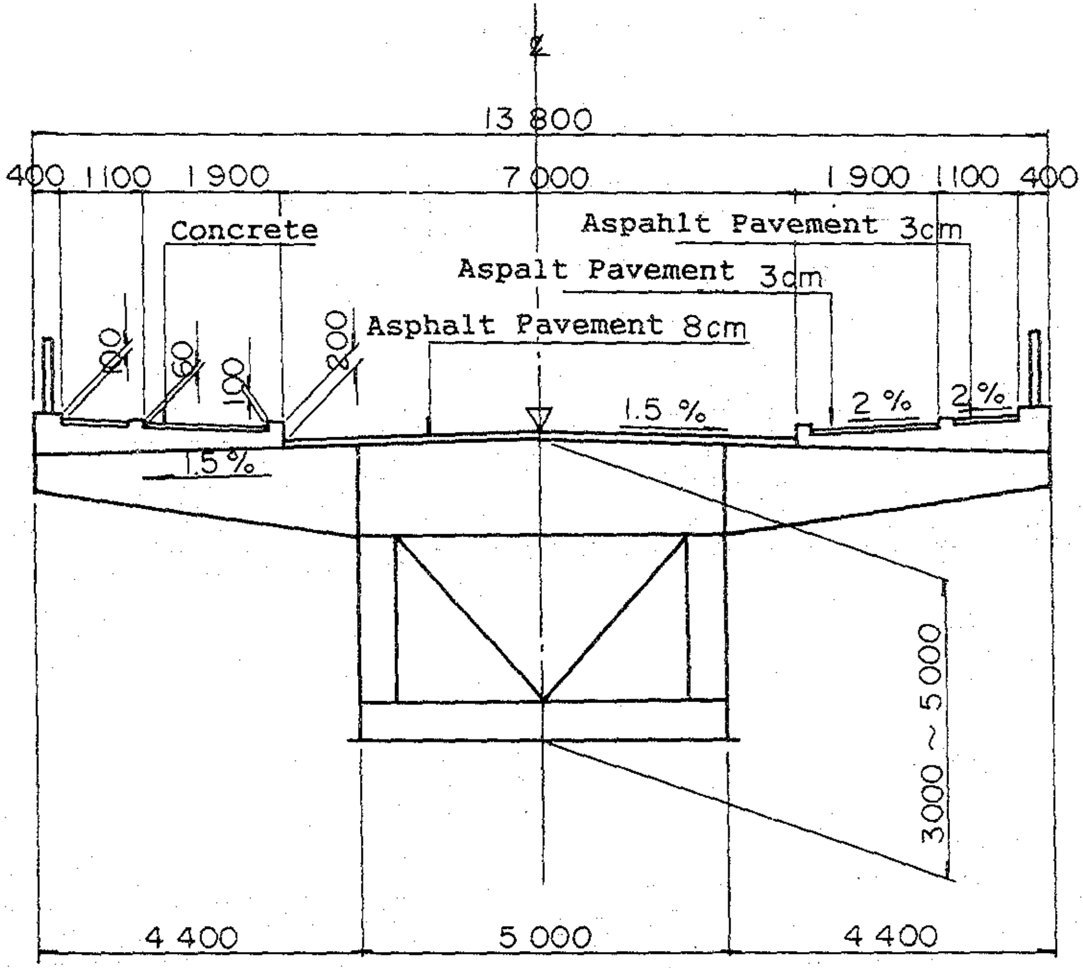


Fig. 4-7 Typical Cross Section

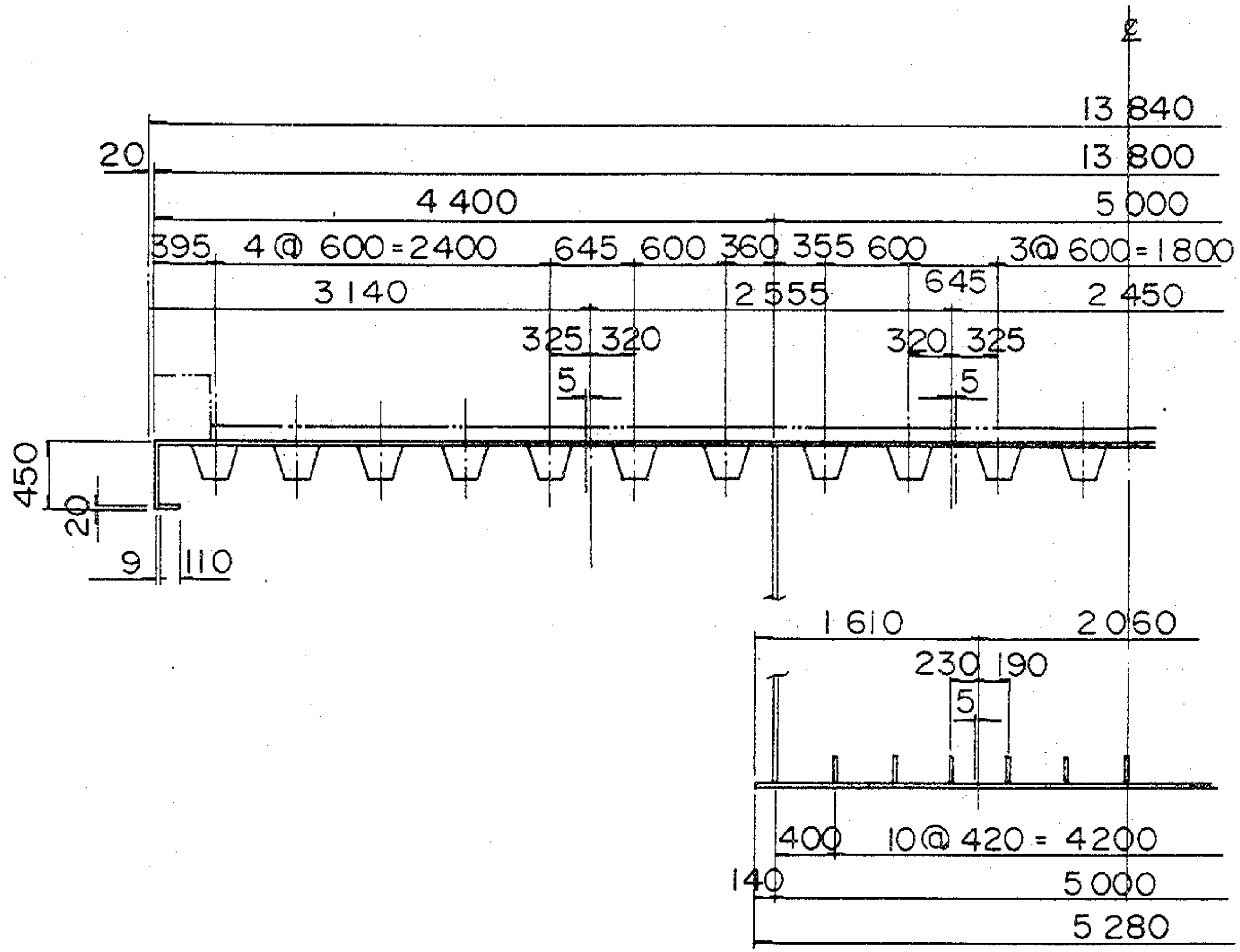


Fig.4.8 Arrangement of Longitudinal Ribs

(3) Analysis of Girder

A main girder is analyzed by deformation method as a beam that has flexural rigidity and torsional rigidity.

The live load, consist of line load, P, and the uniform load, p, defined as "main load" shall be placed on the roadway in accordance with the width of the roadway.

On the sidewalk and cycle track, a uniform distributed load shall be applied.

The bridge is assumed to be erected by the block erection method.

The skeleton for analysis and design is shown in Fig. 4.9.

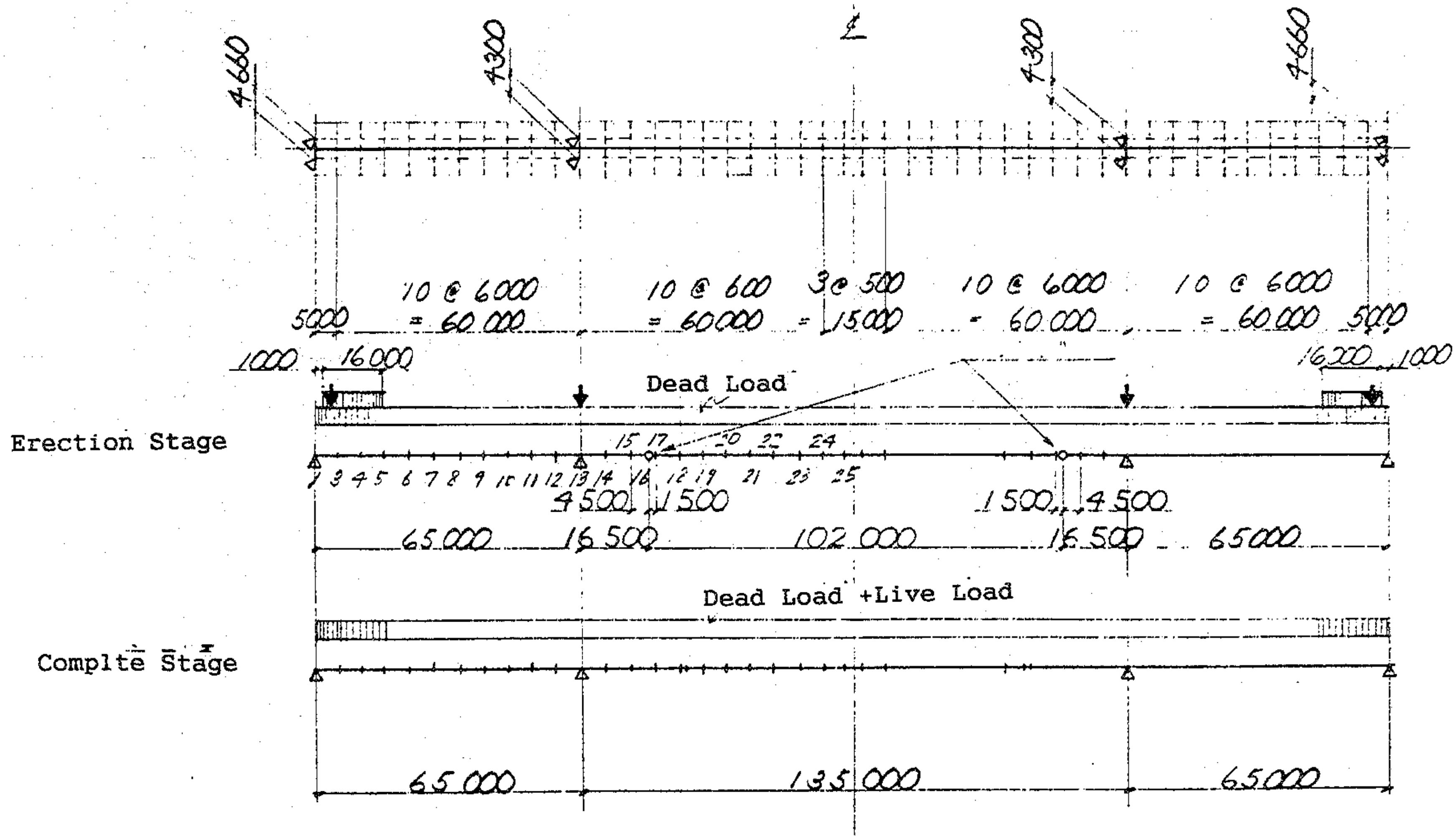


Fig 4.9 Skelton for Analysis of Superstructure

4-3-4 Design of Road

(1) Vertical Alignment

According to the original design drawings, the original vertical alignment is shown in Fig. 4.10. The gradient of tangent at Piers No. 3 and No. 6 are 2.3% and 2.4% respectively, based on the topographic survey conducted by the study team.

To avoid existing foundation structures of Pier No. 4 and No. 5, Central span of 265m long collapsed bridge will increase to 135m long from original 105m long. Accordingly, the height of girder at the center will increase to 3.0m high from original 2.5m high.

To prevent violating navigation clearance under the central span the vertical curve length is to be reduced up to 70m and then the finished grade at the center will become 0.85m higher than that of the original one.

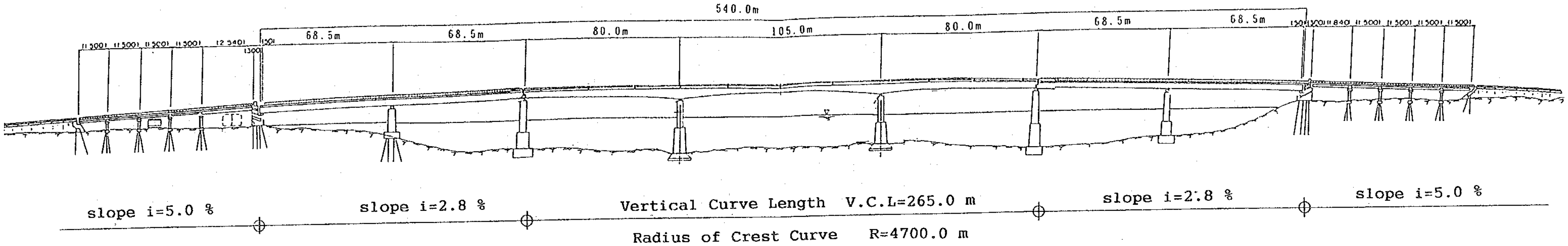
In order to examine the violation of space under the central span, the elevation of lower flange of box girder at 30m apart from the center is compared as shown in Table 4.7.

Table 4.7 Comparison of Lower Flange Elevation

	30m apart		Center	
	Original	Planned	Original	Planned
Finished Grade	24.40	24.97	24.52	25.37
Lower Flange	20.51	21.54	22.00	22.20

The vertical curve length of 70m can secure 77m long stopping sight distance in this case, with which it can satisfy the requirement of design speed of 60 km/h. On the other hand, the gradient in the existing approach roads is surveyed 5%, the same as that of original design, and it is designated as the maximum gradient in the design speed of 60 km/h. Therefore, it is rational to adopt 70m long vertical curve length to the Project.

Old Bridge



New Bridge

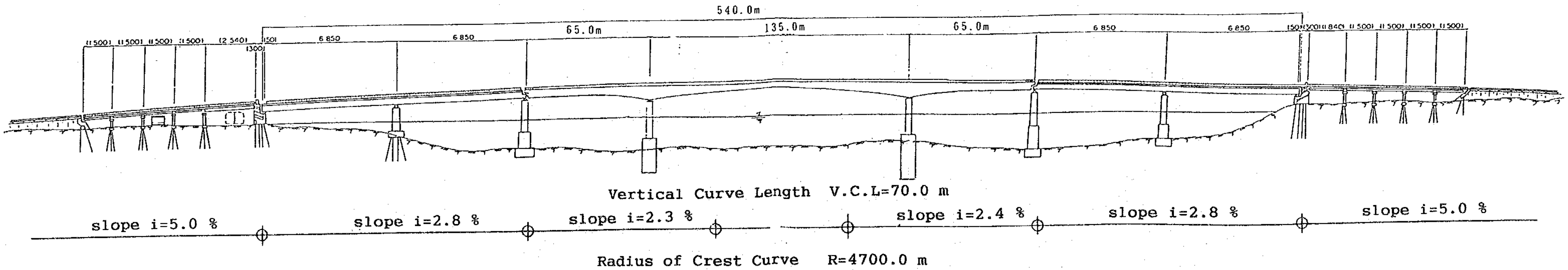


Fig. 4.10 Longitudinal Slope of Chroy Changwar Bridge

(2) Configuration of Cross Section

265m long new bridge will be connected with the existing bridge of which configuration of cross section consists of 7.0m wide through-travelled lane, 3.80m wide (1.90m x 2) cycle track and 2.20m wide (1.10m x 2) sidewalk.

From the viewpoint of traffic capacity, this configuration, which normally has the capacity of 10,000 veh/day excluding motorcycle, may be sufficient because the estimated traffic volume is only 1,100 veh/day with 3,800 motorcycle per day.

4-3-5 Design of Repair Works

Outline of repair works are shown in Fig. 4.11.

1) Repainting of existing steel box girder bridge

It was indicated that in spite of the existing bridge is leaving without repainting for more than thirty years and some portion is becoming rusty, there was no structural deterioration in all bridge members by the visual inspection. To keep this good condition the bridge members shall be repainted.

2) Repainting and repair of damaged hand rails

Some part of the existing hand rails are hardly rusted and corroded. These seriously damaged portion is removed and repaired by new members and the remainder is to be repainted.

3) Demolition and reconstruction of existing pavement

Most of all surface of asphalt pavement is deteriorated and to be reconstructed. Filling of embankment is necessary in the Chroy Changwar side due to the consolidation settlement of foundation layer. Demolition and reconstruction of existing concrete traffic railing are necessary.

4) Repair of cracked concrete

Some concrete cracks were observed at the bottom of column of pile bent type pier. These cracks are not structural and to be repaired by replacement mortar.

5) Repair of deteriorated grouted riprup

Grouted riprup located in front of the abutment of approach concrete bridge is deteriorated in both sides. These are to be removed and to be reconstructed.

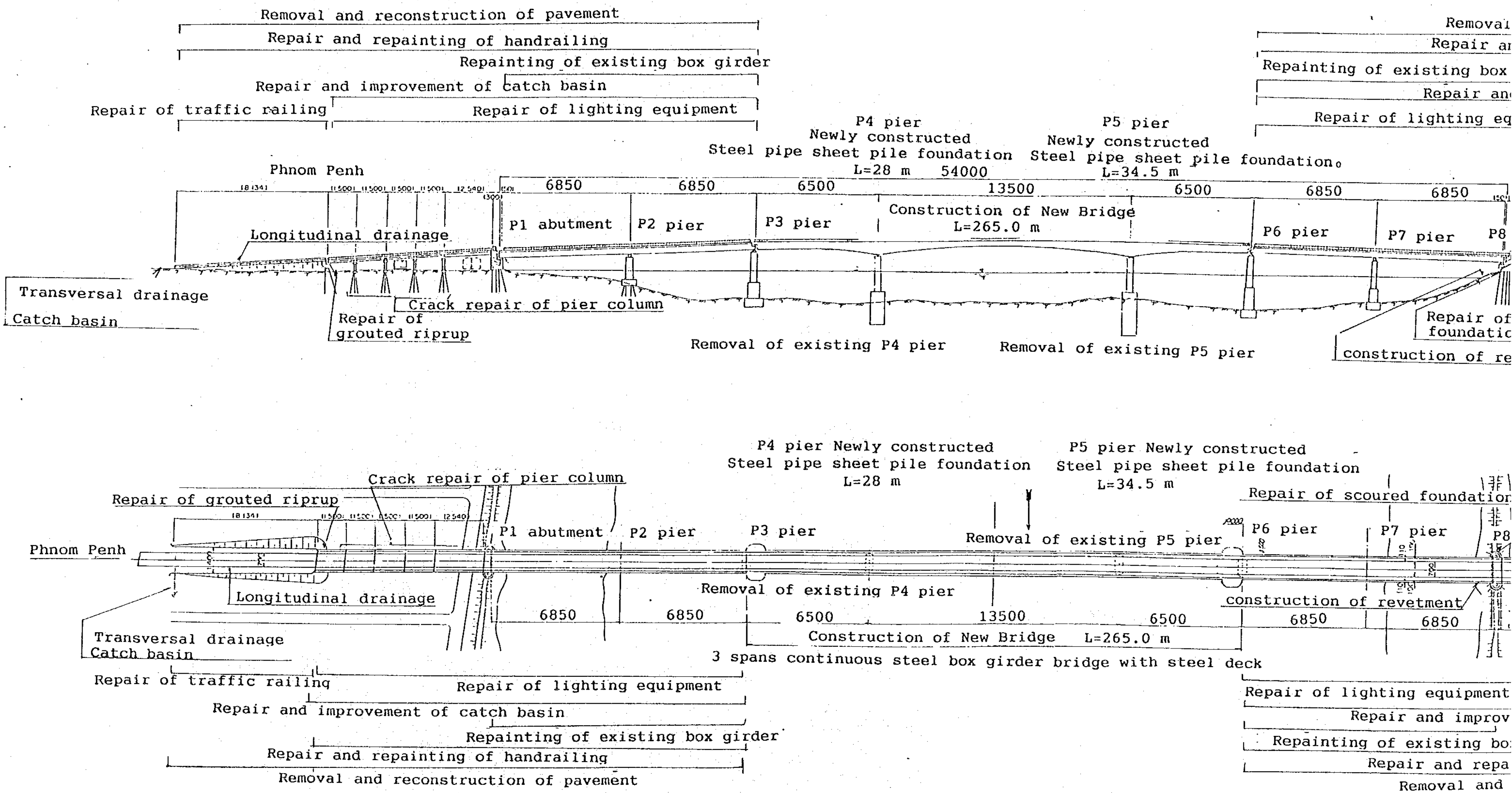


Fig. 4.11 Outline of Repair Works

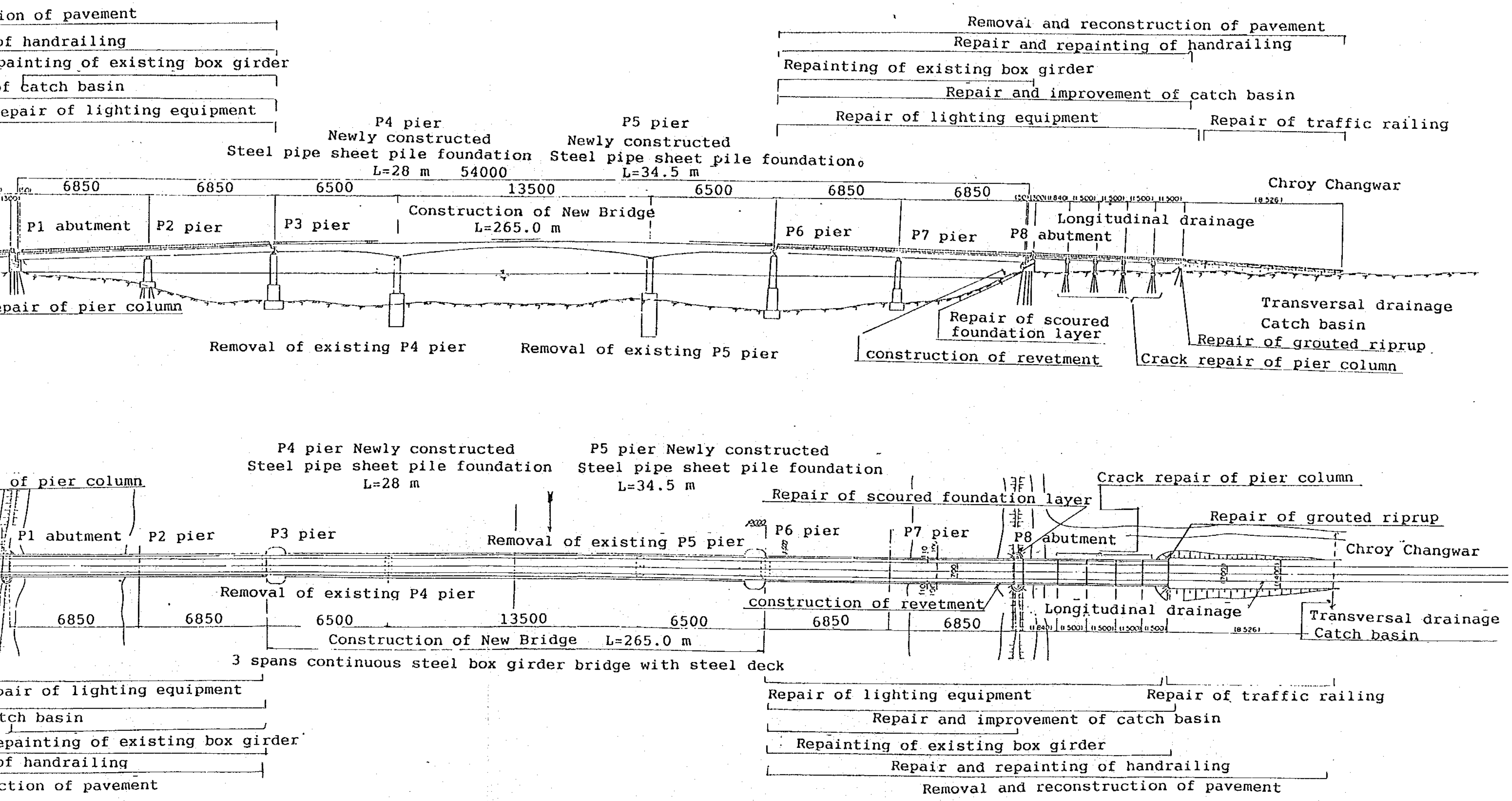


Fig. 4.11 Outline of Repair Works

6) Repair of scored foundation layer

A part of the foundation layer of the left bank abutment of 2 spans continuous steel box girder is scored and to be repaired by prepacked concrete. To prevent same erosion, bank protection is to be constructed.

7) Repair of lighting equipment

All of the lighting equipments were damaged and can not be used. New equipments shall be installed in the bridge section.

8) Repair and improvement of drainage

As the size of the inlets on the bridge is not sufficient, dust and mud are stuffed in the drainage pipes. The size of inlet shall be enlarged so as to let dust and mud can be removed easily. Longitudinal drainage and transversal drainage in the embankment section are to be constructed to improve drainage condition

9) Repair of approach slab

The approach slab is not functionable due to large consolidation settlement that was occurred in the behind of the abutment of Chroy Changwar side approach concrete bridge. The longitudinal length of the original approach slab is too short and to be newly constructed.

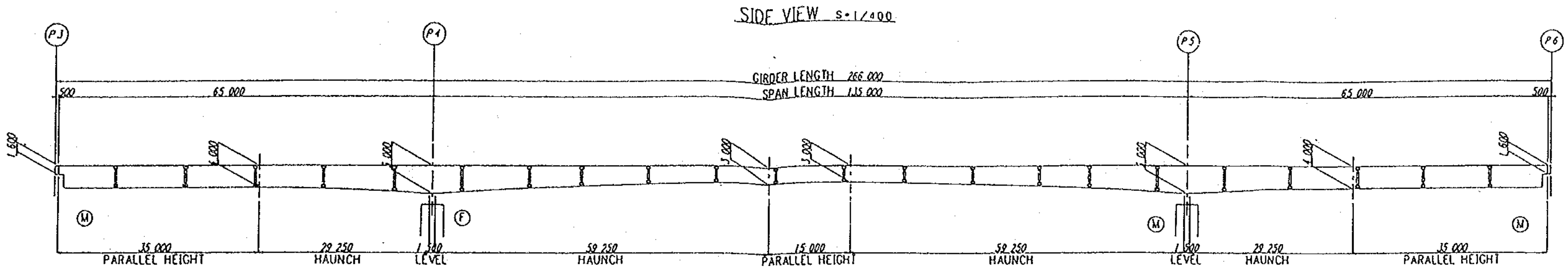
10) Installation of gantry

Only one gantry is installed in the upstream side of Phnom Penh side. Another gantry shall be installed in the down stream side close to the bridge.

4-3-6 Basic Design Drawings

Basic design drawings for Chroy Changwar Bridge are presented as follows:

1) General Plans of Superstructure = Fig. 4-12, Fig. 4-13
2) General Plans of Substructure = Fig. 4-14, Fig. 4-15



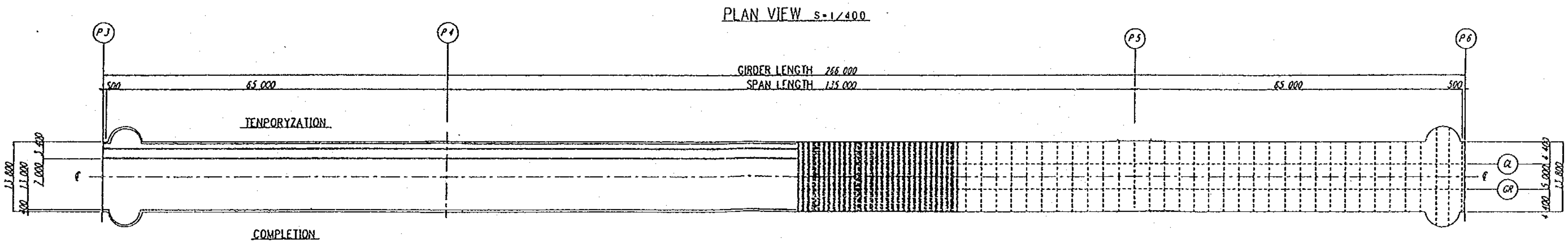
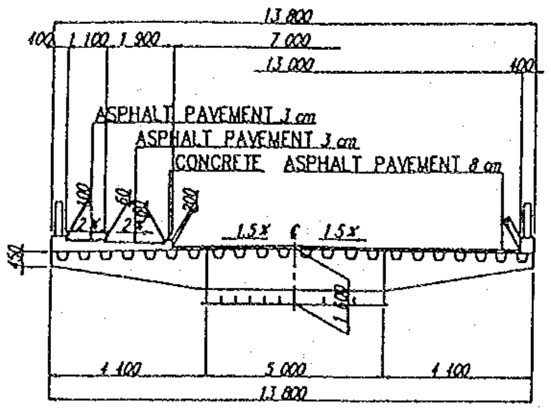


Fig. 4-12 General View of Superstructure

SECTION S=1/100

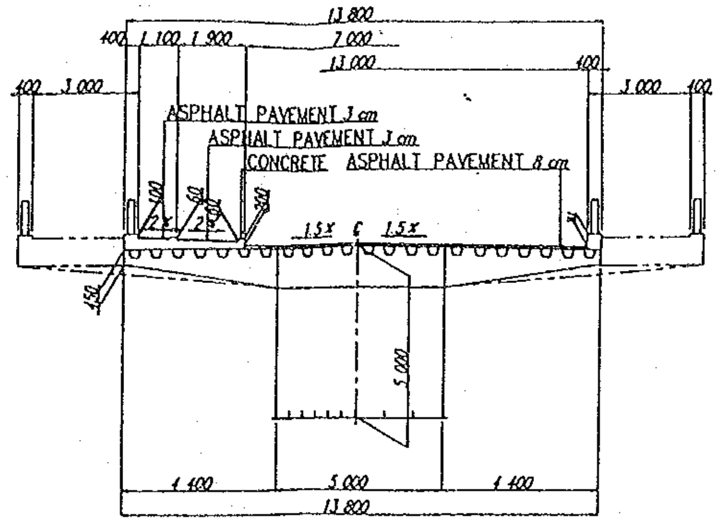
<S1, S2> END SUPPORTING POINT

TENPORYZATION COMPLETION



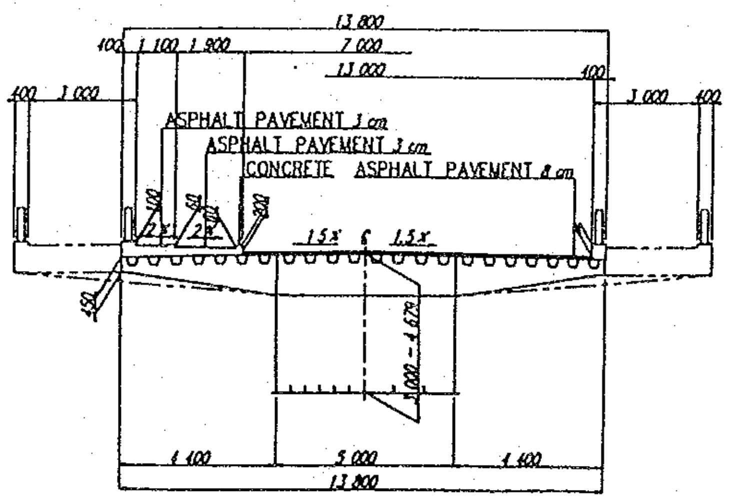
<P4, P5> INTERMEDIATE SUPPORT POINT

TENPORYZATION COMPLETION



INTERMEDIATE DIAPHRAGM

TENPORYZATION COMPLETION



INTERMEDIATE CROSS RIB

TENPORYZATION COMPLETION

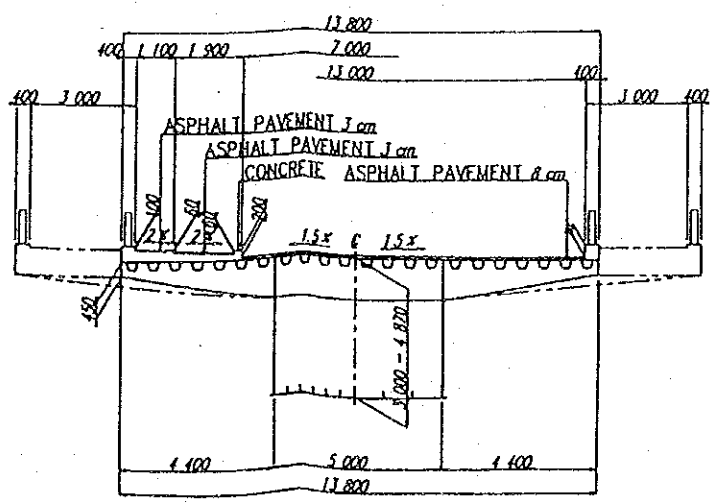


Fig. 4-13 Crosssection of Superstructure

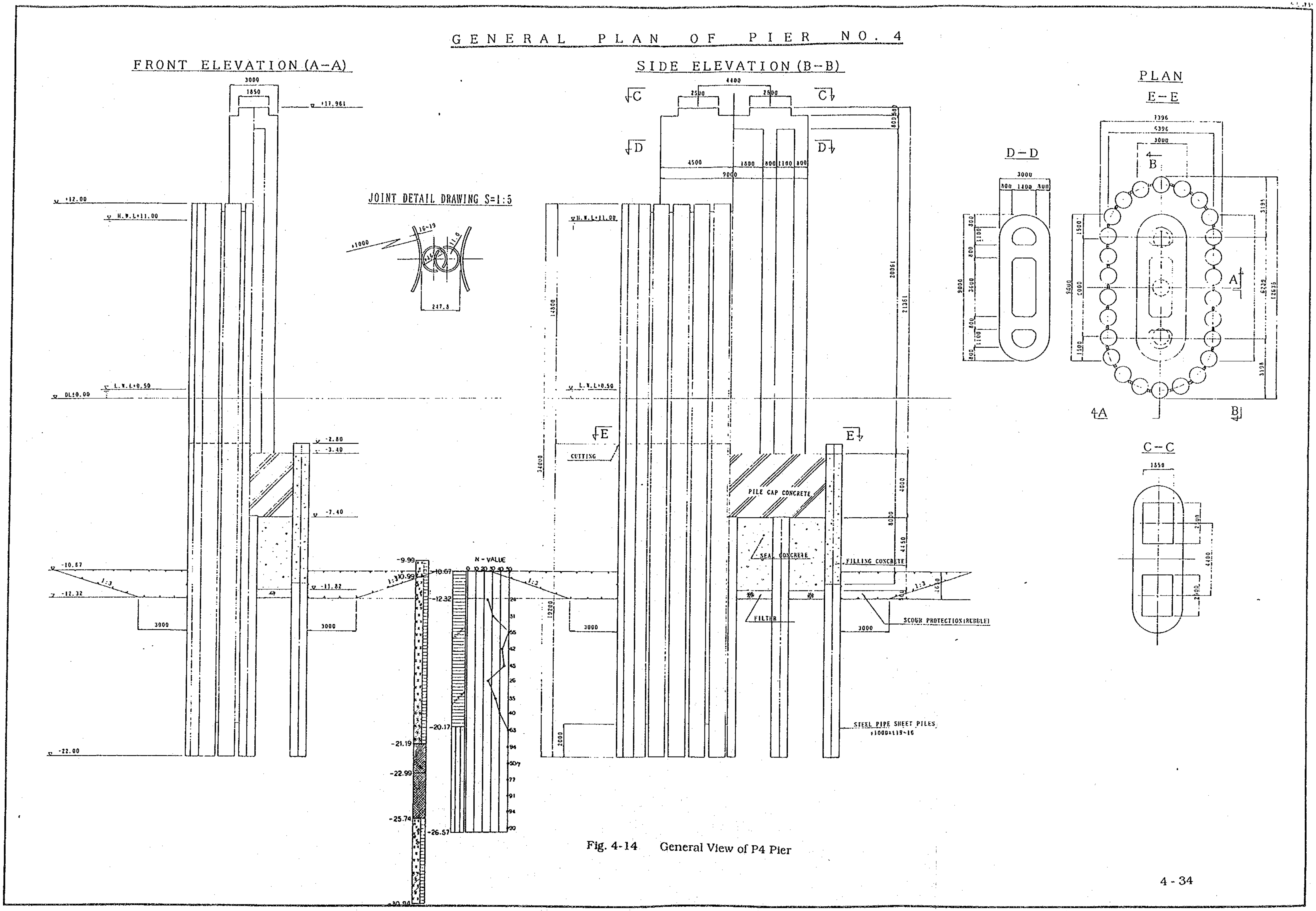


Fig. 4-14 General View of P4 Pier

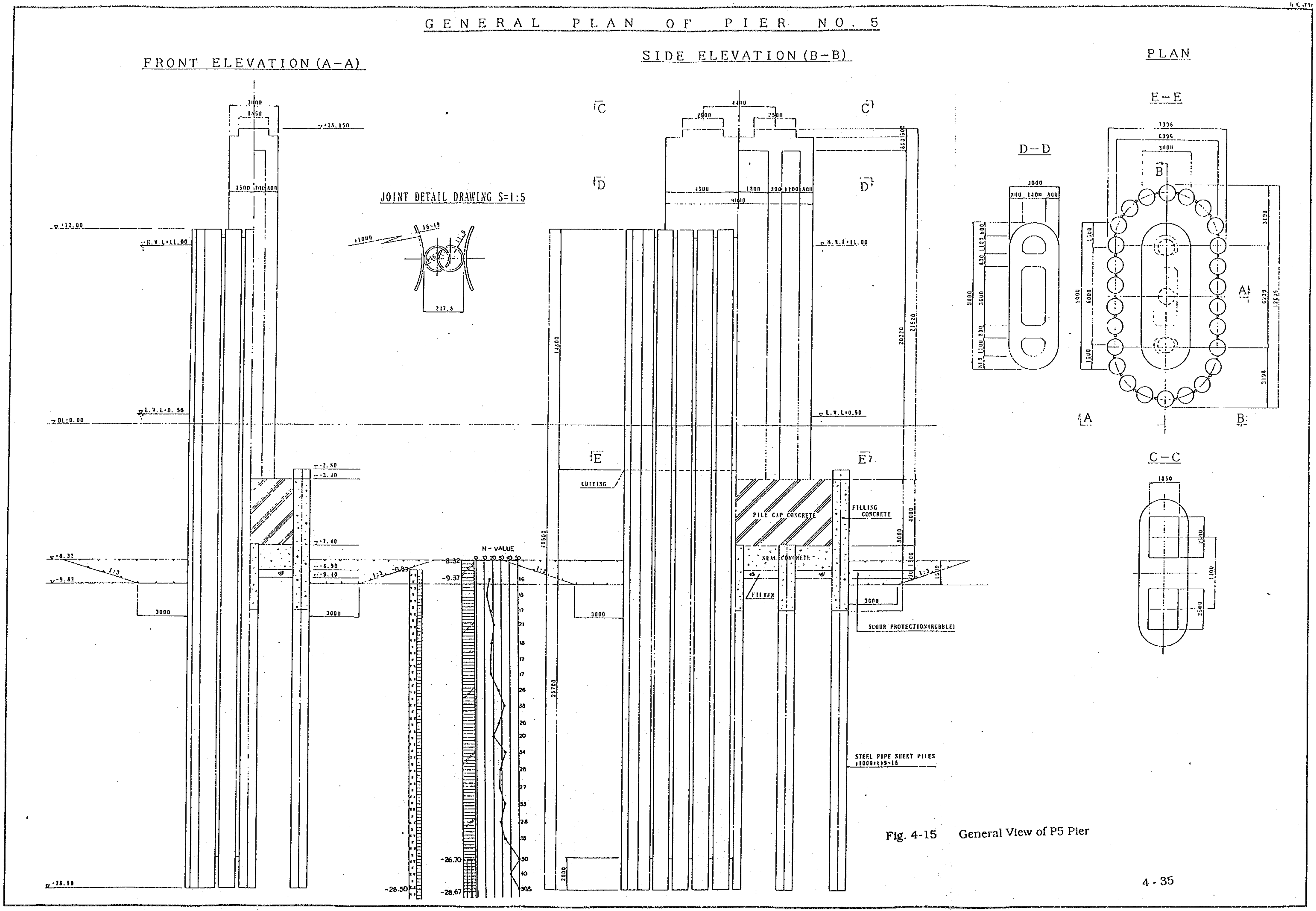


Fig. 4-15 General View of P5 Pier

4-4 Implementation Plan

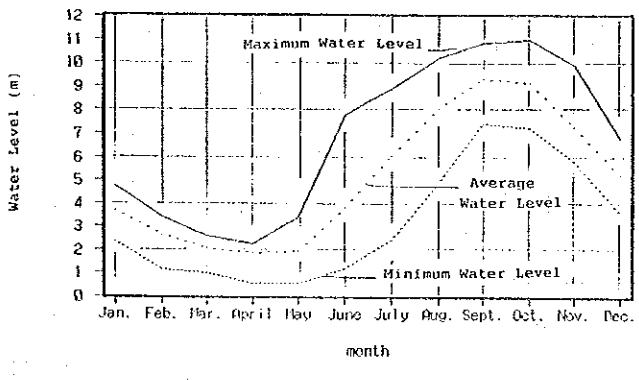
4-4-1 Construction Policy

The bridge is located at about 250m apart from the north end of Phnom Penh port. The port activity, at present, is very busy. The ships utilized the port are of scale 1500-3000 ton. There are ferry services for pedestrian and motor/bicycle by boats connecting Phnom Penh with the opposite river banks at the upstream and downstream of the bridge. Road RN 5 passes under the approach span of the bridge. The traffic volume of about 5,000/day at the point was observed. Due consideration above-mentioned should be paid to ensure the safety while the construction work in progress.

Differences of the water level in dry and rainy seasons are more than 9m and velocity of the stream at rainy season is about 3 m/s. Construction works of the foundations should be conducted in dry seasons.

In the light of its importance and urgent the existing partially collapsed 265m long section should be completed within one year after the commencement. Therefore it is necessary to adopt the special construction method which is required the particular equipment. As a general principle, the local labour forces will be used to the maximum possible extend, nonetheless, a consideration will also be paid to the use of some heavy construction equipment in order to shorten the construction period. To meet this requirement, some Japanese mechanical operators will be assigned immediately upon the delivery of the equipment and some local technicians will be employed as the assistants to the operators.

Due to the timing of the foundation works is restricted according to the water level, construction works of the superstructure shift to the end of construction period. Typical changes of water level is shown in the following figure.



It is necessary to consider the present conditions mentioned above to set up the construction plan for the bridge.

4-4-2 Construction Plan

Based on the design and construction policies as referred to previous sections, the preliminary construction method will be planned as summarized in the following:

(1) Preparatory Works

① Mobilization
② Preparation of Stock Yard
③ Construction of Site Offices
- Site office for consultants and RBD
- Site office for contractor
④ Construction of Storages

(2) Incidental Works

① Preparation of Temporary Stock Yard at River Side
② Preparation of Assembly Yard for Superstructure

(3) Substructure Works

① Construction of Foundations Works
- Steel pipe sheet pile well
② Construction of Concrete Piers

(4) Superstructure Works

① Assembling Work at Site
② Erection Work
③ Bridge Surface Works
- Treatment of bridge surface
- Joint
- Drainage
- Hand rail
- Lighting
- Pavement

(5) Repair Works of Approach Road

① Earth Work

② Bridge Works

- Repainting of existing bridge
- Repair and repainting of existing handrail
- Crack repair
- Repair of scored foundation layer

③ Slope Protection Works

④ Road Structure Works

- Approach slab
- Masonry for abutment

⑤ Pavement Works

⑥ Lighting Works

(6) Demolish Work of Remaining Piers (P4, P5)

4-4-3 Situation of Construction and Considerations for Construction Activities

(1) Situations of Construction

a) Construction Equipment

Heavy construction equipment except trucks and dump trucks cannot be procured in Cambodia. The road and bridge construction projects in Cambodia were implemented by the Government and the construction works are conducted by Road Construction Company and Bridge Construction Company under the Road and Bridge Department, Ministry of Communication, Transport and Post.

Rehabilitation and maintenance works of roads and bridges in Cambodia are implemented by Road Repair and Maintenance Units under the Department.

There is no private contractor who has own construction equipment.

Road and bridge Department has own heavy construction equipment for newly construction or maintenance projects.

The equipment is very old fashion and the efficiency of operation is not satisfactory. And it is difficult to use these equipment for this project, as the RBD has their own construction plan and cannot afford to provide them.

b) Materials Locally Available

The materials need in the construction, in principle will be procured locally in so far as they are available in case their adequate quantity and quality are guaranteed.

c) Labour

The labour's working time, in general, is set forth 8 hours from 7:00 a.m. to 11:30 a.m. and from 14:00 p.m. to 17:30 p.m.

There is no concept of overtime.

In the light of this, the labour cost including an overtime allowance needs to be prepared accordingly for such a short construction period.

In addition, since a labour supplier is not exist in Cambodia at present, in order to recruit a large number of the labour forces, it is necessary to estimate a provision of overhead costs such as the traffic expenses, accommodation costs, insurance, tools, etc.

d) Delivery of Overseas Procurement Products

There is no problem on the transportation for the material procured locally. Materials from Japan will be transported by the following ways:

1) Japan → Kompon Som Port by sea
Kompon Som Port → Phnom Penh by inland 226 km RN 4

2) Japan → Kompon Som Port by sea
Kompon Som Port → Phnom Penh by rail 264 km

3) Japan → Singapore by sea (large scale ship)
Singapore → Phnom Penh by sea (small scale ship)
(passing through Vietnum territory)

(2) Considerations for Construction Activities

Since this bridge had constructed in Cambodia, there is no experience of the big scale civil works.

It is very important to prepare carefully the construction schedule, material procurement plan, and delivery plan of equipment.

Under the above-mentioned situation, the construction should be operated by an experienced contractor and supervised by an experienced consultant.

Taking into consideration not only the situations of the construction as referred to above, but also the construction schedule in the rainy season, the work needs to be proceeded by paying attention to the matters as summarized in the following:

1) Major premise of this repair project is that the superstructure of the rehabilitation section (265m) shall be erected within one year after the commencement.

In general, construction in the river involves many kinds of risks.

It is necessary to pay carefully attention to the construction method and timing.

2) Foundation works should be completed within low water level season. According to the past data, although low water level is changeless in each year, the rising speed of water level is quite different in each year. Therefore it is necessary to pay attention to concentrate on the work at a high elevation.

3) The procurement and the delivery of the materials should be done taking into account the tight schedule of the construction.