CHAPTER 2: BACKGROUND OF THE PROJECT

CHAPTER 2 BACKGROUND OF THE PROJECT

2-1 Outline of Roads in Bangkok

2-1-1 Bangkok in Brief

a. Population

The recent intensive economic development in Thailand has concentrated on the Bangkok region and has had a strong impact and development pressure on the urban system of the Bangkok area. The growth of so-called "Export-led and foreign investment-fueled" economy is significant in its size and speed. Various development activities of industries, office buildings, hotels, residences, shopping centres and other relevant commercial and administrative facilities, are taking place all over the metropolitan region. On the other hand, many existing urban infrastructures have already reached their capacity.

The population of Thailand has increased at an annual rate of 2.44% in 1970 to 1988, while that of Bangkok has a growth rate of 3.31% in the same period.

Comparative Increase in Population and its Growth Rates
for Thailand and Bangkok

Year	1970	1988	Annual Growth Rate: 1970-1988
Bangkok	3,185,000 (8.9%)	5,717,000 (10.4%)	3.31%
Whole Kingdom	35,633,000 (100.0%)	54,961,000 (100.0%)	2.44%

b. Industry and Economy

As influenced by the world-wide economic recession in the years 1980 -1985, the general trend for the growth in GDP (Gross Domestic Product) of Thailand was modest for the same years. From 1986 onward, however, Thailand witnessed an economic upturn due to the influx of investments and good export performance. Hence, the annual growth rate of GDP increased. The GDP share of BMA over the whole kingdom has been steadily increasing.

GDP at Constant 1972 Prices

(Unit: ฿ million)

Year	1980	1985	1986	1987	Annual Growth Rate	
					80 - 85	85 - 87
BMA	104,194 (34.8%)	147,986 (37.5%)	159,012 (38.5%)	178,061 (40.3%)	7.27%	9.69%
Whole Kingdom	299,482 (100.0%)	394,111 (100.0%)	412,608 (100.0%)	441,894 (100.0%)	5.65%	5.89%

(Source: NESDB)

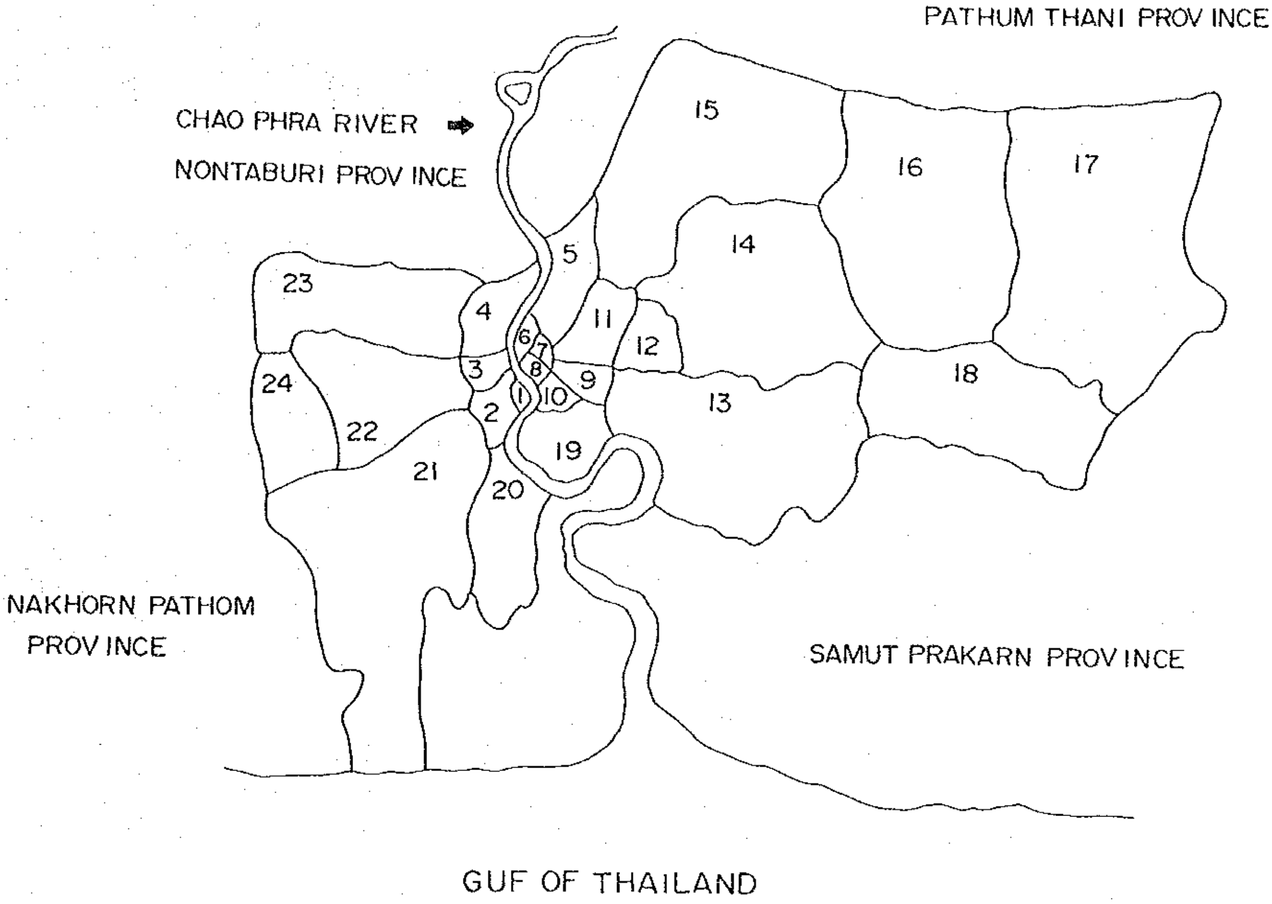
Manufacturing, wholesale and retail trade, and services are the BMA manufacturing is the biggest industry in terms of GDP, sharing 40% of total GDP. The annual growth rate of GDP of the Bangkok area is nearly double that of the Kingdom.

c. **Bangkok Metropolitan Administration (BMA)**

The area under the jurisdiction of BMA is divided into 24 administrative districts. (See Fig. 2-1-1.) The districts which are densely populated areas lie in and around the core centre of Bangkok as shown in Table 2-1-1. Pom Pram Sattrupai (7) is the district which is the most densely populated followed by Sampanthawong (8), Thon Buri (2), Dusit (5), Phya Thai (11), Khlong San (1), Phra Nakhon (6), Bangkok Yai (3), Pathumwan (9) and Bang Rak (10). Among these administrative districts, numbers (7), (8) (9) and (10) are closely related to Rama IV Road.

Reference Data : Tokyo 23 Wards, Average for 1980

Persons / Area (km^2)	Road Length (m) / Area (km^2)	Road Area (m^2) / Total Area (km^2)	Road Area (m^2) / Persons
14,109	8,151	141,000	10.0



1. Khlona San
2. Thon Buri
3. Bangkok Yai
4. Bangkok Noi
5. Dusit
6. Phra Nakhon
7. Pom Prab Sattru Pai
8. Sampanthawong
9. Pathumwan
10. Bang Rak
11. Phya Thai
12. Huai Khwang
13. Phra Khanong
14. Bang Kapi
15. Bang Khen
16. Min Buri
17. Nona Chok
18. Lad Krabang
19. Yan Nawa
20. Rat Burana
21. Bang Khun Thian
22. Phasi Charoen
23. Taling Chan
24. Nong Khaem

Fig. 2-1-1 Bangkok with 24 Districts under BMA

Table 2-1-1 Road Density in Bangkok by Districts

District	District Area (km^2)	Population (persons) 1987	Road Length (m)	Road Area in Row (m^2)	Persons/ km^2 1987	Road length / Area (m/km^2)	Road Area / D. Area (m^2/km^2)	Road Area / Population
1. Khlong San	6.051	146,781	45,161	604,797	24,257	7,463	99,950	4.12
2. Thon Buri	8.626	274,949	37,661	511,736	31,874	4,366	59,325	1.86
3. Bangkok Yai	6.180	108,171	30,390	333,383	17,503	4,917	53,945	3.08
4. Bangkok Noi	23.304	297,324	114,620	1,298,245	12,758	4,919	55,709	4.37
5. Dusit	22.210	561,979	122,832	1,909,728	25,303	5,530	85,985	3.40
6. Phra Nakhon	5.536	104,791	55,413	829,163	18,821	10,009	149,777	7.91
7. Pom Pram Sattrupai	1.931	83,412	38,607	564,780	43,196	19,993	292,481	6.77
8. Sampanthawong	1.461	50,089	24,308	274,978	34,284	16,638	188,212	5.49
9. Pathumwan	8.369	145,110	31,390	742,049	17,339	3,751	88,666	5.11
10. Bang Rak	5.536	88,554	55,050	635,099	15,996	9,944	114,722	7.17
11. Phya Thai	14.050	350,780	157,530	1,755,022	24,967	11,212	124,913	5.00
12. Huai Khwang	22.838	262,262	144,565	1,468,487	11,484	6,330	64,300	5.60
13. Phra Khanong	143.559	650,572	327,914	3,810,631	4,532	2,284	26,544	5.86
14. Bang Kapi	149.283	442,420	353,175	3,474,385	2,964	2,366	23,274	7.85
15. Bang Khen	169.310	581,508	222,035	1,937,255	3,435	1,311	11,442	3.33
16. Min Buri	174.331	81,110	138,630	1,121,714	465	795	6,434	13.83
17. Nong Chok	236.261	60,142	135,850	1,159,139	255	575	4,906	19.27
18. Lad Krabang	123.859	63,875	75,983	1,680,190	516	613	13,565	26.30
19. Yan Nawa	36.909	414,235	170,359	1,480,108	11,223	4,616	40,102	3.57
20. Rat Burana	42.874	154,177	60,728	729,689	3,596	1,416	17,019	4.73
21. Bang Khun Thian	181.156	286,165	135,701	3,168,056	1,580	749	17,488	11.07
22. Phasi Charoen	53.947	236,572	141,414	1,234,661	4,385	2,621	22,887	5.22
23. Taling Chan	79.689	98,552	114,410	2,419,953	1,237	1,436	30,364	24.56
24. Nong Khaem	48.283	65,822	66,668	1,290,334	1,363	1,381	26,724	19.60
BANGKOK TOTAL	1,565.562	5,809,352	2,800,397	34,496,583	3,583	1,798	22,035	6.15

2-1-2 Outline of Transportation in Bangkok

a. Railways

1. State Railway of Thailand (SRT)

   Three lines (south line, north and north-east line and east line) radiate from the Bangkok Terminal. Within Bangkok they do not influence much their wayside areas. The number of passengers using the railways is very small. The SRT railways contribute to the inter-regional transportation rather than the intra-urban transportation. (Refer to Map of Project Area at the outset of this Report)

2. Urban Railway Plan

   As a substitute of the existing bus transport in Bangkok City, the Expressway and Rapid Transit Authority of Thailand (ETA) under the Ministry of Interior has planned a mass transit railway system (MTS) since eight years ago. One of their rail lines is planned to run along Rama IV Road. It is expected that after their completion the bus traffic running on Rama IV Road would decrease. The pier columns of both the viaduct of this Project and the MTS structure will be constructed along the existing median of Rama IV Road. (Refer to Map of Project Area at the outset of this Report)

b. Water Transportation

Canals and small rivers across the adjacent flat areas to the Chao Phraya River used to be traditional transport means of small boats, however, many of these waterways have now been reclaimed to roadways, and nowadays the share of water transportation to the Bangkok urban transportation is very small.

c. Roads/Road Traffic in Bangkok

1. Road Network

   The road network in Bangkok has a significant feature in the difference between the inside and the outside of the Middle Ring

Road as shown in Fig. 2-1-2. The road network inside the Middle Ring Road is better distributed, though insufficient, comprising several radial major roads, with a circumferential road surrounding the central districts. Even the outside the Middle Ring Road, the development of the road network is less, being unbalanced for all traffic corridors. The characteristics of the road network can be further summarized as follows:

(1) The road network is absolutely inadequate in Terms of the quantity and quality. The road density inside the Middle Ring Road is low, about 4% of the area.

(2) A hierarchical structure of roads exists with high class roads such as ETA expressway, major city streets and the access roads to and from major roads called "soi". Generally accessibility and mobility are complicated, reducing the effect of road network, in other words, there are many missing links in the road network which amplifies the overload on the major roads and decreases the efficiency of the road network. This is mainly caused by insufficient road developments for more than 20 years failing to meet increasing traffic needs.

(3) Roads are few in the areas outside the Middle Ring Road where urban development is actively taking place and new traffic demand is occurring. Due to the delay in road developments the degree of traffic congestion is increasing.

(4) For the reasons mentioned in (1) and (2) above, the traffic concentrates on the existing roads. Fig. 2-1-3 shows the traffic volumes on respective major roads in Bangkok. The traffic on Rama IV Road belongs to the greatest among the roads running in the east-west direction.

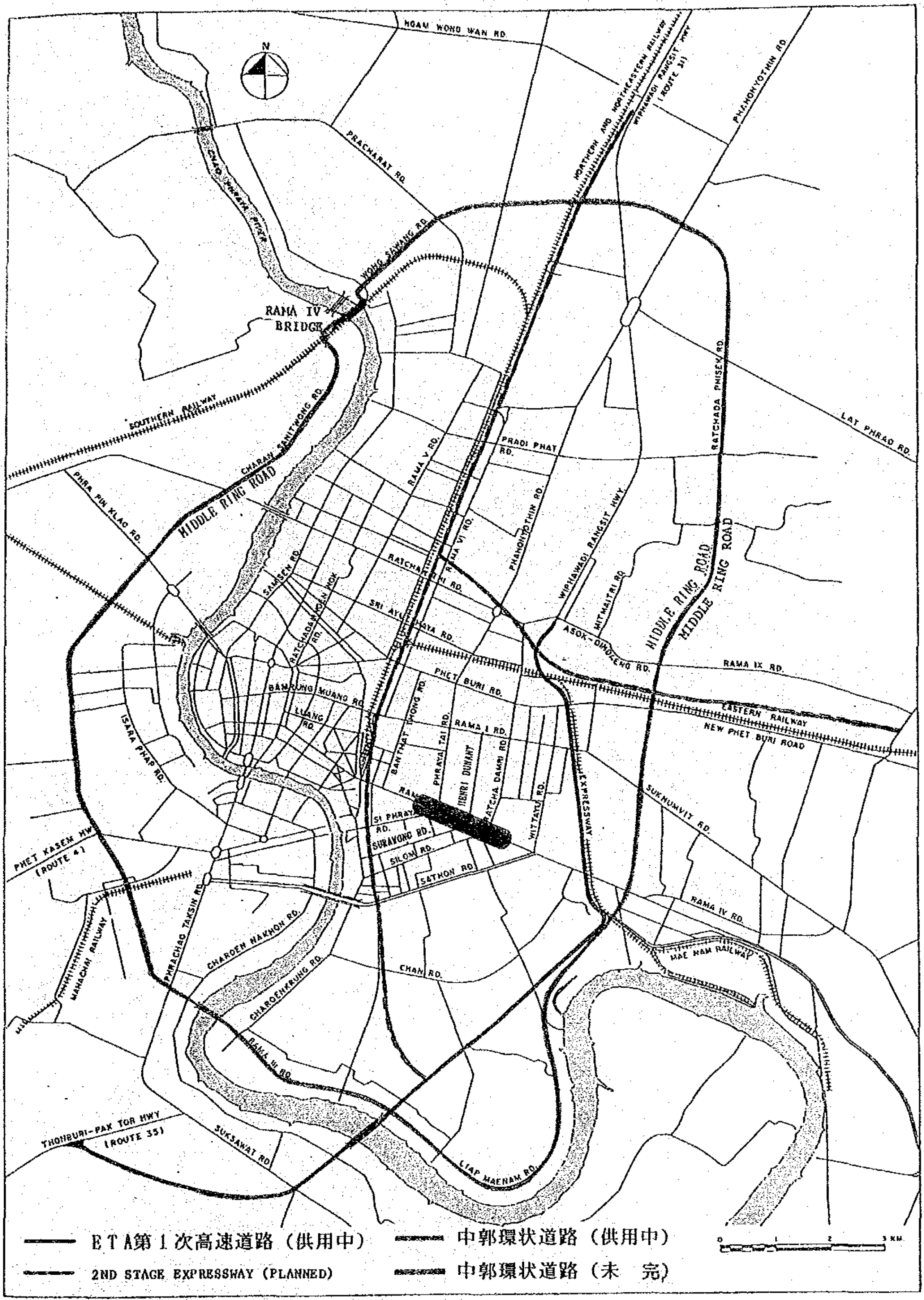


Fig. 2-1-2 Road Network in Bangkok

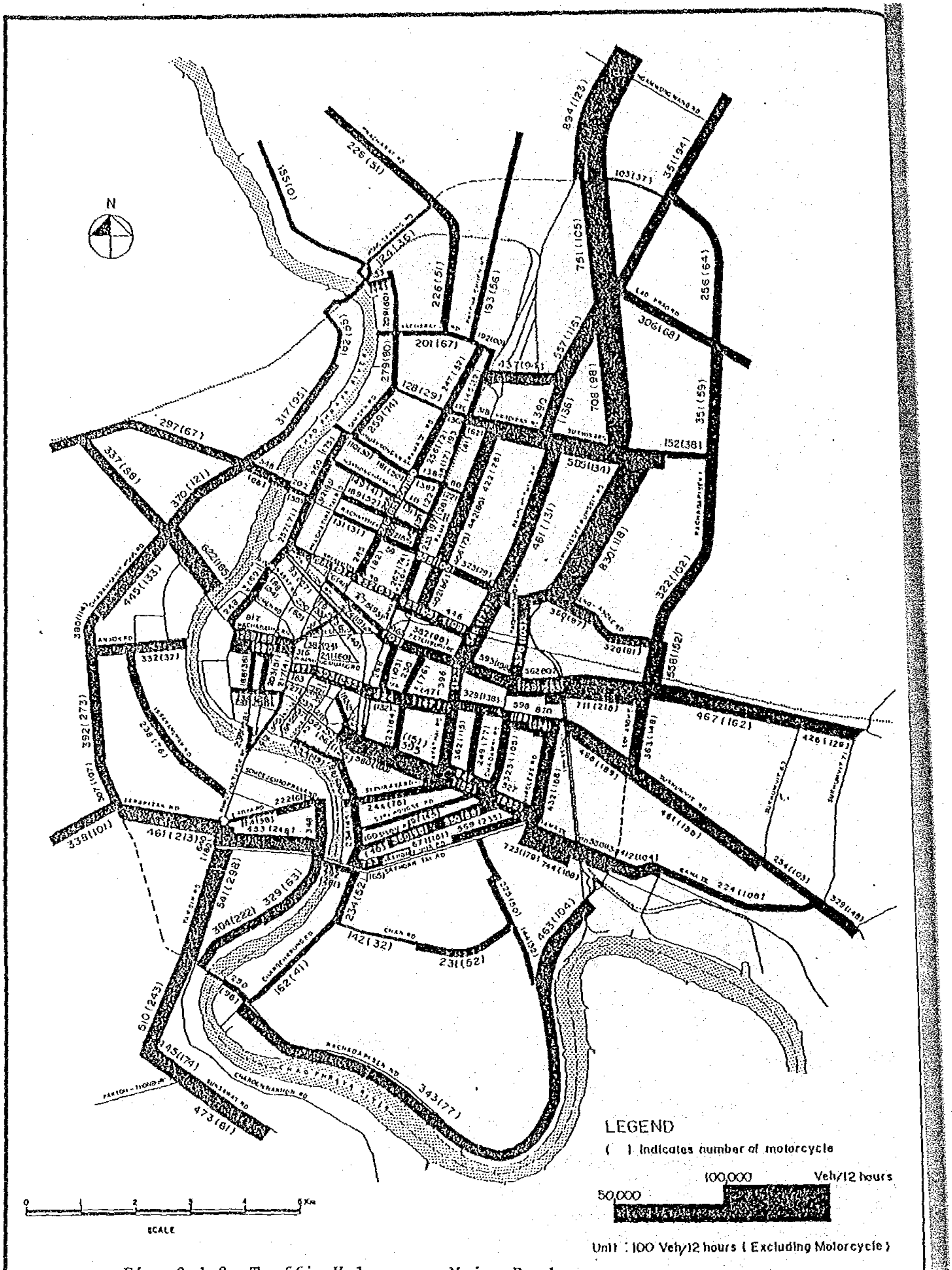


Fig. 2-1-3 Traffic Volumes on Major Roads

(Source: JICA Study 1987)

2. Road Characteristics

Fig. 2-1-4 shows the number of lanes of major roads inside the Middle Ring Road. The road length ratios by lane comprise the following. The 4-lane roads are predominant, compared with others.

2-lane	:	20%
4-lane	:	37%
6-lane	:	26%
8-lane or more	:	17%
Total	:	100%

Most road intersections are at-grade, and at major intersections traffic is controlled by traffic lights. To cope with the rapidly increasing traffic demand in the core area of the city, action has been taken by the Bangkok Metropolitan Administration by means of introducing turning regulations, bus lanes, reversible lanes, etc. giving an improvement in traffic flows and mitigation of traffic congestion at morning and evening peak hours. Recently an overall improvement of the road network is being carried out by widening existing major roads, construction of roads to new standards, grade separation of existing intersections, etc. inside the Middle Ring Road.

3. Traffic Characteristics

In the Bangkok Metropolitan area, the main transportation means both for passengers and goods are the roads, with buses more used than the railway as the public land transport means. In parallel with the recent expansion of social and economic activities, the traffic demand in Bangkok has increased greatly. The record shows an increase in traffic of 30% for 4-wheel vehicles and 36% for motorcycles. It has been noticed, however, that at the city centre where the traffic has reached the road capacity limit, the number of 4-wheel vehicles is on the decrease while that of motorcycle is on the increase at both peak hours.

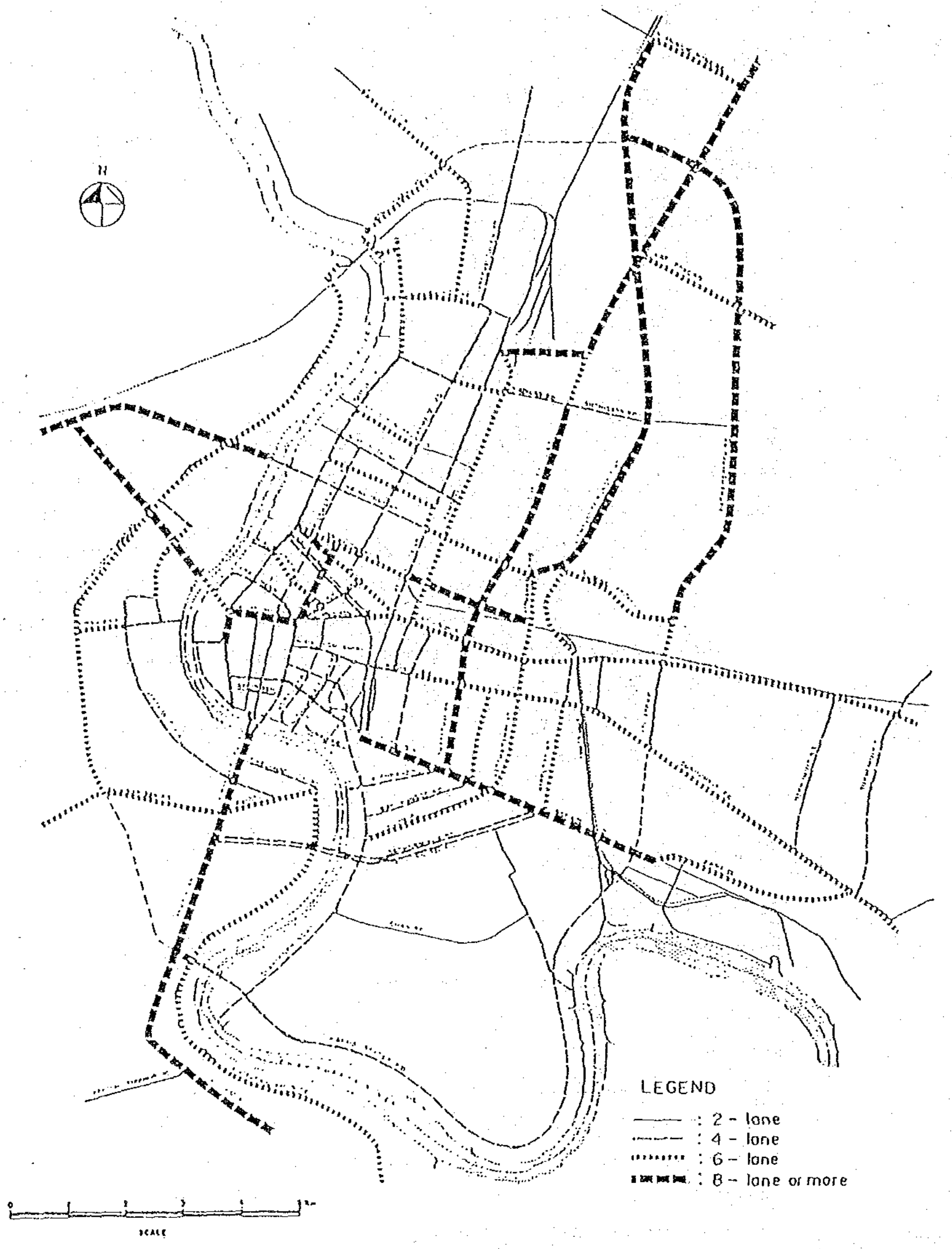


Fig. 2-1-4 Major Roads with Number of Lanes

Regarding the vehicular composition both passenger cars and motorcycles share 60 to 70% of the total, followed by pick-ups and taxis. Buses share more than half the large-size vehicles but the share of large-size trucks is small because heavy trucks are banned during daytime hours to enter the area inside the Middle Ring Road. As a guide on National Road No. 1 the truck share is about 6.5%. However, trucks can enter the city at night. They are overloaded considering their operational economy, having a bad effect on the BMA's road structures. Thus BMA has decided to make an additional allowance in designing its bridge structures.

4. Road Improvement Projects in Bangkok

(1) Road and Intersection Improvement Plans

To cope with the rapid urbanization, the ever-increasing traffic demand and the aggravating traffic condition, as stated in Section 1-1, the Government of Thailand has requested the Government of Japan for technical assistance to conduct a study and JICA had conducted the "Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok" in the period June 1985 to March 1987. The main objectives of the study were to provide BMA with engineering expertise and information necessary to the planning of road and pavement improvement and traffic safety measure, based on the findings and studies for the network of a total length of 350km within the area encircled by the Middle Ring Road. The study covered traffic survey, road inventory, road improvement, pavement rehabilitation, traffic safety, technical guideline and review of BMA road organization.

In the road survey of the above study roads which generated traffic congestion were investigated and the traffic mitigation measures were examined. 28 bottlenecks were identified and finally the study proposed for the improvement of 11 intersections, and that it concluded that the grade separation of Rama IV Road (from Siphraya Road to

Sathon Road) gives the largest effects of all in terms of both engineering and economic aspects. At present BMA has established a scheme for 19 road improvements in Bangkok, aiming for completion in 1993. These road improvement projects are located in Fig. 2-1-5 and their progress listed in Table 2-1-2 (numbered from 1 to 19), out of which three improvement projects proposed by the above mentioned JICA Study 1987 are included. In the figure and table mentioned above are shown the 11 intersections proposed by JICA study 1987.

(2) Middle Ring Road Construction Plan

The plan was established in the 1960s to collect/distribute the traffic inside and outside of Bangkok. The total length is about 45km. The road is a 6-lane dual urban highway and the most part of it has been completed except the northern portion which is in the vicinity of the existing Rama IV Bridge.

For the crossing of the Middle Ring Road over the Chao Phraya River the construction of a new Rama IV Bridge will soon be started by the Public Works Department under the Ministry of Interior, side by side with the existing Rama IV Bridge (rail-cum-road bridge) in the northwest of Bangkok. The new bridge will carry the traffic from the east to the west of the river and vice versa.

(3) Second Stage Expressway Construction Programme

The construction of the second stage expressway network, extension of the existing expressway network (length: 27km) under ETA is scheduled for start in April 1990. The north-south line of the second stage expressways will intersect the western end of Rama IV Road and the east-west expressway line will run in the north of Rama IV Road. Accordingly it is anticipated that after their completion the traffic demand of Rama IV Road would further increase.

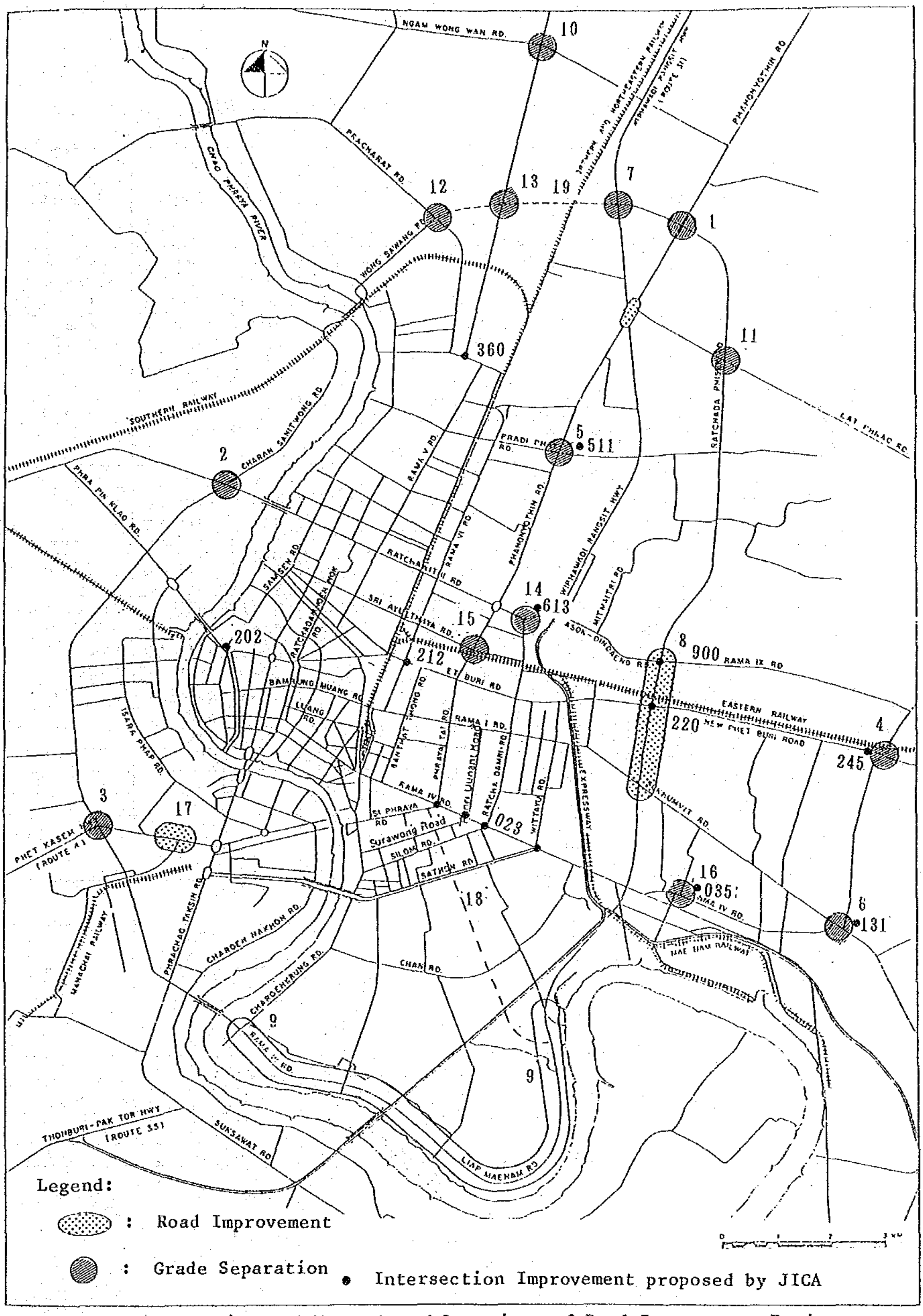


Fig. 2-1-5 BMA's Road Network and Locations of Road Improvement Projects with 11 Intersections Proposed by JICA 1987

Table 2-1-2 Road Improvement Projects by BMA

Contents of Project	JICA Proposal with Node No.	Phasing	Remarks
Flyover Rama IV/Si Phraya-Sathon Roads	023 Flyover	Basic Design Study in 89 by JICA	Grant Aid of Japan (planned)
1. Flyover Ratchada Phisek-Ohahonyothin		Tender for detail design and Construction	BMA's budget
2. Flyover Charansanitwong-Ratchawithi		ditto	ditto
3. Flyover Phet Kasem HWY-Ratchada Phisek		ditto	ditto
4. Flyover Phetburi-Ram Kamhaeng		ditto	ditto
5. Phanonyothin-Suthi San		Tender for detail design	ditto
6. Flyover Rama IV-Sukhunvit		ditto	ditto
7. Flyover Ratchada Phisek-Wiphawadi Rangdit HWY		Tender for Construction	ditto
8. Viaduct Rachada Phisek (M.O.T Intersection to Sukhmvit)	900 At-grade 220 At-grade	Preliminary design	Assistance of Canada
9. Improvement Ratchada Phised (Rama III to Liap Maenam)		Widened in 90	BMA's budget
10. Flyover Ngam Wong Wan-Pracha Chen		Note Decided	
11. Flyover Ratchada Phisek-Lat Pharao		ditto	
12. Flyover Ratchada Phisek-Pracha Rat		ditto	
13. Flyover Ratchada Phisek-Pracha Chuen		ditto	
14. Flyover Dindaeng-Ratcha Chen		ditto	
15. Flyover Sri Ayutthaya-Ratcha Prarop		ditto	
16. Improvement Rama IV Ari		ditto	
17. Bridge and Flyover In Thara Phi Thak-Phet Kasem HWY		ditto	
18. New Road and Improvement Khlong Chong Nonsri		ditto	
19. New Road and Improvement Rachada Phisek		ditto	
Ratchadamnoen Klang/Rachadamnoen Nai Roads	202 Underpass	ditto	
Dindaeng/Ratchapraron Rds	613 Flyover	ditto	
Pradiphat/Phahon Yothin Rds	511 Flyover	ditto	
Petburi/Rama IV Rds	212 Flyover	ditto	
Pracharat II/Pracha Chuen Rds	360 At-grade	ditto	
Sukhumvit/Rama IV Rds	131 Flyover	ditto	
Petburi/Ramkhamhaeng Rds	245 At-grade	ditto	
Rama IV/Kasemrat Rds	035 At-grade	ditto	

2-2 Outline of the Request

A JICA founded study, the "Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok" completed in March 1987 carried out road and traffic surveys in Bangkok to locate bottlenecks in the urban traffic road system and recommended improvements to 11 intersections (See Fig. 2-1-5).

Afterwards, BMA established the improvement scheme for intersections of major roads of Bangkok and the construction of the flyover at the intersection of Rama IV Road with Sathon Road was completed in April 1988 as stated in Section 1-1.

Following upon this, BMA requested, on a grant aid basis from the Government of Japan, the "Project for Rama IV Viaduct Construction" covering three intersections from Siphraya Road to Silom Road which is expected to have tremendous benefit for through traffic on Rama IV Road. JICA sent a Project Formulation Survey Team to Bangkok from March 26 to April 4, 1989 to confirm the request of the Thai Government and to examine the appropriateness and validity thereof as Japan's Grant Aid Programme. The contents of the request of the Government of Thailand for Japan's Grant Aid Assistance for the implementation of this Project are as follows:

(1) The objective of the Project is to construct a viaduct in order to smoothen and improve the traffic flow along Rama IV Road.

(2) The executive agency for the implementation of the Project is the Department of Public Works (DPW), Bangkok Metropolitan Administration (BMA).

(3) The location of the Project is from the intersection of Siphraya Road to that of Silom Road along Rama IV Road.

(4) Outline of Project:

- Superstructure and column: Steel structure and not to be connected with any structure of other projects.
- Foundation: Cast-in-place concrete pile and not to be connected with any structure of other projects.

- Design Standards: Follows JICA Feasibility Study Report submitted to BMA in March 1987.
- Number of lanes: 4 lanes, partly 2 lanes
- Total length: Approximately 1.5km.

CHAPTER 3: OUTLINE OF THE PROJECT

CHAPTER 3 OUTLINE OF THE PROJECT

3-1 Objective of the Project

The objective of the Project is to smoothen and improve the traffic flow along Rama IV Road by constructing a steel viaduct on Rama IV Road covering the three intersections of Siphraya Road.

3-2 Study and Examination on the Request

3-2-1 Location and Condition of Project Site

a. Location of Project Site

The project site for the construction of the viaduct is on Rama IV Road extending from west of the Siphraya intersection east of the Silom intersection with a structure length of about 1,500 meters plus the lengths of the approach sections.

b. Present Conditions of Rama IV Road

Rama IV Road which runs in the core-centre of Bangkok in an east-west direction is a 10-lane dual carriageway arterial road which intersects with all the major roads which run in the north-south direction in the city. On its northern side lie Chulalonkorn University and its hospital, Lumpini Park, etc. and the southern side constitutes the most important commercial area including prominent business, hotel, shopping and restaurant quarters of Bangkok.

Rama IV Road, which is a wide road of 10 lanes, is always congested with traffic because the short distances between intersections. A record shows that the present traffic volume of Rama IV Road amounts to 100,000 - 140,000 vehicles (including motor cycles) per day and 6,300 - 8,400 vehicles per peak hour. The traffic on the intersecting roads, Sathon, Wittayu, Henri Dunant, Phaya Thai is also great with a volume of 40,000 - 90,000 vehicles per day, and the traffic congestion is very serious; the average travelling time

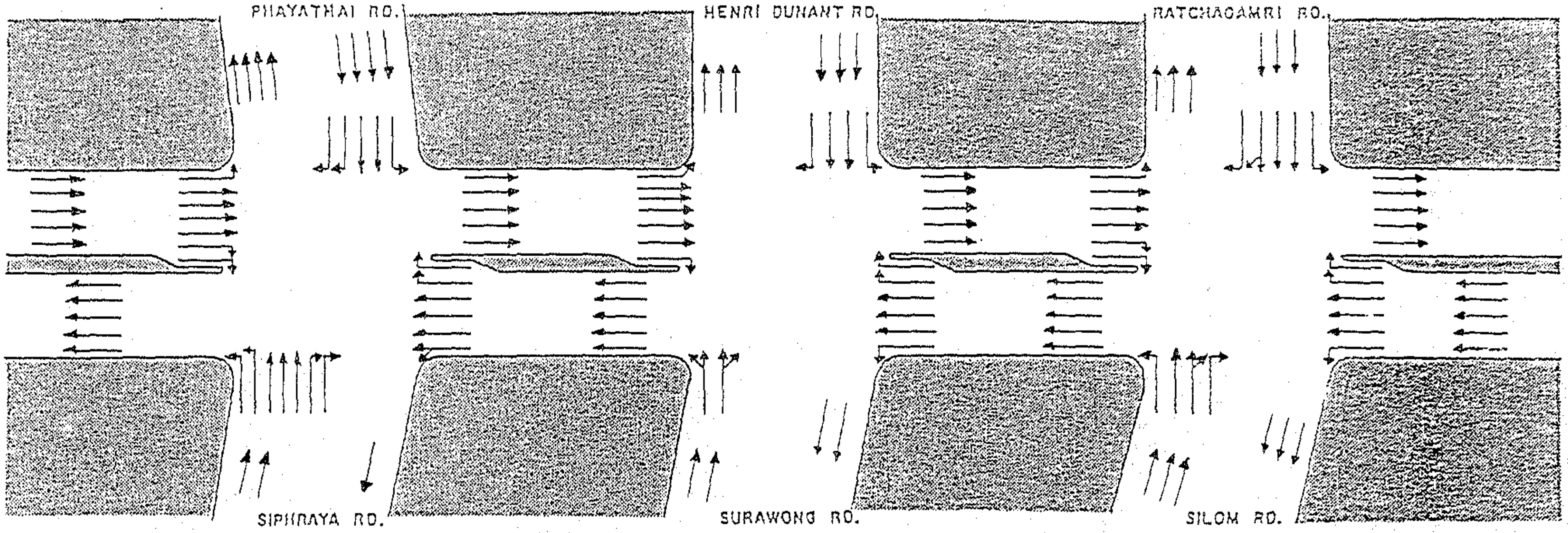


Fig. 3-2-1 Present Number of Lanes at Intersections on Rama IV Road

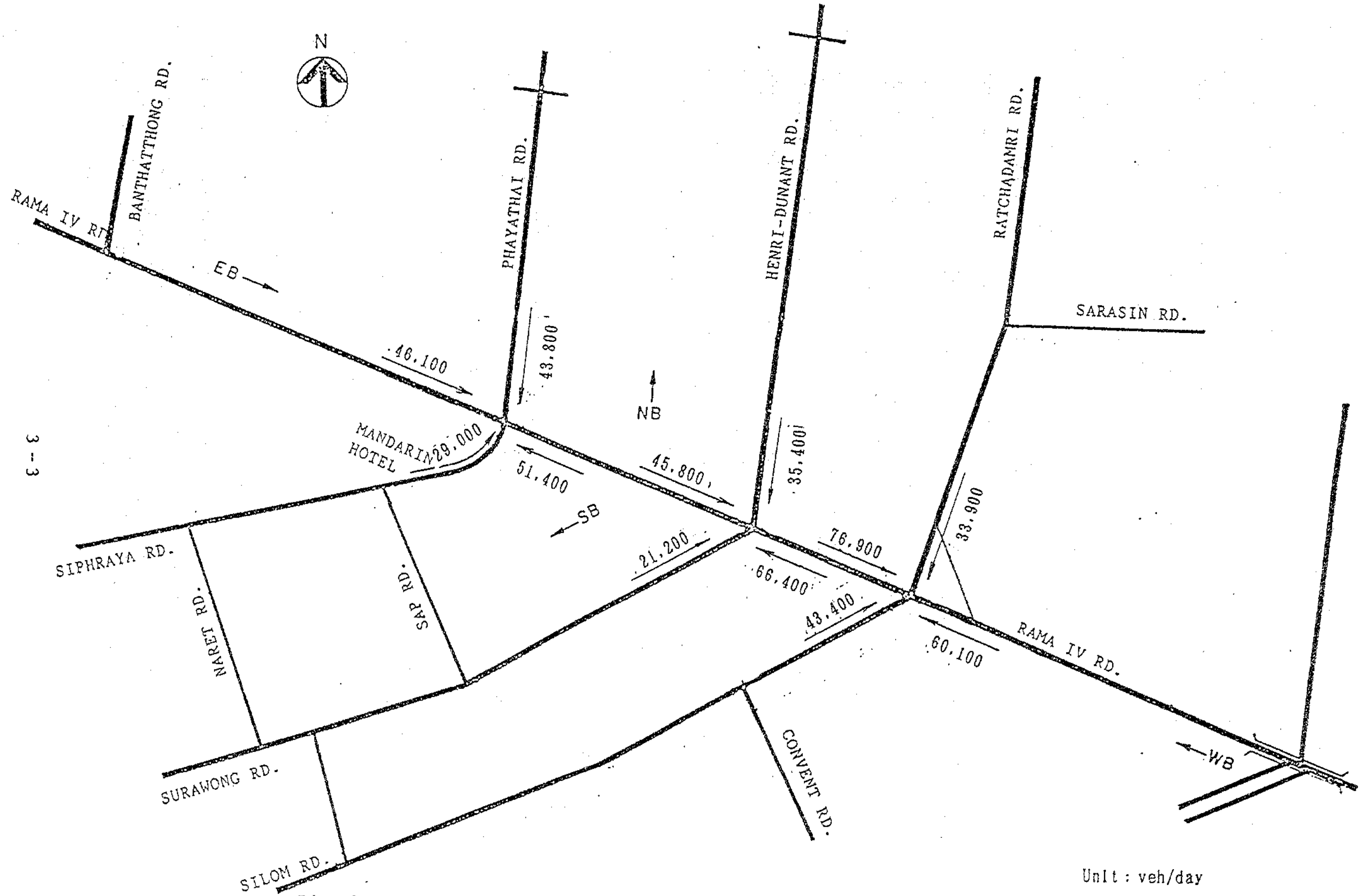


Fig. 3-2-2 Present Traffic at Intersections on Rama IV Road (August 1989)

at peak hours is 12 km/hour; the length of queuing vehicles is 500 - 600m; and the waiting time for signals at each intersection ranges from 3 to 12 minutes. Fig. 3-2-1 shows the present number of lanes and Fig. 3-2-2 indicates traffic volume at each intersection.

In 1988 the intersection with Sathon was grade-separated by the donation of the Belgian Government, and the traffic condition around the intersection has been improved. Eastern stretches of Rama IV Road, which has a predominant east-west direction traffic has not benefited by the flyover (Thai - Belgian Bridge). The present expressway bisects Rama IV Road in a north-south direction and the traffic from the expressway accesses the city core by Rama IV Road. According to the 2nd stage expressway construction plan, a further expressway will be constructed also in a north-south direction at the west end of the project site, and in the vicinity of the Project site another expressway is planned in an east-west direction. The implementation of these expressways has already been determined. It is anticipated that after their completion the traffic demand is expected to increase and that the traffic would concentrate on Rama IV Road for access to and from the expressways.

c. **Topographic Survey**

In order to locate the project site, topographic survey was carried out 1,800m long along Rama IV Road and covered an area of approximately 104,000m^2 or 10.4 hectare. Its major works done are described in Appendix 3.2.1 of this Report.

d. **Traffic Survey**

Traffic survey was carried out to know the present traffic conditions at the project site.

1. Traffic Count Survey

Twenty four (24) hours traffic count survey was conducted at three intersections (Silom, Surawong and Siphraya).
The following seven types of vehicles were counted by each direction:

Type of Vehicle	Passenger Car Equivalency (PCU)
Motorcycle & Samlor	0.175
Sedan	1.0
Taxi	1.0
Light, medium and mini bus	1.5
Large bus	2.1
Pick-up, light and medium truck	1.0
Large truck	2.5

Fig. 3-2-3 presents directional traffic volumes at each intersection during evening peak hours.

2. Travel Speed Survey and Delay Observation

Travel speed of vehicles around the project site was surveyed on Rama IV Road and its intersecting roads as shown in Fig. 3-2-4. Delay of vehicles which had to stop to wait for the traffic signals was observed on Rama IV Road and the three intersecting roads. The results are tabulated in Tables 3-2-1 through 3-2-4.

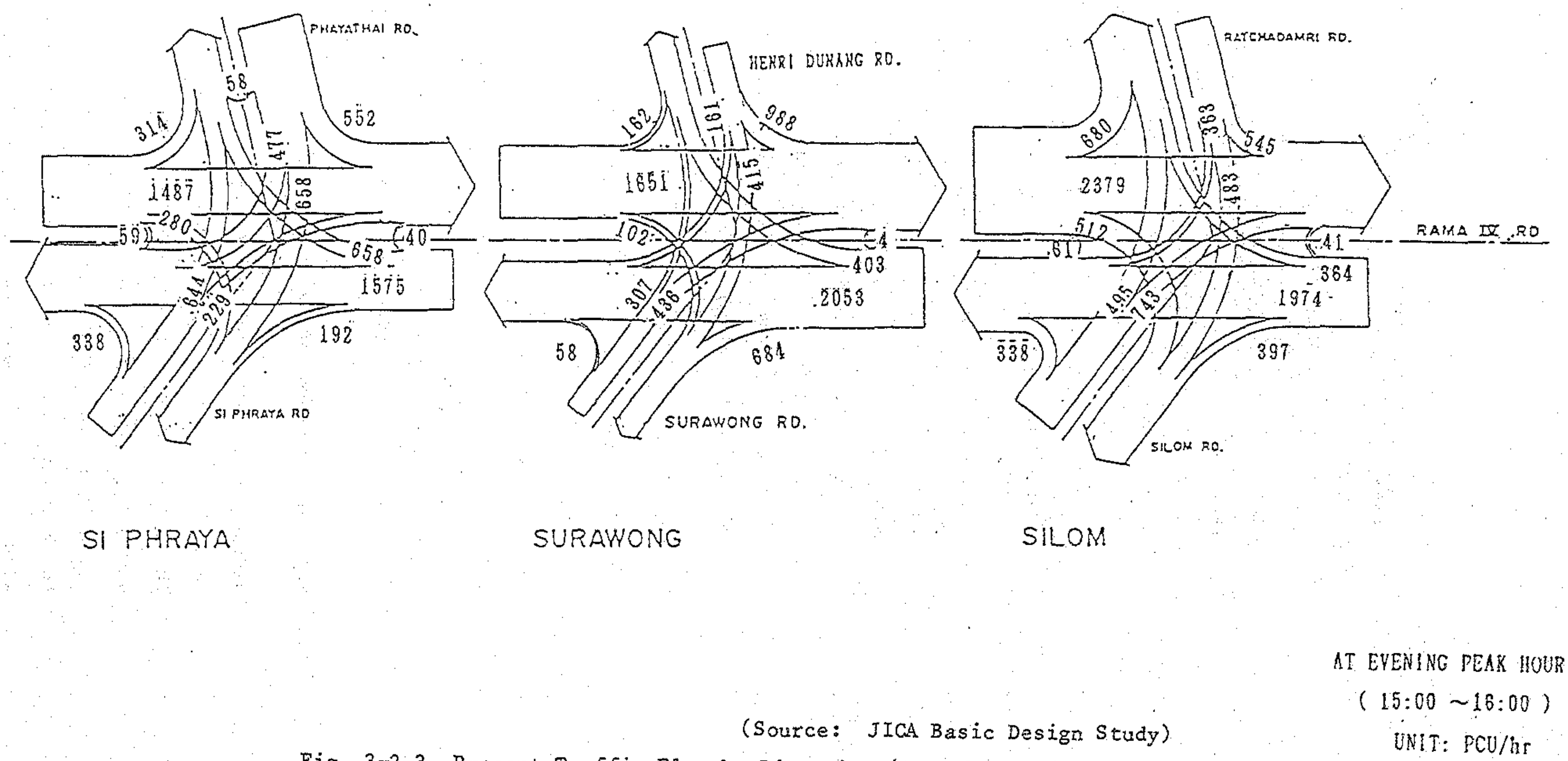
3. Traffic Survey Results

The characteristics of the vehicles on Rama IV Road was found as follows:

Peak hour	:	15:00 - 16:00 hrs.
Peak factor	:	6.2%
Ratio of daily traffic to daytime traffic	:	69.0%
Directional distribution rate	:	53.0% (Eastward)

e. Topography and Geology of Bangkok

Bangkok lies nearly at the centre of the vast Chao Phraya river basin (the Central Plain), some 30km upstream of the estuary. The ground, a typical deltaic river mouth deposit, is quite flat and low, only a few metres above sea level, and subject to flooding in the rainy season. The subsoils are geologically of thick marine sedimentary deposits and classified to quaternary alluvium reaching down to hundreds metres in depth.



(Source: JICA Basic Design Study)

Fig. 3-2-3 Present Traffic Flow by Direction (Aug. 9, 1989)

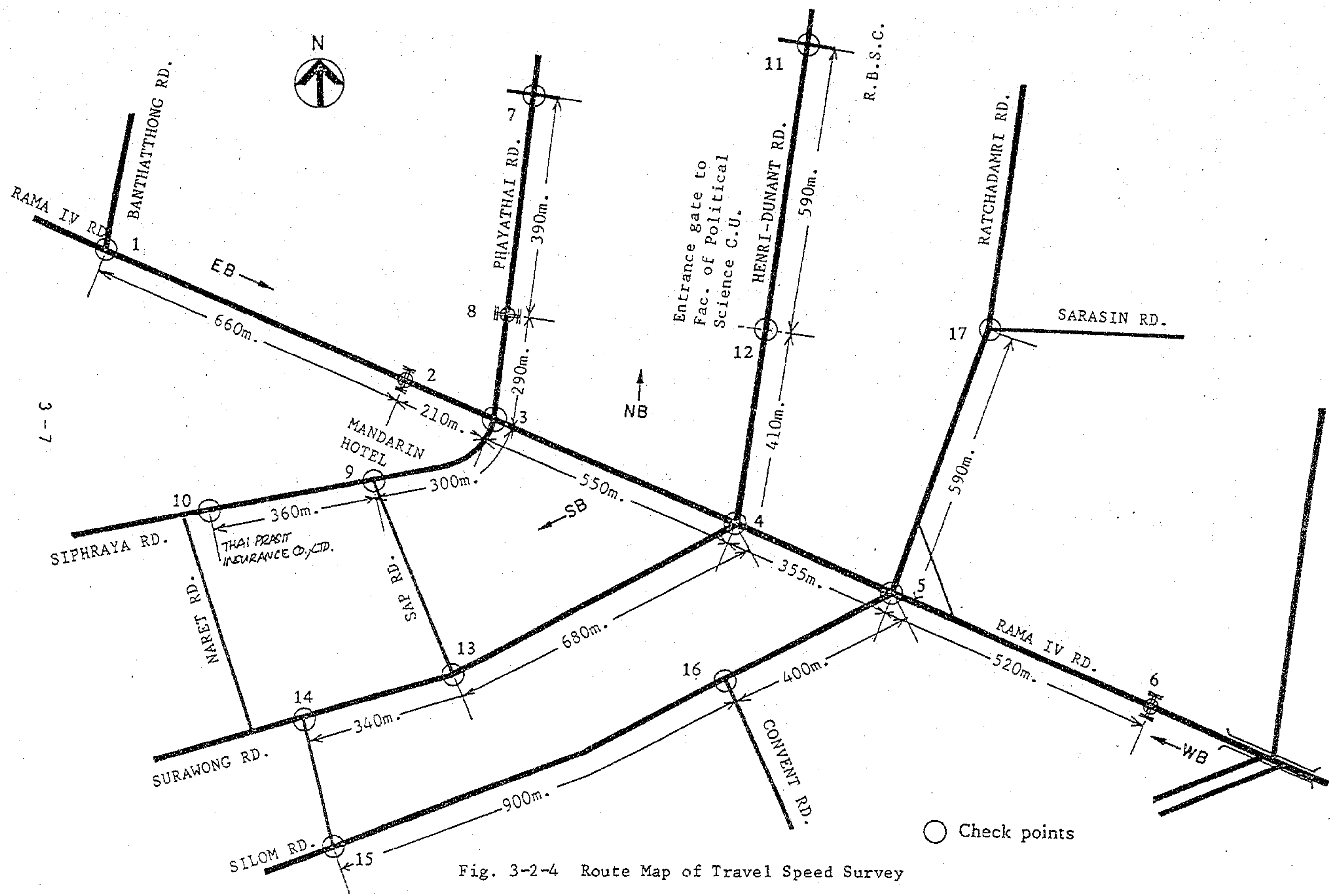


Fig. 3-2-4 Route Map of Travel Speed Survey

Table 3-2-1 Travel Time and Delay Observations: Distance 2,295m

TRAVEL TIME AND DELAY OBSERVATIONS

SUMMARY OF RESULTS FOR EACH DIRECTION TT-5-RM

Study Route : RAMA IV RD.

Total Distance : 2295 metres Date : Wed9th August 1989

Time	Run No.	Travel time (sec)	Running time (sec)	Travel speed (kph)	Running speed (kph)
07:00-09:00	1 -EB	939.05	437.90	8.8	18.9
	2 -EB	728.67	294.67	11.3	28.0
	3 -EB	939.68	482.28	8.8	17.1
	Av. -EB	869.13	404.95	9.6	21.3
	4 -WB	629.80	255.03	13.1	32.4
	5 -WB	455.25	257.72	18.1	32.1
	6 -WB	834.47	396.06	9.9	20.9
	Av. -WB	640.17	302.94	13.7	28.5
11:00-14:00	7 -EB	720.17	254.21	11.5	32.5
	8 -EB	562.15	236.56	14.7	34.9
	9 -EB	702.64	303.51	11.8	27.2
	Av. -EB	661.65	264.76	12.7	31.5
	10 -WB	735.60	301.03	11.2	27.4
	11 -WB	787.87	288.44	10.5	28.6
	12 -WB	423.27	297.43	19.5	27.8
	Av. -WB	648.91	295.63	13.7	27.9
17:00-19:00	13 -EB	2687.00	1103.74	3.1	7.5
	14 -EB	2723.00	1357.00	3.0	6.1
	15 -EB	1569.51	397.98	5.3	20.8
	Av. -EB	2326.17	952.91	3.8	11.5
	16 -WB	902.14	303.33	9.2	27.2
	17 -WB	836.00	317.00	9.9	26.1
	18 -WB	808.21	395.87	10.2	20.9
	Av. -WB	848.78	338.73	9.8	24.7

Table 3-2-2 Travel Time and Delay Observations: Distance 1,340m

TRAVEL TIME AND DELAY OBSERVATIONS

SUMMARY OF RESULTS FOR EACH DIRECTION TT-5-PS

Study Route : PHAYA THAI RD.-SIPHRAYA RD.

Total Distance : 1340 metres Date : Wed.2nd August 1989

Time	Run No.	Travel time (sec)	Running time (sec)	Travel speed (kph)	Running speed (kph)
07:00-09:00	2 -NB	233.93	171.31	20.6	28.2
	4 -NB	692.59	249.49	7.0	19.4
	6 -NB	276.92	202.05	17.4	23.9
	Av. -NB	401.15	207.62	15.0	23.8
	1 -SB	371.49	202.05	13.0	23.9
	3 -SB	584.23	247.34	8.3	19.5
	5 -SB	487.74	178.39	9.9	27.0
	Av. -SB	481.15	209.26	10.4	23.5
11:00-13:00	8 -NB	260.02	138.89	18.6	34.7
	10 -NB	274.66	141.23	17.6	34.2
	12 -NB	243.35	106.48	19.8	45.3
	Av. -NB	259.34	128.87	18.7	38.1
	7 -SB	258.24	176.73	18.7	27.3
	9 -SB	230.08	151.15	21.0	31.9
	11 -SB	263.85	143.45	18.3	33.6
	Av. -SB	250.72	157.11	19.3	30.9
17:00-19:00	14 -NB	426.84	218.35	11.3	22.1
	16 -NB	384.21	221.64	12.6	21.8
	18 -NB	281.12	202.36	17.2	23.8
	Av. -NB	364.06	214.12	13.7	22.6
	13 -SB	283.86	199.36	17.0	24.2
	15 -SB	546.42	280.35	8.8	17.2
	17 -SB	533.64	283.37	9.0	17.0
	Av. -SB	454.64	254.36	11.6	19.5

Table 3-2-3 Travel Time and Delay Observations: Distance 2,020m

TRAVEL TIME AND DELAY OBSERVATIONS

SUMMARY OF RESULTS FOR EACH DIRECTION TT-5-HS

Study Route : HENRI DUNANT RD.-SURAWONG RD.

Total Distance : 2020 metres Date : Wed.2nd August 1989

Time	Run No.	Travel time (sec)	Running time (sec)	Travel speed (kph)	Running speed (kph)
08:00-09:00	2 -NB	819.61	254.65	8.9	28.6
	4 -NB	409.12	215.39	17.8	33.8
	6 -NB	539.45	200.33	13.5	36.3
	Av. -NB	589.39	223.46	13.4	32.9
	1 -SB	936.48	452.45	7.8	16.1
	3 -SB	993.06	519.99	7.3	14.0
	5 -SB	693.71	353.04	10.5	20.6
	Av. -SB	874.42	441.83	8.5	16.9
11:00-12:00	8 -NB	372.33	189.63	19.5	38.3
	10 -NB	367.24	201.74	19.8	36.0
	12 -NB	417.43	158.93	17.4	45.8
	Av. -NB	385.67	183.43	18.9	40.0
	7 -SB	414.49	287.36	17.5	25.3
	9 -SB	638.24	320.76	11.4	22.7
	11 -SB	341.49	232.74	21.3	31.2
	Av. -SB	464.74	280.29	16.7	26.4
16:00-17:00	14 -NB	826.81	262.88	8.8	27.7
	16 -NB	739.52	262.77	9.8	27.7
	18 -NB	902.14	256.68	8.1	28.3
	Av. -NB	822.82	260.77	8.9	27.9
	13 -SB	889.62	278.03	8.2	26.2
	15 -SB	838.46	316.88	8.7	22.9
	17 -SB	1126.30	214.73	6.5	33.9
	Av. -SB	951.46	269.88	7.8	27.7

Table 3-2-4 Travel Time and Delay Observations: Distance 1,890m

TRAVEL TIME AND DELAY OBSERVATIONS

SUMMARY OF RESULTS FOR EACH DIRECTION TT-5-RS

Study Route : RATCHADAMRI RD.-SILOM RD.

Total Distance : 1890 metres Date : Wed.2nd August 1989

Time	Run No.	Travel time (sec)	Running time (sec)	Travel speed (kph)	Running speed (kph)
07:00-09:00	1 -NB	779.26	234.17	8.7	29.1
	3 -NB	834.93	265.38	8.1	25.6
	5 -NB	595.46	213.40	11.4	31.9
	Av. -NB	736.55	237.65	9.4	28.9
	2 -SB	850.02	269.14	8.0	25.3
	4 -SB	894.92	218.43	7.6	31.1
	6 -SB	965.48	286.83	7.0	23.7
	Av. -SB	903.47	258.13	7.5	26.7
11:00-13:00	7 -NB	564.39	200.21	12.1	34.0
	9 -NB	588.35	270.84	11.6	25.1
	11 -NB	578.15	317.73	11.8	21.4
	Av. -NB	576.96	262.93	11.8	26.8
	8 -SB	381.21	224.17	17.8	30.4
	10 -SB	544.29	239.34	12.5	28.4
	12 -SB	577.46	250.01	11.8	27.2
	Av. -SB	500.99	237.84	14.0	28.7
17:00-19:00	13 -NB	833.62	225.19	8.2	30.2
	15 -NB	1481.20	338.53	4.6	20.1
	17 -NB	767.08	331.63	8.9	20.5
	Av. -NB	1027.30	298.45	7.2	23.6
	14 -SB	1717.00	265.31	4.0	25.6
	16 -SB	1336.50	380.63	5.1	17.9
	18 -SB	395.17	219.10	17.2	31.1
	Av. -SB	1149.56	288.35	8.8	24.9

In Bangkok, the subsoil depth for foundation study is generally limited to about 50 to 60m except for the foundations of particularly large constructions. From the top soil the Bangkok subsoils are composed of soft clay, stiff clay in order and beneath lies the dense sand which is about 3 to 10m thick although it varies with places. That is used as a bearing stratum for small to medium constructions. Further below, silty clay continues to the depth of 50 to 60m and then very dense sand (second sand layer) is found. Large structures and high buildings are founded on this layer.

The ground-subsiding problem of Bangkok is considered to be caused by extensive extraction of water from the first sand layer. The reduction of the moisture content had been accelerating the consolidation of the lower stiff clays. However, in the past several years the upper soft clay has also been affected, so the rate of settlement has increased to as much as 6 to 10cm annually which can be observed in some part of the city. Raising the road elevation for flood protection and increase in traffic cause the additional load on the soft clay, which further accelerates settlement.

Thus, the problem extends throughout the Bangkok area and there is phenomenon observed everywhere in the city that foundations protrude above the road surface due to settlement of the surrounding ground. In consequence, the design of pile foundations reaching the dense sand layer should take account of the negative skin friction force imposed from the consolidation of the soft clay.

Battered piles are generally not used in Bangkok because of the large bending moment that may occur due to the settlement of the surrounding soils.

f. Ground Condition of Project Site

At the project site along Rama IV Road, there had been once a khlong (waterway) flowing along the middle of the road, but the present road was constructed to a 10-lane road by filling the khlong. The khlong was substituted by a box culvert drain (2.7 x 2.75m) that was laid on the south of the median.

In order to further the realization of the program, BMA conducted the soil investigation on 5 locations shown in Fig. 3-2-5, and reported the result in May, 1988. The report reveals that the subsoil condition at the site conforms to the general description of Bangkok subsoils mentioned above, and the depth of the first sand layer which is considered as the bearing stratum for the foundation is about 30m. Fig. 3-2-6 shows the subsoil profile that is estimated from these 5 bored holes. The feature of each layer is classified as follows:

1. Top Soil

   The top soil consists of the road filling material (sand) used at the time of Rama IV Road construction. The top layer is about 1.0 to 1.7m thick and well compacted.

2. Soft Clay

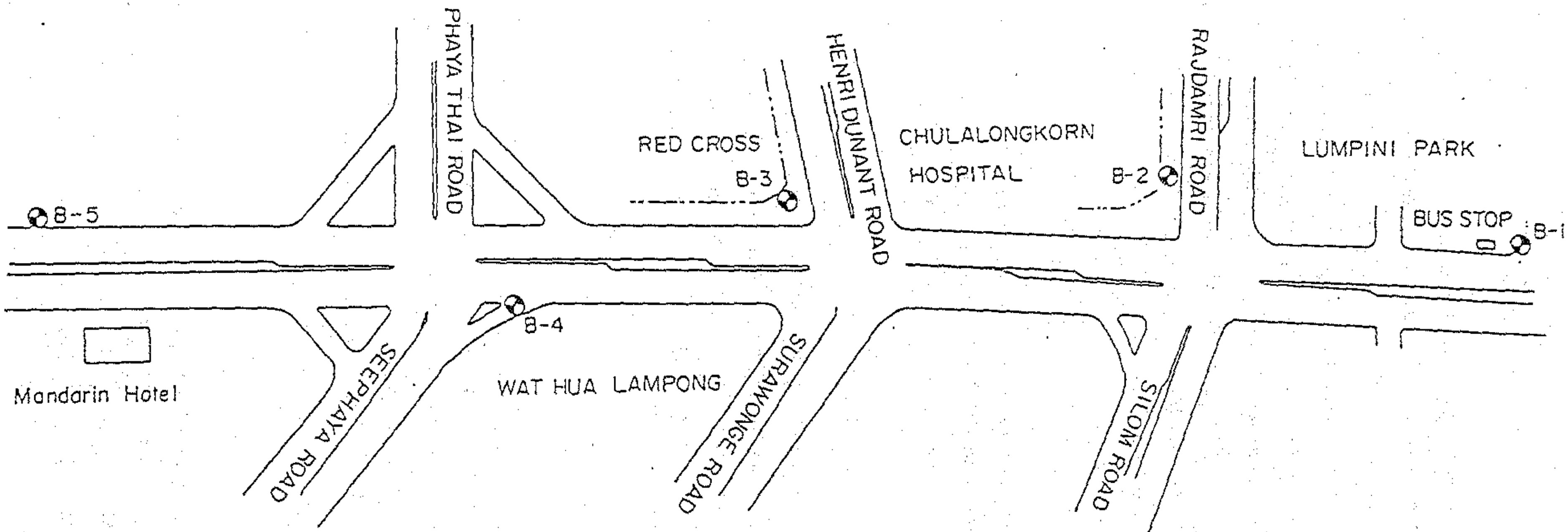
   The layer extending to a depth of about 10m is very weak, the so-called Bangkok Soft Clay. The soil is of the latest marine deposits assuming a dark brown colour and with high compressibility. The values for the standard penetration test in this stratum were not obtained.

3. Stiff Clay

   This layer is a stiff silty clay of dark gray or brown colour and interbedded with thin layers of fine sand. With more sand content, it assumes a yellowish brown colour. Compressive strength is high and standard penetration test N-values are 11 to 40 (average 20). This layer lies approximately from 14m to 28m in depth.

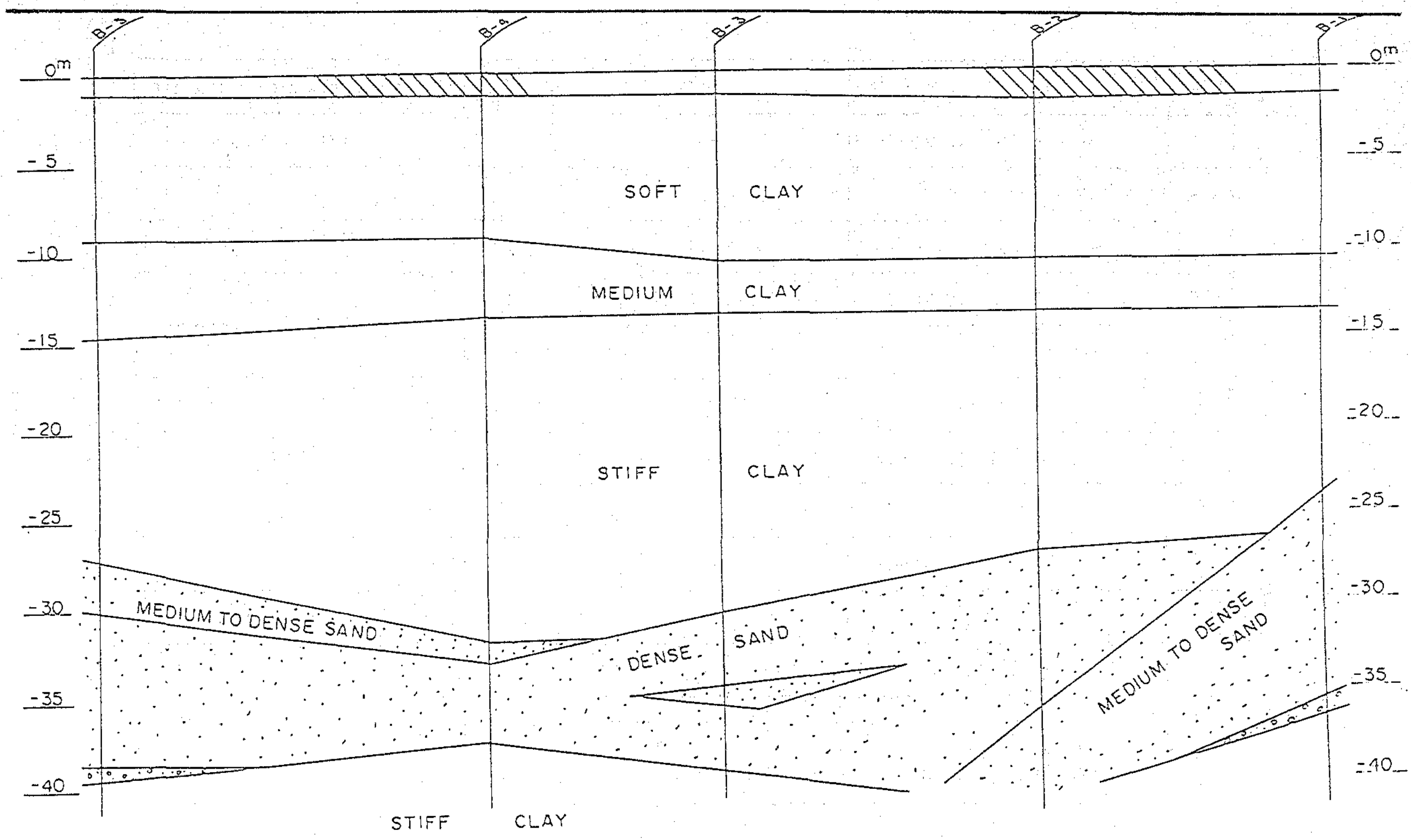
4. Dense Sand

   This layer is a dense silty fine sand, 6 to 14m thick containing thin layers of clay. Standard penetration test varies widely in the layer; the N-value of the layer closest to the clay layer is not high giving 17 - 30 but near the middle dense layer it marks 50 or over.



(Source: BMA)

Fig. 3-2-5 Location of Bored Holes for Flyover Bridge along Rama IV Road



(Source: JICA Basic Design Study)

Fig. 3-2-6 Soil Profile

Table 3-2-5 Physical Soil Properties of Subsoils

Strata / Silt or clay		Soil Properties		Medium stiff clay		Soft clay		Dense sand	
		Range	Average	Range	Average	Range	Average	Range	Average
Depth	m	1.5~10.0		10.0~14.0		14.0~28.0		28.0~38.0	
Gravel	%	3	3	—	—	0	0	0~2	1
Sand	%	25	25	—	—	6~35	23	68~94	82
Stiff clay	%	72	72	—	—	65~94	77	5~32	17
Liquid limit, LL	%	62~94	76	62	62	33~72	53	—	—
Plastic limit, PL	%	23~34	28	25	25	15~25	20	—	—
Plasticity Index, PI	%	39~65	43	37	37	18~47	33	—	—
Water content	%	40~81	63	35~75	55	17~45	26	9~28	19
Wet unit weight	t/m³	1.53~1.80	1.64	1.56~1.86	1.69	1.74~2.10	1.96	—	—
Classification		C H		C H		CL, CH		SC, SM, SP	
Standard penetration	N	—	—	—	—	11~40	20	17~68	39
Unconfined compressive strength	t·f/m²	2.0~5.0	3.5	5.4~12.2	7.2	10.6~45.0	21.8	—	—

Table 3-2-5 presents the summary of physical soil properties of each layer obtained from the above-mentioned 5 bore holes. The water level in the bore holes was observed at about 1.0 to 3.4m deep from the ground level.

The actual location of the bridge foundation is designed approximately at the centre of the existing road where the khlong had been filled, while the location of the soil investigation is at the roadside as shown in Fig. 3-2-5. The thickness of a clay layer of the upper stratum might be different from the data of the soil investigation. However, the depth of bearing stratum of sand is considered not varied.

g. Underground Public Utilities

There are many public utilities installed under Rama IV Road. As shown in Fig. 3-2-7 three main water pipes are installed under the median and on its south side a drainage box culvert (2.70m x 2.75m) is installed. Under the sidewalk on each side of the road, water pipe, telephone cable and power cables are buried. Under the intersecting roads many utilities are installed.

Especially under Silom-Rachadamri Road a main water pipe having a diameter of 1.5m is installed.

Among the above-mentioned utilities the three main water pipes under the median are considered closely related to the Project. MWA has agreed to the re-location of the pipes before the construction.

It is found that to move the drainage box culvert mentioned above is impossible in the light of limited construction time because the drainage structure has a large feeder system. Therefore the foundation of the pier column of the viaduct has been planned so as to avoid the re-location of the drainage box culvert.

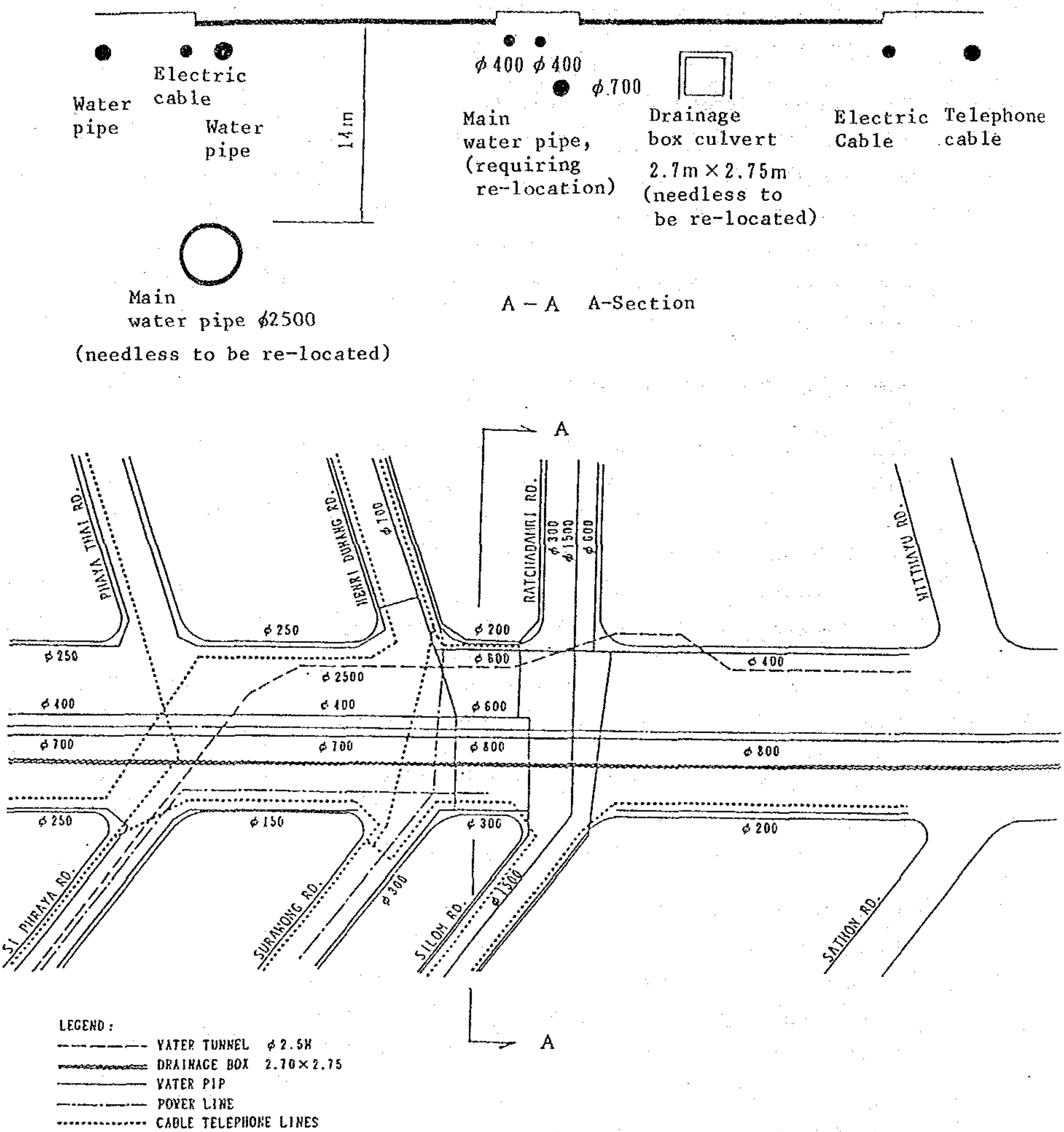


Fig. 3-2-7 Location of Existing Underground Utilities

3-2-2 Study for the Structure Requested

The viaduct structure of the Project has a total length of about 1,500m, and it is divided longitudinally into two structures by direction, with a centre clearance of 2.8 meters in between. Between the two structures the pier columns to support the skytrain (MTS) structure by ETA will be provided. The viaduct consists of one lane in each direction for the section from the western end beyond the Siphraya intersection, where the traffic is not so great, two ramps having one lane in each direction come up between the two intersections, Siphraya and Surawong, joining the above-mentioned two lanes, giving four lanes in both directions. The four lanes of the viaduct overpass the intersections, Surawong and Silom and go down on Rama IV Road at the east end because in this section the traffic is estimated considerably great.

The above-mentioned pier columns of the skytrain (MTS) structure are designed to stand at 30 meter distances. To maintain an aesthetic side view of the row of pier columns, the pier columns of the Rama IV viaduct must be equally spaced, and 30m which is also an economical distance for the pier columns of the viaduct is taken for the standard spans that occupy the most of viaduct spans. However a distance of 50 meters is taken for the span over the intersection which requires a wider horizontal clearance.

3-2-3 Check for Projects Overlapped

As stated in Section 2-2-1, ETA has planned a mass transit railway system (MTS) since eight years ago. The Rama IV rail line is planned to run along Rama IV Road just the same way as the viaduct of this Project. The pier columns of both the viaduct and the MTS structure are to be constructed along the existing median of Rama IV Road, but the superstructure, column and foundation of the viaduct are planned not to be connected with any part of the MTS structure.

3-2-4 Validity and Necessity of the Project

Rama IV Road which involves the construction site of this Project directly links from the Bangkok Port to the centre of Bangkok in the east-west direction and is one of the most important major streets in the road network of the city. Centreing around the project site, several major streets running in Bangkok intersects Rama IV Road in a north-south direction. On its northern side lie Chulalongkorn University and its hospital, Lumpini Park, etc. and the southern side constitutes the most important commercial area including prominent business, hotel, shopping and restaurant quarters of Bangkok. Therefore, great traffic concentrates on Rama IV Road which forms the worst traffic congestion in Bangkok, hindering the development of vehicular transportation of Bangkok.

The Report of the "Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok" issued by JICA in March 1987 presents the economic analysis of the Project including the construction of the flyover across Sathon Intersection. The result in a 10 year analysis period is as follows:

Cost benefit ratio : 2.64
Internal rate of return : 23.3%

The above figures give high returns and mean that the Project including Sathon Flyover is economically viable. In the two years since then, the economic validity is considered not to have changed.

By the implementation of the Project following effects could be expected:

(1) For the stretch of 2.5km including the location of the Thai-Belgian Bridge (Structure length: 330m), the traffic on Rama IV Road will form a smooth flow, divided into the through traffic on the viaduct and the (right and left) turning traffic on the at-grade road thus the traffic congestion will be mitigated with the increase in traffic capacity by about 20% although the number of lanes of Rama IV Road decreases from 10 to 8.

(2) Under the Rama IV Road viaduct, the traffic on Silom, Surawong and Siphraya intersections will be divided into the through traffic and the (right and left) turning traffic. Hence the present waiting time for signals 3 to 12 minutes at peak hours could be reduced to as short as one minute, thus the traffic congestion of the three intersections will be greatly reduced.

(3) From the matters mentioned in (1) and (2) above, the number of accidents of these intersections with Rama IV Road is expected to be reduced, with a proportional reduction in delays.

(4) From the matters mentioned in (1), (2) and (3) above, the national cost for vehicular transportation, fuel consumption and users' travelling time will be greatly reduced.

(5) Due to the smooth traffic flow, traffic pollution such as exhaust gas and vehicular noise will be reduced and the living environments will be much better than the present.

(6) Up to now it is dangerous for pedestrians to walk across Rama IV Road due to the heavy traffic. After the completion of the Project, however, the through traffic can run on the viaduct which will make crossing the road by pedestrians much easier.

(7) After the implementation of the Project Rama IV Road will have more room for the traffic and the emergency transportation of patients to the Chulalongkorn Hospital will be made more easily.

In view of the above effects mentioned above, the implementation of this Project is indispensable not only for alleviating the traffic congestion on Rama IV Road, providing non-stop, smooth traffic flow, improvement to the adjacent living environments by reducing exhaust gas and vehicular noise and development of transportation in Bangkok but also enhancing the urban transport industry and economic situation.

3-3 Project Description

3-3-1 Outline of Viaduct

As shown in Fig. 3-3-1, Rama IV Viaduct begins 320m west of the existing Siphraya - Phaya Thai road intersection and ends at 300m east of the existing Silom - Ratchadamri road intersection. The total road length is about 1,600m including the approach ramps.

The viaduct is divided longitudinally into two structures by direction: east-bound and west-bound, with a centre clearance of 2.8 metres in between. The viaduct consists of one lane in each direction for the section from the western end beyond the Siphraya intersection, two centre ramps having one lane in each direction come up between the two intersections, Siphraya and Surawong, joining the above-mentioned two lanes, giving four lanes in both directions. The viaduct of four lanes overpasses the intersections, Surawong and Silom and ramps down on Rama IV Road at the east end.

600m past the east ramp of the viaduct, there exists the Thai-Belgium Bridge which was completed in April 1988 by the grant aid of the Belgian Government.

The functions of the above-mentioned two centre ramps between Siphraya and Surawong intersections are described as follows:

(1) To raise the service level for the traffic to and from Phaya Thai Road and Siphraya Road through the centre ramps:

(2) To increase the utilization of the viaduct by providing U-turn facilities across the median strip between Silom and Surawong intersections.

(3) To increase the space of Rama IV Road underneath the viaduct by providing the centre ramps.

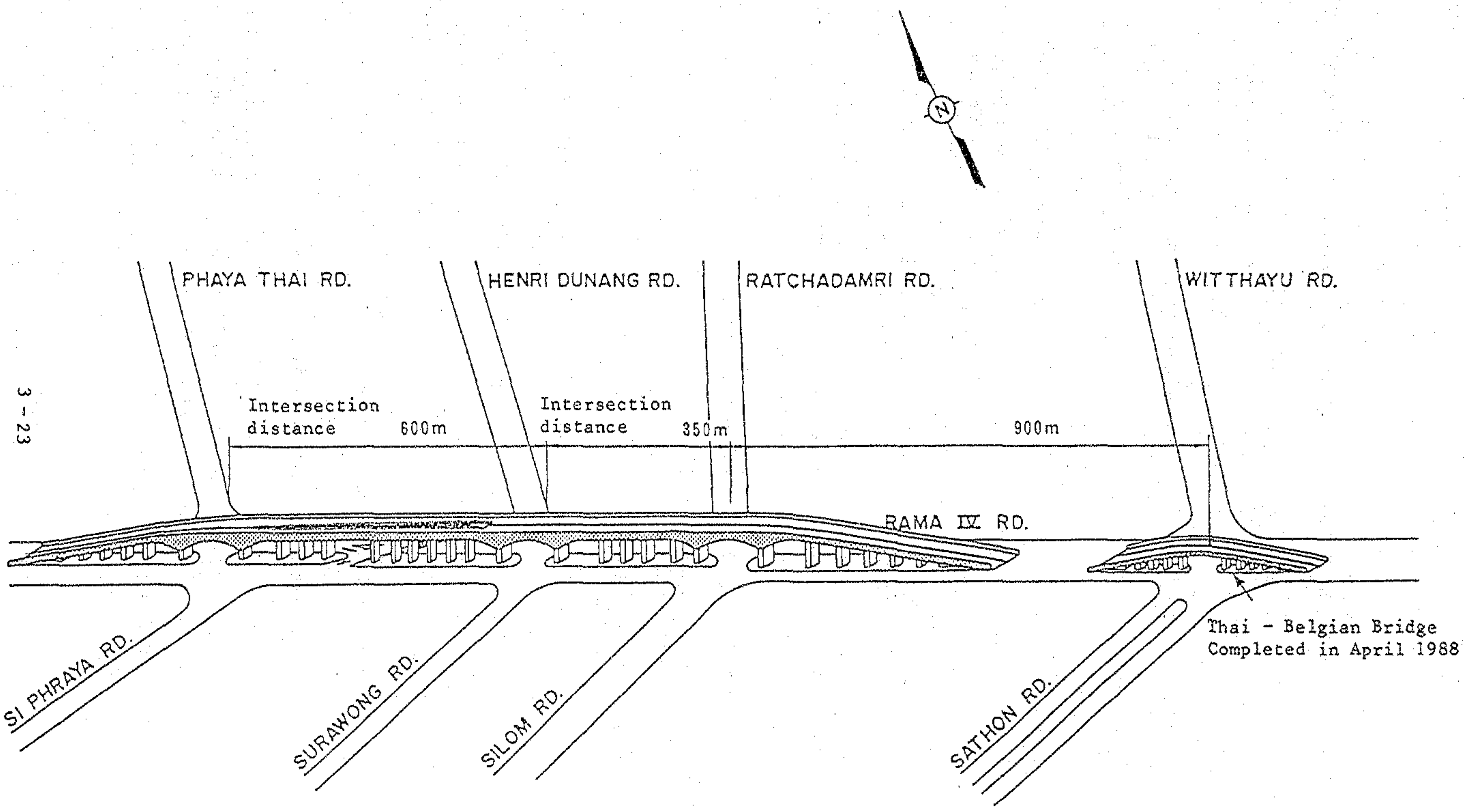


Fig. 3-3-1 Location of Rama IV Viaduct

The outline of the Viaduct is as follows:

(1) Total length of viaduct structure: 1,487m

(2) Type:

(a) Superstructure	:	Steel orthotropic deck simple girder (span length: 50m): 8 spans in 2 ways
	:	Precast concrete deck on simple steel girder (span length: 30m): 90 spans in 2 ways
	:	Approach section: approach slab
(b) Bridge pier	:	Single column T-shaped steel pier: 43 units, column in cylindrical shape and bracket in rectangular section
(c) Foundation	:	Cast-in-place concrete pile, diameter 1,000mm, about 30m deep

(3) Standard effective width	:	7.00m (2-lane carriageway) and 4.75m (one-lane carriageway)
(4) Load	:	1.3 x AASHTO Load, Thai Truck Load
(5) Pavement	:	Asphalt pavement
(6) Design earthquake coefficient	:	Kh = 0.05

3-3-2 Implementation and Operation of the Project

The Project is for the construction of a viaduct and after the completion the viaduct will require maintenance. The Bridge Maintenance Section is under the Department of Public Works (DPW), BMA. The executive agency of the Project is DPW and the Bridge Maintenance Section will take care of the maintenance (which corresponds to the operation of the Project). The organizations of BMA, DPW and the Bridge Maintenance Section are briefed as below:

a. Bangkok Metropolitan Administration (BMA)

As introduced in Section 2-1-1, BMA is the administration of the Bangkok area covering 1,565km^2. It has an organization of 12 departments as shown in Fig. 3-3-2. DPW takes care of roads within the jurisdiction of BMA.

b. Department of Public Works (DPW)

DPW is responsible for planning, design, construction maintenance, construction control and supervision, land acquisition of public works and buildings, and consists of following divisions (See Fig. 3-3-3):

- Chief of Secretary
- Design Division
- Construction & Maintenance Division
- Public Works Planning Division
- Construction Control & Supervision Division
- Building Control Division
- Right-of-Way and Land Acquisition Division

The budget for public works was the largest part of the BMA budget in the period 1985-1988, more than 21% as shown in Table 3-3-1. The budget used for roads was more than 20% of the BMA total corresponding to 90% of the total public works as shown in the same table.

The numbers of staff of DPW and Construction & Maintenance Division (C&MD) are as follows (excluding temporary staff, 1988):

	DPW	C&MD
Civil Engineers	133	16
Mechanical Engineers	3	2
Electrical Engineers	1	-
Architects	41	3
Technicians (civil, survey, draftsmen)	473	127
Technicians (mechanical)	20	20
Legal Officer	1	-
General Admin. & Personnel (include typist & storemen)	175	33
Financial Staff	34	11
Drivers & Cleaners	24	19
Total:	905 persons	231 persons

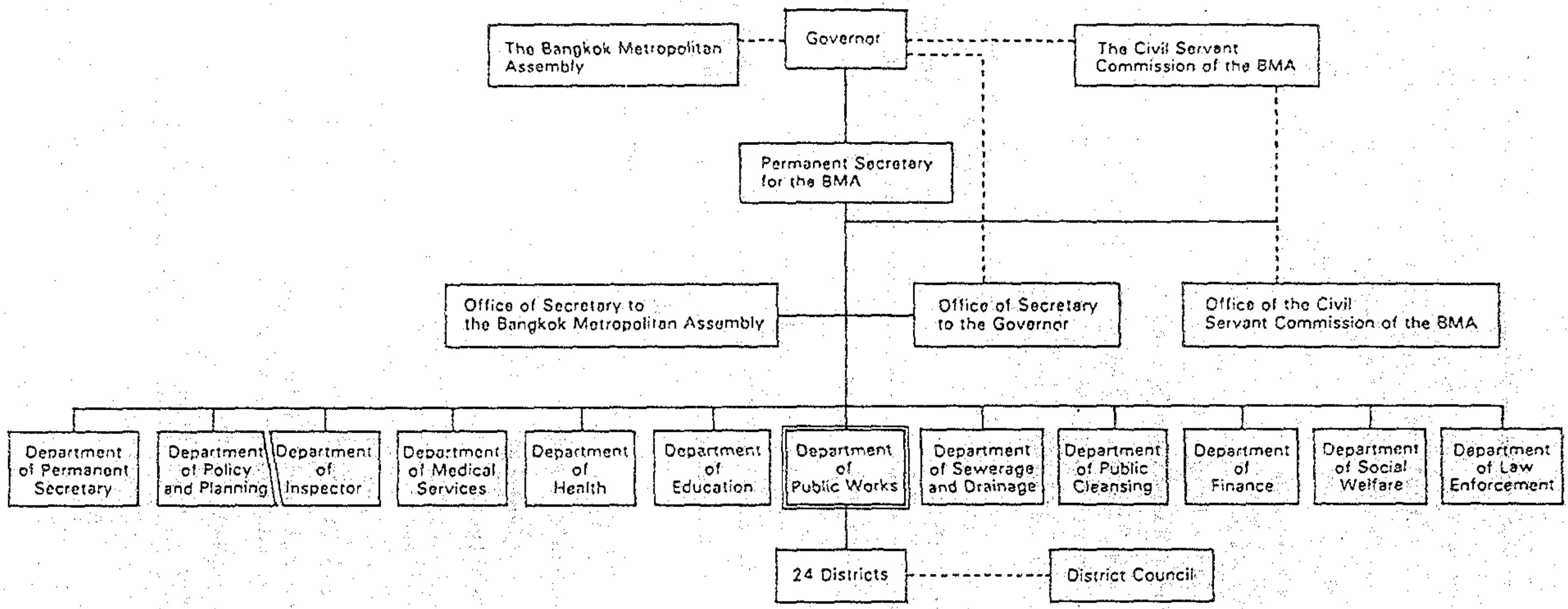


Fig. 3-3-2 Organization of the Bangkok Metropolitan Administration

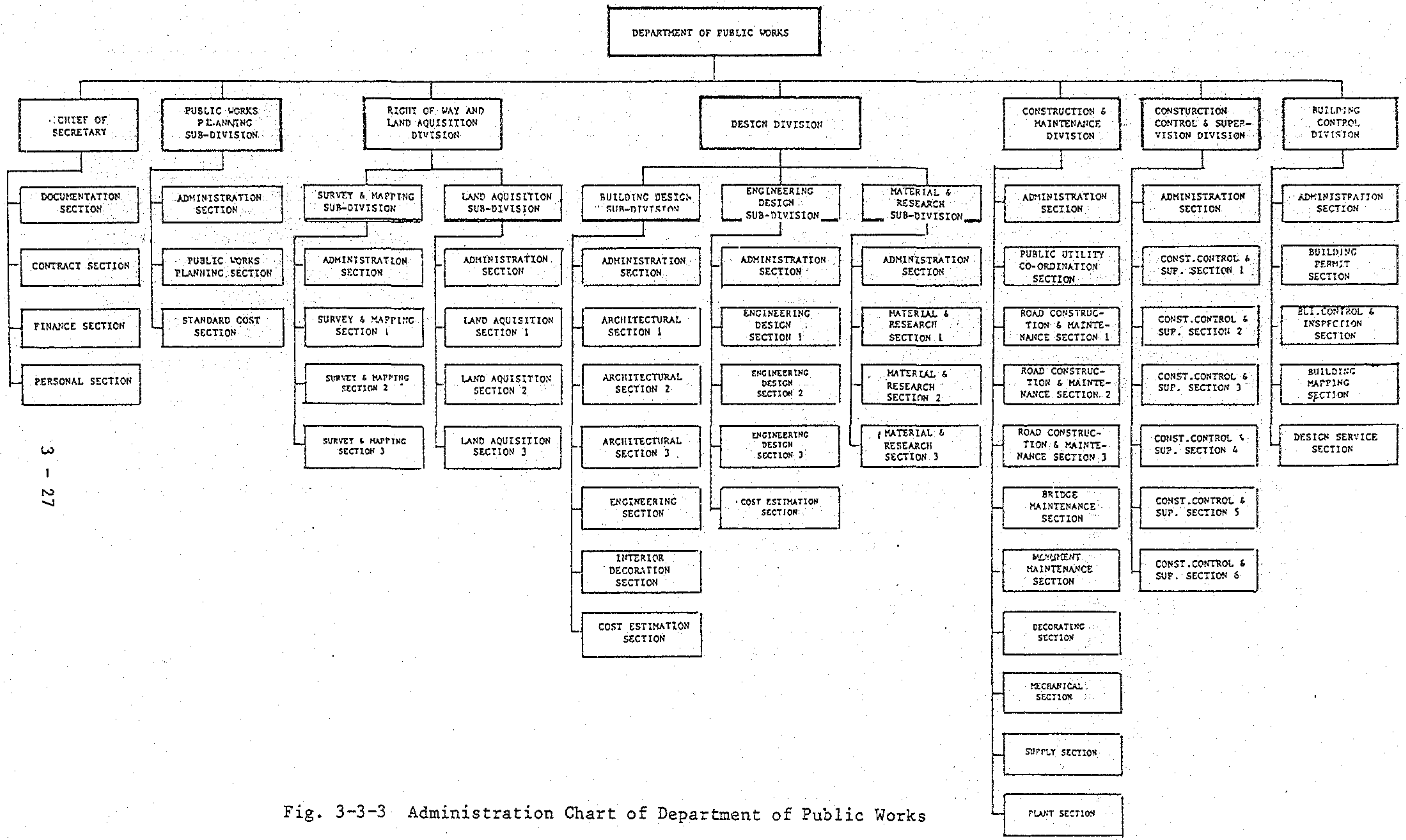


Fig. 3-3-3 Administration Chart of Department of Public Works

Table 3-3-1 BMA Budget Expenditure Appropriation by Activities:

Fiscal Year 1985 - 1988

(Unit : Million Baht)

Year	1985		1986		1987		1988	
Activities	Amount	%	Amount	%	Amount	%	Amount	%
Public Works	1,339.8	21.4	1,968.6	28.9	1,511.2	23.5	1,808.8	26.4
Road : New Construction	729.0	11.6	580.1	8.5	357.3	5.6	893.8	13.0
Improvement	148.6	2.4	148.6	2.2	168.1	2.6	119.0	1.7
Maintenance	326.1	5.2	217.4	3.2	234.4	3.6	286.9	4.2
Traffic	22.8	0.4	903.3	13.3	594.3	9.2	381.5	5.6
Other Public Works	113.3	1.8	119.2	1.7	157.1	2.5	127.6	1.9
Education	1,007.9	16.1	1,039.9	15.3	1,124.6	17.5	1,214.4	17.7
Contingent Fund	707.9	11.3	707.0	10.4	-	-	-	-
General Administration	639.3	10.2	676.7	9.9	1,068.8	16.6	901.2	13.1
Medical and Health Services	610.7	9.8	668.2	9.8	698.0	10.8	780.3	11.4
Public Cleansing	778.1	12.4	573.4	8.4	645.1	10.0	909.2	13.3
Drainage and Sewerage	715.3	11.4	810.0	11.9	998.3	15.5	829.9	12.1
Social Welfare	207.1	3.3	296.9	4.4	330.6	5.1	334.1	4.9
Debt Payment	-	-	-	-	-	-	-	-
BMA Commercial	253.7	4.1	66.3	1.0	57.0	0.9	76.0	1.1
Total	6,259.8	100.0	6,807.0	100.0	6,433.6	100.0	6,853.9	100.0

Source : Budget Division, Department of Permanent Secretary for BMA

c. The Bridge Maintenance Section

The Bridge Maintenance Section is under the jurisdiction of the Construction and Maintenance Division of DPW (See Fig. 3-3-4) and has a comparatively small organization of 3 engineers, 18 technicians and 25 labourers. This section takes care of the inspection of bridges under the jurisdiction of BMA. The 1989 budget for this section amounts to ฿31,002,000.

d. The Executive Agency

BMA has planned construction of bridges, replacement of old bridges and grade separation on major roads. It is anticipated that within these several years BMA will encounter some difficulty in maintaining the road facilities with the present BMA's organization.

Fortunately, however, DPW under BMA has a large sum of budget in terms of road projects, having at present 133 civil engineers. It is considered that if engineers having experienced in the maintenance of steel bridges DPW could dispose of the maintenance problems.

3-4 Maintenance Plan

3-4-1 Recommendation for Steel Bridge Maintenance

After the completion of the Thai - Belgian Bridge (Steel structure) in 1988, BMA has started the maintenance for the steel bridge including painting and the inspection of bolt refastening. Since the viaduct of this Project is scheduled for completion in 1992, BMA will have to reform its present bridge maintenance organization for steel structures. Periodical steel bridge painting can be entrusted to private specialists, but for the routine inspection the staffing force must be strengthened. Judging from the examples of Japan, a steel bridge with the same size and type as Rama IV viaduct will require the following works:

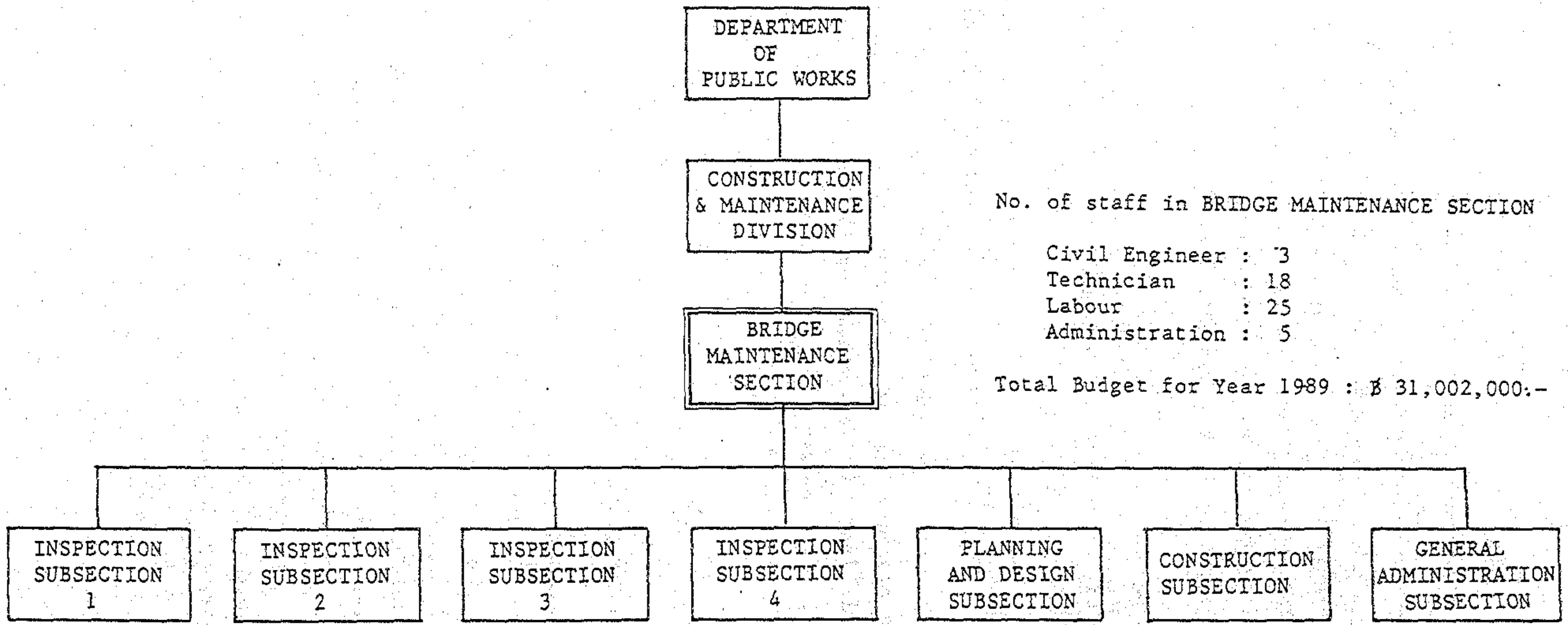


Fig. 3-3-4 Present Organization of "Bridge Maintenance Section", Department of Public Works, BMA

(1) Daily work : Patrol inspection with 2 engineers
Cleaning of drain pipes with 4 labourers
Cleaning of bridge surface with 4 labourers

(2) Work as required : Replacement of illumination lamps

(3) Work in 5-15 years : Painting and scaffolding therefor (entrusted)

Considering the above-mentioned matters, BMA will have to consolidate its present "Bridge Maintenance Section" only for the routine works by adding one engineer, one technician and eight labourers.

It has been found that BMA has no experience in maintenance of steel bridges nor appliances therefor. As described in Section 3-3-2 of this Report, BMA has preeminently much road budget and that a considerable amount of it is appropriated to its road maintenance budget. In view of this fact, it may be defined as not difficult that BMA can assign specialists in steel bridges, being equipped with the maintenance apparatuses.

BMA's Road Maintenance budget Expenditure Appropriation

(Unit: ฿ million)

Year	1985	Increase rate to previous year	1986	Increase rate to previous year	1987	Increase rate to previous year	1988
Road Maintenance Budget	326.1	-33.3%	217.4	7.8%	234.4	22.3%	286.9
Rate to Road & Traffic Budget	26.6%		11.7%		17.3%		17.0%
Rate to BMA Total Budget	5.2%		3.2%		3.6%		4.2%

(Source: BMA)

During the construction of the Project BMA can prepare a manual for steel bridge maintenance with the help of the Consultant and the Contractor and that it also can receive at the site the technology transfer of repair of painting, and refastening of bolts, etc. by setting up an organization necessary for the maintenance of the viaduct within BMA. Additional expenditure incurred by the change and reinforcing of the organization, as stated previously, can be sufficiently covered by the BMA's present budget.

3-5 Technical Cooperation

In response to a request form the Government of Thailand, JICA conducted the "Study on Road Improvement, Rehabilitation and Traffic Safety in Bangkok" from June 1985 to March 1987. The study proposed improvements to 11 intersections to relieve bottlenecks in the road system of Bangkok, as stated previously. This Project that is one of the above-mentioned intersections has been adopted for review and consideration by Japanese grant aid assistance. The project site lies on Rama IV Road which serves as one of the greatest traffic routes in Bangkok, and therefore the construction method will require most sensitive preparation and attention ever given to an urban project. Especially the traffic management and control during the erection of bridge girders, will demand the fullest cooperation of BMA and the Metropolitan Police Bureau.

The Project is for the construction of a large-scale steel viaduct structure, and its detailed design and construction planning and supervision are thought as a rare case in Thailand which has not been experienced in terms of the magnitude. Local engineers desire to have a chance to learn the methods of design and construction supervision of the steel structure, however, full consideration and support by the Consultants and the Contractors will be necessary for BMA staff engineers to obtain the techniques about the steel structures. Exceptional cooperation by the BMA is essential to realize the implementation of this Project.

The proposed structure is of steel which will require periodical maintenance. Such maintenance is not familiar for BMA management who therefore would be required to secure technical know-how for the steel bridge maintenance such as painting, bolt refastening, replacement of noise barriers, etc. which are all regarded as necessary after the completion.

CHAPTER 4: BASIC DESIGN

CHAPTER 4 BASIC DESIGN

4-1 Design Policy

The design standards which have been established for adoption in Thailand shall be considered, and where any supplemental criteria are required, reference shall be made to the design standards of AASHTO and Japan.

4-2 Study and Examination of Design Criteria

4-2-1 Road Design Criteria

Major design criteria for road design are as follows:

(1) Geometric design criteria;
(2) Drainage design criteria;
(3) Pavement design criteria; and
(4) Road facilities design criteria

Discussion on the above-listed criteria was made with BMA's designers and the criteria to be planned for this Project were confirmed.

a. Geometric Design Criteria

For the design standards concerning the geometric design of roads, the technical guideline which was established in the JICA Study shall be considered. The major elements of the design criteria are shown in Table 4-2-1, and the typical cross sections of carriageways of viaduct and at-grade roads are illustrated in Fig. 4-2-1 to Fig. 4-2-3.

b. Drainage Design Criteria

The drainage design criteria for viaduct surface and drainage system of rain water running down to the existing drainage box culvert under Rama IV Road are as follows:

Probability rainfall intensity

Road surface drainage	:	2 years
Roadside area	:	5 years

Design rainfall intensity : Ref. to Fig. 4-2-4.

c. **Pavement Design Criteria**

For the bridge surface pavement of the viaduct, asphalt concrete of normal kind shall be planned because it has an advantage of cost, noise and maintenance.

The repair of pavement damaged due to the foundation construction, the repair of the existing at-grade road and the improvement of intersection will be made in the following ways:

Repair of existing cement concrete pavement	:	cement concrete
Improvement of at-grade road and intersection	:	asphalt concrete
Pavement for viaduct and its approach	:	asphalt concrete

For the repair of the existing cement concrete pavement the same thickness as the previous pavement is planned. The structure of cement concrete pavement will follow the BMA's design standards.

For the improvement of existing intersections and reshaping of channel islands asphalt concrete is applied because the existing pavement is asphalt concrete. Asphalt concrete pavement will be applied as much as possible to the repair of existing pavement because the shape of pavement to be repaired is considered to the rectangular and the re-paved area must be open to traffic in the shortest possible time.

The ground below the approach section, which is apt to sink non-uniformly must be paved with asphalt concrete because the asphalt paving is flexible. The structure of asphalt concrete pavement shall accord to BMA's standard design (See Fig. 4-2-5).

Table 4-2-1 Design Standard for Rama IV Viaduct

	Throughway 2-lane	Throughway 1-lane	Ramp	At-grade Street
Classification of Road in BMA	Major Road			Minor Road
Design Speed (km/h)	60	60	40	40
Design Vehicle	Semi-trailer			Large-Sized Motor Vehicle
Lane Width (m)	3.25	3.25	3.25	3.0 (2.75)
Median	Refer to Technical Guidline			
Shoulder, Outer (m)	0.5	1.5	1.5	0.3
Shoulder, Inner (m)	0.5	0.5	0.5	0.3
Stopping Lane	N/A	N/A	N/A	N/A
Bus Lane (m)	N/A	N/A	N/A	3.5
Bus Bay	N/A	N/A	N/A	N/A
Min Sidewalk Width (m)	N/A	N/A	N/A	2.75
Standard Cross Section	Refer to Fig.3-2-1	Refer to Fig.3-2-2	Refer to Fig.3-2-2	Refer to Fig.3-2-3
Clearance	Refer to Technical Guidline			
Radius of Horizontal Curvature		ditto		
Length of Curve		ditto		
Superelevation		ditto		
Widening on Curves	Refer to Technical Guidline			
Transition Section		ditto		
Superelevation Runoff		ditto		
Stopping Sight Distance		ditto		
Grades		ditto		
Vertical Curves		ditto		
Cross Slope (%)	1.5	1.5	1.5	1.5 - 2.0
At-grade Intersection	N/A	N/A	N/A	Refer to Technical Guidline

Note: Figure in parenthesis shows the absolute minimum.

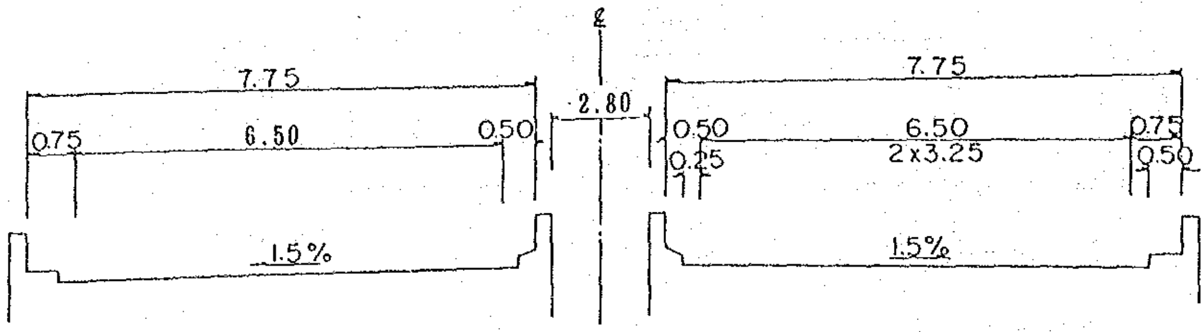


Fig. 4-2-1 Typical Cross Section for 4 Lanes Two Ways, Viaduct

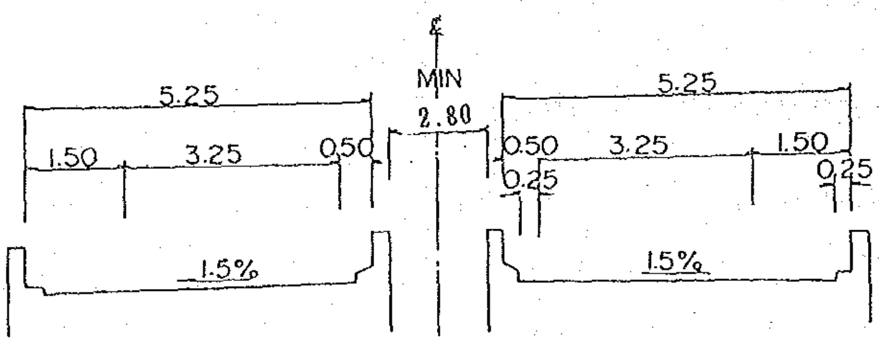


Fig. 4-2-2 Typical Cross Section for 2 Lanes Two Ways, Viaduct

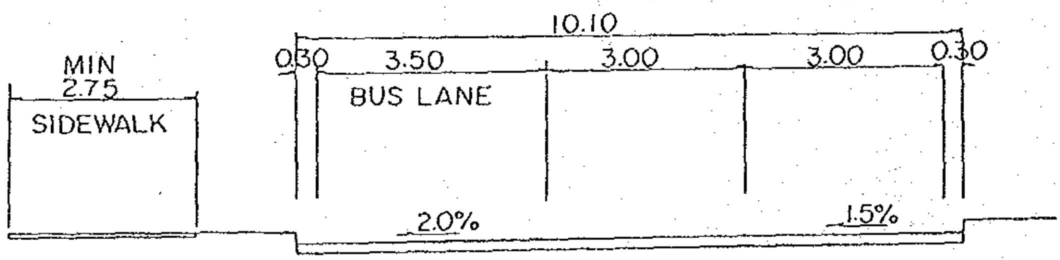
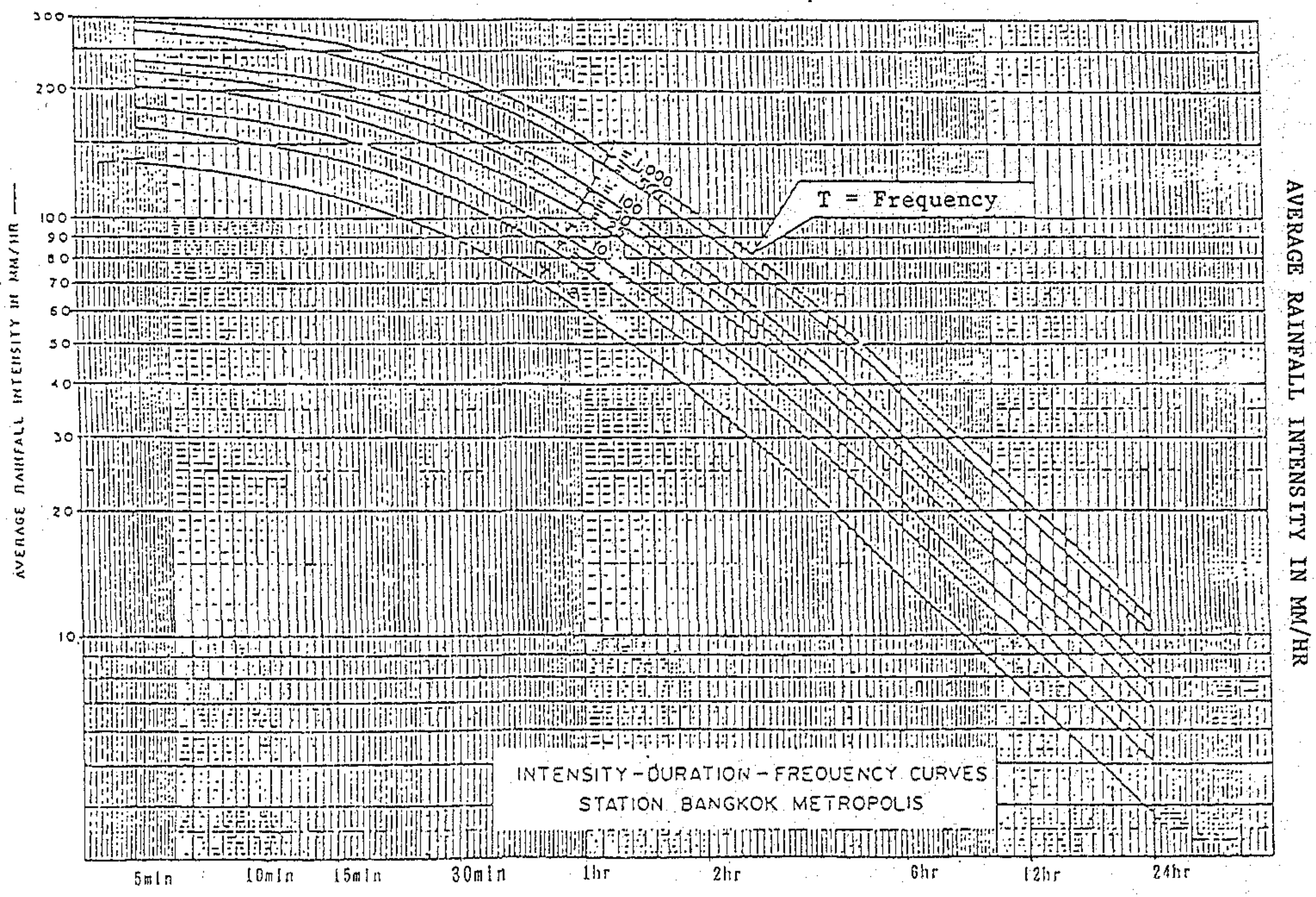
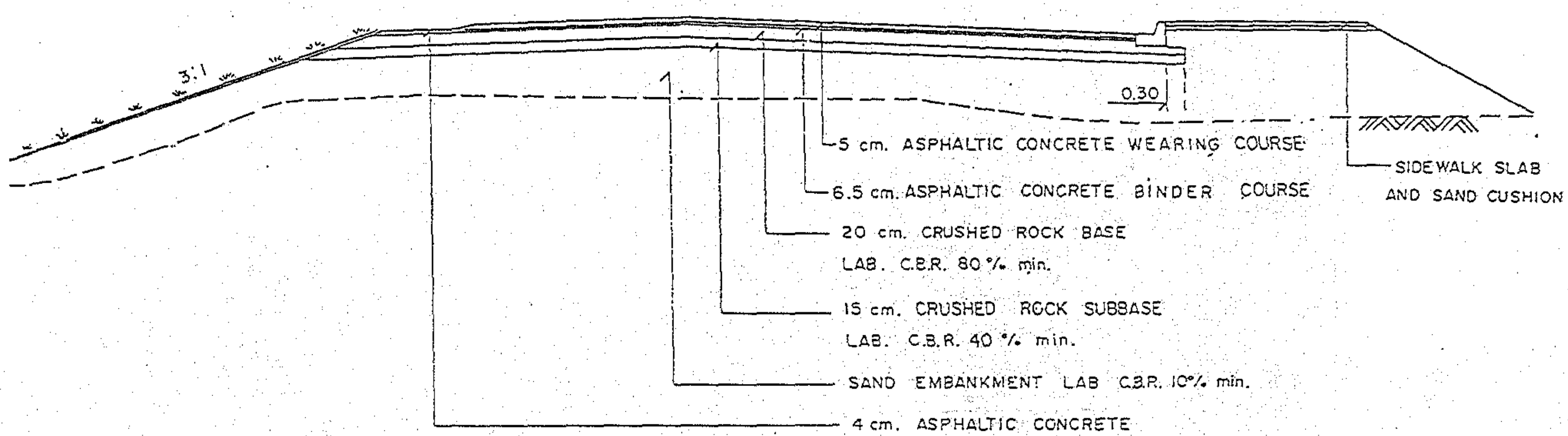


Fig. 4-2-3 Typical Cross Section for At-Grade Street



(Source: BMA)

Fig. 4-2-4 Intensity-Duration-Frequency Curves



(Source: BMA)

Fig. 4-2-5 Standard Asphaltic Concrete Pavement Structure

d. Road Facilities Design Criteria

Road facilities consist of traffic safety facilities and traffic control facilities. Among the traffic safety facilities guard fence and illumination facility are closely related to this Project.

On the viaduct the guard fence is installed for handrailing and at the noses for merging and diverging traffic streams. On the at-grade road it is installed on channelized islands and around pier columns located close to the carriageway.

Road lighting which has an effect to reduce the traffic accidents at night is installed on the viaduct.

Design scope	:	viaduct and approach
Design illuminance	:	10 lux (0.7 cd/m^2)
Lighting pole and its height	:	Taper pole, overhanging type 13m, an angle of less than 5 degrees

A lighting pole provided in the middle of the median can illuminate the two carriageways. However, considering the future location of piers for ETA sky train structure in the above-mentioned median, lighting poles should be provided along the outer edges of the viaduct.

The traffic control facilities includes road signs and marking, road information boards, traffic signals, etc. The design of these facilities shall accord to the Thai Standard.

4-2-2 Design Criteria of Viaduct

a. Design Load

1. Dead load

In estimating the dead load the unit weights of materials listed in the following table are used.

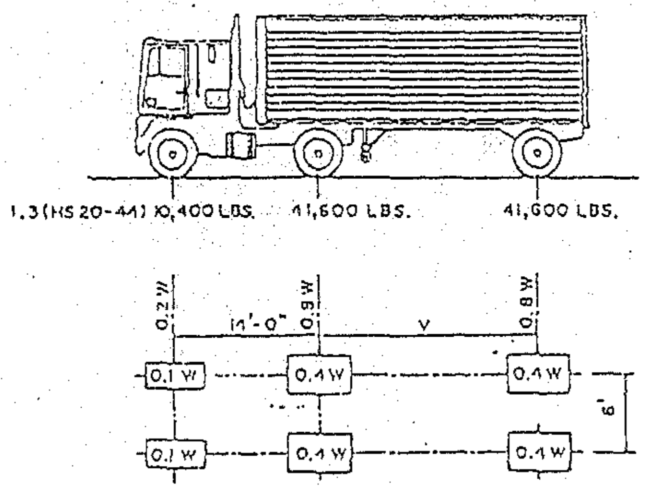
Unit Weights of Materials

Material	Unit Weight	
	Kg/m^3	(#/cu.ft)
Steel or case steel	7,850	(490)
Cast iron	7,200	(450)
Aluminum alloys	2,800	(175)
Timber (treated or untreated)	800	(50)
Concrete, plain or reinforced	2,400	(150)
Compacted sand, earth, gravel or ballast	1,900	(120)
Loose sand, earth, and gravel	1,600	(100)
Macadam or gravel, rolled	2,250	(140)
Cindor filling	950	(60)
Pavement, other than wood block	2,400	(150)
Railway rails, guard rails and fastenings (per linear foot of track)	3,200	(200)
Stone masonry	2,700	(170)
Asphalt plank	1,750	9 lb.sq.ft./ 1in.thick

(Source: Article 3.3.6 of AASHTO 1983)

2. Live Load (Vehicular Load)

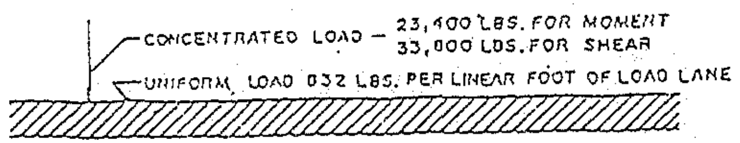
BMA has been affected with an increase in traffic in Bangkok and in the increasing weight of trucks coming into the city, resulting in the damage to the roads. BMA has judged that the traditional AASHTO loadings, H20 and HS20 are too small and has adopted HS20 x 130% together with their own Thai Truck Loading specified as an overload provision for the infrequent heavy loading condition (See Fig. 4-2-6). Since Rama IV Road is part of BMA road network, BMA has requested the adoption of the above-mentioned live loads.



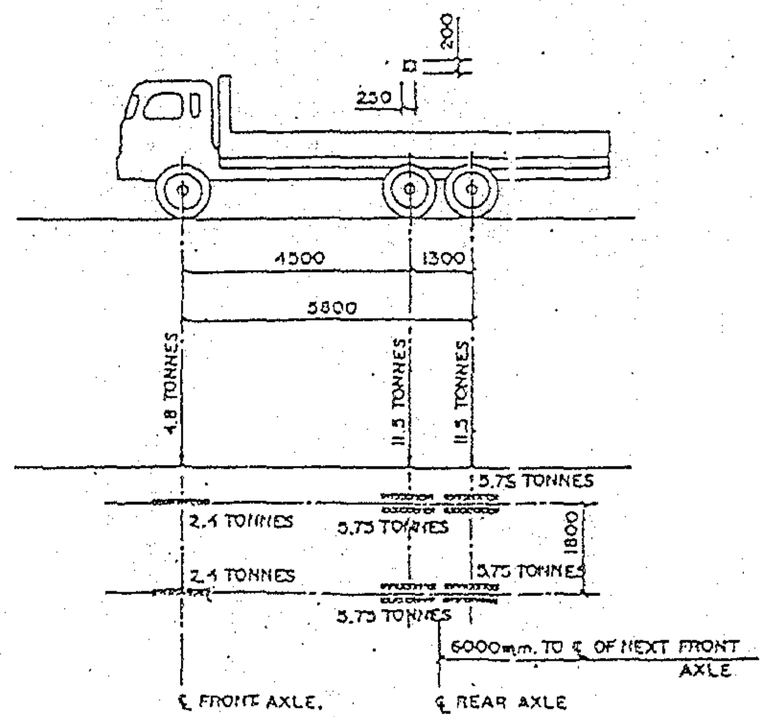
W • COMBINED WEIGHT ON THE FIRST TWO AXLES.

V • VARIABLE SPACING — 14 FEET TO 30 FEET INCLUSIVE. SPACING TO BE USED IS THAT WHICH PRODUCES MAXIMUM STRESSES.

MODIFIED HS TRUCK LOADING



MODIFIED HS LANE LOADING



AVG. • 27.8 TONNES

THAI TRUCK LOADING

Fig. 4-2-6 Design Bridge Loading Used by BMA

3. Impact Coefficient

The amount of the impact allowance or increment shall be determined by the formula:

$$I = \frac{50}{L + 125}$$

where

I = impact fraction (maximum 30 percent);

L = length in feet of the portion of the span that is loaded to produce the maximum stress in the member.

4. Longitudinal Forces

Provision shall be made for the effect of a longitudinal force of 5 percent of the live load in all lanes carrying traffic headed in the same direction.

5. Curb and Railing Loadings

Curbs shall be designed to resist a lateral force of not less than 500 pounds per linear foot of curb, applied at an elevation of 10 inches above the floor if the curb is higher than 10 inches.

The minimum height of a railing used to protect the traffic shall be 3 feet 6 inches.

6. Wind Load

The wind load intensity of 50 kg/sq.m is applied horizontally at the right angle to the superstructure in accordance with the Thai specification of building construction in case of 0 to 10 m height.

7. Thermal Force

According to the climate in Thailand, the range of temperature 10°C - 60°C will be applied to the design of steel structures.

8. Earthquake

5% of the self weight of the structure is applied horizontally by equivalent static force method.

9. Combination of Loads

The following Groups represent various combinations of loads and forces to which a structure may be subjected. Each component of the structure shall be proportioned to withstand safely all group combinations of these forces that are applicable to the particular site or type. Group loading combinations for Service Load Design and Load Factor Design are given by the following formula, and for service load design, the percentage of the basic unit stress for the various groups is given in the table below.

$$\text{Group (N)} = \gamma[\beta_D \cdot D + \beta_L (L + I) + \beta_C CF + \beta_E E + \beta_B B + \beta_S SF + \beta_W W + \beta_{WL} WL + \beta_L \cdot LF + \beta_R (R + S + T) + \beta_{EQ} EQ + \beta_{ICE} ICE]$$

where

- N = group number;
- γ = load factor, see Table 3.22.1A;
- β = coefficient, see Table 3.22.1A;
- D = dead load;
- L = live load;
- I = live load impact;
- E = earth pressure;
- B = buoyancy;
- W = wind load on structure;
- WL = wind load on live load
- LF = longitudinal force from live load;
- CF = centrifugal force;
- R = rib shortening;
- S = shrinkage;
- T = temperature;
- EQ = earthquake;
- SF = stream flow pressure;
- ICE = ice pressure.

Table of Coefficients γ and β

Col. No.		1	2	3	3A	4	5	6	7	8	9	10	11	12	13	14	
GROUP		γ	β FACTORS													%	
			D	$(L+I)_n$	$(L+I)_p$	CF	E	B	SF	W	WL	LF	R+S+T	EQ	ICE		
SERVICE LOAD	I	1.0	1	1	0	1	β_E	1	1	0	0	0	0	0	0	100	
	IA	1.0	1	2	0	0	0	0	0	0	0	0	0	0	0	150	
	IB	1.0	1	0	1	1	β_E	1	1	0	0	0	0	0	0	**	
	II	1.0	1	0	0	0	1	1	1	1	0	0	0	0	0	125	
	III	1.0	1	1	0	1	β_E	1	1	0.3	1	1	0	0	0	125	
	IV	1.0	1	1	0	1	β_E	1	1	0	0	0	1	0	0	125	
	V	1.0	1	0	0	0	1	1	1	1	0	0	1	0	0	140	
	VI	1.0	1	1	0	1	β_E	1	1	0.3	1	1	1	0	0	140	
	VII	1.0	1	0	0	0	1	1	1	0	0	0	0	1	0	133	
	VIII	1.0	1	1	0	1	1	1	1	0	0	0	0	0	1	140	
	IX	1.0	1	0	0	0	1	1	1	1	0	0	0	0	1	150	
	X	1.0	1	1	0	0	β_E	0	0	0	0	0	0	0	0	100	Culvert
LOAD FACTOR DESIGN	I	1.3	β_D	1.67*	0	1.0	β_E	1	1	0	0	0	0	0	0	Not Applicable	
	IA	1.3	β_D	2.20	0	0	0	0	0	0	0	0	0	0	0		
	IB	1.3	β_D	0	1	1.0	β_E	1	1	0	0	0	0	0	0		
	II	1.3	β_D	0	0	0	β_E	1	1	1	0	0	0	0	0		
	III	1.3	β_D	1	0	1	β_E	1	1	0.3	1	1	0	0	0		
	IV	1.3	β_D	1	0	1	β_E	1	1	0	0	0	1	0	0		
	V	1.25	β_D	0	0	0	β_E	1	1	1	0	0	1	0	0		
	VI	1.25	β_D	1	0	1	β_E	1	1	0.3	1	1	1	0	0		
	VII	1.3	β_D	0	0	0	β_E	1	1	0	0	0	0	1	0		
	VIII	1.3	β_D	1	0	1	β_E	1	1	0	0	0	0	0	1		
	IX	1.20	β_D	0	0	0	β_E	1	1	1	0	0	0	0	1		
	X	1.30	1	1.67	0	0	β_E	0	0	0	0	0	0	0	0		Culvert

$(L + I)_n$ - Live load plus impact for AASHTO Highway H or HS loading

$(L + I)_p$ - Live load plus impact consistent with the overload criteria of the operation agency.

b. **Major Construction Materials**

1. Steel Material for Steel Structure

The steel material for steel structure shall accord to JIS and the steel material for welding to JSS as well as JIS.

- Steel material for structure	JIS G 3101	SS41, SS50
	JIS G 3106	SM41, SM50, SM50Y SM53, SM58
- Steel Material for welding	JIS B 1186	F10T
	JSS II 09-1981 ...	S10T
- Anchor bolt	JIS G 4051	S35CN

2. Steel Material for Concrete Structure

The steel material for concrete structure shall accord to AASHTO material standards, or JIS.

	AASHTO	JIS
Reinforcing bar	M31-86, Grade 40	G 3112, SD30
PC steel bar	M275-79	G 3109, SBPR
PC steel strand	M203-83, Grade 270	G 3536, SWPR7B

3. Cement

	AASHTO	JIS
Portland cement	M85-84	R 5210

4-3 Basic Plan

4-3-1 Desing of Road and Intersection

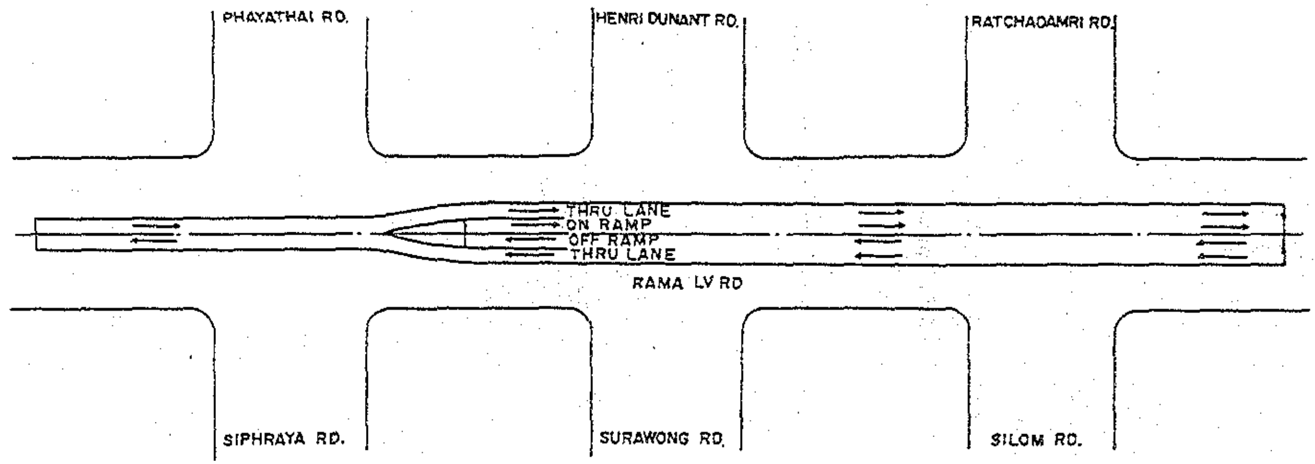
a. Design of At-grade Street

The number of lanes of the existing 10-lane Rama IV Road will be reduced by the construction of the viaduct. Fig. 4-3-1 presents the number of lanes after the completion of the viaduct. In spite of the decrease in number of lanes, the traffic capacity of Rama IV Road will increase because of the availability of non-stop travel by the through traffic, lessening the traffic burden at each intersection.

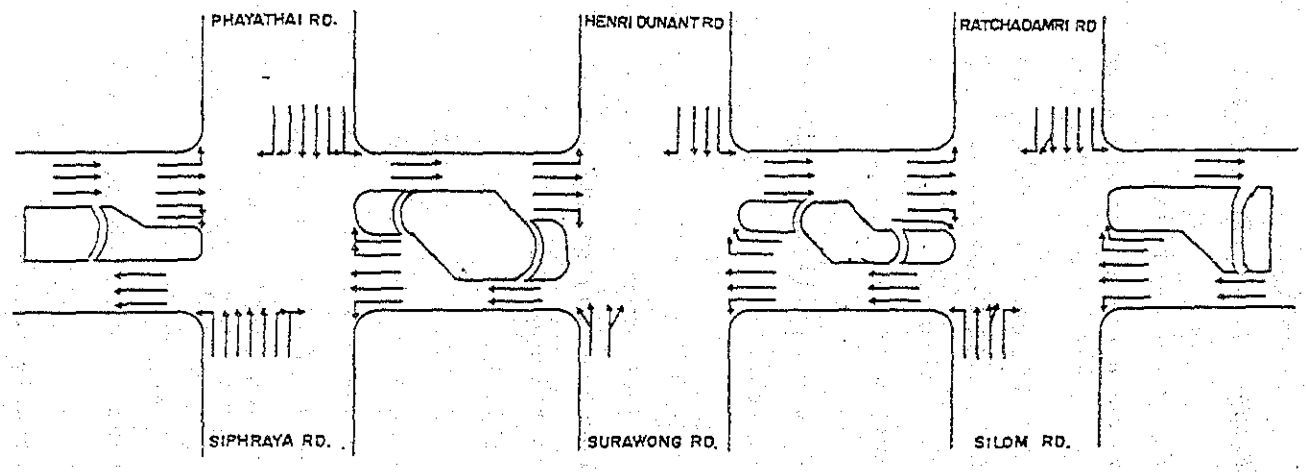
U-turn facilities provided between intersections will bring benefits to vehicle users who at present suffer from long detour travel.

Fig. 4-3-2 shows the expected effects by the completion of Rama IV viaduct which have been revealed by JICA's previous study. By the construction of the viaduct, for the stretch of 2.5km including the location of the Thai-Belgian Bridge, the traffic on Rama IV Road will form a smooth flow, divided into the through traffic on the viaduct and the (right and left) turning traffic on the at-grade road thus the traffic congestion will be mitigated with the increase in traffic capacity by about 20% although the number of lanes of Rama IV Road decreases from 10 to 8. Under the Rama IV Road viaduct, the traffic on Silom, Surawong and Sipharaya intersections will be divided into the through traffic and the (right and left) turning traffic. Hence the present waiting time for signals 3 to 12 minutes at peak hours could be reduced to as short as one minute, thus the traffic congestion of the three intersections will be greatly reduced.

There exist two pedestrian bridges in the project site. These two pedestrian bridges have to be removed before the construction of the viaduct. The western pedestrian bridge which is located near the Siphraya intersection is planned to be relocated further west, while the eastern pedestrian bridge near the Surawong intersection may be replaced by a Zebra Crossing because of reduced road crossing of two lanes with lower traffic volumes.

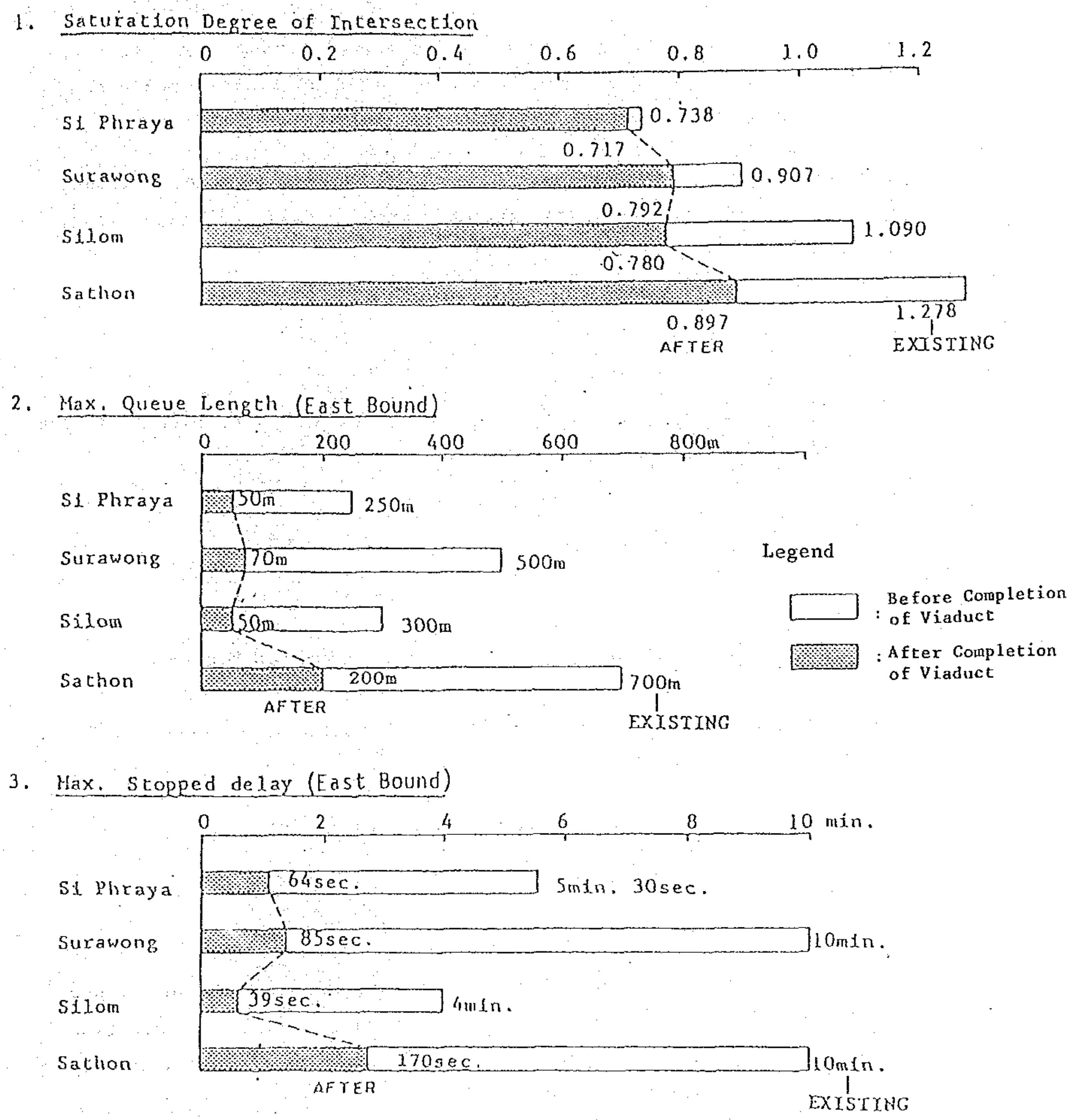


Lane Arrangement of Viaduct



Lane Arrangement of At-grade Street

Fig. 4-3-1 Number of Lanes After Completion of Viaduct



Intersection : Rama IV/Si Phraya - Sathon Rd. (No. 020 - 023) (P.M. Peak)

Fig. 4-3-2 Expected Effects by Rama IV Viaduct Project

b. **Design of At-grade Intersection**

Three intersections are signalised and have predominance through traffic volume. Traffic signals are operated by traffic policemen, and accordingly the cycle time of each signal is not consistent.

Fig. 4-3-3 shows the estimated traffic volume on the viaduct diverted from the at-grade street which JICA's previous study forecast.

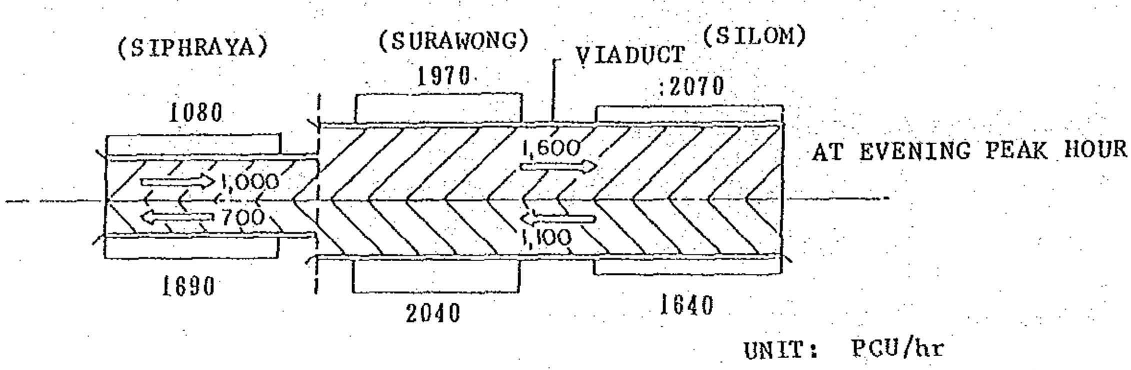


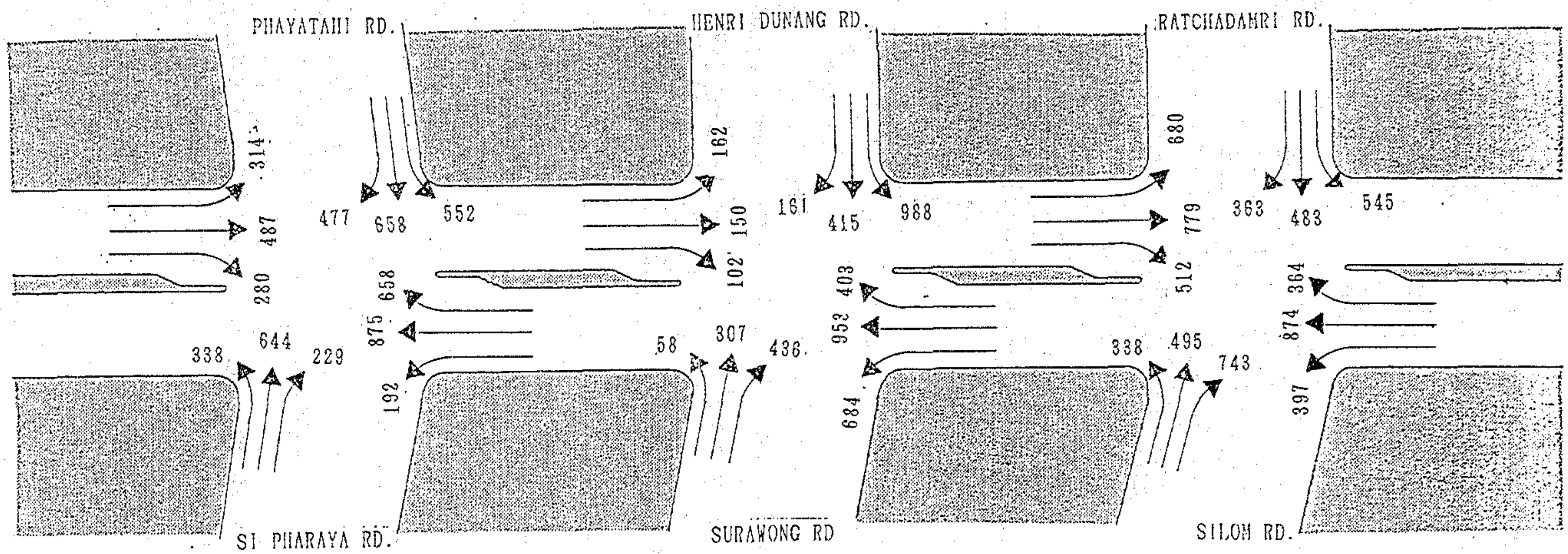
Fig. 4-3-3 Estimated Diverted Traffic Volume on Viaduct

The design of each intersection is based on the peak-hour traffic shown on Fig. 4-3-4.

The following two points are taken into account:

1. Channellization

The channellization of intersection is designed as shown in Fig. 4-3-5 to avoid "interlocking right-turn". Thus, no bridge pier should be provided in the centre of intersection. This type of traffic management has advantage of high capacity and safety due to good sight distances.



At Pea Hour : 15 : 00~16 : 00.

Fig. 4-3-4 Estimated Traffic Volume by Direction after Completion of Viaduct

Unit : PCU/hr

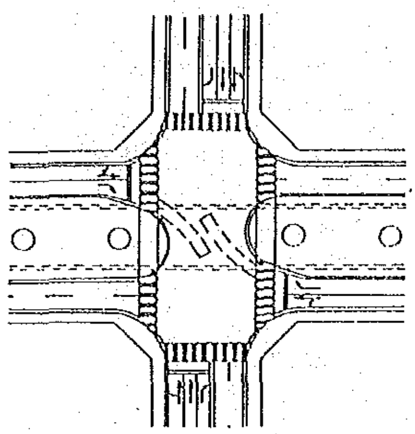


Fig. 4-3-5 Right Turn Channellization Beneath Viaduct

2. Centre Span of Viaduct

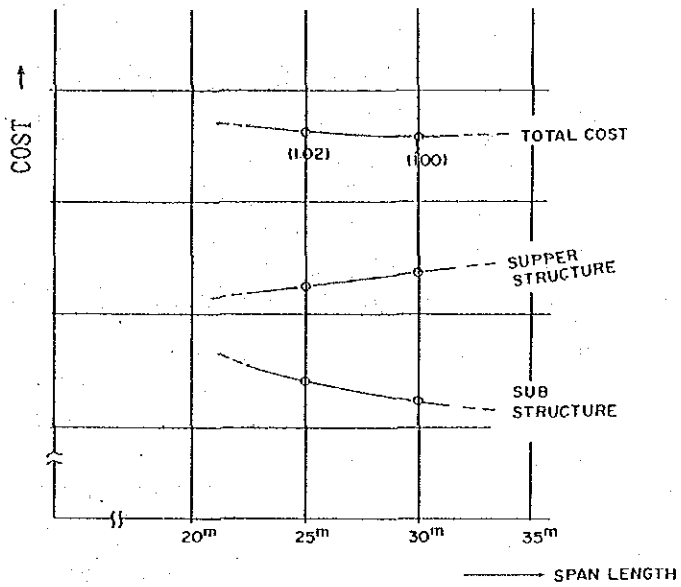
The longer the span of a bridge is the more expensive it becomes. The channellizaton on "interlocking right-turn" method is apt to make the centre span of the viaduct longer. In this Project, however, the width of an intersection has been made as compact as possible, reducing the length of centre span to 50m.

4-3-2 Design of Superstructure of Viaduct

a. Span Length

Generally the span length of a bridge is determined from the condition of substructure and the economy of whole structure. In this Project the length of the span over the intersection has been planned at 50m, based on the improvement design of the existing intersection. For the length of spans except over the intersection, a comparison was made to determine the most economic span length and the result was between 25m and 30m as shown below.

The 30m length is planned as standard span to balance with the MTS substructures which have also been designed at 30m distances on Rama IV Road.



COST COMPARISON BY SPAN LENGTH

b. Steel Orthotropic Deck (Fig. 4-3-6)

The steel orthotropic deck superstructure is light in weight, minimizing the dimensions of the substructure and is excellent in making the bridge quickly available for traffic after its erection and road surfacing.

c. Precast Concrete Deck (Fig. 4-3-7)

Precast concrete deck which is to be non-composite with the steel girder is planned for use in the standard span section, because concrete precast deck is low in cost and provides a good bonding surface for the paving on the bridge, although it is heavy and has an influence over the substructure.

A comparison was made of seven types of decks: cast-in-place concrete deck, grating deck, PC composite deck, precast PC deck, composite deck, precast RC deck and steel orthotropic deck. The result is shown in Table 4-3-1. At the beginning of the detailed design stage the adoption of PC precast deck or RC precast deck will be justified.

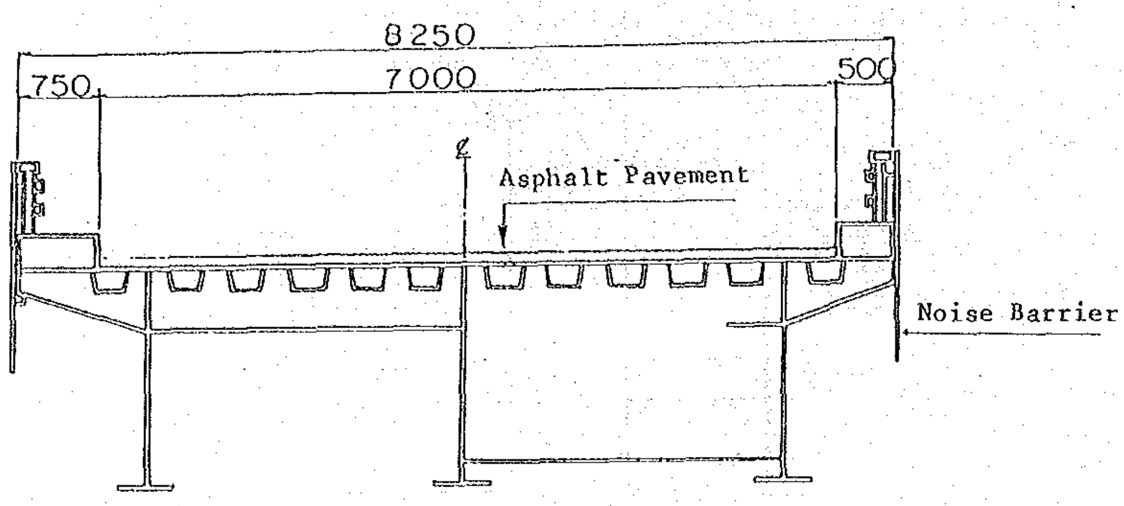


Fig. 4-3-6 Standard Cross Section: Steel Orthotropic Deck

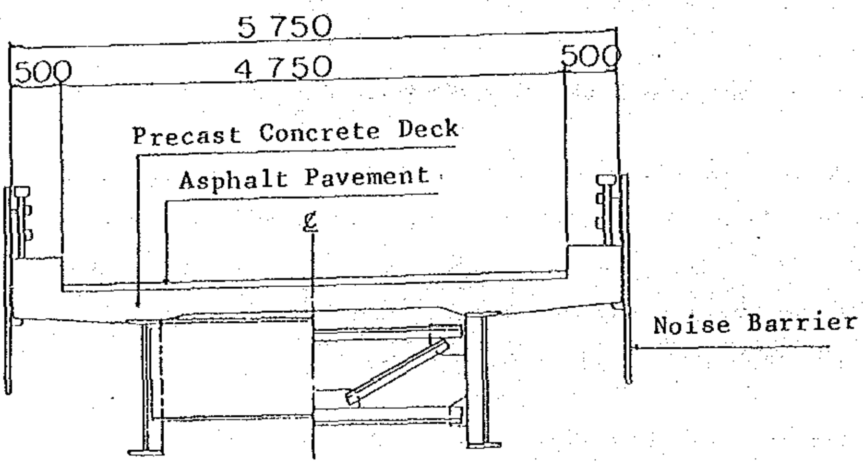
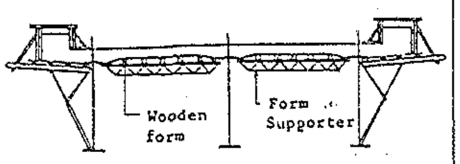
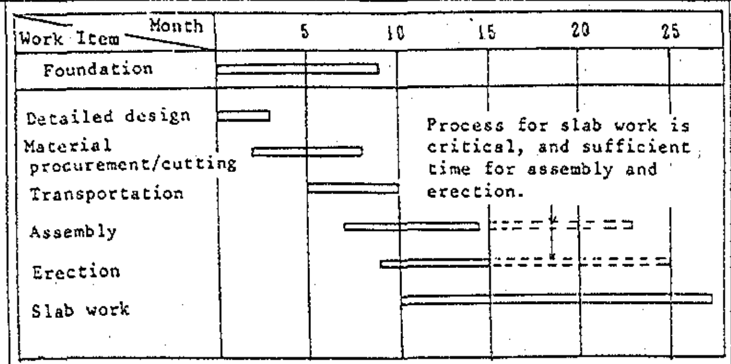
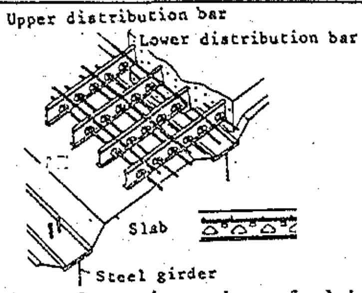
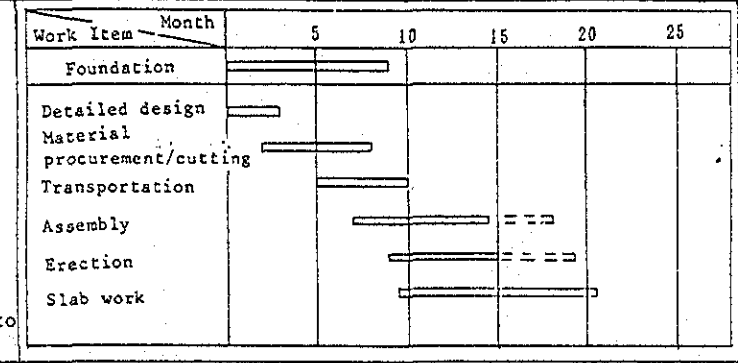
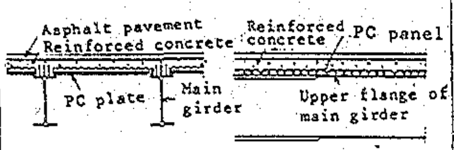
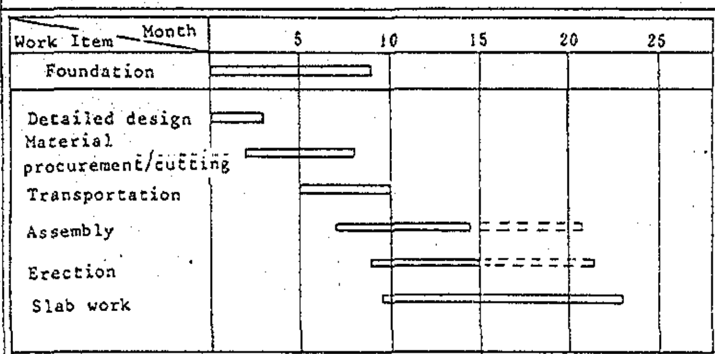
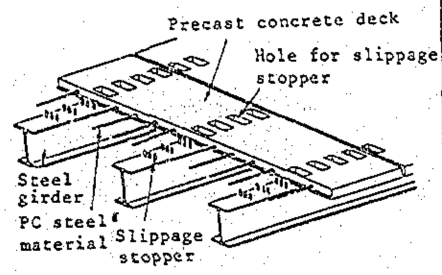
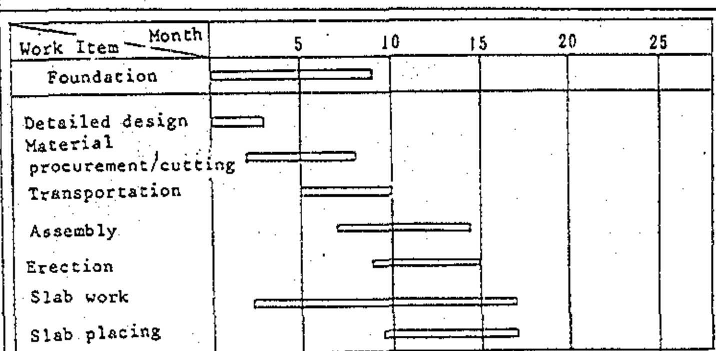
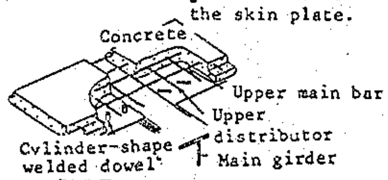
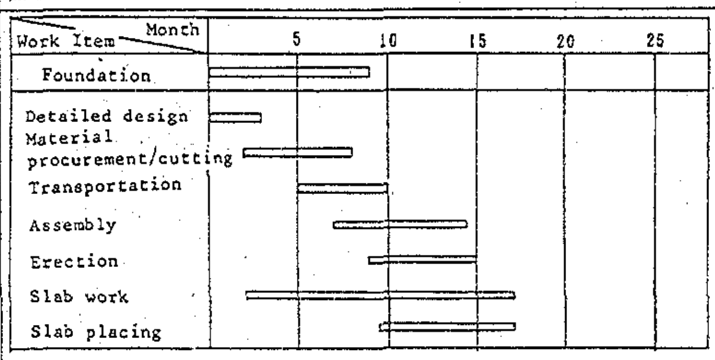
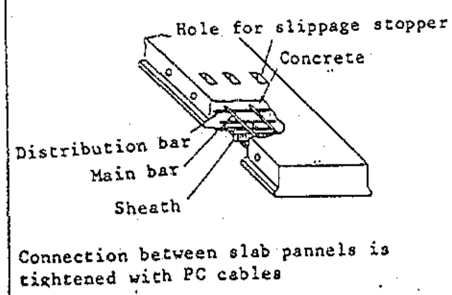
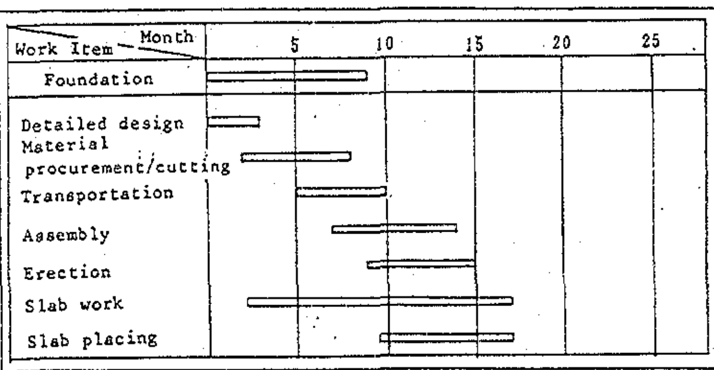
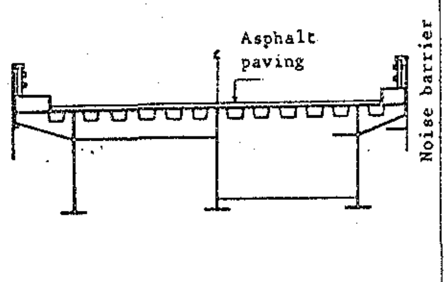
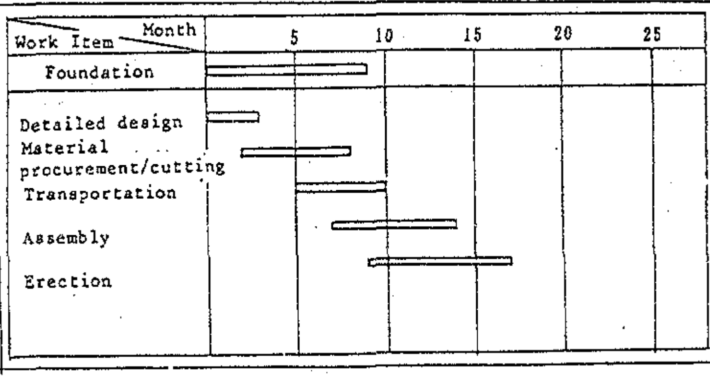


Fig. 4-3-7 Standard Cross Section: Precast Concrete Deck

Table 4-3-1 Comparison of Types of Deck

	Illustration of Slab Structure	Construction Time Period	Direct Construction Cost of Deck (yen/m^2) in case of in Japan	Evaluation	
(A) Cast-in-place Concrete Deck on Suspended Forms	 Wooden form Form Supporter	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work Process for slab work is critical, and sufficient time for assembly and erection.	29.000	· Generally used with low cost but longer construction time. · Not much used in Thailand	
(B) Stay-in-place I-beam Deck	 Upper distribution bar Lower distribution bar Slab Steel girder I-beam for main member of slab and galvalized skin plate form welded to I-shaped steel.	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work	50.000	· Compared with Alternative A, Construction time is shortened by the work of suspended forms. · For preventing corrosion of skin plate, strict water proof is required	
(C) Stay-in-place Precast PC Composite Form	 Asphalt pavement Reinforced concrete Reinforced concrete PC panel PC plate Main girder Upper flange of main girder PC panel form is placed between main girders, bars are placed thereon and concrete is placed, becoming composite with PC panel.	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work	70.000	· Compared with Alternative B, Construction time is longer by the work of re-bar arrangement.	
(D) Precast PC Deck	 Precast concrete deck Hole for slippage stopper Steel girder PC steel material Slippage stopper	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work Slab placing	70.000	· Slab thickness can be smaller than Alternative F. · Prestressing facilities are required for manufacturing. · Construction cost in Thailand is comparatively low. · Favorable for rapid construction.	○
(E) Precast Composit Deck	Skin plate placed at the bottom of slab acts compositely with concrete placed thereon through dowelled joints fixed on the skin plate.  Concrete Upper main bar Upper distributor Cylinder-shape welded dowel Main girder	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work Slab placing	55.000	· Skin plate and dowelled joints must be made in Japan due to their special process required, but concrete can be of Thai product. · Favorable for rapid construction.	
(F) Precast RC Deck	 Hole for slippage stopper Concrete Distribution bar Main bar Sheath Connection between slab pannels is tightened with PC cables	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection Slab work Slab placing	50.000	· Compared with Alternative D, Manufacturing is easier, yard manufacturing is available if site condition allows, because of no facilities for prestressing required. · Cost is same as that of Alternative E but less expensive when manufacturing in Thailand.	○
(G) Steel Orthotropic Deck	 Asphalt paving Noise barrier	 Work Item / Month: 5, 10, 15, 20, 25 Foundation Detailed design Material procurement/cutting Transportation Assembly Erection	120.000	· Lightest deck type in weight · Poor adhesiveness of paving asphalt. · High cost.	△

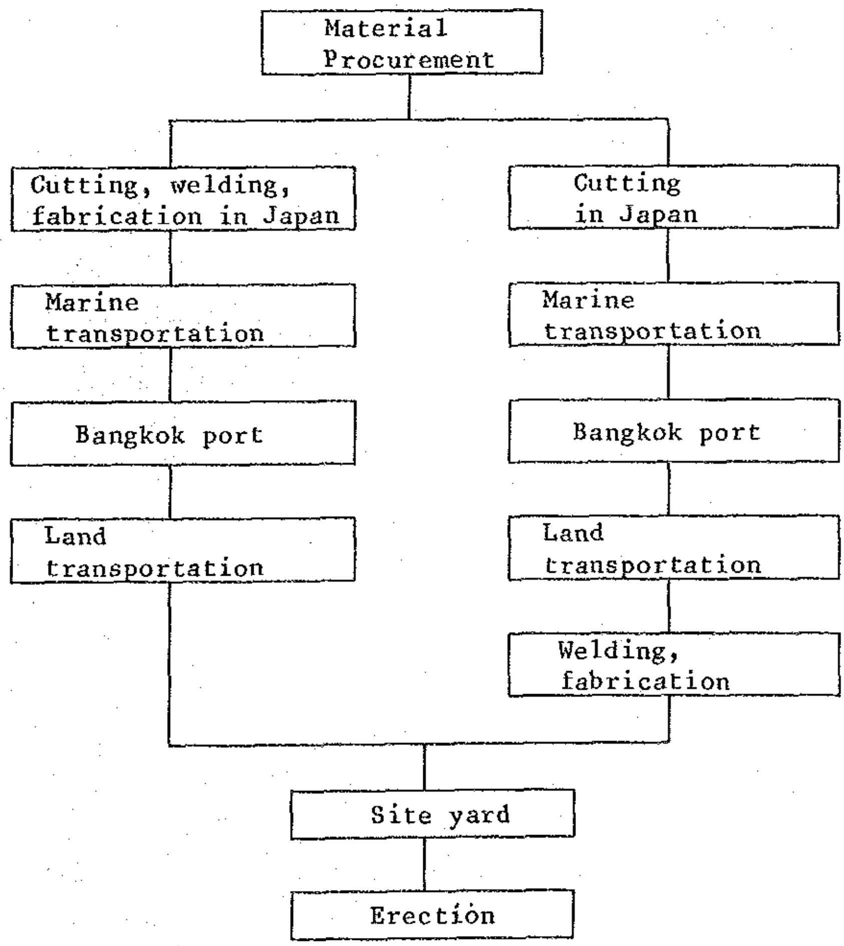
d. **Type of Girder**

The record shows that in the Bangkok area the ground has sunk 5 - 40cm during these 10 years. If the continuous span bridge is constructed on the ground under this condition, it is certain that non-uniform sinking of the structure is envisaged. Therefore the arrangement of simple span is planned.

The major disadvantage of simple span design is that many expansion joints must be provided. For the standard span girder (30m long), however, a simple expansion joint device has been planned over which asphalt pavement will be continuously placed, thus overcoming the above-mentioned demerit.

e. **Erection**

The work flow from procurement of steel material to erection of steel girders can be illustrated as below:



Our survey reveals that the maximum transportable goods from the Bangkok port to the site yard is 4.0m x 3.5m x 20.0m, and 30 -50t. On this basis the maximum dimensions of a superstructure member for road transportation can be planned.

To reduce the erection time, steel members will be assembled to maximum possible size. Judging from the site conditions, a structure having a size 8.5m x 30.0m can be moved in the site area. In this case the 30m long girders will be erected in one operation while 50m long girders over the intersections will require two operations with an intermediate temporary support. In both cases cranes with a capacity of more than 150t and special carriages are required.

f. Bridge Ancillary Facilities

1. Guard Fence

The guard fence on the viaduct is proposed as illustrated in Fig. 4-3-8.

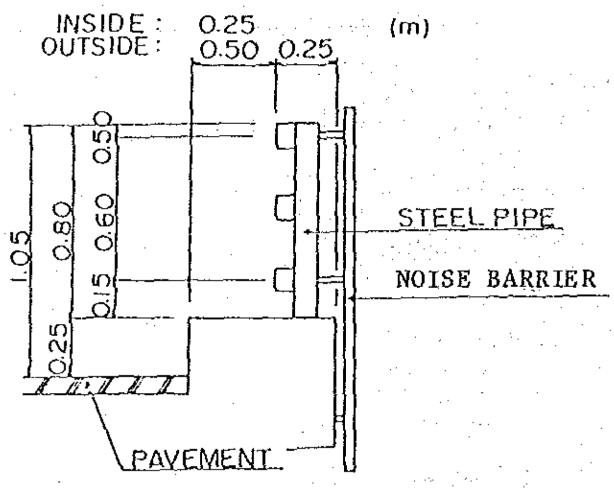
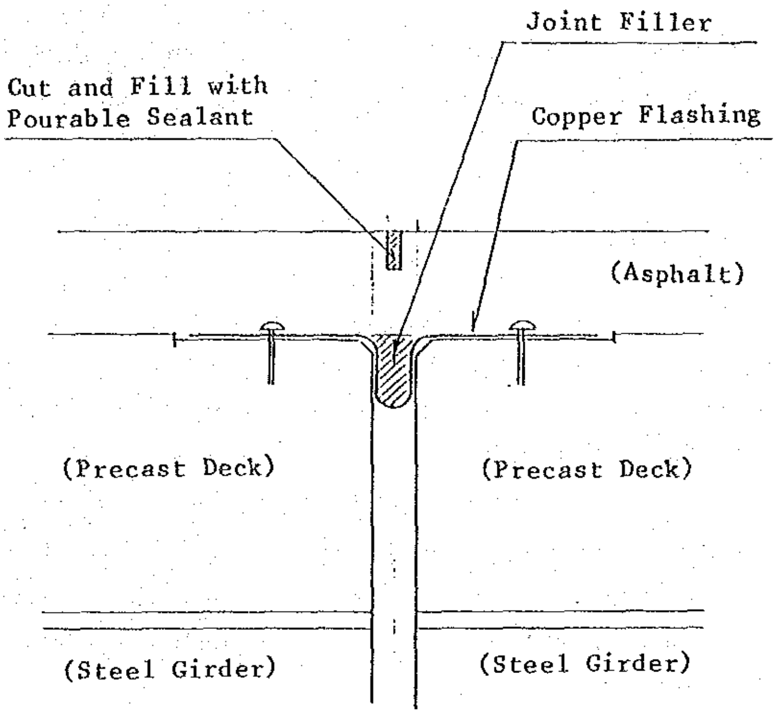
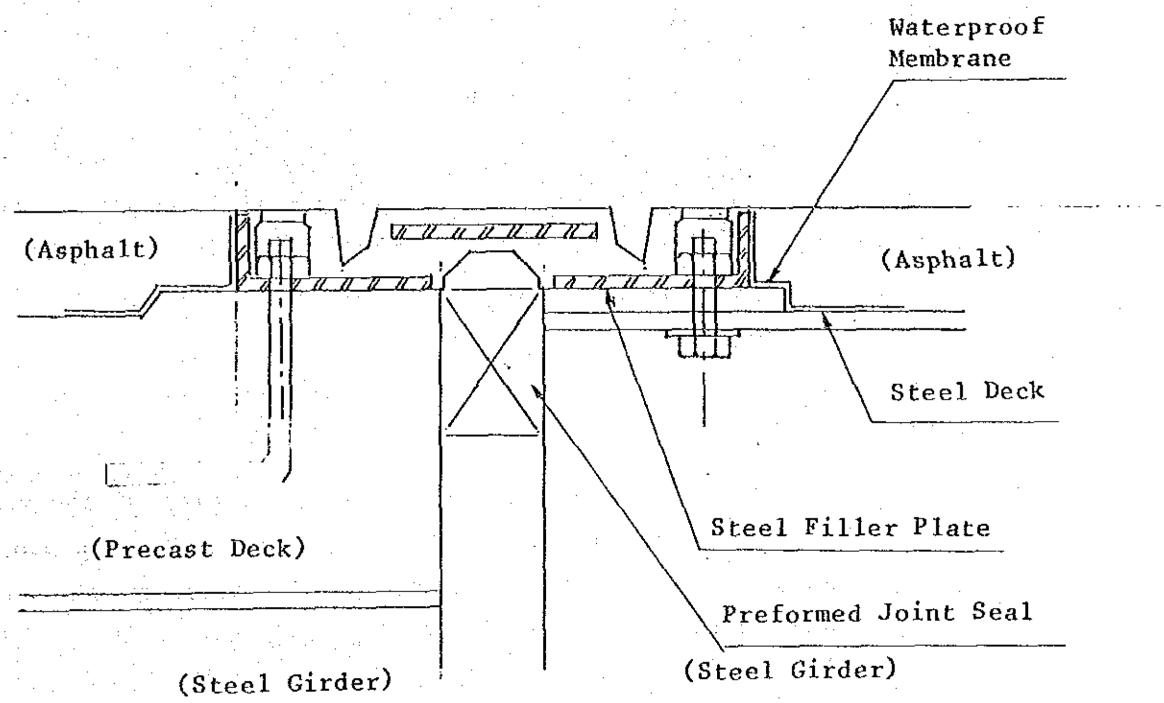


Fig. 4-3-8 Guard Fence of Viaduct



Hot Poured Sealer Joint



Steel Reinforced Elastomeric Expansion Joint

Fig. 4-3-9 Expansion Joint

2. Rubber Bridge Bearings

Rubber bearings are used for most of the bridges in Thailand. These bearings, which are manufactured in Thailand, are planned for use in this Project.

3. Expansion Joint

Expansion joints which have simple structures and are easy for repair have been planned from the point of view of future maintenance. The range of annual temperature change in Bangkok is considerably small and the standard span girders (30m long) will be covered with concrete decks. Assuming that the shrinkage/expansion of the steel girders is small in this case, seal-joint type has been planned. Thus the asphaltic material can be continuously placed over the concrete decks, providing a smooth, comfortable running.

For the steel orthotropic deck girders, however, the temperature rise of the deck girder by the insolation is considered great. Accordingly strengthened rubber joint type which can absorb some shrinkage/expansion of the steel girder has been planned (See Fig. 4-3-9).

Leaking surface water through expansion joints will greatly affect the durability of the bearings and other structural components. Considering the actual maintenance capability of Thailand, the design and installation must ensure perfect waterproofing.

4. Bridge Lighting

If the lighting poles are installed in the median of the viaduct, they will be obstacles to the MTS structure which is scheduled to start construction in the near future. Therefore, the lighting poles are installed along the outer edges of the viaduct.

5. Drainage

The design of bridge drainage will provide for the collection of rain water on the bridge surface, vertical piping to the foot of pier column and discharge into the existing drainage system.

6. Noise Barrier

Noise barrier is installed at the outside of handrailing to reduce the noise from the vehicle running. The barrier must be such that it will function as a fascia panel as well.

7. Police Stand

According to the BMA's request, a police stand will be provided on the edge of the viaduct at each intersection. The actual example can be seen from Photo 4-3-1 below which shows a police stand set on the flyover on New Phet Buri Road.

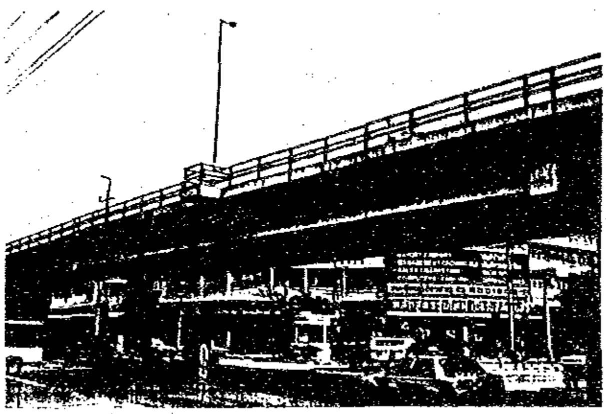


Photo 4-3-1 Police Stand on Flyover on New Phet Buri Road

4-3-3 Design of Substructure of Viaduct

a. Design of Pier Column

1. Shape of Pier

Generally the column type pier of a structure is used in an urban area, because a pier having a narrow width will provide more space under the structure and less obstract the view.

In this Project a T-shape pier has been planned, because the pier must be constructed in the middle of the median due to project site conditions. Fig. 4-3-10 shows the typical cross-sections of piers by sections.

2. Material of Pier

For the pier which must support the whole superstructure load with one single pier column, all the material of the pier is of steel which is superior over concrete:

(1) Shorter construction time

From the degree of traffic congestion of the Project the construction time must be minimum. The steel members which have been prefabricated in a factory can be erected in position much faster than the concrete placement.

(2) Possible mitigation of traffic congestion during construction

Steel prefabricated members can be erected in position in one night occupying a smaller space and in the following daytime the traffic is passable. In the case of the concrete structure part of the carriageway adjacent to the structure is occupied continuously day and night for setting of scaffolding, form work and concrete placing and curing.

(3) Light weight of structure

A large overhanging structure is required as illustrated in Fig. 4-3-10 (2/3). For a concrete structure the beam will have a weight of about 100 tons, its erection without sophisticated launching girders is almost impossible.

In comparison, the erection of a steel structure having the same dimensions is relatively easy. Although the steel structure is generally more expensive compared with a concrete structure in Thailand, it will meet the construction requirements.

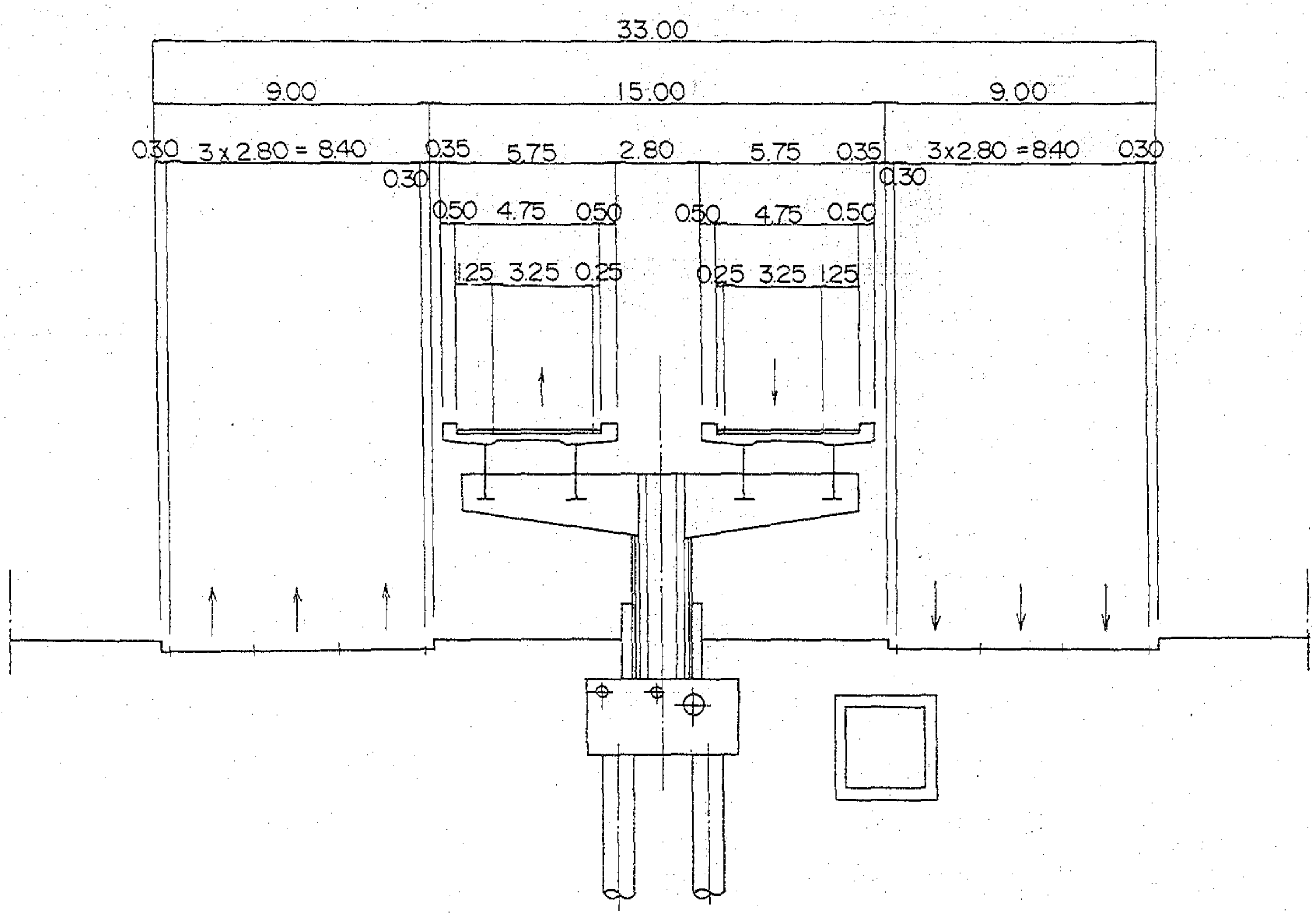


Fig. 4-3-10 Standard Cross Section of Pier (1/3): Two Way Two Lanes

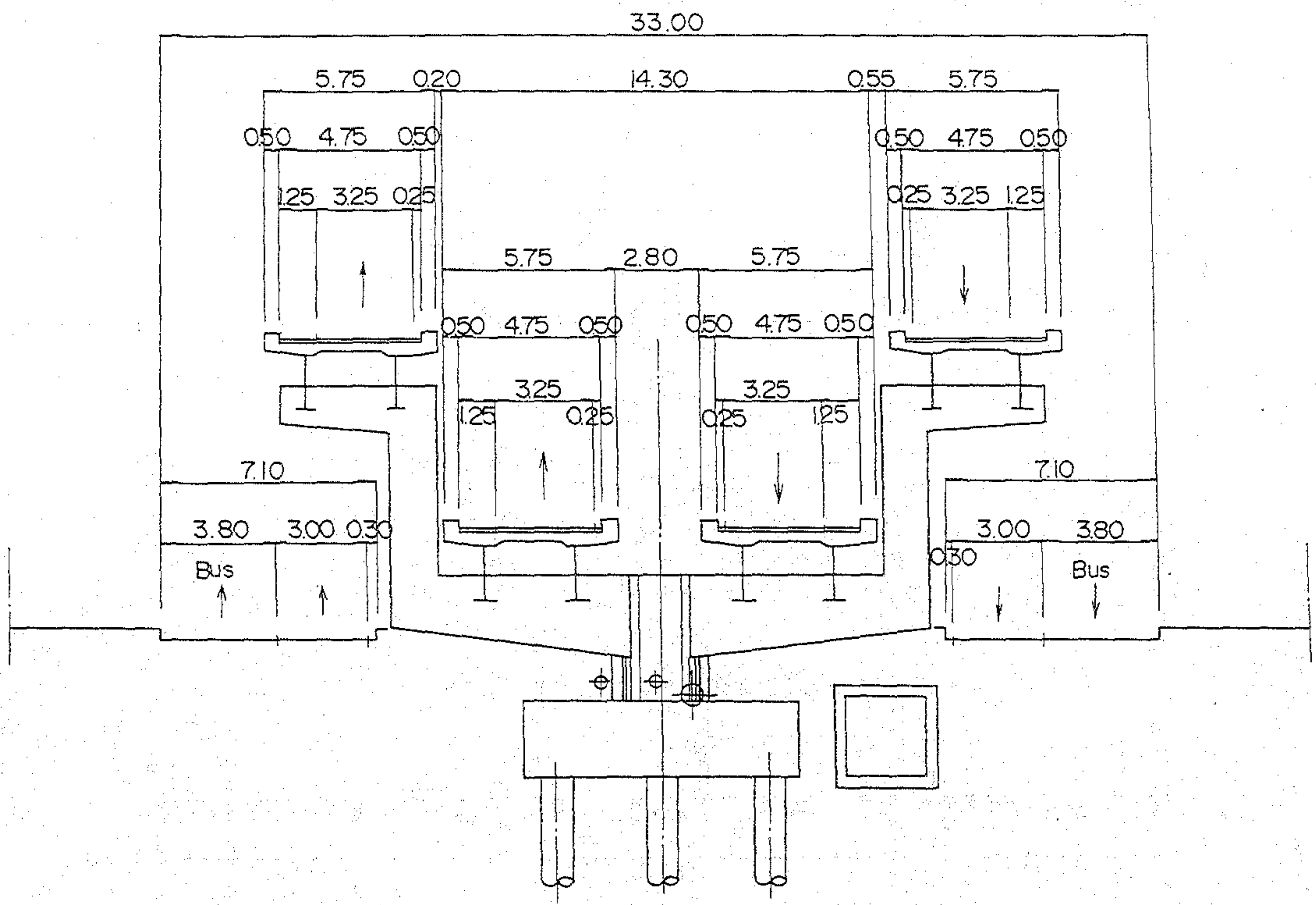


Fig. 4-3-10 Standard Cross Section of Pier (2/3): Section of Centre Ramps

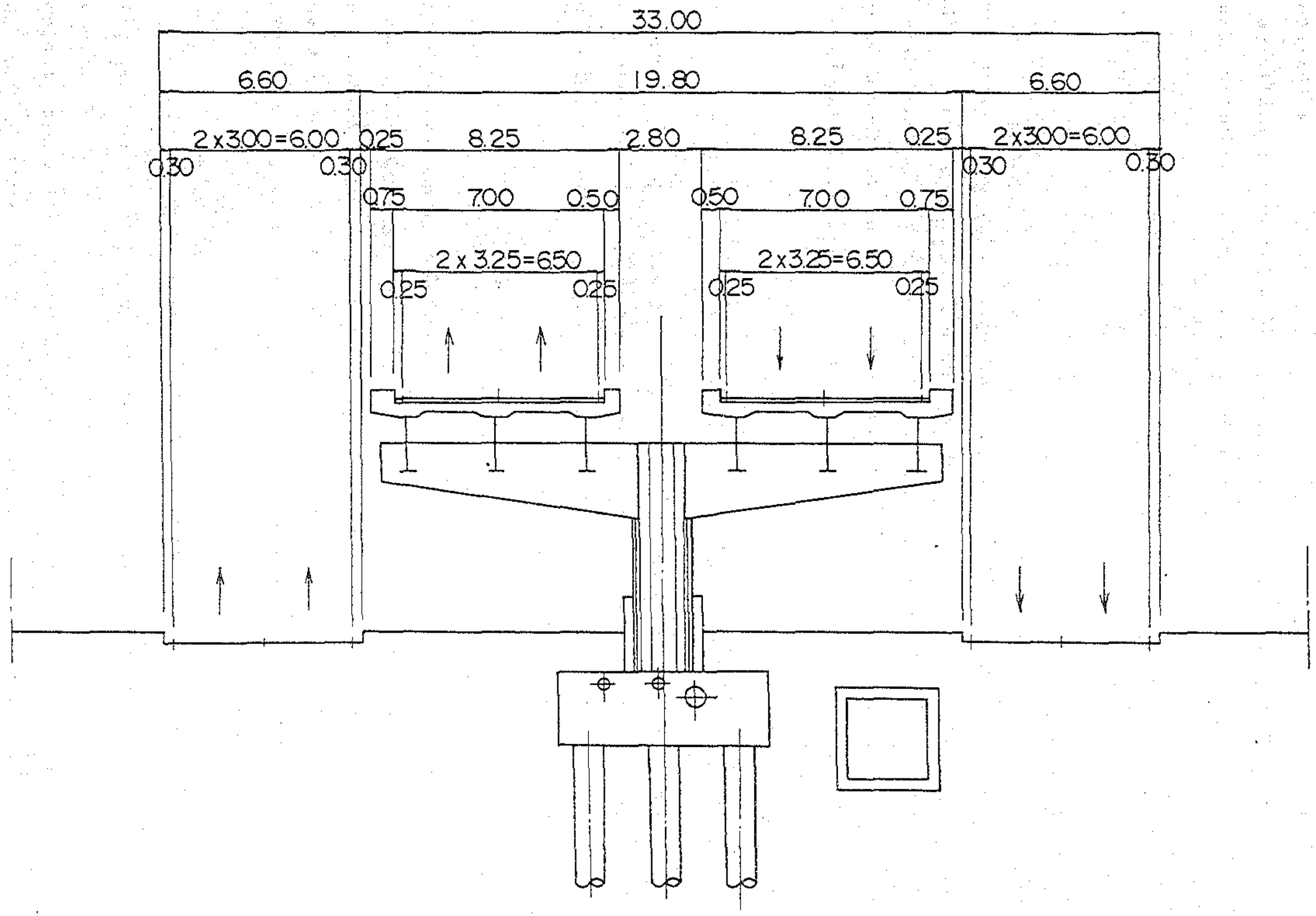


Fig. 4-3-10 Standard Cross Section of Pier (3/3): Two Way Four Lanes

3. Cross-sections of Pier

The cross-sectional shapes of the pier members are box type for beam and cylindrical for column both of which are generally used to unify the outer appearance of a pier from an aesthetic point of view.

b. Design of Foundation

1. Foundation Pile

As stated in Section 3-2-1, f, the upper clay soil layers are soft and not suitable for the support of structures. The foundation of the structure must be supported by the stiff layers of clay or sand existing at the depth of about 30 metres below the existing ground surface. Therefore a piled foundation is planned.

2. Cast-in-place Reinforced Concrete Pile

Three types of piles: "Cast-in-place concrete pile", "precast prestressed concrete pile", and "PC well" have been studied by considering the subsoil conditions of the site, the restraints of piling work in an urban area, and economy.

Alternative 1: Cast-in-place concrete pile, ø1.0m

The bearing capacity per pile (about 280 tons) is large and noise and vibration caused by the piling work are reduced compared with ordinary percussion pile driving. In Thailand there are many practises in cast-in-place concrete pile and many construction companies specializing in pile construction.

Alternative 2: Precast Prestressed Concrete Pile, ø0.6m

This method is most economical and in Thailand there are pile manufacturing factories with many different practises. However, the percussion driving of piles will cause problems in noise and vibration, which is not suitable for the construction in the middle of highly urbanized area.

Alternative 3: PC Well, ∅3.0 = 5.0m

This method is a new technology which must be introduced from Japan. It is favourable in execution time and construction procedure, ie., direct connection between pier column and the PC well, saving the footing. By this method the construction time can be shorter and the working area reduced.

However, the equipment necessary for this method must be brought from Japan.

Merits and demerits of the above alternatives are shown in Table 4-3-2. As the result of the study, the cast-in-place concrete pile method has been planned because of familiarity by Thai Contractors.

c. **Design of Structures for Approach Sections**

1. Height of Embankment

Due to the poor soil conditions a high embankment can not be provided in the approach sections. The limit of high embankment will range from 1.5m - 2.0m.

2. Non-uniform Ground Settlement

Non-uniform ground settlement is easily recognized in the connection between the embankment and the structure supported on a rigid foundation. To minimize the ground settlement, the design of approach sections makes the bridge section longer to make embankment section shorter and run-on slabs are provided to prevent the road surface from sinking abruptly at the bridge abutment.

3. Design of Approach Slab

The construction of the run-on slab which occupies a wide construction space across the road will be a bottleneck for the traffic management. Therefore the approach slab must be designed so as to complete the construction in a short time. The structure of approach slab which is formed of precast plank slab beams has been proposed as shown in Fig. 4-3-11.

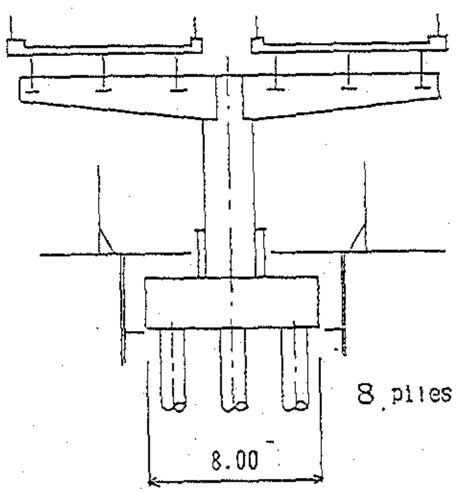
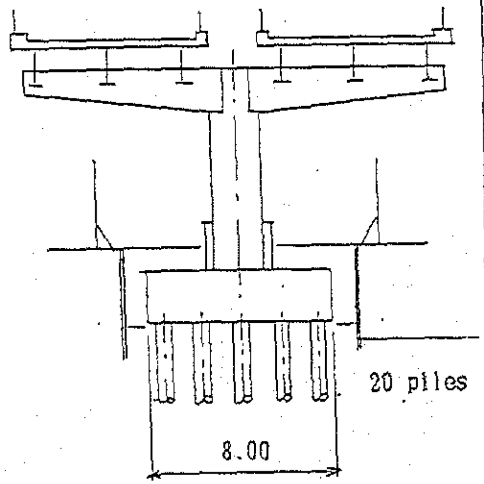
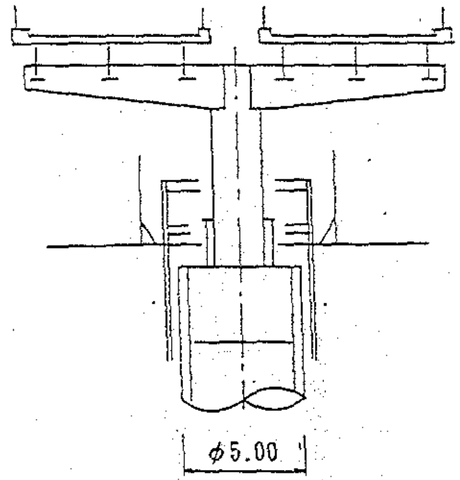
Method	Cast-in-Place Concrete Pile, Dia.1.0m	Precast Concrete Pile, Dia. 0.6m	Prestressed Concrete Well, Dia. 5.0m
Cross -section			
Execution Time	Piles 10 days/unit Footing 25 Sum 35 days/unit	Piles 11 days/unit Footing 25 Sum 36 days/unit	PC Well 9 days/unit Top Con. 9 Sum 18 days/unit
Execution space	W = 12.0m	W - 12.0 m	W = 9.0 m
Noise Vibration	low low	high high	low low

Table 4-3-2 Comparison of Foundation Type