KINGDOM OF THAILAND

FEASIBILITY REPORT
ON
BANGKOK-THONBURI BRIDGE NO. 1 PROJECT

OCT. 1968

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

PREFACE

The Government of Japan, at the request of the Government of Thailand, entrusted the Overseas Technical Cooperation Agency with the task of conducting a feasibility survey for the Bangkok - Thonburi bridge project in Thailand.

The Overseas Technical Cooperation Agency dispatched a survey team, headed by Masanori Nishihata, commissioner of the National Capital Region Development Committee, to conduct the survey.

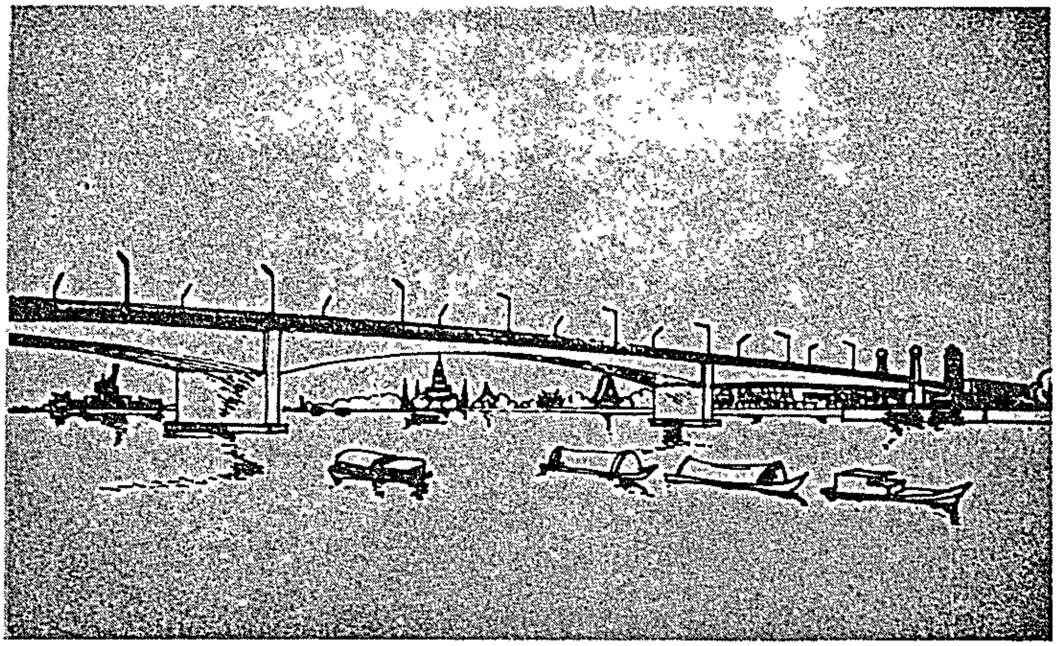
Surveys conducted were: topographical survey, soil exploration and observation of river conditions for the proposed Bangkok - Thonburi bridge. The results of these have been reviewed and compiled into a report submitted to your government.

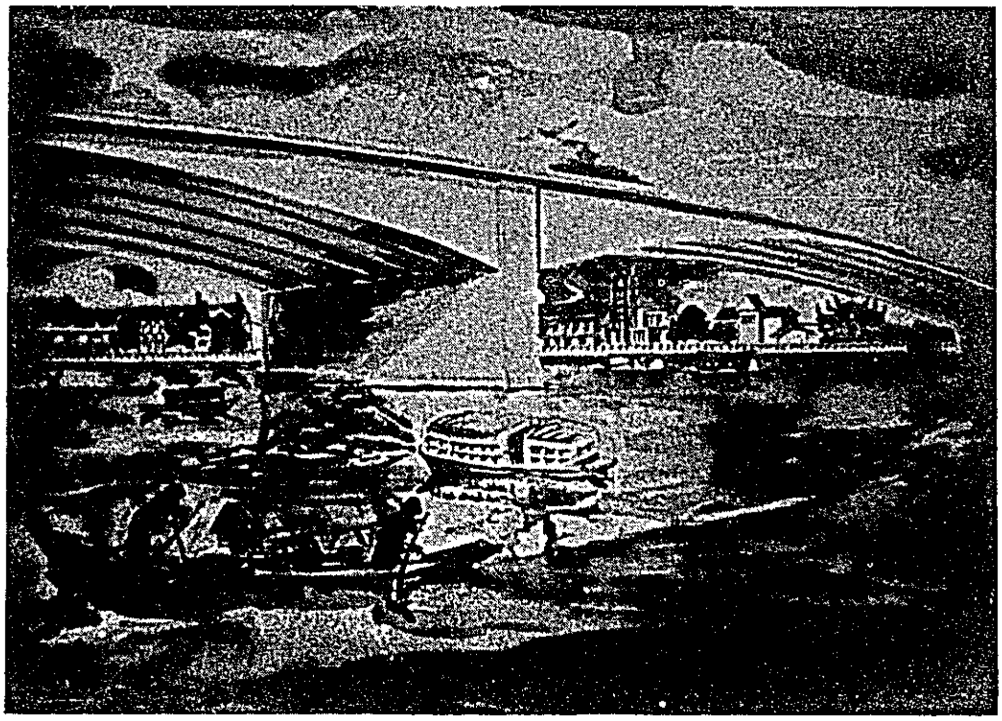
Our agency would be most gratified if this report will contribute in any way to friendship and economic relations between Thailand and Japan.

We deeply appreciate the assistance and co-operation given by the Government of Thailand and its agencies to the members of the team during their stay in Thailand.

Oct. 1968

Shinichi Shibusawa
Director General
Overseas Technical Cooperation Agency





Sketch of the proposed Chao Phya River bridge between Bangkok and Thonburi, Thailand.

CONTENTS

INTRODUCTION

The Japanese survey team arrived in Bangkok Dec. 3, 1967 and commenced work on the Bangkok-Thonburi bridge construction project, which is one of a series of technical co-operation programs of the Colombo Plan. The said team consisted of seven experts as listed hereunder:

Masanori Nishihata	Leader of the team and commissioner of National Capital Region Development Committee
Hiroshi Mori	Deputy leader and civil engineer in charge of foundation engineering, president of Nippon Kaigai Consultants Corp.
Yoshio Niinomi	Civil engineer and chief of operation section, development survey division, Overseas Technical Cooperation Agency
Mitsuo Nishino	Civil engineer in charge of structural engineering, vice president of Nippon Kaigai Consultants Corp.
Hirosuke Shimokawa	Japanese Government civil engineer, assistant chief of national road section, Ministry of Construction.
Toshiro Fukuyama	Civil engineer in charge of structural and traffic engineering, director of Nippon Kaigai Consultants Corp.
Kenichiro Kawaji	Civil engineer in charge of supervision on survey and soil exploration, Chiyoda Engineering Consultants Co., Ltd.

The work to be completed by the Japanese team had been specified in "Plan of Operation (Oct. 1967)" agreed upon between Thai and Japanese governments and "Required Items for the Design of Bridge Crossing the Chao Phya River at Ta Chang" suggested by Department of Public and Municipal Works, Ministry of Interior, Thailand. However, some amendment on the specified work were agreed upon after consultations between Mr. Kanjana and the Japanese team.

The report of the survey work performed of the Japanese team during its stay in Thailand was summarized in the form of memorandum and submitted to the Thai Government.

After the Japanese team returned to Japan, the soil exploration was completed at the beginning of March and the type of foundation was finally decided upon. Including amendments to some sections of the structural design and the results of traffic study in front of the Royal Hotel, the report on the feasibility study of the Bangkok-Thonburi bridge project was compiled as follows:

CHAPTER I

GENERAL INTRODUCTION

Section 1. Background of the Project

The Thailand Government, in the light of the recent rapid increase in population and the mounting traffic problems, is currently pushing a 10-year capital city reformation plan, covering Bangkok and Thomburi, the two largest cities in the country, with an emphasis on the paving and repaving of street network, better land utilization, reformation and face-lifting of old city areas, construction of new city areas, facilities of pure water supply and drainage as well as environment sanitation facilities.

With particular reference to the traffic problem, the existing bridges spanning the Chao Phya River are only four - too small in number to cope with the ever-increasing traffic volume on them.

In the face of fast-rising land acquisition costs resulted from a recent skyrocketing land value, the Government, fully aware of this mounting traffic problem, has now placed the proposed Bangkok-Thonburi bridge construction project top on a priority list, along with the construction of elevated crossings within city areas and the enlarging of streets.

The Government has recently formulated a new 5-year bridge construction project in order to partially avert the traffic from the Memorial Bridge where the traffic volume is considered the heaviest. According to the said 5-year plan, the Government will immediately have two bridges constructed over the Chao Phya River. It is also expected that the Government will have one additional bridge at a later date.

The first bridge to be constructed starting in 1968 is the designated "Bangkok-Thonburi bridge" between Ta Chang and Wang Na. This bridge will soon be followed by the construction of another over the Khlong Bangkok Nai and related roads.

Section 2. Brief Description of the Project Area

Bangkok, the capital of Thailand, is situated on the left of the Chao Phya River, and Thonburi on the right, facing the capital across the river.

Bangkok is the center of Changwat Pranakhon : Thonburi is the hub of Chawngwat Thonburi. Bangkok with it suburbs, Thonburi with its suburbs, a part of Changwat Nonthaburi and some part of Changwat Samut Prakan, collectively form the Metropolitan area. Not only are Bangkok and Thonburi the center of politics, but also the heart of economy, industry and civilization in Thailand.

In Bangkok, the centralization of population is now occuring at a surprisingly fast tempo, thereby posing a grave problem to city planning and traffic congestion.

On the other hand, Thonburi is more a part of civic center of Bangkok than a mere satelite city of the capital city. For this reason, the city planning of Bnagkok cannot be worked out without considering Thonburi as its integral part. One must consider these two cities as one and the same urban area having intimate function relations.

Section 3. Purpose of the Project

As described earlier, Bangkok and Thonburi are divided by the Chao Phya River. Vehicle traffic between these two cities runs mostly over the Memorial Bridge connecting the centers of these cities. According to a traffic survey, conducted in 1967 by the General Engineering Company, whose result is shown in table 3-1, of total daily vehicular traffic of 160,000 vehicles between Bangkok and Thonburi, vehicles passing over the Memorial Bridge were accounted for about 66 per cent or 105,000 vehicles. About three kilometers upstream from the Memorial Bridge, there is the Kruhg Thon Bridge and about three kilometers downstream, is the Krung Thep Bridge. Approximately three kilometers upstream from the Krung Thon Bridge, there is the Rama VI Bridge which carries both railroad and highway traffic. The total vehicular traffic of these three bridges is only 34 per cent, or 55,000 vehicles. Therefore, in the light of the existing heavy traffic over the Memorial Bridge, it is assumed that traffic previously utilizing the said bridge is now passing via other existing bridges despite the somewhat larger cost involved. To keep this extra cost to a minimum, construction of new bridges is highly desirable.

Table 3-1. Vehicular Traffic between Bangkok and Thonburi in 1967

Bridge Vehicular Traffic		Memorial	K. Thon	K. Thep	Rama VI	Total
Actual		105,400	27,000	22,200	5,380	160,040
Percentage		0.658	0.169	0.139	0.034	1.000
Traffic Capacity	Possible	90,000	86,400	72,000	43,200	291,600
	Practical	62,400	72,000	72,000	36,000	242,400
Degree of Congestion		1.38	0.38	0.31	0.15	0.66
Date Traffic Checked		the average of 2/6(Mon.) 1/31(Tue.) 2/1(Wed.) 2/2(Thu.) 1/27(Fri.) 1/28(Sat.) 1/29(Sun.)	2/14(Tue.)	the average of 2/13(Mon.) 2/14(Tue.)	2/17(Fri.)	

Since the Memorial Bridge, measuring only 10 meters in width, has four-lanes, daily vehicular traffic of more than 100,000 vehicles exceeds its practical capacity. Moreover, it is expected that this vehicular traffic between Bangkok and

Thonburi will increase every year keeping pace with the social and economic development and the expected rise in the number of vehicle registrations.

The above mentioned vehicular traffic does not include all traffic between the two cities of Bangkok and Thonburi, as there is also a ferry service operating between the two banks of the Chao Phya River. In fact, the ferry boats are playing an important part as a means of handling a large number of travellers between Bangkok and Thonburi. It is highly likely that a considerably large percentage of the present ferry boat users will come to utilize vehicles once the traffic facilities are improved substantially.

Considering these traffic conditions and the construction site of the proposed bridges, a need for building of such bridges stems from the following reasons.

1) To alleviate the traffic congestion over and around the Memorial Bridge and to shorten travel time and cut costs.

2) The inter-city relations between Bangkok and Thonburi will thus become more and more intimate and develop further as the nucleus of the Metropolitan area.

3) A development will be facilitated in the vicinity of the bridge, particularly in the underdeveloped areas of Ta Chang of Thonburi and there will be brought a more balanced situation in the whole areas of Bangkok and Thonburi.

CHAPTER II

TECHNICAL FEASIBILITY

Section 1. Construction Standards

Design standards, which have been mutually agreed after consultations between the Thailand Government and the Japanese survey team are outlined below:

(1) The bridge should be made of pre-stressed or reinforced concrete.

(2) Design Speed

Bangkok-Thonburi bridge and related road :	50 km/hour (30 mph)
Bangkok-Noi bridge and related road :	50 km/hour (30 mph)

(3) The longitudinal gradient should not exceed 5 per cent.

(4) The width of roadway of bridges

(a) The width of roadway of the Bangkok-Thonburi bridge is 21m for 6 lanes, on both sides of which are installed sidewalks of 2.5 m in width. Therefore the clear distance between handrails becomes 26 m.

(b) The width of the roadway of the Bangkok-Noi bridge is 14 m for 4 lanes, on both sides of which are installed sidewalks of 2.5 m in width. Therefore the clear distance between handrails becomes 19 m.

(5) The width of the related roads (Fig. 1-1 - 1-4)

(a) The standard cross-section of the road connecting Bangkok-Thonburi bridge with Charan Sanit Wong Road is shown in Fig. 1-1.

(b) The standard cross-section of Charan Sanit Wong Road is shown in Fig. 1-2.

(c) The standard cross-section of reconstruction part of the new Issra Phap Road and the road extention beyond the Khlong Bangkok Noi are shown in Fig. 1-3 and Fig. 1-4 respectively.

(6) The navigation channel should be secured with the width of 60 m and the clearance under the girder of 11.5 m (above MSL) at the center of the main Bangkok-Thonburi bridge.

(7) The navigational width of 15.0 m and minimum clearance under the girder of 5.42 m (above MSL) should be secured at the crossing of the Khlong Bangkok Noi.

(8) The clearance under the girder of 5. 15 m should be secured at vertical crossing with a road. '

(9) The crossover portion of the railways has to be so designed as not to invade the construction limit illustrated in Fig. 1-5.

(10) The design load will be computed on the basis of the Japanese design standards.

(11) The earthquake force is not taken into consideration.

(12) The wind load in form of wind velocity against the side of the bridge is 150 km/hr.

(13) The river current force is 10 km/hr.

(14) The impact load against the pier should correspond to the static load equal to 100 tons at MSL, but for the Bangkok-Noi bridge, the impact load should be 30 tons.

(15) The range of temperature change is considered to be ±5°C.

(16) The roadway is to be paved with asphalt concrete, while the sidewalk with cement concrete.

(17) The illuminasion facilities shall be installed at bridges. The standard luminosity will be over 10 lux.

(18) The design of structures is to be according to the standards of specifications of A.A.S.H.O., A.C.I. and/or Japan.

(19) Two pylons are installed at both ends of the main Bangkok-Thonburi bridge, and the sidewalks shall be connected to the ground through the stairs equipped around the pylons.

The pylon is reinforced concrete with a size of 4. 00 x 6. 00 m and a height of approximately 20. 00 m. A thin sheet of marble is needed for decoration in some parts. Name of the bridge must be fixed at the base. Luminous light is also needed at the pylon. Architectural details will be supplied by Thai Government.

(20) The portion where the clearance below the girders becomes less than 2 m may be the embankment.

(21) The water supply conduit having a diameter of 0. 5 m together with power and telephone cables are expected to be installed with the main

Bangkok-Thonburi bridge.

(22) Showing the plan how to guide the traffic flow at the approach terminal of Bangkok side, the planning of traffic and parking in front of the National Theater must be established.

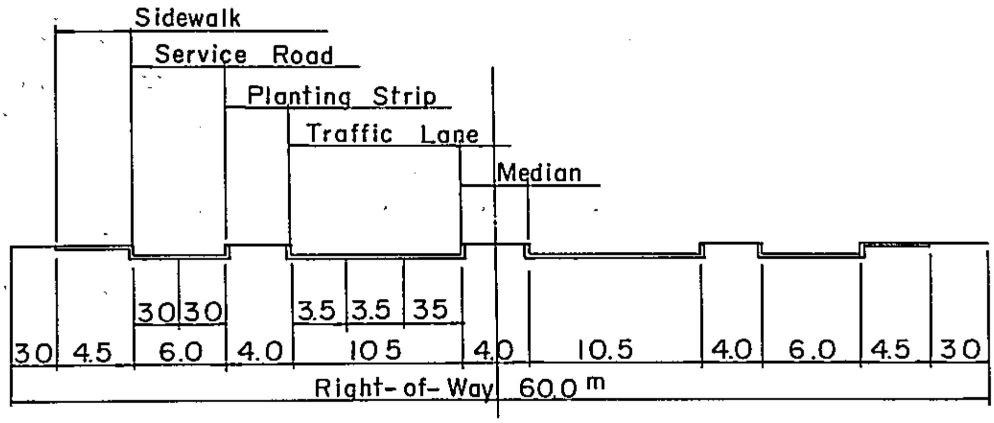


Fig. 1-1

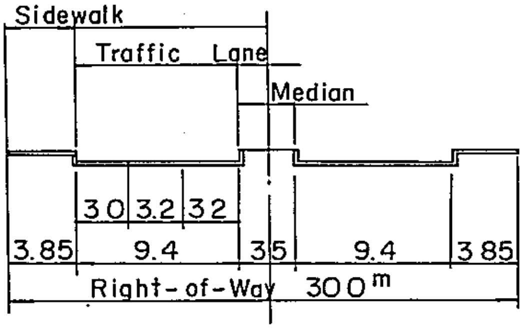


Fig. 1-2

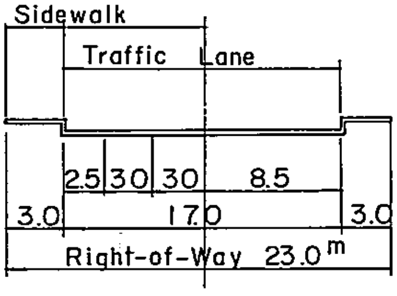


Fig. 1-3

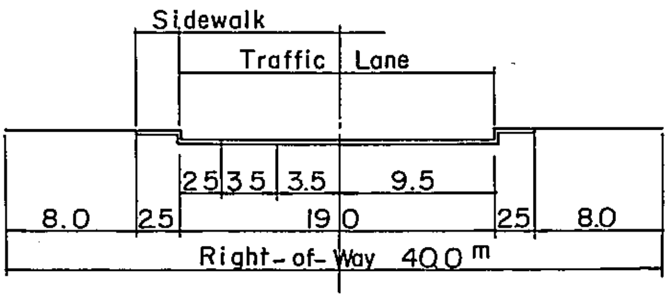
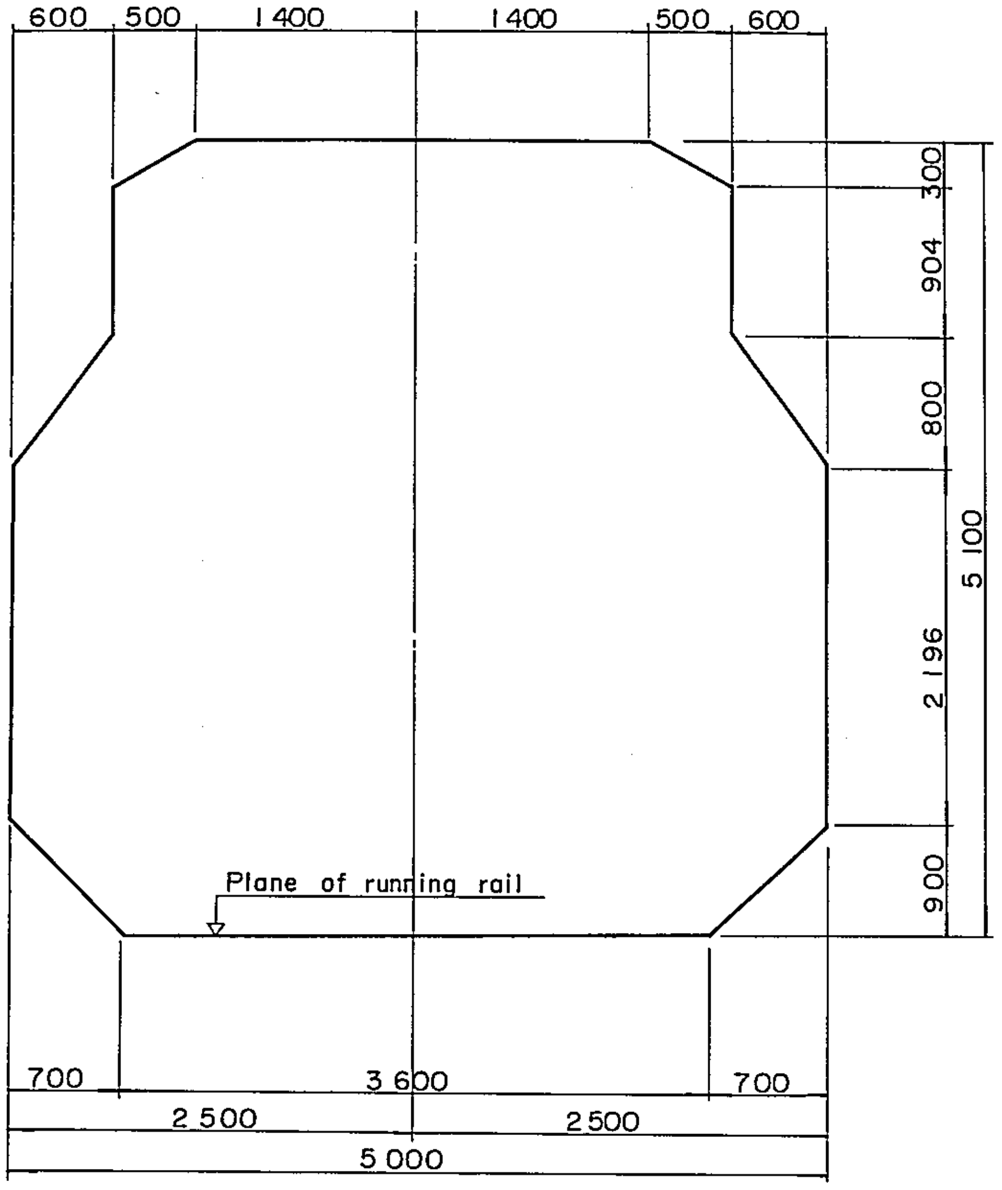


Fig. 1-4



unit: mm

Fig. I -5 CLEARANCE DIAGRAM FOR ROAD BRIDGE OVERHEAD CROSSING

Section 2. Technical Investigation

(1) Soil Exploration

With respect to the proposed site of the Bangkok-Thonburi bridge, boring on hole Nos. 1, 2, 3, 4 and 7 of total five holes was advanced to the maximum depth of 50 m. For the proposed site of Bangkok Noi bridge, boring No. 5 and No. 6 were drilled at the proposed sites of abutments of both sides. The locations of those holes drilled are illustrated in Fig. 2-1.

By the standard penetration test for every meter of depth, the distribution of soil layers and the relative density or consistency of each layer was studied. The shear strength of the soft clay type soil in relatively shallow depth was measured by vane shear test. The shear strength and deformation characteristics of the clay type or sandy deposits were measured by pressure meter test.

Undisturbed samples of clay type soil were taken out of drilled holes Nos. 4, 5 and 7 by means of thin wall tube sampler or Denison sampler. For those twenty samples, unconfined compression test and consolidation test as well as test for index properties of soil such as density, water content or Atterberg limits were carried out.

The results of laboratory soil tests are summarized in Table 2-1. Connecting the boring logs, the distributions of soil layers at the sites of the Bangkok-Thonburi and Bangkok-Noi bridges are shown in Fig. 2-2 and Fig. 2-3, respectively. A detailed discussion on the results of soil exploration will be separately reported together with the detailed design of this project.

(2) Topographic Survey

The Japanese team has carried out a cross-sectional distance survey along the proposed center line of the Bangkok-Thonburi bridge and the sounding survey crossing the Chao Phya River. The Japanese team has also completed the survey of two hundredth (1/200) scale in the vicinity of Bangkok-Noi station along the proposed center line of the Bangkok-Noi bridge. A land Survey of the left bank of the Khlong Bangkok Noi and Thonburi side of the Chao Phya River shall be undertaken by Thai Government.

Table 2-1. Summary of Soil Test (1)

(Bore Hole No. 4 & 5)

Sample No.		S4-1	S4-2	S4-3	S4-4	S4-5	S4-6	S5-1	S5-2	S5-3	S5-4
U: Undisturbed Sample D: Disturbed Sample		U	U	U	U	U	U	U	U	U	U
Sample Depth (m)		4.00- 4.60	5.50- 6.30	9.20- 10.00	14.00- 14.80	18.00- 18.60	38.50- 39.10	5.00- 5.70	7.00- 7.70	9.00- 9.70	11.00 11.80
Natural Water Content : Wc (%)		69.7	60.0	53.4	46.8	33.1	23.5	72.5	71.6	68.3	77.0
Specific Gravity of Soil Particles · GS		2.649	2.599	2.671	2.612	2.676	2.679	2.670	2.689	2.612	2.615
Wet Density : rt (t/m^3)		1.587	1.672	1.641	1.736	1.924	2.003	1.587	1.612	1.572	1.566
Dry Density : rd (t/m^3)		0.935	1.043	1.070	1.183	1.444	1.645	0.920	0.940	0.935	0.890
Natural Void Ratio : e		1.83	1.49	1.50	1.21	0.85	0.63	1.90	1.86	1.80	1.94
Degree of Saturation : S (%)		100	100	95.0	100	100	100	100	100	99.1	100
Liquid Limit : L. L. (%)		63	46	68	51	59	56	82	60	69	71
Plastic Limit : P. L. (%)		27	21	27	23	19	19	29	23	27	32
Plasticity Index : P.I.		36	25	41	28	40	37	53	37	42	39
Grain Size Analysis	Gravel (%)	0	0	0	0	0	0	0	0	0	0
	Sand (%)	1	32	2	14	2	32	12	4	9	4
	Silt (%)	41	34	44	39	48	41	41	46	47	34
	Clay (%)	22	14	22	20	13	8	17	16	18	20
	Colloid (%)	36	20	32	27	37	19	30	34	26	42
	Percentage (%) No. 200 Sieve	99	68	98	86	98	68	88	96	91	96
Classification		CH	CL	CH	CH	CH	CH	CH	CH	CH	CH
Unconfined Compression Test	Unconfined Compression Strength of Undisturbed Sample (kg/cm^2)	0.094	0.201	0.277	0.426	0.674	0.144- 1.520	0.411	0.400	0.319	0.312
	Unconfined Compression Strength of Remolded Sample (kg/cm^2)			0.0476	0.0420	0.482	0.647				
	Sensitivity Ratio			5.82	10.14	1.40	2.35				
Consolidation Test	Pre-Load (kg/cm^2)			0.61	0.99	2.18	3.90			0.96	1.00
	Compression Index (Cc)			0.447	0.395	0.250	0.219			0.830	0.890

Table 2-1 Summary of Soil Test (2)

Sample No.		S7-1	S7-2	S7-3	S7-4	S7-5	S7-6	S7-7	S7-8	S7-9	S7-10
U: Undisturbed Sample D: Disturbed Sample		U	U	U	U	U	U	U	U	U	U
Sample Depth (m)		7.50- 8.30	9.00- 9.80	10.00- 10.75	11.00- 11.75	14.00- 14.80	15.00- 15.80	17.00- 17.75	19.00- 19.65	21.00- 21.80	24.00 24.70
Natural Water Content: Wc (%)		81.2	64.2	70.2	69.3	32.0	34.7	38.4	30.4	24.4	28.1
Specific Gravity of Soil Particles : GS		2.621	2.651	2.616	2.688	2.655	2.692	2.623	2.647	2.683	2.623
Wet Density : rt (t/m^3)		1.525	1.571	1.596	1.594	1.949	1.906	1.848	1.921	2.011	1.993
Dry Density : rd (t/m^3)		0.838	0.957	0.938	0.942	1.477	1.414	1.334	1.472	1.615	1.560
Natural Void Ratio : e		2.13	1.72	1.79	1.86	0.80	0.90	0.97	0.80	0.66	0.68
Degree of Saturation : S (%)		100	99.0	100	100	100	100	100	100	99.3	100
Liquid Limit : L. L. (%)		87	70	78	81	60	65	80	40	56	41
Plastic Limit · P. L. (%)		26	25	28	26	20	25	36	17	22	17
Plasticity Index : P.I.		61	45	50	55	40	40	44	23	34	24
Grain Size Analysis	Gravel (%)	0	0	0	0	0	0	0	0	0	0
	Sand (%)	6	5	4	2	3	4	1	45	2	14
	Silt (%)	26	31	30	27	36	37	26	25	40	40
	Clay (%)	23	26	19	22	15	17	21	8	15	7
	Colloid (%)	45	38	47	49	46	42	52	22	43	39
	Percentage (%) No. 200 Sieve	94	95	96	98	97	96	99	55	98	86
Classification		CH	CH	CH	CH	CH	CH	CH	CL	CH	CL
Unconfined Compression Test	Unconfined Compression Strength of Undisturbed Sample (kg/cm^2)	0.264	0.464	0.733	0.352	0.851	0.424- 0.701	0.567	0.430	1.301	1.186
	Unconfined Compression Strength of Remolded Sample (kg/cm^2)					0.540	0.295	0.302	0.279	0.832	0.401
	Sensitivity Ratio					1.58	1.44- 2.38	1.88	1.54	1.57	2.96
Consolidation Test	Pre-Load (kg/cm^2)			1.18	0.74	1.95	1.60			3.10	4.90
	Compression Index (Cc)			0.960	0.820	0.190	0.168			0.166	0.217

Fig2-1 PLAN OF BORING SITE

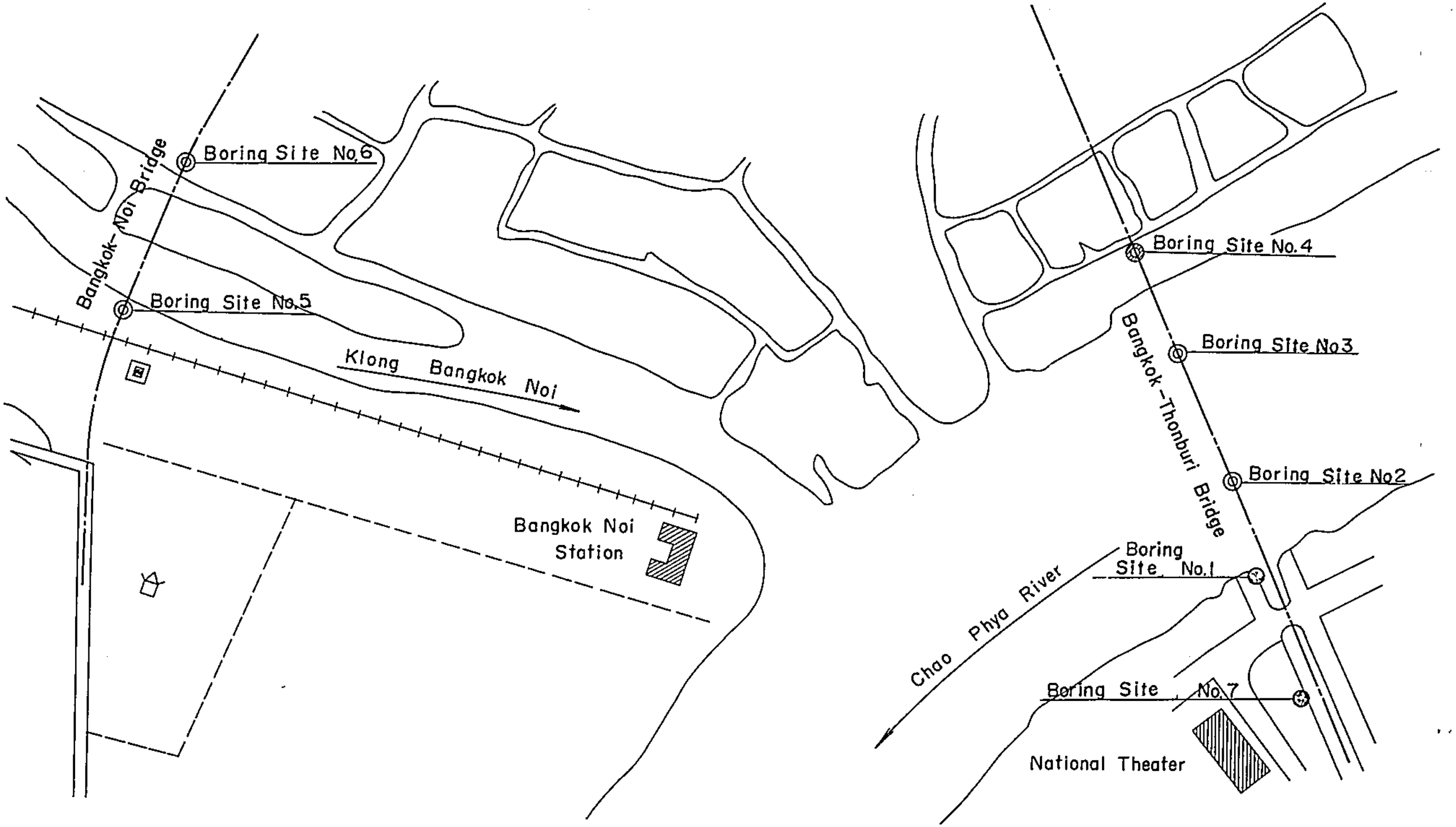


Fig-2-2 SOIL PROFILE OF BANGKOK-THONBURI BRIDGE

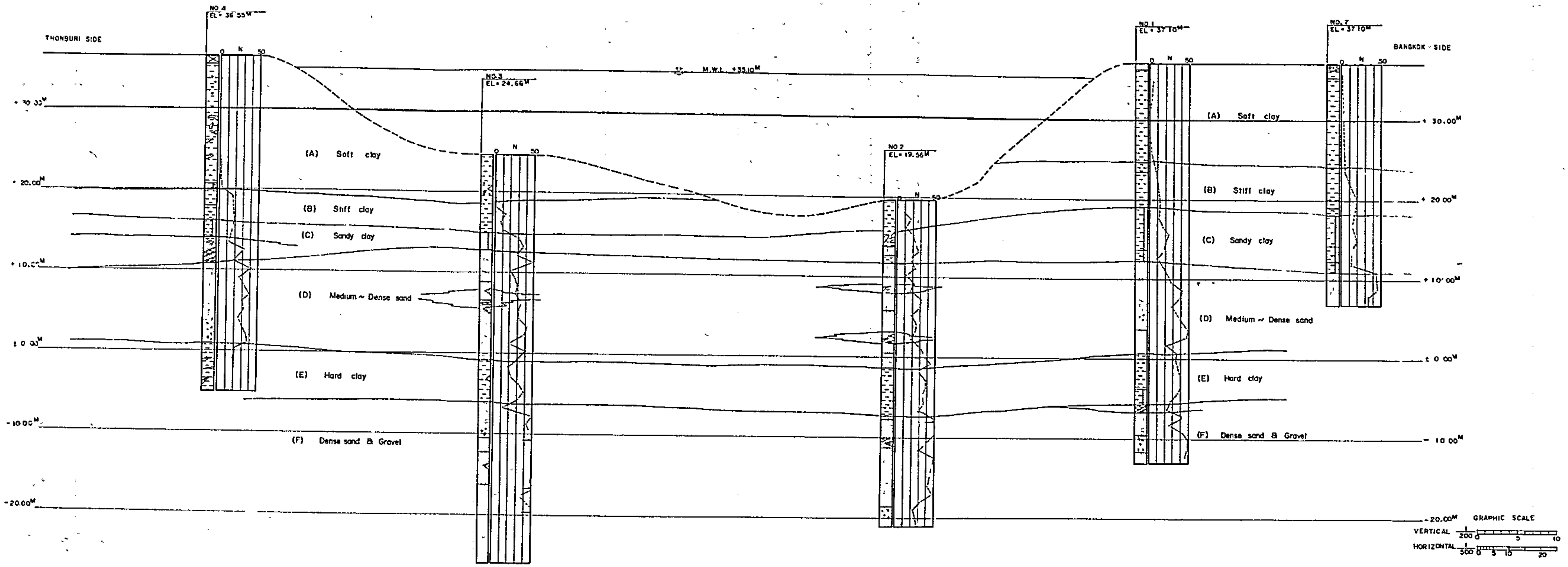
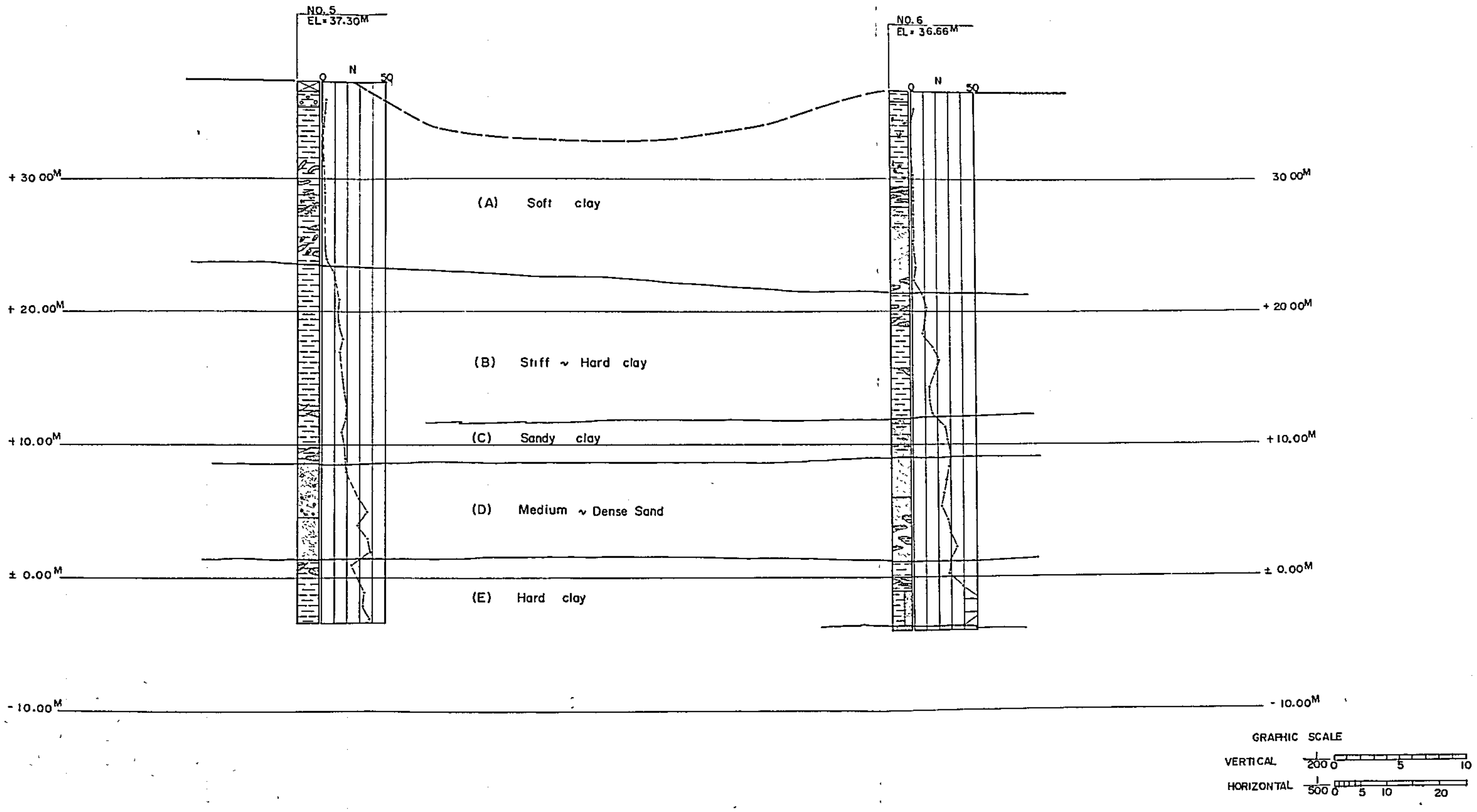


Fig-2-3 SOIL PROFILE OF BANGKOK-NOI BRIDGE



Section 3. Principles of Design and Planning

The general view of the project is shown on Fig. 3-1. According to the construction standards and results of the technical investigation, the principles of the design and planning have been undertaken as follows:

(1) Bangkok-Thonburi bridge

(A) Main Bridge (Fig. 3-2)

(a) A length of 280 m from an abutment to the other is recommended for the main bridge, because it was known from a survey across the Chao Phya River that the width of the water surface was about 265 m.

(b) Since a main span length greater than 60m is required for the navigation in the Chao Phya River, a comparative design study will be made to determine whether the number of spans to be recommended shall be three or five.

(c) Among the various types of prestressed concrete bridges, 3 or 5 span continuous bridge utilizing the Dywidag Method is considered recommendable from the following viewpoints.

The span length is greater than 60 m. The depth of water at the proposed erection site being more than 12 m, temporary support work during construction is difficult. The construction work should not seriously interrupt navigation. By the Dywidag Method, form work, settling of steel and concrete, and prestressing work can be made on a movable working platform called "Vorbauwagen" placed on the bridge girder as a scaffold. The girder starting its construction from the part above a bridge pier is extended in both directions symmetrically similar to cantilever beams. Therefore this method does not need support work or scaffolding which may interrupt navigation during construction.

In the case of either a 3 or 5 span bridge, there shall be provided in the center of each span a hinge that restrains vertical movement but instead permits horizontal movement. This method will result in a considerable cost saving over a continuous bridge of conventional design.

(d) With respect to the sub-structure, among various types of foundation, on the basis of soil properties obtained from the exploration described in Section 2, steel pipe piles, prestressed or reinforced concrete piles and pneumatic caissons are selected and subjected to our comparative design study. The open caisson or well is not recommended because the open caisson having required size is not likely to be sunk to a required depth, probably more than 20 m with required accuracy in its precisely correct location.

The cast-in-place concrete pile is not recommended, too, because the load on each pier will be 5, 000 to 10, 000 tons and a large number of piles have to be used to obtain adequate bearing strength, considering a soft and compressive clay observed and tested as described in Section 2. This will make the foundation area too large and uneconomical.

(e) For the intermediate piers, the foundations supported by steel pipe piles resting on dense sand and gravel of the layer F in Fig. 2-2 are recommended. The piles resting on the Layer D are worthwhile to considering, while the piles penetrated into layer F are not only more stable but even more economical since they can carry considerably higher axial load than the piles resting on the layer D.

For the end piers, however, the piles resting on the layer D are recommended because the sandy soil of the layer D is compacted enough as observed in the results of the standard penetration test at the location of the end piers and the load to the end piers is less than half the one to the intermediate piers, or safely supported by the piles resting on layer D without deterimental differential settlement with respect to the foundations of the intermediate piers. As shown in Fig. 3-2, the intermediate pier supported by steel piles has a considerably large footing always showing itself above water level, though it will not seriously disturb navigation.

(f) In case of pneumatic caissons, the method of sinking two caissons of circular cross-section parallel each other and the method of sinking a single caisson having rectangular cross-section are considered. The former type of foundation or circular caisson is to penetrate through hard clay presumably existing from EL. + 16. 10 to EL. + 7. 36 m and rest on the sand underlying the hard clay. However, after studying the results of boring carried out in the river bed, penumatic caissons are considered not recommendable, for sandy clay of the layer D is not stable because of the thickness of the layer in the river bed. The depth of the caisson having enough bearing capacity may exceed 30m. below the mean water level which gives maximum allowable atmospheric pressure to the laborers working at the bottom of caissons.

(g) The cost of construction for the main bridge of 3 and 5 spans has been roughly estimated together with the cost of comparative types of foundations. The cost of a 3 span is a little higher than that of a 5 span if it is compared with respect to the super-structure only, but the overall cost including foundations is almost equal for either a 3 span or 5 span. The 3 span bridge having better appearance and making navigation more convenient is therefore recommended.

(B) Bangkok Side Approach (Fig. 3-2 and Fig. 3-3)

(a) The Bangkok side approach is guided to the existing-roadway in the shortest possible distance by the maximum allowable gradient of 5 per cent in order not to damage the landscape of the National Theater and to make traffic control easy in connection with the related road.

(b) As the structures in this portion are going to be built on the canal, special attention was paid in design not to spoil the funcion of the canal. It was also intended to provided as wide a space as possible under the girder and use it as a parking area. For this purpose it was decided to replace existing canal structures with approach structures to be newly constructed and to span a slab bridge over the canal.

(c) For sub-structures in this portion, P.C. piles which have a square section of 35 cm long side and commonly used in Thailand were recommended. The super-structure was designed using a 3 span continuous bridge of R.C. hollow slab type having low girder height as the major part of it.

(d) In order to control the traffic at the approach bridge and the related roads, the traffic as far as the Royal Hotel crossing must be considered together. In other words, the road in front of the National Theater, the roads facing the Department of Medical Science, the road in the eastern side of the National Theater and a loop way around the

Plaza of elliptical shape have been made for oneway traffic. As a result of this oneway control, vehicles out of Chakrapong Road can not proceed to the Bangkok-Thonburi bridge directly as a U-turn in front of the Royal Hotel crossing is prohibited. Then, vehicles have to proceed to the approach bridge after going around the Plaza. However, the detour of a few minutes is considered inevitable in order to increase the overall traffic capacity of this area. The route on the left side of a creek was made four lanes for making the traffic from Thonburi side to Bangkok flow more smoothly. For this purpose, one lane has to be expanded on the creek as a slab bridge. Then, an additional bridge crossing the creek is required for both traffic from Thonburi to National Theater and that from the south through Chakrapong Road. (See Fig.3-3)

(e) The parking area which can accomodate 63 vehicles is provided in the space under the girder. The traffic to the parking area is separated from street traffic by a green belt, which will contribute to the landscape by planting trees.

(C) Thonburi Side Approach (Fig. 3-2)

(a) Thonburi side approach having no structural restriction was designed using the same type of structures as that of the Bangkok side approach, which is a 3 span continuous R.C. hollow slab bridge.

(b) It was planned to utilize the right-of-way of 100 m in width as a small bridge side park with parking for 80 vehicles.

(c) The road entering this portion from the approach bridge was designed so that it may be separated from main roadway through a horizontal transition in order to let vehicles acceralate or decceralate safely, since a pre-cast was used for both sides of the road.

(2) Bangkok-Noi Bridge (Fig. 3-4)

(a) Bangkok-Noi bridge crosses over Bangkok Noi station yard and the Khlong Bangkok Noi. At the station yard, a clearance of 5.10 m being required, the formation of the bridge was decided on the basis of this requirement.

(b) The interval between columns was decided as 30 m in accordance with the interval between rails. Then the structure of the bridge was designed by placing 11 T-beams of the post-tension type parallel to each other.

(c) According to the results of the soil exploration, prestressed concrete piles are recommended for the foundation.

(d) The approach having a gradient of 5 per cent was designed by simple T-beams of pre-stressed concrete having a length of 20m.

(e) The ramp shall be provided with two left and right branch roads in an outward direction of the bridge to facilitate traffic to and from the Bangkok Noi railway station. In compliance with a strong request by the Thailand National Railway Corporation, this ramp will be a rather long one having a 5 per cent longistudinal gradient at the straight portion and 3 per cent at the curved portion.

(3) Planning the Related Roads in Thonburi Area (Fig. 3-5 and Fig. 3-6)

(a) During the initial period of planning, two Thonburi inner circle lines which would intersect with the planned radial road connecting Bangkok-Thonburi bridge to Charan Sanit Wong Road were proposed by the Thailand Government.

(b) According to this plan, it was necessary to construct wto bridges at 500 m intervals over the Khlong Bangkok Noi. The plan had the disadvantage in that those two bridges had to cross Bangkok Noi station yard.

(c) The outside road of the inner line (Issara Phap Road) has already been widened up to the side of the yard, but in order to extend this road, a bridge of 760 m in length crossing both the station yard and the Khlong Bangkok Noi was required. Besides the distance from this road to the outer circle line (Charan Sanit Wong Road) is only 500 m, and it becomes shorter as the road continues to north. (See Fig. 3-5)

(d) The inside road of the inner line (Arun Amarin Road) is sufficient for a bridge with a span of 570 m for crossing the station yard and the Khlong Bangkok Noi. The distance from the outer ciycle line can be approx. 500 m. Therefore, this road is supposed to be more effective than the outside road with respect to the configuration of the main streets. Moreover the Department of Town Planning has already considered this road involved in the city planning. (See Fig. 3-6)

(e) From those above mentioned, we recommend that the Thonburi inner circle consist of Arun Amarin Road and its extension.

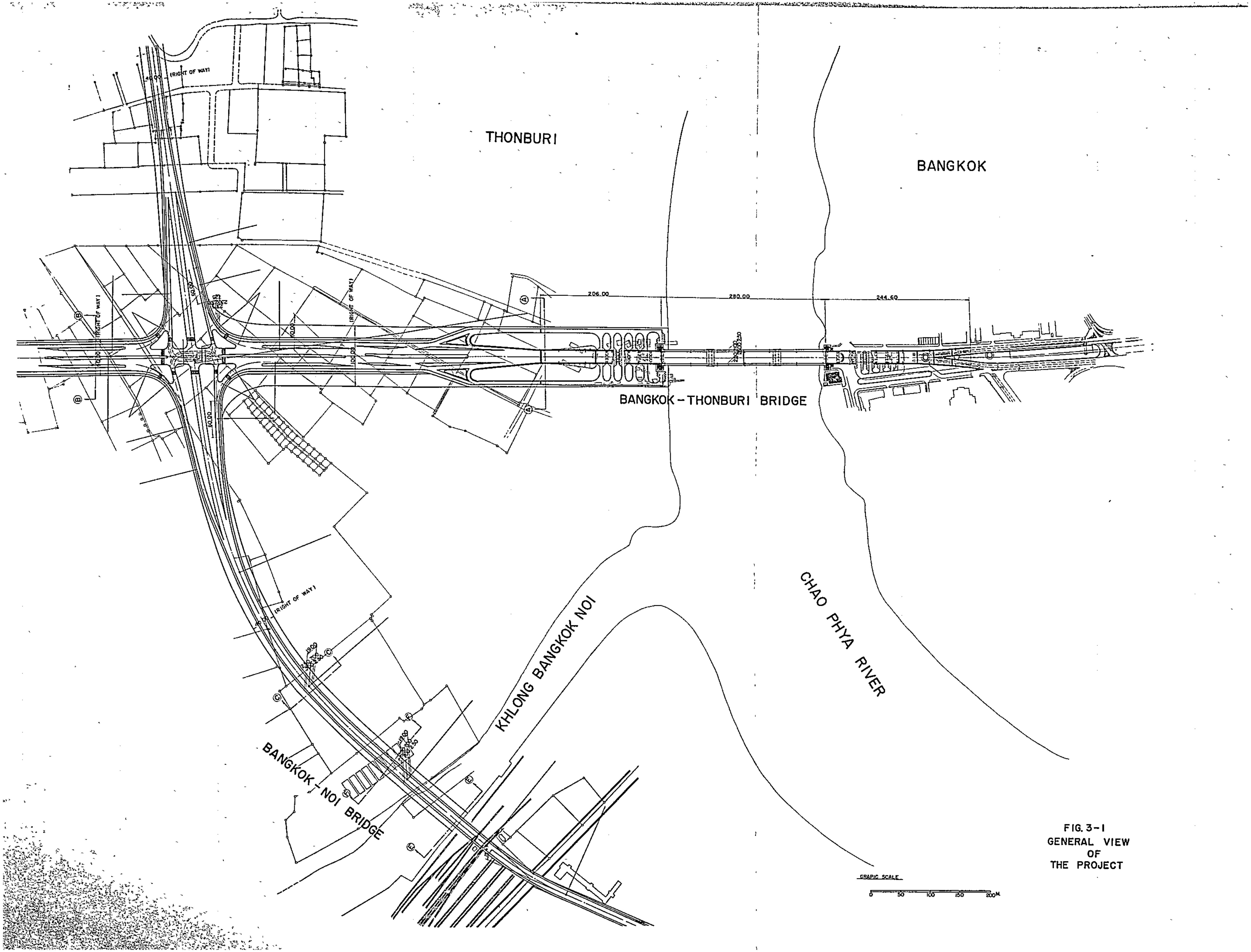
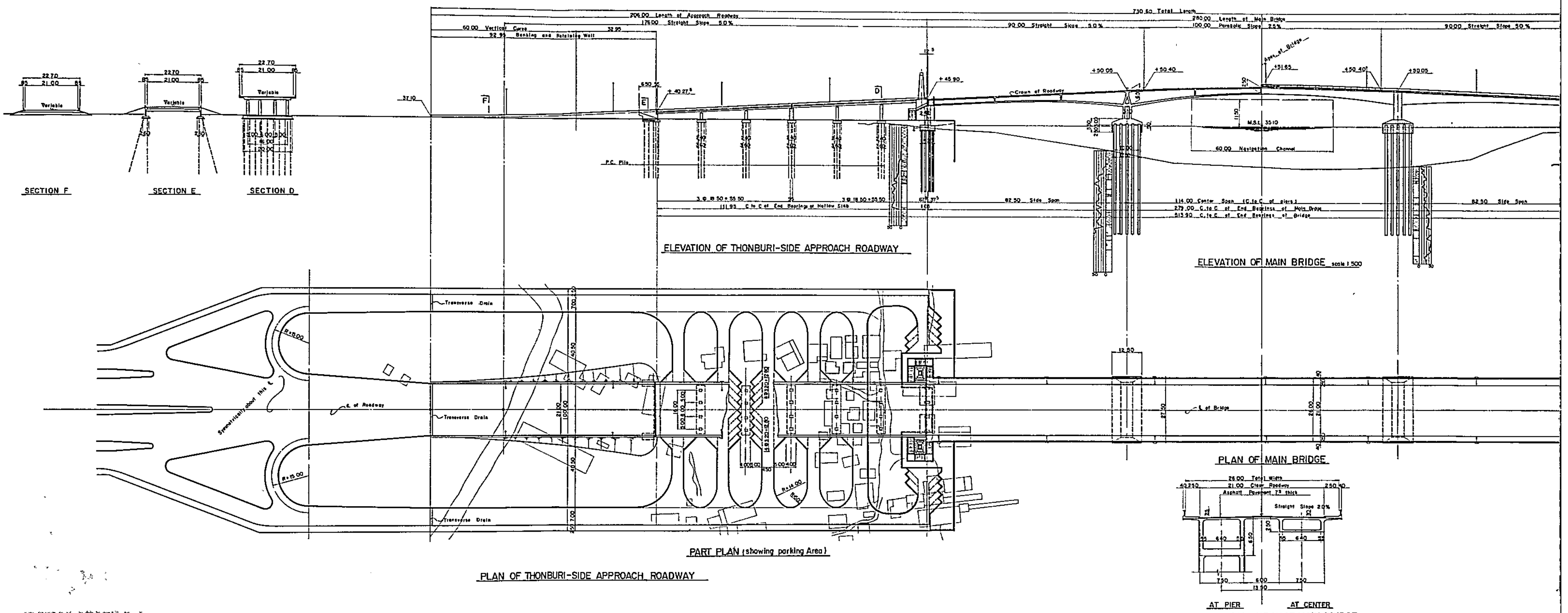


FIG. 3-1
GENERAL VIEW
OF
THE PROJECT



SECTION F

SECTION E

SECTION D

ELEVATION OF THONBURI-SIDE APPROACH ROADWAY

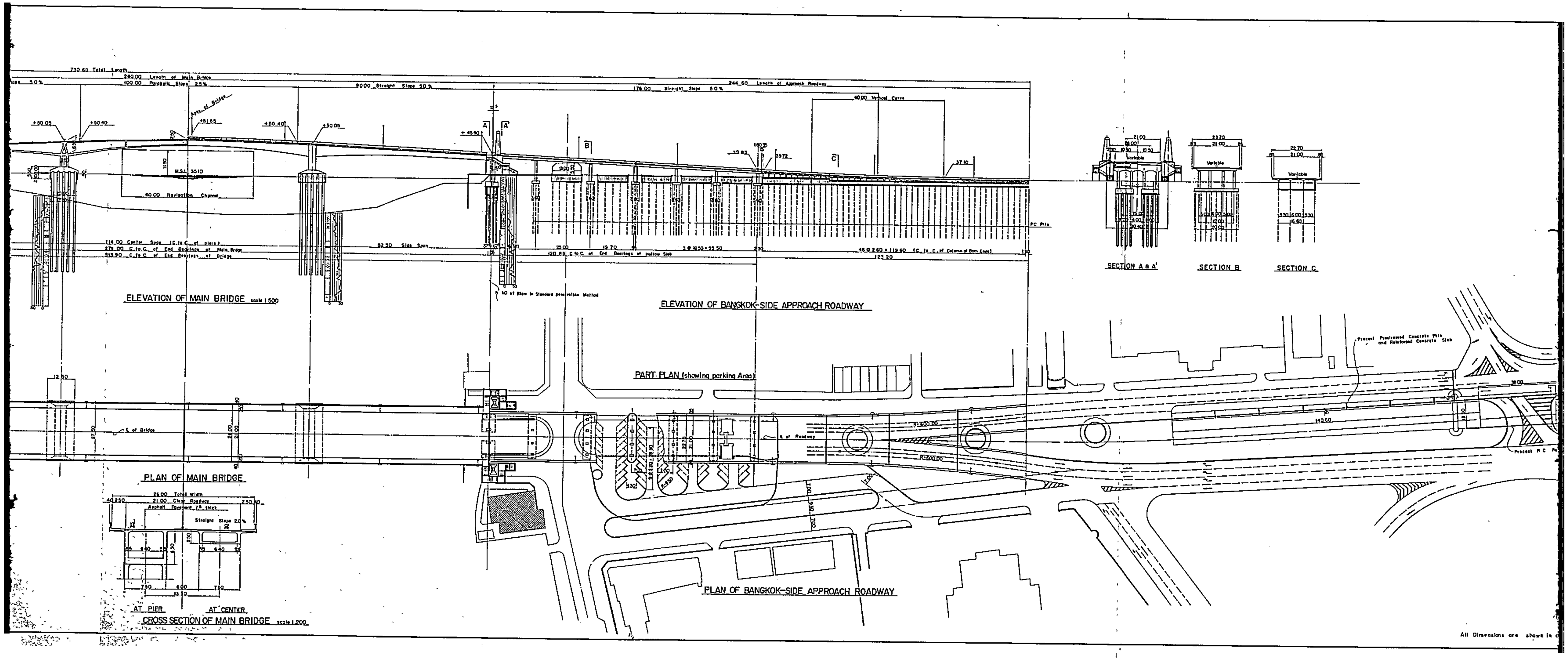
ELEVATION OF MAIN BRIDGE scale 1:500

PLAN OF MAIN BRIDGE

PART PLAN (showing parking Area)

PLAN OF THONBURI-SIDE APPROACH ROADWAY

CROSS SECTION OF MAIN BRIDGE scale 1:200


730.60 Total Length
280.00 Length of Main Bridge
Slope 5.0%
100.00 Parabolic Slope 2.5%
9000 Straight Slope 5.0 %
176.00 Straight Slope 5.0%
244.60 Length of Approach Roadway
60.00 Vertical Curve
Apex of Bridge
+50.05
+50.40
+51.85
+50.40
+50.05
+45.90
M.S.L. 35.10
60.00 Navigation Channel
114.00 Center Span (C. to C. of piers)
279.00 C. to C. of End Bearings of Main Bridge
513.90 C. to C. of End Bearings of Bridge
82.50 Side Span
120.85 C. to C. of End Bearings of Hollow Slab
25.00
19.70
3 @ 18.50 = 55.50
46 @ 2.60 = 119.60 (C. to C. of Column of Both Ends)
123.20
39.83
39.72
37.10
PC Pile
N NO of Blow in Standard penetration Method
ELEVATION OF MAIN BRIDGE scale 1:500
ELEVATION OF BANGKOK-SIDE APPROACH ROADWAY
A
A'
B
C
21.00
18.00
19.50
10.50
Variable
15.00
4.00
20.40
22.70
21.00
10.00
20.00
5.30
6.00
16.60
SECTION A & A'
SECTION B
SECTION C
PART PLAN (showing parking Area)
12.50
℄ of Bridge
26.00
21.00
℄ of Roadway
PLAN OF MAIN BRIDGE
26.00 Total Width
21.00 Clear Roadway
Asphalt Pavement 7.5 thick
Straight Slope 2.0%
40 2.50
2.50 40
6.40
6.50
7.50
6.00
13.50
AT PIER
AT CENTER
CROSS SECTION OF MAIN BRIDGE scale 1:200
Precast Prestressed Concrete Pile and Reinforced Concrete Slab
140.60
38.00
Precast R C
PLAN OF BANGKOK-SIDE APPROACH ROADWAY
All Dimensions are shown in c

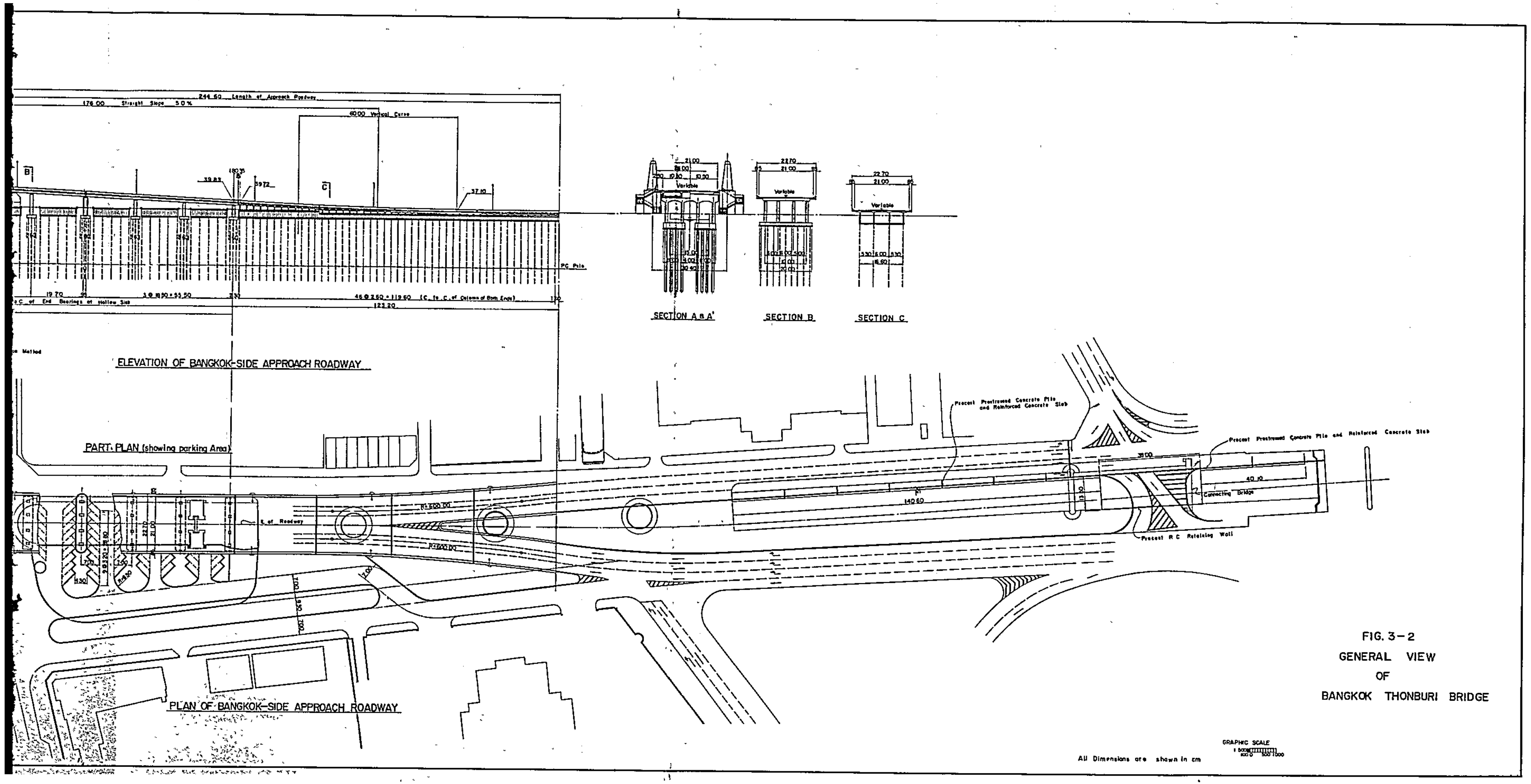
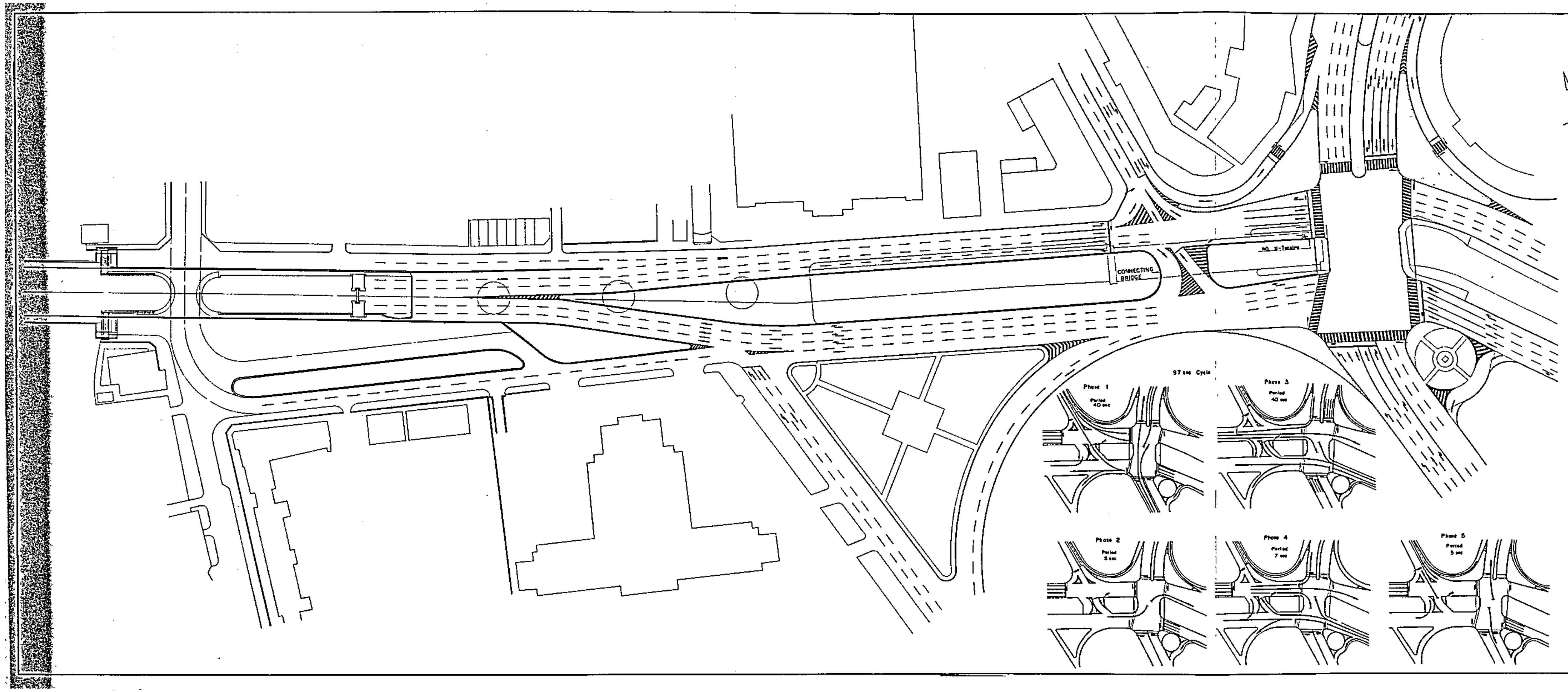


FIG. 3-2
GENERAL VIEW
OF
BANGKOK THONBURI BRIDGE



NOTE
1. THE NECESSARY CYCLE OF TRAFFIC SIGNAL SHALL BE REGULATED ACCORDING TO THE CONDITION OF TRAFFIC FLOW
2. THE MAXIMUM CYCLE SHALL BE LIMITTED WITHIN 150 SECONDS
3. THE EFFICIENCY OF THIS CROSSING WILL REACH ITS LIMIT WHEN THE TRAFFIC VOLUME OF THE BANGKOK-THONBURI BRIDGE GROW TO 60 000 VDV DAY

FIG 3-3
PROPOSED TRAFFIC FLOW
UPON THE COMPLETION
OF CONNECTING BRIDGE

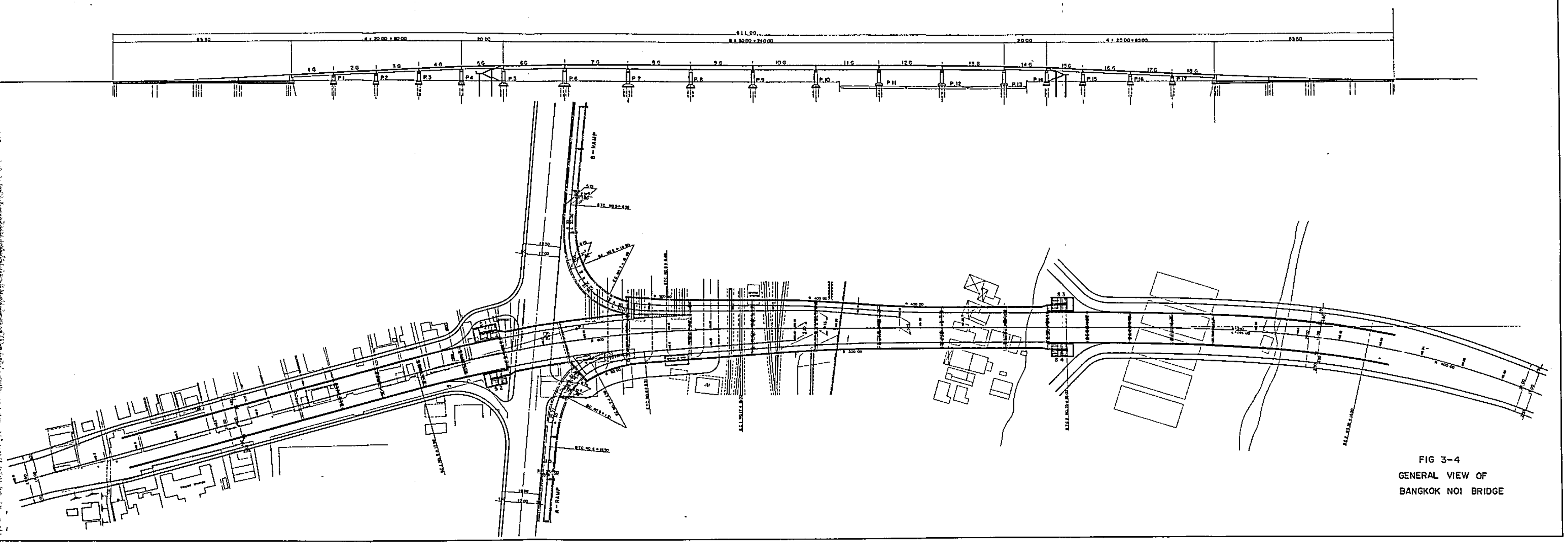


FIG 3-4
GENERAL VIEW OF
BANGKOK NOI BRIDGE

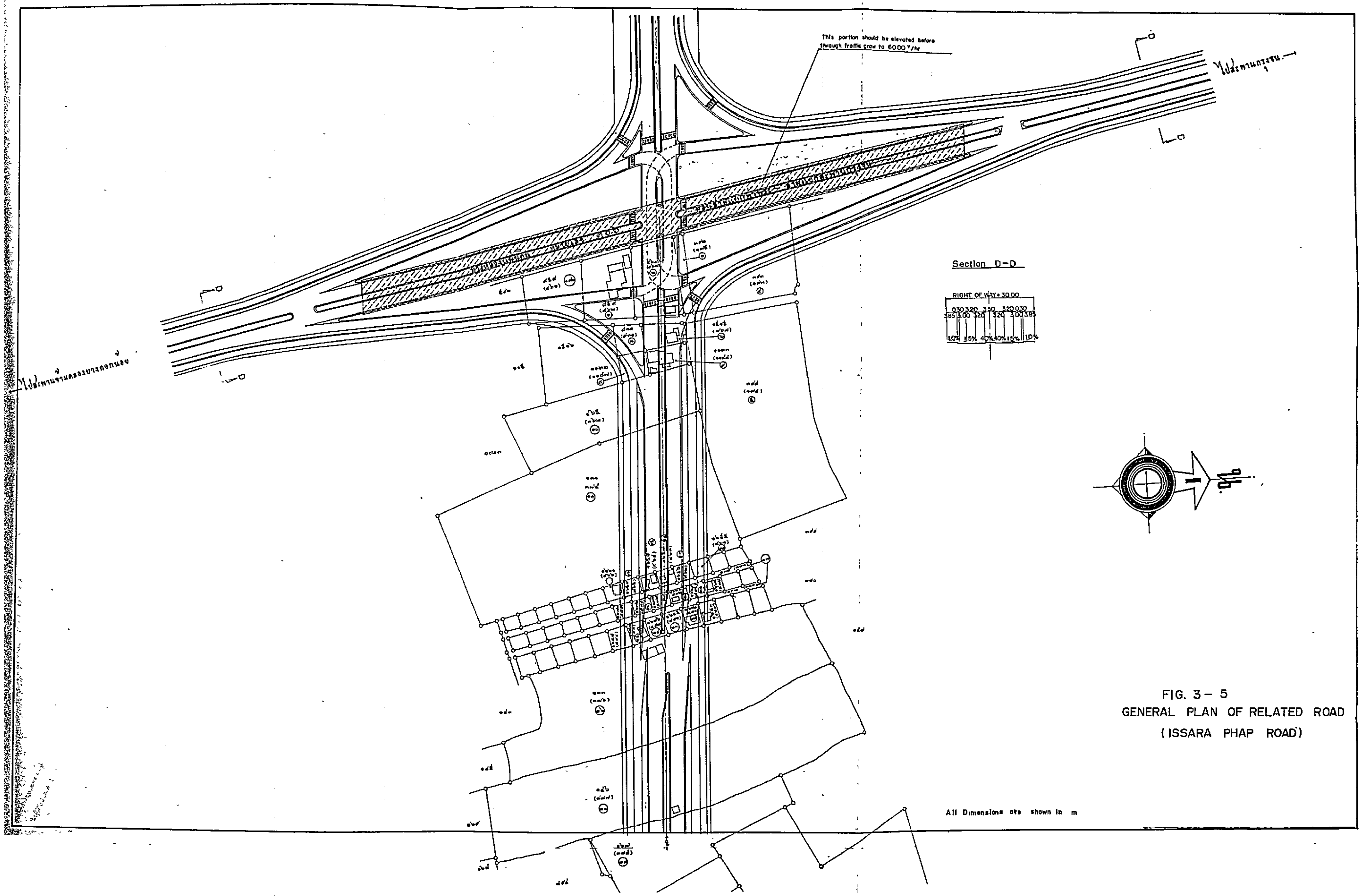


FIG. 3– 5
GENERAL PLAN OF RELATED ROAD
(ISSARA PHAP ROAD)

All Dimensions are shown in m

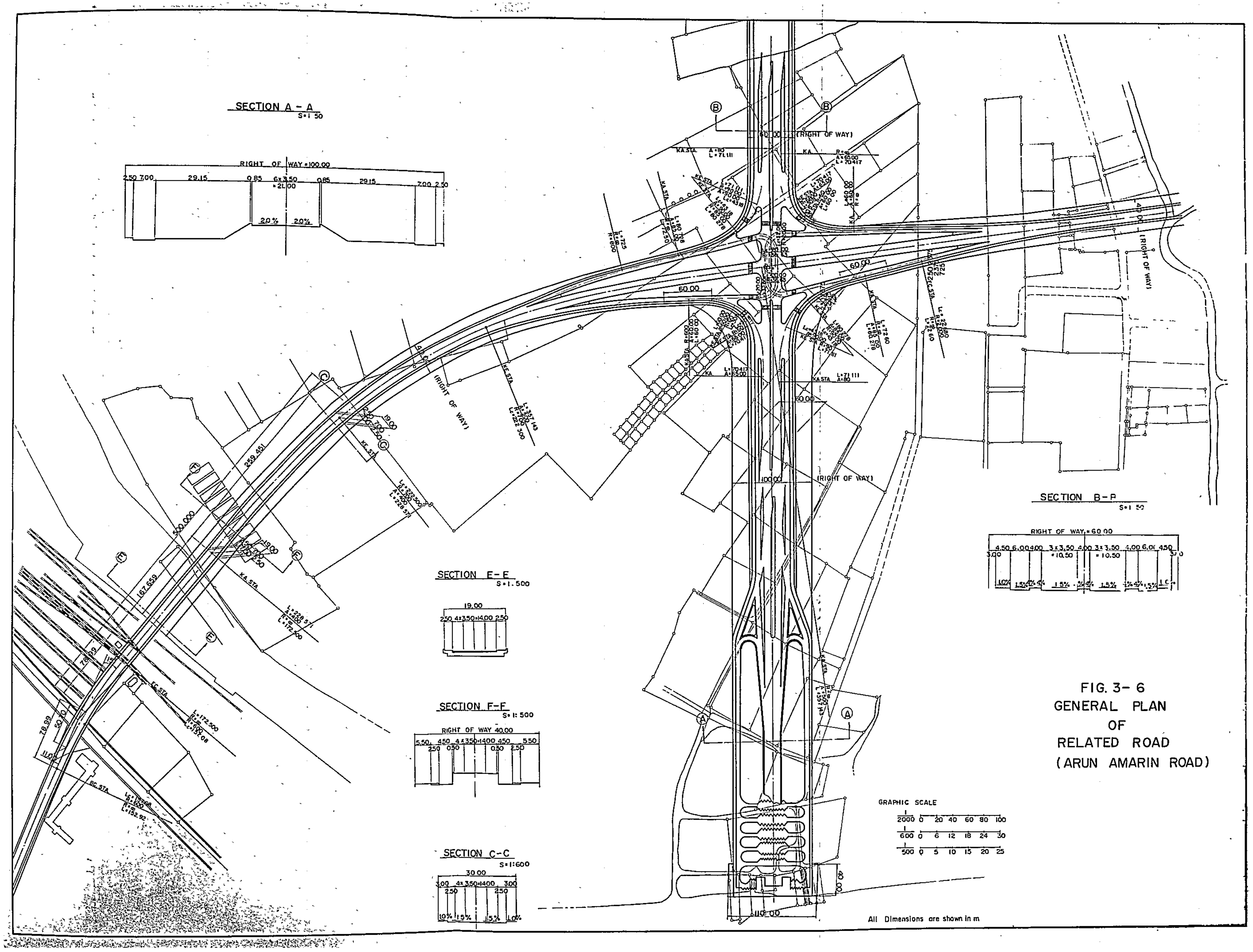


FIG. 3- 6
GENERAL PLAN
OF
RELATED ROAD
(ARUN AMARIN ROAD)

Section 4. Major Materials, Equipments and Construction Cost

The major construction materials and equipments are briefly discribed in Tables 4-1 and 4-2.

The cost of construction is roughly estimated in Table 4-3. Regarding taxes, duties and miscellaneous expenditures, more detailed study on them and correction to the estimated amount is considered necessary.

The term of investment is shown on Table 4-4.

Table 4-1. List of Major Construction Materials

Part		Bangkok-Thonburi Bridge								Bangkok-Noi Bridge		Total	
Unit		Main Span		Approach				Total					
				Bangkok Side		Thonburi Side							
Item		Imported	Local	Imported	Local	Imported	Local	Imported	Local	Imported	Local	Imported	Local
Steel Pipe	t	1,850						1,850				1,850	
Reinforcement	t	670		940		340		1,950		560		2,510	
P C Steel	t	650						650		120		770	
Concrete	m^3		11,300		5,900		2,600		19,800		8,600		28,400
Cement	t		4,500		2,100		900		7,500		3,400		10,900
Concrete Pile	each				650		200		850		1,100		1,950

Table 4-2. List of Major Construction Equipments

	Bangkok-Thonburi Bridge								Bangkok - Noi Bridge		Total	
	Main Span		Approach				Total					
			Bangkok Side		Thonburi Side							
	Imported	Local	Imported	Local	Imported	Local	Imported	Local	Imported	Local	Imported	Local
Batcher Plant (Set)	1		1				2		2		4	
Asphalt Plant (Set)					1		1				1	
Soil Plant (Set)						1		1		1		2
Bulldozer (Vehicle)				1		1		2		1		3
Heavy Compresser (Set)	2						2		2		4	
Pile Driving Hammer (Set)	1						1				1	
Cable Crane (Vehicle)	1						1				1	
Finisher (Vehicle)						1		1		1		2
Truck Crane (Vehicle)		1		1		1		3		1		4
Shovel (Vehicle)				1		1		2		1		3
Tractor Shovel (Vehicle)				1		2		3		2		5
Moter Grader (Set)				1				1		1		2
Wagon (Set)	4						4				4	
P.C. Equipment (Set)	1						1				1	

Table 4-3. Estimate of Construction Cost

Unit ,1,000 Bahts

Item	Part	Bangkok-Thonburi Bridge								Bangkok-Noi Bridge		Total		
		Main Span		Approach				Total						
				Bangkok Side		Thonburi Side								
		F.C.	L.C.	F.C.	L.C.	F.C	L.C.	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	Total
Major Construction Materials	Steel Pipe	8,540						8,540				8,540		8,540
	Reinforcement	1,820		2,560		930		5,310		1,530		6,840		6,840
	P.C Steel	6,720						6,720		1,240		7,960		7,960
	Cement		2,250		1,050		450		3,750		1,700		5,450	5,450
	Concrete Pile				1,890		550		2,440		3,030		5,470	5,470
Others	Labour, Other Materials, Temporary Works and Import Tax	5,380	22,770		9,830		9,540	5,380	42,140	3,230	13,020	8,610	55,160	63,770
	Major Construction Equipments	9,820	3,110	1,140	2,740	520	1,930	11,480	7,780	1,600	4,350	13,080	12,130	25,210
Sub-Total		32,280	28,130	3,700	15,510	1,450	12,470	37,430	56,110	7,600	22,100	45,030	78,210	123,240
Site Expense, Overhead, Tax and Profit		8,730	6,400	3,000	1,840	1.950	1,530	13,680	9,770	4,300	3,140	17,980	12,910	30,890
Total Construction Cost		41,010	34,530	6,700	17,350	3,400	14,000	51,110	65,880	11,900	25,240			
		75,540		24,050		17,400		116,990		37,140		63,010	91,120	154,130

Note : F C. = Foreign Currency

L.C. = Local Currency

Except the above construction cost, it is considered necessary to provide 6,000,000 Bahts for the supervision cost, half of which is to be in Foreign Currency.

Table 4-4. Term of Investment

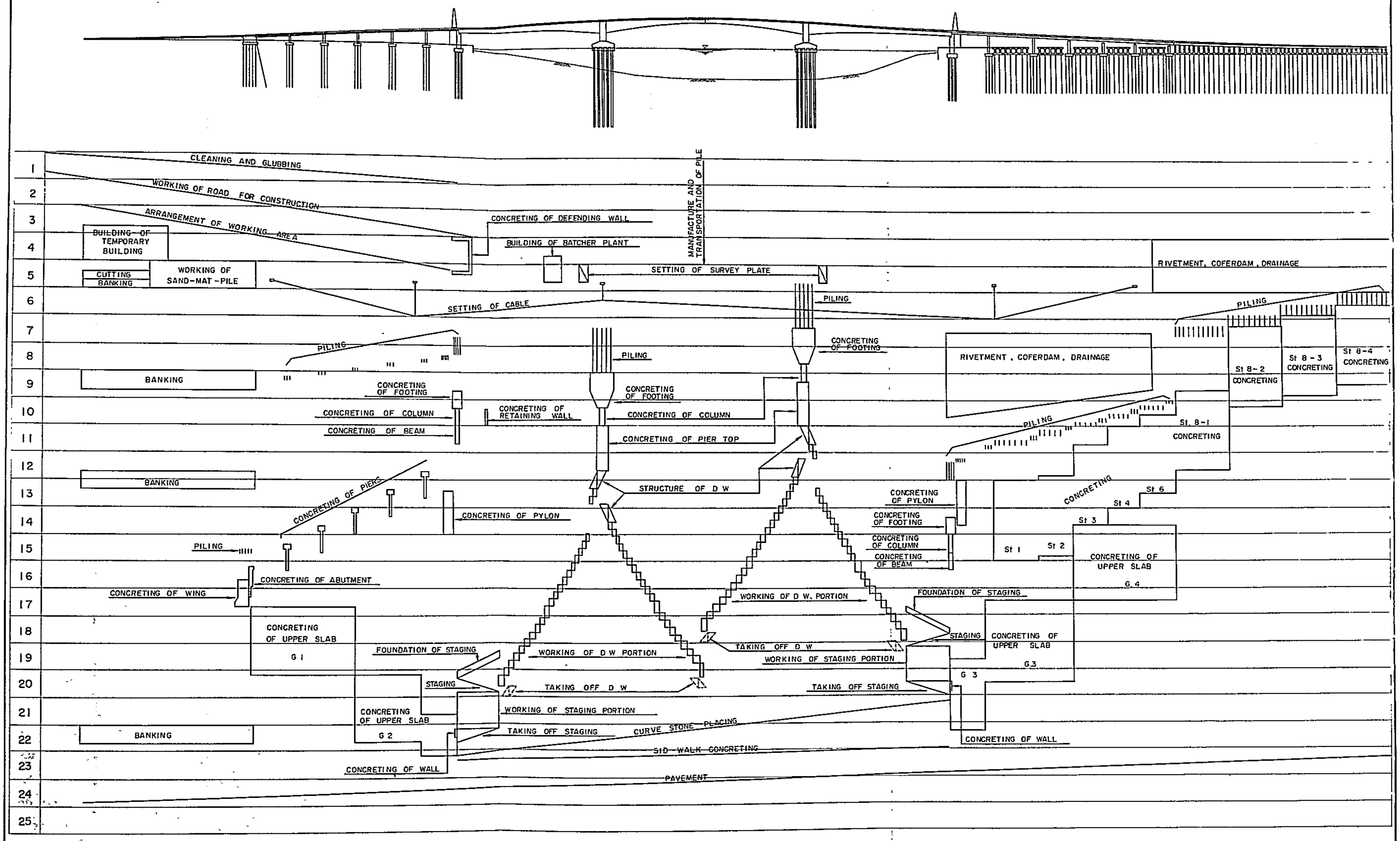
Year / Currency	1st	2nd	3rd	Total
Local	32,800	46,120	12,200	91,120
Foreign	52,100	10,910	-	63,010
Total	84,900	57,030	12,200	154,130

Note : The supervision costs of the government of Thailand are not included in this table.

Section 5. Construction Schedule

Regarding the period of construction, from beginning to completion, will take about two years and one month. Details of the work schedule of the Bangkok-Thonburi bridge is shown by an operation diagram in Fig. 5-1.

FIG. 5-1 WORK SCHEDULE OF THE BANGKOK-THONBURI BRIDGE



CHAPTER III

ECONOMIC ANALYSIS OF THE PROPOSED PROJECT

Section 1. Forecast of Traffic Between Bangkok and Thonburi

1.1. Method of Traffic Forecasting

In formulating a proper traffic plan, it is necessary to estimate first the anticipated trafic volume in a proper manner. Basic data such as OD tables (origin and destination tables), economic statistics and a road improvement plan are necessary for estimating properly the amount of future traffic, but they are completely insufficient at present. For this reason, traffic forecasting in this report has relied largely on our assumption. It will be desirable to make an accurate forecast after conducting a series of a proper traffic survey and making a traffic plan at an early date. We are obliged to forecast traffic with rather insufficient data under the following procedure.

An OD survey, which is performed to determine the movement of vehicular traffic, serves as an important basis to forcast the anticipated volume of traffic. In this survey, all the movements of normal daily vehicular traffic have been checked taking into consideration the type of vehicles, origin, destination, travel time, purpose of travel, load, etc.

However, since no vehicle OD survey has ever been conducted in Bangkok, we had no choice but to rely on the person trip survey on bus passengers conducted in 1965 by the Ministry of Transportation, Thailand, which seems the only available survey. This survey is rather incomplete for person trip survey, because the purpose of trip was limited only to daily commutation and persons surveyed for the most part were governmant office people. The data, therefore, was considered not reliable, but we had to consider the OD table as a vehicle OD distribution.

In order to convert this bus passenger OD table to a vehicle OD table, we have multiplied the bus passenger OD tables by the ratio of the number of vehicles crossing the Chao Phya River to the number of bus passengers crossing the Chao Phya River. In other words, a vehicle OD distribution is assumed to show substantially the same pattern as that in bus passenger OD table, and the volume of vehicular traffic crossing the Chao Phya River has been adjusted to correspond to actual traffic observations.

The future trips generated by each zone, which is necessary as part of the data to calculate the future vehicle OD table, has been estimated by multiplying the present trips generated by each zone obtained from the OD table by the rate of population increase in each zone.

For an accurate and proper forecast of trips generated by each zone, it is essential that a regression formula is obtained by adjusting the present trips generated by each zone derived from the OD survey to economic factors of each zone, such as population, number of workers, products and sales. Applied to the future values of economic factors anticipated from the city planning to this formula, the future trips generated by each zone can be forecast.

While it is necessary to know economic statistics of each zone and city planning, we have relied upon population data only, the most fundamental of the economic statistics, because we were not able to obtain other useful informations. The anticipated volume of the population has not been found from the city planning but from a simple presumption.

On the other hand, we have figured out the total trips of anticipated vehicular traffic in Bangkok and Thonburi by the number of trips per vehicle and anticipated vehicle registrations reported by Dr. Gun Nagamati, Deputy Director General, Department of Road Transportation, Ministry of Communications, Thailand. From the present vehicle OD table and the present total vehicle registrations, we have now calculated the number of trips per vehicle.

In order to properly forecast the volume of future vehicle traffic, we must accurately estimate the anticipated vehicle registrations. In this case, it is desirable to predict the future vehicle registrations by each vehicle type for the reason that both vehicle registrations and the trips vary with the type of vehicle.

The future traffic distribution has been predicted from the above anticipated trips generated by each zone and the total trips using the Entropy method.

It will be necessary to estimate traffic assignment by assigning the anticipated traffic throughout the road network. The road network in which traffic is to be assigned has been considered herein to consist of the existing roadways, the proposed Bangkok-Thonburi bridges and their access roads, for we know little or nothing of future road plan. It should be noted, however, that we have taken into consideration a probable increase in street width.

It will be appreciated that future road traffic cannot be forecast without considering a certain road network. In order to determine whether such a road plan is quite proper or not, it would be an idea to assign OD traffic to some conceivable road network, so that a reliable and accurate selection of a proper road network can be made.

Years predicted are 1975, a few years after the proposed bridges are scheduled to be constructed, and 1990, when the current Bangkok city planning is expected to be completed.

Traffic assignment for 1975 has been arranged for two cases - with and without incorporating the proposed Bangkok-Thonburi bridges and their access roads. This is for comparing the former with the latter, in order that the benefits expected from the proposed bridge can be estimated. This comparison is attempted in Section 2 "Benefit of the Project ".

Fig. 1. 1-1 is the flow diagram showing the method of estimating the anticipated traffic between Bangkok and Thonburi.

Most of the data necessary to forecast the anticipated traffic in such a manner as above have been compiled from other data or our assumptions.

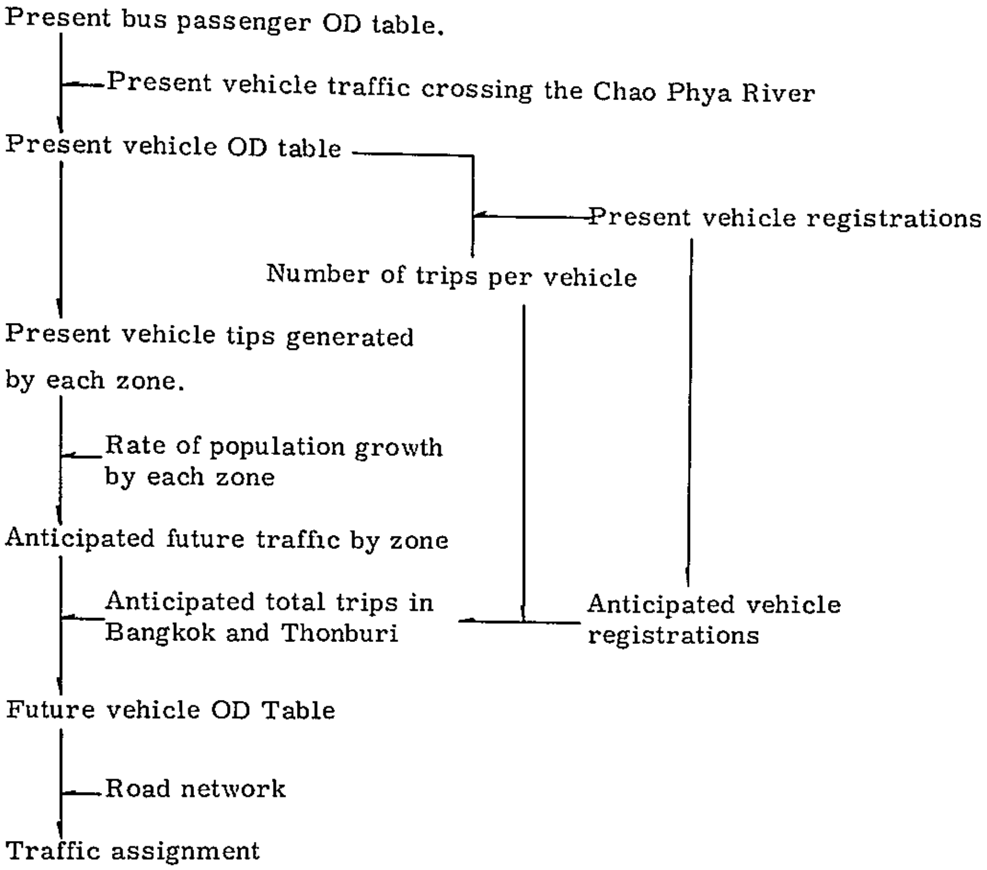
Various data necessary for traffic forecasting are herein given for your ready reference:

(1) Present vehicle OD table
(2) Present and future economic factors of each zone
(3) Future vehicle registrations by eacy type of vehicle
(4) Future road networks

In order to make results of forecast highly reliable and trustworthy, we feel it will be necessary to re-estimate anticipated traffic volume by performing a more extensive survey and having a new city planning laid out.

The results of traffic foreacasting are mentioned in this report. Another report "Traffic Forecast Between Bangkok and Thonburi in 1975 and 1990" deals with the details of the data and methods used.

Fig. 1.1-1 Flow Diagram for Traffic Forecast Between Bangkok and Thnburi.



1.2. Estimated Area and Zoning

Bangkok and Thonburi are two different cities, but they can be considered one and the same city, as they form the nucleus of the Metropolitan area. Therfore, the areas to be estimated herein are Bangkok and Thonburi.

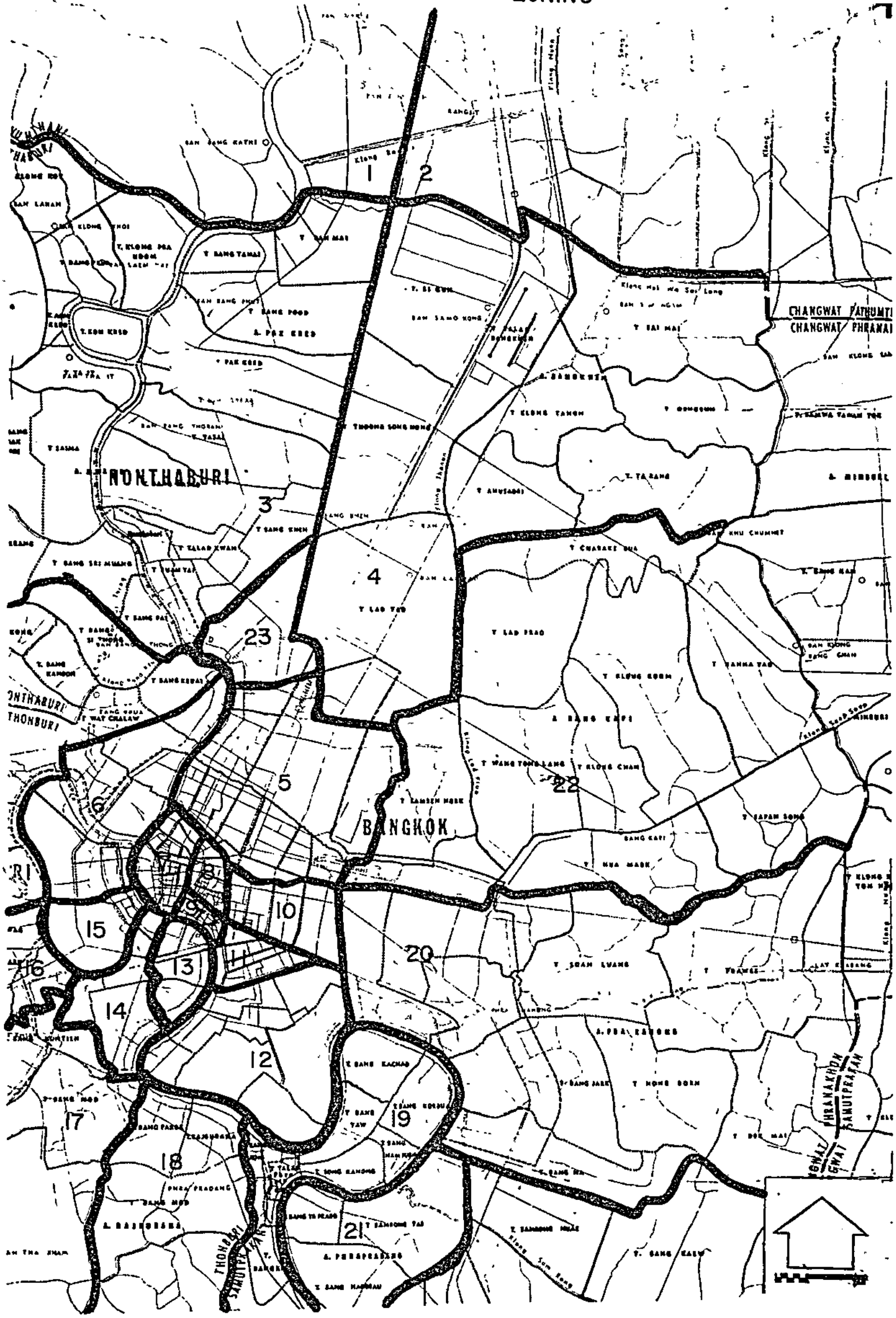
Considering the purpose of traffic forecasting and the possibility of obtaining economic statistics, the zoning has been arranged in unit of Amphur. Amphur Dusit, however, was divided into two areas - one that uses the Krung Thon Bridge and the other the Rama VI Bridge. These two zones have been designated as zone No. 5 and Zone No. 23.

Refer to Table 1.2-1 and Fig. 1.2-1 for further information on zoning.

Table 1.2-1 Zoning

Zone No.	Zone Name
1	Bang Tanai
2	Bang Mai
3	Pak Kred
4	Bang Khen
5	Dusit
6	Bangkok- Noi
7	Prana Korn
8	Ponprab
9	Sampantawong
10	Patumwan
11	Bangrak
12	Yanawa
13	Klongsarn
14	Thonburi
15	Bangkok-yai
16	Pharsicharoen
17	Bangkunthien
18	Rajburane
19	Prapradong
20	Prakanong
21	Samrong Nua
22	Bang Kapi
23	Bang Sue

FIG. 1.2-1 ZONING



1. 3. Forecast of Future Total Trips

As a preliminary to estimating the OD tables, it is necessary to predict the total future trips of vehicles in both Bangkok and Thonburi.

We have estimated the total future vehicle registrations in Bangkok and Thonburi from the mean rate of growth shown by the lines in Fig. 1. 3-1, based on the estimation made by Dr. Gun Magamati, Deputy Director General, Deportment of Road Toransportation, Ministry of Communications, Thailand. According to his estimation shown in Fig. 1. 3-1, the anticipated number of vehicle registrations will be 493×10^3 vehicles and 731×10^3 vehicles in 1975 and 1990 respectively.

As will be described in Section 1. 4, the trips of each vehicle are estimated to be 3. 92. Assuming this figure remains unchanged in the future, the total trips of vehicles in Bangkok and Thonburi may be calculated as followes :

Year 1975

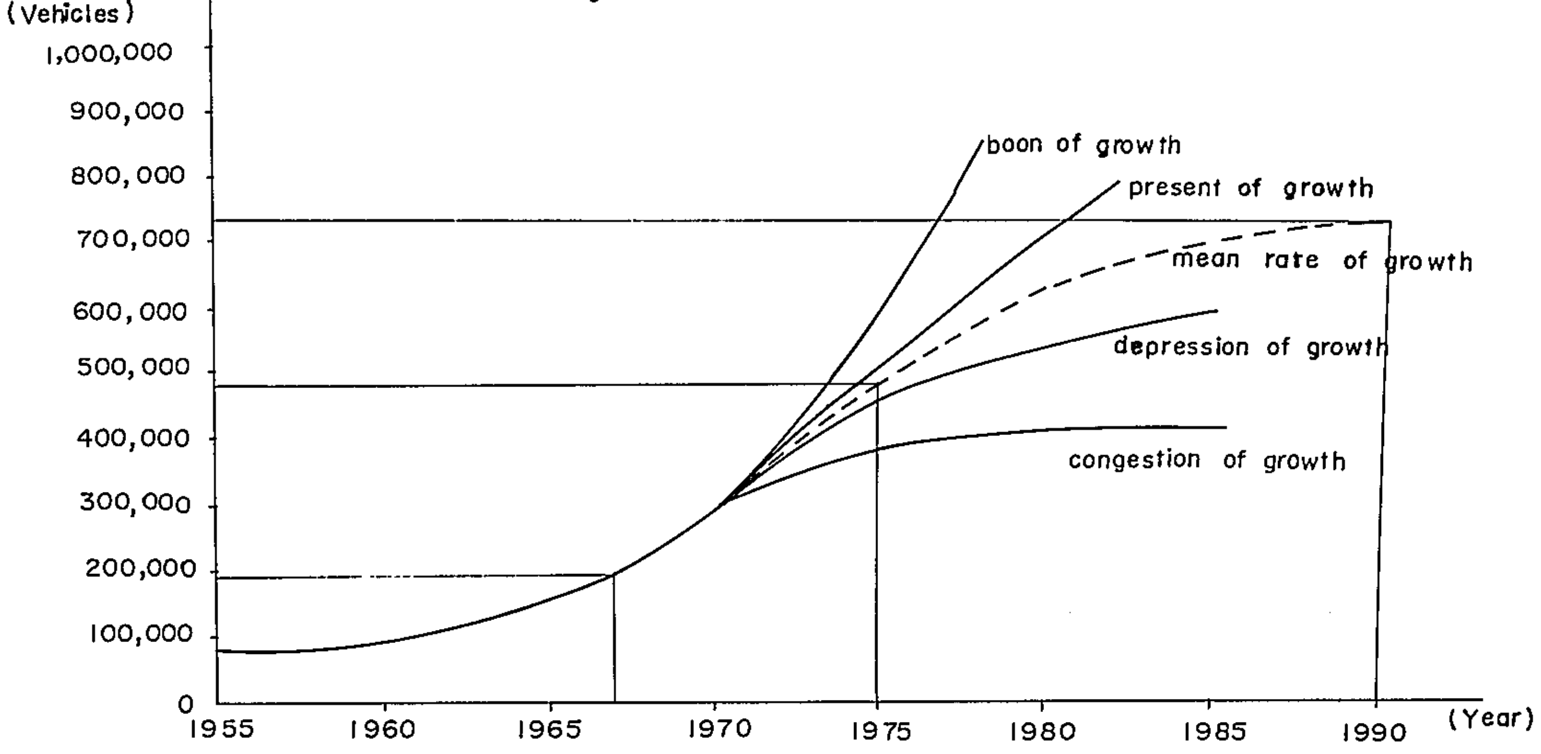
$$493^{(1,000\text{ veh.})} \times 3.92^{(\text{trips/veh.})} = 1,933^{(1,000\text{ trips})}$$

Year 1990

$$731^{(1,000\text{ veh.})} \times 3.92^{(\text{trips/veh.})} = 2,866^{(1,000\text{ trips})}$$

FIG. I. 3-1 Estimation of Future Vehicle Registration

in BangKok and Thonburi



1.4. Forecast of Anticipated Traffic Distribution

The present OD table, which provides a basis for estimating the future traffic distribution, has been prepared on the basis of the bus passenger OD survey conducted by the Department of Road Transportation, Ministry of Communications, Thailand, in 1965.

Because the survey was conducted only on from-home-to-office trips, the trip generations of each zone in this OD survey are considered to be roughly proportionate to the population, but the rate of the trip generation to the population in each zone as of 1965 is highly variable. We assume this is because the number of people sampled each zone are not in proportion to the population in the same zone. Thus, in such zones as Nos. 16, 17, and 22, where the rate of trip generation is too large in comparison with the population, the trip generation of these zones have been revised to reflect the average rate of trip generation of other zones. With the above points in mind, the present bus passenger OD table has been prepared.

Table 1.4-1 has been obtained by comparing the ratio of the volumes of the bus passenger traffic corssing the Chao Phya River over each bridge, which was derived on the assumption that OD traffic volume flow through the minimum path, with the ratio of the volumes of vehicle traffic obtained from the field observations by the General Engineering Company in 1967. The figure for vehicular traffic has been borrowed from Table 3-1 in Chapter I.

Table 1.4-1 Comparison of Bus Passenger versus Vehicle Traffic Crossing the Chao Phya River.

Bridge / Traffic volume		Memorial	K. Thon	K. Thep	Rama VI	Total	Ratio
Vehicle	Number	105,400	27,060	22,200	5,380	160,040 (veh)	7.72
	Ratio	0.658	0.169	0.139	0.034	1.000	
Bus Passenger	Number	14,278	3,270	2,942	241	20,731	1.00
	Ratio	0.688	0.158	0.142	0.012	1.000	

According to Table 1.4-1, the ratio of the vehicular traffic passing over each existing bridge almost equals that of bus passengers with the exception of Rama VI Bridge. Thus, the bus passenger OD distribution may be considered to show vehicle OD distribution. But to convert the bus passenger OD table to vehicular table, the figure must be multiplied by the ratio of 7.72 for the volume of vehicular traffic crossing these bridges is 160,040 vehicles, while that of bus passengers amounts to 20,731 persons. Therefore, the total trips of the present vehicles will become :

Total trips of bus passengers x 7.72
= 95,363 x 7.72
= 736,202 trips

On the other hand, since the number of vehicle registrations in 1967 is given in Fig. 1.3-1 as 188,000 vehicles, the average trips of each vehicle in 1967 can be expressed by $\frac{736,202 \text{ trips}}{188,000 \text{ veh.}} = 3.92$ trips/veh.

The above is the basis which we have used to form the anticipated total number of trips of vehicles given in Section 1.3.

It is now necessary to find the vehicle trips generated by each zone in both 1975 and 1990. Though the Entropy Method permits the calculation of trip generation completely independent of the trip attraction, we can normally consider both of the above traffic volumes to be almost equal each other. We shall simply use hereinafter a term "trip generation" as the sum of trip generation and attraction.

The trip generation of each zone both in 1975 and 1990 can be found the same as that given in Table 1.4-2, if we multiply the trip generation of bas passengers of 1965 by the ratio of the population in 1975 and 1990 to that in 1965, based on the assumption that the trip generation of each zone will increase proportionately to the population in the same zone.

The future population in each zone has been estimated by using the actual population increase during the years 1960 and 1965 and then revised at the following two points.

1. The population increase in each zone will stop at the time when the population density goes up to the maximum determined from the viewpoint of land use.

   In zones where the present population density is very high, the population density is considered to have reached the maximum and not to increase any more.

2. The total population of the Metropolitan area is assumed to increase at the constant rate during the years 1965 and 1990, and to become

6, 300, 000 people in 1990, whose figure is given by the Greater Bangkok plan.

Now the trips generated by each zone have been obtained. At this point, it should be noted that, since the trip generation, when the Entropy Method is applied, could mean only relative largeness of each zone, it is not required to convert trip generation of bus passengers shown in Table 1. 4-2 to that of vehicles. In this case, however, it is necessary to find the ratio of trip generation of each zone to that of all zones, just as shown in the right-hand side column of each year in Table 1. 4-2.

By the Entropy method, in addition to the relative trip generation of each zone, it is necessary to decide the exponent γ that represents the effects of the time required to travel from one zone to another. We have used the value of 1. 1 by applying the gravity model to the bus passenger OD table.

Table 1. 4-2. Trips generated by each zone both in 1975 and 1990

Zone No.	Trip generation in 1965	1975			1990		
		Multiple 1975/1965	Trip generation	Composition rate	Multiple 1990/1965	Trip generation	Composition rate
1	107	1.234	132	0.00055	2.865	307	0.00083
2	51	1.234	63	0.00026	2.865	146	0.00040
3	1,941	1.234	2,395	0.01000	2.865	5,561	0.01511
4	12,848	1.058	13,064	0.05453	1.381	17,053	0.04632
5	51,172	1.315	67,291	0.28089	2.390	122,301	0.33223
6	6,673	2.750	18,351	0.07660	3.660	24,423	0.06634
7	21,602	1.000	21,602	0.09017	1.000	21,602	0.05868
8	6,612	1.000	6,612	0.02760	1.000	6,612	0.01796
9	7,370	1.000	7,370	0.03076	1.000	7,370	0.02002
10	10,026	1.000	10,026	0.04185	1.000	10,026	0.02724
11	10,869	1.041	11,315	0.04723	1.672	18,173	0.04937
12	6,851	1.155	7,913	0.03303	1.534	10,509	0.02855
13	10,509	1.410	14,818	0.06185	1.625	17,077	0.04639
14	7,526	1.189	8,948	0.03735	1.440	10,837	0.02944
15	6,835	1.227	8,387	0.03501	1.790	12,235	0.03324
16	1,402	1.220	1,710	0.00714	1.840	2,580	0.00701
17	1,200	1.575	1,890	0.00789	4.660	5,592	0.01519
18	2,077	1.234	2,563	0.01070	2.865	5,951	0.01617
19	1,896	1.234	2,340	0.00977	2.865	5,432	0.01476
20	12,550	1.574	19,766	0.08251	3.370	42,294	0.11489
21	2,281	1.234	2,815	0.01175	2.865	6,535	0.01775
22	5,565	1.060	5,899	0.02462	1.385	7,708	0.02094
23	3,263	1.315	4,291	0.01791	2.390	7,799	0.02119
Total	190,726	———	239,561	1.00000	———	368,123	1.00000

While OD distribution probability may be drawn from the above input data using a digital computer, OD tables can be obtained by multiplying this value by the total number of trips derived in Section 1. 3.

Tables 1. 4-3 through 1. 4-4 show both the OD tables in the years 1975 and 1990, which are given in trigonometric form.

Table 1.4-3~~(No.1)~~ Vehicle OD Table in 1975

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
1	82	2	44	128	714	128	148	44	50	66	66	42	78	44	42	8	14	10	10	148	10	128	42	2,130
2		18	10	128	328	74	60	20	22	34	42	24	38	22	24	4	6	6	4	58	6	50	10	1,018
3			13,054	1,128	5,243	1,036	904	288	324	391	387	208	388	223	200	44	64	46	36	644	40	405	484	38,645
4				72,871	32,071	3,383	5,107	1,664	1,162	2,104	2,449	1,284	2,416	1,384	1,290	206	416	288	212	3,881	264	3,475	622	210,804
5					245,409	62,963	109,795	35,269	21,828	49,211	31,988	14,264	36,998	31,758	19,811	2,804	7,966	2,429	2,407	49,599	3,217	27,721	46,743	1,085,945
6						42,065	28,258	4,988	5,516	6,574	7,536	3,846	20,228	10,156	22,388	1,830	2,830	932	645	19,862	1,800	5,312	1,736	296,161
7							28,511	15,254	11,752	10,114	13,330	6,245	27,250	16,034	16,364	1,651	2,897	1,216	773	13,427	716	6,012	4,286	348,615
8								3,171	3,876	7,036	5,531	1,834	7,002	3,406	3,108	528	652	386	261	5,902	250	2,196	866	106,703
9									5,321	11,330	16,758	4,264	11,498	6,042	4,216	692	712	638	370	4,682	310	1,554	698	118,936
10										8,654	17,750	5,180	6,382	3,528	4,004	542	846	549	430	13,263	586	3,408	1,160	161,796
11											19,759	11,174	8,510	4,878	4,036	583	1,472	851	675	10,666	488	2,926	982	182,597
12												30,489	3,654	2,916	1,864	284	830	767	420	5,110	256	1,508	750	127,702
13													29,124	24,144	14,124	1,744	2,982	1,502	823	6,616	438	2,806	1,264	239,133
14														10,082	7,354	922	3,406	1,343	550	3,686	238	1,562	642	144,402
15															13,578	1,548	1,240	518	319	3,500	234	1,436	574	135,350
16																6,467	152	106	67	574	40	232	98	27,594
17																	598	662	222	1,272	70	436	158	30,501
18																		13,722	336	884	60	257	127	41,357
19																			13,833	1,124	48	258	95	37,751
20																				81,773	3,609	5,540	1,382	318,985
21																					16,132	361	114	45,419
22																						13,111	1,390	95,195
23																							2,513	69,249
Total																								1,932,989

Table 1.4-4 ~~(No.1)~~ Vehicle OD Table in 1990

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
1	254	6	120	246	1,782	244	214	64	74	94	156	82	138	80	92	16	54	26	24	394	28	236	98	4,776
2		58	28	250	836	144	88	30	34	50	100	46	70	40	52	8	28	14	12	186	14	94	24	2,270
3			31,269	1,913	11,511	1,747	1,159	370	428	490	797	357	603	350	383	84	232	110	88	1,518	94	664	994	86,578
4				87,498	49,856	4,038	4,636	1,508	1,088	1,868	3,570	1,564	2,654	1,540	1,748	278	1,070	493	357	6,480	445	4,037	904	265,539
5					493,909	97,310	129,041	41,378	26,469	56,562	60,353	22,486	52,621	45,727	34,760	4,894	26,487	5,368	5,253	107,218	7,003	41,685	87,959	1,904,377
6						49,924	25,504	4,494	5,136	5,804	10,920	4,656	22,092	11,228	30,164	2,452	7,228	1,581	1,081	32,971	3,009	6,134	2,508	380,293
7							19,568	10,452	8,322	6,789	14,687	5,750	22,633	13,482	16,768	1,682	5,626	1,569	985	16,949	910	5,280	4,709	336,371
8								2,169	2,740	4,714	6,084	1,686	5,806	2,860	3,180	538	1,262	498	332	7,437	317	1,924	948	102,960
9									3,888	7,846	19,050	4,050	9,852	5,242	4,456	728	1,428	849	487	6,098	406	1,408	790	114,757
10										5,680	19,126	4,664	5,184	2,902	4,012	540	1,606	693	536	16,373	729	2,926	1,246	156,114
11											34,948	16,514	11,346	6,586	6,638	956	4,588	1,762	1,379	21,616	995	4,126	1,732	282,977
12												37,648	4,070	3,288	2,562	386	2,162	1,327	718	8,652	438	1,778	1,104	163,636
13													29,272	24,566	17,514	2,150	7,006	2,345	1,269	10,108	673	2,982	1,682	265,908
14														10,386	9,230	1,152	8,102	2,123	859	5,700	370	1,680	864	168,743
15															20,769	2,356	3,593	997	607	6,595	445	1,882	942	190,514
16																9,785	438	203	127	1,077	74	302	160	40,171
17																	3,287	2,414	802	4,542	254	1,084	492	87,072
18																		33,272	804	2,097	144	424	262	92,647
19																			32,729	2,634	112	421	194	84,539
20																				189,866	8,440	8,948	2,792	658,557
21																					38,002	587	234	101,725
22																						14,731	1,956	120,020
23																							4,422	121,438
Total																								2,865,991

1.5. Estimation of Traffic Assignment

This section deals with the problem of just how the OD traffic distribution predicted in Section 1-4 will flow and how great the anticipated volume of traffic might be in each section of the road network.

While a number of various methods have hitherto been introduced to estimate the traffic assignment, in this report, the traffic has been assumed to flow via the route which offers the shortest travelling time between zones. We have divided traffic assignment into several steps for convenience and any desired volume of the OD traffic shown in the OD table is assigned in each step through the shortest route. The running speed will change according to the volume of each road section's traffic volume that might increase in each step of assignment, and the shortest route is determined by the speed thus changed. Then the volume of traffic is added to the shortest route thus determined, until the entire OD traffic volume is assigned.

Needless to say, in this method of traffic assignment, the presence and absence of certain roads will give delicate effects on the assigned volume of traffic of other roads. For this reason, it is necessary to consider all the projected routes ; otherwise, the traffic volume in one section of road cannot be estimated accurately. The above remark particularly is applied to routes that are in competition with others. In order to find the volume of traffic passing over the first Bangkok-Thonburi Bridge in Ta Chang-Wangn Na, we have included in the road network the second Bangkok-Thonburi Bridge linking the Sathon or Silom Road. This road network is shown in Fig. 1.5-1.

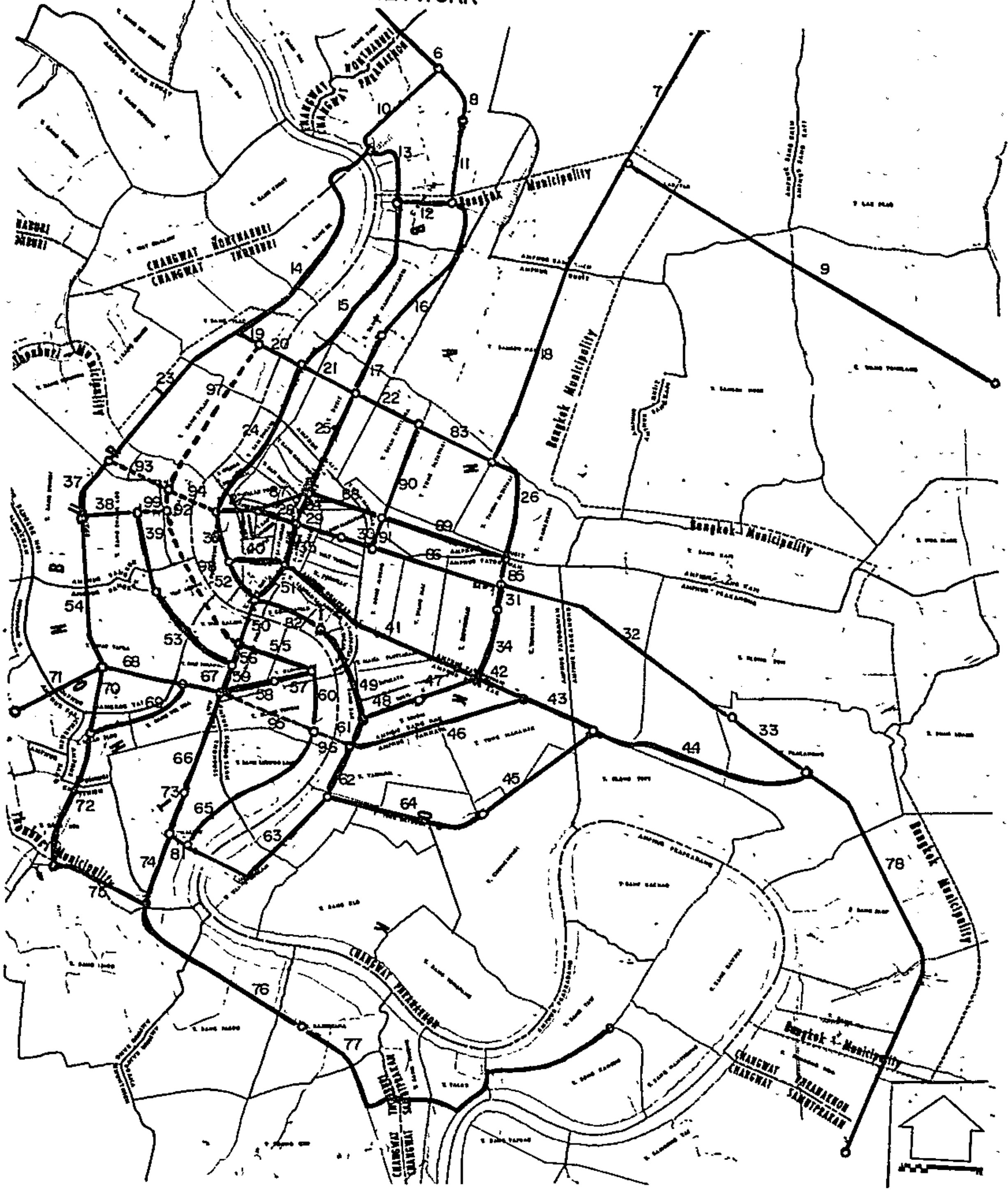
In computing the traffic assignment with a digital computer, OD traffic volume is divided into four equal volumes. While traffic between Bangkok and Thonburi in 1990 is expected to be too large for an exact computation to be handled by the combined traffic-carrying capacity of this road network, traffic assignment has nevertheless been carried out to ascertain as to how large the traffic volume of the proposed bridge will be when a certain period of time has passed after the completion of the bridge.

Of the results of assignment computations, the traffic between Bangkok and Thonburi are indicated in Table 1.5-1 alongside the 1967 for the purpose of comparison. All results are also given in Fig. 1.5-2 through 1.5-3.

Table 1-5-1 Traffic between Bangkok and Thonburi

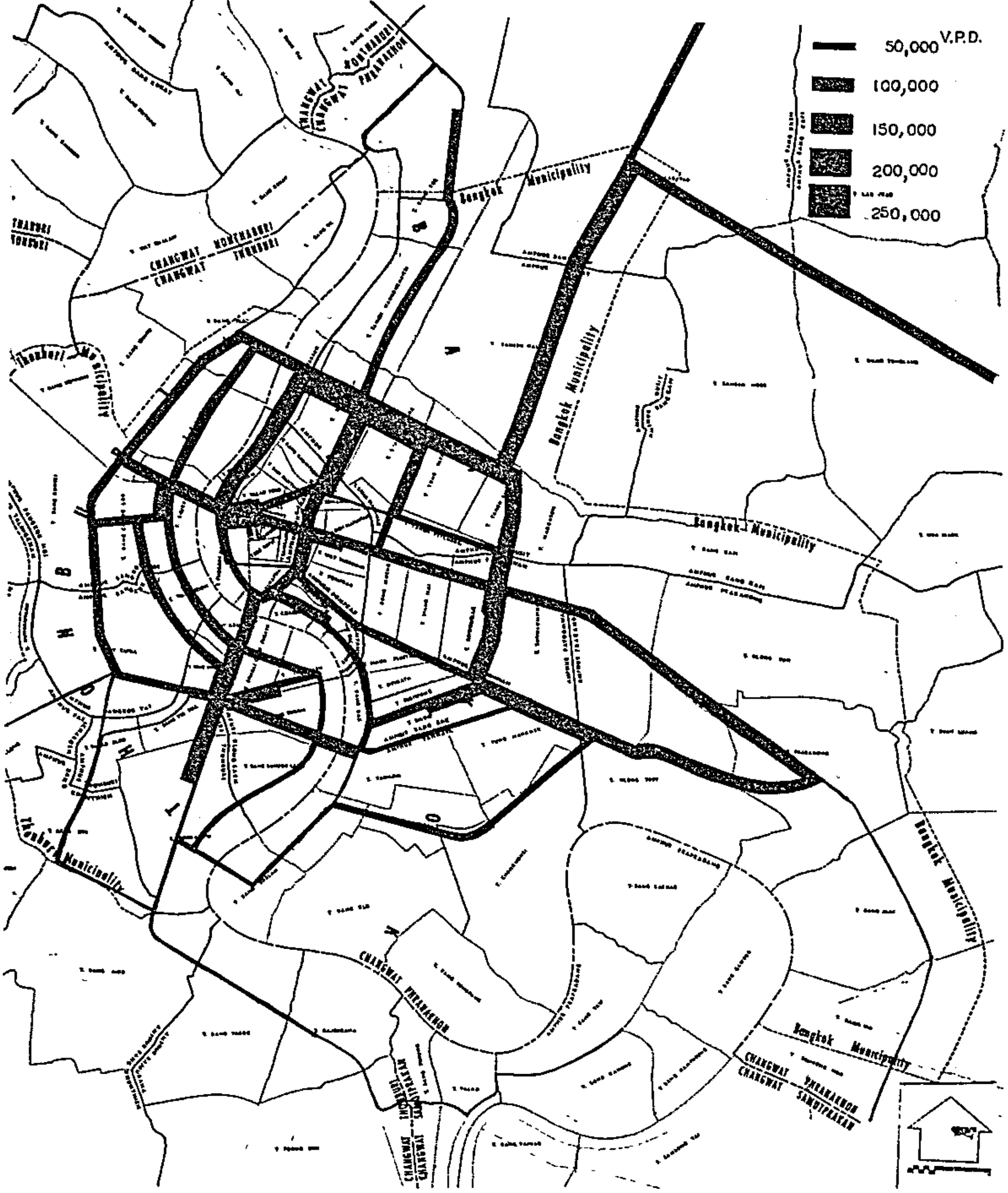
Link No.	Brige	1967	1975	1990
14	Rama VI	5, 380	24, 565	35, 757
20	K. Thon	27, 060	73, 356	104, 151
50	Memorial	105, 400	112, 455	114, 527
63	K. Thep	22, 200	61, 538	79, 855
94	First	——	91, 384	134, 854
96	Second	——	83, 857	132, 929
Total	——	160, 040	447, 155	602, 073

FIG. 1.5-1 ROAD NETWORK



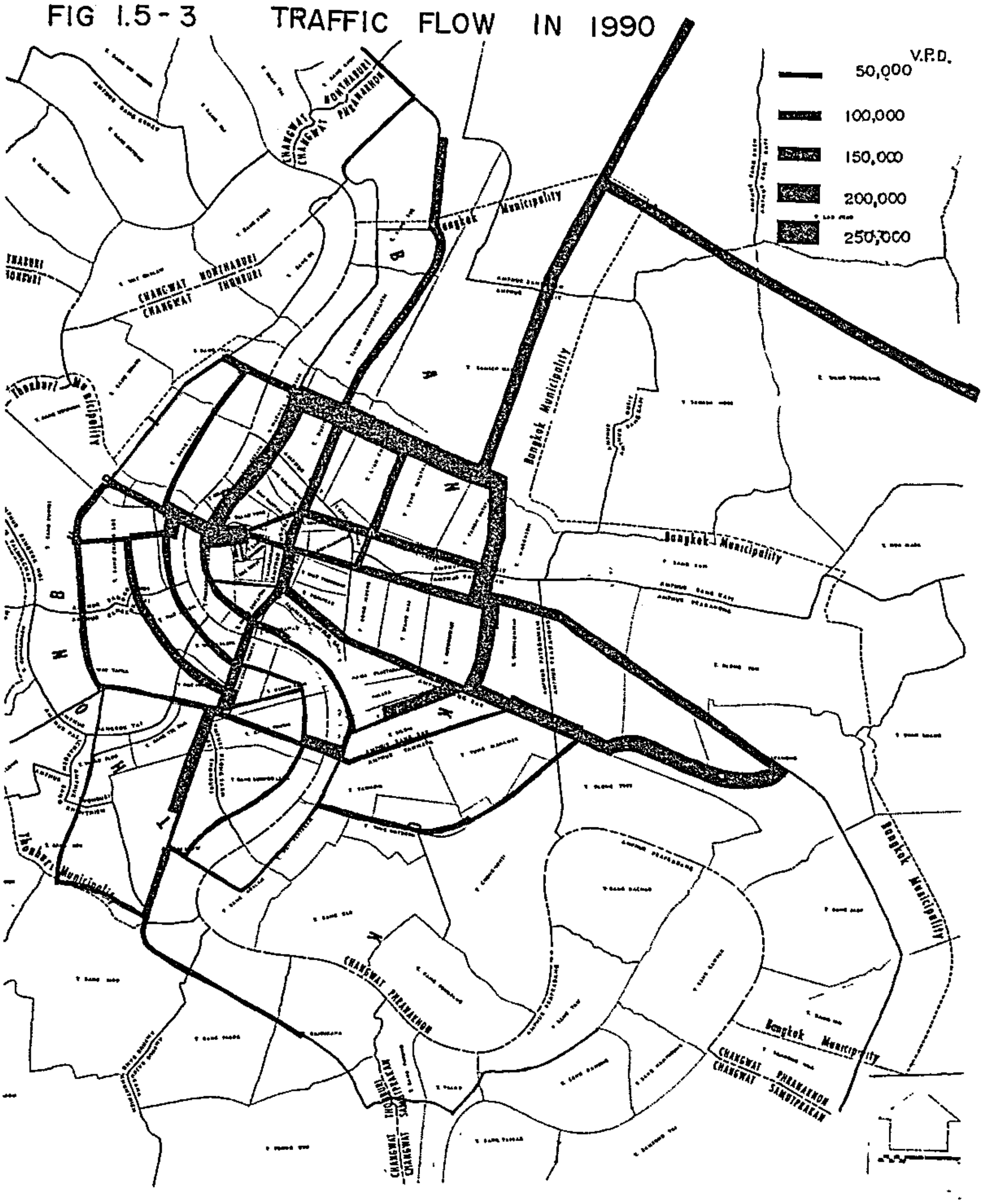
Note: For convenience of computations, two or three roads extending in the same direction are shown as one roadway. Since a main emphasis is placed on the forecasting of traffic volume on the bridge and its access roads, there may be slight inaccuracy on the traffic volume of other roads.

FIG 1.5 — 2 TRAFFIC FLOW IN 1975



Note: For convenience of computations, two or three roads extending in the same direction are shown as one roadway. Since a main emphasis is placed on the forecasting of traffic volume on the bridge and its access roads, there may be slight inaccuracy in the traffic volume of other roads.

FIG 1.5-3 TRAFFIC FLOW IN 1990



Note: For convenience of computations, two or three roads extending in the same direction are shown as one roadway. Since a main emphasis is placed on the forecasting of traffic volume on the bridge and its access roads, there may be slight inaccuracy in the traffic volume of other roads.

Section 2. Benefit of the project.

2.1. Types of Benefit and Unit Cost

The economic effects of investment on roads include indirect effects such as rationalization of production planning and transportation planning, development of natural resources, proper distribution of population and so on, in addition to direct effects such as saving in running cost, reduction of travelling time, improvement of passengers' comfort, reduction of traffic accidents and so on. It, however, is very difficult to measure these direct and indirect effects in terms of monetary value except the effects of saving in running cost and reduction of travelling time. Therefore, these two effects only are taken into consideration in general cases. This report confines its scope of economic effects to saving in running cost and time benefit.

The term "cost saving" used herein is difined as a saving in travel costs, and the "time benefit" as the reduction of travelling time expressed in terms of time cost.

Section 2 deals with the computation of benefits using the results of traffic assignment as calculated in Section 1. The total number of vehicles have only been estimated as traffic to be assigned to each road section, but inasmuch as the amount of benefit might vary with each type of vehicle involved, the average composition of vehicle types for 1975 and 1990 have been estimated by adding the composition rate of Samlors to that of passenger cars obserbed in 1967 by the General Engineering Company on the traffic passing over the existing four bridges.

We have worked out benefit unit costs by multiplying the composition of the types of vehicles passing over the bridges by time unit cost or travel cost of each type of vehicle. The future compositions of vehicle types are given in Table 2.1-1.

Table 2.1-1. Composition of Types of Vehicles between Bangkok and Thonburi in 1975 and 1990

Year	Types of Vehicles				
	Passenger Car	Bus	Truck	Motor cycle	Total
1975	277,684 62.1	35,325 7.9	49,187 11.0	84,959 19.0	447,155 100.0
1990	373,887 62.1	47,564 7.9	66,228 11.0	114,394 19.0	602,073 100.0

Upper position : Number of vehicles.
Lower position : Percentage.

2.2. Time Benefits

The average time unit cost of all types of vehicles has been carried out by multiplying the future composition of the types of vehicles by the time unit cost of each type of vehicle. The result of this computation is 0.050 ฿/min. per vehicle. The time unit cost of each type of vehicle herein refered to is based on the date available from Nihon Doro Kodan (Japan Highway Public Corporation).

The total travel time of vehicles of zone pairs whose traffic is assigned over the first Bangkok-Thonburi Bridge, in 1975, will be as follows :

Road network not including the first and second Bangkok-Thonburi bridges and their access roads : 2,224,565 min. x veh/day.

Road network including the first and second Bangkok-Thonburi bridges and their access roads : 1,423,852 min. x veh./day.

Therefore, total time saving of the traffic using the first bridge will be 800,713 min. x veh./day.

The total time benefit can be found by multiplying the foregoing total time saving by the time unit cost of 0.050 ฿/min. veh.

Time benefit for 1975
= saving in travel time x time unit cost
= 800,713 min. veh./day x 0.050 ฿ /min. veh.
= 40,036 ฿ / day.

2.3. Cost Saving

The running unit cost has been obtained from data available from Nihon Doro Kodan (Japan Highway Public Corporation). Since the running cost of vehicle varies with the running speed of each vehicle, the running speed of vehicle has been classified into four classes to determine the running unit cost of each type of vehicle from the above data. The running speed of each road section has been derived from the traffic assignment given in Section 1.5.

And then, multiplying the travel costs at each speed by vehicle type by the future composition of vehicle types, it is possible to forecast the average running unit costs at each speed.

The result of the computations is shown on the column "Unit running cost" in Table 2.3-1.

Now, it is necessary to find the total running cost in 1975 based on the above running unit cost for cases with and without the first and second Bangkok-Thonburi bridges and their access roads.

First, in case including the proposed bridges and their access roads, the number of vehicles of zone pairs whose trafic is assigned over the first bridge is maltiplied by the length of each road section used by the above traffic and then the products are totaled by standard speed. In addition, we again multiply the figures thus totaled by the running unit costs according to speed and total of such figures will provide predication of total running cost of the traffic using the first bridge.

On the other hand, we can estimate the total running cost by the similar calculation regarding to the above zone pairs in case that the proposed bridges and their access roads are not included. The results of these compulations are shown in Table 2.3-1.

Table 2.3-1 Running Costs

Case		Not Including the Proposed Bridges and Their Access Roads		Including the Proporsed Bridges and Their Access Roads	
Standard Speed (km/hr)	(a) Unit Running Cost (฿/km.veh)	(b) Road Length x No. of vehicles (km.veh)	(a)x(b) Running Costs (฿)	(c) Road Length x No. of vehicles (km.veh)	(a)x(c) Running Costs (฿)
45	1.109	5,909	6,553	6,858	7,606
35	1.426	5,104	7,278	5,584	7,963
25	1.558	53,882	83,948	50,237	78,269
15	2.057	69,682	143,336	31,343	64,473
Total	———	———	241,115	———	158,311

Therefore

Cost Saving in 1975

= Running cost not including the proposed bridges and their access roads

- Running cost including the proposed bridges and their access roads

= 241,115 (฿/day) - 158,311 (฿/day)

= 82,804 (฿/day)

2.4. Benefits of the Project

The sum of the benefits obtained in paragraphs 2-2 and 2-3 is the total amount of benefits i.e.

40 + 83 = 123 (1,000 ฿/day)

Since this value is the amount of daily benefits estimated to accrue therefrom, it is necessary to canvert this figure into annual benefit amount.

annual benefit in 1975

= 123 x 365 = 44,895 (1,000 ฿/year)

While the anticipated annual benefit expected to accrue will be proportionate to an increase in the traffic volume over the first bridge.

Therefore, annual benefit in 1990

$$= \text{benefit for 1975 x} \frac{\text{traffic volume over the bridge in 1990}}{\text{traffic volume over the bridge in 1975}} \cdot$$

$$= 44,895 \times \frac{134,854}{91,384}$$

$$= 66,252 \text{ (1,000 ฿ /year)}$$

Section 3. Maintenance and Operation Costs

Annual maintenance and operation costs have been worked out on the basis of our past experience in the Meishin (Nagoya - Kobe) Highway in Japan. Table 3-1 tabulates the anticipated annual maintenance and operations costs. It will be appriciated that these costs will be relatively low during early years after construction, but that costs will gradually increase as the years pass. We have given in the table the mean values.

The costs given in the table do not include those for restration, repair, etc., that may be caused through accidents, natural calamities, or the like, or those for government officers assigned to maintenance and inspection.

Table 3-1 Annual Maintenance and Operation Cost

(Unit : Bahts)

<table>
<tr><th colspan="2">Item</th><th>Unit Price</th><th>Quantity</th><th>Amount</th><th>Remarks</th></tr>
<tr><td colspan="2">Partial painting, expansion joint, minor repair, etc.</td><td>1.44/m lane. per year .</td><td>750mx6 (Roadway)
+ 280mx2 (Sidewalk)
= 5, 060 m</td><td>7, 308</td><td>Past experience in Meishin Highway :
5. 78/m 4 lane. year
Sidewalk considered as 1 lane.</td></tr>
<tr><td colspan="2">Painting (for illuminating poles)</td><td>23. 11/m² year</td><td>270x¹/₂ = 135m²</td><td>3, 120</td><td>Illuminating poles are repainted every 2 years.</td></tr>
<tr><td rowspan="3">Asphalt</td><td>Repair</td><td>0. 72/m² year</td><td rowspan="3">750m x 21m(Roadway)
+ 280m x 2. 5m x 2
(Sidewalk) = 17, 150m²</td><td>12, 384</td><td>After completion, unit price will increase as follows.
Average rate is taken for estimation.
<table><tr><td>Number of year after completion</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>Average</td></tr><tr><td>Expenses (฿/m2)</td><td>0.23</td><td>0.46</td><td>0.52</td><td>0.58</td><td>0.64</td><td>0.69</td><td>0.75</td><td>0.81</td><td>0.87</td><td>0.87</td><td>0.92</td><td>0.92</td><td>0.98</td><td>0.98</td><td>0.72</td></tr></table></td></tr>
<tr><td>Repaving</td><td>63.55/m² 15-year</td><td>72, 655</td><td>Average rate is taken for estimation. Once every 15 years, meaning 1/15th each year.</td></tr>
<tr><td>Total</td><td></td><td>85, 039</td><td></td></tr>
<tr><td colspan="2">Lane mark</td><td>4. 04/m. year</td><td>750mx5 = 3, 750m</td><td>15, 165</td><td></td></tr>
<tr><td colspan="2">Power for illumination</td><td>0. 58/kw. hr.</td><td>0. 4kwx36units x10^{hr}
/day x365 daysx0. 6</td><td>18, 218</td><td>At midnight, lamps illuminate only at 60% brillance.</td></tr>
<tr><td colspan="2">Lamp</td><td>369. 73</td><td>36 units x0. 6</td><td>7, 986</td><td>60% should be replaced each year.</td></tr>
<tr><td colspan="2">Cleaning</td><td>0. 72/m. lane. per year</td><td>750mx6 (Roadway)
+280mx2 (Sidewalk)
= 5, 060m</td><td>3, 654</td><td>Past experience in Meishin Highway : 2, 889/km. 4 lane. year.
Sidewalk considered as 1 lane.</td></tr>
<tr><td colspan="2">Total</td><td></td><td></td><td>140, 490</td><td></td></tr>
</table>

Section 4. Comparison Between Benefits and Costs

A comparison is made between the cost and benefit. For this purpose, the construction cost of the first bridge obtained from Section 2.4 and that of related roads including land acquisition cost are added altogether with the result that we now have the project cost of 430,000 x 10^3 ฿. On the other hand, the maintenance costs of 1,806 x 10^3 ฿ are obtained by multiplying 140 x 10^3 ฿ of the maintenance cost of the bridge by the ratio of 12.9, which is derived from dividing 9.7 km long access roads extension including the bridge by the 0.75 km long bridge extension.

Assuming the project cost is invested in its entirety in 1974, and its interest is 8 per cent per annum, the cost and benefit in 'n' number of years are calculated on the basis of evaluation at the first year of use, namely, that in 1975, as follows :

The first Bangkok-Thonburi bridge and related cost ('n' number of years):

$$430{,}000 \times 10^3 \times 1.08 + 1{,}806 \times 10^3 \sum_{i=1}^{n} (1.08)^{-i+1}$$

The first Bangkok-Thonburi bridge and related benefits ('n' number of years):

$$= \sum_{i=1}^{n} B_i (1.08)^{-i+1}$$

where the benefit in 'i' year is 'B_i'.

Let it be assumed that the life of the bridge is 50 years, the ratio of the cost to benefit for these 50 years can be obtained by

$$\frac{\text{The first Bangkok-Thonburi bridge and related benefits}}{\text{The first Bangkok-Thonburi bridge and related costs}}$$

$$= \frac{509{,}394^{(1{,}000\ ฿)}}{481{,}659^{(1{,}000\ ฿)}} = 1.06$$

Therefore, judging from the value indicated above, it can be said that the present proposed bridge construction project is adequately compensated when considered from the standpoint of national economy. Years till the benefits to equal the invested capital will be as follows :

$$n = 13.76$$

It is now clear that the invested capital can be depreciated in relatively short period of time when viewed from the standpoint of national economy.