KINGDOM OF THAILAND

FEASIBILITY REPORT

BANGKOK/THONBURI BRIDGE NO.1 CONSTRUCTION PROJECT

JUNE 1968

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 River Bridge Project in Thailand.

Therefore, the Overseas Technical Cooperation Agency dispatched the survey team, headed by Mr.Masanori Nishihata, commissioner of the National Region Development Committee, to conduct the survey from 1967 to 1968, was fully aware of the significance of the project to Thailand's economic growth caused by the construction of the Bangkok - Thonburi River Bridge.

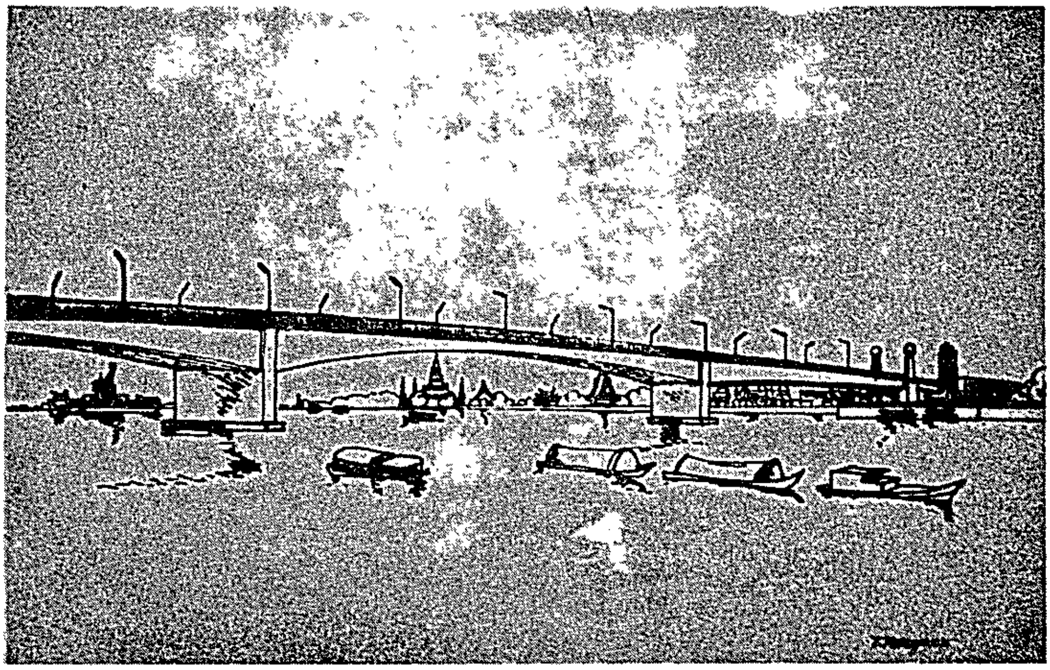
The investigations conducted were: topographical survey, soil exploration and measurment of river conditions for the proposed Bangkok - Thonburi River Bridge. The results of the field investigations have been reviewed and compiled into the report that is hereby submitted to your government.

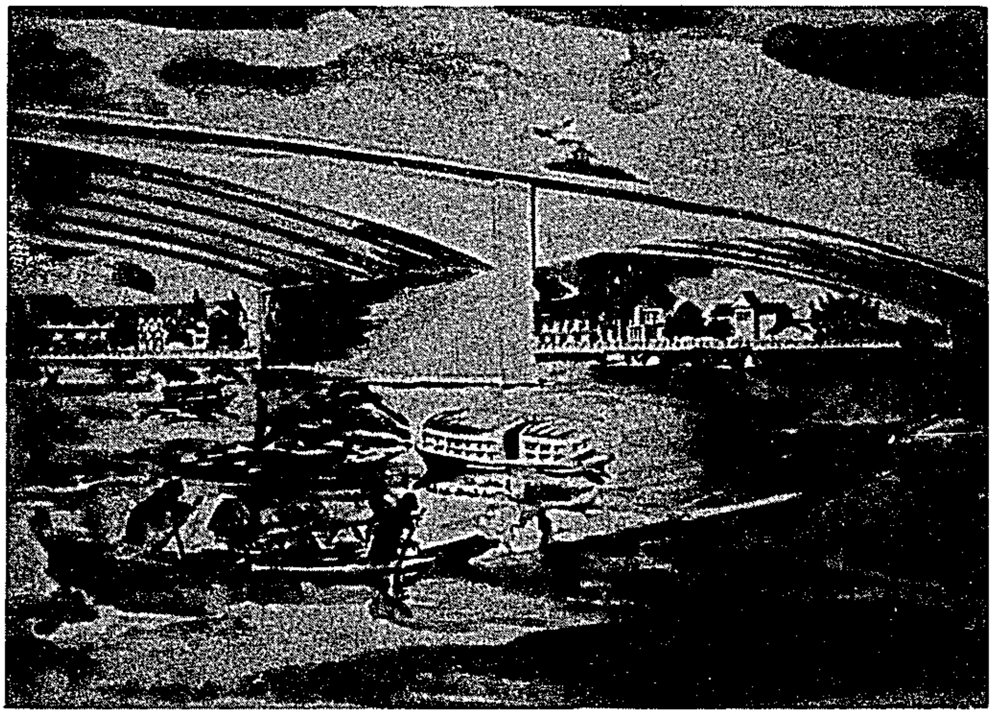
Our agency would be most gratified if this report will contribute in any way to friendship and economic relations between Thailand and Japan.

We deeply appreciate the full assistance and cooperation given by the Government of Thailand and its agencies to the investigators during the stay of the team in Thailand.

June 1968

Shinichi Shibusawa
Director General
Overseas Technical Cooperation Agency





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

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INTRODUCTION

The Japanese Survey Team for Bangkok-Thonburi Bridge Construction Project, as a series of Technical Cooperation Programme of Colombo Plan, arrived Bangkok on the 3rd., December, 1967 and commenced its survey work. The said team was organized with seven experts as listed below:

Masanori Nishihata,	Leader of the team, Commissioner of National Capital Region Redevelopment Committee
Hiroshi Mori,	Acting leader of the team, Civil Engineer in charge of foundation engineering, President of Nippon Kaigai Consultants Corp.
Yoshio Niinomi,	Civil Engineer, 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,	Civil Engineer of Japanese Government, 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 done by Japanese Team had been specified in "Plan of Operation (Oct. 1967)" agreed upon between Thai and Japanese Government 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. However some amendments on the specified work were agreed upon after the consultation between Mr. Kanjana and Japanese Team.

The report of the work performed by Japanese Team during its study 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 being completed, in the beginning of March, the type of foundations was definitely decided. Including amendment to some parts of structural design and the results of traffic study in front of Royal Hotel, the report on the preliminary study of Bangkok-Thonburi Bridge Project was organized as described hereafter.

CHAPTER I GENERAL INTRODUCTION

1. OUTLINE OF THE PROJECT

In recent years, the traffic between Bangkok and Thonburi is becoming increasingly so heavy that today there too often exists a serious traffic stagnation or a state of paralysis on bridges linking the said two cities.

This serious traffic problem suggests and emphasizes the pressing need for the immediate construction of additional bridges not only to alleviate the present traffic congestion, but also to pave the way for further development and welfare of these two important cities and the Kingdom of Thailand as a whole.

This report relates to the proposed Bangkok-Thonburi bridge construction project, and more particularly to the feasibility study of the Bangkok Thonburi and bridge, and contains traffic forecast, importation of equipment and materials required, estimation of cost involved, etc.

2. PURPOSE AND EFFECT OF THE PROJECT

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

With particular reference to the traffic problem, the existing bridges spanning over the Chao Phya River count only four - too small in number to cope with the ever-increasing traffic flow on these four bridges.

In the face of fast-rising land acquisition costs resulting from a recent sky-rocketing land value, the Government, being fully aware of this mounting traffic problem, now places the proposed Bangkok/Thonburi Bridge Construction Project stop on the priority list, along with the building of elevated crossings within city areas and the enlargement of street width.

And the Government has lately formulated a new 5-year bridge construction project in order to partially avert the flow of the traffic from the Memorial Bridge where the traffic jam is considered to be 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 built at a later date.

The first bridge to be constructed starting this year is one designated "the Bangkok Thonluri Bridge" at Ta Chang Wandor. This bridge erection will soon be followed by the construction of the second bridge over Bangkok Noi Canal and related roads along the said canal.

The traffic survey conducted in 1959 shows that the amount of traffic on the Memorial Bridge at peak hour was 4,000 veh/hour. This figure grew to 6,100 veh/hour in about ten years, registering an increase of 7.5 per cent, according to the supplementary 1967 survey. While the amount of traffic in western direction to Nakon Pathom and in southern direction to Pom Pachul registered 480 veh/hour and 400 veh/hour, respectively, in 1959, it then increased to 1,363 and 1,303 veh/hour or an increase of 15.5 and 11.5 per cent, respectively, in 1967.

The fact that the rate of traffic growth on the Memorial Bridge is lower than the rate in the related roads indicates that the amount of traffic on the Memorial Bridge has reached its capacity. If the traffic to the suburbs should increase at the above mentioned rate, still more an alarming state of paralysis would take place in and around the Memorial Bridge in the very near future. Thus, it can be said that the construction of the proposed Bangkok/Thonburi Bridge is indeed very timely and effective measures to solve the serious traffic problem.

In other words, firstly, the proposed project has the original objective of dispersing the traffic coming from the suburbs to commercial and business center of Bangkok from the Memorial Bridge. Secondly, the proposed bridge is intended to prepare for the anticipated traffic increase due to the development of Thonburi Area along Chao Phya River. Thirdly, the proposed bridge is expected to absorb the traffic of the area along Bangkok Noi Canal.

However, because an Origin and Destination survey has not been included in the previous traffic survey in Thailand, the importance of the project cannot be discussed without considering the amount of future traffic passing through the proposed bridge. In this respect, the traffic survey presented in this report will serve as a useful recommendation.

It is suggested that an OD survey be made on the basis of a person trip at first in the western part of Bangkok around C.B.D. area and Thonburi Area. Then the survey data shall be studied in relationship with the city planning and the planning of land utilization. In so doing, we can estimate anticipated traffic on the proposed bridge and in the related roads.

3. BRIEF DESCRIPTION OF THE PROJECT AREA

Needless to say, Bangkok, the capital of the Kingdom of Thailand, is situated on the left bank of the Chao Phya River, while Thonburi exists on its right bank, facing the capital city across the said river.

Bangkok is the center of Changwat Pranakhon ; Thonburi is the heart of Chawngwat Thonburi. Bangkok with the suburbs and Changwat Notanburi and Thonburi with its suburbs and Changwat Samut Prakan, collectively form Metropolitan area. Not only is Bangkok the center of politics, it is also the heart of economy, industry, and civilization in Thailand.

In this Metropolis, the centralization of population is now occuring at a surprisingly fast tempo, thereby posing a grave problems of city planning and traffic congestion.

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

As has been described and discussed earlier, Bangkok and Thonburi are divided by the Chao Phya River, but the traffic between these two cities are culminated in the vicinity of the Memorial Bridge (Buddha Yod Far Bridge), that links the center of the two cities. About three kilometers upstream from the Memorial Bridge, there is the Krung Thon Bridge ; downstream from it, there is the Krung Thep Bridge. Still about three kilometers upstream from the Krung Thon Bridge, there is the Rama VI Bridge, carrying both railroad and highway.

While there are no other overland transportation means to come and go between these two cities, ten ferry port facilities are availavle today on each bank along the Chao Phya River, to carry traffic between the cities, thereby helping to lessen the ever-increasing heavy traffic.

4. FORECAST OF TRAFFIC BETWEEN BANGKOK AND THONBURI

4-1 Method of Traffic Forecasting

In formulating proper traffic or road plan, or both, it is first necessary to estimate the anticipated traffic volume in a proper manner to meet the amount of future traffic.

For this purpose, it is believed that performing an OD survey is essential to the acquisition of basic data necessary for estimating the amount of future traffic, and without which it is next to impossible to make an accurate future traffic forecasting.

Unfortunately, no OD survey has previously been conducted neither in Bangkok nor Thonburi, and we are therefore obliged to base our forecast on what little data currently available, which is obviously too insufficient to form a more satisfactory forecasting.

Illustrated in Fig. 4-1-1 is the method used to forecast the amount of future traffic for a 15-year period between 1975 and 1990.

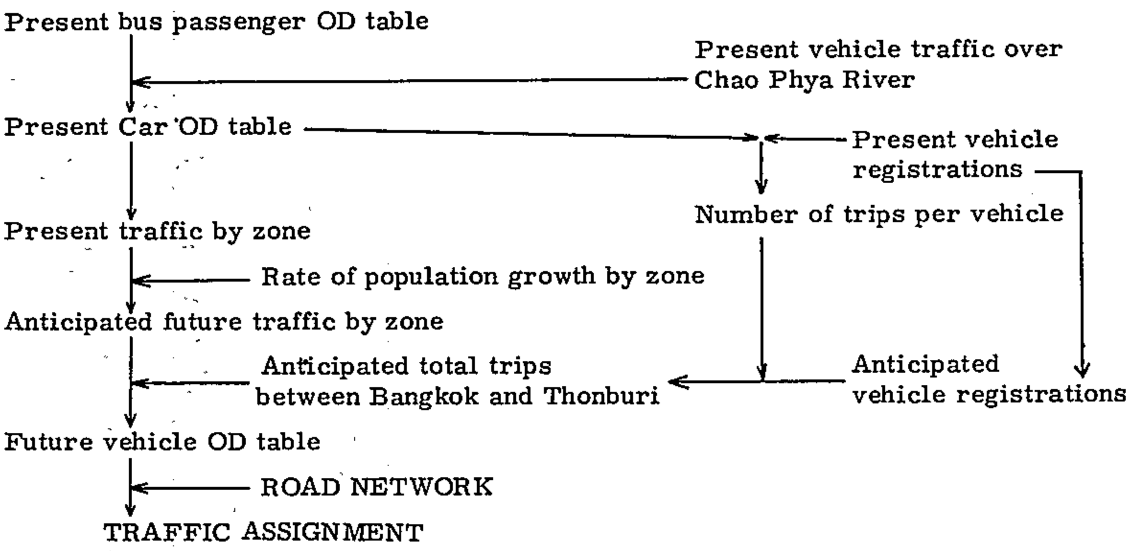

Fig. 4-1-1 Flow Diagram for Traffic Forecast Between Bangkok and Thonburi

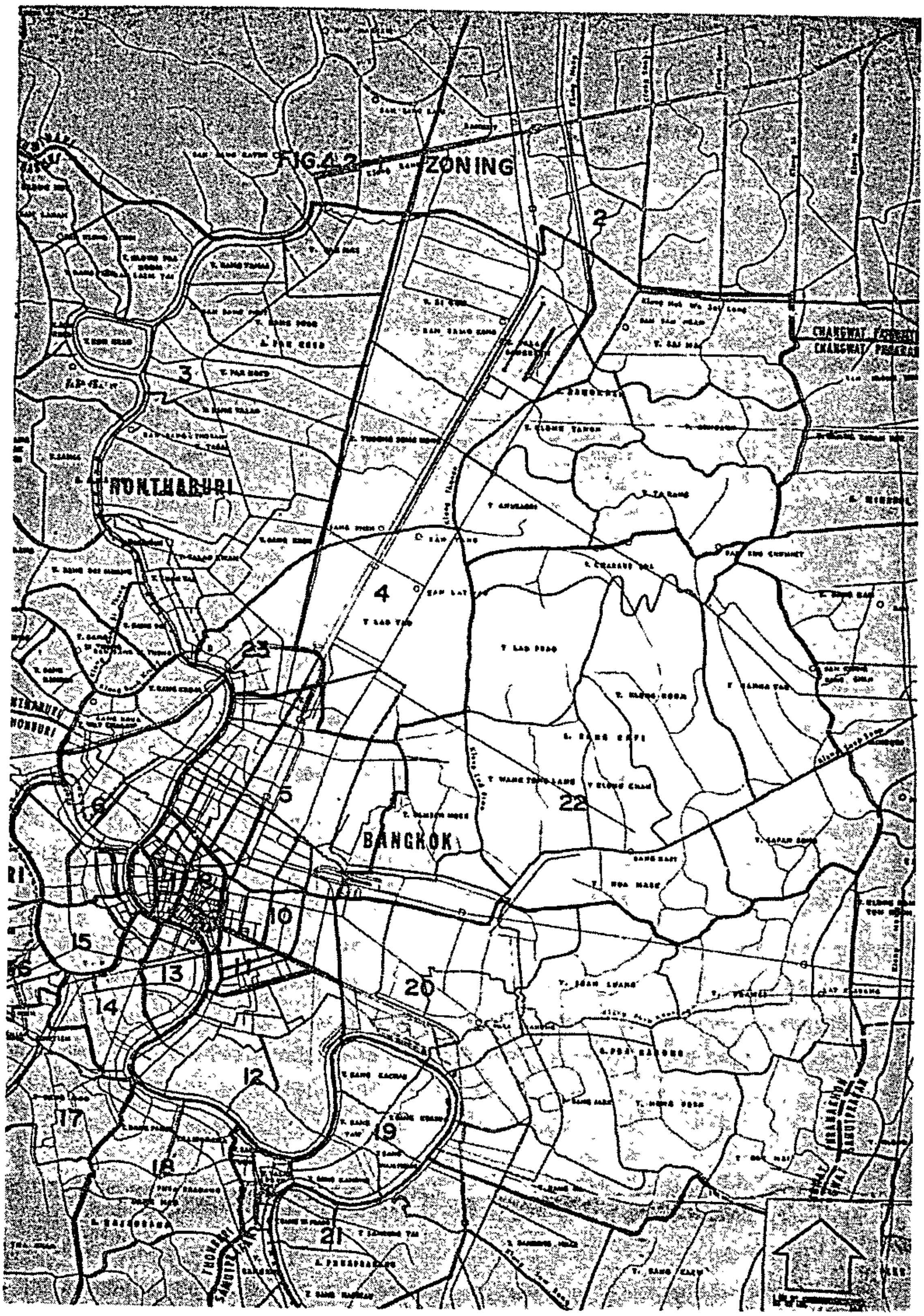
FIG.4.2
ZONING
NONTHABURI
BANGKOK
1
2
3
4
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14
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17
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19
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21
22
23

4-2 Estimated Area and Zoning

Bangkok and Thonburi are teritòrially two different cities, but they are functionally one and the same city, forming the nucleus of the Metropolitan area. For this reason, the area under review embraces both of these cities.

In this report, the zoning has been arranged by the difference of Amphur, inasmuch as the zoning given in the bus passenger OD survey is too narrowly divided. Refer to Table 4-2-1 and Fig. 4-2-1 for futher zoning details.

Table 4-2-1 Zoning

ZONE NO.	ZONE NAME	ZONE NO.	ZONE NAME
1	Bang Tanai	13	Klongsarn
2	Bang Mai	14	Thonburi
3	Pak kred	15	Bangkok-yai
4	Bang khen	16	Pharsicharoen
5	Dusit	17	Bangkhunthien
6	Bangkok-noi	18	Rajburane
7	Prana korn	19	prapradong
8	Ponprab	20	Prakanong
9	Sampantawong	21	Samrong Nua
10	Patunwan	22	Bang Kapi
11	Bangrak	23	Bang Sue
12	Yanawa		

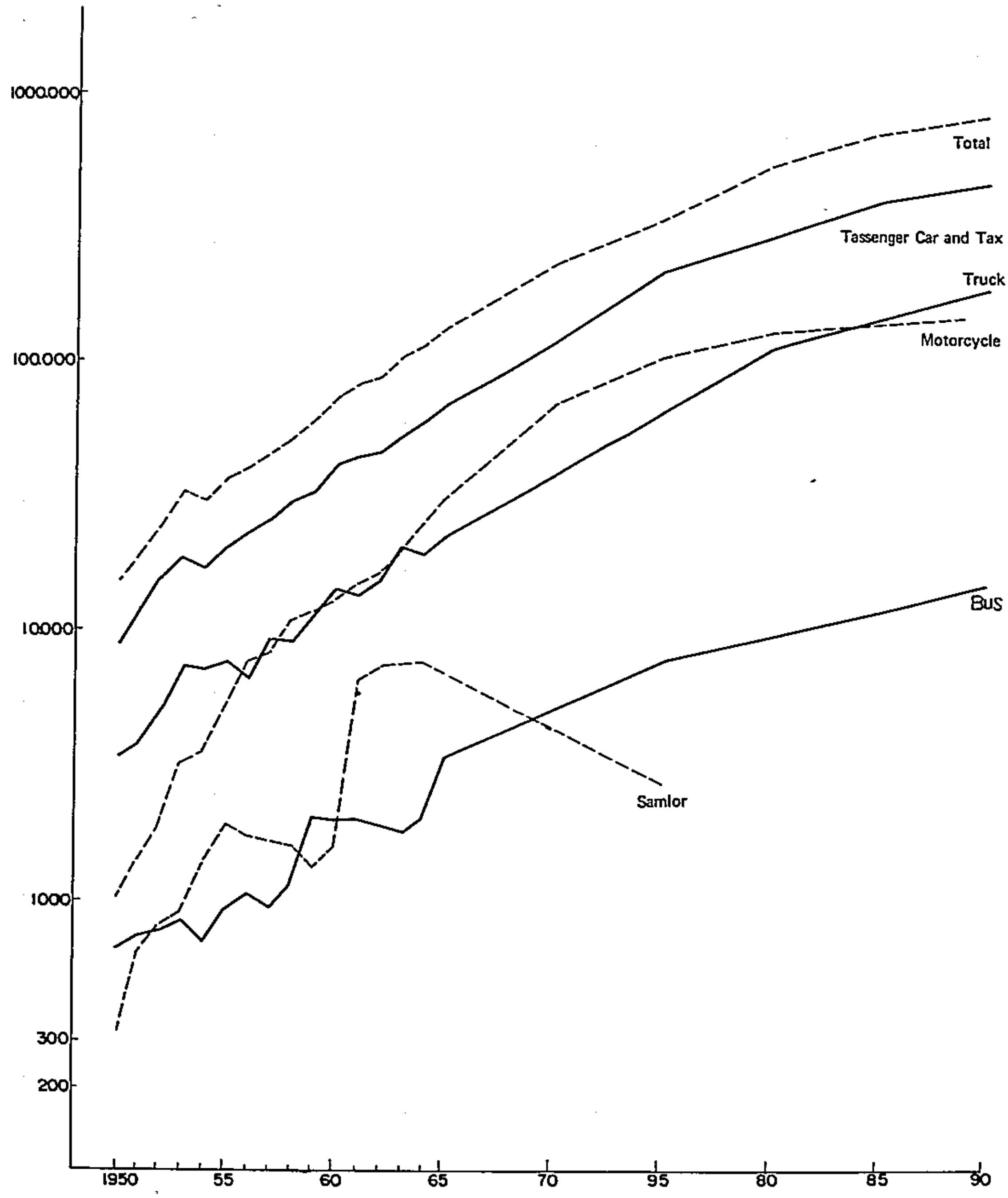
4-3 Forecast of Total Future Trips

To calculate the anticipated total future trips of vehicles, it is necessary to find yearly vehicle registrations from the movement of vehicle registrations in the past and then to multiply the figure by the number of trips of each vehicle.

In other words, first find annual mean growth rate from the movement of yearly vehicle registrations for the past 7 years between 1958 and 1965 and then set a proper growth rate by vehicle type thereafter assuming that the rate of yearly vehicle registrations to continue at the same rate for ten years ending the year 1975. This has yielded anticipated vehicle registrations such as shown in Table 4-3-1 and Fig. 4-3-1.

The trips per vehicle at present, as will be described in the subsequent paragraph 4-4, is estimated to be 4.43. Assuming that the rate of vehicle registrations continues at the same rate, the anticipated total trips of each vehicle coming and going between Bangkok and Thonburi in 1975 and 1990 would be found by the formula

Fig. 4. 3 - 1   Anticipated Vehicle Registration by Vehicle Type



Total trips in year 1975

346, 700 veh. x 4. 43 trips/veh. = 1, 535, 881 trips

Total trips in year 1990

848, 000 veh. x 4. 43 trips/veh. = 3, 756, 640 trips

Table 4-3-1 Bangkok and Thonburi Anticipated Vehicle Registrations (Bangkok and Thonburi)

Type of Vehicle \ Year	1950	1955	1960	1965	1970	1975	1980	1985	1990
Passanger Car & Taxi					1, 129		1, 065	1, 0325	
	8, 801	19, 935	41, 848	67, 409	119, 000	218, 000	299, 000	410, 000	481, 000
Bus					1, 087		1, 044		
	689	945	2, 003	3, 438	5. 200	7. 900	9, 800	12, 100	15. 000
Truck						1, 114			
	3, 414	7, 711	14, 455	22, 487	38, 500	66, 000	113, 000	149, 000	196, 000
Motor-cycle.					1, 176	1, 088	1, 044	1, 022	1, 011
	1, 019	5, 196	13, 051	31, 259	70, 300	107, 000	133, 000	148, 000	156, 000
Samlor					0, 909		0, 000		
	333	1, 997	1, 616	7, 266	4, 510	2, 800	0	0	0
Total	14, 256	35, 784	72, 973	131, 859	233, 000	346, 700	554, 800	719, 100	848, 000

Upper position : Annual Rate of Growth

Luwer position : Number of vehiles.

4-4 Forecast of Anticipated Traffic Distribution

The present OD table, which constitutes a basis for estimating anticipated traffic, has been prepared based upon the bus passenger OD survey performed by the Department of Road Transport, Ministry of Communications in 1965.

The zoning given in the OD table is so narrowly divided that each sampling zone is not directly proportionate to the residing population. The zoning has thus been arranged on an Amphur basis, so as to utilize OD table as the bus passenger OD table. (This OD table is a revised version to make the sampling rate of each zone to be uniform.)

When comparing the rate of traffic of each bridge, that has been derived on the assumption that the OD traffic flows through the minimum path, with the results of survey performed by General Engineering Company and also with the amount of vehicle traffic on each bridge, the amount of vehicle traffic becomes 160, 040, whereas passenger traffic volume is 2, 073. The present vehicle's total trips of 736, 202 times were obtained by multiplying the rate by 7. 72 times.

On the other hand, the anticipated vehicle traffic in 1967 based upon the table 4-3-1 is expected to be 166, 000 vehicles, while an average trips of each vehicle in the same year is

$$\frac{736,202 \text{ trips}}{160,000 \text{ veh.}} = 4.43 \text{ trips/veh.}$$

The answer now obtained by the above formula is the very basis for estimating anticipated total trips of vehicles.

In order to find future generating and attracting volumes from 1965's generating and attracting volumes by zone, the following method has been employed :

(1) Calculate anticipated amount of traffic in each zone through 1990 in accordance with yearly rate of population growth in each zone from 1960 to 1965.

(2) Calculate this growth rate continuously until a maximum of population, that has been determined with land utilization and the position of each zone is reached.

(3) With respect to zones which have uniform rise in population between years 1960 and 1965, population increase has been assumed to be at somewhat higher rate taking into account such factors as land utilization, population density, etc.

(4) Either Bangkok or Thonburi's annual mean rate of population growth applies to each zone whose annual rate of population growth given in (1) above is unknown.

(5) On the other hand, the total population in the entire urban area, now computed on a zone basis will show a slight discrepancy from the value estimated from the overall urban area. Thus, the total population of the entire city is first calculated and population increase in each zone corrected and revised as a controlled total.

In computing the anticipated OD distribution, we have taken liberty to adopt the so-called entropy method originally introduced by Professor Sasaki of Kyoto University, Japan.

According to this method, while it is necessary to provide a constant representing the effect of the required time between zones on the traffic volume and a zone, in addition to relative traffic volume, we have been able to find out the value of 1.1 through application of gravity model to the present bus passenger OD table.

The OD tables shown in Table 4-4-1 and 4-4-2 have been derived by representing the required time between zones by the difference of distance. Incidentally, in this report, the OD table has been prepared in a trigonal form.

Present OD Table (1975) (No. 1 of 2)

	1	2	3	4	5	6	7	8	9	10	11	12
1	63	0	36	110	691	54	128	33	42	54	60	36
2		13	9	110	319	30	51	15	18	27	36	18
3			10,612	1,001	5,273	441	817	229	274	325	352	176
4				70,458	35,180	1,570	5,038	1,439	1,079	1,912	2,426	1,192
5					148,522	33,150	122,888	34,586	22,958	50,732	35,930	15,021
6						9,369	13,380	2,068	2,453	2,867	3,582	1,714
7							7,055	13,455	11,118	9,378	13,467	5,915
8								1,354	3,212	5,716	4,896	1,523
9									1,071	9,870	15,907	3,797
10										2,459	16,515	4,518
11											20,030	10,621
12												27,167
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
Total												

Present OD Table (1975) No. 2 of 2

O \ D	13	14	15	16	17	18	19	20	21	22	23	Total
1	57	36	36	6	9	9	6	101	9	110	30	1,779
2	30	18	21	3	3	3	3	48	3	42	6	839
3	297	188	173	36	42	39	30	466	33	364	340	32,165
4	2,010	1,278	1,216	188	294	259	188	3,066	238	3,406	477	204,593
5	34,923	33,282	21,180	2,885	6,368	2,470	2,442	44,460	3,291	30,819	4,659	840,551
6	8,077	4,503	10,126	796	957	401	277	7,533	779	2,497	638	116,631
7	23,134	15,112	15,734	1,526	2,083	1,112	705	10,823	659	6,011	3,353	289,997
8	5,209	2,813	2,619	429	411	310	209	4,169	201	1,924	593	88,767
9	9,172	5,352	3,808	602	483	548	316	3,546	268	1,460	513	98,938
10	4,989	3,063	3,546	462	560	462	361	9,849	498	3,138	834	134,594
11	7,250	4,616	3,895	542	1,061	781	617	8,630	450	2,935	772	175,395
12	2,917	2,587	1,687	247	560	659	361	3,877	224	1,418	551	113,953
13	20,850	19,191	11,452	1,359	1,809	1,159	633	4,500	340	2,366	834	183,408
14		8,898	6,622	799	2,292	1,150	471	2,783	206	1,463	471	126,092
15			12,470	1,368	852	453	277	2,694	206	1,371	429	114,705
16				5,495	101	89	57	426	33	212	72	23,228
17					124	432	146	733	48	312	89	19,894
18						11,394	277	647	51	232	89	34,420
19							11,434	821	39	234	69	31,407
20								52,797	2,660	4,437	864	222,727
21									13,571	331	82	37,791
22										13,021	1,082	92,207
23											1,527	19,901
Total												1,501,991

Future OD Table (1990) (No. 1 of 2)

D / O	1	2	3	4	5	6	7	8	9	10	11	12
1	159	4	88	278	1,998	262	138	40	48	62	134	104
2		34	20	274	904	150	54	18	20	32	82	56
3			26,904	2,538	15,108	2,198	864	272	328	380	796	526
4				179,069	100,917	7,836	5,335	1,712	1,286	2,232	5,501	3,555
5					480,859	186,748	146,880	46,466	30,902	66,840	91,973	50,548
6						91,841	27,826	4,836	5,748	6,574	15,952	10,034
7							3,113	6,672	5,524	5,524	12,726	7,348
8								755	1,794	1,794	5,200	2,126
9									600	600	16,930	5,310
10											17,204	6,188
11											40,539	28,256
12												95,022
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
23												
Total												

Future OD Table (1990) (No. 2 of 2)

D / O	13	14	15	16	17	18	19	20	21	22	23	Total
1	150	126	124	14	20	20	18	204	20	284	74	6,792
2	74	62	68	8	10	10	8	94	10	110	16	3,228
3	772	645	604	92	102	96	78	922	84	932	872	123,189
4	5,241	4,369	4,247	476	724	662	483	6,068	609	8,732	1,223	783,667
5	102,776	128,380	83,516	8,262	17,706	7,126	7,050	99,301	9,491	89,180	117,705	3,557,232
6	41,362	30,218	69,472	3,968	4,632	2,012	1,391	29,272	3,909	12,580	3,218	980,816
7	25,133	21,520	22,904	1,614	2,138	1,184	751	5,925	701	6,422	3,582	478,541
8	6,360	4,502	4,284	510	474	370	250	3,864	240	2,310	712	146,469
9	11,222	8,582	6,244	718	556	658	380	3,294	321	1,757	616	163,265
10	5,976	4,808	5,690	538	634	543	424	8,951	583	3,696	984	222,099
11	16,868	14,074	12,142	1,228	2,334	1,781	1,409	15,239	1,027	6,718	1,766	525,624
12	8,926	10,364	6,911	734	1,622	1,979	1,081	8,998	666	4,269	1,658	526,951
13	55,777	67,288	41,051	3,542	4,569	3,037	1,662	9,133	890	6,224	2,196	714,005
14		40,890	31,101	2,726	7,594	3,953	1,617	7,404	703	5,042	1,622	657,717
15			59,886	4,776	2,882	1,588	978	7,330	723	4,834	1,513	649,122
16				13,927	248	228	144	841	86	544	182	88,993
17					294	1,070	360	1,404	114	774	220	76,163
18						29,298	715	1,288	130	602	232	131,823
19							29,444	1,636	102	603	174	120,312
20								81,348	5,292	8,856	1,728	589,110
21									34,864	851	212	144,749
22										33,677	2,796	353,204
23											3,955	226,816
Total												7,513,258

4-5 Estimation of Assignment

Presented in this paragraph is an outline of the estimation of the actual traffic flow to show just how the amount of traffic can be averted.

(1) It should be noted that node number incidental to each link (this is used to represent the traffic network), the so-called QV relation between the amount of traffic in each link and traveling speed, generating node number, and OD traffic volume are needed as input data.

(2) First, derive a certain node at random from the amount of traffic under O condition : then, select a minimum path leading to the entire attracting nodes.

(3) Add part of OD traffic to minimum path and compute the new link traveling time using QV equation, so that new link traveling time can be determined to freely show just how much percentage that part really is.

(4) All the attracting nodes can be arrived at from the traffic node selected out at random on the basis of time required for traveling (as given in (3)). Then add part of the OD traffic (the same rate as (3)) to the minimum path to compute the traveling time in each link.

(5) The step (4) should be repeated until such time as all the traffic nodes are selected.

(6) Repeat computation given in the steps (4) and (5) and discontinue it when the entire OD traffic has been completely assigned. Just how many times the computation should be repeated can be determined without regard to the rate of assignment of the OD traffic each time.

(7) The amount of traffic in each link, link traveling time, direction of moving traffic at the crossings, etc. can be obtained as outputs. Road network, as shown in Fig. 4-5-1, has been prepared to such an extent that it does not affect future estimation.

(8) Of the results of assignment computation, part of traffic between Bangkok and Thonburi area are indicated in Table 4-5-1 alongside the 1967 figure for purposes of comparision. All the results are also given in Fig. 4-5-2 -- 4-5-4.

Table 4-5-1 Traffic between Bangkok - Thonburi

Link No.	Bridge	1967	1975		1990
			Bride building plan excluded	Bridge building plan included.	
14	Rama VI	5, 380	34, 251	17, 914	34, 348
20	Krung Thon	21, 060	113, 120	71, 280	194, 955
50	Memorial	105, 400	123, 500	104, 618	169, 547
63	Krung Thep	22, 200	67, 264	34, 950	90, 388
85	Ta Chang	-	-	48, 026	246, 906
87	Sathorn or Silom	-	-	61, 347	247, 859
Total	-	160, 040	338, 135	338, 135	984, 003

FIG. 4.5-1 ROAD NETWORK TO BE ESTIMATED

FIG. 4.5 - 2 TRAFFIC FLOW EXCLUDING PLANNED BRIDGES AT 1975

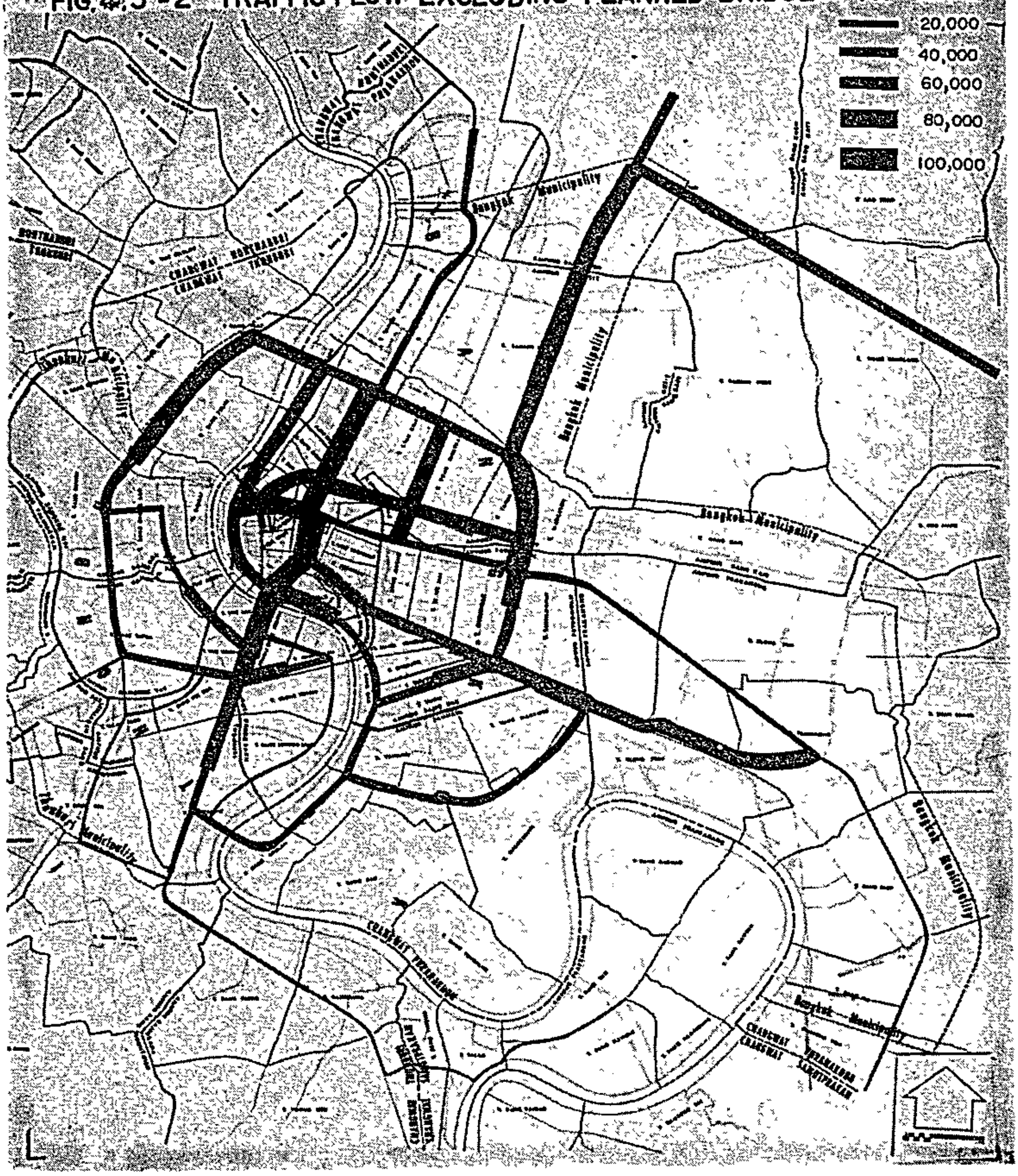


FIG. 4.5-3 TRAFFIC FLOW INCLUDING PLANNED BRIDGES AT 1975

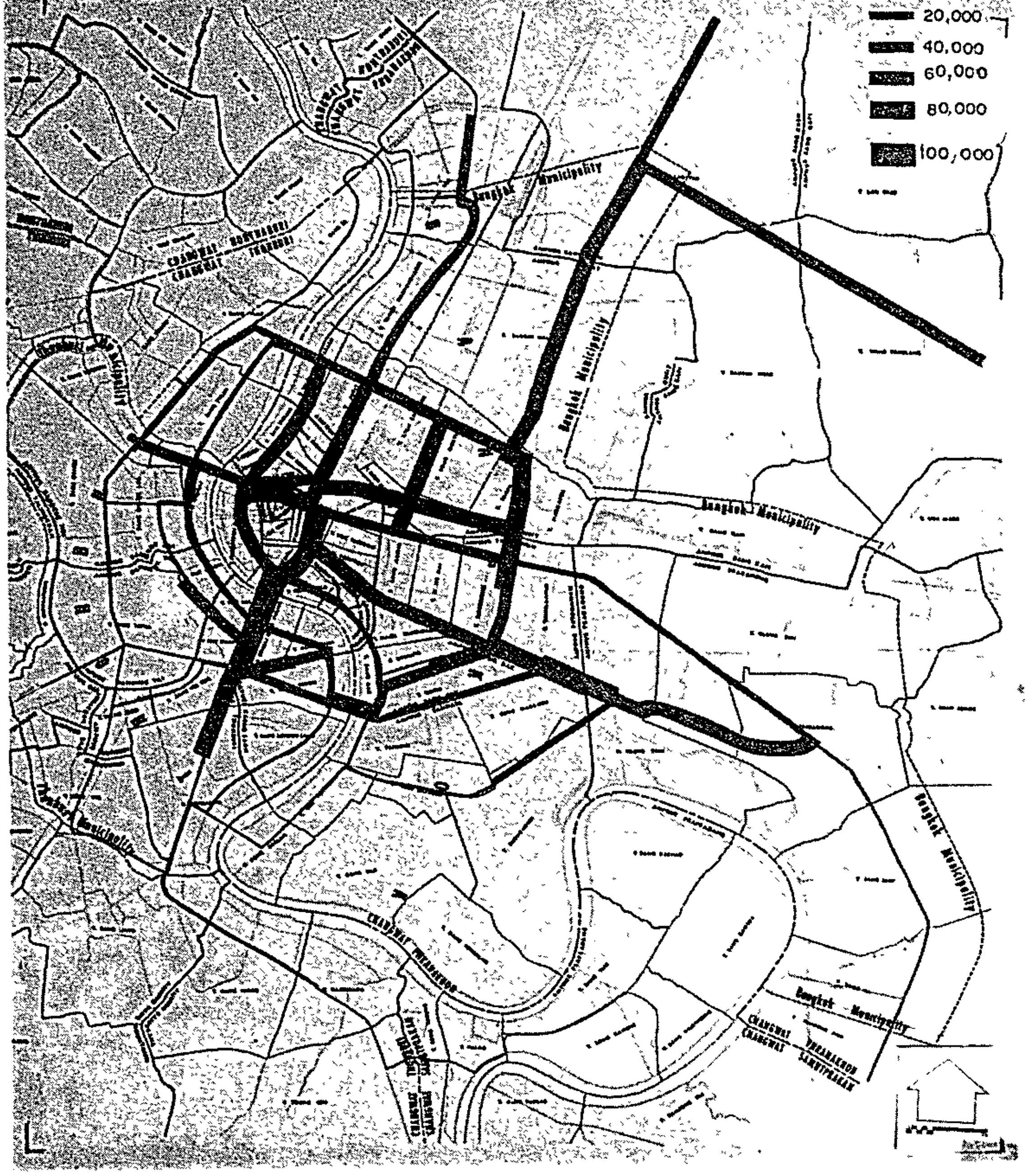
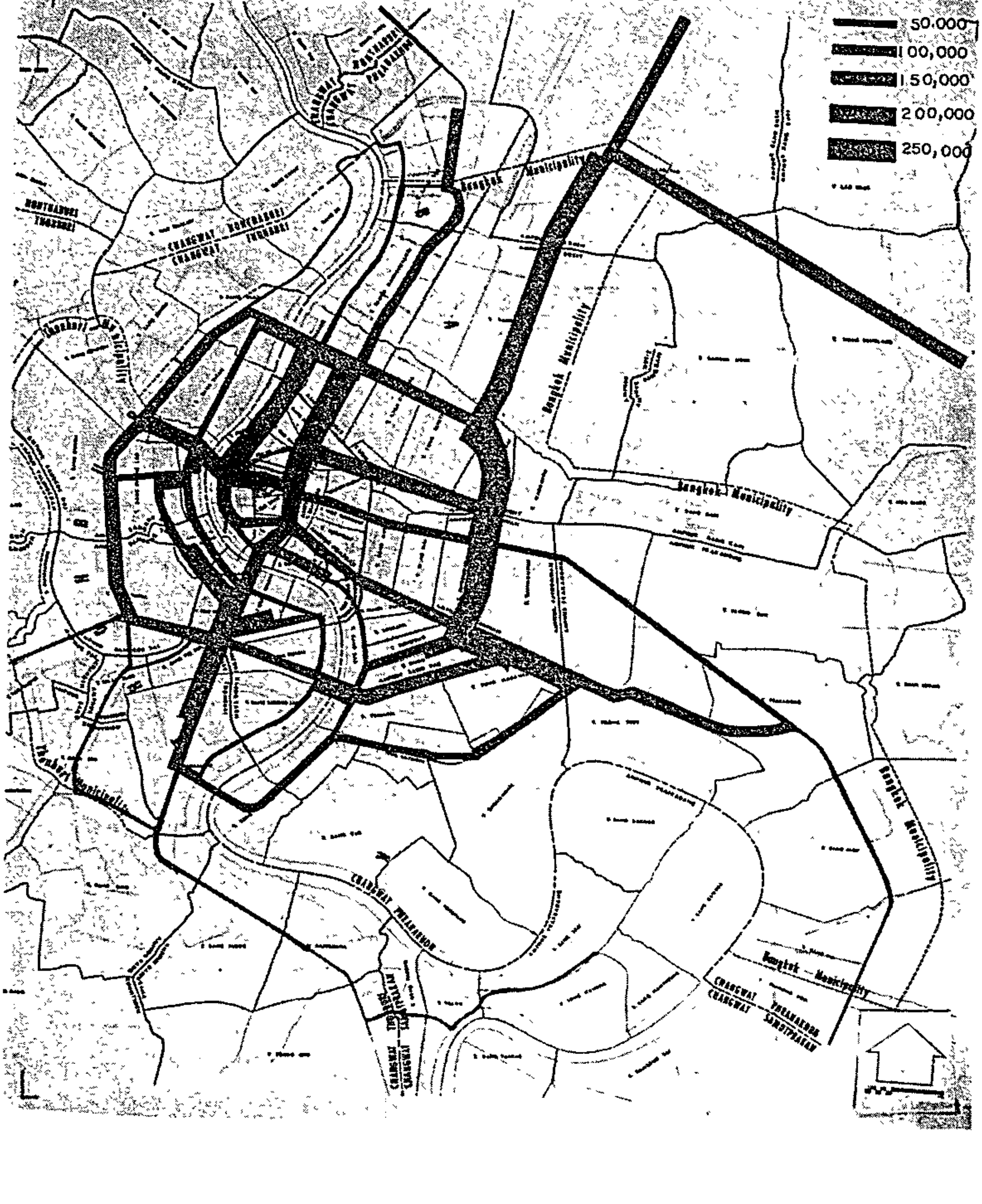


FIG. 4.5-4 TRAFFIC FLOW AT 1990



5. CONSTRUCTION STANDARDS

The construction standards are as follows:

(1) Design Speed

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

(2) The Structure of Bangkok-Thonburi Bridge

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

(b) The width of road way is 21m for six lanes, in both sides of which are installed side walks of 2.5m wide. Therefore the clear distance between hand-rails becomes 26m.

(c) Reinforced concrete pylons are installed at the both ends of the bridge, and the side-walks shall be guided to the ground through the stairs equipped around the pylons.

(d) The approach portions in Bangkok side and Thonburi side have only the road way equipped with curbs or 0.5m wide and 0.2m high in its both sides. The hand rails of wall type should be made of reinforced concrete.

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

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

(g) The navigation channel should be secured with the width of 60m and the clearance under the girder of 11.5m (above M.S.L.) at the center of the main bridge.

(h) The clearance under the girder of 5.15m should be secured at vertical crossing with a road.

(i) The water supply conduit having the diameter of 0.5m and power and telephone cables are expected to be installed with main bridge.

(3) The Structure of Bangkok-Noi Bridge

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

(b) The width of road way is 14m for 4 lanes, in both sides of which are installed side walks of 2.5m wide. Therefore the clear distance between hand-rails becomes 19m.

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

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

(e) The navigation width of 15.0m and minimum clearance under the girder of 5.42m (above M.S.L.) should be secured at the crossing of Bangkok Noi Canal.

(f) The portion overcrossing railways has to be so designed not to invade the construction limit illustrated in the Fig. 5 - 1.

(g) The clearance under the girder of 5.15m should be secured at vertical crossing with a road.

(4) The width of the Related Roads (Fig. 5-2 – 5-5)

(a) The standard cross section of the road connecting Bangkok Thonburi Bridge with Charan Sanit Wong Rd. is shown in Fig. 5-2.

(b) The standard cross section of Charan Sanit Wong Rd. is shown in Fig. 5-3.

(c) The standard cross section of reconstruction part of Issra Phap Rd. (New) and the road extention beyond Bangkok-Noi Canal are shown in Fig. 5-4 and Fig. 5-5 respectively.

(5) The Design of Bridges

(a) The design load will be computed on the basis of the Japanese design standard.

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

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

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

(e) The impact load against the pier should correspond to the static load equal to 100 tons at M.S.L.

(f) The range of temperature change will be judged by Japanese Team in reference to meteorological data.

(g) The design is to be followed the pattern of "Standard Specifications for Highway Bridges" adapted by the American Association, the latest publication. The theory, for calculation of prestressed concrete and reinforced concrete, is to be used that of the "American Concrete Institute (A.C.I.) 1966.

(6) Others

(a) The illumination facilities shall be installed with Bangkok-Thonburi Bridge. The standard luminous of it will be over 10 lux.

(b) Concrete Pylon: The structure must be reinforced concrete of the size 4.00 x 6.00m and with the height approximately of 20.00m. Thin sheet of marble is needed for decoration in some part. There must be the name of the Bridge fixed at the base. Luminour light is also needed at the pylon. Architectural detail will be given by Thai Government.

(c) The road way is to be paved with asphalt concrete, while side walk with cement concrete.

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

According to above-mentioned items, the principals of the design and planning are as follows:

(1) Bangkok-Thonburi Bridge (Fig. 5-6)

(A) Main Bridge

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

(b) Since the main span length greater than 60m is required for the navigation in Chao Phya River, the recommendable number of span to be subjected to the comparative design is five or three.

(c) Among various types of pre-stressed concrete bridges, 3 or 5 span continuous bridge in use of Dywidag Method is considered recommendable from the view points as follows:

The span length is greater than 60m. The depth of water at the proposed erection site being more than 12m, temporary support work during construction is difficult. The construction work should not interrupt navigation seriously. By the Dywidag Method, form work, placing of steel and concrete, and pre-stressing work can be made on a movable working platform called "Vorbauwagen" placed on the bridge girder. The girder starting its construction from the part above a bridge pier is extended in both direction symmetrically like cantilever beams. Therefore this method does not need support work or scaffold which may interrupt navigation during construction. The bridge constructed by this method is adapted to have relatively large span as it becomes 3 or 5 span continuous girder bridge equipped with a hinge movable laterally in its center span.

(d) With respect to the sub-structure, among various types of foundation, on the basis of soil properties obtained from the exploration described in Chapter II-1, steel pipe piles, prestressed or reinforced concrete piles and pneumatic caissons are selected and subjected to our comparative design. The open caisson or well is not recommended because the open caisson having required size more than 20m long is not likely to be sunk to a required depth with required accuracy in its precisely correct location. The cast-in-place pile or caisson is not recommended because this type of foundation is considered not dependable as a foundation supporting 5,000 to 10,000 tons load to the pier or abutment considering a soft and compressive clay observed and tested as described in Chapter II-1.

(e) The steel pile foundation is so designed as to have a footing above M. S. L. supported by steel pipe piles resting on dense sand at the elevation -10.00 (45.00m below M.S.L.). For the piers, the foundations supported by steel pipe piles resting on dense sand and gravel of the layer F in Fig. 1-2 are recommended. The piles resting on the layer D are worthwhile to consider, but 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 abutments, however, the piles resting on the layer D are recommendable because the sandy soil of the layer D is enough compacted as observed in the results of the standard penetration test at the location of the abutments and the load to the abutments is less than half of the one to the piers, or safely supported by the piles resting on the layer D without deterimental differential settlement with respect of the foundations of the piers. As shown in Fig. 5-6, the pier supported by steel piles have a considerably large footing always showing itself above water level, though it will not disturb navigation seriously.

(f) In case of pneumatic caissons, the method sinking two caissons of circular cross section parallel each other and the method to sink a single caisson having rectangular cross section. The former type of foundation or circular caisson is to penerate through hard clay presumably existing from EL. +16.10 to EL. +7.36m and rest on the sand underlying the hard clay. However, after studying the results of boring carried out in the river bed, pneumatic caissons are considered not recommendable, Sandy clay of the layer D is not stable by the thickness of the layer in the river bed. The depth of the caisson haveing enough bearing capacity may exceed 30 m. below the mean water level which gives maximum allwable atomospheric pressure to the laborers working at the bottom of caissons.

(g) The cost of consturction for the main bridge of 3 span and 5 span has been roughly estimated together with the cost of comparative types of foundations. The cost of 3 span is a little higher than 5 span if it is compared with respect to the super structure only, but the overall cost including foundations is almost equal for either 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 5-6 and Fig. 5-7)

(a) The Bangkok side approach is guided to the ground in the shortest distance as possible 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 is going to be built on the canal, special attention was paid in design not to loose the mechanism of the canal. It was also intended to provide wide 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.

(c) For the sub-structures in this portion, rectangular or circular P.C. piles of 30 to 40cm size popularly used in this country were recommended. The super-structure was designed using 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 in the approach bridge and the related roads, the traffic as far as the Royal Hotel crossing has to be considered together. In other words the road in front of the National Theater, the roads facing to the Department of Medical Science of Soldiers, the road in the eastern side of the National Theater and loop way around the plaza of elliptical shape have been made oneway traffic. As the results of this oneway control, the vehicles out of Chakrapong Road can not proceed to the Bangkok-Thonburi Bridge directly as the U-turn of traffic in front of the Royal Hotel crossing is prohibited. Then vehicles have to proceed to the approach bridge after going around the Plaza of elliptical shape. However, the detour in a few minutes is considered inevitable in order to increase the overall traffic capacity of this area. The route in the left side of a creek was made four lanes for making the traffic from Thonburi side to Bangkok flow smoothly. For this purpose one lane has to be expanded to the creek. Then an additional bridge crossing the creek is required for both traffic from Thonburi to National Theater and the traffic from south through Chakrapong Road.

(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. 5-6)

(a) Thonburi side approach having no structural restriction was designed using same type of structures as Bangkok side approach.

(b) It was planned to utilize the right of way of 100m wide as a small bridge side park which allow parking of 80 vehicles. The detail of gardening is expected to be designed by Thai Government separately.

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

(2) Bangkok-Noi Bridge (Fig. 5-8)

(a) Bangkok Noi Bridge crosses over Bangkok Noi Station Yard and Bangkok Noi Canal. At the Station Yard, the clearance of 5.10m being required, the formation of the bridge was decided from this requirement.

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

(c) According to the results of soil exploration the restressed concrete piles are recommended for the foundations.

(d) For the foundation of bridge piers, prestressed concrete piles were recomended. The footing capping those concrete piles shall be constructed above the M.S.L. Three piers in the Noi Station Yard were made cylindrical piers for the convenience of trucks loading in cargo coaches.

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

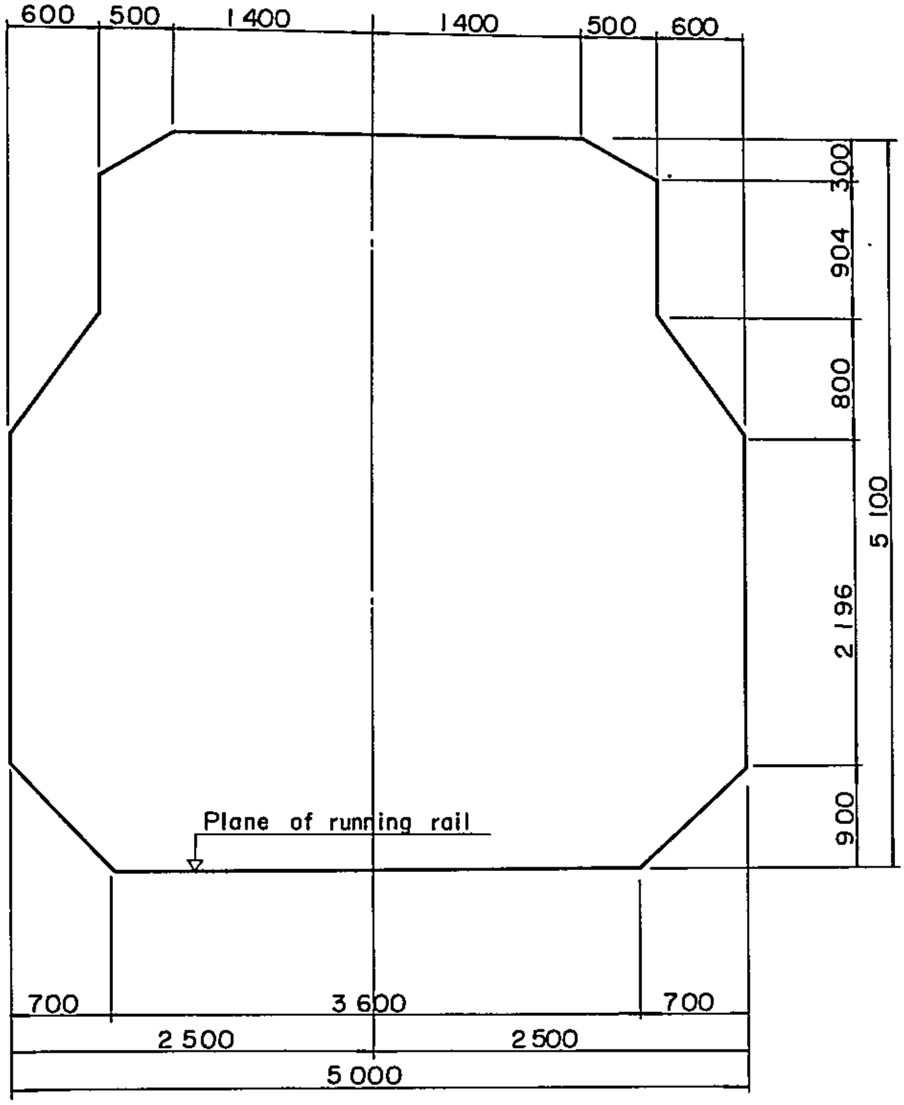
(f) A ramp way shall be installed near the station yard in order to take the approach traffic to Bangkok Noi Station. A part of the main bridge has to be expanded for this purpose.

(3) The Planning the Related Roads in Thonburi Area (Fig. 5-9 – 5-11)

(a) During initial period of planning. Thonburi inner circle line consisting of two roads which intersect perpendicularly with the planned radial street connecting Bangkok-Thonburi Bridge to Charan Sanit Wong Rd. was taken into consideration.

(b) According to this plan, it was necessary to construct two bridges in 500m interval in Bangkok Noi Canal. The plan had the demerit that those two bridges had to cross over the yard of Bangkok Noi Station.

(c) The outside road of the inner line (Arun Amerin Rd.) has already been widened up to the side of the yard, but in order to extend this road, a bridge of 760m long crossing both station yard and canal was required. Besides the distance from this road to the Outer Circle Line (Charau



unit: mm

Fig. 5 - 1 CLEARANCE DIAGRAM FOR ROAD BRIDGE OVERHEAD CROSSING

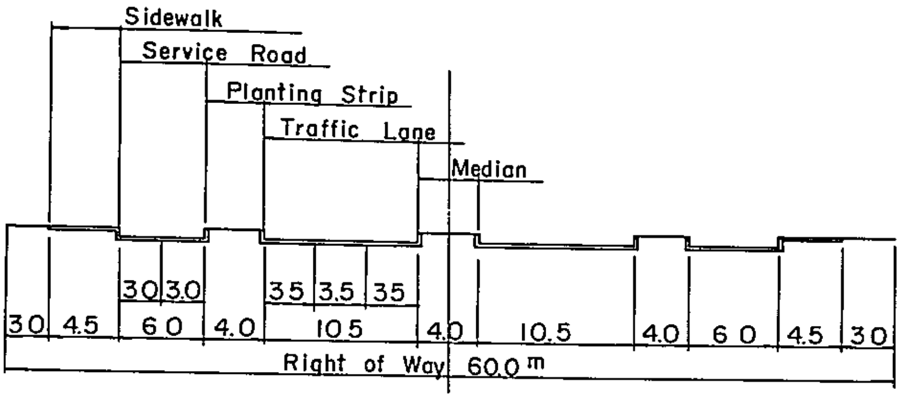


Fig.5-2

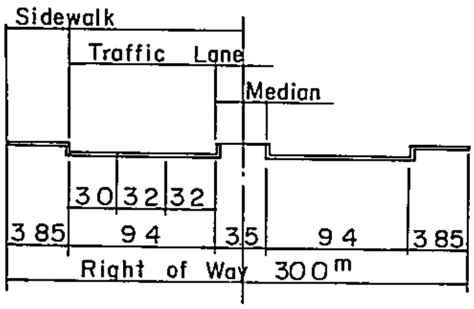


Fig.5-3

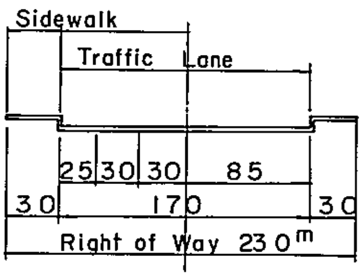


Fig.5-4

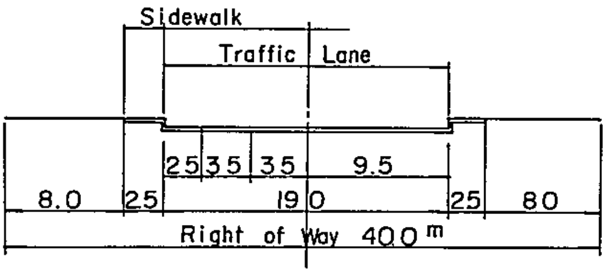
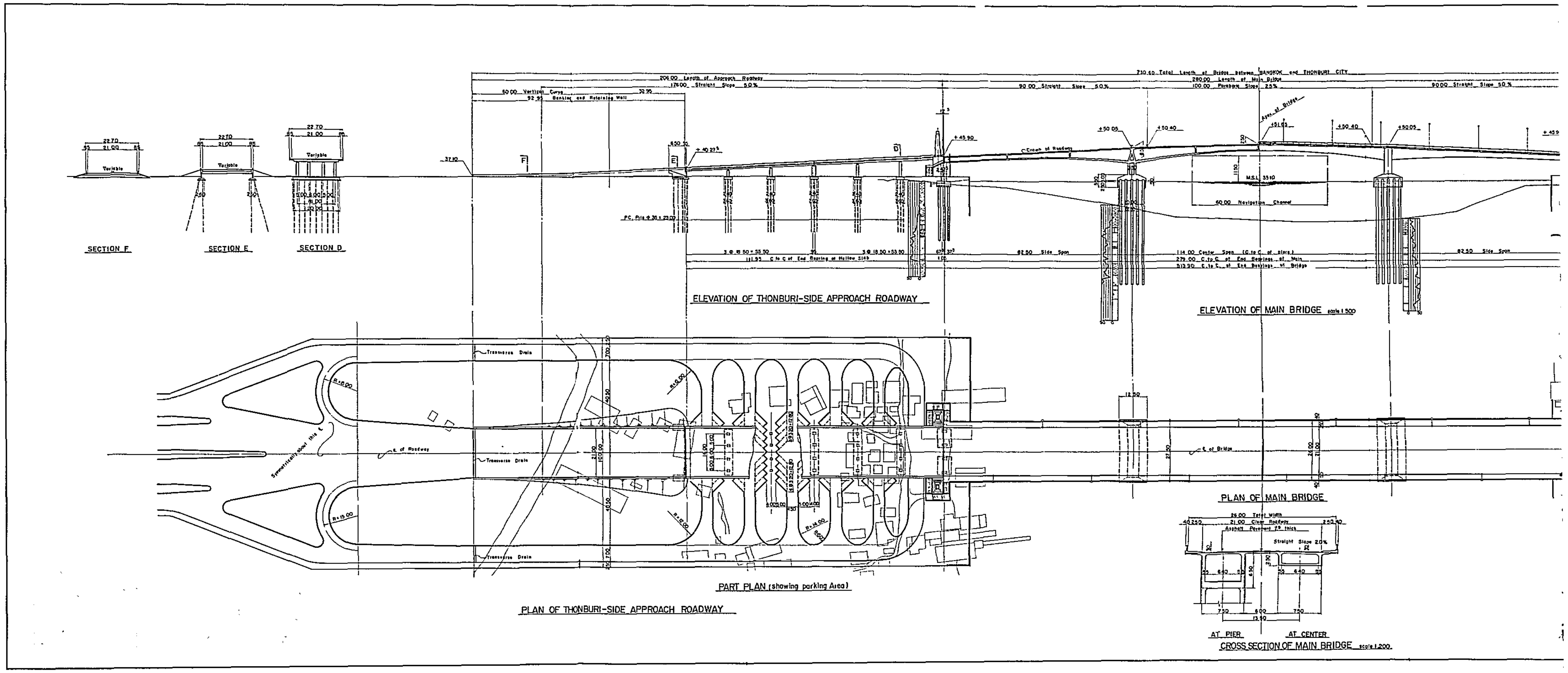


Fig.5-5


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
AT PIER
AT CENTER
CROSS SECTION OF MAIN BRIDGE scale 1:200

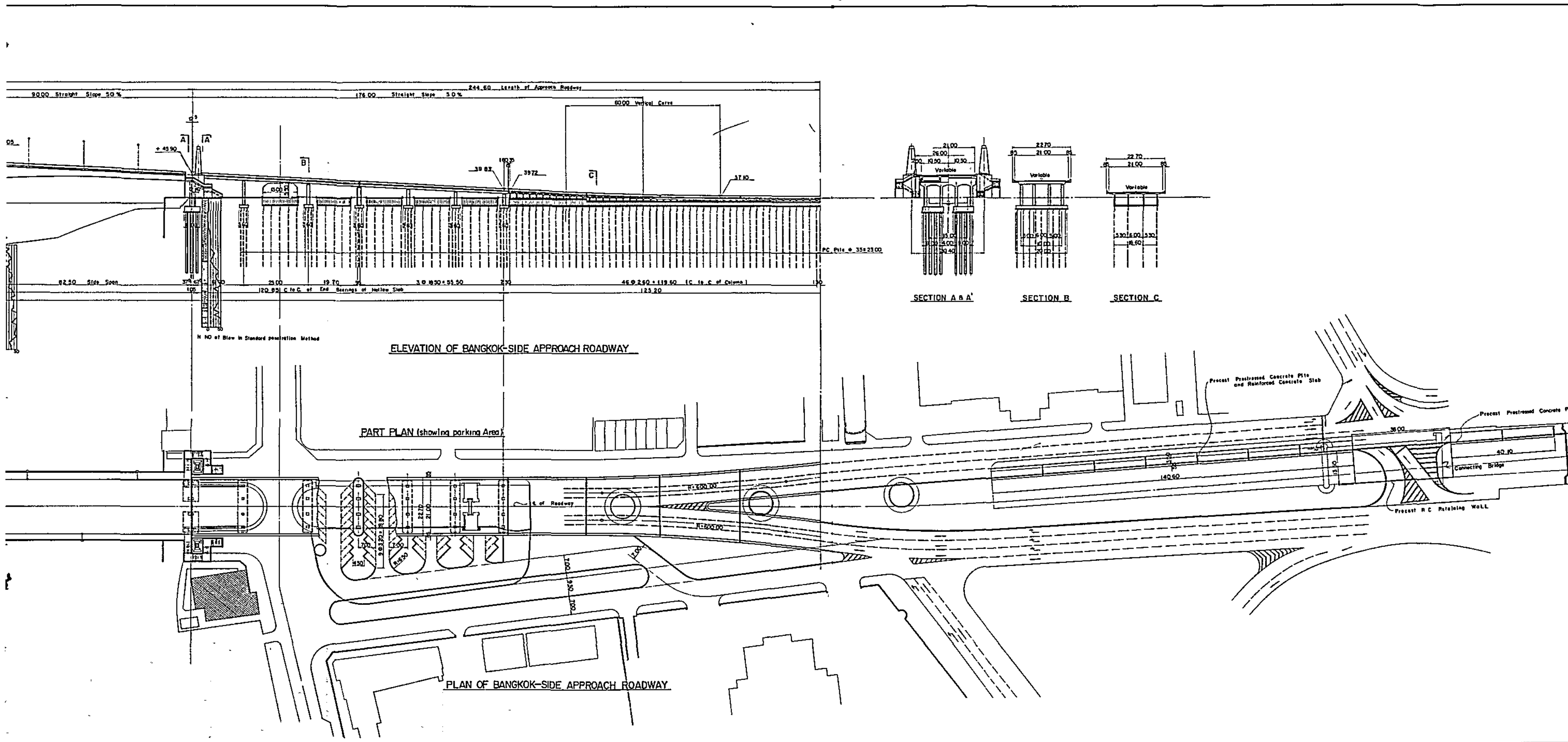


FIG 5-6
GENERAL VIEW
OF
BANGKOK THONBURI BRIDGE

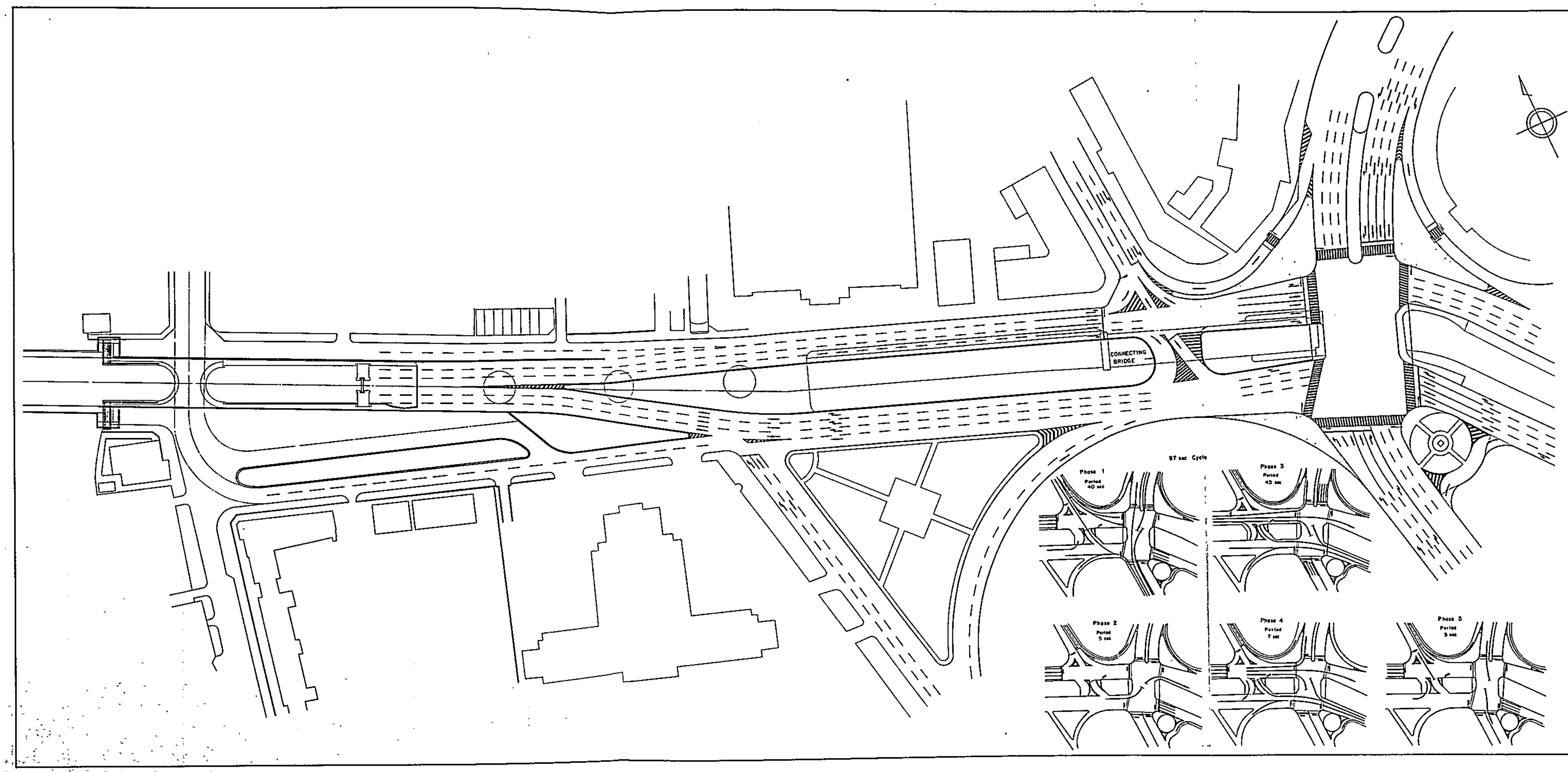


FIG 5-7

PROPOSED TRAFFIC FLOW UPON THE COMPLETION OF CONNECTING BRIDGE

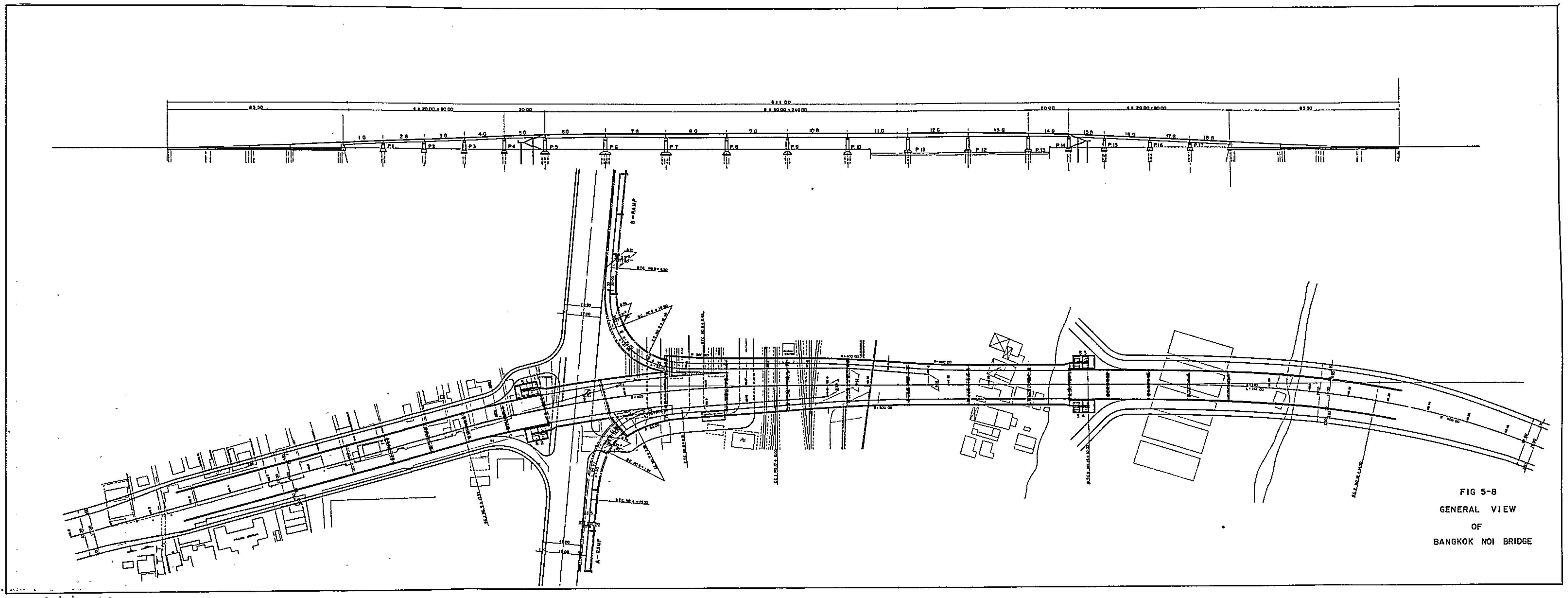


FIG 5-8
GENERAL VIEW
OF
BANGKOK NOI BRIDGE

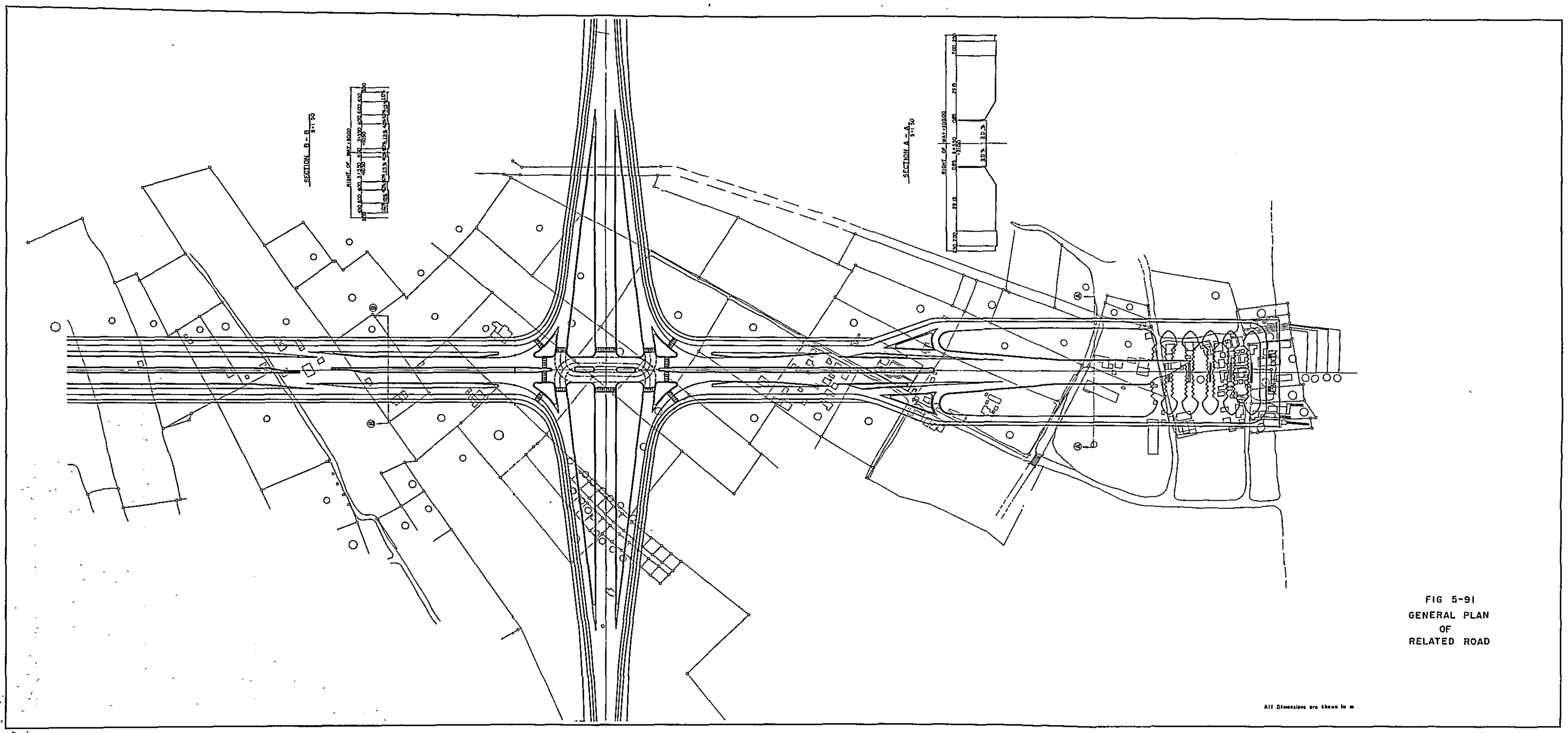


FIG 5-91
GENERAL PLAN
OF
RELATED ROAD

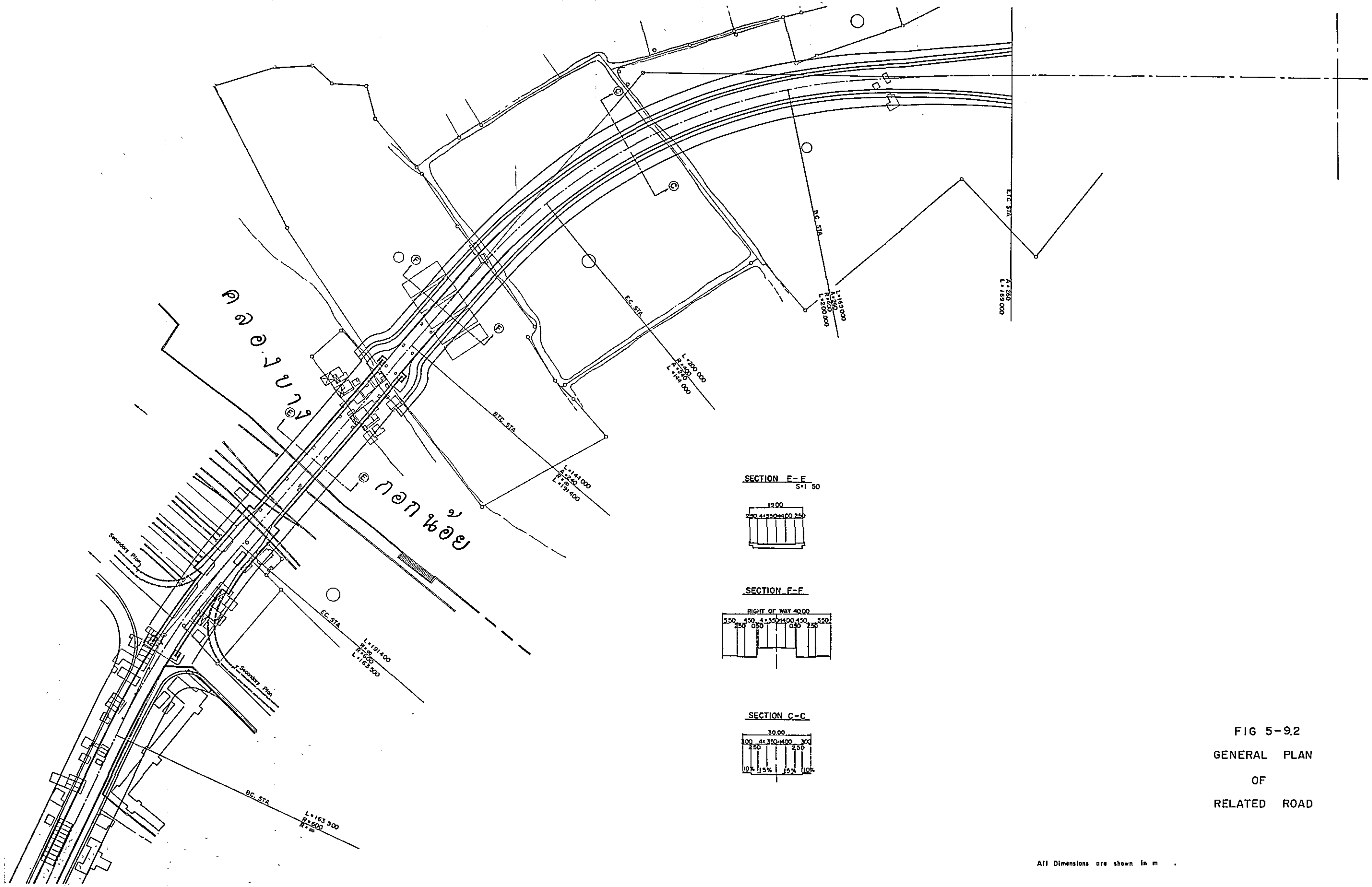


FIG 5-9.2

GENERAL PLAN

OF

RELATED ROAD

All Dimensions are shown in m .

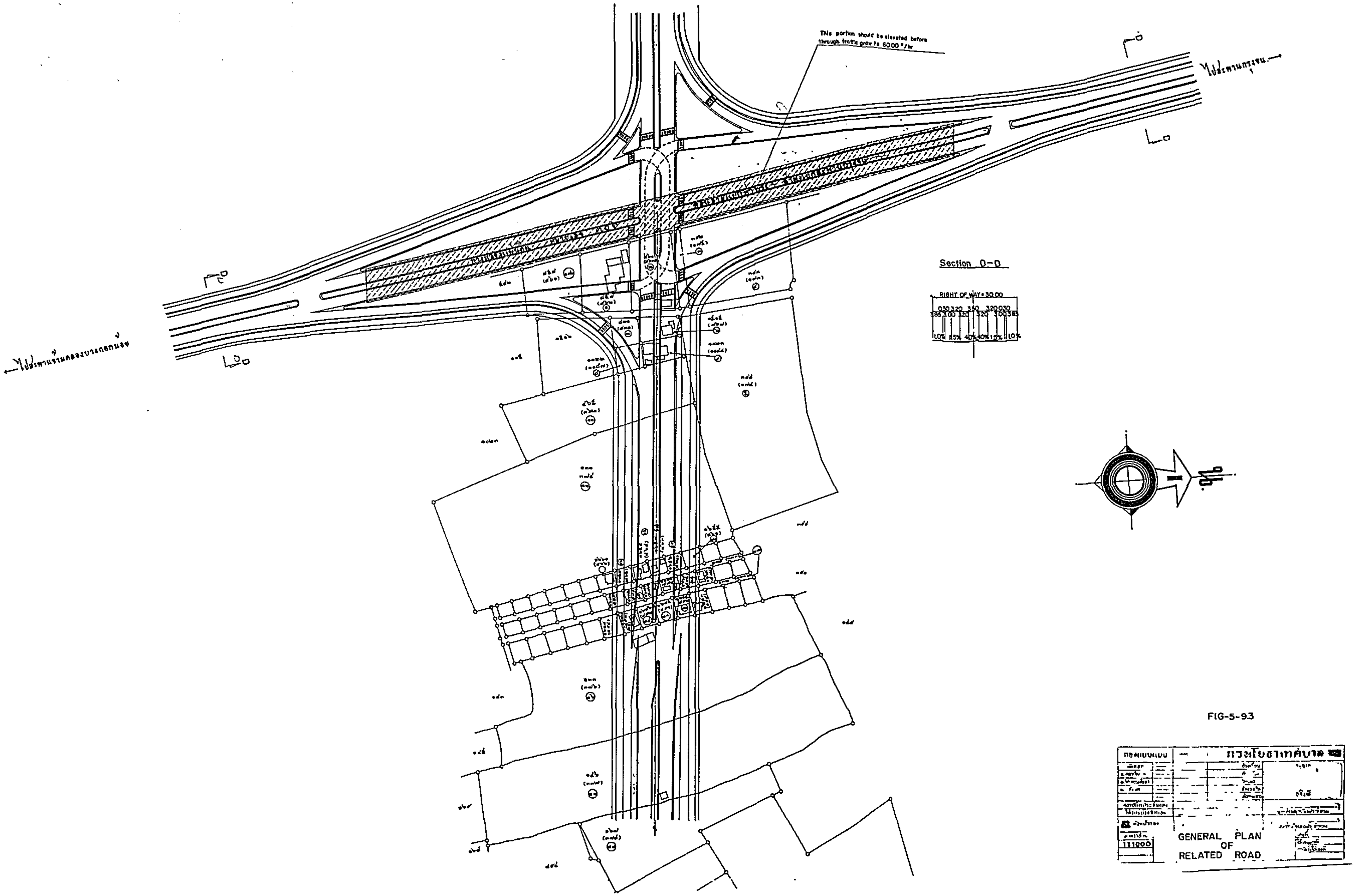

This portion should be elevated before through traffic grow to 6000 V/hr
ไปสะพานกรุงธน
ไปสะพานข้ามคลองบางกอกน้อย
Section D-D
RIGHT OF WAY = 30.00
กองแบบแผน
กรมโยธาเทศบาล
1:1000
GENERAL PLAN OF RELATED ROAD

FIG-5-93

Sanit Wong Rd.) is only 500m, and it becomes shorter as the road goes to north.

(d) The inside road of the inner line (Arun Amarin Rd.) is enough with a bridge of 570m span for crossing Station Yard and canal. The distance from the Outer Circle Line can be about 1000m. Therefore this road is supposed to be more effective than the outside road with respect to the configuration of the trunk streets. Moreover Department of Town Planning has already considered this road involved in the city planning.

(e) From those mentioned above, as the Thonburi Inner Circle Line, we recommend the inside road of the inner line extending Arun Amarin Phap Rd.

6. TYPE OF EQUIPMENTS AND/OR MATERIALS TO BE IMPORTED

The type of equipments and materials to be imported are roughly described in Table 6-1.

Table 6-1. Type of Equipments and/or Materials to be Imported

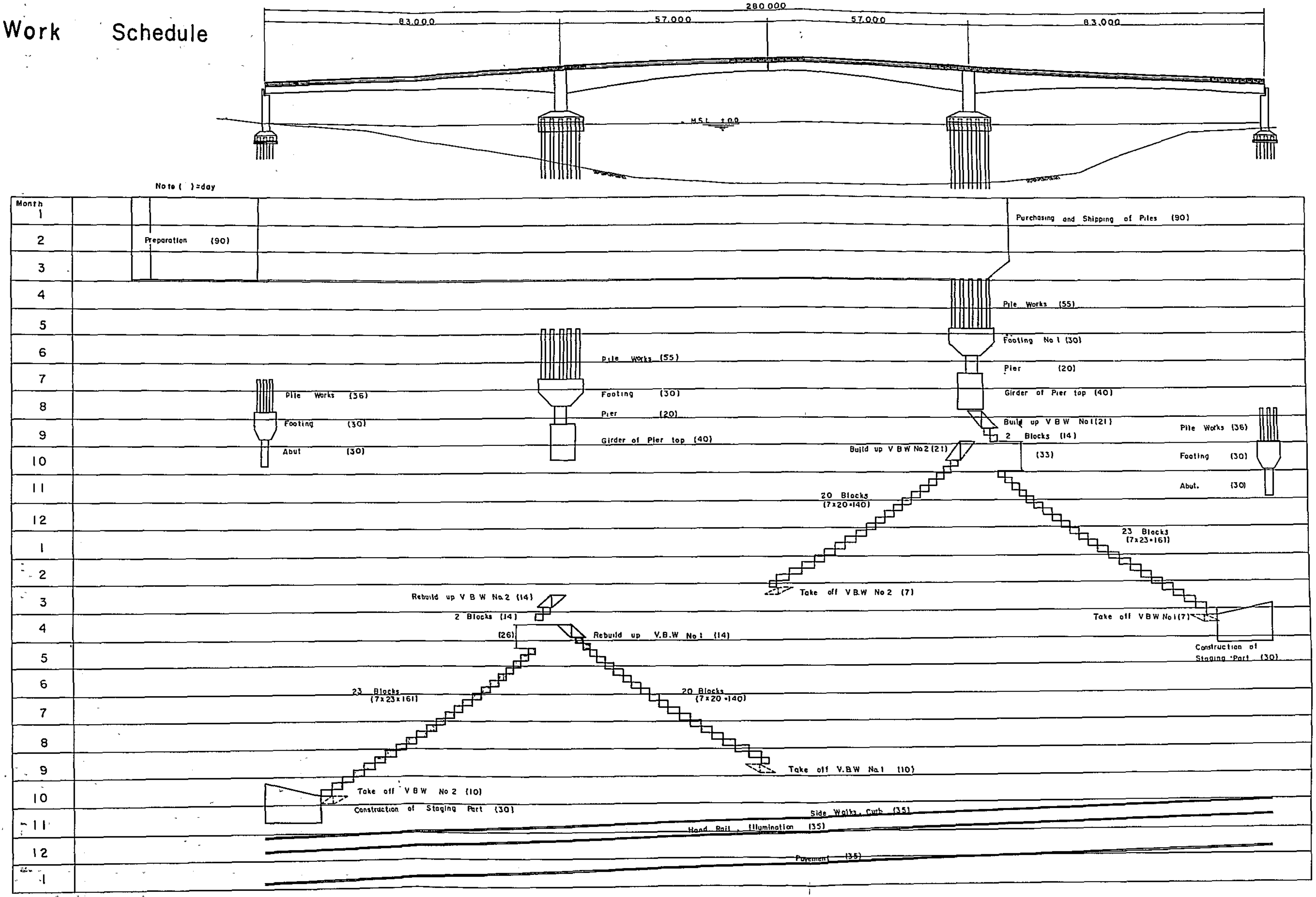
Item	Unit	Bangkok-Thonburi Bridge				Bangkok Noi Bridge	Total
	Part	Main Span	Approach Bangkok Side	Approach Thonburi Side	Total		
Steel pipe	t	21,200					21,200
Reinforcement	t	1,150	750	510	2,410	710	3,110
P.C. Steel	t	630	90	20	740	140	880
Concrete	m^3	13,300	6,300	3,800	23,400	7,600	31,000
Other materials and facilities	1,000 Bahts.	1,000	600	200	1,800	900	2,700
Major construction machine & equipment	1,000 Bahts.	6,300			6,300		6,300
Freight charge over sea	1,000 Bahts.	7,400	500	300	8,200	600	8,800

7. CONSTRUCTION SHEDULE

Regarding the period of construction, the period from start of construction to the completion of it, it takes about two years and one month. The detail of work schedule is shown by an operation diagram of Fig. 7-1.

Fig-7-1

Work Schedule



CHAPTER II. TECHNICAL FESIBILITY

1. TECHNICAL INVESTIGATION

(1) Soil Exploration

With respect to the proposed site of Bangkok-Thonburi Bridge, boring of Hole No. 1, No. 2, No. 3, No. 4 and No. 7, five holes in total, was advanced to the maximum depth of 50m. 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 drill holes are illustrated in Fig. 1-1.

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 soft clayey soil in relatively shallow depth was measured by vane shear test. The shear strength and deformation characteristics of clayey or sandy deposits was measured by pressure meter test.

Undisturbed samples of clayey soil were taken out of drill holes No. 4, No. 5 and No. 7 by means of thin wall tube sampler or Denison sampler. For those twenty samples, unconfined compression test, triaxial compression test and consolidation test as well as test for index properties of soil such as density, water content or Atterberg limits.

The results of laboratory soil testing are summarized in Table 1. Connecting the boring logs, the distribution of soil layers at the site of Bangkok Thonburi Bridge and Bangkok Noi Bridge is shown in Fig. 1-2 and Fig. 1-3 respectively. The detail discussion on the results of soil exploration will be separately reported together with the detail design of this project.

(2) Topographic Survey

Japanese Team has carried out cross-sectional distance survey along the proposed center line of Bangkok-Thonburi Bridge and the sounding of Chao Phya River. Japanese Team has also completed the plain survey of two hundredth (1/200) scale in the vicinity of Bangkok Noi Station along the proposed center line of Bangkok Noi Bridge. All of land survey along the center line of the road extended beyond Bangkok Noi Canal shall be undertaken by Thai Government.

(3) Others

As regards to the meteorological data and hydrological informations of Chao Phya River, Table 1-1 is to be utilized.

Table 1 - 1 Summary of Soil Test

(Bore Hole No. 4, 5)

Sample No.		S4-1	S4-2	S4-3	S4-4	DS-4-5	DS4-6			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
West 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 •		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.P. (%)		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						
Triaxial Compression Test	Angle of Internal Friction in degree												
	Cohesion (kg/cm^2)												
	Drainage Condition												
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
Remarks													

Fig I-1 PLAN OF BORING SITE

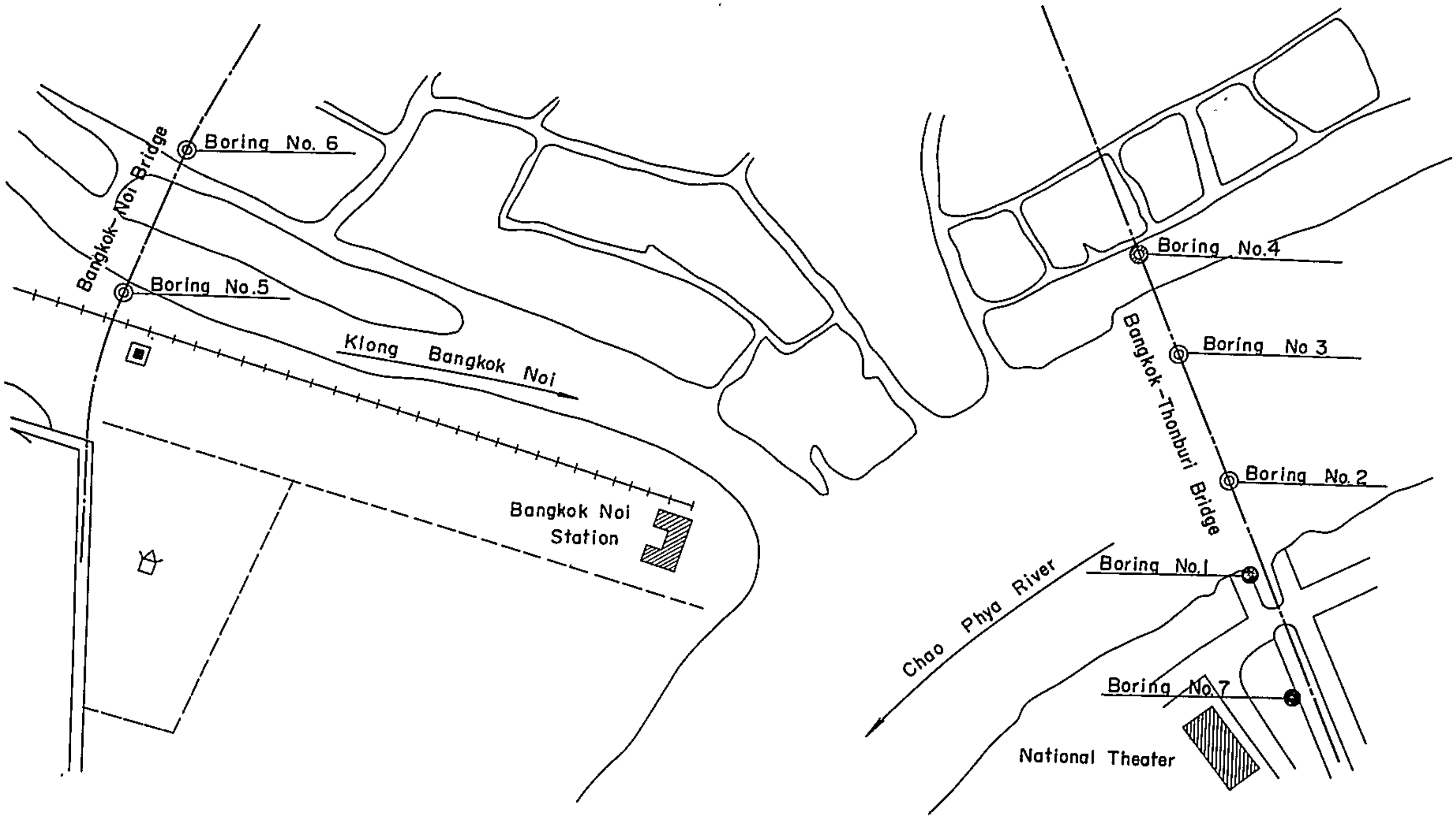


Fig-1-2 SOIL PROFILE OF BANGKOK-THONBURI BRIDGE S: H: 1/500 V: 1/200

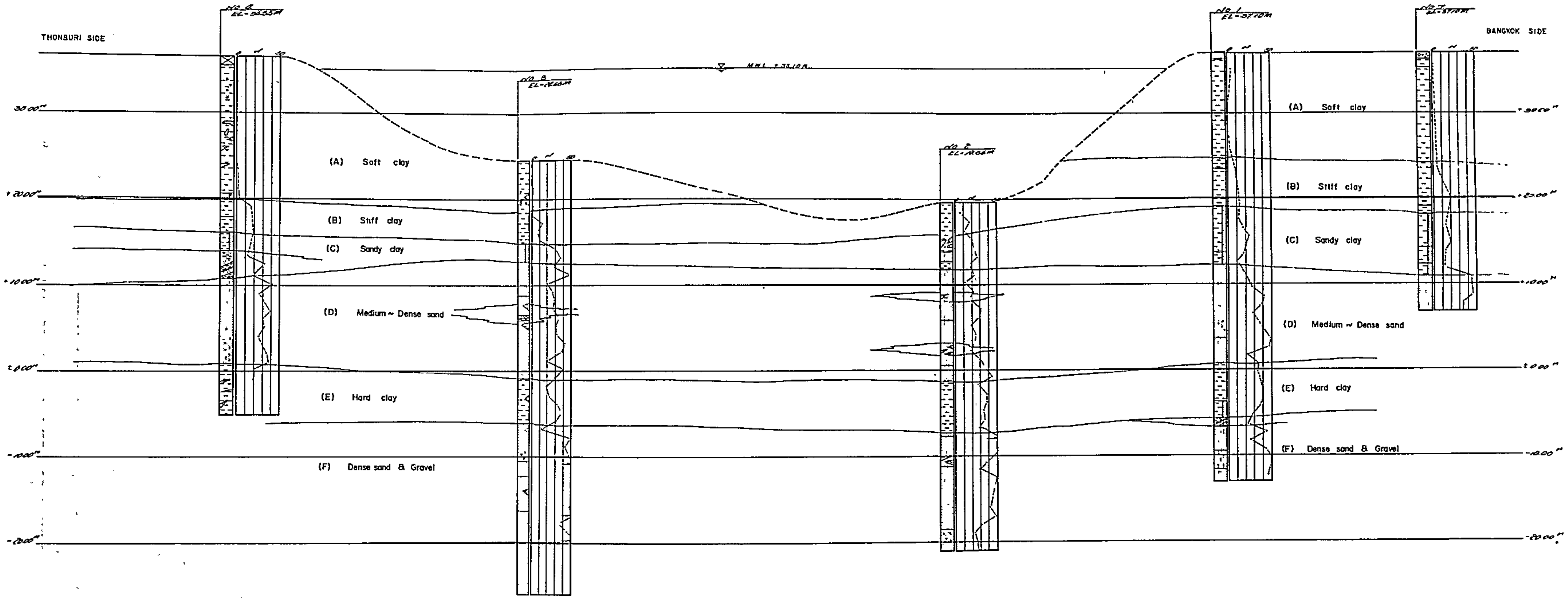
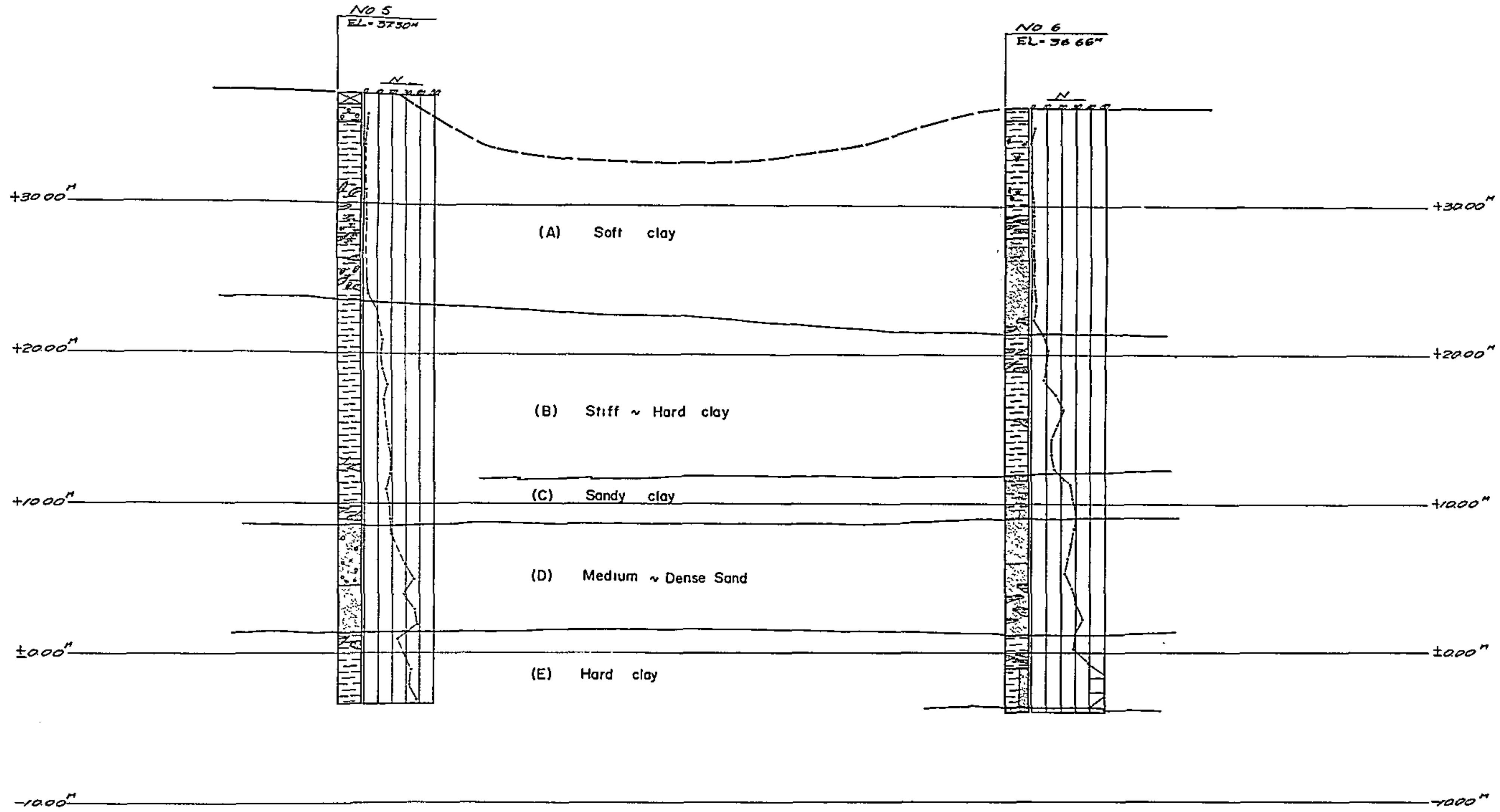


Fig-1-3 SOIL PROFILE OF BANGKOK-NOI BRIDGE S = H : 1/500, V : 1/200



CHAPTER III.

ECONOMIC FEASIBILITY AND FINANCIAL ASPECTS

1. ESTIMATED PROJECT COST

The major construction materials are briefly described in Table 1-1.

The cost of construction is roughly estimated in Table 1-2. Regarding taxes, duties and miscellaneous expenditures, more detail study on them and correction to the estimated amount is considered necessary.

The time of investment is shown on Table 1-3.

Table 1-1. List of Major Construction Materials

Item	Unit \ Part	Bangkok-Thonburi Bridge				Bangkok Noi Bridge	Total
		Main Span	Approach		Total		
			Bangkok Side	Thonburi Side			
Steel pipe	t	2,120					2,120
Reinforcement	t	1,150	750	510	2,410	700	3,110
P.C. Steel	t	630	90	20	740	140	880
Concrete	m^3	13,300	6,300	3,800	23,400	7,600	31,000
Cement	t	5,500	2,600	1,400	9,500	3,000	12,500
Concrete pile	Each		400	300	700	500	1,200

Table 1-2. Estimation of Construction Cost

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.	
Major Construction Materials: Steel pipe		8,200						8,200				8,200		8,200
Major Construction Materials: Reinforcement		2,600		1,700		1,200		5,500		1,600		7,100		7,100
Major Construction Materials: P.C. Steel		7,300		700		100		8,100		1,200		9,300		9,300
Major Construction Materials: Cement			2,700		1,300		700		4,700		1,500		6,200	6,200
Major Construction Materials: Concrete pile					1,800		1,400		3,200		2,300		5,500	5,500
Others (labour, others materials, facilities)		1,000	14,600	600	13,700	200	5,600	1,800	33,900	900	13,700	2,700	47,600	50,300
Major construction machine & equipment		6,300						6,300				6,300		6,300
Freight charge over sea		7,400		500		300		8,200		600		8,800		8,800
Import tax	15%		3,800		400		200		4,400		700		5,100	5,100
Sub-total		32,800	21,100	3,500	17,200	1,800	7,900	38,100	46,200	4,300	18,200	42,400	64,400	106,800
Miscellaneous expenses & taxes	20%		10,800		4,200		2,000		17,000		4,500		21,500	21,500
Total		32,800	31,900	3,500	21,400	1,800	9,900	38,100	63,200	4,300	22,700	42,400	85,900	128,300
		64,700		24,900		11,700		101,300		27,000				

Note : F.C. = Foreign Currency

L.C. = Local Currency (1000 - Bahts.)

Table 1-3. Time of Investment

(1,000 Bahts)

Year / Currency	1st	2nd	3rd	Total
Local	36,100	41,200	8,600	85,900
Foreign	40,800	1,600	–	42,400
Total	76,900	42,800	8,600	128,300

2. MAINTENANCE AND OPERATION COSTS (ANNUAL)

Annual maintenance and operation costs have been worked out on the basis of our past experience in the Meishin (Nagoya - Kobe) Highway Project in Japan. Table 2-1 tabulates the anticipated maintenance and operation costs. It will be appreciated that these costs would be relatively low during early years after construction, but that the costs will gradually increase as the year goes by. We have given in the table a mean value.

Incidentally, the costs given in the table do not include the costs for restoration, repair, etc., that may be caused through accidents, natural calamities, or the like, and costs for government officers assigned to maintenance and inspection, so that annual maintenance and operation costs is shown Table 2-1.

Table 2-1 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 and contruction, joint, minor repair, etc.</td><td>1.39/m. lane. year</td><td>Roadway Sidewalk
750m x 6 + 280m x 2
= 5,060m</td><td>7,028</td><td>Past experience in Meishin Highway.
5.56/m. 4 lane year
Sidewalk considered as 1 lane.</td></tr>
<tr><td colspan="2">Painting</td><td>22.22/m². 6 year</td><td>5,789m² x 1/6 + 270m² x 1/2 (Illuminating pole) = 1,100m²</td><td>24,446</td><td>Painting is done every 6 years. Thus, 1/6 of the entire painting work is considered for each year. Illuminating pole is repainted every 2 years.</td></tr>
<tr><td rowspan="3">Asphalt</td><td>Repair</td><td>0.69/m². year</td><td rowspan="3">750m x 21m (Roadway) + 280m x 2.5m x 2 (Sidewalk) = 17,150m²</td><td>11,911</td><td>After completion, traffic will increase as follows Thus, 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>4</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>15</td><td>16</td><td>16</td><td>17</td><td>17</td><td>12.5</td></tr>
</table></td></tr>
<tr><td>Repaving</td><td>0.06/m². 15 year</td><td>69,876</td><td>Thus, average rate is taken for estimation. Once every 15 years, meaning 1/15th each year.</td></tr>
<tr><td>Total</td><td>——</td><td>81,787</td><td></td></tr>
<tr><td colspan="2">Lane mark</td><td>3.89/m. year</td><td>750m x 5 = 3,750m</td><td>14,585</td><td></td></tr>
<tr><td colspan="2">Power for illumination</td><td>0.56/kw</td><td>0.4kw x 36 units x 365days x 0.6</td><td>17,521</td><td>At mid-night, eight illuminates only at 0.6% brilliance.</td></tr>
<tr><td colspan="2">Lamp</td><td>355.58</td><td>36 units x 0.6</td><td>7,681</td><td>60% should be replaced each year.</td></tr>
<tr><td colspan="2">Cleaning</td><td>0.69/m. lane. year</td><td>Roadway Sidewalk
750m x 6 + 280m x 2
= 5,060m</td><td>3,514</td><td>Past experience in Meishin Highway
Sidewalk only one lane.</td></tr>
<tr><td colspan="2">Total</td><td></td><td></td><td>156,562</td><td></td></tr>
</table>

3. BENEFIT OF THE PROJECT

3-1. Type of Bebefit and Unit Cost

The benefit of road investment from the economic aspect could be far-reaching and numerous Such benefits as traveling and time are generally considered hither to as a normal benefit to the users of the project road, giving them a real monetary benefits. The present report is in line with the above policy and thus traveling and time benefits are only discussed herein.

The traveling benefit herein referred to is the saving on the traveling costs of vehicle and the time benefit the shortening of transporting time. We consider these benefits the benefits of the entire road network in Bangkok and Thonburi.

Section 4 deals with the computation of benefits using the results of traffic assignment as worked out in Chapter I, Section 4. The breakdown of types of vehicles for 1970, 1975, 1980, 1985, and 1999, were estimated in consideration of some change in the type of vehicles to be registered in such a 5-year period and general breakdown of vehicle type going and coming through the four existing bridges in 1967. The figure derived therefrom is used as a basis of vehicle type breakdown in each link and unit cost of benefit is computed by multiplying it by time unit cost by the difference of vehicle type, or by traveling cost.

When it comes to the method of computation of yearly benefit unit cost in the time benefit, multiply the mean vehicle breakdown by time unit cost on the basis of vehicle type, and add them to obtain the average time unit cost of the entire vehicles.

Now, with respect to the method of computing benefit unit costs in the traveling benefit, traveling cost may very with the speed of each vehicle passing through the link. For this reason, the traveling speed of each vehicle in each link has been derived from the result of traffic distribution in Chapter I. Section 4, but the traveling costs by vehicle type were established by dividing the traveling speed into 4 classes.

3-2 Time Benefits

To work out time benefit, time (minutes) required for a vehicle to pass each link both including and excluding the proposed bridges to be completed in 1975 is multiplied by the number of vehicle traffic each day so that the entire traffic's required time each day in the project area can be found. The time for the entire traffic each day in the project area as can be shortened due to construction of a new bridges will be given by

26, 842, 655 (min. veh/day) – 22, 728, 742 (min. veh/day)

= 4, 113, 913 (min. veh/day)

With this formula, now it is possible to estimate total time benefit as can be expected from construction of the proposed bridge, if it is multiplied by the benefit unit cost for 1975.

4, 113, 913 (min. veh/day) x 0.046/min. = 189, 240 (min.)

3-3. Vehicle's Traveling Benefit

Since vehicle's traveling costs will vary with the speed of vehicle passing through each link, the product of link distance and the number of vehicles by each speed range is combined and then multiplied by average traveling cost, so that total traveling costs can be derived. Thus, the difference produced between the amounts including and excluding new bridges becomes traveling benefits.

13, 683, 531 – 13, 080, 417 = 603, 114 (฿/day)

3-4. Benefits of the Project

The product of the benefits obtained in paragraphs 3-2 and 3-3 are the total amount of benefits, i. e.

189 + 603 = 792 (1, 000 ฿)

The above amount applies to the cost covering Bangkok-Thonburi Bridge (ling No. 85) and a bridge (link No. 87) scheduled to be connected to either the Sathorn Sathorn or Silon road, and related approaching roads. Here, in this report, the benefit amount of only the Bangkok-Thonburi Bridge and related roads in determined. In order to improve the overall road network, the ratio of the required cost for improving road network and costs for construction of the Bangkok Thonburi Bridge and related roads should be the ratio of the total benefits of the entire road network to the benefit of the Bangkok-Thonburi Bridge, etc. This ratio is 0.10, but this needs further investigation and check-up.

Ta Chang Bridge and related benefits

= 792 x 365 x 0.10 = 28, 908 (1, 000฿)

Suppose the yearly benefit increases in proportion to the growth of traffic volume through construction of Bangkok Thonburi Bridge, Table 3-4-1 shows the anticipated traffic volume through 1990 and yearly benefits. Incidentally, let it be supposed that the traffic flows does in no way exceed 120, 000 veh/day.

Table 3-4-1. Total Yearly Benefit

Year	Traffic (veh/day)	Growth Rate	Benefit (1000฿/day)
1975	48,026	1.000	792
1976	61,285	1.276	1,011
1977	74,544	1.552	1,230
1978	87,803	1.828	1,448
1979	101,062	2.104	1,667
1980	114,321	2.380	1,886
1981	120,000	2.499	1,980
1982	120,000	2.499	1,980
1983	120,000	2.499	1,980
1984	120,000	2.499	1,980
1985	120,000	2.499	1,980
1986	120,000	2.499	1,980
1987	120,000	2.499	1,980
1988	120,000	2.499	1,980
1989	120,000	2.499	1,980
1990	120,000	2.499	1,980

4. COMPARISON OF BENEFITS AND COSTS AND PLAN FOR RECOVERY OF THE INVESTED CAPITAL

First compare the project cost and the maintenance costs with the benefits obtained from Section 3. Add to the cost for building related roads from Sections 1 and 2 to the project and maintenance costs to derive 403,300 (1000 Bahts) and 2024 (1000 Bahts), respectively.

Assume that the project cost is actually invested in 1974 and its yearly interest is 8% per annum. If the costs for, and benefits from, Bangkok-Thonburi Bridge are evaluated at the time of construction, i.e., 1975

Bangkok-Thonburi Bridge costs (n number of years)

$$= 403,300 \times 10^3 \times 1.08 + 2,024 \times 10^3 \times 2,024 \sum_{i=1}^{n} (1.08)^{-i+1}$$

Benefits from Ta Chang Bridge (n number of years)

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

Where the benefit in i year is Bi.

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

$$\frac{\text{Bangkok-Thonburi Bridge and related benefits}}{\text{Bangkok-Thonburi Bridge and related costs}} = 1.79$$

Therefore, judging from the value indicated above, it can now be said that the present proposed bridge construction project will be highly beneficial then viewed from the standpoint of the national economy. The years needed before the benefits to equal the invested capital amount will be

$n = 11.68$

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