- Therefore, from the point of view of construction cost, the steel cable-stayed girders may become a competitive alternative to the balanced cantilever PC box girders.

- Moreover, the steel cable-stayed girders are more advantageous than the balanced cantilever PC box girders in aethetics and construction periods, while disadvantageous in the availability of domestic materials and future maintenance problems.

Consequently, the following is concluded:

Recommendation .... Balanced Cantilever PC Box Girders
Alternative .... Steel Cable-Stayed Giders

In the preliminary design, the recommended type was studied in more detail.

9.3.2 Approach Bridge

As the whole bridge consisting of the main bridge and approach span bridge has a length of approximately 1,760 m, much attention has to be paid to the bridge planning in a way that the aethetics harmony and repetitious construction methods are maintained as much as possible.

The balanced cantilever PC box girders were selected as the most preferable type of main bridge. Therefore, appropriate types of superstructures for approach span bridge were limited to concrete type bridges. Among concrete type bridges, prestressed concrete box girders, prestressed concrete T-beams (or I-beams) and reinforced concrete hollow slabs were first considered as alternatives. The prestressed concrete T-beams (or I-beams) were, however, discarded because of their aethetic incongruity with the main bridge.

As for foundation type, 60 cm diameter precast prestressed concrete driven piles, which had been employed in Thailand, and 1.5 m diameter cast-in-place reinforced concrete piles were considered applicable alternatives.

The following are the alternatives taken into consideration in this study.

Superstructure Alternatives:

- Prestressed concrete box girders
- Reinforced concrete hollow slabs

Foundation Alternatives:

- Precast prestressed concrete driven piles (60 cm diameter)
- Cast-in-place reinforced concrete piles (1.5 m diameter)

As the pier height of the approach span bridge varies very much from 6 m to 30 m approximately, the required size and cost of foundation will be much affected by the span length of superstructure as well as pier height. Therefore, the cost study of foundation alternatives has to be carried out by incorporating span length of superstructure and height of pier, simultaneously.

1) Economic Span Lengths and Foundation Types by Pier Heights

As the reinforced concrete hollow slab was generally limited to its use in a span length of 10 m to 20 m, the cost-span relation was examined only for the prestressed concrete box girders. In Fig. 9.3.3, the relation between cost per square meter and span length is diagrammed.

The costs in Fig. 9.3.3 exclude the common items, i.e., pavement, curbs, handrails and others.

From the economic point of view, the following approximate span lengths and foundation types are recommended for the subsequent study.

a) Pier Height less than 10 m

- Span length of RC hollow slab = 13 m
- Foundation type = Precast prestressed concrete driven piles (60 cm diameter, pile tip elevation = -30 m MSL)

b) Pier Height from 10 m up to 25 m

- Span length of PC box girder = 35 m
- Foundation type = Precast prestressed concrete driven piles (60 cm diameter, pile tip elevation = -30 m MSL)

c) Pier Height over 25 m

- Span length of PC box girder = 45 m
- Foundation type = Cast-in-place reinforced concrete piles (1.5 m diameter, pile tip elevation = -30 m MSL)

2) Span Arrangement and Bridge Type

In determining the span arrangement, the following were taken into consideration:

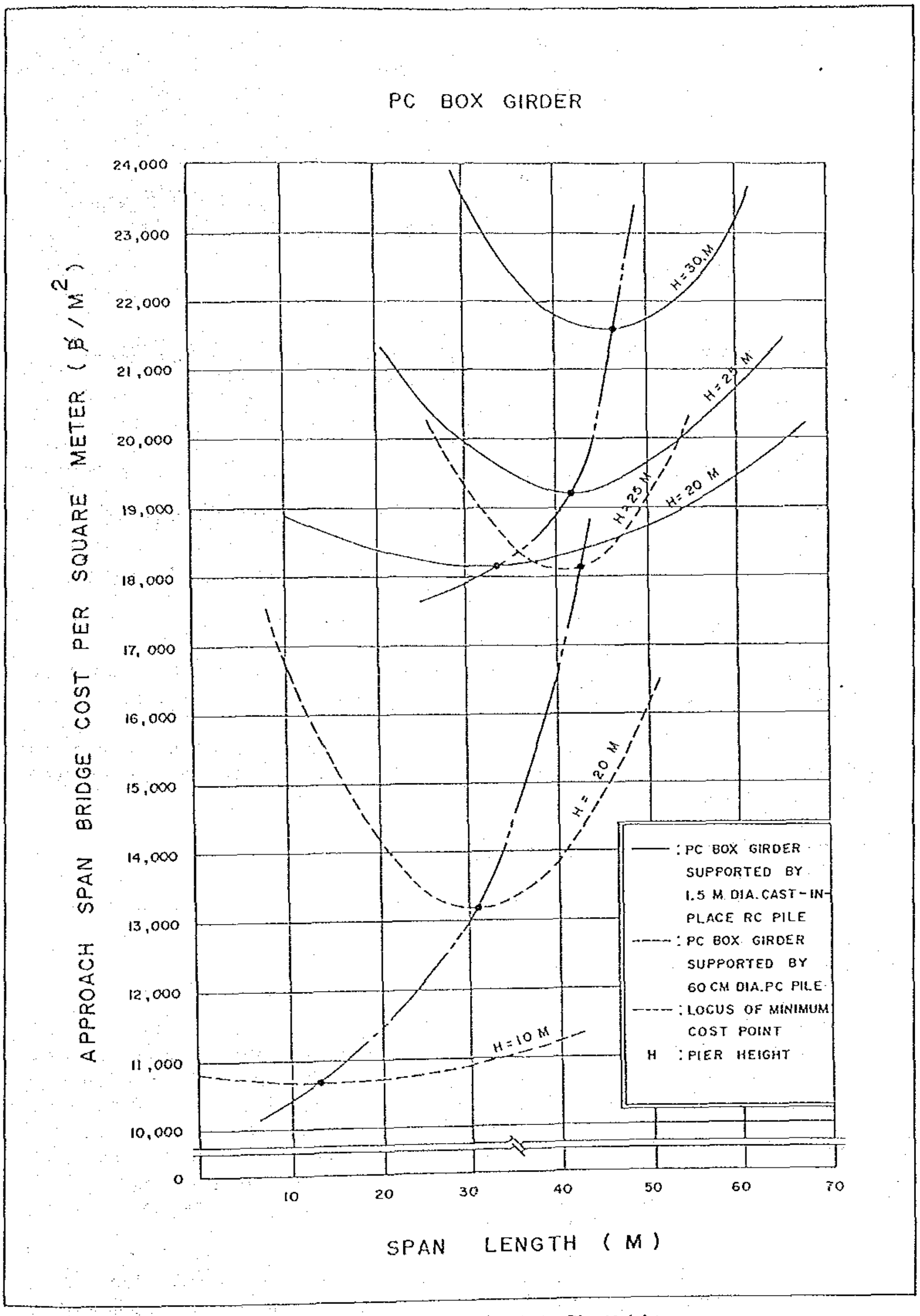


Fig. 9.3.3 Cost-Span Relationship by Pier Heights

a) Flyover Bridges Crossing Existing Roads

From the topographic survey, the location and the widths of the existing roads were obtained as:

- Taksin Road (Thonburi Side)

Location	:	805 m from the navigation center of the Chao Phraya River
Roadway Width	:	30 m

- Charoen Nakhon Road (Thonburi Side)

Location	:	445 m from the navigation center of the Chao Phraya River
Roadway Width	:	28 m

- Charoen Krung Road (Bangkok Side)

Location	:	695 m from the navigation center of the Chao Phraya River
Roadway Width	:	13 m

b) Existing Road Alignment

The alignment of the approach bridge almost overlaps the existing road (MRR).

One of the principles for determining span arrangements was to site piers so as not to disturb public traffic (4 lanes) on the existing road during and after construction.

c) Economic Span Lengths by Pier Height

Refer to the preceding sub-section (1).

9.3.3 Abutment Structure

According to the subsoil investigation, the soil condition of surrounding areas of New Krungthep Bridge is categorized as soft ground. The possible maximum embankment height was estimated at 2.5 m and 6.0 m for the case of natural ground and ground artificially consolidated by sand drains or other appropriate methods. Where the ground is improved artificially by sand drains, a stable embankment can theoretically be carried out up to 6.0 m in height, but the bottom width of embankment (toe to toe) becomes wider and more land acquisition is needed. Also roadway alignment becomes more difficult.

In this respect, abutment structures are considered from the abutment (embankment height of 6 m) to the point where the embankment height is 2 m. For the rest, with an embankment height of 2 m to 0 m, a transition slab, which has been employed in many projects in Thailand, is to be adopted.

The following structures were taken into consideration as the conceivable abutment structure alternatives:

a) Reinforced concrete retaining wall, supported by precast prestressed concrete driven piles

b) Reinforced concrete box-type structure, with latticed pile caps supported by precast prestressed concrete driven piles

c) Reinforced earth abutment, founded on ground improved by the sand drain method.

A comparative study was made from the view points of construction cost, availability of domestic materials, durability and others, and a summary is shown in Fig. 9.3.4 together with their layout and outlines.

As a result, b) RC box type structure was selected as the recommendation for the following reasons:

- RC box type structure has been employed in many bridge projects as an abutment structure, and its advantages and reliability were already proven in Thailand.

- From the cost comparison (refer to Fig. 9.3.4), RC box type structure was judged as the most economical.

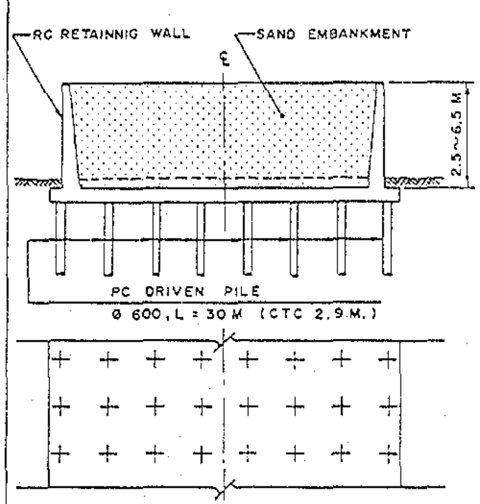
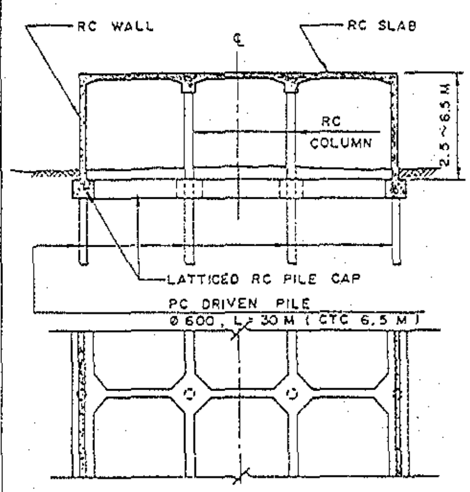
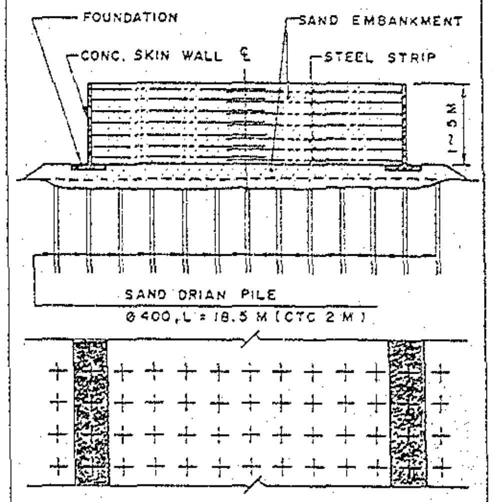
	a) RC RETAINING WALL	b) RC BOX TYPE STRUCTURE	c) REINFORCED EARTH ABUTMENT
TYPICAL CROSS SECTION PLAN			
CONSTRUCTION COST PER SQUARE METER	RC RETAINING WALL : ฿ 4,700 / M^2 PC DRIVEN PILES : ฿ 7,000 / M^2 SAND EMBANKMENT : ฿ 1,400 / M^2 TOTAL : ฿ 13,100 / M^2	RC BOX TYPE STRUCTURE : ฿ 5,700 / M^2 PC DRIVEN PILES : ฿ 1,600 / M^2 TOTAL : ฿ 7,300 / M^2	SAND DRAIN PILE : ฿ 1,900 / M^2 REINFORCED EARTH A. : ฿ 3,600 / M^2 SAND EMBANKMENT : ฿ 2,100 / M^2 TOTAL : ฿ 7,600 / M^2
AVAILABILITY OF MATERIALS IN DOMESTIC MARKET	AVAILABLE	AVAILABLE	MOSTLY AVAILBLE, BUT STEEL STRIPS ARE TO BE IMPORTED
EXPERIENCE IN THAILAND	EXPERIENCED	EXPERIENCED	NIL
DURABILITY	DURABLE	DURABLE	LESS DURABLE, ESPECIALLY IN FLOOD - PRONE AREAS
OTHERS			CONSTRUCTION PERIOD IS LONGER THAN OTHERS
OVERALL EVALUATION	NOT RECOMENDABLE	RECOMMENDED	NOT RECOMENDABLE

Fig. 9.3.4 Comparison of Abutment Structure by Type

9.4 Road Elements

9.4.1 Bridge Alignment and Cross-Section

1) Design Standards

A design speed of 80 km/hr on the New Krungthep Bridge was adopted considering its function and characteristic and design speed of Middle Ring Road. The geometric design standards for 80 km/hr of design speed is described in section 12.1.

2) Horizontal Alignment

The horizontal alignment study was carried out using a topographic map at a scale of 1:1000 as prepared by The Study Team in 1986.

Major considerations for the alignment study were as follows:

- To maintain 20 m distance between the existing bridge and the New Krungthep Bridge.
- To avoid the shrine located at the right bank of the Chao Phraya River.
- To keep the extent of land acquisition to a minimum
- To maintain the geometric design standards
- To maintain the traffic comfort and safety

The horizontal alignment is shown in the Drawings Volume.

3) Vertical Alignment

Controlling factors for the vertical alignment study were as follows:

- 4.0% maximum gradient was adopted considering the vehicle conditions in Thailand
- Vertical and horizontal navigation clearances for the center channel were adopted at 34.0 m from MSL and 68.0 m respectively.
- 5.0 m vertical clearance in the grade separated intersection was adopted.
- Vertical clearance of the existing Khlong near the STA -3+20 was kept at the same as the existing condition.

The vertical alignment is shown in the Drawings Volume.

4) Cross-section

Cross-section design was carried out with consideration to the following:

- 4-lane dual carriageway (total 4 lanes) on the New Krungthep Bridge was adopted considering forecast traffic volumes for 2011.

- 2-lane carriageway (total 2 lanes) on the existing Krungthep Bridge was adopted considering forecast traffic volumes for 2011.

- 3.25 m lane width was adopted, the same as that of MRR.

- 0.75 m shoulder width on left side and 0.50 m shoulder width on right side of the road were adopted considering traffic comfort and safety.

- 1.0 m median width was decided to follow the MRR design.

The typical cross-sections are shown in Fig. 9.4.1.

5) Examination on the Necessity of Providing a Climbing Lane

As discussed in Section 8.3, the gradient of 4% was adopted as the maximum longitudinal slope for New Krungthep Bridge in both sides. The slope length of 4% is 1,025 m in Bangkok side and 975 m in Thonburi. An additional 3 m - climbing lane for exclusive use of trucks or low speed cars is generally not required unless the running speed of trucks on upgrade declines lower than 40 km/hour which is the minimum tolerable speed as 50% of the Design Speed of 80 km/hour.

The running speed of trucks passing the New Bridge was examined by Truck Speed Diagram and revealed as follows:

- In Bangkok side, the speed declines to 45 km/hour from the initial speed of 80 km/hour after climbing of 800 m, however, not declines lower than this speed until the crest of the Bridge with the same speed of 45 km/hour using the 3rd gear;

- In Thonburi side, the speed declines to 45 km/hour at about, 100 m point before the crest and keeps the same speed to the top by 3rd gear; and

- Theoretical possibility to climb with the speed of 45 km/hour was confirmed under the assumption that the efficiency of engine power for the 3rd gear would be 70%, because no specific data on the trucks of Thailand were available.

Therefore, it is not necessary to provide a climbing lane for the slopes of New Krungthep Bridge, the data to prove the above: the truck speed diagram and the analysis of relation between Engine Power and Running Resistance were shown in Appendix 9.4.3.

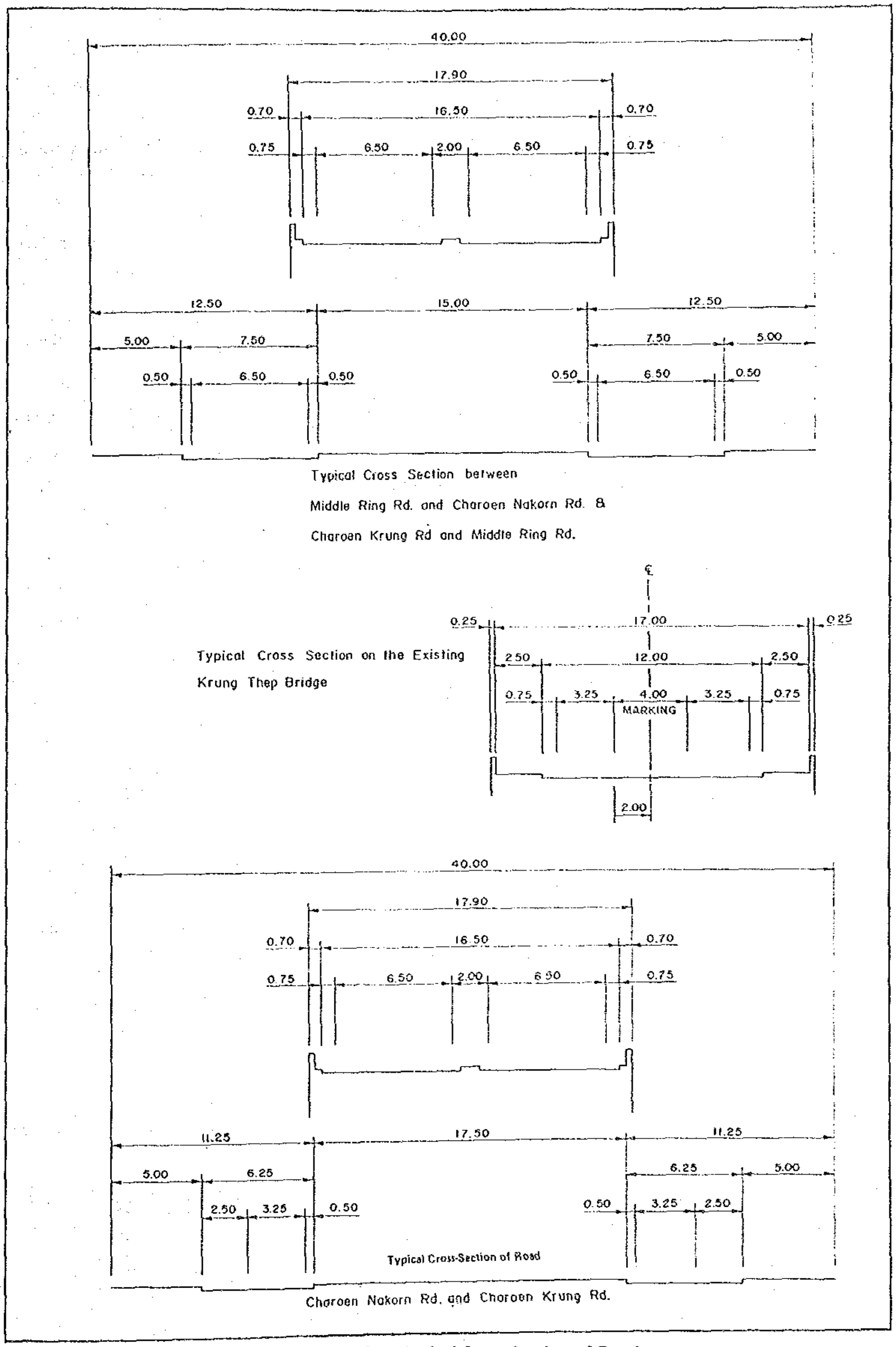


Fig. 9.4.1 Typical Cross-Section of Road

9.4.2 Frontage Roads

1) Design Speed

The design speed for the existing Krungthep Bridge and its approach frontage road was adopted as 60 km/hr considering the following matters.

- The area along the road has already been developed as commercial and residencial areas with various different types of traffic demand.
- This road will be used mostly for short trip traffic. It does not require a high design speed. High speed vehicles will use the New Krungthep Bridge.

The design elements of 60 km/hr design speed are shown in Table 9.4.1.

2) Alignment

Alignment study was conducted considering following items.

- Horizontal alignment follows the existing road horizontal alignment.
- Vertical alignment follows the existing road level.

3) Cross-section

Cross-section design was determined as follows:

- Frontage road was established on both sides of the through traffic lane (New Krungthep Bridge and its approach road).
- 2-lane carriageway was adopted at STA. -3 to STA. 3+70 considering the forecast traffic volume in 2011.
- 1-lane carriageway was adopted at STA. 4-End considering the forecasted traffic volume in 2011.
- 3.25 m lane width was adopted, the same as MRR.
- 2.50 m shoulder width on one lane carriageway was adopted considering car parking space.
- Spaces for construction activities for the New Krungthep Bridge and its approach bridges have been reserved.

Table 9.4.1 Design Elements for Existing Krungthep Bridge

Design Speed	km/hr	60
Minimum Radius of Horizontal Curve, R	m	150
Maximum	%	4
Length of Vertical Curve (Parabolic)		
Absolute Minimum	m	50
Desirable Minimum	m	100
Maximum Superelevation	%	4
Stopping Sight Distance Absolute Minimum	m	75
Carriageway Cross Slope	%	2.0
Sidewalk Cross Slope	%	2.0

9.4.3 Intersections

1) Types of Intersection

In this section, desirable types of intersection such as grade separated or at-grade intersection, are examined taking into account the following points:

- Structure of road network and its function;
- Relationship between forecast traffic volume and traffic capacity of intersection;
- Staged construction; and
- Land acquisition, requirements

a) Road Function and Network Structure

Continuous traffic flows are generally interrupted at intersections and running speed on road network drops down. Intersections on trunk roads ensuring high running speed are generally required to be grade separated.

In general, the intersections of a ring road and a radial road is required to be grade separated taking into account their functions and characteristics.

Three intersections, namely A, B and C, are located on Middle Ring Road (MRR) in Bangkok. MRR forms a part of the trunk road network in Bangkok. The existing traffic volumes on MRR are very heavy and future traffic volumes are expected to exceed 8,000 V/H (CPU). The design speed of 80 km/hr is adopted and it is an 8-lane divided highway. Connected roads, such as Charoen Krung Road, Charoen Nakhon Road and Taksin Road are also very heavily trafficked and these roads are sub-trunk roads, especially Taksin Road is a 6-lane divided highway. Taking into account of the above matters, A, B and C intersections should be constructed as grade separated intersections.

b) Traffic Volumes

Intersection type was also examined on the basis of traffic saturation degree (forecasted traffic volume/traffic capacity)* on approaches of the intersections.

If traffic saturation degree exceeds 1.0, severe traffic congestion occurs and it is difficult to control. The results of the traffic saturation degree analysis for each intersection are shown in Table 9.4.2.

Table 9.4.2 Saturation Degree

Intersection Name	2011	2001
A	1.31	1.18
B	1.05	0.76
C	1.26	0.96

Saturation degrees in 2001 at the intersection A, B and C exceed or close to 1.0. From the viewpoint of traffic volume, alone, A, B and C intersections are required to be grade separated.

Detailed calculations of saturation degree are shown in Appendix 9.4.1.

2) Intersection Design

a) Principles

Intersection design were carried out based on the following principles

Note: * Capacities of each of the three intersections were recalculated using assigned volumes by direction and associated through, right-turn, and left-turn lane numbers in each approach. The capacity thus obtained corresponds to the services level E as specified in the "Highway Capacity Manual, 1985", TRB special Report 209.

* Avoiding the widening of existing road as much as possible.

* Forecast turning movements in 2011 were adopted as the design traffic volume.

* Number of lanes in each intersections were decided to ensure the saturation degree of intersection less than 0.9 considering the signal control.

* Saturation flow volume was determined at 2200 (V/H) and 2000 (V/H) for through lane and right and left turn lane respectively.

Design speed of ramp at grade separated intersections was adopted at 40 km/hr considering the design speed of through traffic lane.

Design elements for Ramp is described in Table 9.4.3.

Typical cross-section is shown in Fig. 9.4.4.

Table 9.4.3 Design Elements for Ramps

Design Speed	km/hr	40
Minimum Radius of Horizontal Curve, R	m	50
Clothoid Parameter, A	m	R/3 A R
Critical Radius for Using Clothoid	m	140
Maximum Grade	%	7
Length of Vertical Curve (Parabolic) Absolute Minimum	m	35
Maximum Superelevation	%	7
Stopping Sight Distance Absolute Minimum	m	40
Carriageway Cross Slope	%	2.0

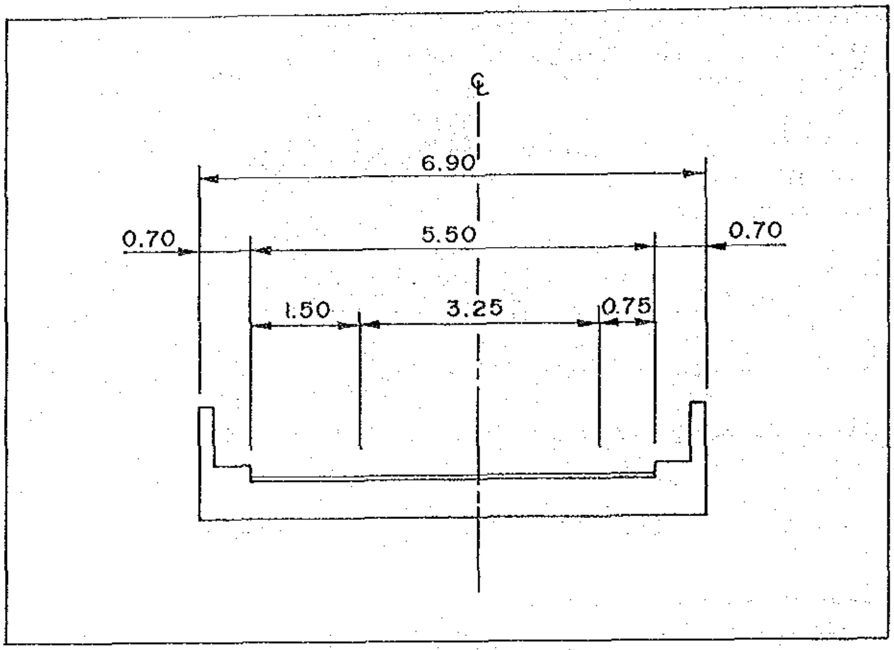


Fig. 9.4.2 Typical Cross-Section of Ramp

b) "A" Intersection

i) Grade Separated Intersection

"A" intersection was planned as a grade separated one considering road network, and traffic flow characteristics. ON and OFF ramps which are connected with the New Krungthep Bridge and the existing Charoen Nakron Road were planned as shown in the Drawing Volume.

ii) At Grade Intersection

Under the flyover bridge in the "A" intersection, a 4-leg intersection is planned as shown in the Drawings Volume.

This 4-leg intersection can be controlled by a signal system upto the year 2011.

c) "B" Intersection

i) Grade Separated Intersection

"B" intersection is planned as a grade separated one. ON/OFF ramps which are to be connected with New the Krungthep Bridge and the existing road are not planned due to the excessive vertical distance between the New Krungthep Bridge and the existing road at this intersection.

ii) At Grade Intersection

Under the flyover bridge, a 4-leg intersection is planned as shown in the Drawings Volume.

This 4-leg intersection with signal control can accommodate the future traffic in 2011.

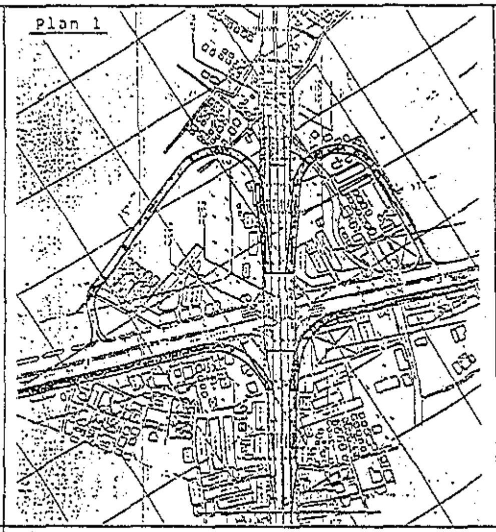
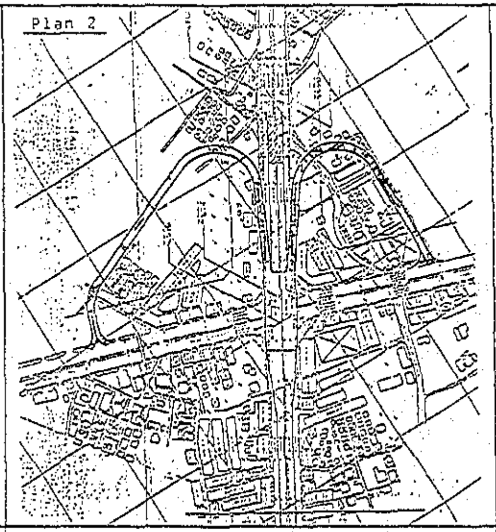
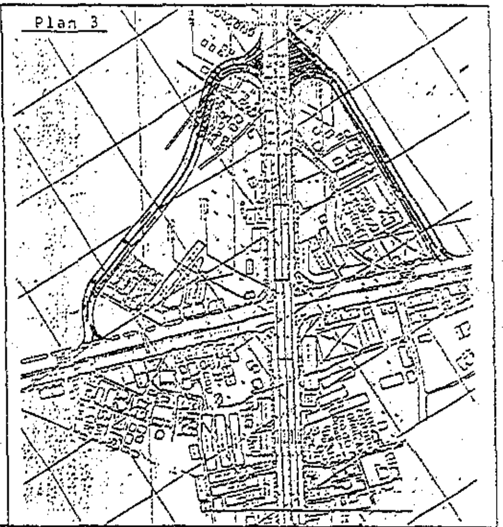
The traffic movements in 2011 in this intersection and calculation of traffic saturation degree are shown in Appendix 9.4.2.

d) "C" Intersection

i) Grade Separated Intersection

"C" intersection is planned as grade separated as shown in the Drawings Volume.

Three alternative intersection plans, namely plan 1, 2 and 3 were considered as shown in Fig. 9.4.3.

Plan	Plan 1	Plan 2	Plan 3
			

Cost (Unit: million baht)	Plan 1	Plan 2	Plan 3
A. Construction Cost	288	220	125
a. PC Box Girder	65	48	38
b. RC Hollow Slab	29	29	16
c. RC Slab	15	15	11
d. RC Rampways	60	36	-
e. RC Wall&Road Fill	7	7	9
f. Pavement	7	5	6
g. Miscellaneous	55	55	24
h. Contingency	24	18	10
i. Engineering	26	20	11
B. Land & Compensation	147	68	168
j. Land Acquisition	67	43	138
k. Building compensation	80	25	30
Total	Baht 435 million	Baht 288 million	Baht 293 million

Fig. 9.4.3 Comparison of Taksin Interchange Alternative Plans

Plan 1

Basic considerations for planned were as follows:

* To minimize the traffic crossing points between through traffic flows and right turn or left turn traffic flows.

Plan 2

Basic considerations were as follows:

* To minimize the land acquisition cost
* To minimize the compensation cost
* To minimize the traffic crossing points between through traffic flow and right turn and left turn traffic flows.

Plan 3

Basic considerations were as follows:

* To minimize the land acquisition cost
* To minimize the compensation cost
* To minimize the construction cost

Plan 2 was adopted in this study. The main reasons are as follows:

* Plan 2 is the most economic plan among the alternatives.
* Plan 2 is less expensive in the land acquisition and compensation costs.
* It is very difficult to acquire the land along the existing Taksin Road by plan 1.
* Traffic can be more easily controlled than by plan 3.

ii) At Grade Intersection

A 4-leg intersection in "C" intersection is planned under the flyover bridge. Two 3-leg intersections are also planned for the ON-ramp and OFF-ramp.

A 3-leg intersection with signal namely "C-1" is located at intersection point between ON Ramp and the existing Taksin Road and second 3 legs intersection namely "C-2" is located at intersection point between OFF Ramp and the existing Taksin Road.

These three intersections with signal can accommodate future traffic in 2011. Traffic movements and calculation of traffic saturation degree on "C" intersection are shown in Appendix 9.4.2. For the three intersections "C", "C-1" and "C-2", required lengths of right turn lane were also calculated. The results of this calculation confirmed the adequacy of the three intersections as shown in Appendix 9.4.4.

9.5 General Features of the New Bridge

The proposed layout of the major elements of the New Krungthep Bridge is shown in Fig. 9.5.1 and the configuration of the preliminary design of the bridge is described below.

1) Main Bridge

The main bridge is a three-span continuous PC box girder bridge constructed by balanced cantilever erection method, and have two single-cell box girders in a total length of 442 meters consisting of a 220 meter center-span and 110 meter side-spans for each sides.

The whole bridge width in the standard section is 17.9 meters as shown in Fig. 9.5.1. The girder depth is 13.5 meters at the main pier, and varies to 4.0 meters toward the end pier and 3.5 meters toward the mid-span (see Fig. 9.5.2).

A parabolic curve was adopted in the transition curve for the girder depth change in order to minimize the girder depth at the point where the navigational clearance requirements would govern the proposed height of the bridge, while a sine curve is usually adopted for that purpose.

The water depth at the proposed location of main piers is approximately 11 meters. As serious local scour was observed at the proposed bridge site, the stability calculation for the pile foundation of main piers was made taking into consideration a scour depth of 25 meters below MSL based on Laursen's formula. Thirty eight (38) 2.0 meter diameter cast-in-place RC piles support one main pier, superstructure and live loads. The tip of these piles is founded at -54.0 meter MSL where a dense sand layer (so call "Second Bangkok Sand Layer") exists.

2-meter diameter of the cast-in-place RC pile is applied by reasons of the followings.

- Large diameter pile is advantageous in resistance for bending moment caused by the outstanding 25 meter from riverbed scored.
- Less number of pile foundation using the large diameter pile is suitable for shortening of construction period and reducing the influence for vessels.
- As for the diameter of cast-in-place pile, 2.0 meter is the maximum drilled in Thailand so far.

The result of stability calculation for the cast-in-place (2.0 meter) is shown in Table 9.5.1.

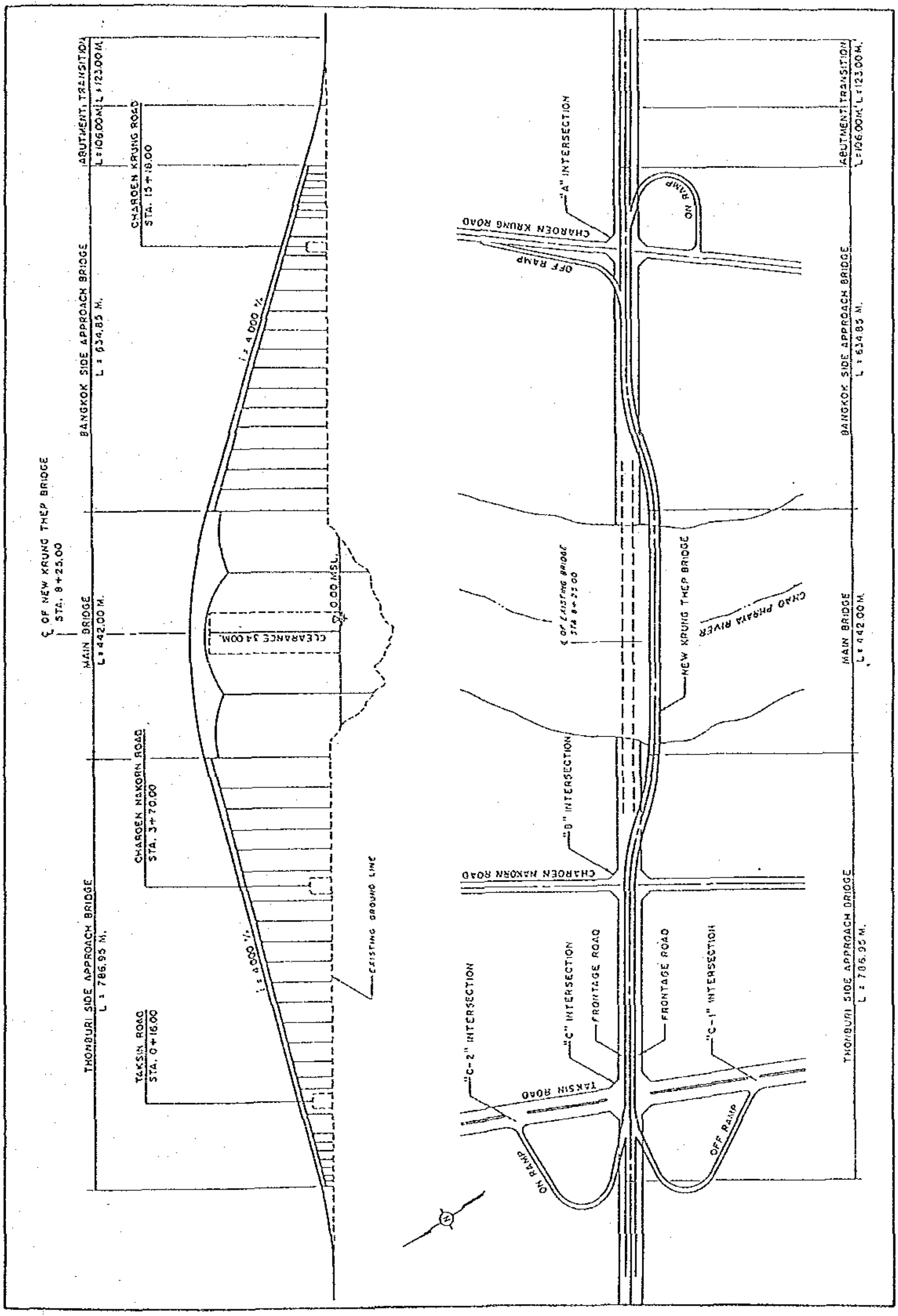


Fig. 9.5.1 Layout of Bridge Structure

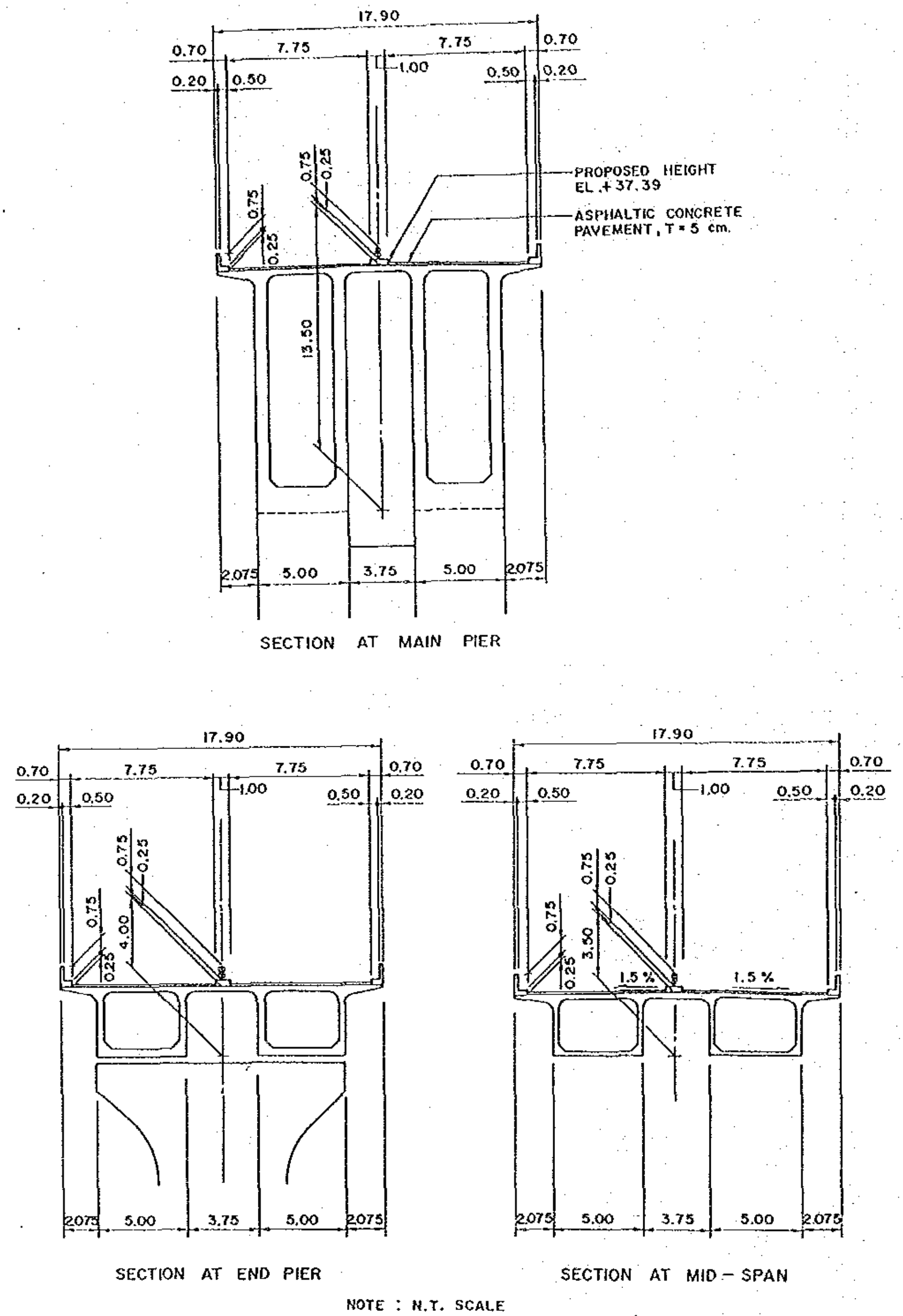


Fig. 9.5.2 Cross-Section of Main Bridge

Table 9.5.1 The Result of the Stability Calculation

	Normal Time		Earthquake Time	
	Calculated Value	Allowable Value	Calculated Value	Allowable Value
(TON/pile) Bearing Power	1002	1008	1312	1668
(T·M/pile) Bending moment acting pile	58	610	933	940
(cm) Horizontal Displacement at cap of pile	0.7	-	11	-

The end piers of the main bridge are located in the riverbanks and piles are founded directly into the ground. Therefore, large diameter RC piles, which attain much rigidity against horizontal forces, were thought unnecessary. Precast PC driven piles (0.6 meter diameter) support the end pier weight and the external forces transmitted by the superstructure.

A comparative study for the foundation of end pier for main bridge is summarised below:

- Total cost of PC pile (0.6 meter diameter) was smaller than that of RC piles (1.5 meter diameter); and
- Construction period of the PC piles may be shorter than the RC piles.

Details of the comparative analysis are shown in Table 9.5.2.

Table 9.5.2 Comparison of Pile Foundation

Kind of Pile		Precast PC Driven Pile		Cast-in-place RC Pile	
Pile diameter (m)		0.6		1.5	
Pile length (m/pile)		29.0		52.0	
Nos. of pile (Nos)		81		8	
Construction Cost (M฿)		4.86		7.41	
Result of Stability Calculation	Bearing power (t/pile) Normal time	82.7	139**	743	828**
	Bearing power (t/pile) Earthquake time	124	208**	1087	1226**
	Horizontal bearing power (t/pile)	4.5	16.4**	40.9	49.3**
	Bending moment acting pile (t·m/pile)	7.8	11.0**	124	49.3**
	Horizontal Dis-placement at cap of pile (cm)	0.5		2.0	

Note: * - Allowable limit in normal time

** - Allowable limit in earthquake time

- Construction cost estimated is only the total of piles and pile-caps cost

2) Approach Bridge

The approach bridges have a length of 786.95 meters on the Thonburi side and 634.85 meters on the Bangkok side. The difference in lengths between the two sides result from the constraint of longitudinal alignment that requires the appropriate transition length from the crest point of the newly constructed bridge at Thonburi side MRR.

As for the superstructures, continuous PC box girders are adopted in case of relatively high piers and RC hollow slabs are planned for the rest. These two types of superstructure will achieve an aesthetic uniformity with the main bridge. Further, these types have a significant advantage that their high rigidity will effectively bear the torsion forces which will result from the winding road alignment.

A standard span length of 35 meters is mainly adopted for the PC box bridges and 45 meters span box girders are planned only at the places crossing over existing roads, e.g. Taksin, Charoen Nakhon and Charoen Krung roads. On the other hand, a standard span length of 13 meters is mainly adopted for RC hollow slab bridges.

Due consideration was given to determining column arrangements of piers in order to allow the passings of general traffic on the existing road (MRR) during and after construction.

Multi-column RC rigid frames are adopted in the places where rampway bridges cross over the existing roads. In other places where no rampway is planned, inverted T-type piers are adopted.

As the pier heights are quite high and piers will be observed by so many people in the future, both the rigid frame and inverted T-type piers have curved lines at the conjunction between column and top beam for the aethetic effect.

Precast PC driven piles of 0.6 meter diameter are adopted in all the piers because of the least cost. The reliable bearing strata are anticipated at -25 meters and -29 meters approximately in depth from MSL, for Thonburi Side and Bangkok side respectively.

The details of piers are shown in Appendix 9.5.1.

3) Abutment Structure and Transition Slab

A 106 meter long abutment structure and 123 meter long transition slab follows the Bangkok side approach bridge.

The Abutment structure is supported 0.6 meter diameter precast PC driven piles while the transition slab is supported by RC driven piles having a square section of 0.22 m x 0.22 m.

9.6 Construction Method

9.6.1 Main PC Box Girder Bridge

1) Foundation Works

The locations of the two main piers in the river will not disturb the navigational waterway. The pier-to-pier distance of about 200 meters will be enough for ships even during construction. Construction sites on the platform in the river can be accessed by temporary bridges of less than 100 meters from banks of each side.

The variation in river water level is mainly caused by tidal movement not by seasonal flood. The high water level is 1.5 to 2.0 m above MSL through the year. Therefore, the elevation of platforms should be kept higher than 2.0 m above MSL.

Reverse circulation drilling is the most suitable method for cast in situ concrete piles with two (2) meters diameter and 56 meters in depth. Approximately 15 meters of upper part of the piles will protrude above river bed, covered by steel casing pipes.

Water mixed with bentonite must be controlled to avoid discharge into the river.

These foundation works can be completed within 8 or 9 months.

2) Bridge Works

The balanced cantilever construction by in situ concreting of the segments should be applied to the main bridge works. The main span is 220 m long and side spans 110 m. The bridge girder has a double box type section and is to be divided into 84 segments, each of which is no more than 5 m in length.

A mobile carriage, with upper main beams is usually placed above the webs of the segments to be concreted. According to experience in Japan, a large size mobile carriage could cover the whole bridge width of 17.9 m.

Concreting of main bridge, therefore, will be made at four (4) sites to keep the balance of the cantilevered girders above the two (2) main piers. The prestressing method is not designated due to wide variety of anchoring methods.

The above bridging works can be completed in 10 months since less than 15 days are needed for each segment.

Delivery of concrete to the site will be made by tower cranes or concrete pump vehicles.

9.6.2 Approach Bridge and Approach

1) Management of Existing Traffic

Most piers of the approach bridges are planned to be built in the center of the existing road. Twenty-seven (27) piers in Thonburi side and twenty-two (22) piers in Bangkok side will have to be constructed without disruption of existing traffic.

The present carriageway width in Thonburi side is about 30 meters, and its right of way width is about 40 meters. A 15 meters wide space for construction will be required in the center of the road for foundation piles and sheet piles. It should not be difficult to prepare two temporary 2-lane carriageways in each direction within the remaining 25 meters. However, a stretch of about 100 meters from the intersection with Charoen Nakhon road to the river bank in Thonburi side has an elevated access road in the road center, which may cause the traffic management difficulties unless a temporary steel bridge is constructed on the north side within the right of way.

A difficult portion in terms of traffic management in Bangkok side is seen around four (4) piers (P 39 to P 42) near the intersection with Charoen Krung road due to the 16.5 meters wide foundation. The arrangement is possible, however, by relocating side-walks. The construction strategies described above are outline in Fig. 9.6.1.

2) Construction Noise Control

Driving precast piles of 60 cm diameter for the approach bridges could be a serious source of construction noise. According to the experience in Japan, the noise level by diesel hammer was measured in the range of 93-112 decibel, dB(A) at a distance of 10 m from the driving site, and 80-90 dB(A) at 50 m from the site. It is already a common practice for contractors to cover the driving machine by a noise prevention cover in the city works, so that the noise could be less than 80 dB(A) at 30 m from the site.

It may be noted that the subsoil in the project area can be said to be soft with N value of 20 at around 30 m depth and less than 5 upto the depth of 15 m. The amount of hammering would be less than in case with hard soil.

3) Site Safety Control

Approach bridges of about 1,500 meters long will be contructed over the existing trunk road with densely built-up areas and along its length. Measures to minimize hazards and disturbances to traffic and other general public should be given high priority. The following are some of measures for the purpose.

- Moving of construction machinery and materials could be done during the night.

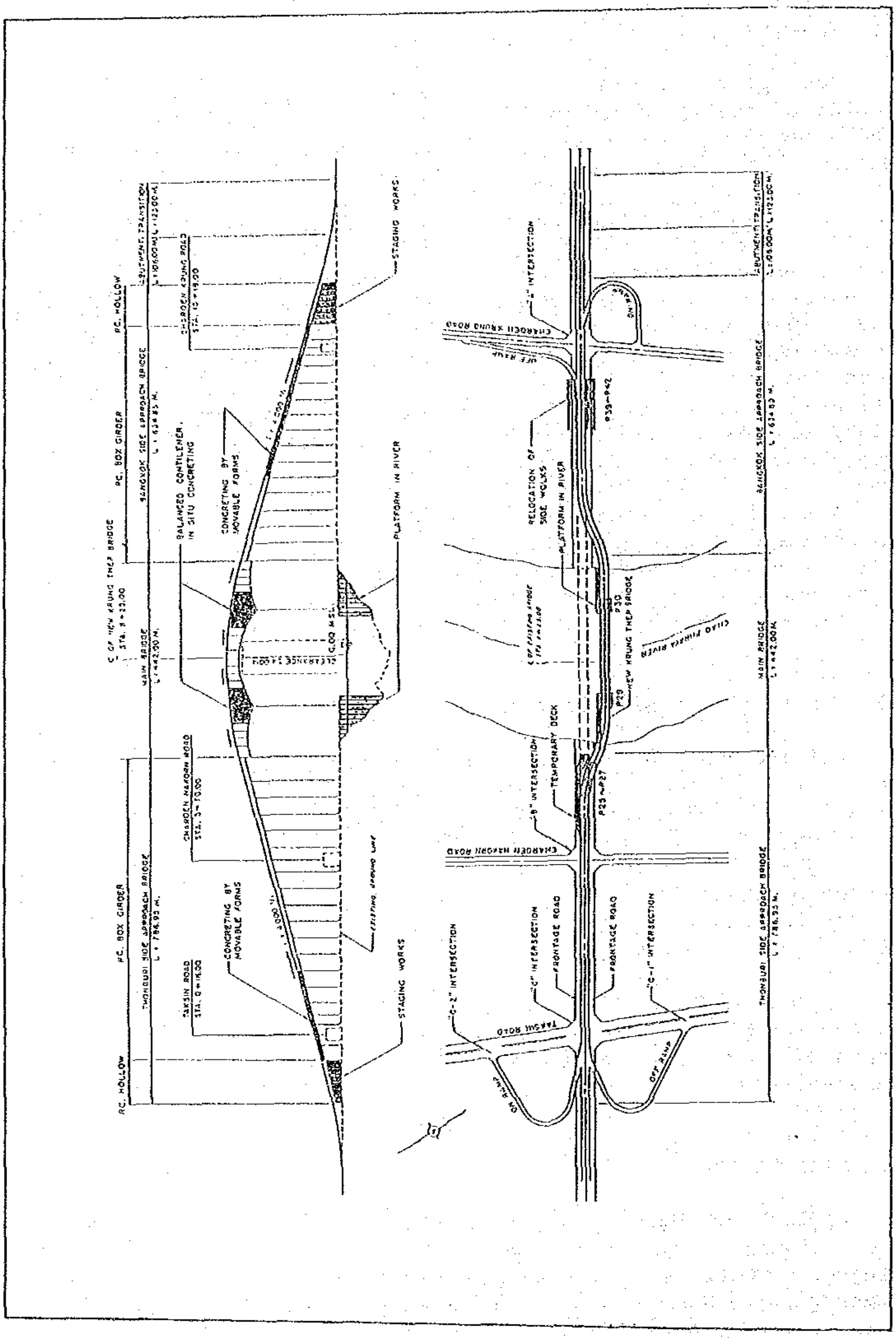


Fig. 9.6.1 Outline of Construction Strategy

- Temporary traffic signal or flag-sign bearer should be placed where construction machinery is in operation.

- Excavated holes for pile cap construction should be kept from collapse by sheet-piling protection;

- Concreting works above the level of 3 meters should be covered by nets or other covered sheets;

- All activities of self running construction machines should be under the control of a site manager. Idle machines should be kept outside the road area.

4) Construction Schedule Control

A key point in construction will be keeping the construction period as short as possible. The Study Team envisages that the following methods and work periods as shown in Fig. 9.6.2 would be required:

a) Foundation & Substructure Works

A set of diesel hammer will have to be installed on both Thonburi and Bangkok side to complete the foundation works within 9 months. Erection of the pier can be done within 1 month immediately after the completion of the foundation works. The total construction period for substructure works is estimated at 10 months. A total of four (4) construction sites, two sites of piling works and two sites of pier concreting works are assumed for minimum interruption to traffic.

b) PC Box Girder Works

PC box girder type approach bridge is to be constructed by a movable form work, with hunger type movable steel girder installed on the span to be concreted.

The width of the bridge designed, however, partly exceeds 20 meters even for one side of the bridge. As this is generally considered to be the maximum size for this kind of movable forms. 2 sets each on Thonburi and Bangkok sides, totaling 4 sets of movable formwork may have to be installed to complete the bridge works within 12 months since 20 days are required for 1 span.

c) RC Hollow Slab Bridge

An RC continuous hollow slab bridge is proposed in the low pier sections at the ends of the approach bridges. These could be concreted on forms supported by staging in order to avoid disturbing the public and traffic.

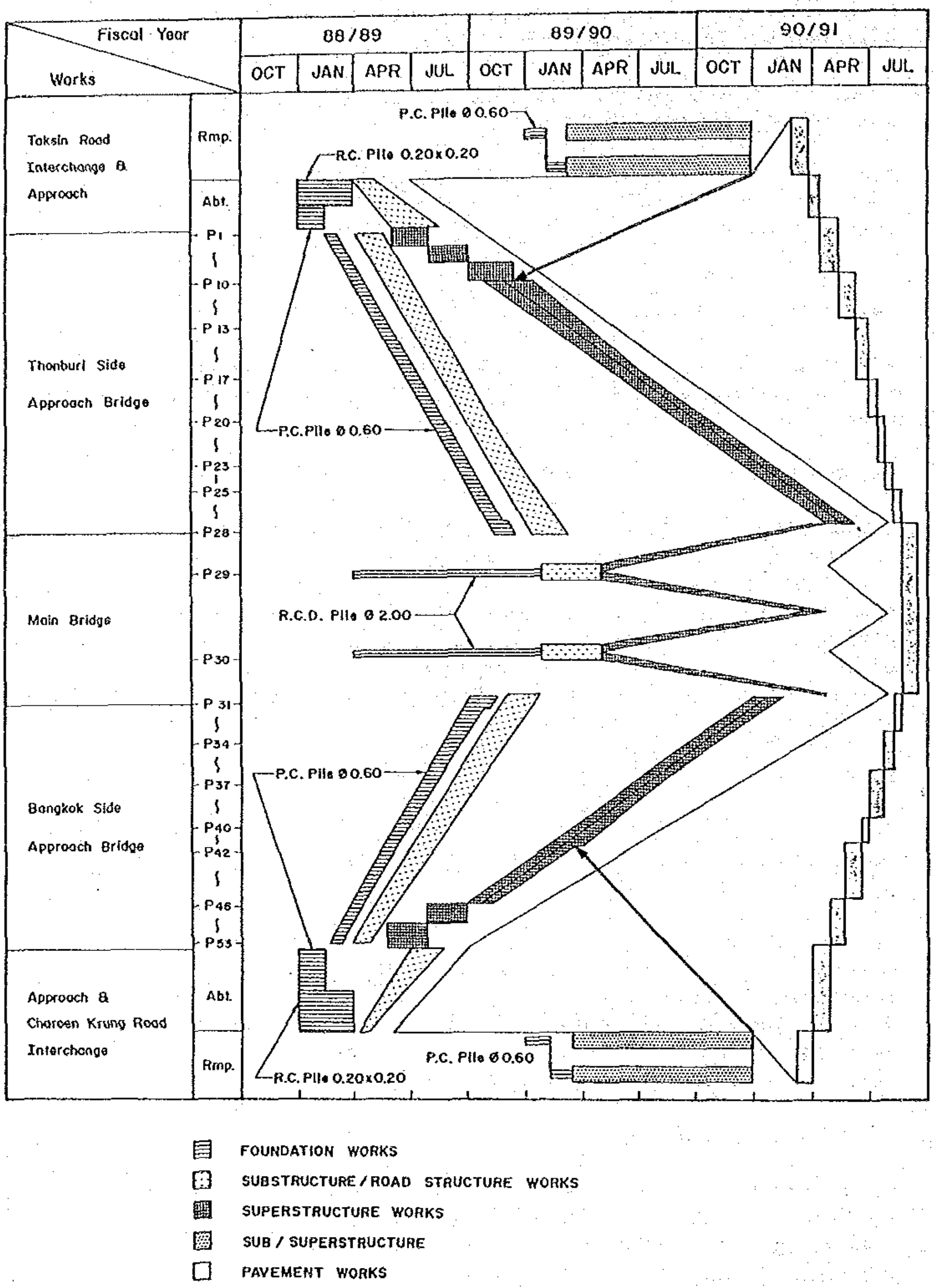


Fig. 9.6.2 Construction Schedule of New Krungthep Bridge

d) Abutment Structure

An abutment structure is proposed for the access portion on the Bangkok side. The foundations of 22 x 22 cm RC precast piles could be driven by vibration hammer to avoid construction noise.

9.6.3 Construction Schedule Estimated

The construction schedule of this bridge project is estimated at 36 months as follows:

- Preparation and mobilization	3-6 months
- Substructures of main bridge and approach bridges	13 months
- Superstructures of main bridge and approach bridges	18 months
- Other interchanges and approach works, and pavement works	3-6 months

9.7 Cost Estimates

9.7.1 General

1) Exchange Rate

Prices used to construction cost estimates were as of October 1986, and the exchange rate used were:

US dollar 1.00 = 26.1 Baht = Yen 153

2) Contractors and Labour Force

The current membership of the Thai Contractors Association exceeds 500. The capital of each firm ranges from 15 to 35 million Baht. Some are experienced even in field requiring high technical level. Their activities are regulated by the Construction Profession Control Act issued in 1979.

According to a survey of the labour force during the agricultural season in 1982, about 500,000 or 2% of the total employed persons were engaged in construction, repair and demolition.

3) Market Price Levels

The JICA Study Team sent questionnaires on cost basis to seven (7) selected contractors who are experienced in highway or bridge construction projects in Thailand. The results are shown in Appendix 9.7.1. Machinery rental charges in Bangkok are compared with the

Japanese Depreciation Table 1984 issued by the Japan Construction Mechanization Association. It can be concluded that the effects of sea transportation charges from machine producing countries are negligible.

4) Taxation and Cost Component

a) Income Tax

According to the Revenue Code of Thailand, the tax ratios on private income may be summarized as follows:

Total Taxable Amount	Tax Ratio
less than 40,001 Baht	7 %
40,001 - 90,001 Baht	10 %
⋮	⋮
over 2,000,000 Baht	55 %

The definition of the taxable amount is the balance of the total income of the year after deduction of approved essential living charges either 30% of total income or less than 40,000 Baht per year.

The income tax of construction workers, therefore, is almost negligible except such monthly paid workers as machine operators, foremen, and expert workers who get on annual income of more than 40,000 Baht.

Company income tax of a contractor as a firm is either 35% of total profit or 5% of gross income for the year.

The income tax of contractors of projects, may be estimated as 5% of the contract amount included in their overhead.

b) Customs Duty and Business Tax

According to the Custom Tariff of Thailand 1986, the customs duties and business taxes on imported goods are calculated as follows:

Custom Duty = CIF price x Rate of Duty ...... (1)

Business Tax =

$$(\text{CIF price} + \text{Duty}) \times (100 + P) \times T \times \frac{110\%}{100 \times 100} \times 98\% \quad \text{...... (2)}$$

where P : Rate of Standard Profit (%)
T : Business Tax Rate (%)

100% of T allows for the addition of local tax, and 98% of total business tax represents the deduction due to advance payment at custom office.

The total tax amount on imported goods, therefore, was calculated as the total amount of (1) and (2) as shown in Appendix 9.7.1.

c) Cost Components

The project cost is generally required to be devided into foreign, local and tax components.

The Study Team applied the calculated data shown in the Basic Input Output Table of Thailand issued by NESDB.

5) Capital Cost

The foreign component as estimated in this study turned out to be about 40% of the total, which is same as previous estimates for similar projects in Bangkok: but smaller than those for other developing countries.

Detailed cost calculation papers were submitted to PWD as Internal Working Paper No. 3 in February 1987. Procedures taken and assumptions made in the capital cost estimation were as follows:

a) Itemized cots were estimated based on the quantities determined from the preliminary design work carried out from November 1986 to January 1987. Relevant drawings are attached as a separate volume "Drawings Volume".

b) Temporary work costs considered were transportation of machinery to the site and partial sea transportation, site survey, temporary facilities, construction noise control, existing traffic management, safety control, land rental charges, engineering quality control, site office and site office operation.

c) Overhead cost of about 30% of the total direct cost were allocated including site management charge, some business tax amount excluded from the direct cost, head office management cost with profit and the income tax (5%) of the contractor;

d) About 7.5% of the total construction cost were added as physical contingency. Price contingency was neglected;

e) The Engineering Service charge was estimated at 10% in total, 3% as detailed design charge and 7% as construction supervision charge.

f) Land acquisition cost and compensation cost for buildings and houses were estimated based on the price source given to the Study Team by PWD;

g) Economic costs were calculated excluding the tax component from the capital cost.

6) Maintenance Cost

Three (3) kinds of maintenance cost per km were estimated for the long span PC bridge crossing the river, short span bridges and viaducts, and cement concrete surface roads.

The maintenance cost for the long span PC bridge was estimated at about 500,000 Baht per km or 0.3 x 10^{-2} x construction cost, the maintenance cost for viaduct was estimated at about 200,000 Baht per km or 0.1 x 10^{-2} x construction cost. The source was given at the Symposium on Bridge Repair Maintenance and Rehabilitation sponsored by the International Association for Bridge and Structural Engineering (IABSE), Washington in 1982.

The maintenance cost of the cement concrete surface road was estimated at 26,000 Baht per km based on the past records of DOH.

9.7.2 Cost of New Krungthep Bridge

1) Capital Cost

Capital costs of the New Krungthep Bridge Project are summarized in Table 9.7.1, Details itemized costs are shown in Appendix 9.7.2.

2) Maintenance Cost

The annual maintenance cost of the New Krungthep bridge was estimated as a total of the main river bridge of 0.42 km, the approach bridges of 1.42 km and the access roads of 0.36 km, as shown in Table 9.7.2. Detailed breakdown of the maintenance costs per km is shown in Appendix 9.7.2.

3) Main Materials

The main materials for the project is listed in Table 9.7.3 as shown hereinafter, it is noted that the total concrete volume to be placed in the site is 86,700 cu.m which will require to operate mixing plants more than two (2) sets.

Table 9.7.1 Capital Costs of New Krungthep Bridge

(Unit: 1,000 Baht, October 1986 prices)

Item	Financial Cost	Components (%) F	L	Tax	Economic Cost
a) Construction Cost					
Main Bridge Work	314,282	39.2	60.8	9.8	283,474
Approach Bridge	397,376	35.7	64.3	10.7	354,918
Interchange & Access Rd.	125,967	34.6	65.4	10.0	113,421
Temporary Works	233,000	47.2	54.5	15.5	196,885
Direct Cost Total	1,070,625	39.1	60.9	8.9	948,698
Overhead	314,449	45.5	54.5	35.6	202,504
Total Construction Cost	1,385,074	40.5	59.5	16.9	1,151,202
Physical Contingency	114,926	40.5	59.5	16.9	95,503
Total	1,500,000	40.5	59.5	16.9	1,246,705
b) Engineering Service					
Detail Design Cost	45,000	57.4	42.6	9.3	40,807
Supervision Cost	105,000	40.7	59.3	11.5	92,880
Total	150,000	40.4	59.6	10.9	133,687
c) Land Acquisition					
Land Acquisition	183,000	-	100.0	4.4	175,000
Compensation	52,000	-	100.0	3.8	50,000
Total	235,000	-	100.0	4.3	225,000
Total Capital Cost	1,885,000	35.4	64.6	14.8	1,605,392

Note: F, foreign component
L, local component

Table 9.7.2 Maintenance Costs of New Krungthep Bridge

(Unit: 1,000 Baht, October 1986 prices)

Item	Financial Cost	Components (%) F	L	Tax	Economic Cost
a) Annual Maintenance Cost of Main Bridge (0.42 km)	221,391	33.2	66.8	7.6	204,483
b) Annual Maintenance Cost of Approach Bridge (1.42 km)	284,465	27.7	72.3	8.1	261,557
c) Annual Maintenance Cost of Access Road (0.36 km)	9,232	20.3	79.7	6.0	8,682
Total	515,088	29.9	70.1	7.8	474,722

Note: F, foreign component
L, local component

Table 9.7.3 Main Materials for New Krungthep Bridge

Item / Site	Main Bridge	Approach Bridge	Others	Total
Concrete cu.m				
fc = 350 kgf/sq.cm	13,890	18,310	1,710	33,910
fc = 300 kgf/sq.cm	13,370	-	-	13,370
fc = 240 kgf/sq.cm	10,120	23,220	6,040	39,380
Total cu.m	37,380	41,530	7,750	86,660
Cement ton 0.38 ton/cu.m	14,200	15,780	2,950	32,930
PC Tendon ton	1,270	1,730	160	3,160
Re-bar ton	3,470	5,940	1,260	10,670
Embank cu.m	-	-	13,500	13,500
PC pile 0.6 m dia.	-	35,550	9,350	44,900
RC pile 0.2 x 0.2 m	-	-	9,600	9,600

9.8 Economic Evaluation

The method of estimating the amount of benefit in monetary terms has been described in Section 4.6. The procedure was applied for the assumed opening year of 1991, the tenth year of 2001 and the twentieth year of 2011 to obtain annual benefit amounts for the three years. Benefits for the intermediate years were estimated by means of interpolation.

The method and the results of the estimation of project costs are described in the preceding Section 9.7. Economic costs of construction and maintenance works were determined and year by year stream of construction and maintenance costs were established.

The residual value of the bridge and approach structures at the end of 20 year period, i.e. year 2011, should be the initial construction cost less the amount needed to restore the whole to the initial conditions.

The total life of superstructure is normally considered 70 years whereas the substructure is considered to have an unlimited life. The replacement of the superstructure at the end of its life would cost 60% of the initial construction cost. Taking a straight line depreciation, the residual value at the end of the 20 year period was determined. Eighty three percent of the initial cost was assumed at the end of the 20 year project period and was counted as a negative cost in the year 2011.

Benefit stream and cost stream thus derived are presented in Appendix 9.8.1.

Standard economic evaluation procedures were taken against these streams of costs and benefits and the results are shown in Table 9.8.1. The construction of the new Krungthep bridge as proposed in this report is soundly economically feasible. The project would yield an internal rate of return of 20.7%.

If the total project cost overruns by 15%, the internal rate of return would drop to 18.9% and likewise it would be 18.6% if the benefit stream is uniformly 15% less. In either cases the project is still economically justificable.

Table 9.8.1 Economic Evaluation of New Krungthep Bridge

Case	Net Present Value at 12% (Baht million)	B/C Ratio at 12%	Internal Rate of Return (%)
Base	1247	2.09	20.71
Cost 15% Up	1075	1.82	18.86
Benefit 15% Less	888	1.78	18.57

9.9 Other Considerations

1) Environmental Considerations

The general environment of the existing Krungthep bridge is not particularly attractive, being at the fringe of the central part of the city. On the Bangkok side old warehouses with piers and jetties decaying due to the lack of attention because of inactivity line the shore upstream of the bridge. The adjacent land downstream is occupied by a customs training center and then by a private slipway. On the Thonburi side the bridge lies between a concrete batching plant and a rice mill on the upstream side and warehouses on the downstream side. No aesthetically appealling structure exists on either side of the river at this location. Approaches to the bridge are lined with ordinary two or three storey shophouses. None of them nor the street view itself can hardly be claimed to be aesthetically appealling.

The work on approach structures would give the general view of this area a modern look, if not aesthetically superior. To the residents and customers of shophouses along the road who would remain after construction of the approaches their view would be severely limited by the overhead structures. However, a general improvement of the area is possible by landscaping and provision of facilities such as parking spaces and park facilities.

The new main bridge would not cause any significant changes to the general view if its height is similar to the existing one. However, the addition of a high bridge towering over the existing bridge would be a major change in the general view of the area. It will dominate the landscape. The combination with the existing low bridge would give the viewer a somewhat uneasy feeling. If there are structures with profiles making valuable aesthetic contributions to the skyline of the area, a high structure blocking the effects of those beautiful structures is certainly not desirable. However, it is decidedly not the case for this area. The aesthetic disadvantage of a high bridge would be minimal in this area. It may even be speculated that such a dominant structure would give a focus in this otherwise non-descript area and may induce some orderly urban development in the surrounding areas. This may be judged from the Frontis piece.

Other factors such as ecological effects should be given due consideration during the detailed design stage.

2) Comments on Project Scale

The recent big highway and bridge construction projects in Bangkok are listed below with their construction costs:

Costing Year	Project	Planned Project Cost		
1977	Sathorn Bridge	Baht	717 (1,181)	Million

Table 9.9.1 List of Highway and Bridge Project Costs in Bangkok

Costing Year	Project	Planned Project Cost		
1978	First Stage Expressway Phase (I) 8.9 km	Baht	1,283 (1,859)	Million
1979	First Stage Expressway Phase (II) 7.9 km	Baht	1,621 (2,078)	"
1980	New Memorial Bridge	Baht	855 (971)	"
1981	Nonthaburi & Pathumthani	Baht	858 (908)	"
1982	First Stage Expressway Phase (III) 10.3 km	Baht	7,119 (7,262)	"
1986	New Rama VI Bridge	Baht	1,300 (1,300)	"

Note: Costs at 1986 prices are in parentheses.

The total project cost for each as packaged project in the past 10 years has been around Baht 1,000 Million except for Phase III of the first stage expressway project, which was subdivided into three subprojects of two approach bridge projects and the main Wat Sai bridge project.

The Baht 1,885 Million estimated for the New Krungnthep Bridge project may be somewhat higher than past projects in Bangkok. It is natural, however, that urban infrastructure construction projects tend to become costlier as land use intensifies.

PART IV
THONBURI ROAD EXTENSION

CHAPTER 10

EXISTING CONDITIONS AND REVIEW OF EXISTING STUDY

10.1 Existing Conditions

10.1.1 Existing Road Conditions

Seven existing roads, namely Phet Kasem Highway, Wutthakat Road, Ekkachai Road, Sukha Phiban Road, Phatthanakan Road, Soi Nil Kaj Road, and Middle Ring Road are located or under construction in the area surrounding the survey site as shown in Fig. 10.1.1.

1) Phet Kasem Highway

Phet Kasem Highway is a National Highway of Route 4 connecting Bangkok with Nakhom Pathom. Its traffic volume was counted at 54,000 - 74,000 V/D including motorcycles in 1986. The road is of 6 lanes (both directions) with a median but without shoulders in the area close to the center of Bangkok. Bridges crossing Khlongs were constructed as 4-lane-bridges but expansion work is underway to make them 6-lane bridges. The outer lanes of this highway are used for short time car parking and exclusive bus lanes (part time). Thus generally, the total of traffic lanes of the highway in this section is 4. The width of this highway west of the Wat Chanpradittawan is 6 lanes (both directions) divided by a median and with shoulders. Bridge are constructed as 6-lane bridge. In this section the outer lanes of the highway are also used for short time car parking and exclusive bus lanes. Buildings (3-5 stories) are located close to both sides of this highway.

2) Wutthakat Road

Wutthakat Road is located in a built up area with 2 lanes without shoulder. This road is to be overpassed by the project road. Therefore, a suitable valley is required among buildings, which generally stand close to both sides of the road.

3) Ekkachai Road

Ekkachai Road is now under rehabilitation work financed by IBRD, which is to be completed in August 1987 as a 4 lane dual carriageway with shoulders. However no widening work is planned for the congested section from the center of Bangkok to the intersection with Soi Nil Kaj of the paved 2-lane road, which connects the Ekkachai Road and Phatthanakan Road.

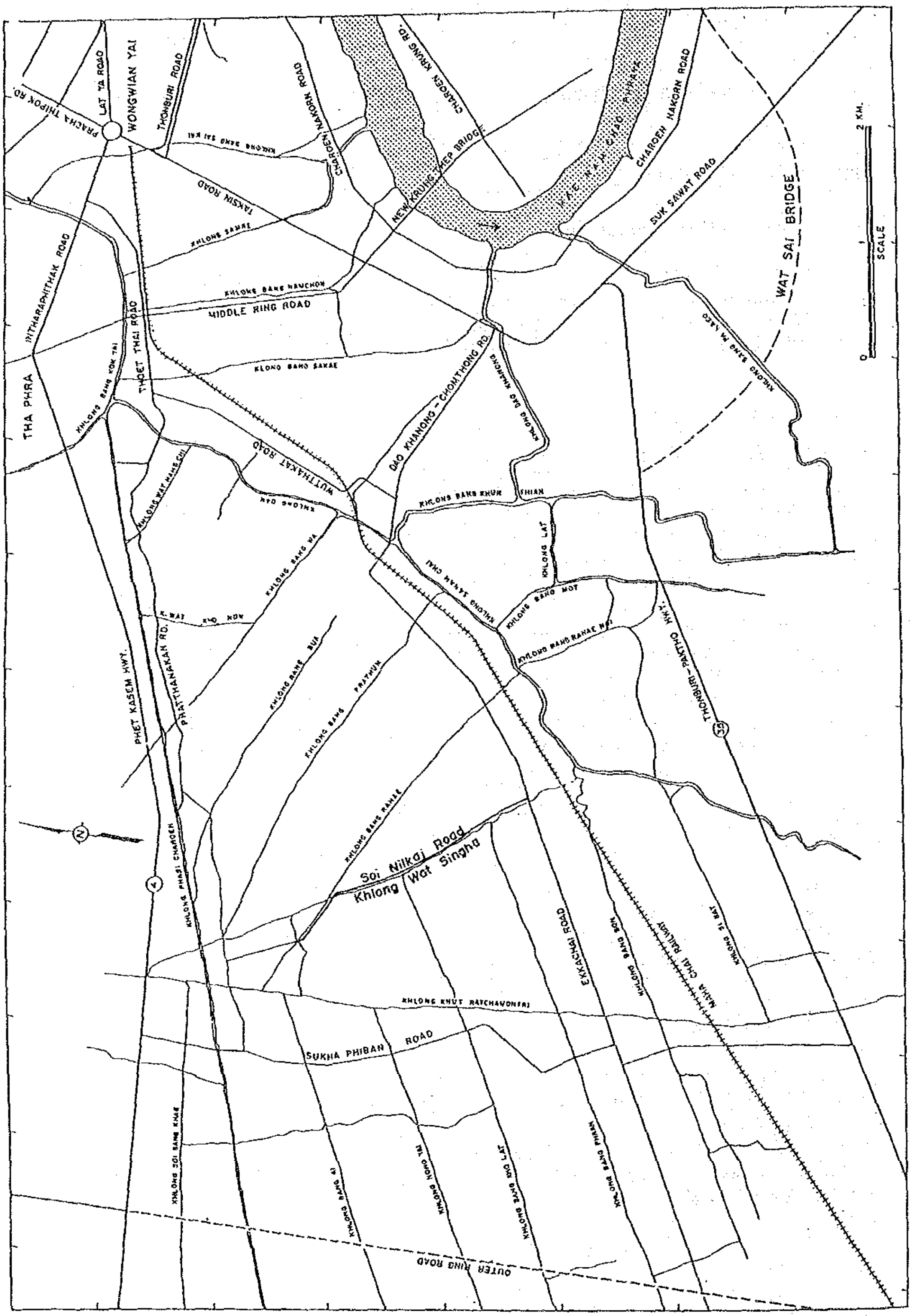


Fig. 10.1.1 Location Map of Existing Road and Khlong

4) Sukha Phiban Road

Sukha Phiban Road connects Phet Kasem Highway and Ekkachai Road. This is a 2-lane road (both directions). Many houses are located along the existing road about 1.5 km from the Ekkachai Road to Phet Kasem Road. BMA rcently improved the road to 2 lanes with shoulders and pedestrian path on both sides.

5) Phatthanakan Road

Phatthanakan Road runs parallel with the Khlong Phasi Charoen between the Sukha Phiban Road No. 1 and the Wutthakat Road. The road is only one lane with shoulder allowing vehicle passing or overtaking. Recently potholes in the pavement were covered and a wooden bridge was replaced by a precast concrete bridge.

6) Soi Nil Kaj Road

Soi Nil Kaj Road connects Phatthanakan Road and Ekkachai Road passing through an agricultural area. The width of this road is about 6.0 m and traffic volume low. In some parts, new housings has been constructed along both sides of the road.

7) Middle Ring Road (MRR)

The Middle Ring Road in the 3 km stretch between Phet Kasem and Taksin Road is under construction for a flyover crossing of the Mahachai Railway and the elevated roadway on the Thoetthai Road (Wutthakat Road). The responsible agency of the project, BMA, reported that it planned to open the MRR in 1988 completely at the steering committee of the project on 16th April 1986. The road will have 8 lanes.

8) Outer Ring Road (ORR)

The 7.7 km stretch of Outer Ring Road between Phet Kasem Highway and Thonburi-Paktho Highway has also been under construction since February 1986, and is to be completed by January 1988.

10.1.2 Land-use

In the project area the built up area extends along an existing roads and khlongs within a band of 200 m to 300 m in width. Regarding Phet Kasem Highway, housings development is taking place to the northern side of the road, and as for Ekkachai Road, housing and commercial development is gradually extending both northwards and southwards.

Existing land-use in the area between Phet Kasem Highway and Ekkachai Road is almost entirely agricultural. Urban development in this area has been slow due to shortage of roads. When the Project Road is constructed in this area, housing development will be accelerated.

The Project Road will induce development pressure in the area. The Project Road can be called a development road because of the following:

a) Bangkok Noi-Nakhorn Chaisri Highway was constructed in 1982. The road was constructed in an agricultural area like the Project Road. In the four years since, many houses, factories and commercial buildings have been built along the road within 200-300 m. As mentioned in Section 4.4. Population growth in this area has been rapid.

b) Many housing estates are being implemented along Sukha Phiban Road.

c) The study area will be directly connected to MRR and ORR by the Project Road. So, the development potential in this area is very high.

10.1.3 Existing Khlong Conditions

Two comparatively wide khlongs namely Khlong Phasi Charoen and Khlong Dan exist in the study area. The width of the khlong Phasi Charoen is about 20-25 m and it flows from west to east. Many small wooden houses are located along the khlongs on both sides. The width of the Khlong Dan is about 20-30 m and there are also many small wooden houses along the khlong on both sides. The general conditions of the other small khlongs are almost the same. Width of small khlongs is about 5-10 m many and small wooden houses are located along these khlongs.

10.1.4 Water Levels

1) General

Bangkok Metropolitan Administration (BMA) is examining the flood control system in Bangkok and its surrounding area. Master Plan and Feasibility Study on Eastern Suburban Bangkok Project was conducted by Japan International Cooperation Agency (JICA) in 1984 to 1985 and the City Core Project on East Bangkok Main Polder was studied by the Government of Holland in 1984.

Basic analysis and planning of the flood control system on the Bangkok side has thus already been completed by the above mentioned studies. On the other hand, the basic analysis on the Thonburi side has been just commenced as below:

- Improvement of Canals in West Bank of the Chao Phraya River Project was planned in 1985 by Department of Drainage and Sewerage (DDS), BMA.

- Internal Drainage Polder of Thonburi Area in West Bank Main Polder Project is to be studied by the Government of Holland in 1986 to 1987.

- The Flood Protection of Bangkok Chao Phraya II (West bank Inland Dyke - By Pass) Project will be also studied by Government of Austria. Both project sites are illustrated in Fig. 10.1.2.

Improvement of sidewalls of waterways and pedestrian path on existing khlongs and gates at the Chao Phray River are also under construction by DDS, BMA. This improvement plan covers the Khlong Bangkok Yai, Klong Dan, Dao Khanong Chom Thong and Charoen Nakhon Road.

2) High Water Level in the Study Area

As mentioned above, study and basic analysis of the flood control system in Thonburi area has not been completed, so the basic data for examination of high water level is not read yet. Khlong Phasi Charoen runs parallel with Phet Kasem Highway in the study area. The high water level of this khlong in 1983 was about 1.6 m above MSL. Floods have occurred frequently in the past decade such as in 1975, 1978, 1880, 1983 and 1986.

The high water level in 1983 may have been the highest of the period of 1960-1983, seeing the highest water levels recorded at regulators along the Chao Phraya River and the Tha Chin River.

Therefore, it may be possible to consider that the high water level in the study area is 1.6 m above MSL. However, when the Internal Drainage Polder of Thonburi in West Bank Main Polder Project is completed, this high water level should be reexamined.

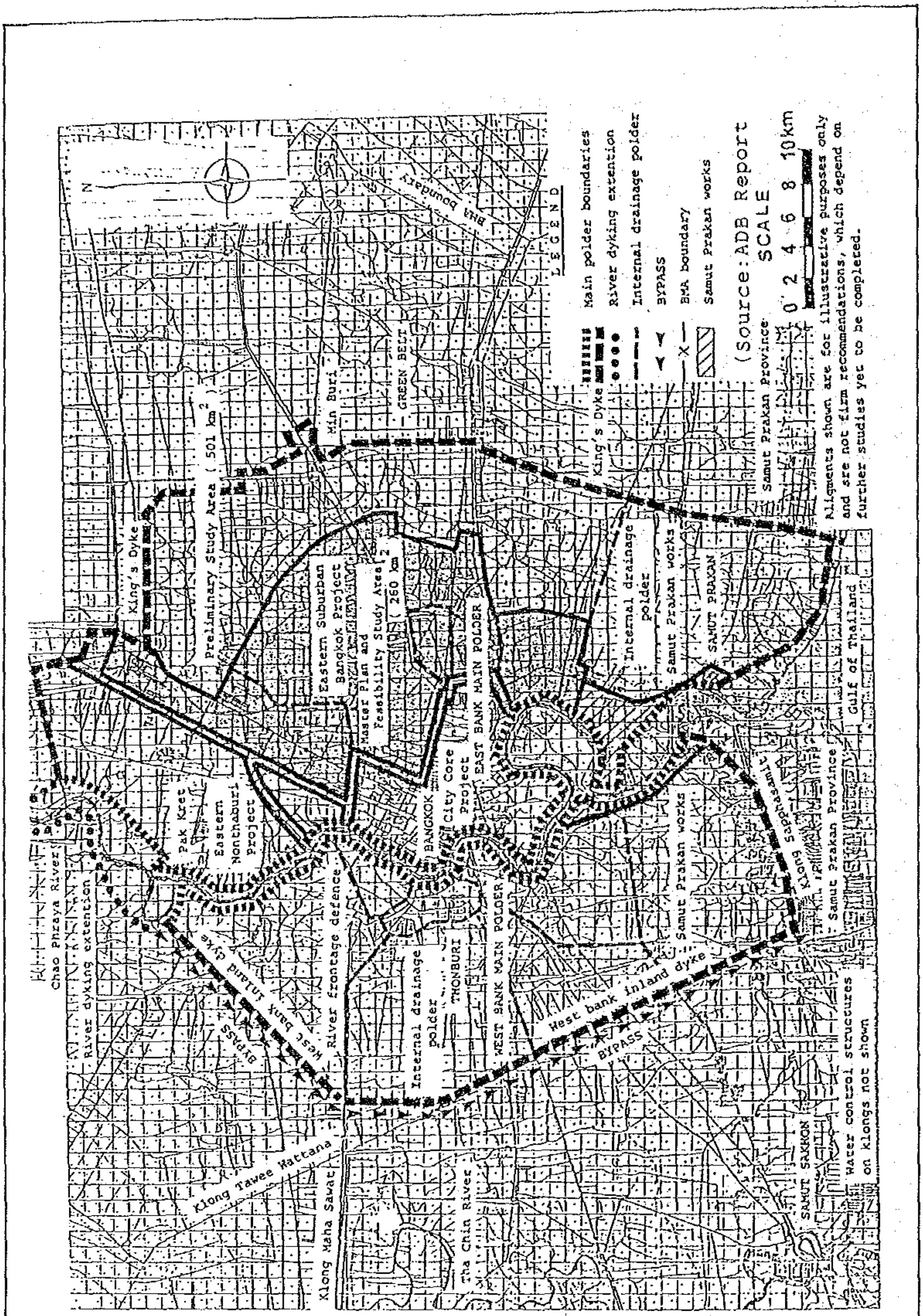


Fig. 10.1.2 Location of Water Control Projects

10.2 Review of Existing Study Report and Related Project

10.2.1 Review of Existing Study Reports

There are three existing study reports for Thonburi Road Extension Project which were prepared by Cowi Consult and AEC.

1) Feasibility study of Thonburi Road Extension Report by Cowi

The feasibility study was carried out in 1976 based on seven major alternative routes, namely A, B and C, and their combinations.

The conclusions and recommendations of this report are as follows:

a) The comparative evaluation of the alternative projects concluded that the optimum alignment of a road from the proposed Sathorn Bridge to Phet Kasem Road will be an "A short" alternative. In the further design work, it should be determined whether A-A2 or A-A1-B should be selected. The alignment terminates on Phetkasem Road approximately 2 kms west of the junction with Charan Sanit Wong Road. The alignment is preferable both in terms of economics and in term of environmental impact.

b) It is further established that this alignment will be the optimum one irrespective of which of the three urban development plans would be realized.

c) The optimum opening year of the road would be 1980.

d) The estimated time for completion of the project is 36 months including the design and tendering period.

e) The alternative alignments, denoted A long and B short and B long would also be economically feasible. The alternatives, however, yield considerably less economic returns than does "A short".

f) It may further be concluded that it would be economically advantageous to construct, at about 1990, a continuation of the Thonburi Road Extension further westwards joining the Phet Kasem Road west of Bang Khae.

g) A decision in this respect is not required, however, until around 1985; and it should then be made after a reevaluation based on the development then realized and to be foreseen in terms of land use and transportation west of the Chao Phraya River in general and in the direct influence area of the road in particular.

2) Feasibility Study of Thonburi Road Extension by AEC

The feasibility study was conducted in March 1986 based on four alternative routes, namely A through D. The conclusions and recommendations of this report are as follows:

a) Based upon the economic evaluation, and taking into account operational, environmental and developmental considerations it is recommended that alternative A should be implemented with flyover bridges at Taksin Road and Ratchada Phisek Road. The recommended structure for the Taksin Road flyover is Alternative 2: prestressed concrete simply supported girder bridge.

b) This finding conforms with the "B-short" route recommended by Cowi Consult.

c) IRR of each alternative routes A to D is calculated as 28.82%, 26.99%, 23.52% and 24.41% respectively.

d) The optimum opening year of the road would be 1991.

e) The estimated time for completion of the project is 66 months including the design and tendering period.

f) Implementation is recommended in three phases:

Phase 1 - at-grade road between Taksin Road and Ratchada Phisek Road;

Phase 2 - flyover at Taksin Road;

Phase 3 - Ratchada Phisek Road to Phet Kasem Highway, incorporating a flyover at Ratchada Phisek Road.

It is strongly recommended that Phase 2 and 3 should be implemented simultaneously in order to achieve the full benefits of the Taksin Road flyover at the earliest possible date.

3) Detailed Design of Thonburi Road Extension Report by AEC

The detailed design of section about 2.0 km long between Taksin Road and Middle Ring Road (MRR) was conducted in November 1986 by AEC based on the feasibility study of Thonburi Road Extension Report. Outline of the detailed design are as follows:

a) 60 km/hr - 80 km/hr design speed was adopted.

b) Proposed road height was adopted at 2.30 m to 2.60 m above MSL and 5.0% maximum gradient was adopted.

c) The road was designed for 6-lane with frontage road and side walk on both sides. 3.25 m lane width was adopted for through traffic lane.

d) Intersection with Taksin Road was designed a as grade separated intersection.

e) Intersection with MRR was designed as an at-grade intersection with three legs.

f) 19.50 m width central reservation was maintained for future Mass Transit System (stage 2).

4) Others

a) STTR Report

STTR Principal Finding Report by HFA, July 1985. The short term urban transport review of Metropolitan Bangkok was studied by HFA Consultants.

Sathorn Road Extension (No. 503) is listed in the project sheets recommended to NESDB. Sathorn (Thonburi) Road extension west of Taksin Road was proposed to connect with Phet Kasem Highway at about 2 km west of junction with Middle Ring Road. This concept is almost the same as the "A" short route proposed by Cowi consult in 1976.

b) General Plan of DTCP

According to the General Plan prepared by DTCP, it was found that New Ring Road is almost the same as their Intermediate Middle Ring Road and the alternative route which connects the COWI short route and the interchange proposed by New Rama VI project is almost the same as the route for the future 3rd stage Expressway.

10.2.2 Related Projects

There are two roads under construction, namely Outer Ring Road and Middle Ring Road, and three planned roads, namely Intermediate Middle Ring Road, new connection road and Thonburi Road Extension in and around the area. In addition to these roads, two mass transit lines namely, the Sathorn line and the Memorial line are planned as stage 2 plan of the MRT by ETA.

Above mentioned projects are illustrated in Fig. 10.2.1 and outlines of each project are summarized below:

1) Outer Ring Road (ORR)

The stretch of ORR in the study area is under construction by Department of Highways (DOH) and it will be completed in 1988.

As shown in Fig. 10.2.1 its alignment crosses at the point on Phet Kasem Highway 7.5 km from the intersection between Phet Kasem Highway and Middle Ring Road and passes through to the southern direction and connects with Ekachai Road.

The design speed of this road is 80 km/h to 100 km/h and it is planned as a 4 lane dual carriageway with 2.5 m shoulder.

2) Middle Ring Road (MRR)

The part of MRR in the study area is under construction by BMA. It will be completed in 1987. The alignment is shown in Fig. 10.2.1.

The design speed is 80 km/h and it is planned as a 8 lane dual carriageway.

3) New Connection Road to Rama VI Bridge

This road is planned by PWD. This will connect Rama VI Bridge approach road with the Project Road and may be completed by 2001.

4) Intermediate Middle Ring Road

According to the General Plan prepared by DTCP, Intermediate Middle Ring Road is planned in parallel with the existing Middle Ring Road crossing Phet Kasem Highway, Ekkachai Road and Thonburi-Paktho Highway. It will be planned to open before the year 2001.

5) Thonburi Road Extension

A part of Thonburi Road from Taksin (Sathorn) Bridge to Taksin Road is already open to public and the section from Taksin Road to Middle Ring Road had been under detailed designed which was completed in October 1986 by PWD. Its construction is planned to be completed by 1991.

6) Mass Transit System

Three mass transit lines, namely the Rama line, the Sathorn line and the Memorial line are planned by ETA as shown in Fig. 10.2.1. Its construction is divided into 2 stages, stage 1 and stage 2. Prequalification of firms for stage 1 of Mass Transit System was called in 1986. The implementation schedule of the stage 2 of Mass Transit system has not been examined.

The alignment of the stage 1 of Mass Transit passes in the northern part of Bangkok. Therefore, the New Krungthep Bridge and the Project Road are not affected.

The alignment of stage 2 of the Sathorn line and the Memorial line is planned on Thonburi Road and Taksin Road. Therefore, these basic plans at related intersections are subject to discussion.

The related projects discussed above are listed in Table 10.2.1.

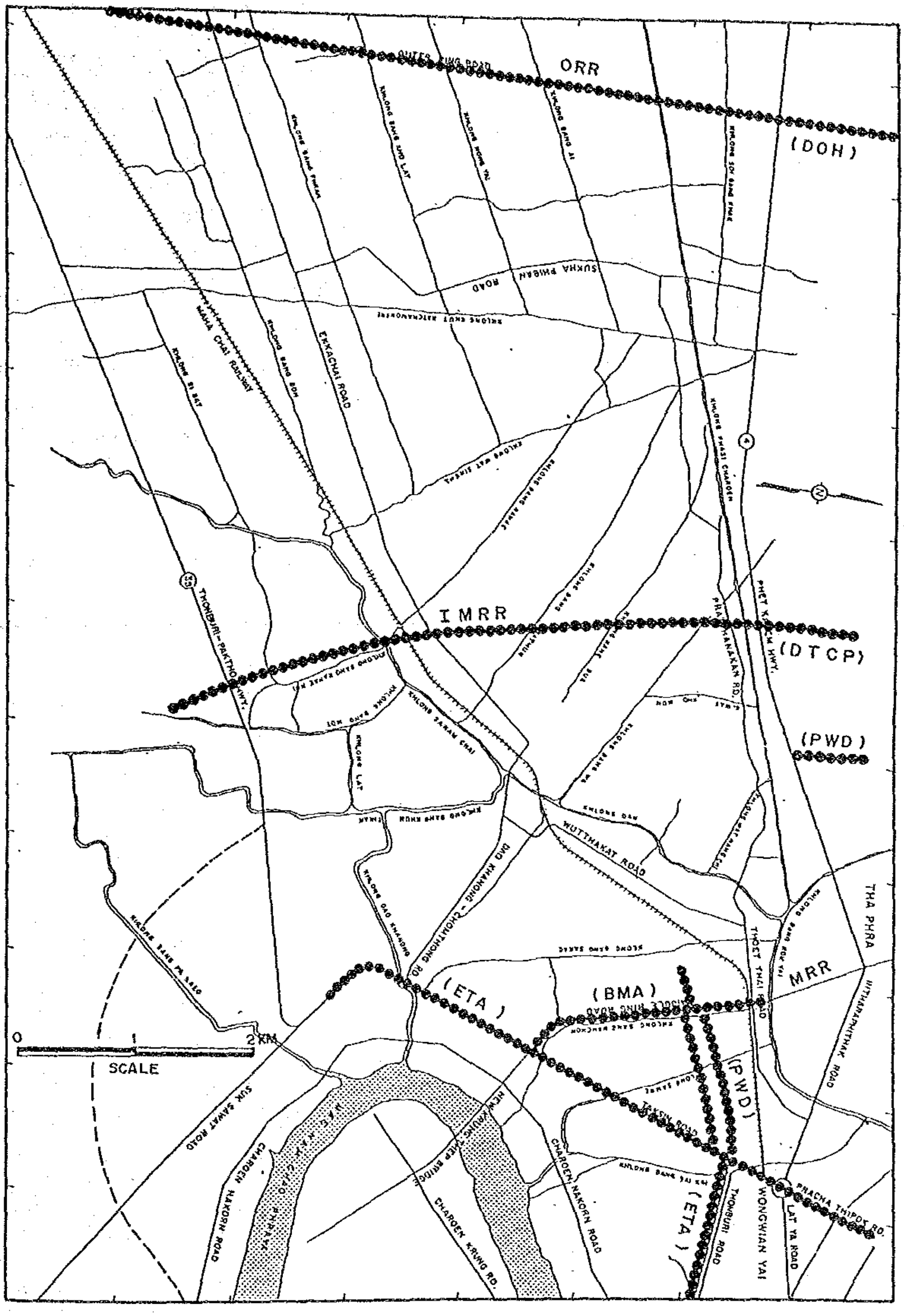


Fig. 10.2.1 Location of Related Projects

Table 10.2.1 List of Related Projects

Project Name	Responsible Agency	F/S	D/D	Implementation	Completion Year	Design Speed	No. of Lanes
Outer Ring Road	DOH	-	Done	Under-Construction	1988	80-100	4
Middle Ring Road	BMA	-	Done	Under-Construction	1987	60-80	8
Intermediate Middle Ring Road	DTCP	-	-	-	2001	60-80	4
New Connection Road	PWD	-	-	-	?	60-80	4
Thonburi Road Extension	PWD	Done	Done	-	1991	60-80	6
Mass Transit (Sathorn Line)	ETA	Done	-	-	?	-	-
Mass Transit (Memorial Line)	ETA	Done	-	-	?	-	-

10.3 Field Surveys

10.3.1 Cone-Penetrometer Survey

The Study Team conducted a site reconnaissance of ground surface conditions together with the subsoil in the project area. The whole project area is covered by soft Bangkok clay. Most parts are well cultivated farmland with trenches.

The cone-penetrometer used for penetration test into the soft ground is a simple and handy apparatus which can penetrate upto a depth of 5 meters. Its dialgauge shows the bearing capacity expressed by a cone Value or qc.

The tests were tried at the following 4 points as described below:

a) Near Outer Ring Road accessible through Soi Rongrian Khlong Nong Yai along Sukha Phiban Road;

b) At a cultivated farm with trenches accessible through Soi Yimuplejuun at the south side of Sukha Phiban Road;

c) Housing area named Chum Chon Bang Khuntien at the south side of Soi Nil Kaj; and

d) A cultivated farm behind the Wat Koh Noon approachable from Phatthanakan Road.

There is no significant difference between the cone values measured at each point. Results can be summarized as follows:

a) The area was observed with a high water, level, almost at the same level as the ground surface even in the dry season of April 1986.

b) The maximum cone value of 8.5 was found only at the ground level in the housing area.

c) Other area's cone values are less than 5.0 which means that their bearing capacities are less than 7 ton/sq.m.

The penetration of a 3 meters long bar could be done very easily and quickly into the ground anywhere in the area.

10.3.2 Subsurface Investigation

A subsurface investigation was carried out in this study. Locations of bore holes and soil profile are illustrated in the Drawings Volume together with the boring logs. As a result of subsurface investigation, the following conditions were comfirmed. The soil profile along the Thonburi Road Extension route indicates that under a thin layer of weathered surface clay a 10-13 m thick soft clay line exists at a level of 10-17 m below MSL. This soft and medium clay is underlain by a 5-15 m thick stiff to very stiff silty clay. The thickness of this layer is about 5 m at the locations of boreholes B-1 and B-2, about 10 m at the location of borehole B-3 and about 15-17 m at locations between Ratchada Phisek Road and Taksin Road. Underlying the stiff to very stuff silty clay is a strata of medium dense to dense silty fine sand where the borings were terminated. Detailed information is described in the Subsurface Investigation Report.

The groundwater level is shown below from the results of the subsurface investigation.

Groundwater Level

Borehole	Existing Ground	(+MSL) Groundwater Level
B1	1.28 m	0.30 m
B2	1.00 m	0.09 m
B3	1.05 m	0.30 m

10.3.3 Topographic Surveys

Topographic surveys including plane table surveys, leveling survey and cross-section survey were conducted by the Study Team in 1986. Location of survey sites were illustrated in Fig. 10.3.1.

1) Plane Table Survey

Following survey sites were conducted

Site A; Scale 1:1000
Site B; Scale 1:1000
Site C; Scale 1:1000
Site D; Scale 1:500
Site E; Scale 1:500

The horizontal control network was arranged to identify the location of the new Krungthep Bridge, to aid in selecting the most suitable interrelationship between the bridge approaches, and to establish supplementary stations directing the positioning of the bathymetric survey across the Chao Phaya River.

Plane coordinates of the site maps emanated from utilisation of the control stations of Thonburi Road Extension (TRE) Project which refer to the Universal Transverse Mercator (UTM) Grid Systems Zone 47 with its central meridian at 99 degree East of Greenwich.

2) Leveling Survey

Leveling survey was conducted along the existing Krungthep Bridge and the proposed Project Road as shown in Fig. 10.3.1. This survey was carried out at 50 m intervals.

All elevations were based on the Royal Thai Survey Department Datum, the same datum as used in Thonburi Road Extension (TRE) Project which is Mean Sea Level, Kolak Datum.

Tie lines were run from existing first order benchmarks; BM 11 with its elevation of +1.9054 meters from MSL, located within the compound of Phra Pin Klao Hospital, Taksin Road, and BMS 8448, with an elevation of +2.4747 meters from MSL, located on the east abutment of the Krungthep Bridge. The coordinates and elevation of this latter benchmark have already been plotted and shown on the relevant site map.

3) Cross-section Survey

Cross-section survey was conducted along the same alignment as the leveling survey. This survey was also carried out at 50 m intervals.

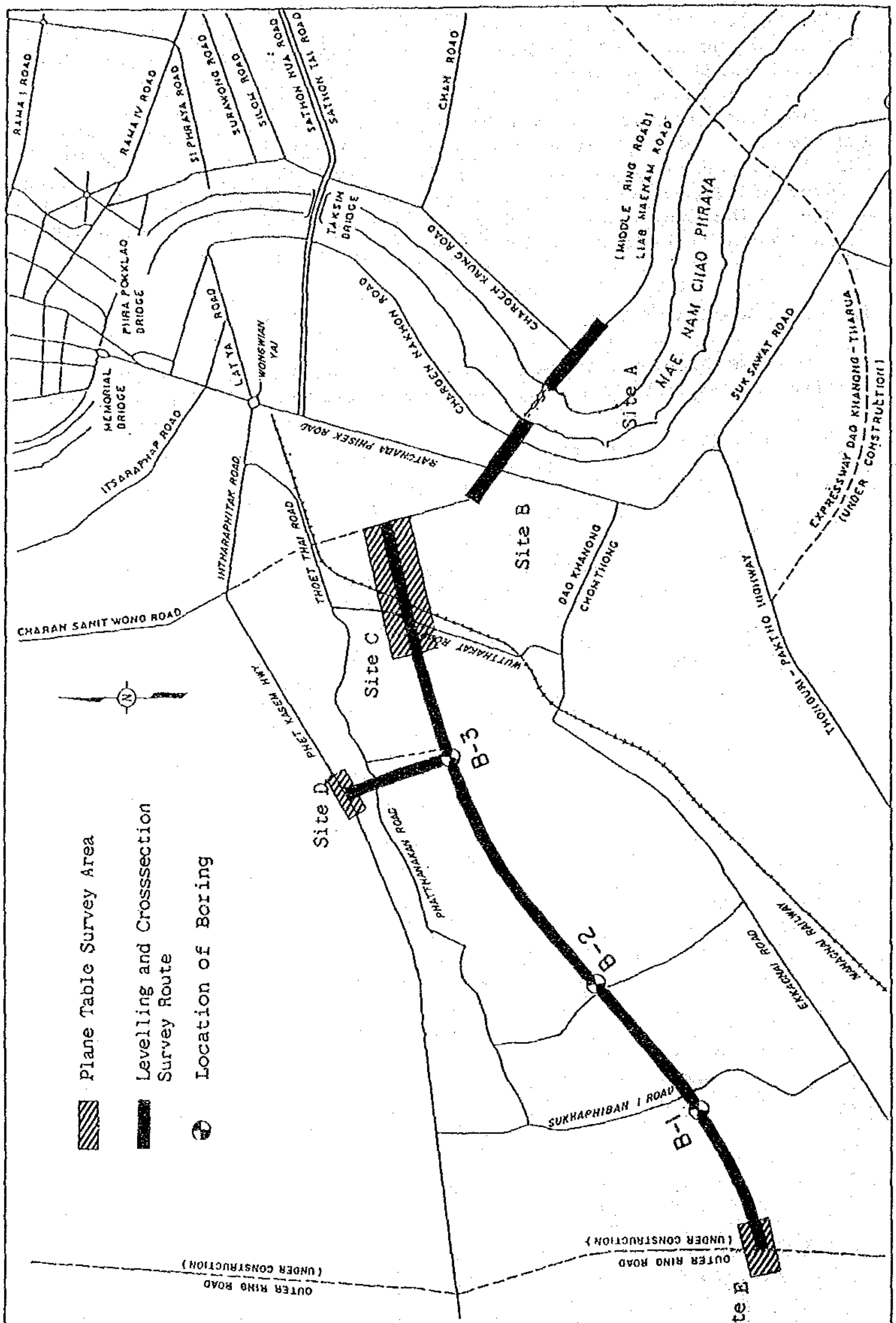


Fig. 10.3.1 Location of Survey Sites

CHAPTER 11

ROUTE ALTERNATIVES

11.1 Introduction

The existing Thonburi Road which connects the Taksin Bridge and Taksin Road was constructed by PWD in 1982 and the Thonburi Road Extension to Middle Ring Road is under detailed design also by PWD. The Project Road is to be linked with the above mentioned Thonburi Road, and possibly connected to Outer Ring Road.

Through a reconnaissance survey in the Project area, The Study Team found that widening of the existing Phet Kasem Highway as a solution to traffic problem is impossible due to difficulties in space acquisition and in arrangement of diversion during widening works. Therefore, this study has focused on construction of a new road.

11.2 Alternative Route Location

11.2.1 Locating Principles

Various possible routes are conceivable for the Thonburi Road Extension (TRE) in the area bordered by Phet Kasem Highway, Middle Ring Road, Outer Ring Road, Ekachai Road and Dao Kanong-Chamthong Road. The following principles were taken into account in determining the alternative routes:

a. To avoid wats (temples), schools and other large buildings as much as possible;

b. To avoid built-up areas as much as possible;

c. To avoid the crossing of klongs as much as possible; and

d. To minimize the construction cost.

11.2.2 Locating Methods

An exhaustive survey was made of existing schools, wats, other large buildings and houses. The study area was divided into meshes of 40,000 sq.m. (200 m x 200 m) and locations of existing obstruction were determined in terms of the meshes. Each mesh within the study area was classified into the following categories:

Category 1

This should be absolutely avoided as the area contains wat, school and other big public buildings.

Category 2

This should better be avoided as the area contains closely built three (3) to five (5) storey brick or concrete buildings.

Category 3

This area is relatively difficult to pass as it contains two (2) to three (3) storey wooden buildings and houses which are crowded.

Category 4

This area is not so difficult to pass as it contains only some wooden houses.

Category 5

This area is easy to pass as it contains no buildings.

Fig. 11.2.1 shows the resulting land use classification indicating the degree of difficulty in land acquisition.

A preliminary route selection study of the project was conducted based on the results of reconnaissance survey and information for aerial photographs at a scale of 1:6,000.

A more detailed route selection was carried out using the aerial photographs at a scale of 1:2,000 which were enlarged from the above mentioned aerial photographs. A plane table survey at a scale of 1:1,000 wad conducted for the most congested areas with houses and commercial buildings. The final route selection in other urban areas was carried out by use of topographic maps at a scale of 1:1,000.

11.2.3 Indentification of Alternative Routes

Various alternative routes are shown in Fig. 11.2.2 with combination of segments.

1) Area between MRR and Wutthakat Road

This area is already a built-up area. There are many houses, offices, buildings, schools and wats to be avoided in route location. In this area, two alternative segments of Segment A and Segment B are proposed.

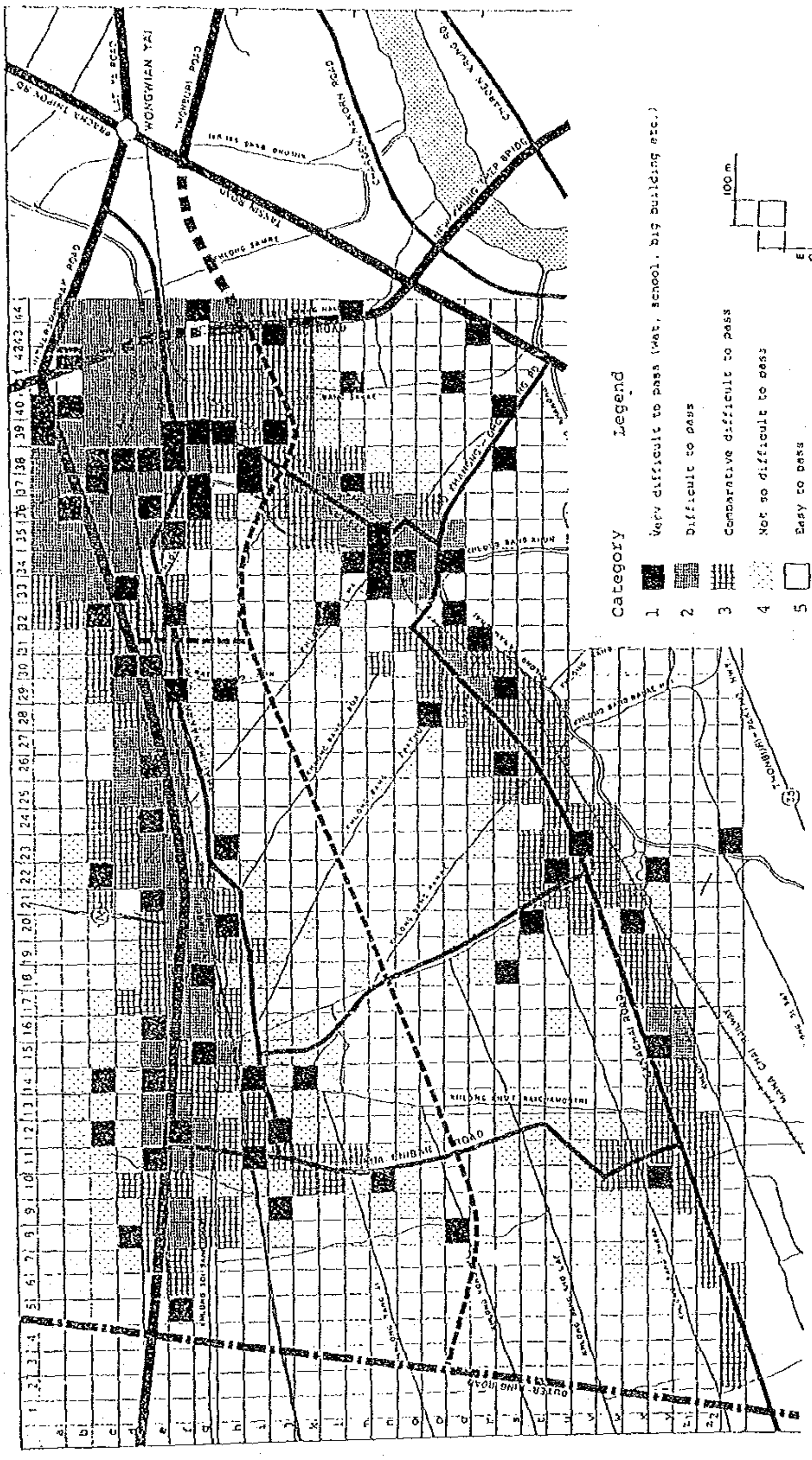


Fig. 11.2.1 Land-use Condition

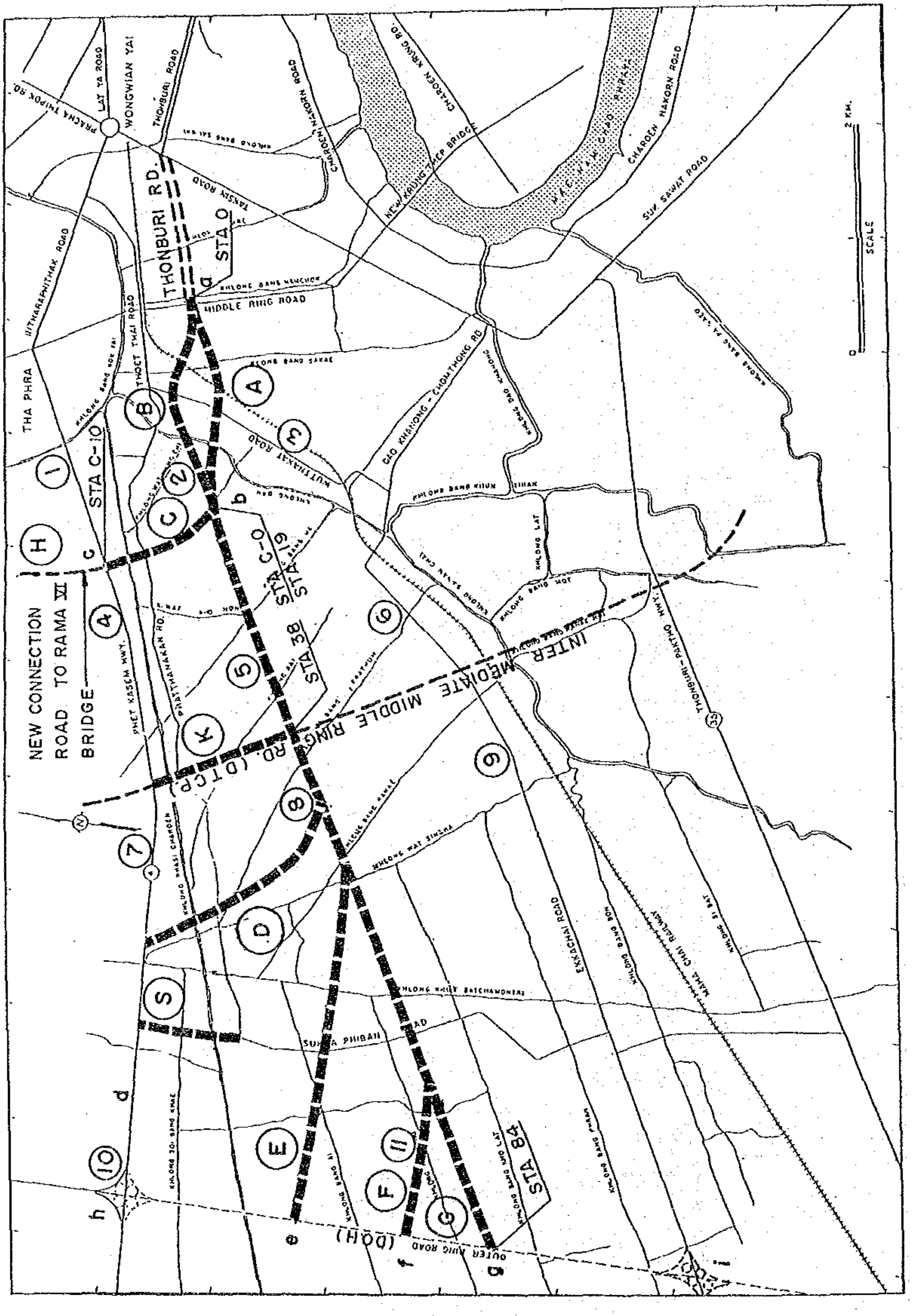


Fig. 11.2.2 Alternative Route Segment

Segment A:

The alignment of segment A passes through the southern part of the most congested area of houses, and office buildings while avoiding wats, schools and other big buildings.

Segment B:

The alignment of Segment B passes through the northern part of the most congested area of houses, and office buildings while avoiding wats, schools and other big buildings.

2) Junction with Phet Kasem Highway

Considering the future road network, conditions along Phet Kasem Highway and improvement of traffic congestion on Phet Kasem Highway, four alternative routes were considered, namely Segment C, Segment D, Segment K and Segment S.

Segment C:

The main purpose of Segment C is to ease traffic congestion on a part of Phet Kasem Highway, Intharaphitthak Road and Taksin Intersection. The route is located at the site with the highest possibility of construction, where a few obstructions for implemention of the project road exist and a high accessability to the future road network including New Connection Road proposed by PWD can be ensured.

Segment D:

The main purpose of Segment D is to ease traffic congestion on most parts of Phet Kasem Highway. The route was chosen near the intersection with ORR considering the future road network and accessibility to existing roads.

Segment K:

This portion of Intermediate Middle Ring Road proposed by DTCP will work as an access route to Phet Kasem Highway. One possible alternative is to use this segment with no provision of other access to the highway.

Segment S:

The existing Sukha Phiban Road is a narrow two lane road and will require major widening work involving demolition of buildings if it is to be used as a major access from Thonburi Road Extension to Phet Kasem Highway.

3) Junction with Outer Ring Road

For the possible junction with ORR, three alternative segments, Segment E, F and G, were considered as shown in Fig. 11.2.2. The connecting point of each segment is as follows:

Segment E:

1.5 km south of Phet Kasem Highway.

Segment F:

2.5 km south of Phet Kasem Highway.

Segment G:

3.2 km south of Phet Kasem Highway.

11.3 Evaluation of Alternative Routes

11.3.1 Network Evaluation

The introduction of a major road to an urban area often has far-reaching effects. This is particularly true in Bangkok where a large part of the network is operated at or near capacity. Not only existing drivers change their routes but others hitherto discouraged from driving by congestion may start making trips, and such additional traffic in turn aggravate congestion in unchanged parts of the network and affect route selection decisions for general traffic. Effects are quite complex. It was decided therefore to evaluate the alternative routes by means of examining effects on traffic in the road network particularly on the west bank of the Chao Phraya River.

1) Method

Traffic assignments by a computer model specifically developed for this study were carried out for alternative networks of Bangkok including each of the alternative Thonburi Road Extension routes. The model structure and assumptions are described in Chapter 4. Assignments for the purpose were done for the year 1991 for the comparison of alternative junctions with Phet Kasem Highway, and for the year 2001 for the alternative junctions with ORR.

Resulting traffic volumes and average link travel speeds including intersection waiting time were compared link by link and at screenlines. Traffic benefits were calculated for each alternative cases and compared with their construction costs.

2) Origins and Destinations of Diverted Traffic

Origins and destinations of traffic likely to divert to the project road in 2001 are summarized in Tables 11.3.1 and 11.3.2 for the case of the long alternative. Table 11.3.1 shows O&D of traffic on the segment immediately west of Middle Ring Road and Table 11.3.2 shows O&D of traffic on the segment west of Intermediate Ring Road. On the eastern segment 77% are river crossing traffic and 16% are trips within the area

Table 11.3.1 Origins and Destinations of Diverted Traffic on Segment A

From To	Aggregate Zone	East Bank	West Near	West Middle	West Far	Total
East Bank	1-7, 10-13, 20, 22-25	11	23	-	-	34
West Near	8-9, 14-16	2607	699	-	-	3306
West Middle	17-19, 21	641	111	-	-	320
West Far	26, 27	151	169	-	-	320
	Total	3410	1002	-	-	4412

Table 11.3.2 Origins and Destinations of Diverted Traffic on Segment F

From To	Aggregate Zone	East Bank	West Near	West Middle	West Far	Total
East Bank	1-7, 10-13, 20, 22-25	-	-	-	-	-
West Near	8-9, 14-16	150	147	-	-	297
West Middle	17-19, 21	59	45	-	-	104
West Far	26, 27	22	125	-	-	147
	Total	231	317	-	-	548

bordered by the river, Outer Ring Road, and Bangkok Noi-Nakorn Chaisi Highway. On the western segment 42% are river crossing and 27% are trips within the above area i the west bank. Long distance traffic with origins west of Outer Ring Road and destinations east of the river are only 18% on the eastern segment and 15% on the western segment.

It is a common misunderstanding that urban trunk roads carry mostly long distance traffic. People do so by extending personal infrequent experience of using such roads. However, as shown above, in most cases heavily trafficked urban roads are used primarily for short distance trips. The project road is no exception.

3) Difference by the Access Point with Phet Kasem Highway and Outer Ring Road

Computer modeling runs were carried out for each of the four different access plans of TRE to Phet Kasem Highway for the 1991 morning peak period. Amounts of traffic benefit were calculated for each alternative by comparing results with the do-nothing case.

Preliminary construction cost estimates were obtained on the basis of per kilometer costs with allowance for structures.

Table 11.3.3 shows traffic benefit per morning peak, construction cost, and the ratio of the former and the latter. The case with the Segment C for the access to Phet Kasem Highway shows the highest benefit/cost ratio.

Difference in traffic due to the alternative access point to Outer Ring Road was examined by means of traffic assignment runs for the 2001 morning peak period. It was found that the difference between the three was slight but the alternative with Segment F turned out to give the best balance in traffic conditions in the road network.

Additional modeling runs were carried out for the 1991 morning period for the case with Segment C and Segment F and for the case with Segment F only. As shown in Table 11.3.3 the amount of additional benefit in comparison with the case with Segment C only was small whereas additional cost high, resulting in a significant drop in the benefit/cost ratio. The case with Segment F and without access to Phetkasem Highway results in so small benefit as to disqualify itself.

Table 11.3.3 Benefit/Cost Ratio by Different Access Points

	No TRE	TRE Access Plans C	K	D	S	F	C+F
Total Traffic Cost	10.460	10.301	10.306	10.326	10.320	10.312	10.289
Traffic Benefit	-	0.159	0.154	0.134	0.140	0.148	0.171
Construction Cost	-	1.654	2.003	2.323	2.275	2.203	3.857
Ratio	-	0.096	0.077	0.058	0.062	0.067	0.044

Note: Traffic costs are for 1991 morning peak period in million Baht per hour. Benefits are in million Baht per hour. Construction costs are in billion Baht.

11.3.2 Technical Evaluation

1) Area between MRR and Wutthakat Road

Two alternative routes, Segment A and Segment B were located in this area. A comparison of Segment A and Segment B was carried out as shown in Appendix 11.3.1 and Segment A was selected. The main reasons are as follows:

- Construction costs are almost the same.
- Horizontal alignment of Segment A is more gentle than that of B.
- Route B cannot avoid passing through part of the area belonging to Wat Nang Chi.

2) Junction with Phet Kasem Highway

Four alternative routes, Segment C, Segment D, Segment K and Segment S were located in this area.

a) Segment C

Following points were considered:

* Segment C can be set in the area with few houses and other building, ensuring an easy land acquisition.
* Least construction cost compared with Segments D, K and S.
* It is comparatively easy to extend the road to Rama VI Bridge or Bangkok-Noi Nakhorn Chaisi Highway.

b) Segment D

Following points were considered:

* Segment D cannot avoid many existing houses and buildings.

* It would be very difficult to acquire land for the road.

* Construction costs including land acquisition and compensation are high.

* The existing community will be disrupted by this road.

c) Segment K

Following points were considered:

* Segment K cannot avoid many existing houses and buildings.

* It would be very difficult to acquire land for the road.

* It would be difficult to access the existing Phet Kasem Highway due to the Khlong Phasi Charoen runs closely to Phet Kasem Highway, and 4.50 m navigation clearance for this Khlong is required.

* It is comparatively difficult to extend the road to Rama VI Bridge or Bangkok-Noi Nakhorn Chaisi Highway.

d) Segment S

Segment S is a part of the existing Sukha Phiban Road widened to accommodate heavier traffic. Following points were considered:

* There are already many 3-4 storey buildings along the existing road on both sides.

* It will be very difficult to acquire land and is expected to incur high construction costs including land acquisition cost and compensation cost.

* It is expected that the existing bridge on Khlong Phasi Charoen will be demolished.

* It is comparatively difficult to construct the road while keeping it open to traffic.

3) Junction with Outer Ring Road (ORR)

Three alternative routes, Segment E, Segment F and Segment G were located in this area. As shown in this report, various traffic analyses were conducted for the alternative routes.

No significant difference could be found among three alternative routes. However, Segment F seems to give the best overall balance. Following points were considered:

- The Segment F gives the least cost.
- Regarding the land acquisition problem, Segment F and Segment G do not pose any problems. However, Segment E will require the removal of 30-35 houses.
- An existing community will be disrupted by route E.
- Regarding the interval between intersections on ORR, each of the three alternatives provides a sufficient length.
- Regarding future extension to westward direction Segment E is slightly disadvantageous to considering the road network configuration.

11.4 Selection of Alternative Routes

Considering the effects of the Project Road on surrounding existing road, economic technical and environmental aspects, following Segments were selected for the work of preliminary road design.

* Segment A
* Segment C
* Segment F

CHAPTER 12

PRELIMINARY ENGINEERING FOR THE ROAD

12.1 Preliminary Engineering

In the preceding chapter, various alternative routes were examined and the optimum alternative routes were selected. Preliminary road design was carried out for the selected routes including Segment A, Segment C and Segment F.

The results of the preliminary design are illustrated in the Drawings Volume which contains plan, profile, typical cross-section, bridge and intersection design.

12.1.1 Design Standards

1) Geometric Design

Design standards for roads as published by relevant authorities in Thailand are provided mainly for rural roads. The Project Road will function as a rural as well as an urban road.

Geometric design elements were determined considering local conditions such as types of vehicle, driver characteristics, and functions and characteristic of the road.

However, the Thailand design standards were basically adopted. The main design elements of the adopted standards for 80 km/h are summarized in Table 12.1.1.

2) Design Speed

The design speed is one of the fundamental elements affecting design standards such as minimum curvature, maximum gradient, stopping sight distance and other related design standards.

The 80 km/h design speed on the Project Road was adopted. Major factors determining the design speed are as follows:

a) Comparatively high speed is required considering the function and characteristics of the road.

b) The design speed of related roads such as Outer Ring Road, Middle Ring Road and Thonburi Extension Road are 80 km/h - 100 km/h, 80 km/h and 60 km/h - 80 km/h respectively.

c) When the Project Road will be completed, it is obvious that the average running speed will exceed 60 km/h or 70 km/h due to the route passing through the flat terrain. The design speed should cover the average running speed for keeping the traffic safe.

Table 12.1.1 Design Elements

Design Speed	km/hr	80
Minimum Radius of Horizontal Curve, R	m	280
Critical Radius for Using Clothoid	m	1,800
Maximum Grade	%	4
Length of Vertical Curve (Parabolic)		
Absolute Minimum	m	70
Desirable Minimum	m	140
Maximum Superelevation	%	4
Stopping Signt Distance		
Absolute Minimum	m	110
Desirable Minimum	m	140
Carriageway Cross Slope	%	2.0
Sidewalk Cross Slope	%	2.0

d) The terrain of the study area is flat. The construction cost does not differ by the design speed of 80 km/h or 60 km/h.

3) Typical Cross-section

a) Lane Width

A maximum lane width of 3.5 m in rural area is specified in the DOH standards. However, a lane width of 3.25 m was adopted for the Project Road taking into account the lane width of the related roads, Middle Ring Road and Thonburi Road Extension.

b) Shoulder Width

The shoulder space is needed to serve many functions as follows:

* To contribute to traffic safety and traffic comfort by keeping lateral clearance;

* To provide emergency parking; and

* To contribute to the establishment of the drainage, traffic signal and other facilities.

Generally speaking, shoulders of urban roads within Bangkok are not provided due to the very high land value and difficulty in acquiring the land. But 2.5 m shoulder width for rural roads is established by the DOH standards. A 2.50 m shoulder width for the Project Road was adopted taking into account the above mentioned standards. The shoulder is meant for temporary parking. When a vehicle stops on the shoulder for emergency parking or loading and unloading of materials, it does not affect others in through traffic lanes.

c) Median Width

A 5.0 m median width was adopted for the Project Road taking into account the right turning lane, opening space for U-turns and allowance for sufficient space for guardrail, traffic signals and so on. Minimum turning radii of passenger cars and trucks are 6.0 m and 12.0 m respectively. Passenger cars will be able to turn around using inner lanes and the trucks and buses will have to turn using outer lanes.

d) Sidewalk Width

A 5.0 m sidewalk width was adopted for the Project Road taking into account the balance of Sathorn Bridge and Thonburi Extension Road which have 6.0 m pedestrian path. Pedestrian paths may not be constructed from the beginning. Space for them, however, should at least be reserved.

e) Right of Way

Based on the above mentioned each cross-section components the right of way width was determined. The embankment widths of the Project Road at mass transit section, grade separation section and at grade section were calculated as 90.00 m, 60.00 m and 70.00 m respectively. The right of way width is the embankment width plus embankment slope width and drainage space.

4) Other Related Design Criteria

a) Vertical Clearance of Road

A 5.0 m vertical clearance was adopted in accordance with the specified DOH design standards.

b) Vertical Clearance of Railway

A 5.6 m vertical clearance was adopted for Project Road taking into account the 5.6 m vertical clearance at the section between Middle Ring Road and Mahachai Railway.

c) Vertical Clearance of Khlong

The vertical clearance of khlong is described later in Section 12.1.6.

12.1.2 Alignment Design

1) Horizontal Alignment

The horizontal alignment in the area from Middle Ring Road to the existing Khlong Dan was examined based on a topographic map with a scale of 1:1,000.

The horizontal alignment in the other area from Khlong Dan to Phet Kasem Highway and to Outer Ring Road was examined based on aerial photograph with a scale of 1:2,000 which was enlarged from aerial photographs with a scale of 1:6,000.

Taking into account the route selection policy and guidelines and the results of the reconnaissance survey and technical study, the horizontal alignment was decided as shown in the Drawings Volume.

2) Vertical Alignment

a) Controlling Limits

The controlling limits of the vertical alignment study were as follows:

* Vertical clearance over roads at 5.0 m.

* Vertical clearance over the railway at 5.6 m.

* Vertical clearance from the existing ground level on Khlong Dan at 3.5 m.

* Vertical clearance from the existing ground level on Khlong Phasi Charoen at 4.5 m.

The vertical alignments are shown in the Drawings Volume.

b) Proposed Road Surface Height

The proposed road surface height was examined in the following aspects:

* High water level

* Thickness of pavement

* Thickness of sub grade

* Settlement and residual settlement of embankment and its construction method

* Accessibility to houses located along the road

The proposed height of the Project Road was determined considering the thickness of the pavement which should be above the high water level.

High water level	1.60	(+MSL)
Thickness of sub grade	0.60	
Thickness of pavement	0.40	(0.25 + 0.15)
Total	2.60	(+MSL)

Therefore, the proposed height of this road was determined at 2.60 m (+MSL). The proposed height of related roads are shown below as reference:

* Outer Ring Road	2.5 m
* Middle Ring Road	2.00 m - 2.45 m
* Thonburi Road Extension	2.30 m - 2.60 m

12.1.3 Cross-Section Design

1) Traffic Capacity of A Lane

The traffic capacity per lane depends on land-use conditions along the road, lateral clearance, longitudinal grade and width of lane.

Taking into account the typical cross-section and land-use conditions in the future, the traffic capacity was estimated at 1,800 V/H per lane in this study.

2) Number of Lanes

The number of lanes was decided based on the comparison between future traffic volumes and lane capacity.

As mentioned in the preceding chapter, the project road is divided into three segments of Segment A, C and Segment F. The number of lanes on each segment are shown in Table 12.1.2.

3) Cross-section

The Project Road can be classified into four sections considering the type of road structure, number of lanes and related projects such as the Mass Transit System.

a) STA.0 - STA.5

Typical cross-section in this area is shown in Fig. 12.1.1. Basic considerations are as follows:

* Lateral clearance for the Mass Transit system of 16.5 m is planned as 16.50 m based on the typical cross-section of the Mass Transit system prepared by ETA.

* 2 lane for through traffic for one direction is planned based on the future traffic volumes in 2001 and 2011.

* 6 m wide frontage roads and 5 m wide sidewalk are proposed on both sides for services to inhabitants who live along the Project Road.

* 5.5 m wide ON, OFF Ramps is planned for access to the Middle Ring Road.

b) STA.6 - STA.12

Typical cross-section in this area is shown in Fig. 12.1.2. Basic considerations are as follows:

* 6 lanes for through traffic for both directions are planned based on the forecasted traffic volumes in 2001 and 2011.

* 6.0 m wide frontage roads and sidewalk on both sides of the road are proposed for services to inhabitants.

c) STA.13 - STA.19

Typical cross-section in this area is shown in Fig. 12.1.3. Basic considerations are as follows:

* 6 lanes for through traffic for both directions are planned based on forecasted traffic volume in 2001 and 2011.

Note: STA.0 - STA.5 means 500 m long in center line.

Table 12.1.2 Number of Lanes

(Morning Peak PCU/H)

Station	Lane Capacity	Traffic Volume			Number of Lane to be Required			Number of Lane to be Adopted		
		1991	2001	2011	1991	2001	2011	1991	2001	2011
0 + 0.00 To 19 + 0.00	1800	2800*	4700*	4900*	2	3	3	3	3	3
	1800	3500#	4100#	4100#	2	3	3	3	3	3
C-0 + 0.00 To C-10 + 4.00	1800	1700*	2100*	2100*	1	2	2	2	2	2
	1800	2400#	2300#	2300#	2	2	2	2	2	2
19 + 0.00 To 38 + 0.00	1800	-	1900*	2700*	-	2	2	2	2	2
	1800	-	900#	1800#	-	1	2	2	2	2
38 + 0.00 To 84 + 0.00	1800	-	600*	1500*	-	1	1	2	2	2
	1800	-	400#	500#	-	1	1	2	2	2

Note: * = to Bangkok
= to Thonburi

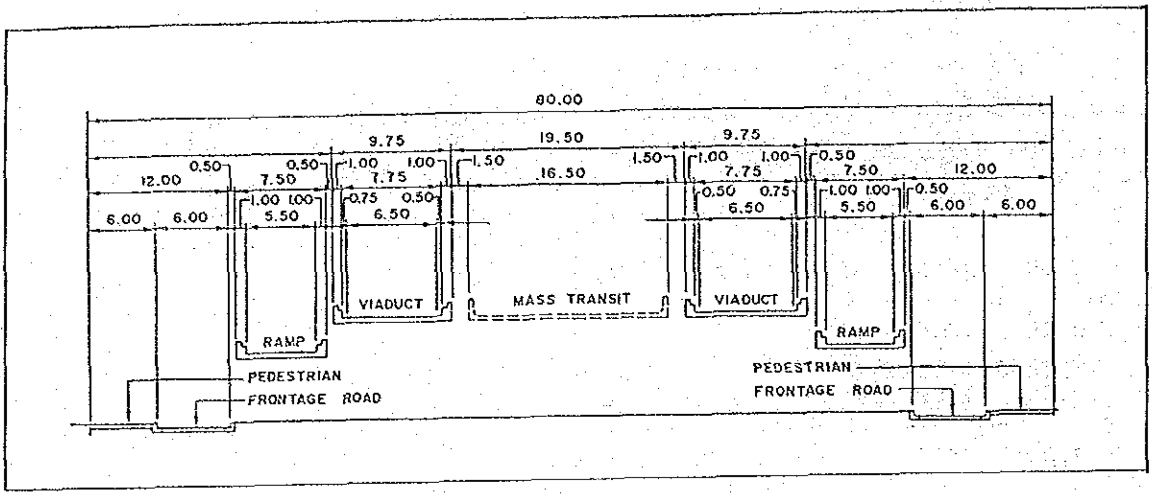


Fig. 12.1.1 Typical Cross-Section (STA.0 – 5)

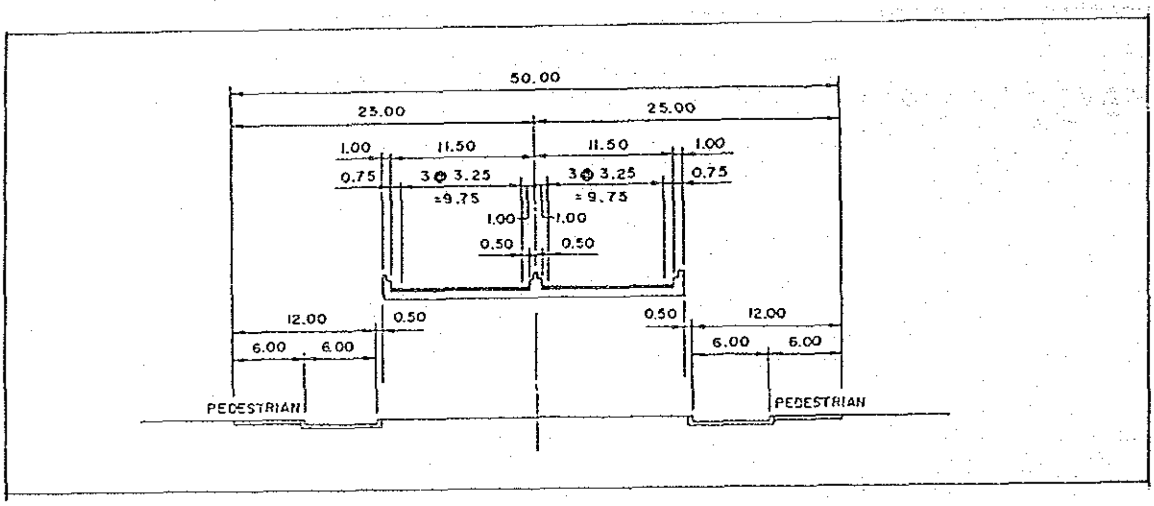


Fig. 12.1.2 Typical Cross-Section (STA.6 – 12)

* 6.0 m wide side walk on both sides of road are planned because this area is already a built up area.

d) STA.20 - STA.84

Typical cross-section in this area is shown in Fig. 12.1.4. Basic considerations are follows:

* 4 lanes for through traffic for both directions are planned based on forecasted traffic volume in 2001 and 2011.

* Sidewalks on both sides of the road are planned considering the future land-use. However, existing land-use is mostly isolated fields. A stagewise construction may be considered. The first stage is to construct without sidewalk. When this area is developed, the sidewalk will be constructed.

e) STA.C-1 - STA.C-10

Typical cross-section in this area is shown in Fig. 12.1.4. Basic condition are as follows.

* 4 lanes for through traffic for both directions are planned based on forecast traffic volume in 2001 and 2011.

* 5.0 m wide sidewalk on both side of the road and 3.0 m wide sidewalk on both sides of bridge section are planned considering the existing land-use.

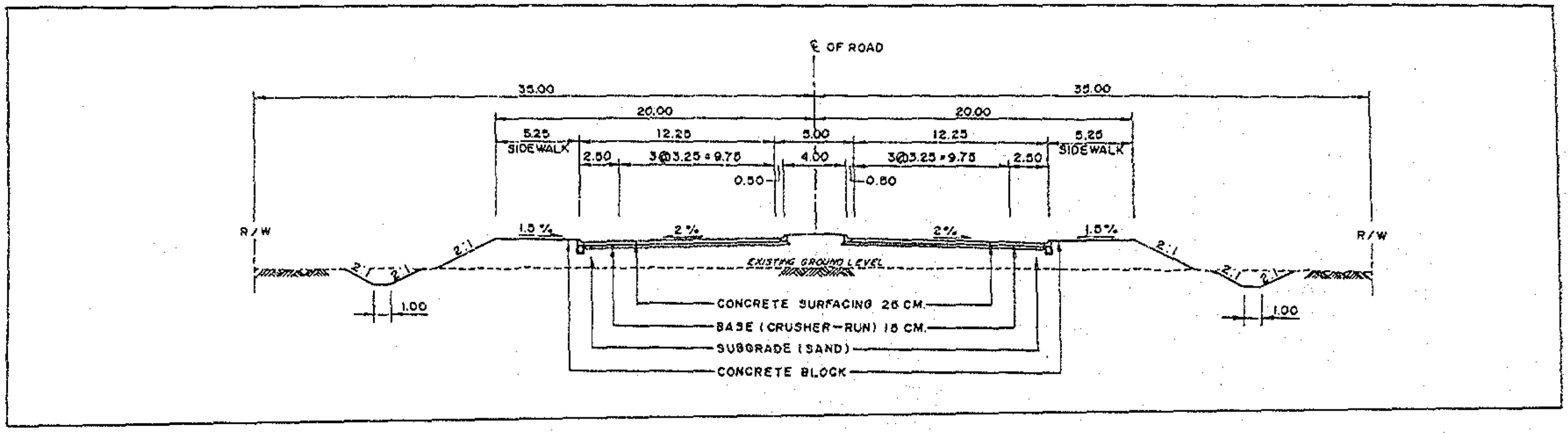


Fig. 12.1.3 Typical Cross-Section (STA.13 – 19)

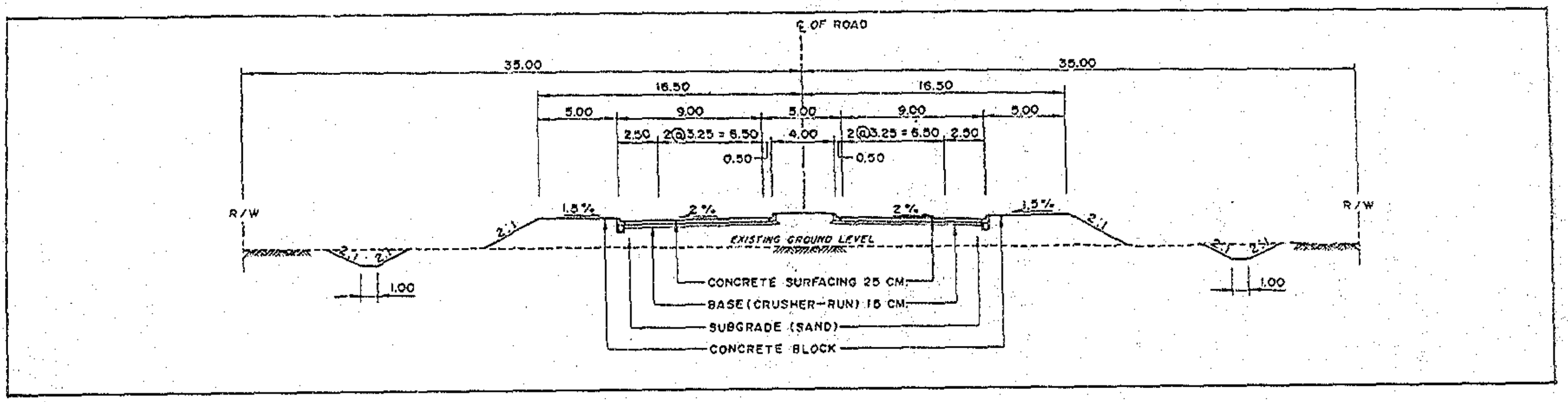


Fig. 12.1.4 Typical Cross-Section (STA.20 – 84)

12.1.4 Pavement Design

1) Type of Pavement

There are basically two different types of pavement, i.e. flexible asphalt concrete pavement and rigid cement concrete pavement. The cement concrete pavement has the following advantages:

a) The initial construction cost of asphalt concrete pavement and cement concrete pavement were tentatively calculated at 450 baht per square meter and 530 baht per square meter respectively. Generally speaking, the design life of asphalt concrete and cement concrete pavement are 20 years and 40 years respectively according to "A guide to the structural design of pavement for new road, Road Note 29".

   It is rather difficult to estimate the maintenance cost of the pavement due to few available data. However, taking into account the flood conditions of Bangkok, it can be said that the construction cost and maintenance cost of the cement concrete pavement may be less expensive than the asphalt concrete pavement due to the former's strong durability under water.

b) In Bangkok, inundation occurs at two or three year intervals such as in 1975, 1978, 1980, 1983 and in 1986. When the water comes into the pavement, asphalt concrete pavement becomes very brittle. The cement concrete pavement is stronger than asphalt pavement in flood periods, as observed for the existing road pavements in Bangkok area. Almost all existing road pavements in Bangkok area were constructed by cement concrete pavement.

c) The cement concrete materials can be producted in Thailand. However, main part of asphalt concrete materials must be imported. The cement concrete pavement can be constructed by using local materials. In this situation, it contributes to increase of employment opportunities and to save foreign currency for Thailand.

2) Pavement Structure Design

The thickness of each pavement layer of the cement concrete pavement depends on the design wheel load, number of axle loading accumulated within the design life of the pavement (40 year design life of the cement concrete pavement was adopted) and condition of the subgrade construction materials.

The thickness of the pavement was examined on the basis of "Manual for Design and Construction of Cement Concrete Pavement, Japan Road Association" (J.R.A.), "DOH Typical Cross-section" (DOH) and "Road Note 29. A Guide to the Structural Design of Pavement for New Road (Road Note 29)".

The results of the comparison of pavement designs are as follows:

		J.R.A.	DOH	Road Note 29
a.	RC Pavement Slb (cm)	25	23	27
b.	Blanket Material (cm)	-	10	-
c.	Crushed Rock Sub-base (cm)	15	15-30	15

For the purpose of preliminary cost estimates, the following pavement structure is proposed.

* Thickness of R.C. Pavement slab at 25 cm.
* Thickness of the crushed rock sub-base at 15 cm.

12.1.5 Intersection Design

1) General

Nine major intersections are included in the New Krungthep Bridge Construction Project and Thonburi Road Extension Project. The seven intersections are named "A" intersection to "J" intersection as illustrated in Fig. 12.1.5 Intersections A to C are discussed in Chapter 9, other D to J are discussed in this chapter.

Generally, desirable types of intersection such as grade separated or at grade intersection, and number of lanes required for right and left turn movements are examined here.

The intersection design was examined considering the relationship between forecasted traffic volume and traffic capacity in the intersection, land acquisition problems and the possibility of stage-wise construction.

2) Type of Intersection

Types of intersection were examined taking into account the following considerations:

- Function from the viewpoint of road network

- Number of lanes by direction with forecasted traffic volume and traffic capacity of intersection.

- Possibility of stage-wise construction or economical intersection design

- Land acquisition requirements and compensation.

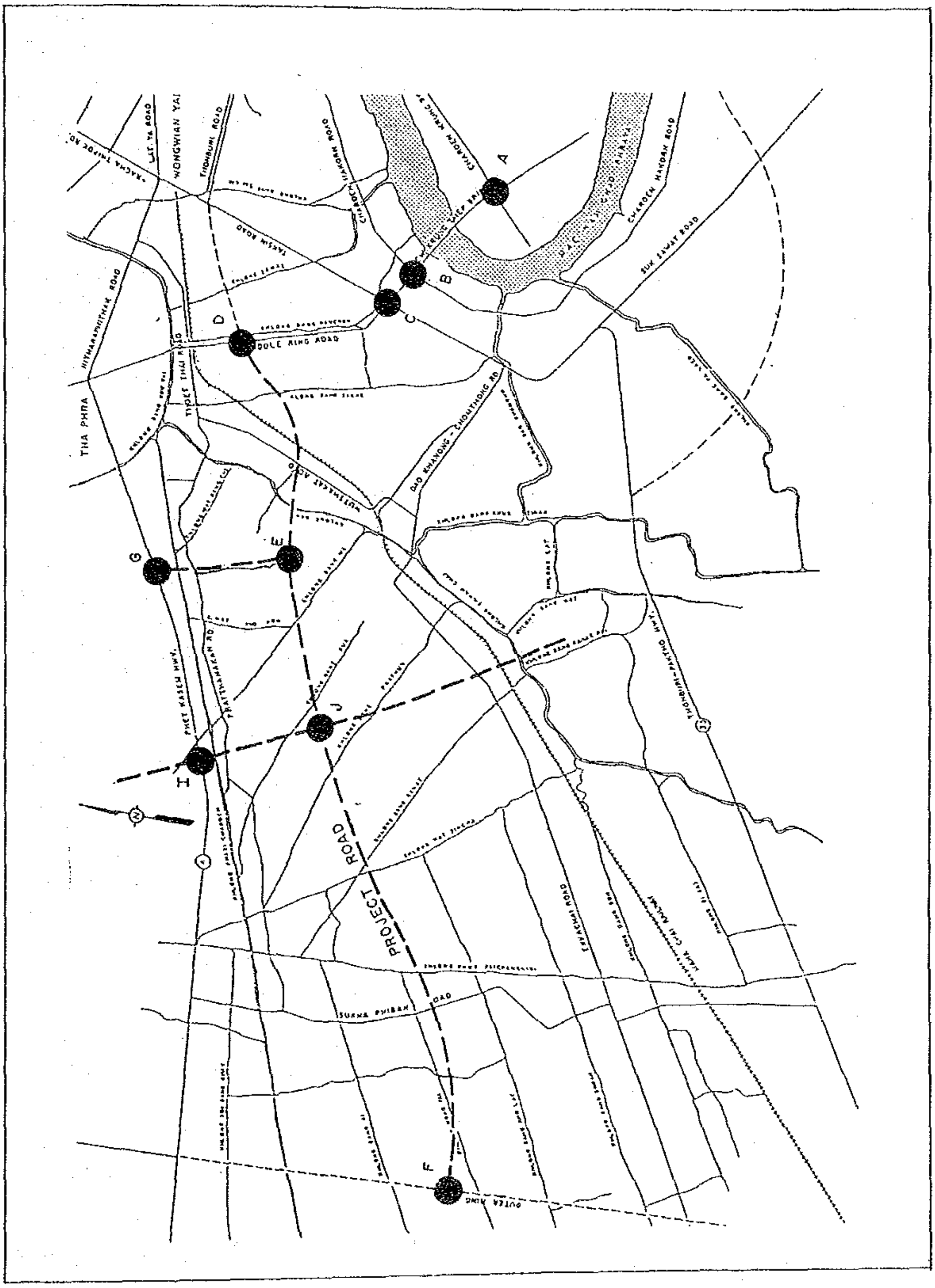


Fig. 12.1.5 Location of Intersections

a) From the Viewpoint of Road Function and Network

Intersections along truck roads for which a high running speed is desired should better be grade separated.

The MRR is one of the important trunk roads and so the Project Road. Therefore, first of all, the intersection D should be given a consideration for grade separation.

b) From the Viewpoint of Traffic Volume

Intersection type was examined on the base of traffic saturation degree (forecasted traffic volume/traffic capacity) at approaches.

If traffic saturation degree exceeds 1.0, an excessive congestion occurs. The results of the traffic saturation degree analysis of each intersection are shown below.

Saturation Degree

Intersection Name	Saturation Degree 2011	2001	Remarks
D	1.67	1.49	Grade separated
E	1.00	-	At grade
F	0.30	-	At grade
G	1.04	-	At grade
I	0.99	-	At grade
J	0.97	-	At grade

The forecasted traffic volume in 2001 and 2011 are shown in Fig. 12.1.6 - 12.1.8.

E, F to J intersections are recommended to be at grade intersections considering the following:

- Forecasted traffic volumes are not so high even in 2011.
- Traffic saturation degrees are not well exceeding 1.0.

However, after 2011, grade separation will be required at E, G, I and J intersections. Therefore, the right of way for grade separation should be reserved in this stage.

Regarding D intersection, the saturation degree in 2001 is already over 1.0, the D intersection should be constructed as a grade separated intersection.

Detailed analysis of traffic saturation degrees by direction are shown in Appendix 12.1.1.

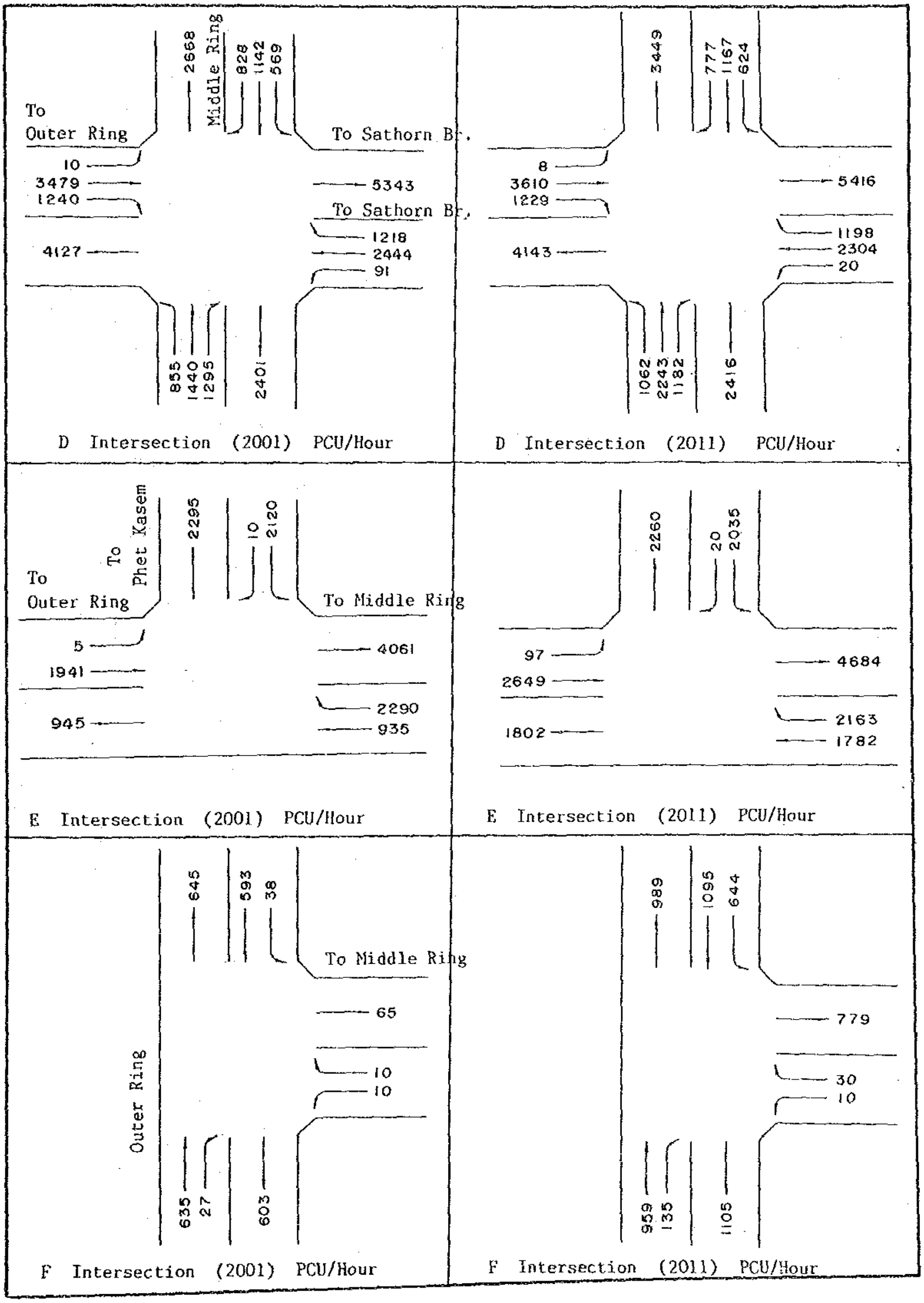


Fig. 12.1.6 Traffic Movement at Intersections of D, E & F

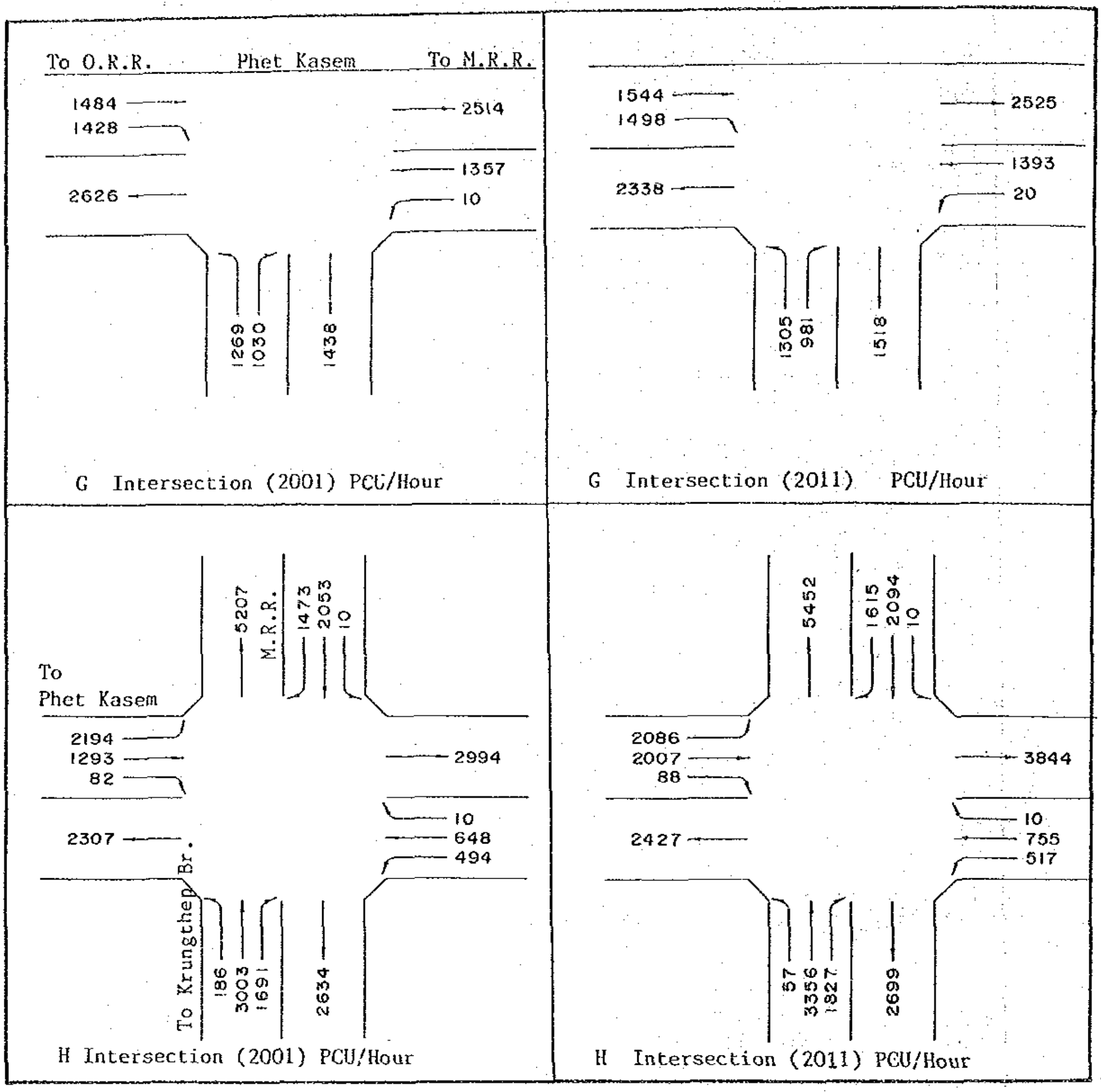


Fig. 12.1.7 Traffic Movement at Intersections of G & H

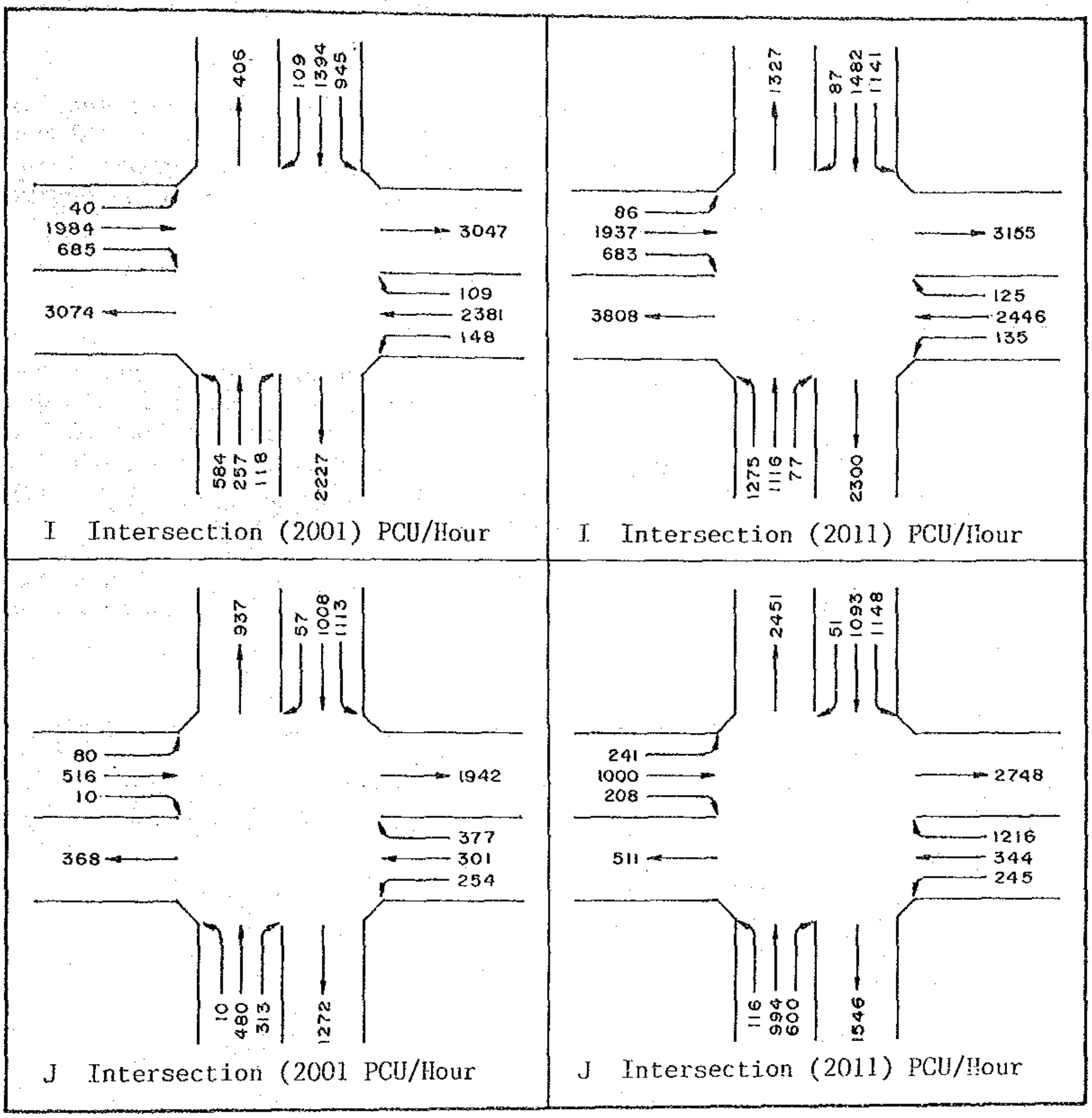


Fig. 12.1.8 Traffic Movement at Intersections of I & J

12.1.6 Drainage Design

1) General

The reconnaissance survey of the existing khlong conditions such as width of khlong, vertical clearance and the relationship between existing ground height and water level was conducted in October 1986. The results of the survey are shown in Fig. 12.1.9. The drainage design was carried out based on the survey results.

2) Clearance on Khlongs

The clearance above khlongs was decided taking into account the existing clearance above khlong and the existing usage of the khlongs. The widths of Khlong Phasi Charoen and Khlong Dan are 24 m and 21.5 m respectively, these two khlongs are used for transportation of goods and other materials by barges. Other small khlongs are used for transportation of goods and other materials by small boats.

The minimum clearance between the existing ground level and the under-face of slab structure of the existing khlongs were examined as shown in Table 12.1.3.

Table 12.1.3 Minimum Clearance from Existing Ground Level

Name of Khlong	Minimum Clearance (m)
1. Khlong Dan	3.5
2. Khlong Phasi Charoen	4.5
3. Khlong Wat Nang Chi	0.7
4. Khlong Wat Kho Non	0.6
5. Khlong Bang Wa	0.8
6. Khlong Rang Bua	0.6
7. Khlong Bang Prathum	1.1
8. Khlong Wat Singha	0.9
9. Khlong Khut Ratchamontri	1.2
10. Khlong Soi Bang Khae	0.4
11. Khlong Bang Ai	0.5
12. Khlong Nong Yai	0.4
13. Khlong Bang Kho Lat	0.4
14. Khlong Bang Phran	0.3

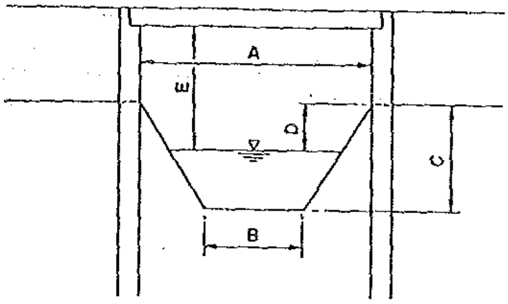
3) Drainage Structure for Crossing Khlongs

There are two types of structure for crossing the existing khlongs, bridge type and box culvert type.

The selection of the structure type was made taking into account the following factors:

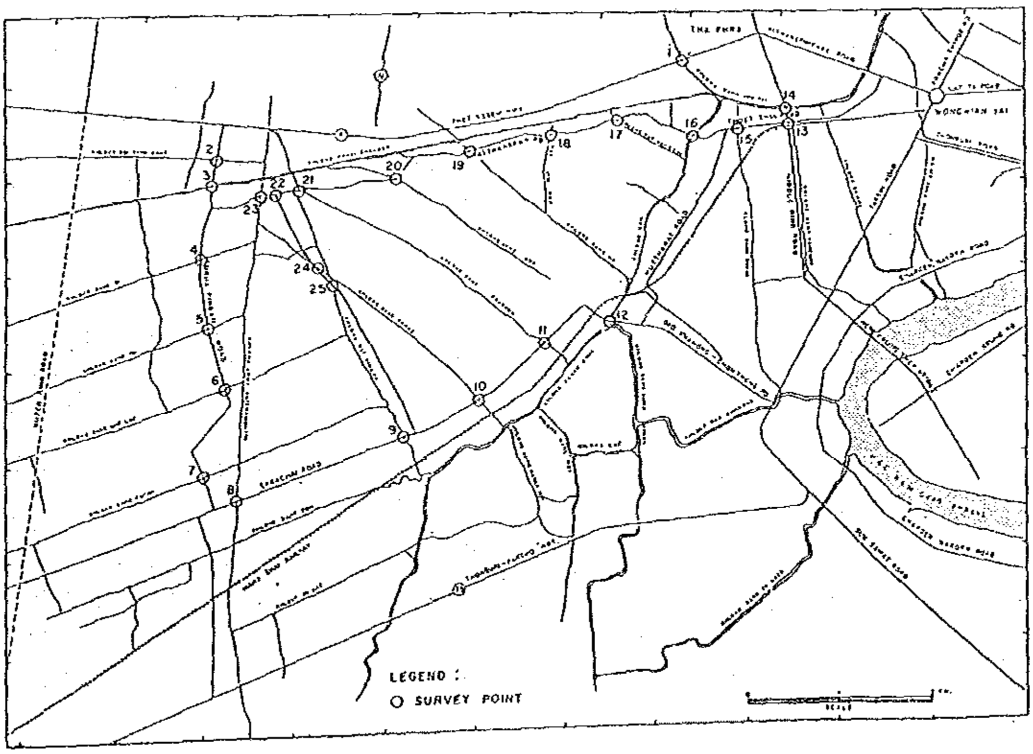
* To economize the construction cost
* Easy construction and maintenance
* Purpose of the existing khlong as waterway

Fig. 12.1.9 Existing Khlong Condition



MEASURE (m) / POINT	A	B	C	D	E	REMARKS
1	45.0	15.0	3.3	0.3	3.6	BR 10:00 AM.
2	10.0	4.5	1.8	0.7	1.1	BR 10:35 AM.
3	24.0	14.0	2.5	0.4	4.9	BR 10:42 AM.
4	7.7	6.5	1.4	0.6	1.1	BR 11:05 AM.
5	8.0	6.2	1.9	0.8	1.2	BR 11:15 AM.
6	8.1	7.2	1.9	0.6	1.2	BR 11:25 AM.
7	8.1	5.2	1.8	0.5	0.8	BR 11:40 AM.
8	24.5	6.2	2.4	0.9	1.6	BR 13:15 AM.
9	7.4	7.4	2.5	0.2	0.8	BOX 13:35 PM.
10	10.0	7.9	3.0	1.2	1.6	BR 13:50 PM.
11	10.0	7.2	3.1	1.2	1.9	BR 13:55 PM.
12	22	12	2.7	0.4	3.5	BR 14:15 PM.
13	6.3	3.0	1.4	1.0	1.7	BR 14:40 PM.
14	42.0	13.0	5.0	1.8	6.5	BR 13:40 PM.
15	6.0	2.5	0.8	0.6	0.8	BR 14:35 PM.
16	21.5	12.1	3.0	0.6	4.1	BR 14:55 PM.
17	10.0	6.3	2.1	1.0	1.7	BR 15:25 PM.
18	6.5	4.0	1.7	0.3	1.3	BR 15:35 PM.
19	12.6	7.0	2.5	0.6	1.4	BR 15:45 PM.
20	8.0	6.5	3.0	0.8	1.4	BR 15:55 PM.
21	16.0	4.5	2.1	0.4	1.5	BR 16:04 PM.
22	NO KHLONG (ROAD INTERSECTION)					
23	5.5	3.8	3.2	0.8	2.1	BR 16:55 PM.
24	NO BRIDGE (MAP MISTAKE)					
25	10.0	5.5	1.6	0.6	1.5	BR 16:33 PM.

Survey date: 6-7/10/86



a) Khlong Phasi Charoen and Khlog Dan

These khlongs are used for the transportation of goods and other materials and also are used for drainage. Many boats with mobile power run through these khlongs. In addition, there are many houses located along the khlongs. It will be very difficult to construct a diversion khlong for the construction when the box culvert is constructed. In addition, the construction cost of the bridge is more economical than box culvert due to the long span of about 25 m.

b) Other Small Khlongs

The other small khlongs are mainly used for the drainage and sometimes are used for the transport of goods and other materials.

The width of these khlongs are about 8.0 - 10.0 m, and there is no difficulty to construct diversion channel when box culvert is constructed. The construction cost of the box culvert is more economical than a bridge for small khlong. Therefore, box culverts are recommended.

12.1.7 Median Opening

1) General

Median openings designed to accommodate vehicles making U-turn only are needed in some divided highways in addition to openings provided for cross and right turning movements. Basic considerations of the locations where median openings for U-turn are as follows:

a) Beyond important intersections at grade or beyond some interchange to enable drivers, unfamiliar with the intersection and finding themselves beyond it, to correct the mistake.

b) Just ahead of an intersection where through and other turning movements would be interfered with U-turn movements.

c) In conjunction with minor crossroads where traffic is not permitted to cross the major highway, but instead is required to turn left, enter the through traffic stream, weave to the right, U-turn and then return.

d) On highways without control of access where median openings at optimum spacing and locations are provided to serve existing frontage developments and at the same time minimize pressure for future median openings.

2) Location of Midian Opening

Taking into account of the above mentioned matters, median openings are planned at following sections:

a) 200 m before the intersection of the Project Road and Outer Ring Road.

b) 200 m before and beyond the intersection of the Project Road and Sukha Phiban Road.

c) 200 m before and beyond the intersection of Segment A and Segment C on the Project Road.

d) 200 m before the intersection of the Project Road and Phet Kasem Highway.

e) Mid-point of above mentioned b. and c.

12.1.8 Bridge Design

Two bridges are planned in this project, one is a viaduct in Segment A and the other is a river crossing over the Khlong Phasi Charoen in Segment C.

The type of superstructure and substructure for these bridges were determined as PC T-beams and invert T-type piers with 0.6 meter diameter precast PC driven piles respectively, taking into consideration the past construction experiences by Thai construction firms and the least construction cost.

The features of bridges proposed in the preliminary design are as follows:

1) Viaduct

The viaduct begins at the conjunction of the flyover bridge over MRR (STA.0) and ends after passing Khlong Dan (STA.11+50.6). As a mass transit system has been planned and will be constructed in the future, a space for it is kept between the north line (toward Bangkok) and south line (toward ORR) of the Project, from STA.0 to STA.2. Therefore, the north line and south line bridges are separated independently. The total bridge length of the north line is 1,155 meters and that of south line is 1,145 meters.

PC T-beams of 25 meters and 30 meters in length are adopted in the viaduct on the view points of construction ease and least costs. The 30 meters long beams are used for the crossing over existing roads (i.e. Soi Wat Bang Sakae, Wutthakat Road and others), Mahachai Railway and Khlong Dan.

The results of subsoil investigations conducted in the Study show that the bearing stratum for the viaduct would exist at a depth of approximately 25 meters from MSL. Precast PC driven piles of 0.6 meter diameter are adopted in the pier foundations similarly to New Krungthep Bridge.

At the ending portion of the viaduct where the viaduct crosses over Khlong Dan, two 25 meter span bridges are scheduled for both sides in parallel with the viaduct as the use for the frontage road.

Abutment structures and transition slabs are scheduled for the east side of frontage bridges and also for the west side of viaduct/and frontage bridges.

2) Khlong Phasi Charoen Bridge

The Khlong Phasi Charoen Bridge is located from STA.C-6 + 65.0 to STA.C-8 + 20.0 in Segment C. This bridge is of a 155.0 meters long bridge consisting of 25 meter and 30 meters span PC T-beams similarly to the above mentioned viaduct. The latter is adopted for the span over Khlong Phasi Charoen, and for the rest the former is adopted.

For both sides in the bridge approach road, 85 meters abutment structures and 60 meters transition slabs are scheduled.

12.1.9 Construction Methods and Schedules

1) General

As discussed in Section 10.3.2, "Subsurface Investigation" in this report, soil conditions of Bangkok and its surrounding areas are generally soft ground layer with 20-30 m depth.

A part of Bangkok is sinking about 5 cm yearly and some parts of the existing roads have also subsided. The most important item to consider for construction is how to make a countermeasure against the soft ground layer. In this section, consolidation settlement and circular slip analysis were done for the establishment of construction method.

2) Calculation of Circular Slip Safety Factor

a) Premises in Calculation

Following premises were adopted for the calculation of the circular slip safety factor.

* The top width of road bank is 40 m.

* Slope gradient is 1 to 2.

* Underground water level is 1.0 m below the existing ground level.

* Depth of soft clay is 13 m from ground surface with Shear strength, C = 1.05 ton/sq.m and unit weight γ = 1.52 ton/cu.m.

* Thickness of medium soft clay is 5.5 m below the soft clay layer with C = 3.29 ton/sq.m. and unit weight γ = 1.69 ton/cu.m.

* Embankment materials with unit weight, γ = 1.85 tons/cu.m. and inner friction, C = 30 degree are considered.

b) Calculation

The circular slip safety factor was calculated for two different types of not improving the existing soil conditions and of improving the existing soil conditions by sand drain method. Three different embankment heights of 1.0 m, 3.0 m and 6.0 m were calculated. The results of the calculation was shown in Table 12.1.4.

Table 12.1.4 Minimum Safety Factor (Fs) by Height

	H = 1.0	H = 3.0	H = 6.0
Not improved	2.945 (U = 80%)	0.960 (U = 0%)	0.492 (U = 80%)
Improved by sand drain	3.772 (U = 80%)	1.724 (U = 80%)	1.156 (U = 80%)

The relationship between the embankment height and the minimum safety factor of circular slip is shown in Fig. 12.1.10.

When the adopted safety factor is at 1.2, the maximum embankment heights of not improved and improved cases are 2.5 m and 6.0 m respectively.

Proposed embankment height of the Project Road is 1.5 m - 2.0 m, so, it is not necessary to improve the existing soil conditions. However, it is necessary to improve nearby abutments of bridges when the proposed height exceeds 2.5 m. The calculations of each case are shown in Fig. 12.1.11 to 12.1.13.

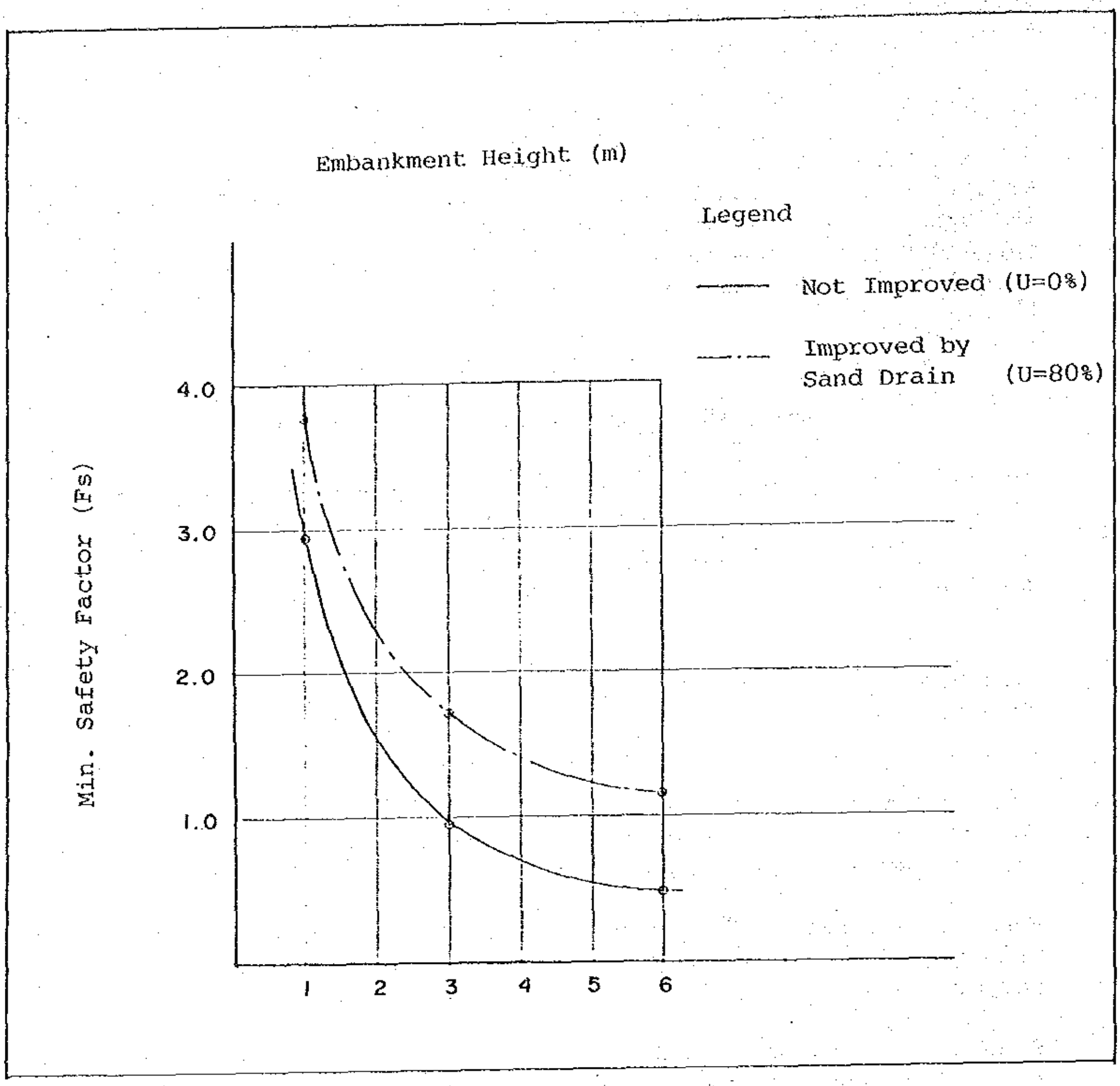


Fig. 12.1.10 Relation between Embankment Height and Safety Factor

3) Calculation of Settlement

There are two types of settlement, one is the settlement and the other is the subsidence of soft ground itself. In this section, settlement of embankment is calculated.

a) Calculation of consolidation settlement

Following formula was adopted for the calculation of consolidation settlement.

$$S = \frac{eo - e}{1 + eo} Ho$$

S = Final consolidation settlement
e = pore water pressure before settlement
eo = pore water pressure after settlement
Ho = depth of layer to be consolidated

Consolidation settlement was calculated at different road heights of 1.0 m to 6.0 m. The results of consolidation settlement calculations are shown in Fig. 12.1.14.

b) Time of consolidation settlement can be calculated using the following formula.

$$t = \frac{T * H}{Cv}$$

t ; time of consolidation settlement
T ; time coefficient for consolidation degree
H ; 1/2 x thickness of layer to be consolidated (Ho)
Cv ; coefficient of consolidation

The time of consolidation settlement was calculated for two cases of not improved condition and improved by sand drian method. The results are shown in Fig. 12.1.15.

4) Construction Method

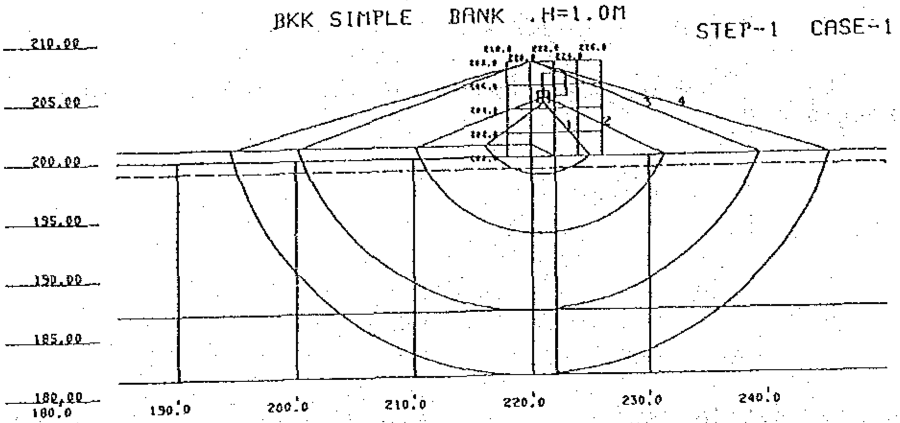
a) General

Generally, the construction methods for this road on the soft ground layer are as follows:

* Slow banking construction method
* Surcharge embankment construction method
* Sand drain construction method
* Replacement soft clay construction method

Before the construction method is decided, following factors should be considered.

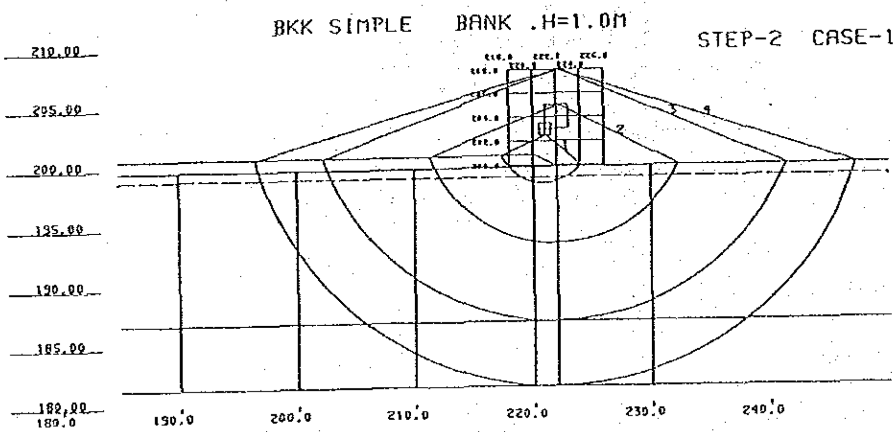
* Scale of the project
* Construction difficulty



FS-MINIMUM

	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(198.5)	221.0	204.5	6.0	-18.6	57.6	3.092
2(193.5)	221.0	205.0	11.5	-106.3	313.0	2.945
3(187.0)	220.0	208.0	21.0	-365.0	1095.7	3.002
4(181.5)	220.0	208.0	26.5	-613.5	3930.4	6.402

Note: Not improved
H = 1.0m



FS-MINIMUM

	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(198.5)	221.0	202.5	4.0	-10.3	38.3	3.772
2(193.5)	222.0	205.0	11.5	-101.8	393.1	3.863
3(187.0)	222.0	208.0	21.0	-353.6	1390.5	3.932
4(181.5)	222.0	208.0	26.5	-592.7	4422.5	2.407

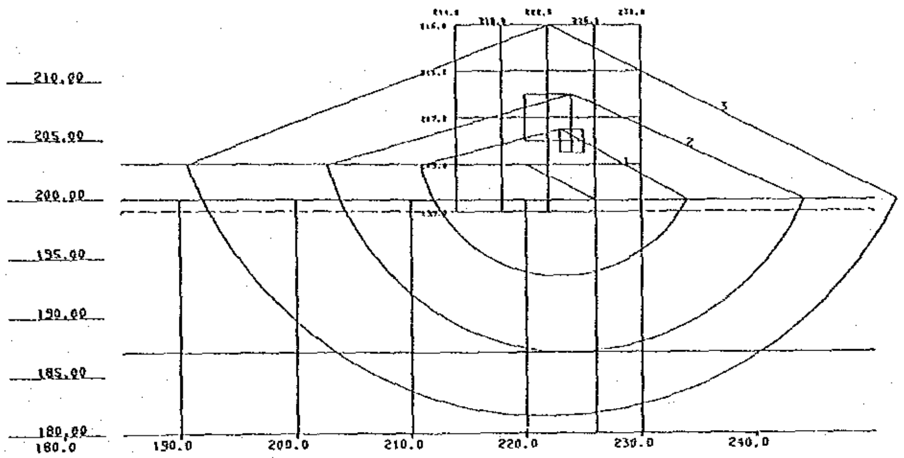
Note: Improved by Sand Drain Method

H = 1.0m

Fig. 12.1.11 Circular Slip Safety (H = 1.00 m)

BKK SIMPLE BANK .H=3.0M

STEP-1 CASE-1



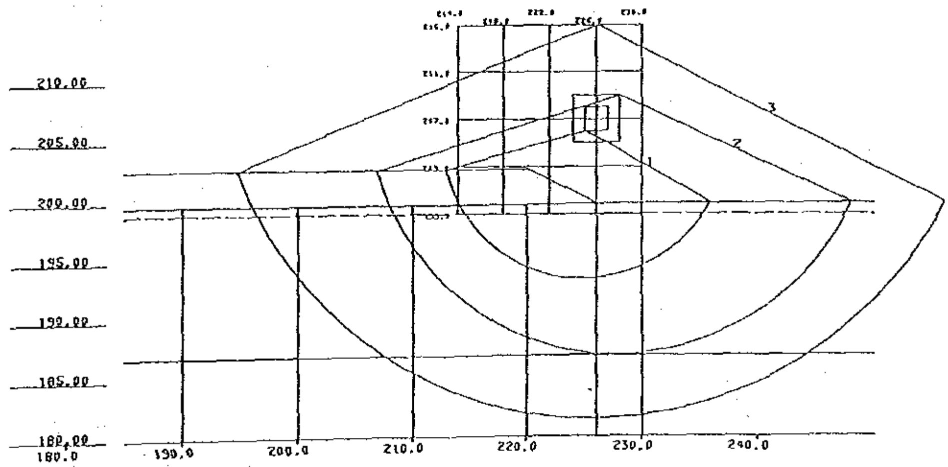
FS-MINIMUM

	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(193.5)	223.0	206.0	12.5	-377.1	362.2	0.961
2(187.0)	224.0	209.0	22.0	-1206.1	1183.2	0.981
3(181.5)	222.0	215.0	33.5	-2662.0	5560.8	2.085

Note: Not improved
H = 3.0m

BKK SIMPLE BANK .H=3.0M

STEP-2 CASE-1

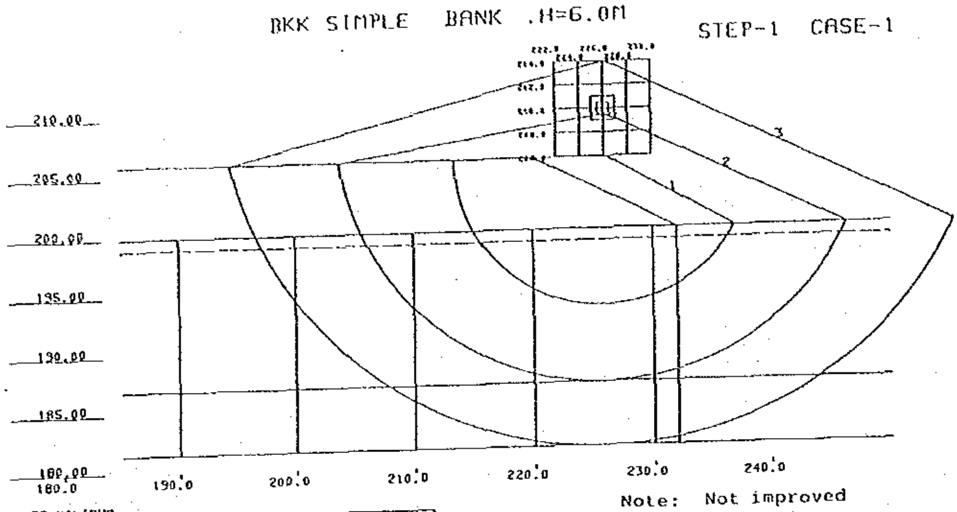


FS-MINIMUM

	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(193.5)	225.0	206.0	12.5	-352.0	615.4	1.724
2(187.0)	228.0	209.0	22.0	-1115.8	1966.6	1.762
3(181.5)	226.0	215.0	33.5	-2602.2	2517.2	2.888

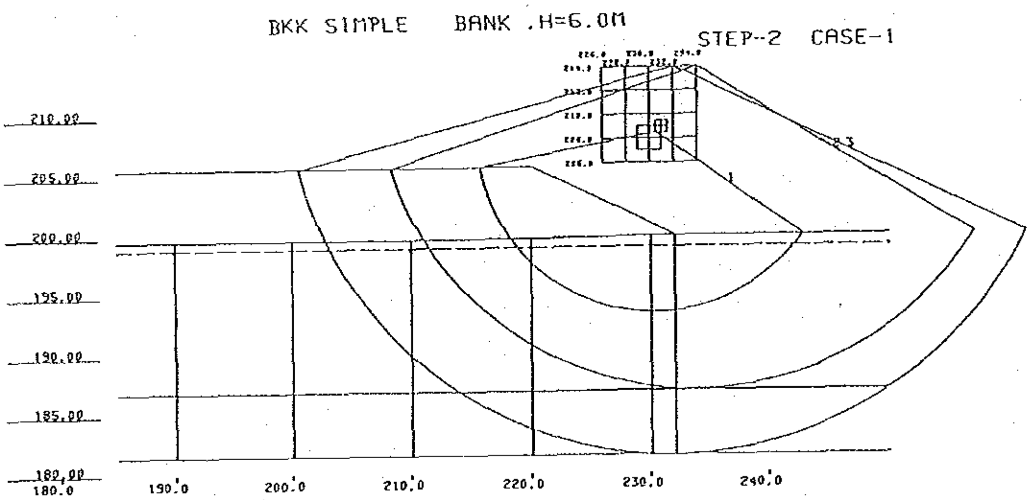
Note: Improved by
Sand Drain Method
H = 3.0m

Fig. 12.1.12 Circular Slip Safety (H = 3.00 m)



FS-MINIMUM

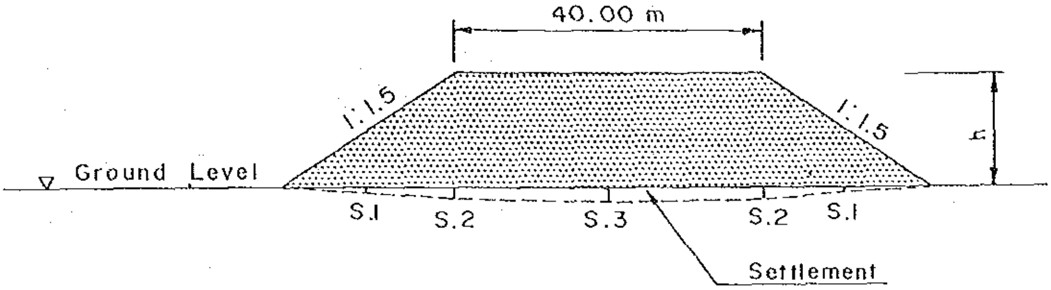
	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(193.5)	226.0	206.0	12.5	-754.0	381.2	0.506
2(187.0)	226.0	209.5	22.5	-2559.7	1259.1	0.492
3(181.5)	226.0	214.0	32.5	-5245.9	5383.0	1.026



FS-MINIMUM

	X (M)	Y (M)	R (M)	DRM (T.M)	RSM (T.M)	F
1(193.5)	230.5	208.5	15.0	-889.8	1028.6	1.156
2(187.0)	234.0	214.0	27.0	-2975.3	3518.8	1.183
3(181.5)	232.0	214.0	32.5	-5991.4	8285.8	1.259

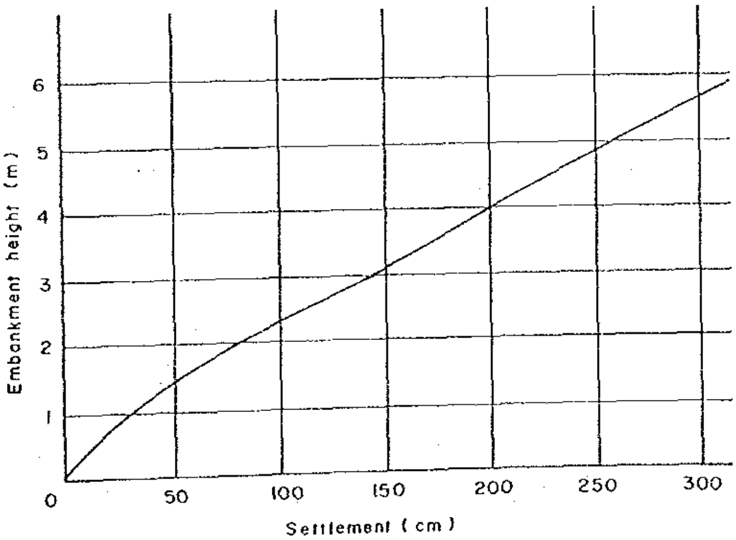
Fig. 12.1.13 Circular Slip Safety (H = 6.00 m)



Settlement (cm)

h / Point	S.1	S.2	S.3	S.2	S.1
1.0 m	5	22	28	22	5
1.5 m	10	41	51	41	10
2.0 m	16	64	79	64	16
2.5 m	22	91	112	91	22
3.0 m	29	117	145	117	29
6.0 m	64	257	318	257	64

Embankment height and Settlement



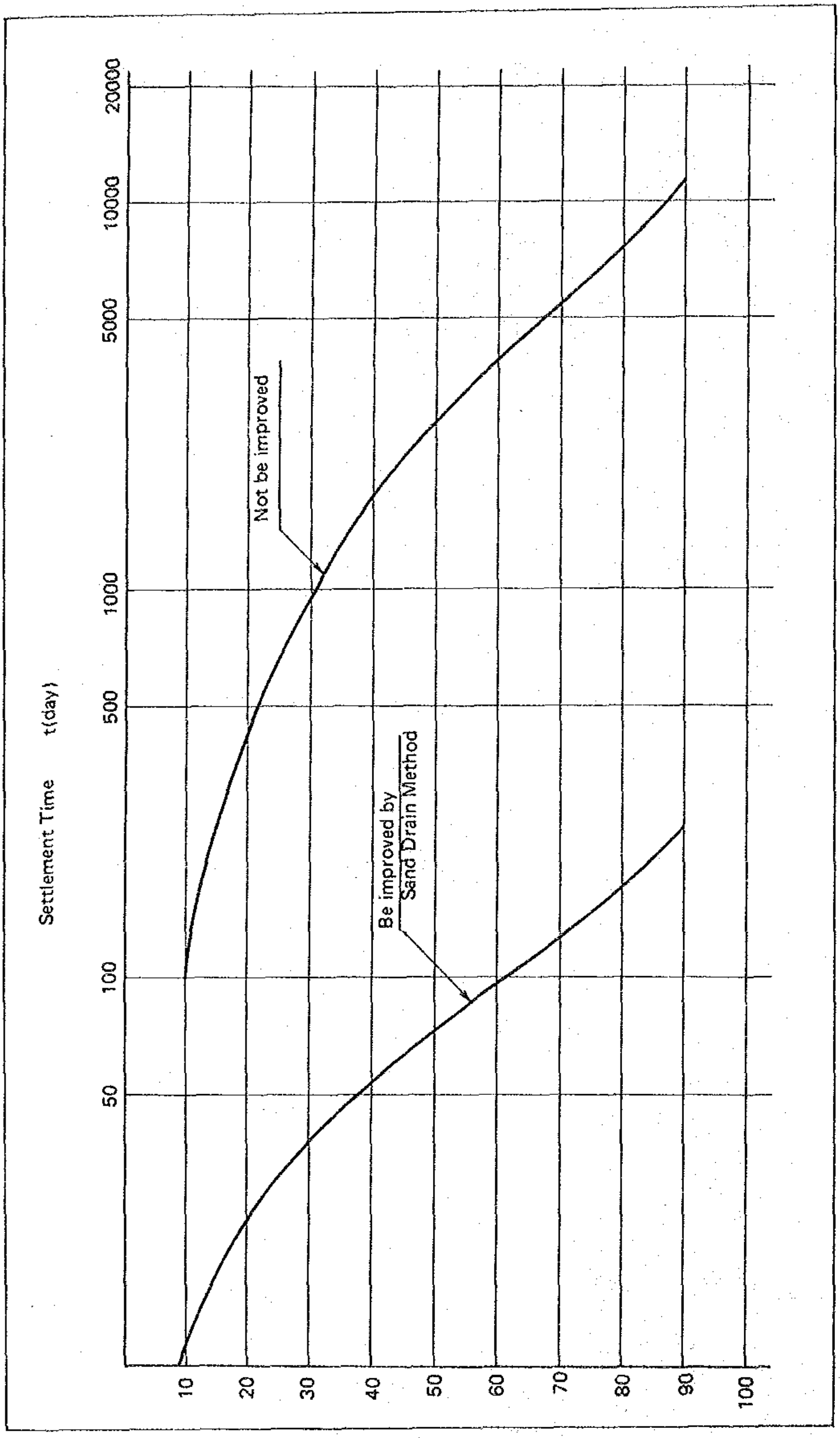


Fig. 12.1.15 Settlement Time

* Availability of construction materials
* Construction period
* Construction cost
* Construction method examples of other highways near the project area

b) Construction method

Among the above mentioned construction methods, sand drain and replacement construction method were eliminated considering the cost and examples of other similar highway constructions projects in Thailand. The slow banking and surcharge embankment methods were examined.

The slow banking method.

The average embankment height is about 1.7 m. The final settlement of embankment 1.7 m high is 60 cm from Fig. 12.1.14. The relation between consolidation degree and settlement period are shown in Table 12.1.5.

Table 12.1.5 Settlement Period by Slow Banking

Consolidation Degree (%)	Settlement (cm)	Remaining Settlement (cm)	Settlement Period (day)
10	6	52	110
20	12	48	420
30	18	42	960
50	30	30	2,600
80	48	12	7,800

In this case, the practicable construction period of 960 days is selected in which period only 30% of consolidation will take place, remaining 70% take place in a long time period. However, the remaining amount to be settled is about 40 cm, which is the subject of future maintenance.

The surcharge embankment construction method

The final settlement of 60 cm is adopted as the same as the previous construction method. The maximum embankment height of 2.5 m is adopted based on the result of circular slip safety factor examination. The surcharge height is also 2.5 m due to the maximum embankment height without slip failure. The settlement of 112 cm is calculated. The relationship between consolidation degree and settlement period is shown in Table 12.1.6.

Table 12.1.6 Settlement Period by Surcharge

Consolidation Degree (%)	Settlement (cm)	Remaining Settlement (cm)	Settlement Period (day)
5.4 (10)*	6	52	110
10.7 (20)*	12	48	130
16.1 (30)*	18	42	270
26.8 (50)*	20	30	700
42.8 (80)*	48	12	2,000

In this case, about 30% of consolidation is obtained in the period of 700 days.

The Study Team proposes a 2 year construction period for the Project. In this case, the slow banking method is proposed for the Project. The main reasons are as follows:

- The settlement period of 80% consolidation degree by slow speed and surcharge of embankment construction methods are estimated as 7,800 days and 2,000 days respectively. These two periods are not realistic.

- The construction cost of the surcharge method was estimated at about 75,000,000 Baht for the Project (300,000 cu.m. x 250 Baht/cu.m.), which is substantial.

- The remaining settlement amounts after 2 years of construction period of embankment with surcharge and without surcharge were calculated at 30 cm and 44 cm respectively.

- The remaining settlement of 44 cm can be maintained by the road maintenance office.

5) Consideration of Maintenance

When the construction period for an embankment is 2 years, the final settlement remains as 44 cm. In other words, the road will subside by a further 44 cm. Therefore, in the road design as shown in Fig. 12.1.16, following matters should be considered.

- The pavement including base course should be set up at least 44 cm above high water level.

- Structures such as pipe or box culvert for drainage should subside with road embankment section at the same rate for the running comfort of vehicles.

- Bridges will be constructed with pile foundations, so that the bridges will not be subside. The approach section of bridges should constructed by asphalt concrete pavement for easy maintenance.

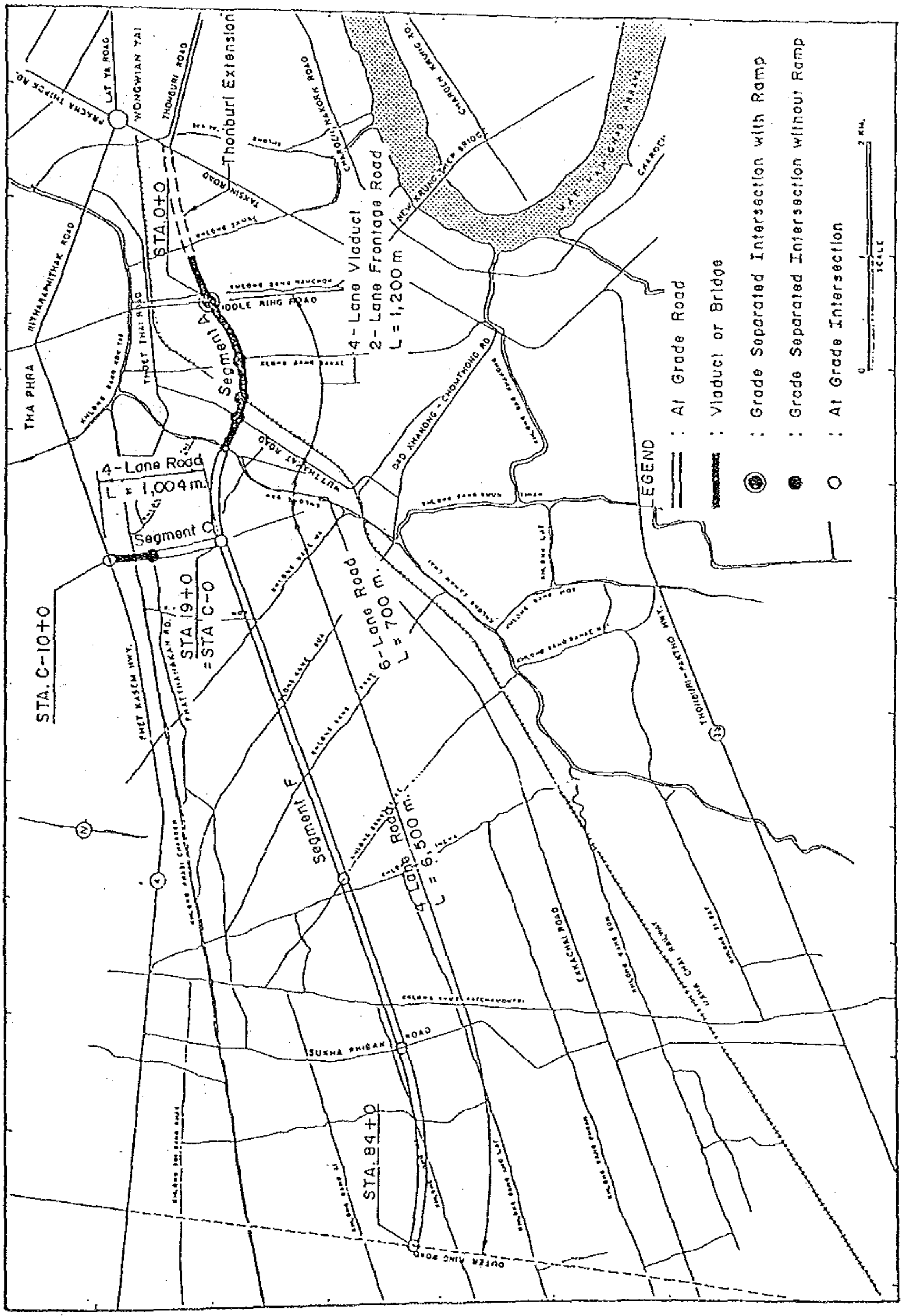


Fig. 12.1.16 Layout of Thonburi Road Extension Route