CHAPTER 5
ENGINEERING DESIGN

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5-1 ROAD DESIGN AND ALIGNMENT

The Preliminary Design has been conducted on the basis of Route Alternative III recommended in the Feasibility Study, using 1/1000 scale maps.

A comment on the Alternative III has been issued from the Thai Committee on 7 September 1981 to the effect that at grade intersection connected with the existing roads has not been favorable due to its short distance between the ends of bridge viaduct.

Accordingly, in the Preliminary Design, the connection with the existing roads has been so designed as not to use intersections but to adopt a small scale trumpet-type interchange.

The configuration of the trumpet-type interchange is shown in Fig. 5-1 below, due to relative locations of the present roads, railway viaduct and the end of main bridge viaduct.

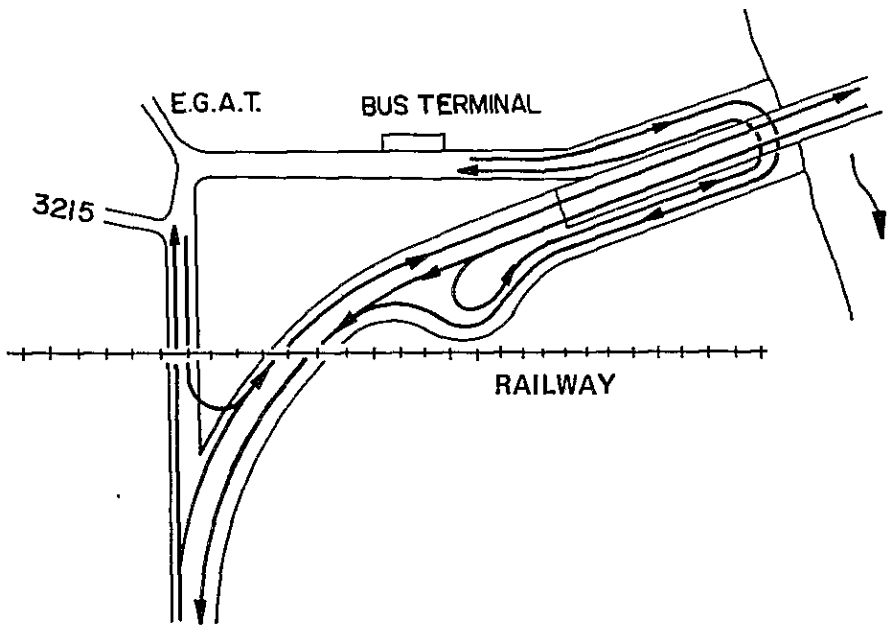


FIG. 5-1 TRAFFIC CURRENT OF INTERCHANGE

In general, at the stage of the Preliminary Design, various engineering problems have to be assessed, such as the access of the planned roads to the existing buildings, determination of the navigational clearance and the utilization plan of the remaining land after purchases.

5-1-1 Horizontal Alignment

The study has been carried out for determining a horizontal alignment, utilizing 1/1000 scale topographic maps which have been produced from 1/1600 aerial photos provided by PWD.

(1) Control Point

The important control points in designing the horizontal alignment exist on both Thonburi and Bangkok sides of the site.

On the Bangkok side, control points consist of two elements : one is the width of the frontage road including a bus-stop at Wongsawang-Pibul Songkhram intersection and the other is the frontage road width of Wongsawang road at the terminal of the bridge viaduct. It is considered necessary to check the widths of the off-ramp terminal and C.P.A.C side frontage road.

On the Thonburi side, the two most critical control points exist at the premise boundary of North Bangkok Sub-Station and the toe of the embankment slope of SRT railway line.

Determinations of the width and exact locations for each of above control points have been considered necessary in the first stage of this Preliminary Design.

1) Bangkok Side

a) The cross-section of Wongsawang road

A bus-stop has been installed at the Wongsawang - Pibul Songkhram Intersection.

The present location of the bus-stop is shown in Fig. 5-2.

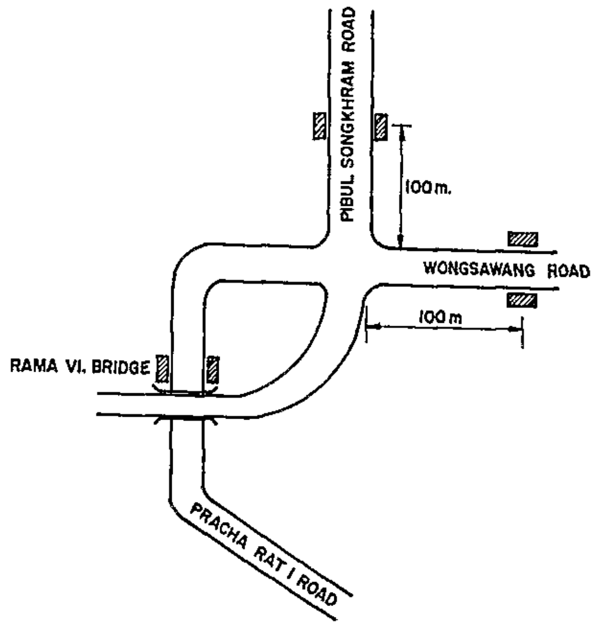


FIG. 5–2 LOCATION OF EXISTING BUS STOPS

The present bus operating routes have been shown in Fig. 5-3.

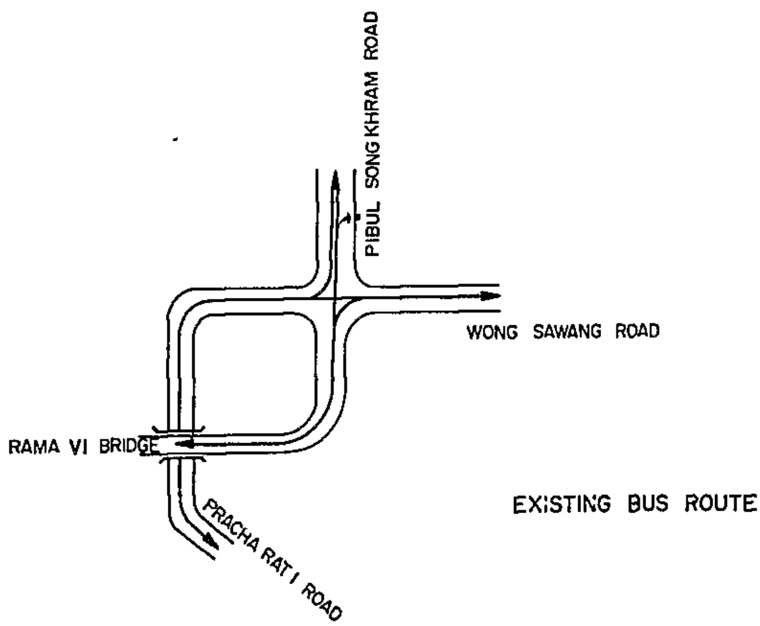


FIG. 5–3 EXISTING BUS ROUTE

A conceivable future bus routing after the completion of the New RAMA VI Bridge is as shown in Fig. 5-4.

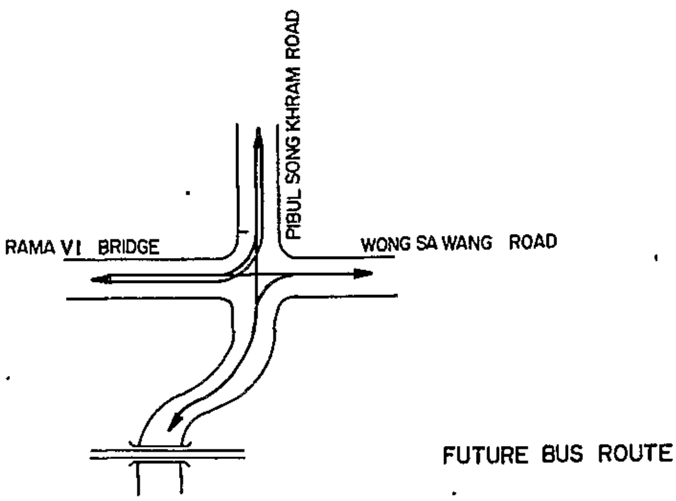


FIG. 5-4 FUTURE BUS ROUTE

Nevertheless, this intersection will constitute an important junction of the Middle Ring Road and Pibul Songkhram Road as the radial arterial road.

Therefore, a more cautious study has been considered to be necessary in future bus routings.

In this designing, a bus stop layout has been adopted so as to provide the all-directional services of bus operation.

It has been impossible, however, to install a bus-stop between the new RAMA VI Bridge and the intersection because of the existence of of a rampway.

Also, the bus-stop on the entering section to the intersection has to be placed 100 meters ahead of the intersection in order to provide a viewing section for other vehicles' operation.

However, on the south side of intersection, a bus-stop for Pracha Rat I Road has been installed at 50 meters ahead because the bus-stop would be served only for buses to the RAMA VI Bridge direction.

In out-going sections from the intersection, the bus-stops which anticipate more operational frequencies have been placed 100 meters apart of the intersection and others having less frequencies have been placed 50 meters apart.

A schematical sketch of bus operating routes is shown in Fig. 5-5.

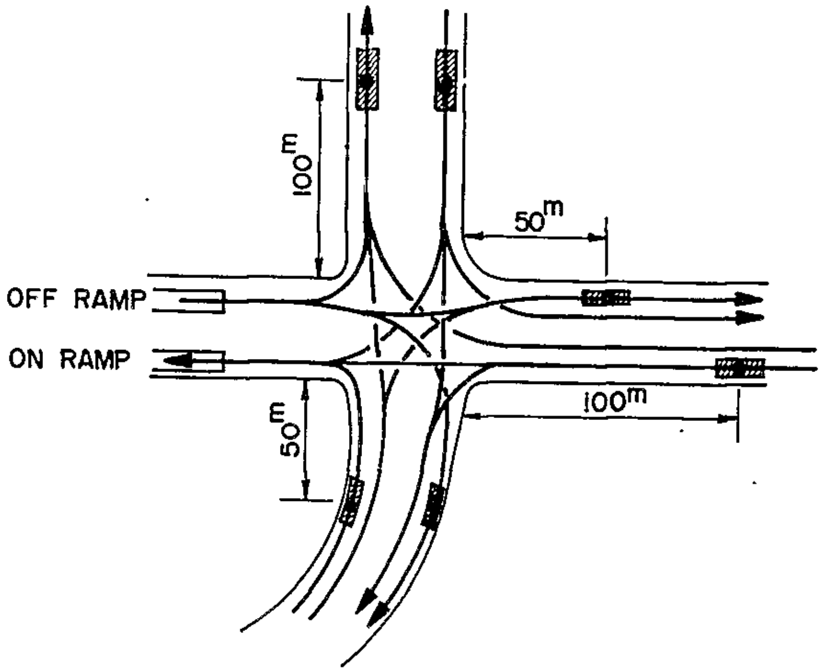
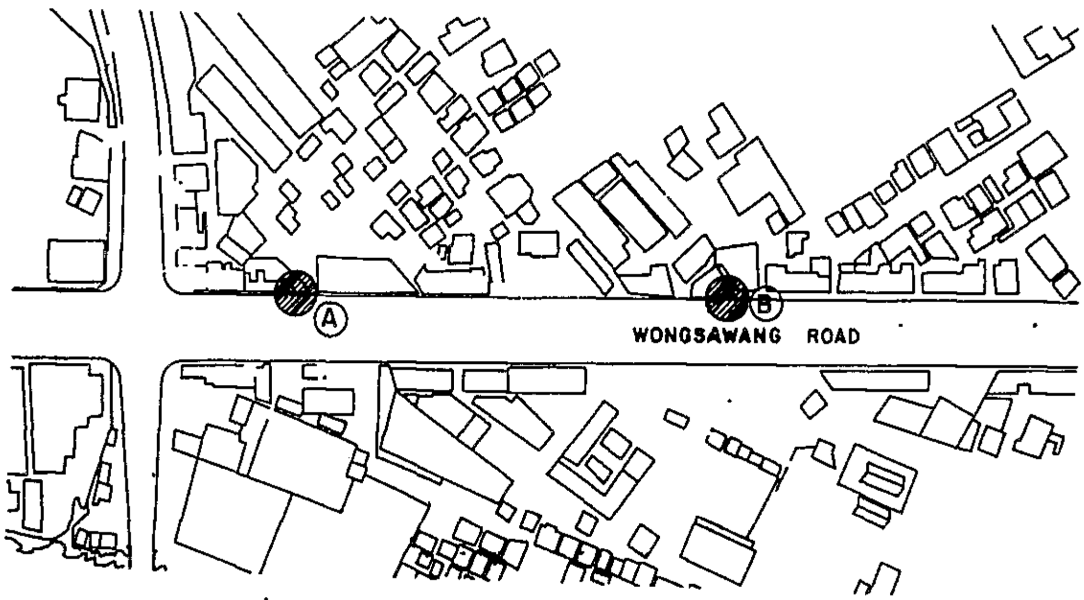


FIG. 5-5 PLAN OF BUS STOPS

Based on the assumed location of the above mentioned bus-stops, a detailed site survey has been conducted at the site and as a conclusion, the widening of the Wongsawang Road has been planned only on the south side of the road, while the north side is still unchanged.

Widening of both sides of the Wongsawang Road has been regarded as not preferable because of the existence of a rampway on the C.P.A.C. factory yard.

Accordingly, the exact location of the control points in Bangkok side are shown in Fig. 5-6.



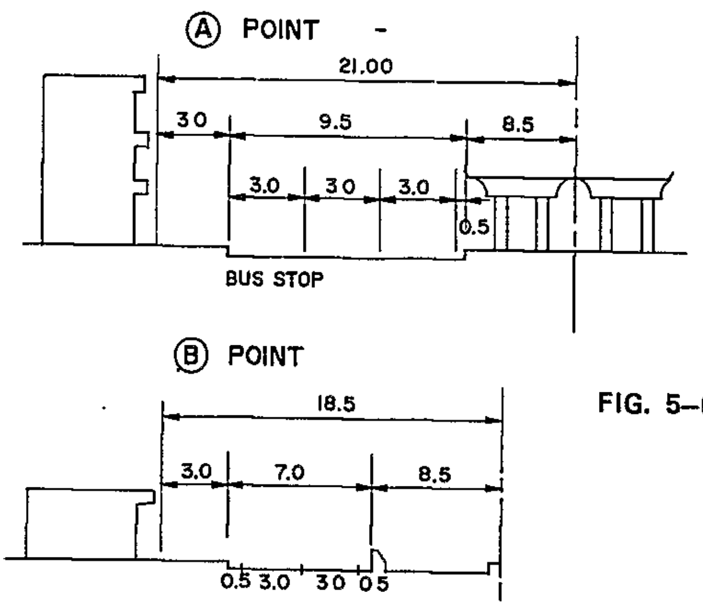


FIG. 5-6 CONTROL POINT OF BANGKOK SIDE

b) Rampway and C.P.A.C. factory

The traffic for the section between the rampway and the C.P.A.C. factory has usually been negligible.

A side-clearance has to be acquired, however, either for passages of emergency vehicles in case of accidents at the river sides or for maintenance vehicles for the parks utilizing the remaining pieces of land in case of total land purchase of the plywood factory premises facing the Chao Phraya River. (See Fig. 5-7)

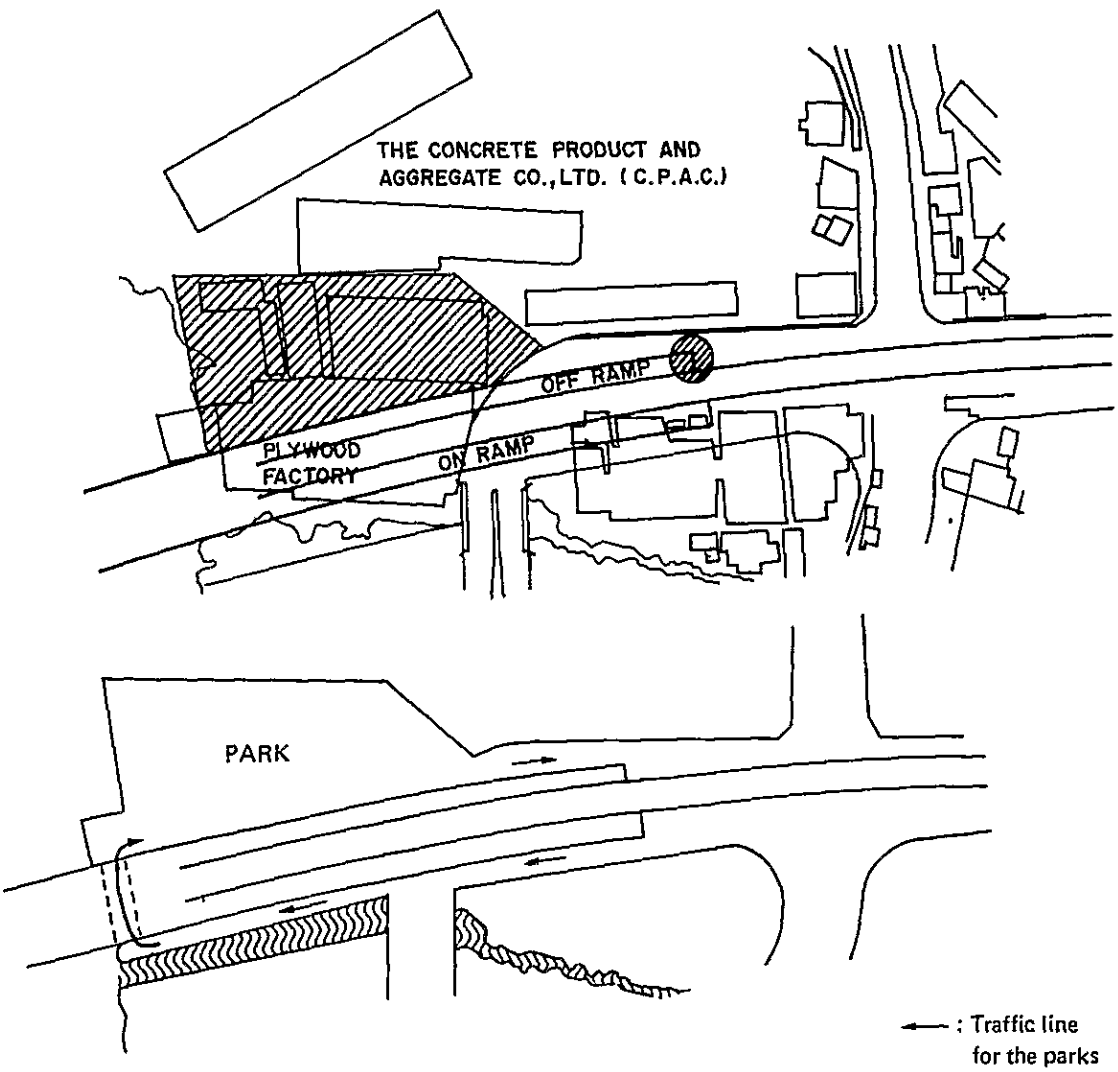


FIG. 5-7 RAMPWAY & C. P. A. C.

2) Thonburi side

a) Cross-section of viaduct section frontage road

The future traffic on the portion of the viaduct section of frontage road has been anticipated as 20,000 Veh/day in two directions.

Although basically 2-lanes width has been considered sufficient, a parking lane due to future land use should be taken into account (See Fig. 5-8).

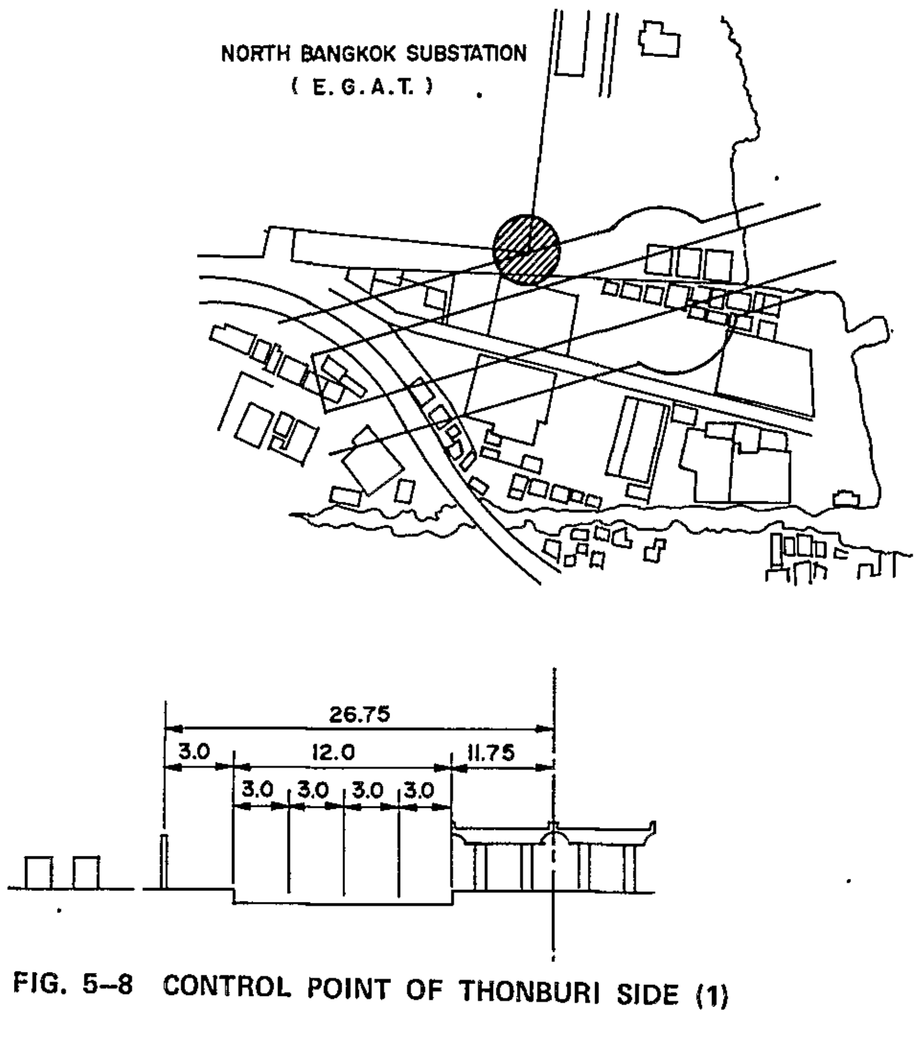


FIG. 5-8 CONTROL POINT OF THONBURI SIDE (1)

b) Right-of-way width of railway track

The proposed small trumpet-shaped interchange comes upon very closely to the existing SRT railway track, and the toe of embankment slope has been selected as a control point. (See Fig. 5-9)

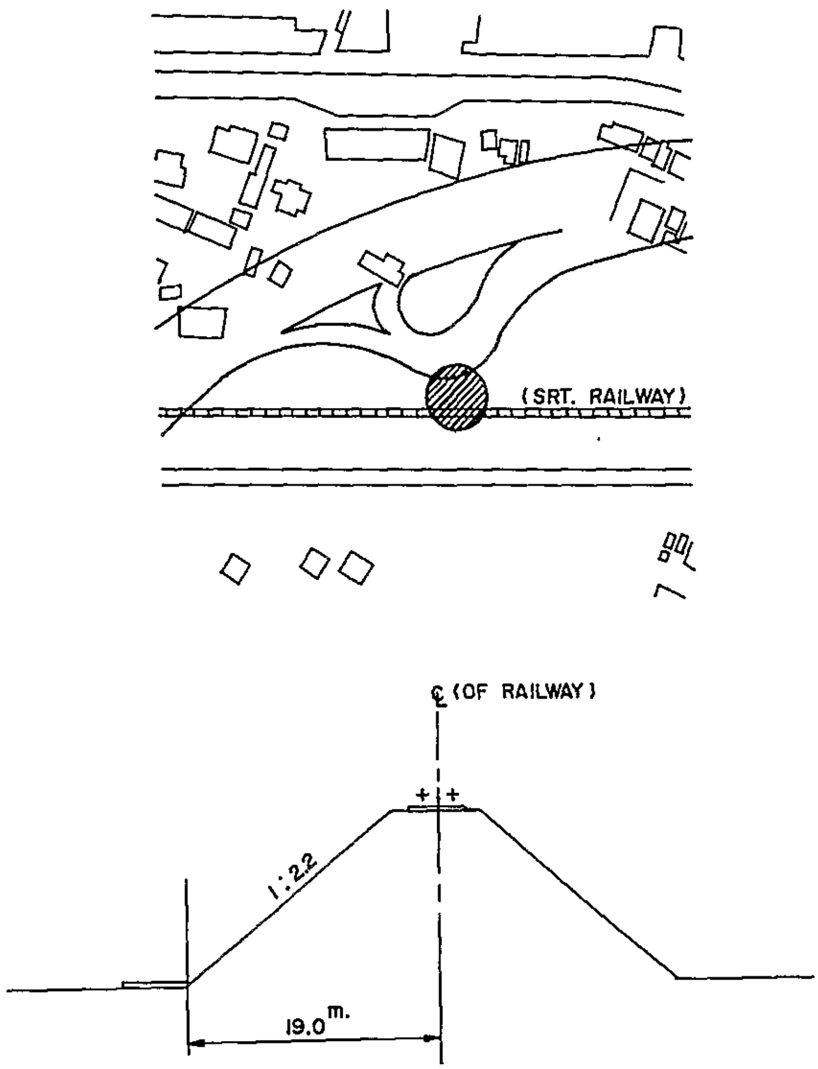


FIG. 5-9 CONTROL POINT OF THONBURI SIDE (2)

(2) Design of horizontal alignment

Based on the control points set in the previous section (1), the final alignment has been fixed as shown in Fig. 5-10.

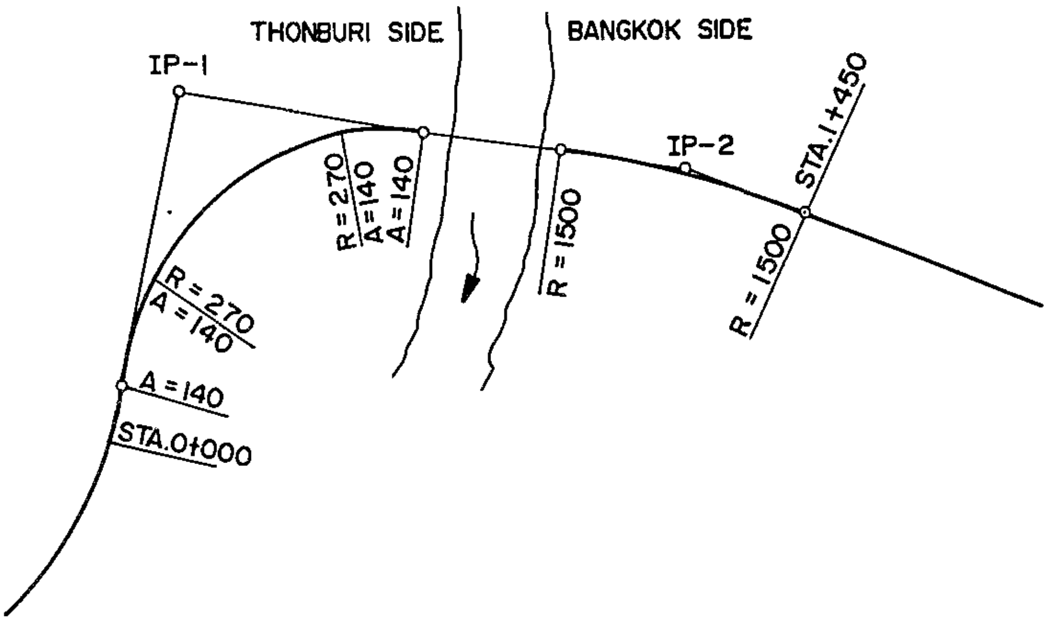


FIG. 5-10 HORIZONTAL ALIGNMENT

Although the radius of curvature planned in the Feasibility Study has been 300 meters, in this Preliminary Design, the radius has been reduced to 270 meters, utilizing the Clothoid curve corresponding the design speed of 60 km/h.

On the Bangkok side, the radius of 1,500 meters has been adopted since a Clothoid curve has not been regarded as necessary.

5-1-2 Vertical Alignment

Designing of vertical alignment has been conducted simultaneously in parallel with horizontal alignment design, taking due considerations regarding necessary accesses to the existing roads and buildings.

(1) Control points

Control points have been set up as follows :

1) Navigation on the Chao Phraya River

As the bridge location has coincided with the curved section (a radius of 700 meters) of the river, the navigational clearance has been investigated for both the central stream line of the river and the center line of the middle span of the existing RAMA VI Bridge.

The existing center line of the river has been slightly moved towards the Thonburi side since the time of the construction period of the existing bridge.

In this design, therefore, the new navigational clearance has been composed applying the specified 60 meters clearance to both the above mentioned center lines.

A vertical navigational clearance of 5.5 meters from HWL (2.00m) has been secured as in the cases of previously completed bridges in the Chao Phraya River. (See Fig. 5-11)

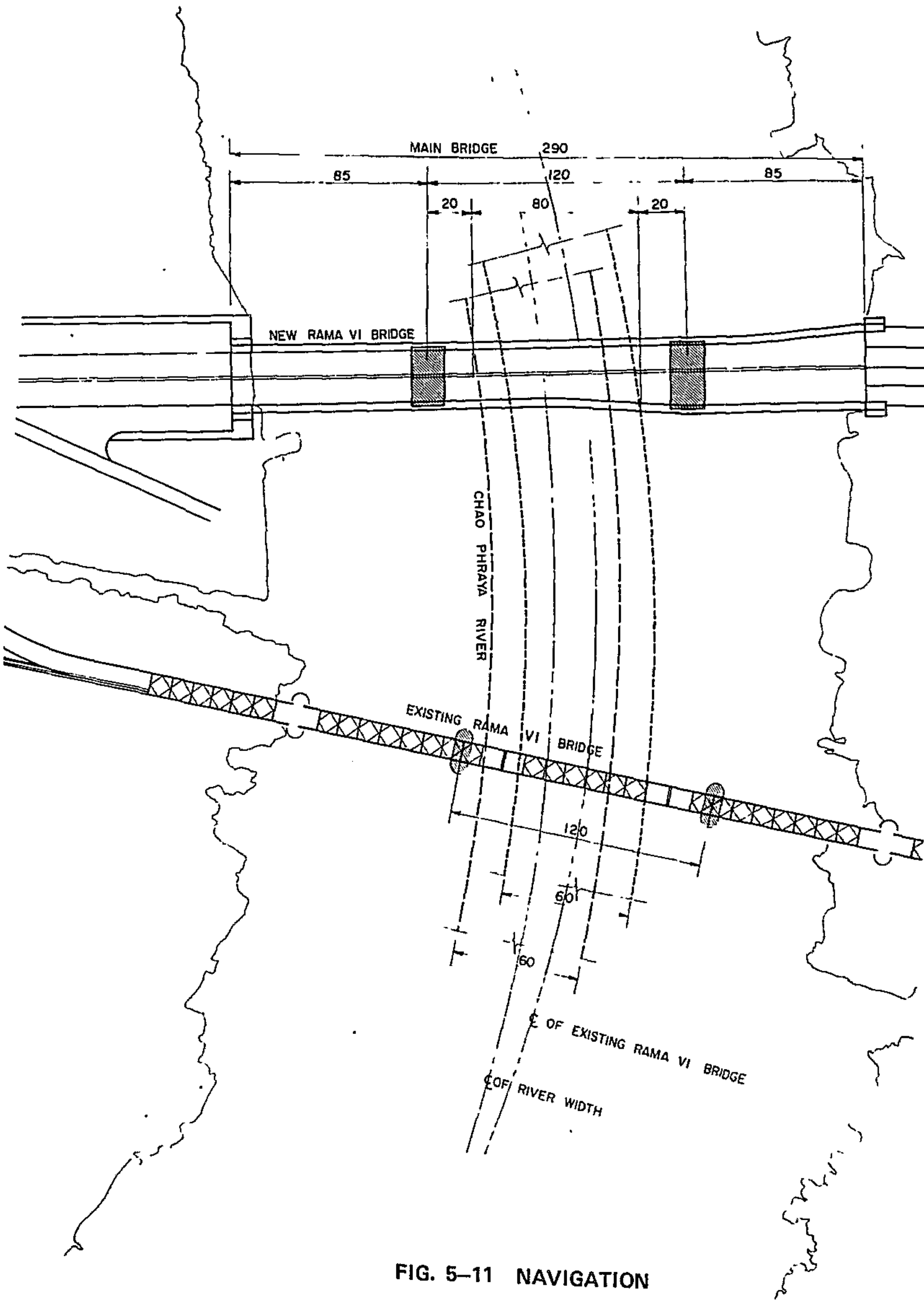


FIG. 5–11 NAVIGATION

2) Bangkok Side

In this project, the extremely short distance between the main bridge and the Wongsawang-Pibul Songkhram intersection brings forth the necessity of installing both acceleration and deceleration lanes on the roadways of the main bridge.

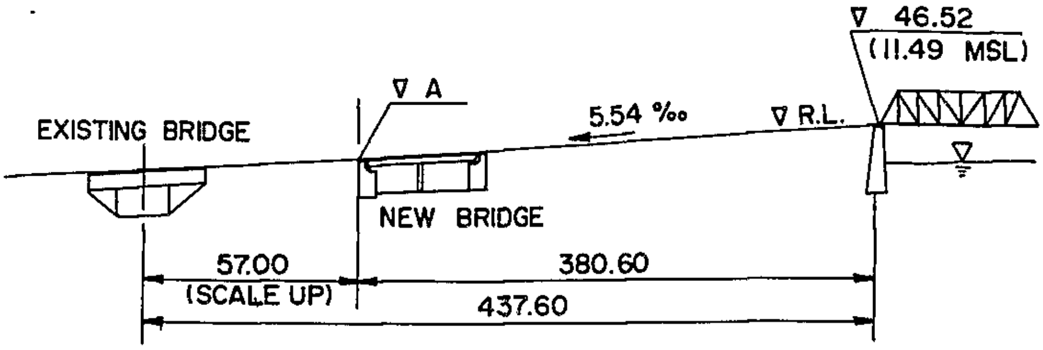
Therefore, the control points concerning vertical alignment exist in two locations.
The one is at the Wongsawang-Pibul Songkhram intersection concerning BMA specified cross section and road clearance and the other is the location of rampway noses on the bridge. The noses of rampways have been considered as to be best located structurally upon the piers of the bridge and also to be economical. According to the designed rampway, noses have been situated upon the end piers of the main bridge.

3) Thonburi Side

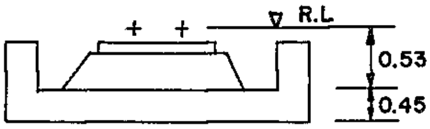
The most critical control point in Thonburi side is that of underpass crossing with the existing SRT railway track.

As there exist two small khlongs on both sides of the railway, the final vertical level has to satisfy all of restrictions set by HWL of these two khlongs, the planned level of the roadway and the clearance under the railway track.

First of all, the underpass clearance has been determined as shown in Figure below.



$$\nabla\ A = 11.49 - 0.0055 \times 380.60 = 9.40$$



On the other hand, the roadway level has been determined as follows. As the above section of the roadway has been planned using the radius of curvature of 270 meters, a superelevation has to be used.

Adopting the minimum value of superelevation of 4% specified in AASHTO, and also setting the clearance height of 40 cm above HWL for the minor bridge on the khlongs, the resulting cross-section is as shown in the following drawing. (See Fig. 5-12)

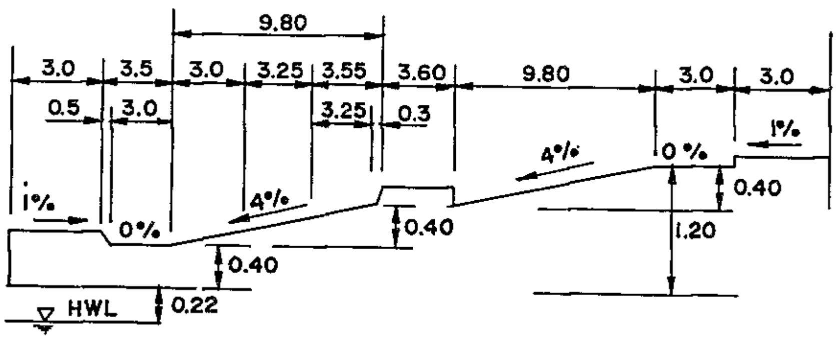


FIG. 5–12 CROSS SECTION OF MINOR BRIDGE

Setting the HWL as 2.00 meters and deducting both roadway height and the depth of main bridge girder of 1.20 meters from the clearance height of the railway underpass, the roadway level of 2.22 meters has been obtained leaving remaining height of 22 cm for extra space.

On the Thonburi side, the roadway clearances have to be confirmed for the U-shape river-side portion of the planned frontage road.

All of these control points are shown in Fig. 5-13 as below.

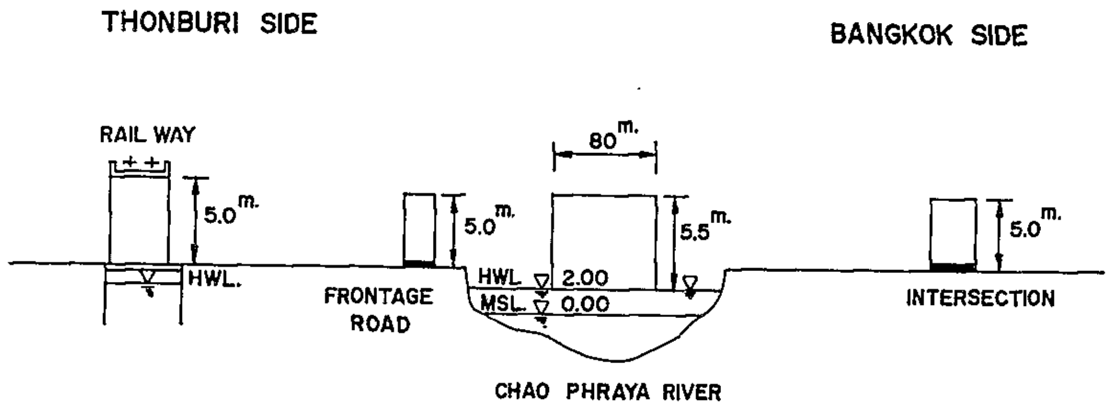


FIG. 5–13 CONTROL POINT OF VERTICAL ALIGNMENT

(2) Vertical alignment of the main bridge

Crest vertical curves have been specified in AASHTO as shown in the diagrams of Fig. 5-14 below.

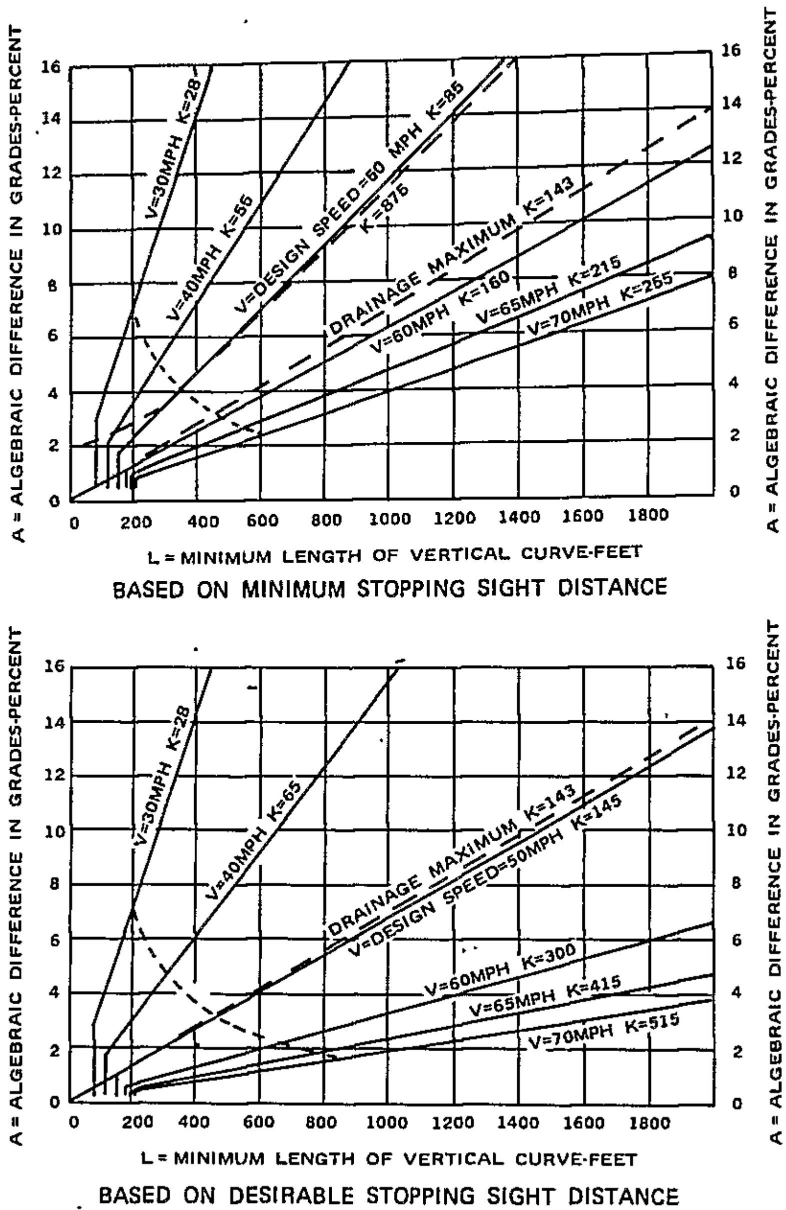


FIG. 5–14 DESIGN CONTROLS FOR CREST VERTICAL CURVES

The desirable stopping sight distance at the design speed of 60 km/h can be obtained as 135 meters from Fig. 5-14-b.

Also using the minimum value, the distance of 115 meters can be applied, thus making the length of curvature 210 meters at the travelling speed of 80 km/h.

Hence the minimum length of 210 meters has been used for vertical curve design.

On the other hand, in the main bridge section, the proposed elevation as a whole can be lowered since the vertical curve length decreases, because of the existence of the navigational control point in the middle span.

However, with the total bridge length as long as 300 odd meters, the vertical curve radius of 4,000 meters has been adopted taking both safety and aesthetical effects into account.

Hence the length of vertical curvature of 320 meters has been used in the design.

5-1-3 Cross Section Design

The main purpose of this project is to connect the Wongsawang Road on the Bangkok side to the Charan Sanitwong Road on the Thonburi side.

Since each of the roads has been administrated and maintained by BMA and DOH respectively, the basic lane width for each roadway has been identical except those of the median and sidewalks.

However, in this design, a slightly different cross section has been applied for roadway of each side section.

(1) The typical cross section

The typical cross sections for Bangkok and Thonburi side are given in Fig. 5-15.

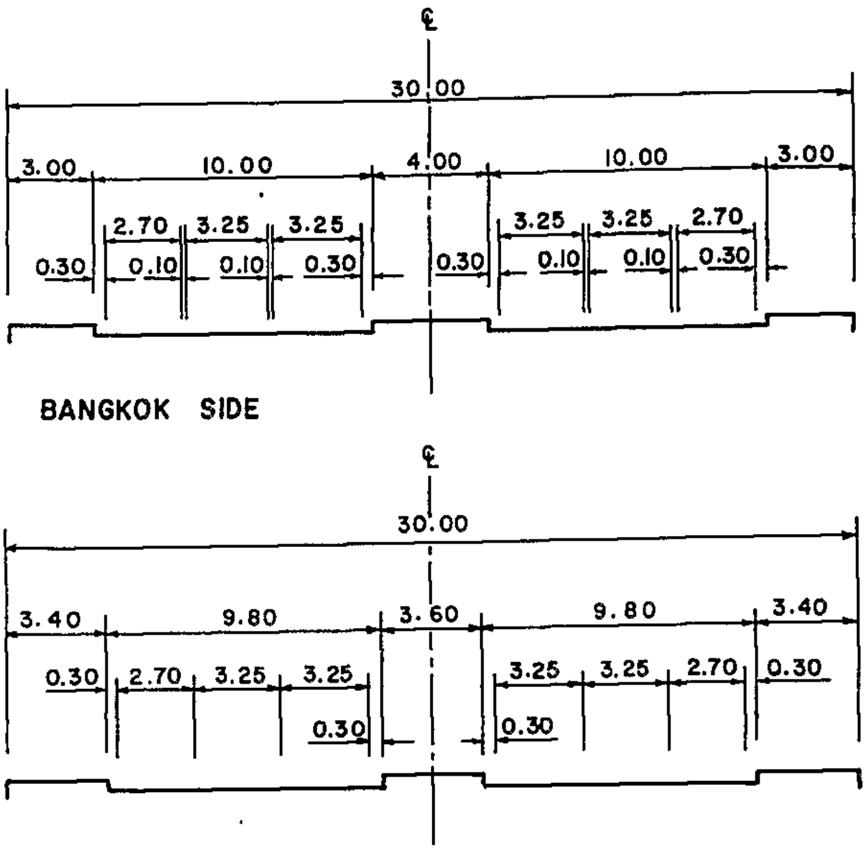


FIG. 5-15 TYPICAL CROSS SECTION

1) Bangkok side

No problem has risen in connecting the Wongsawang Road to the bridge viaduct since both center 4 lanes roadway have the same lane width of 3.25 meters and also the same 4-lanes cross section.

In the outermost lane of the Wongsawang Road, however, it has only 2.70 meters width. Hence the cross section of viaduct section frontage road has been so designed as to provide a 3.00 meter wide roadway for frontage use and an additional outside lane of 2.70 meters for bus-stop use. (See Fig. 5-16)

On the south frontage road of rampway section, one lane and an additional parking lane have been provided in view of future land use in the project site.

2) Cross-River Section

The identical roadway width of 3.25 meters has been adopted. The width of 2.5 meters for side-walks has been provided.

3) Thonburi side

In the Thonburi side section of the roadway, an additional lane of 3.00 meters wide has been installed because of the trumpet-type small scale interchange follows the 6-lanes viaduct section. For bus stop, the lane width of 2.70 meters has been applied as in the case of the Bangkok side section. (See Fig. 5-17)

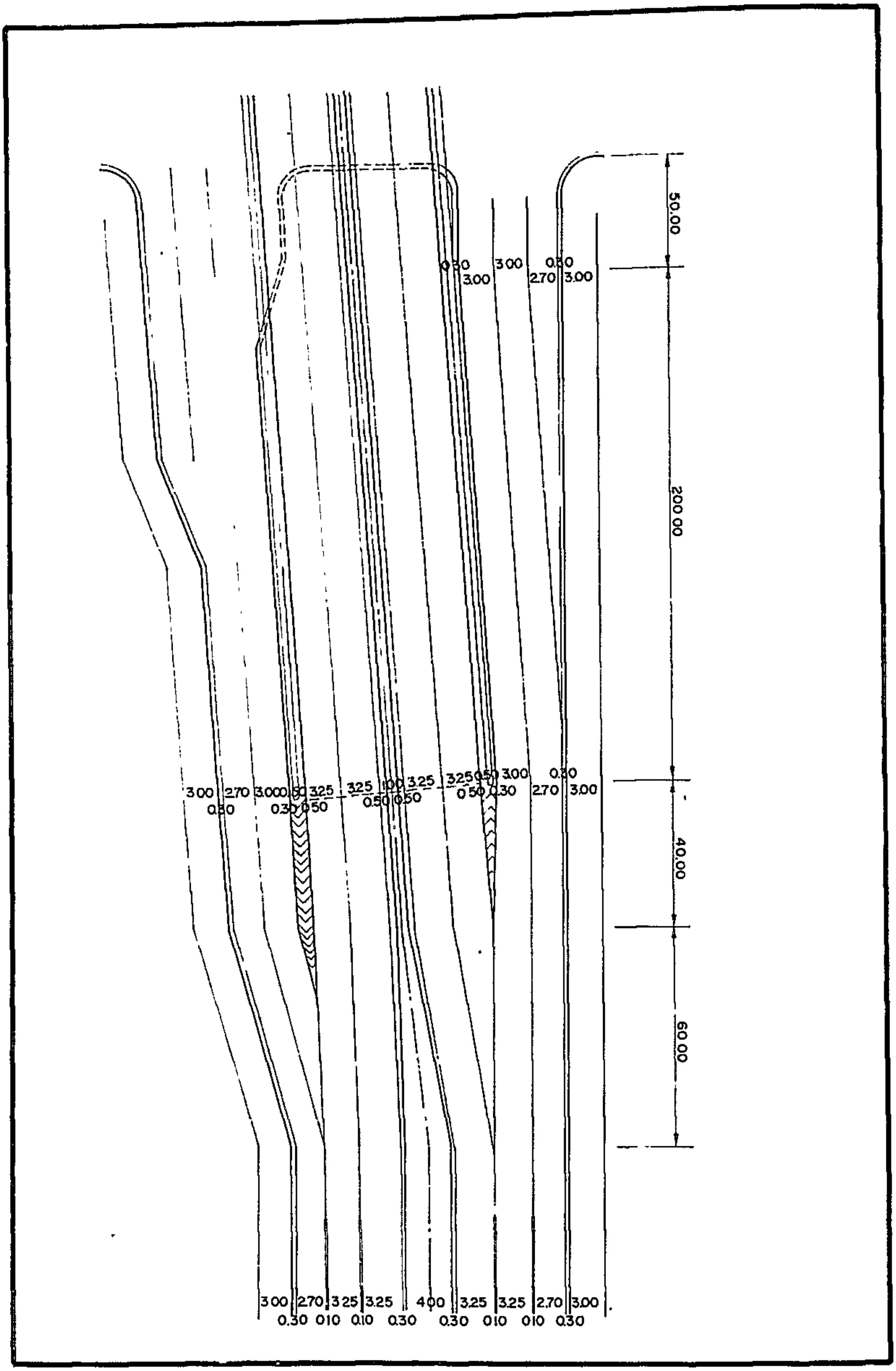


FIG. 5–16 ROADWAY PLAN (BANGKOK SIDE)

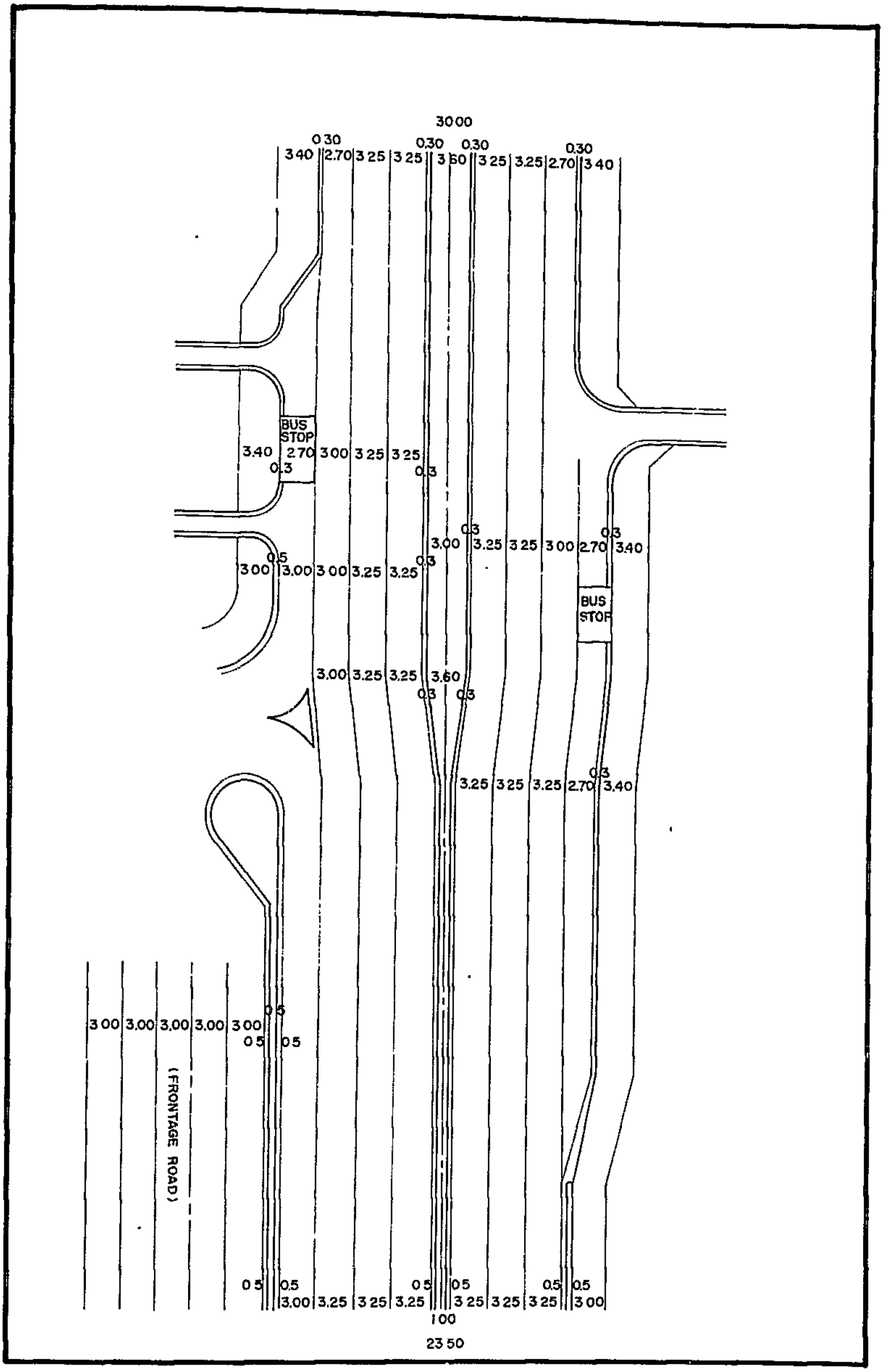


FIG. 5-17 ROADWAY PLAN (THONBURI SIDE)

(2) Superelevation

The maximum superelevation has been set as 4% in the geometric design standard and, in that case, the minimum radius of curvature could be determined as 175 meters. In this design, however, the radius of 270 meters has been adopted as more desirable in order to attain better trafficability and also in view of restriction caused by surrounding buildings. Although, in the case of adopting 270 meters radius, 3% superelevation is sufficient, the 4% superelevation has been used in design considering traffiability at travelling a speed of 80 Km/h.

5-1-4 Design of rampways

A notable feature of the design for the Bangkok side approach is the necessity of providing rampways for a flyover at the intersection.

(1) Horizontal alignment

Future one-way traffic of 12,700 Veh/day has been anticipated for the rampways.
Although one-lane width could be regarded as sufficient for the forecast traffic, 2-lanes rampways have been designed with 3.25-meter lane width which is used for the main roadways.

1) Acceleration lanes

An acceleration lane has been designed with a combination of crest and sag curves as shown in Fig. 5-18.

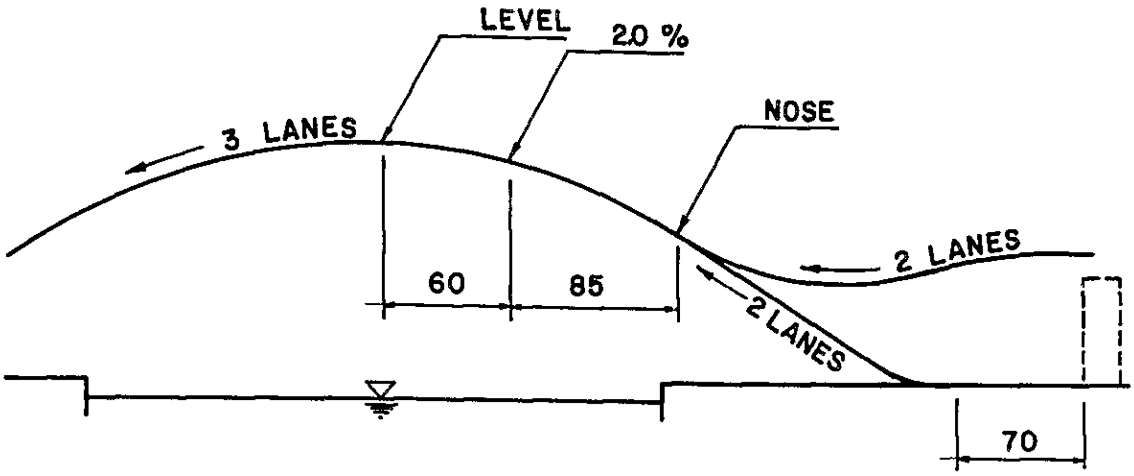


FIG. 5-18 VERTICAL ALIGNMENT OF RAMP WAY

For the main bridge section, the grade has had to be slower entering into the crest vertical curve of the main bridge and then almost level off at the center of the bridge.

On the other hand, the horizontal alignment has been so designed as to have 2 lanes for roadways and rampways and 3 lanes for the section beyond the taper ends as shown in Fig. 5-19.

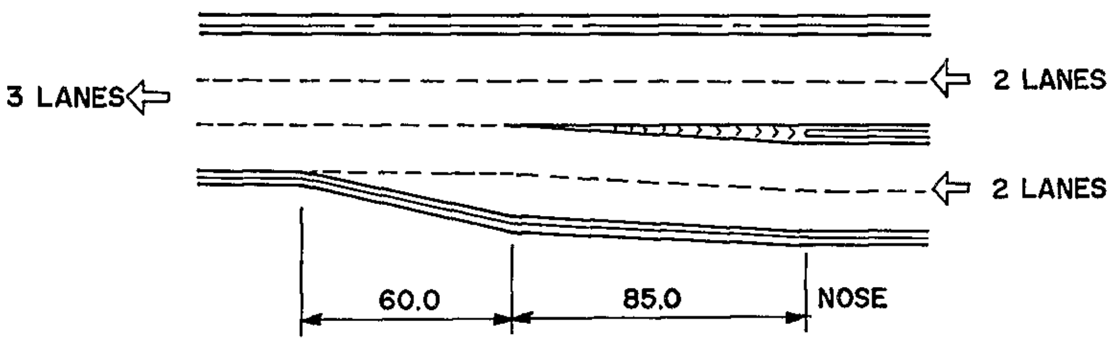


FIG. 5-19 ACCELERATION LANES PLAN

In case "No-change-lane" prohibition should be applied for the main bridge roadway, the traffic entering from two-lanes rampways would merge into the one-lane acceleration lane on the main bridge. Therefore, the acceleration lane could be regarded as a part of the through roadway. Hence, the grade of 2% has been used enabling easy merging even for heavy trucks and buses and the length of tapered section has been set up to the grade levelling point at the center of the main bridge.

2) Deceleration lanes

Deceleration lanes can be defined as the diverging part of the roadway in which the 3-lanes through roadway diverge into 2-lanes through roadways and 2-lanes rampways. The exiting traffic in off-ramps can use the outermost lane of the through roadway to enter into the exit ramp and in view of the future traffic volume one-lane rampway is regarded as sufficient. However, in this design, a 50-meter long taper has been installed in order to provide the drivers a clear indication of the point of departure from the through lane. (See Fig. 5-20)

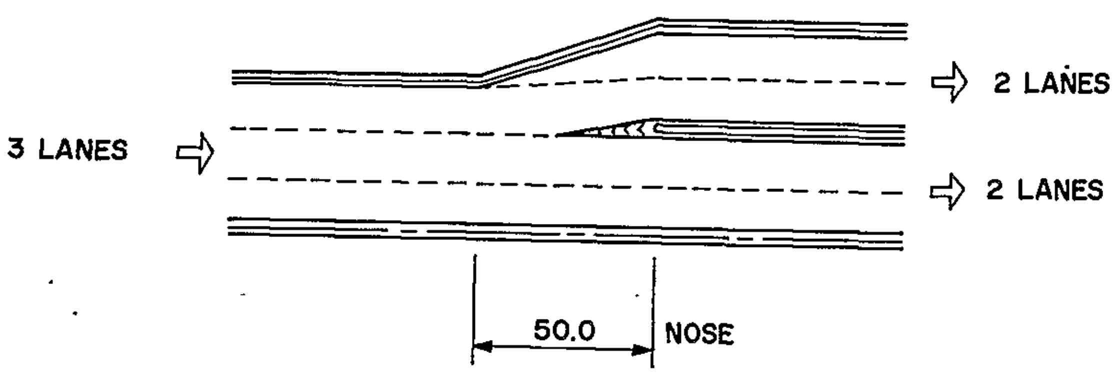


FIG. 5–20 DECELERATION LANES PLAN

5-1-5 Intersection

As the intersection described here constitutes a crossing of the Middle Ring Road (the Wongsawang Road) and one of radiating arterial highway (the Pibul Songkhram Road), the traffic capacity of the intersection has to be studied carefully.

(1) Peak traffic volume in each direction

Traffic peaks which have been calculated in the Feasibility Study are shown in Fig. 5-21.

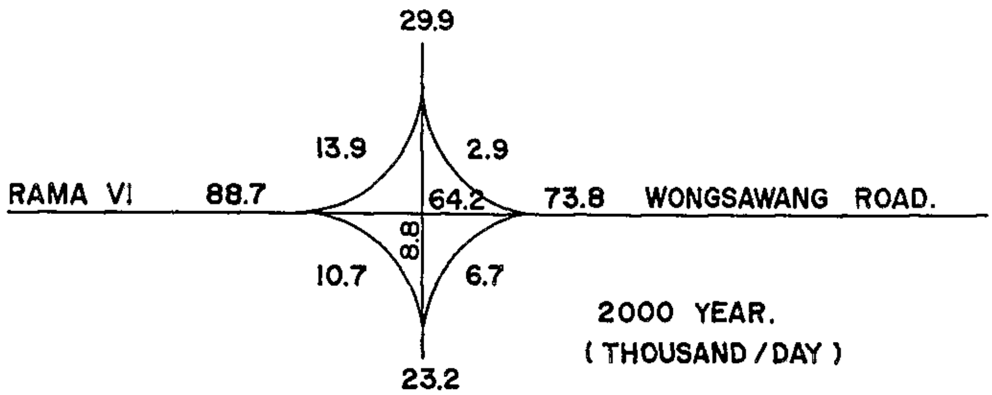


FIG. 5–21 TRAFFIC FORECAST OF INTERSECTION

These directional traffic volumes have been shown in the term of an average daily 2-way traffic and the volume for each direction is 50% of the former.

The peak-hour ratio for each direction has been determined as in Table 5-1 using the present peak-hour ratio obtained in the traffic survey.

Table 5-1

FROM \ TO	URBAN	RURAL
URBAN		
RAMA VI BRIDGE	7.5	7.5
PRACHA RAT 1 ROAD	8.0	10.5
RURAL		
WONGSAWANG ROAD	11.0	7.5
PIBUL SONGKHRAM ROAD	7.0	8.0

Upper : peak-hour ratio in the morning
Lower : peak-hour ratio in the evening

The each directional peak-hour traffic volume has been calculated using the ratios shown in Fig. 5-22.

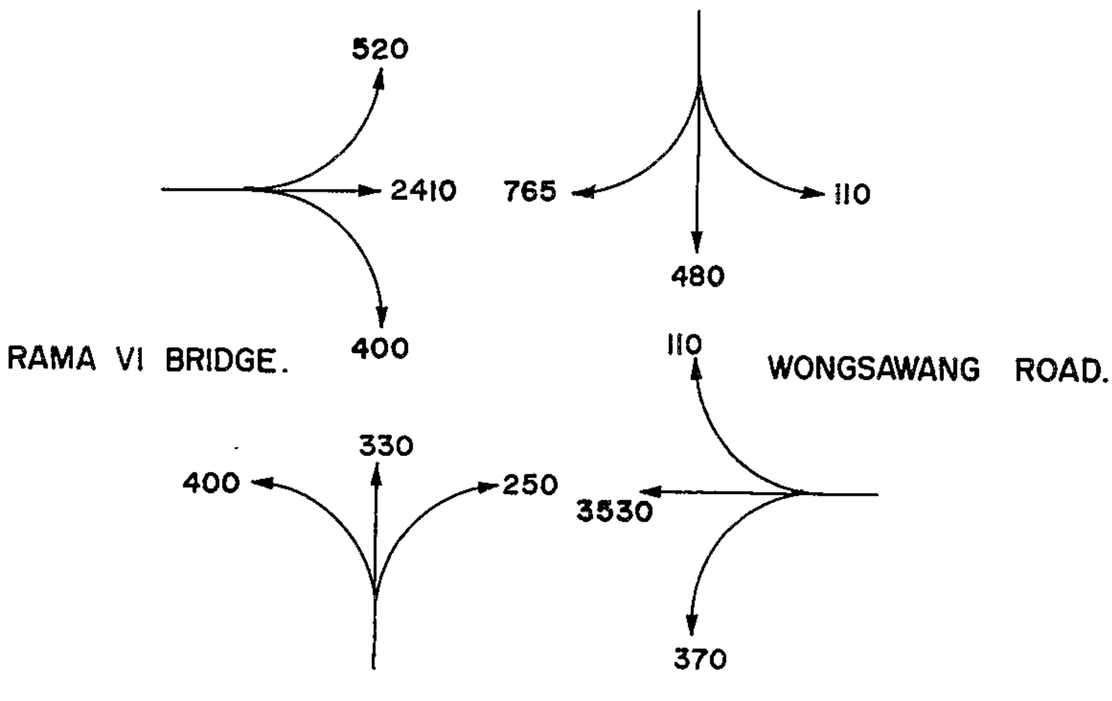


FIG. 5–22 TRAFFIC FLOWS BY DIRECTION OF PEAK HOUR

(2) Traffic control

1) Design conditions

a) Number of lanes for entering traffic

The number of lanes for each lane of entering traffic has been determined as in Table 5-2.

Table 5-2

Entering Section	Through	Left Turn	Right Turn
RAMA VI BRIDGE	1	2	2
WONGSAWANG ROAD	1	1	1
PRACHA RAT 1 ROAD	1	2	1
PIBUL SONGKHRAM ROAD	1	1	2

b) Saturation traffic volume

The saturation traffic volume for each lane has been set in accordance with the specification used by the Japan Traffic Engineering Association. (See Table 5-3)

Table 5-3

Lane Classification	Saturation flow rate V/Green 1 Hr
Through	2,000
Left Turn	1,800
Right Turn	1,800

c) Large vehicle ratio

The ratio of large vehicles in the whole traffic has been observed as 17% at the present. The ratio for future traffic has been anticipated as 20% and a correcting value of 0.85 has been used for saturation flow rate using a table in the Japan Highway Structural Manual.

2) Traffic capacity at the intersection

In order to check future traffic capacity at the intersection, a signal phase has been assumed and saturation degree has been calculated using peak-hour traffic volumes.

a) Signal phase

Signal phases have been assumed as in Fig. 5-23.

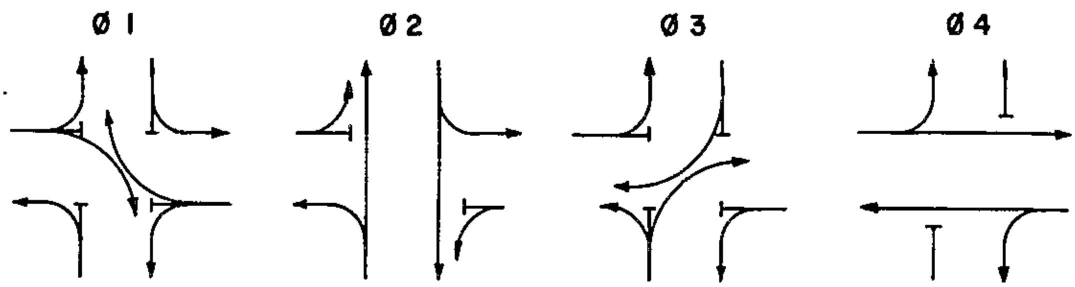


FIG. 5–23 SIGNAL PHASE

The case of $\phi 4$ has been omitted from the study due to its low traffic volume.

b) Rate of phase

Rate of phase can be obtained as the ratio of each directional design traffic volume against saturation traffic volume and provides the ratio of the necessary green-light duration time for the specific direction.

The traffic control can be feasible when the maximum total rates of phase for one direction exceeds the value of 0.9.

The total of rates of phase is generally called the saturation degree and the value of 0.9 can be used as a criterion for determining necessity of traffic signal control.

c) Calculated saturation degree

Although it is a common practice to make separate calculation of saturation degree for each of morning and evening peak-hour, only the higher morning peak-hour volume has been used in the calculation. The results are shown in Table 5-4.

Table 5-4 Calculated Saturation Degree

Signal phase	Direction	Saturation Traffic Volume	Peak-hour volume	Rate of phase
1	Right-turning traffic from RAMA VI Bridge	1800x2x0.85 = 3060	400	0.13
2	Through traffic from Pibul Song-khram Road	2000x0.85 = 1700	480	0.28
3	Right-turning traffic from Pibul Songkhram Road	1800x2x0.85 = 3060	765	0.25
	TOTAL			0.66

The results show that a signal control could be feasible if the number of lanes described in Table 5-2 had been provided at the intersection.

(3) Intersection Design

The whole configuration of the intersection has been designed based on the number of lanes determined in the previous section. The design principle used for each directional traffic flow and the results are described as follows:

1) RAMA VI Bridge

As results of calculations, one-lane for through traffic and 2-lanes each for right and left turning traffic have been designed.

The one-lane for through traffic has been regarded as necessary for serving the north-side inhabitants of the flyover viaduct and also for bus operation.

The right turning lane has been installed underneath the viaduct to minimize land acquisition because the girder design enables provision of necessary space in this section of the viaduct.

2) Wongsawang Road

All through, right and left turning traffic can be controlled with one lane each. In order to make the left turning from Wongsawang Road always possible, the 2-lane design has been adopted including one bus lane. The right turning lane has been installed underneath the viaduct.

3) Pracha Rat I Road

One lane for through and right-turning and 2 lanes for left turning traffic have been provided respectively.

To conform with the peak-hour traffic of 330 Veh/h, two lanes have been designed for through traffic.

4) Pibul Songkhram Road

One lane each for through and left turning traffic and two lanes for right turning traffic have been provided for this section. As in the case of Pracha Rat 1 Road, the through traffic volume is as high as 480 Veh/h, so 2 lanes have been installed for the through traffic with one lane being used also for left turning traffic. The left turning traffic is thus governed by signal control.

(4) Connection with Parcha Rat I Road

The connection with the Pracharat 1 Road has been made using a S-shaped curve with 110 meters and 80 meters radius.

A 4-lane configuration has been designed in order to conform with the adjacent sections taking the future traffic volume of 23,600 Veh/day into consideration.

5-1-6 Interchange

In this Preliminary Design, a trumpet-shaped interchange has been designed in Thonburi side in accordance with the route alignment Alternative III of the Feasibility Study.

Horizontal configuration of the interchange is described in following sections.

(1) Design Speed and Curvature

A radius of curvature of around 20 meters have to be used for left turning traffic coming from Bangkok side, taking the alignment of through roadway, width of railway embankment and the end position of approach viaduct into consideration.

Then the corresponding design speed can be obtained from chart described in AASHTO. (See Fig. 5-24)

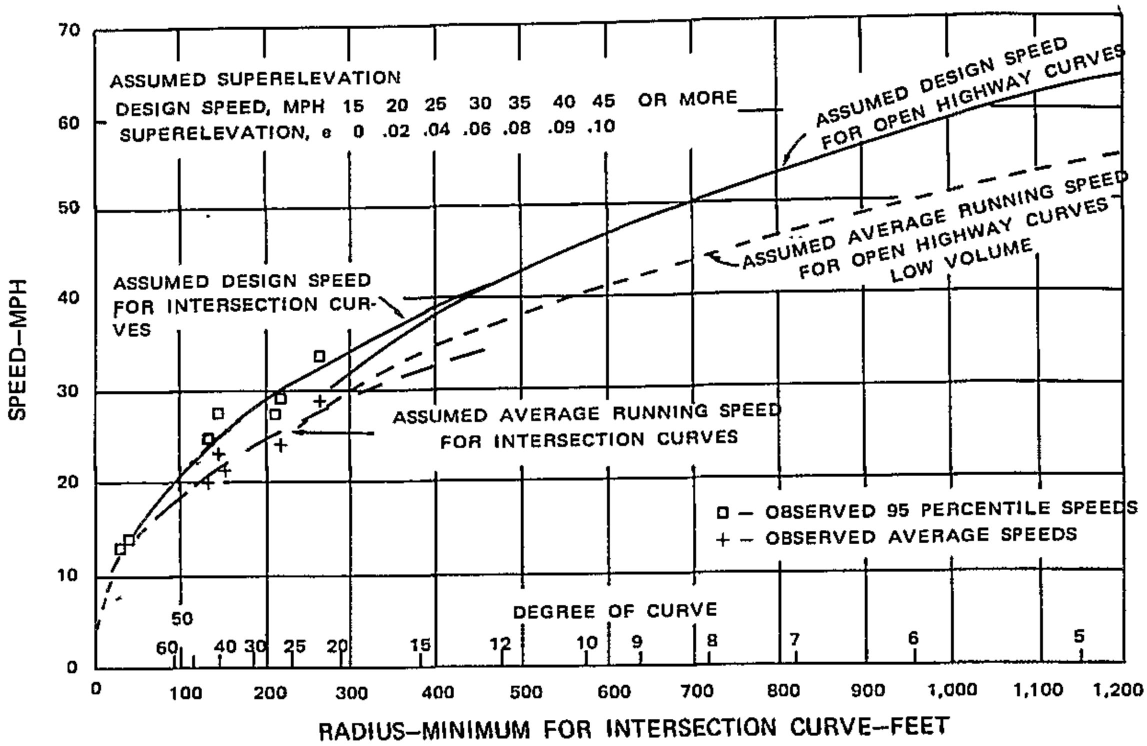


FIG. 5–24 MINIMUM RADII FOR CURVES AT INTERSECTIONS

Also the design speed of ramp as related to highway design speed is recommended in guide values described in Table 5-5. (as follows)

Table 5-5 Guide values for ramp design speed as related to highway design speed

Highway design speed, mph	30	40	50	60	65	70
Ramp design speed, mph						
Desirable	25	35	45	50	55	60
Minimum	15	20	25	30	30	30
Corresponding minimum radius, feet						
Desirable	150	300	550	690	840	1040
Minimum	50	90	150	230	230	230

Note: Ramp design speeds above 30 mph seldom are applicable to loops.

From this chart, the design speed of the rampway can be calculated as 19 mph (30.4 Km/h) when the main roadway design speed is assumed as 60 Km/h.

Using Fig. 5-24, the corresponding radius of curvature for the speed of 30.4 Km/h is calculated as 20 meters and this satisfies design requirements. Therefore the design speed of the trumpet interchange is 30 Km/h in case of adopting 20 meters radius.

(2) Minimum deceleration length

Minimum lengths of deceleration lanes are described in AASHTO as follow: (See Table 5-6)

Table 5-6 Design lengths of speed-change lanes all main highways
Flat Grades - 2 Percent of Less

Design speed of turning roadway curve, mph		Stop condition	15	20	25	30	35	40	45	50
Minimum curve radius, feet			50	90	150	230	310	430	550	690
Design speed of highway, mph	Length of taper, feet	Total length of DECELERATION lane, including taper, feet:								
40	190	325	300	275	250	200	-	-	-	-
50	230	425	400	375	350	325	275	-	-	-
60	270	500	500	475	450	425	400	325	300	-
65	290	550	550	525	500	475	450	375	325	-
70	300	600	575	550	550	525	500	525	400	350
75	315	650	625	600	600	575	525	475	450	400
80	330	700	675	650	650	600	575	525	475	450
Design speed of highway, mph	Length of taper, feet	Total length of ACCELERATION lane, including taper, feet:								
40	190	-	325	250	225	-	-	-	-	-
50	230	-	700	625	600	500	400	-	-	-
60	270	-	1125	1075	1000	900	800	600	400	-
70	300	-	1550	1500	1400	1325	1225	1000	825	575

NOTE: Uniform 50:1 tapers are recommended where lengths of acceleration lanes exceed 1300 feet, or where design speeds exceed 70 mph, or elsewhere if appropriate and space permits.

Although the minimum deceleration length is calculated from the above table as 75 meters, it should be taken into consideration that the down grade is 4% on the main roadway and also that the left turning traffic lane is only one-lane. It must, therefore, be considered that the actual running speed in the through traffic lane can be as high as 80 Km/h and also that the running speed at the exit of ramp can be slowed down to 20 Km/h because of its narrow one-lane width.

It is recommended in this design of the trumpet interchange to accommodate a 125-meter long deceleration lane assuming design speeds of 80 Km/h for highway and 20 Km/h for rampway.

5-1-7 Pavement design

There are many published methods of designing road pavement which are of varying complexity and which produce different results. The latest theoretical work on this complex problem, however, indicates that due to the reduced strength of bituminous materials in hot climates, any of the design methods developed in the U.S.A. and Europe are inapplicable to tropical areas. The significant result of these findings is that in climates such as Bangkok there is little technical merit in using thick bituminous base courses as these materials have only marginal higher strength's, at the prevailing temperatures, than good quality granular bases. The economic ramifications of this are clear in view of the present prices of bitumen.

(1) Embankment

1) Stability Analysis

Possible height of embankments at the Project site was analysed in this stage by Taylor's Curves giving a non-dimensional stability number for slopes in cohesive soil ($\emptyset=0$), i.e. total stress analysis.

Then, the possible height of embankments are guided as below:

Height of Embankment, m	Factor of safety
1.0 m	2.3
1.5 m	1.7

However, more detailed study on the stability due to tension crack, side ditch excavation and etc. should be investigated by means of trial-slip circle failure.

2) Settlement Analysis

Prediction of primary consolidation settlement in the highly compressible clay due to the embankment mentioned in previous section was carried out by the conventional Terzaghi method.

The results of the settlements are presented in Fig. 5-25,26. The rate of settlement on Thonburi side is greater than that on Bangkok side due to the presence of 4m thick sand layer at the depths 9.5 to 13.5 m. leading to a shorter path of pore water pressure dissipation.

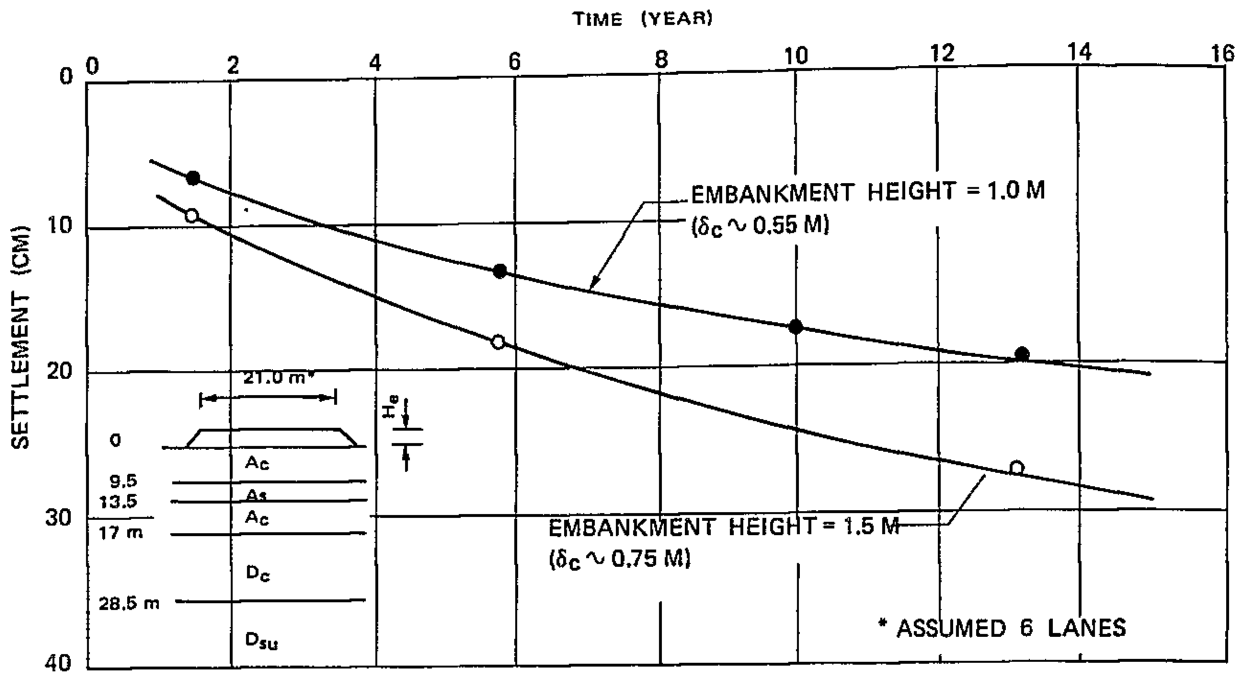


FIG. 5-25 ESTIMATED TIME – CONSOLIDATION SETTLEMENT ON BANGKOK SIDE

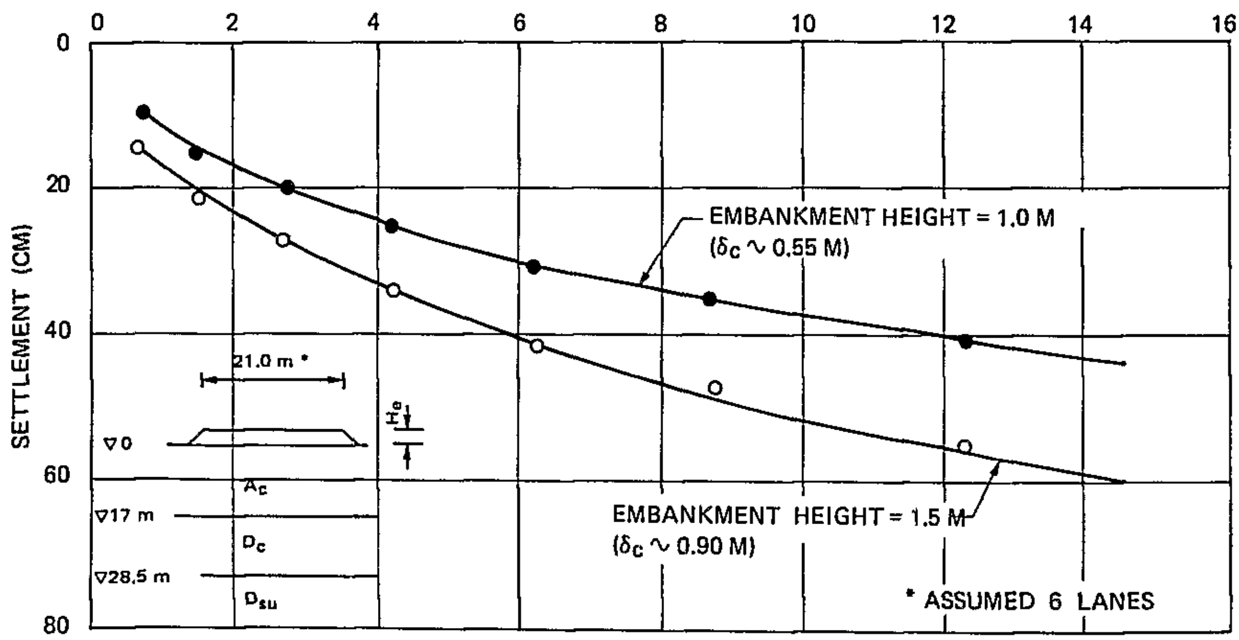


FIG. 5-26 ESTIMATED TIME – CONSOLIDATION SETTLEMENT ON THONBURI SIDE

(2) Pavement Design

Because both the DOH and BMA each has its own design standard for the design of pavement, the design for this project has to be divided into two section using slightly different standard for the Thonburi side and Bangkok side sections.

Generally, the composition of the pavement design has been so designed for each section as to comform the characteristics of each section taking the future design capacity and embankment material into consideration.

However, in this project, as both of the design standards are based on the same AASHTO standard, no problem is expected in using each of the two standards in spite of slight differences in pavement compositions.

5-1-8 Road Facilities

(1) Roadway lighting

To maintain traffic flows and reduce traffic accidents during the hours of darkness, roadway lighting is to be provided in the project area.

The average intensity of illumination used in the design of the lighting installations is 10 lux which is in conformity with "An Informal Guide to Roadway Lighting" (AASHTO).

Because of the long period of use each day, the large area to be illuminated, and the need to minimize maintenance, light sources having a long life, high efficiency and a large capacity are required. Three types of lamp are suitable for use in installations of this type :

- Fluorescent mercury vapour type
- Low pressure sodium type
- High pressure sodium type

Low pressure sodium lamps (135 W each) were adopted for use on these routes as they have a high efficiency, long average life, low replacement costs and are in keeping with the existing lighting installations along Ngamwongwarn Road. The mounting position and heights of the luminaires is determined by the degree of road surface luminance required and the glare tolerated by drivers. In order to keep the level of glare low, the more powerful the light source and the higher it must be from the road surface. The height of lighting columns recommended are 10 m high tapered steel columns with overhangs. A spacing of 30 m will normally be used. Base plate type foundations are to be preferred as the columns are simplier to install and replace with this type of base than those with embedded type bases.

(2) Road signs

Fabrication and erection details of the signs and delineators used are according to the standard suggested by the Department of Highways. According to this standard, there are three kinds of traffic signs: Guide Signs, Regulatory signs and Warning Signs.

Traffic signs must be clear and large in size so they may be immediately understood by drivers who are driving at high speed or in heavy traffic flow.

Placement of road signs will be according to the DOH standard. However, since the importance of a road sign is its visual impact, the sign must stand out from the surrounding background. It must also be located where it can be related to the road feature to which it refers and far enough in advance of that feature to ensure that all drivers will see the sign, read it, and make a decision before reaching a point where they must act. The placement of signs will, therefore, be affected by the road geometry and the surroundings.

(3) Pavement marking

Pavement markings used in the design are according to the standard suggested by the DOH. The following type of pavement markings are used:

Longitudinal Pavement Marking

- Broken Line
- Solid Line
- Edge Line

Transverse Pavement Marking

- Stop Line
- Cross Walk

Other Markings

- Turn Lines
- Pavement Message
- Curb Markings
- Pavement Arrows

Major road markings and those subject to wear by heavy traffic will be of thermo plastic material. Minor lines and curb markings will be in road paint.

The standards used for the design of pavements, street lighting, storm-water drainage and other road facilities are shown on Drawing No. 5.

5-2 STRUCTURAL DESIGN

The preliminary structural design is mainly concerned with further refinement of the structural analysis bases on the outlined design of the Feasibility Study. This work enbodies comfirmation of span arrangements and determination of structure dimensions.

5-2-1 Main Bridge

(1) Design Criteria

The basic design criteria such as the location, span arrangements and the type of the main bridge have been determined in the Feasibility Study as follows:

1) Span arrangement

85 m + 120 m + 85 m = 290 m

2) Width

The width of the bridge surface has been gradually enlarged from the center towards the Bangkok side to provide necessary rampways. The general view and cross sections of the main bridge are shown in Fig. 5-27.

3) Type of bridge

Prestressed concrete box-girder constructed by cantilevering method has been adopted in accordance with the comment issued by PWD. The bridge structure consists of two T-shaped frames which are connected by sliding shear hinge in the central span and supported by sliding bearings at the ends of the side spans.

(2) Type of bridge structure

For the prestressed concrete bridges constructed by the cantilevering method and for the span length of above mentioned dimension, the following alternatives of structural type can be conceived.

- Alternative I: Continuous girder
- Alternative II: Rigid frame
- Alternative III: T-shaped frame connected by central hinge

1) For the trafficability of vehicles, a continuous girder bridge is preferable, because of its having no expansion joint on the bridge surface. As the bearing is arranged at each supporting point, the continuous girder transmits no bending moment into the pier. Therefore, the reaction force caused in each pile is even, and the bearing capacity of each pile can be utilized to the maximum effectiveness, thus giving more merit to use the continuous girders.

   On the other hand, the cost of steel bearing becomes more expensive as the loading capacity increases. The rising of the cost is far faster than the increase of the load. Since the main girder is supported on the bearing which allows rotation of the girder, in order to make possible the cantilevering, the main girder shall be temporarily fixed to the pier, and a lot of temporary materials and working time are required.

   In case of continuous girder constructed by cantilevering method, the maximum value of negative bending moment at the supporting point which is caused during the cantilevering process, is considerably larger than that which is estimated to be caused after the completion. On the other hand, the prestressing tendons arranged in the bottom of main girder are of no use during cantilevering work. Therefore, usually more prestressing tendons are required for continuous girder than for T-shaped frame.

2) If the bridge is made in the form of a series of rigid portal frames, the need for bearings is eliminated. However, in this case, relatively high stresses are induced in the piers due to temperature change and shrinkage of concrete. If the piers were high and relatively flexible, the induced stresses would be quite low. Since this bridge has high rigidity of substructure, which consists of piers and piles projected out of river bed, continuous rigid portal frame is not an adequate solution.

3) The third of the possible configurations consists of T-shaped frames connected at mid span by hinges which transmit shear but allow rotation and longitudinal movements. This type of structure eliminates the cost of bearings for the main piers, overcomes the problems with cantilever construction methods and allows for movement due to temperature change and shrinkage of concrete to be accommodated. Additionally, it is reasonably efficient from the structural aspect because the maximum stresses induced in any section during construction work do not exceed the maximum values estimated to be caused after the completion.

As a result of the considerations above-mentioned, the Alternative III has been adopted as the most reasonable solution.

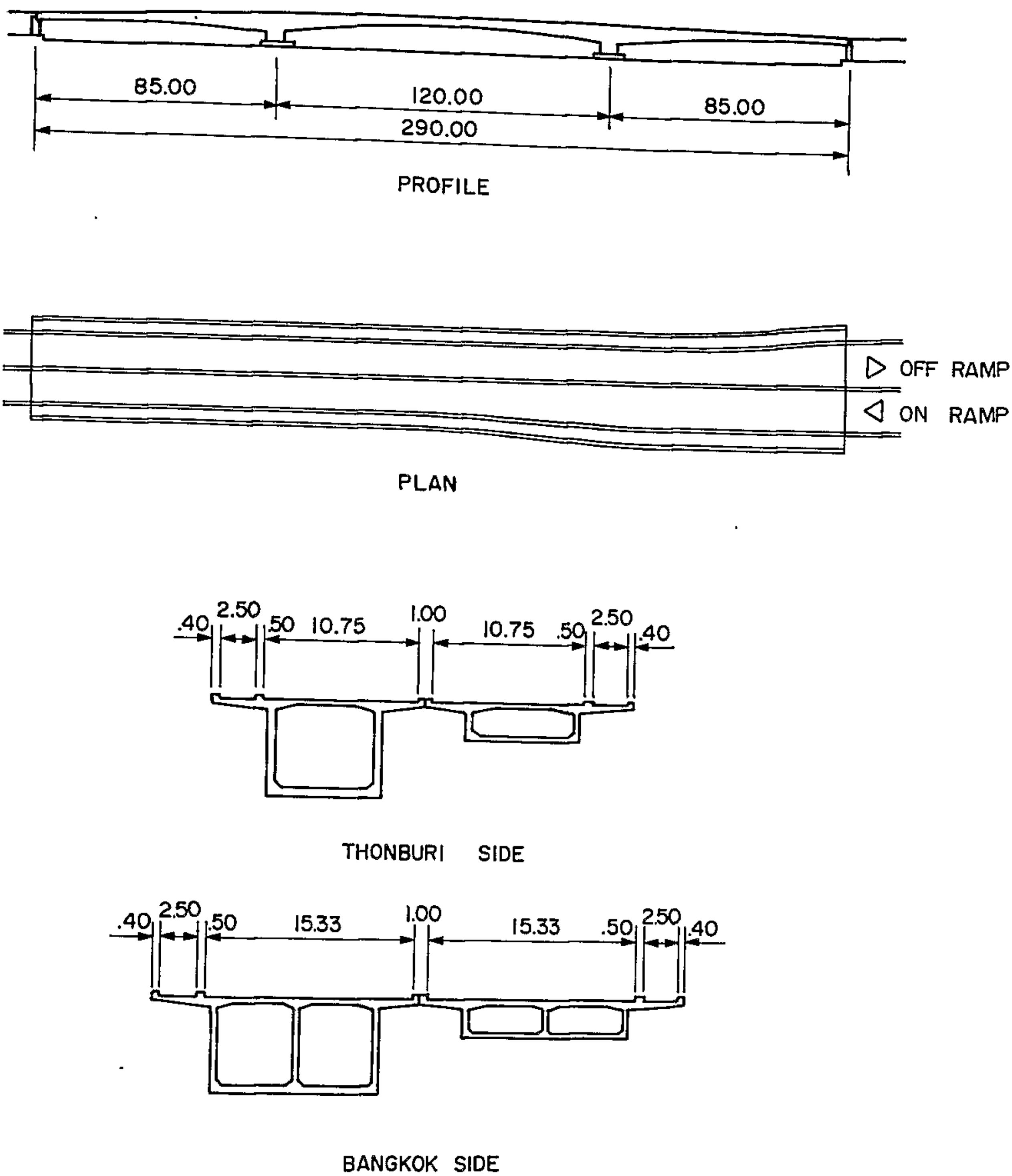


FIG. 5–27 CROSS SECTION OF MAIN BRIDGE

(3) Span Arrangements

The total length of the main bridge has been decided to be 290 meters. On the previously selected alignment, the horizontal alignment of the proposed bridge cannot help being not parallel with the existing RAMA VI Bridge.

As the location of both bridges comes upon a curved section of the river, navigational tails of long convoys of barges pulled by tugboat would not coincide with the center stream line. Hence, a horizontal clearance of 80 meters, instead of the 60 meters minimum requirement in the direction perpendicular to the stream in the straight section of the river, has been considered to be necessary.

The span arrangement decided in the Feasibility Study (85 m + 120 m + 85 m) is in compliance with this requirement.

In the Preliminary Design, further structural analyses have been made in order to eliminate the possibility of undesirable structural effects with regard to the bending moments either during construction or on completion of the structures, and it has been studied if minor change of the span arrangement is necessary.

It is known that, with this type of structure, unbalanced moments can occur in the main piers both during construction and on completion. These moments are undesirable as they transmit differential reactions to the piers and may cause differential plastic settlement of the piles over a long period of time. Hence in the worst case, slight leaning of the piers may occur. These moments are derived from the differences in bending moments at the piers due to the different configurations of the adjacent main girders on either of the span lengths.

· This bridge consists of four T-shaped rigid frames. In terms of a frame which is situated on the Bangkok side and the downstream side, structural analysis shows that it is better to shorten the side span by 2 to 3 meters because of widening for the on-ramp. However, the span arrangement of the adjacent frame is reasonable. The analysis shows also that the unbalanced moments in the pier of the frame can be eliminated utilizing the statically indeterminate moments caused by prestressing force. Therefore, minor change for span arrangement adopted in the Feasibility Study was unnecessary.

(4) Construction Methods

1) Superstructure

The bridge is to be of prestressed concrete construction and, in view of the requirements for the main spans, there is no real alternative to the use of prestressed concrete box sections, which are constructed from either precast segmental boxes (SB) or by cast in-situ methods (CI).

In CI method, which is often adopted for constructing prestressed concrete box girder bridges, the boxes are cantilevered out equally on either side of the piers, casting new sections in-situ while providing temporary support for the formwork by use of cantilevered travelling scaffold. When the in-situ concrete is of the required strength, it is prestressed back to the existing box girder and the process is repeated until the boxes join to form a continuous girder. This method may be used for all the river spans, cantilevering out from each pier either at the same time or by turns.

An adoption of the SB method means to precast the segments in a central casting yard, on the river bank, ship them to the site on a barge, lift them into position using a cantilever gantry and winches, and apply epoxy resin to the box joints and prestressed back to the existing boxes.
The initial box over the pier must be cast-in-situ.
The advantages of the SB method is that

boxes may be made on dry land in advance of erection and during the erection a progress rate of one block per day is possible for each gantry. The overall construction time is thus less than with CI construction.

Much of the economy of SB method results from the standardization and mechanization of the process of manufacturing the segments. When design details permit repetition of daily actions, one segment per day can be manufactured from each form by a comparatively small crew. To achieve this rate of production, it is important to avoid changes in the forms, to standardize the cage of mild steel reinforcement and to use a repetitive layout of the post-tensioning tendons.

Because of varying widths for ramps, the horizontal alignment of the main bridge is asymmetrical both in longitudinally and transversely as shown in Fig. 5-27, and the standardization of the dimensions of the box girders for whole bridge is impossible. In view of the above, the CI method has been adopted.

2) Substructure

a) Foundation

As reliable bearing stratum for substructure can only be located at the depth of 40 meters below MSL, foundation structure also has to sink down to approximately 45 meters below MSL.

Sinking of open caisson through hard clay stratum is considered to be very difficult work, but pneumatic caisson method also cannot be used for deep stratum as in this case.

Only in-situ-concrete piles by reverse

circulation drilling method can be utilized for the foundation structure.

The method has been practiced in many cases in Thailand and equipment and skilled labor can be mobilized abundantly.

b) Pile Caps

For safety reasons, the elevations of the top of the pile caps have been fixed so that they will be above the level for all but the most severe floods. However, the bottom of the pile caps are above the water level during construction periods in order to achieve good and speedy construction of pile caps, and thus economical construction. This level of the bottom of the pile caps is 1.0 m above MSL.

To maintain the appearance of the pile caps at low water levels a PC facing will be fixed to all faces of the pile cap. This facing will extend to approximately 1.0 m below MSL.

(5) Dimensions of box girders

1) Overall Depth

In general, for concrete box girder bridges, variable depth structures become appropriate economically and structurally for span lengths exceeding 60 meters. Also in using a variable depth girder for the central span, the required clearance height for navigation can be maintained most effectively, thus shortening the whole bridge length including approach viaducts. A variable depth girder has therefore been adopted.

In this case, the span/depth ratios have normally been selected as 18 to 20 at supports and 40 to

50 at midspan.

In this design, the following span/depth ratios have been adopted:

Span/depth ratios

at main pier	: 18
at mid span	: 48
at end pier	: 30

2) Configuration of box girder section

The bridge structure is so separated that Bangkok bound and Thonburi bound traffics are respectively carried by each single main girder, and the whole bridge consists of four T-shaped structures.

For the structure on the Bangkok side, the width varies from 14.65 m at midspan to 19.23 m at the end pier.

To keep the carriageway slabs within an economical thickness, the span length of the slabs cannot exceed approximately 6m, thus a box section with three webs has been adopted for the main girders on the Bangkok side.

Although for the central span of the upstream side, ordinary single box section is possible, in order to keep the smooth flow of the stresses caused in the girder, it is preferable not to change the configuration of the section in a continuous girder. Thus the whole structure on the Bangkok side consists of single box section with three webs. On the Thonburi side, the ordinary single box section is adopted without any problems.

The necessary web thickness has been determined by considering both the longitudinal shear strength and the minimum space requirement for longitudinal prestressing tendons. The web thickness is generally 360 mm or more to provide room for the anchorage hardware of 12T12.7 strand tendons which are frequently used in Thailand.

Vertical presstressing has been adopted in order to achieve the minimum possible thickness of web, thus reducing the weight of the girder structure. The thickness of the top slab has been controlled mainly by transverse bending moments, and has not been affected by longitudinal compression due to bending moments occurring in the box girder structure. As the top slab area forms a large part of the total cross sectional area of the box girder, the most economical design is achieved by reducing the top slab thickness. In view of this fact, transverse prestressing has been adopted in order to achieve the minimum possible thickness of top slab, thus reducing the weight of the girder structure.

3) Diaphragms

AASHTO specifications specify diaphragms at relatively small intervals in box girders. However, practice has proved that they are seldom required in box girders unless the bridge is sharply curved when diaphragms are needed to provide torsional rigidity.

The omission of intermediate diaphragms expedites construction since the diaphragms interfere with the repetitive construction cycle. Practically all of the recent long-span, cast-in-place segmental bridges have diaphragms only at the piers and the hinges.

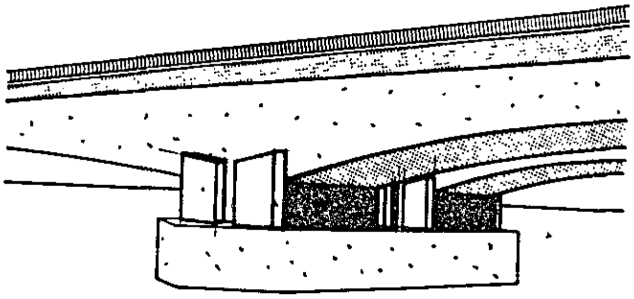
The omission of intermediate diaphragms requires that torsional moments must be transferred through bending of the slabs and webs. This load transfer is similar to that in a closed frame. The resulting additional bending moments in the top and bottom slabs and in the webs are small, requiring only a small increase in transverse deck and web reinforcement. For the above reasons, diaphragms have been omitted except at the piers and hinges. The cross sections of the main span box girders are shown on Drawing No. 12.

4) Prestressing Tendons

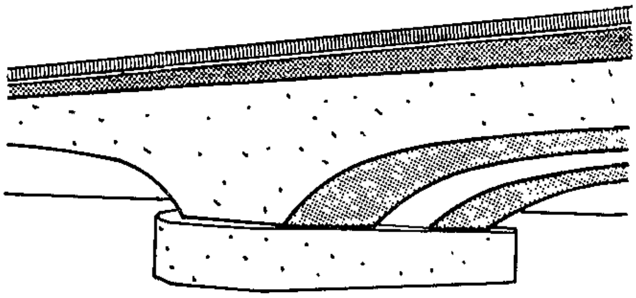
The following prestressing tendons have been assumed to be used for the main bridge:

Longitudinal prestressing tendons	- 12T12.7
Transverse prestressing tendons	- monostrand T 21.8
Vertical prestressing tendons	- PC Bar ϕ26

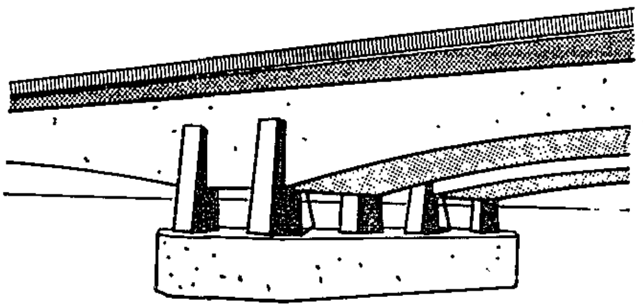
The unit price of prestressing strand per unit tensile force are generally cheaper than that of bar. However, for almost all of the prestressed concrete bridges having the span length of more than 100 meters, PC Bars have been usually adopted because of ease of handling. On the other hand, the convenient apparatus inserting strand tendons into the conduit which has been set up in the concrete member or automatic tensioning jacks have been recently developed in most countries. In case similar apparatuses were available in Thailand, strand tendons could be used for the cantilevering procedures without any problem. Therefore, the selection of prestressing tendons recommended for this bridge construction depends upon the availability of the said apparatus.



ALT. 1



ALT. 2



ALT. 3

FIG. 5-28 ALTERNATIVE OF MAIN PIER CONFIGURATION

5) Configuration of main bridge

To achieve lower cost and improve vertical alignment of rampways, providing shortest lengths, the lowest vertical alignment which maintains navigational clearance, has been adopted. Therefore, the distance between the bottom of the box girder and the top of the pile cap can be made very narrow causing a very important aesthetical problem to be solved.

Comparing many alternatives of the configuration, for instance as shown in Fig. 5-28, Alternative I has been adopted as the solution eliminating the unfavarable appearance mentioned above.

(6) Miscellaneous items

Care is required in selecting the types of railing, pavement, lighting facilities and drainage so that materials can be purchased in Thailand and minimum maintenance costs can be achieved.

1) Railings

Two types of railing will be used: Steel hand railing is to be used on the outsides of pedestrian walkways on the main bridge; an AASHTO type steel guard rail will be erected on the median strip and concrete barrier will be installed at the boundary between the carriageways and walkways.

2) Pavement

In order to achieve a good driving surface, an asphaltic concrete pavement 50 mm thick has been adopted for carriageways on bridge decks. On the pedestrian walkway, a concrete pavement of 50 mm thickness will be used.

3) Lighting

On the main bridges and the approach span, lighting facilities will be provided. Lighting poles will be erected on the outside of carriageways or walkways as appropriate.

4) Drainage

For drainage, catch basins will be installed on the boundary of the carriageways and the walkways on the main bridges and at the outer edge of carriageways on the approach viaducts.

On the main bridge, water can be drained directly to the river. On the viaducts water will be led to the lowest piers or abutment structures by use of steel box shaped gutters and led to their feet by use of PVC drainage pipes.

5) Staircases

Considerations regarding pedestrain usage of these bridges dictate that staircases should be installed at both ends of the main bridges to allow pedestrian access. As these staircases remove the need to continue the walkways along the approach spans, they also result in cost savings. By using the staircases, pedestrians crossing the main bridges can descend to the service roads on the river banks.

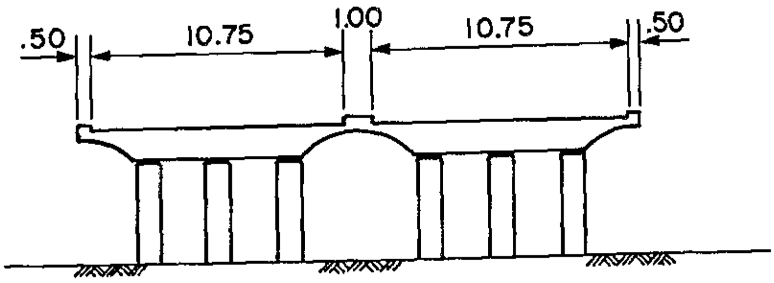
Standard details of railing, drainage and lighting facilities are shown on Drawings No. 28 and 27. The details of the staircases are shown on Drawing No. 17.

5-2-2 Viaducts

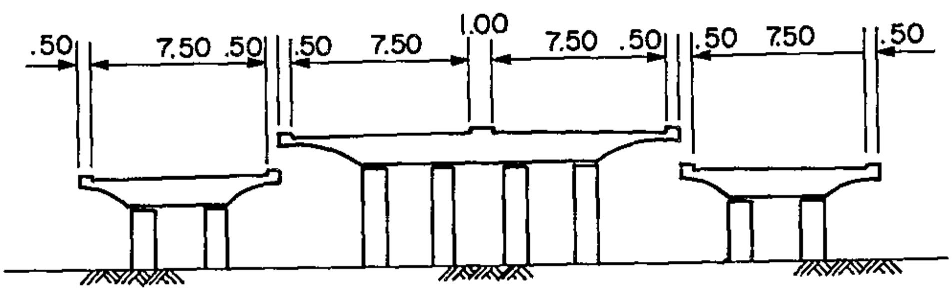
(1) Superstructure

On the Bangkok side of the bridge, a viaduct has been designed to flyover the Pibul Songkhram - Wongsawang intersection.

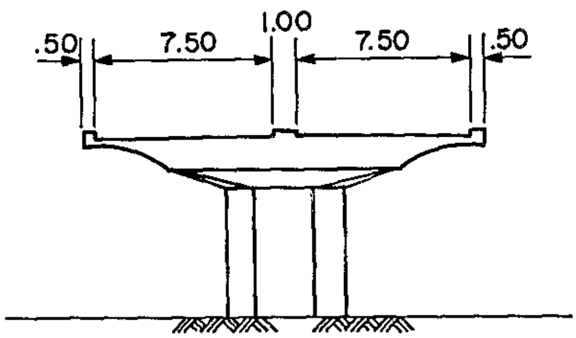
As the flyover viaduct goes through a busy commercial



THONBURI SIDE



BANGKOK SIDE



INTERSECTION

FIG. 5–29 CROSS SECTION OF VIADUCT

area, consideration must be made in designing the appearance of viaduct structures so as not to create an unpleasant feeling to pedestrians or inhabitants especially in looking-up at the viaduct structures.

Since it is necessary to provide waiting zones for right-turning vehicles under the viaduct, and also to attain sufficient sight distance, (a traffic signal will be installed at the intersection) slender piers at long spacings are more preferable in the design.

Under these designing conditions, a mushroom type prestressed concrete structure as shown in Fig. 5-29 has been considered as the most appropriate viaduct design.

For the section adjacent to the flyover section, a one-leg mushroom type pier and longer span will not be necessary. Also if rampways diverging from the end of main bridge would be so designed as to join into surface streets right under the viaduct, the right-of-way could be reduced substantially.

As a solution, the reinforced concrete slab has been adopted with cross sections shown in Fig. 5-29 having a span length of 17m for continuous 4 to 15 spans. Continuous structure promotes good trafficability and also reduced maintenance cost for expansion joints.

A cantilever slab configuration in both ends of cross section is similar with that of flyover section and also has the same girder depths resulting in a aesthetically harmonious appearance. Having span length of not less than 3.25 meters for the cantilever slab, one lane of rampway can be installed under the slab.

Viaduct portion of rampways and also of the Thonburi side approach will have same cross section with Bangkok side approach, in order to achieve more repetition of forms and falseworks and subsequently more economy.

Cross sections for each section shown in Fig. 5-29 have no voids to reduce weight in order to make construction easier. The increase of the dead weight is compensated by the ease of construction work and the reduction of formwork cost; thus it is economical.

(2) Foundation

Since the loading from the approach viaducts has been considerably smaller than that from the main bridge, the foundation can be sufficiently supported by the stiff clay stratum exsiting below MSL 20-meter depth.

Therefore, the foundation for the viaduct sections has been formed on driven piles made of precast prestressed concrete having 0.52 m x 0.52 m square cross-section.

In the vicinity of EGAT, pre-boring piling method of precast concrete piles will be used in order to eliminate unfavorable effects resulting from the driving method of precase concrete piles.

(3) Piers of concrete slabs

In designing the piers of the approach viaduct for the portion of the intersection on the Bangkok side, a sleek mushroom type structure has been adopted in order to attain an aesthetic appearance for drivers.

Accordingly, also for the adjacent section of the viaduct, a structure which has a favorable appearance and is also harmonious with the slender mushroom type piers, must be conceived.

As one-leg piers have been considered as uneconomical and also unnecessary from traffic control aspects, instead, multi-column type piers having a one-meter square cross-section have been adopted.

(4) Bearing

The loading from the superstructure is transmitted to the piers and the abutment structure through the bridge bearings; the bearings may be of rubber, or teflon/steel. The type of bearing used depends on the amount of movement expected and the purpose of the bearing, i.e. fixed or sliding.

The longitudinal movements by temperature change in the continuous viaducts, are about 5 to 50 mm and these movements can be accommodated by rubber bearings in suitable combination for the above types.

(5) Abutment Structure and Transition Structure

For the section with vertical clearance of less than 2.5m under the viaduct, abutment structure and transition structure will be adopted. These are of the same design used for all new bridges recently designed in Bangkok.

5-2-3 Minor bridges

The abutments of all minor bridges have been designed as modified structures of concrete sheet piles using king posts.

The arrangement of typical minor bridge substructure is shown on Drawing No. 22.

Superstructures of minor bridges are in accordance with DOH standards and consist of simply supported cast-in-situ reinforced concrete slabs. These slabs must be supported by temporary staging until the required concrete strength is achieved.

5-2-4 Railway Viaduct

(1) Bridge Type

As described in the Feasibility Study, the following difficulties have been involved in the structural choice and the construction method of the Thonburi side railway viaduct.

1) The difference in elevation between the railway and the proposed roadway is so narrow that the viaduct type has to be the through-type railway bridge in

order to attain the necessary vertical clearance thus making construction cost more expensive than in the case of a deck-type bridge.

2) Halting of train operation has to be avoided during the construction of the viaduct.

In order to solve these problems, the through-type prestressed concrete bridge for single-track railway has been proposed at the Feasibility Study stage.

However, during the first Preliminary Design stage, the SRT expressed its intention to start the Feasibility Study with regard to double tracking of the railway line.

Therefore, the following considerations have to be taken in order to avoid any critical problem in the realization of the double-tracking scheme.

In the case of double tracking of the existing RAMA VI Bridge, the distance between the center of the two tracks would be approximately 5.0 meters.

Upon adopting the prestressed concrete girder proposed in the Feasibility Study, the said distance would have to be widened to about 7.50 meters because of the use of 7.35 meters wide girders.

It is considered preferable to adopt the same 5-meter distances of the two track center lines for the RAMA VI Bridge section and also for that of the railway viaduct in the design of double-tracking scheme.

Although it is feasible to construct a through type prestressed concrete girder type for the double track usage with the center line distance of 5.0 meters, the weight of the girder would become so heavy that it would be difficult for short time construction. Also, even if the double tracking would be delayed considerably from the construction of the new RAMA VI Bridge, the viaduct should be constructed in advance in parallel with the construction of the main bridge.

As the solution, a through type steel girder bridge is proposed in this design, because the centerline distance of the two tracks can be reduced to 5.2 meters even in the case of constructing two separate single tracks. Also, the construction of the double track bridge in one-time can be much easier compared with the prestressed concrete bridge.

Due to the reasons stated above, the through-type steel girder bridge for single track railway has been adoped as shown in Drawing No. 23.

Also, as reference, a plan for one-time double tracks construction for the same steel type bridge has been described in Drawing No. 24.

(2) Construction Method

A highly complicated construction method has to be adopted in the construction of the railway viaduct. Although various technically feasible methods have been introduced recently, only one of the desirable methods is described below:

a) Select the time of day when train traffic is lightest.

b) H-shaped steel piles are driven at the encircling positions through embankment into a bearing stratum without touching any rails or sleepers. The piles are to be used for trench timbering during construction of pier and abutment and as temporary supports of the railway.

c) After driving all the piles, stringers and cross beams which directly support the sleepers are connected to H-shaped piles.

d) At this stage, works can proceed within the site area surrounded by H-shaped piles, without hindering any railway traffic, by excavating embankment and inserting sheathing plates between the adjacent two H-piles, thus building substructure of the viaduct including bored piles.

e) Girders are erected alongside the railway track and sleepers and rails will be placed upon the girders. After removing existing railway and ballasts and earth fill up to the bottom of the girder in a short period of time, an erected steel girder bridge will be placed on the substructure using a truck crane.

5-2-5 Construction Schedule

The whole period construction schedule including the main bridge and approach viaducts has been described in the schematic diagram in Fig. 5-30.

Supplement to 5-2-1 (Main Bridge)

Technical aspects of asymmetrical cross sections

The main bridge has its asymmetrical characteristics both traversely and longitudinally, which required some designing considerations.

On the Bangkok side half of the bridge, both accelaration and deccelaration lanes have to be installed besides both bound roadways, thus making the width of the bridge vary from the central span towards Bangkok. This has been caused because the distance between the end of the bridge and the Pibul-Wongsawang intersection has been too short.

As shown in Fig. 5-27, on account of different taper lengths of on-and-off rampways, variable cross sections for both Bangkok-bound and Thonburi-bound carriageways have to be adopted thus producing asymmetrical configurations.

To respond to these width-changing cross sections, 2-cell in 1-box section have been designed on Bangkok side half. During construction, therefore, width-changeable moving gantry (Vorbauwagen) has to be utilized for tapered sections.

Meanwhile, on Thonburi side, no speed changing lane has been needed and 1-cell in 1-box cross sections has been designed for T-frames. Many bridges with these asymmetrical features have been constructed in Japan and methods of structual analysis and construction procedures have long been established. It is generally recognized that there has been no technical difficulty in both designing and construction processes.

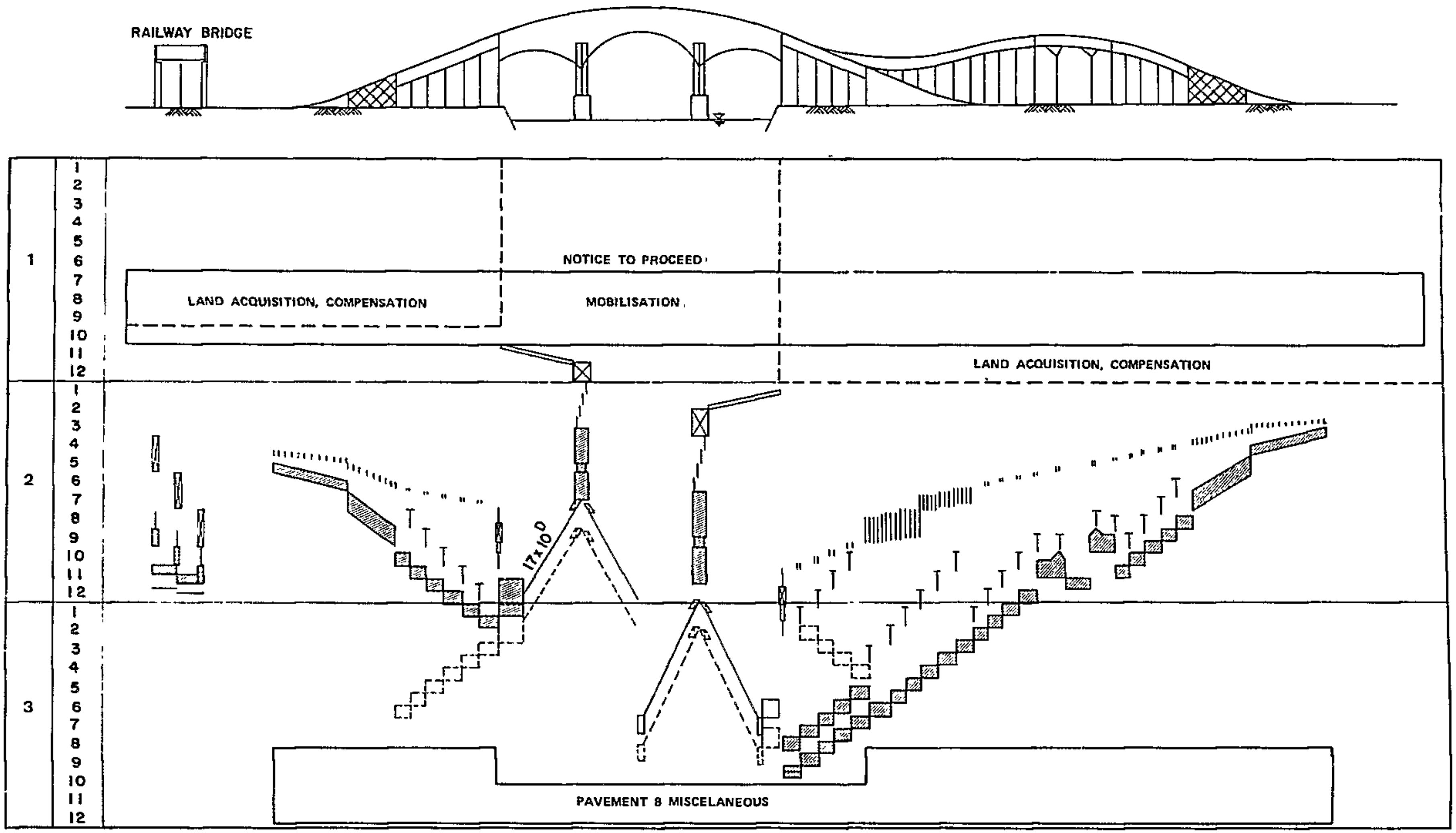


FIG. 5–30 CONSTRUCTION SCHEDULE

CHAPTER 6
COST ESTIMATES

CHAPTER 6
COST ESTIMATES

The costs derived in this report are based on the unit prices computed for the Feasibility Study, November 1981. During the Preliminary Design stage, the unit prices of the main items have been reviewed and unit prices of additional items have been calculated.

Based on the Preliminary Designs, new and more detailed bills of quantities have been prepared and these have been used in conjunction with the unit prices to obtain the cost estimates.

6–1 TOTAL PROJECT COST

The total project cost which include land acquisition costs, consultancy fees, construction costs and contingency sums is shown in Table 6-1.

6–2 CONSTRUCTION COSTS

The quantities for the construction items have been calculated based on the Preliminary Design drawings and standard methods of measurement. In order to obtain the total construction cost, these quantities have been multiplied at the unit rates. In developing the cost estimates, the following factor has been assumed.

- All construction costs are estimated on the basis of the recommended route alignment Alternative III-b.

The summary of the construction cost estimates and the cost breakdown are shown in Tables 6-2 and 6-3, respectively.

6–3 LAND ACQUISITION AND COMPENSATION COSTS

The land acquisition and compensation costs have been calculated based on data of land prices obtained from the local Government Administration officers in Bangkok and Nonthaburi Provinces. It is inevitable that there will be some minor modifications to the estimated prices at the time of actual negotiations. The cost breakdown of land acquisition and compensation costs is shown in Tables 6-4 and 6-5, respectively.

Table 6-1 Summary of Total Project Cost

Million Baht

Description	Amount	Remarks
Construction cost	505.8	Road & Bridge
Land Acquisition cost	52.0	
Compensation cost	107.0	
Subtotal	664.8	
Physical contingency	66.5	
Administrative cost	50.6	
Total	781.9	

Table 6-2 Summary of Construction Costs

Million Baht

Description		Amount	Remarks
A	Road	85.0	Incl. minor bridges
B	Main Bridges	254.0	
C	Viaducts	155.4	Incl. staircases
D	New railway bridge	11.4	
Total		505.8	

Table 6-3 Cost Breakdown

A : ROAD (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount	Remarks
A01	Embankment	CM	25,070	270	6,768,900	
02	Base Course 0.30 meter thick	CM	5,489	325	1,783,925	
03	Soil-Aggregate Subbase 0.15 meter thick	CM	3,161	325	1,027,325	
04	Sand Cushion 0.05 meter thick	CM	3,022	270	815,940	
05	Concrete Pavement 0.25 meter thick	SM	18,297	370	6,769,890	Bangkok side
06	Concrete Pavement 0.23 meter thick	SM	21,070	340	7,163,800	Thonburi side
07	Sidewalk	SM	11,115	170	1,889,550	
08	Island	SM	8,304	20	166,080	
09	Concrete Curb	LM	6,362	210	1,336,020	
10	Drainage : ø1.50 m.RCP W/Manholes @ 30.0 m.	LM	1,980	5,000	9,900,000	Bangkok side
11	Drainage : ø0.60 m.RCP W/Manholes @ 10.0 m	LM	1,980	2,345	4,653,100	
12	Drainage : Box Culvert	LM	1,586	7,300	11,577,800	Thonburi side
13	Lighting	SM	50,482	40	2,019,280	
14	Road Marking	SM	1,570	200	314,000	
15	Traffic Signal System	LS	-	-	390,000	
16	Minor bridges	LS	-	-	28,434,000	
	TOTAL				84,999,610	

Note - LM ; linear meter SM ; square meter
CM ; cubic meter LS ; lump sum

B. MAIN BRIDGE

B.1 FOUNDATION WORKS

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
B1 01	Concrete piles of ø 1.50	LM	2520	23,400	58,968,000
02	Testing load of concrete pile, ø 1.50	EA	2	225,000	450,000
Total Amount					59,418,000

NOTE EA : each

B.2 REINFORCEMENT

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
B2 01	Round bar, SR 24	T	3	13,720	41,160
02	Deformed bar, SD 30	T	965	13,400	12,931,000
03	PC tendon 12T12.7	T	511	61,500	31,426,500
04	PC tendon bar	T	235	93,800	22,043,000
Total Amount					66,441,660

NOTE T : metric ton

B.3 CONCRETE

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
B3 01	Substructure, pile cap on river	CM	1,685	4,500	7,582,500
02	Substructure, pier on river	CM	298	6,830	2,035,340
03	Superstructure, box girder	CM	8,511	12,600	107,238,600
04	Superstructure, curb and barrier	CM	276	3,740	1,032,240
Total Amount					117,888,680

B.4 BRIDGE PAVEMENT (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
B4 01	Asphaltic concrete, carriageway, t=50 mm	SM	6,970	125	871,250
02	Concrete, sidewalk, t=50 mm	SM	1,450	102	147,900
Total Amount					1,019,150

B.5 BRIDGE RAILING (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount	Remarks
B5 01	Steel guard rail	LM	290	610	176,900	median
02	Steel hand rail	LM	580	860	498,800	sidewalk
Total Amount					675,700	

B.6 VARIOUS ACCESSORIES (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount	Remarks
B6 01	Steel sliding bearing (A)	EA	10	300,000	3,000,000	
02	Steel sliding hinge	EA	4	216,000	864,000	
03	Expansion joint, steel finger type (A)	LM	53.5	51,600	2,760,600	end pier
04	Expansion joint, steel finger type (B)	LM	21.5	54,000	1,161,000	center of mid span
05	Drainage	LS	-	374,000	374,000	
06	Street lighting, 200 W lamp, 10 m pole	LS	-	395,000	395,000	
Total Amount					8,554,000	

Total Amount of Main Bridge 253,997,190

C. VIADUCTS

C.1 EARTHWORKS

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C1 01	Excavation and backfill	CM	12,099	110	1,330,890
	Total Amount				1,330,890

C.2 FOUNDATION WORKS

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C2 01	Concrete pile of 0.525 x 0.525	LM	17,940	1,100	19,734,000
02	Concrete pile of 0.35 x 0.35	LM	4,830	1,090	5,264,700
03	Test piles of 0.525x0.525	EA	2	33,600	67,200
	Total Amount				25,065,900

C.3 TRANSITION STRUCTURE

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C3 01	Transition Structure	LS	-	-	6,011,000
	Total Amount				6,011,000

C.4 RIVER BANK STRUCTURE (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C4 01	River bank structure (Incl. take out cost of obstacles)	LS	-	-	14,570,000
	Total Amount				14,570,000

C.5 REINFORCEMENT (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C5 01	Round bar, SR 24	T	114	13,720	1,564,080
02	Deformed bar, SD 30	T	2,162	13,400	28,970,800
03	PC strands 12T12.7	T	123	61,500	7,564,500
	Total Amount				38,099,380

C.6 CONCRETE (unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C6 01	Substructure, pile cap on land	CM	4,691	1,870	8,772,170
02	Substructure, pier and wall	CM	2,086	2,610	5,444,460
03	Superstructure, prestressed concrete slab	CM	1,535	4,020	6,170,700
04	Superstructure, reinforced concrete slab	CM	9,629	3,880	37,360,520
05	Superstructure, curb and barrier	CM	519	3,740	1,941,060
	Total Amount				59,688,910

C.7 BRIDGE PAVEMENT

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C7 01	Asphaltic concrete t = 50mm	SM	14,236	125	1,779,500
Total Amount					1,779,500

C.8 BRIDGE RAILING

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount	Remarks
C8 01	Steel guard rail	LM	583	610	355,630	median
02	Steel hand rail	LM	55	860	47,330	stair-cases
Total Amount					402,930	

C.9 VARIOUS ACCESSORIES

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
C9 01	Rubber bearing (A) R=120^t	EA	130	4,680	608,400
02	Rubber bearing (B) R=240^t	EA	14	9,120	127,680
03	Expansion joint	LM	133	48,000	6,384,000
04	Drainage	LS	-	848,000	848,000
05	Street lighting, 200 W lamp, 10m pole	LS	-	458,000	458,000
Total Amount					8,426,080

Total Amount of Approach Bridge 155,374,590

D. NEW RAILWAY BRIDGE

(unit: Baht)

Item	Description	Unit	Quantity	Unit Rate	Amount
01	New railway bridge	LS	-	-	11,400,000
Total Amount					11,400,000

Table 6-4 Land Acquisition Cost

(unit: Baht)

STA. NO.	Area SM	Unit Rate B/SM	Amount	Remarks
No. 0+0.0 0+300.0	4,463	750 2,250	7,044,750	
No. 0+350.0 0+650.0	14,317	280 940	4,914,470	
No. 0+650.0 0+800.0	10,307	280 940	3,647,850	
No. 1+100.0 1+250.0	12,617	560 2,250	13,638,320	including plywood factory
No. 1+250.0 1+400.0	4,730	2,250	10,642,500	
No. 1+400.0 Pracharat I Road	3,980	560 2,250	3,573,240	
No. 1+400.0 1+750.0 (END)	3,780	2,250	8,505,000	
Total			51,966,130	

NOTE :

1. No. 0+300.0 0+350.0 .... railway space
2. No. 0+800.0 0+1,100.0 .... on river

Table 6-5 Compensation cost

(unit: Baht)

Description	Unit	Unit Rate	Remarks
Removing of cables across the river	LS	35,000,000	69 KV 1 circuit 12 KV 1 circuit
Removing of cables on land	LS	5,000,000	69 KV 1 circuit 12 KV 1 circuit
Houses :-Concrete Frame :-Wooden Frame	 LS LS	 3,224,000 8,066,400	including Removing cost
Commercial Buildings :-Concrete Frame :-Wooden Frame	 LS LS	 13,024,260 3,508,890	including Damage and Removing cost
Factories :-Thonburi side :-Bangkok side	 LS LS	 15,237,440 15,728,400	including Removing and Relocation cost
Removing of public utilities of M.E.A. and N.W.W.A.	LS	8,230,000	
TOTAL		107,419,390	

CHAPTER 7

REVISED ECONOMIC EVALUATION

CHAPTER 7
REVISED ECONOMIC EVALUATION

In this Preliminary Design stage, a refinement of the design outlined in the Feasibility Study has been made and more accurate construction costs as well as land acquisition and compensation costs have been obtained.

The total cost of the project estimated in the previous chapter is 781.9 Million Baht which totals approximately 98% of the 800 Million Baht estimated in the Feasibility Study.

7-1 BENEFIT-COST RATIO

Since the economic benefit has not been changed either in the Feasibility Study or in this Preliminary Design, analysis is based on the revised economic cost stream in this study and the estimated economic benefit stream in the previous Feasibility Study, each converted to initial year by 12%, which is an assumed opportunity cost in Thailand. The discounted benefit and cost totals are summarized below.

		Thousand Baht, mid 1981 price
Present value of benefits		1,380,960
Present value of costs		721,244
Net Present Value (B - C)	=	659,716
Benefit-Cost Ratio B/C	=	1.91

Since the benefits of the Project are almost double the costs, the project can be strongly considered to be viable.

7-2 INTERNAL RATE OF RETURN

Discounting both the revised economic cost stream and the previously obtained economic benefit stream over 30 years project life period, IRR has been calculated by the following formula using the data in Table 7-1.

$$\text{I.R.R.} = (20\%) + \frac{24771}{24771 + 15472} \times (21\% - 20\%)$$

$$= 20.6\%$$

The new IRR of 20.6% is 0.3% higher than the previous IRR 20.3% obtained in the Feasibility Study stage. The value indicates that the New RAMA VI Bridge Project is highly feasible since the IRR exceeds the nation's assumed opportunity cost of funds which is 12%.

Table 7-1 Cash Flow for IRR

Thousand Baht, Mid 1981 price

Project Year	Calendar Year	COST			BENEFIT		
		Undiscounted	Discounted at 20%	Discounted at 21%	Undiscounted	Discounted at 20%	Discounted at 21%
1	1981	238454	238454	238454	0	0	0
2	1982	227693	189744	188176	0	0	0
3	1983	250018	173623	170765	0	0	0
4	1984	12220	7071	6897	151100	87442	85292
5	1985	12220	5893	5700	165200	79668	77067
6	1986	12220	4910	4711	177700	71413	68511
7	1987	12220	4092	3893	186300	62391	59360
8	1988	12220	3410	3217	197200	55034	55928
9	1989	12220	2841	2659	212000	49304	46137
10	1990	20720	4015	3726	183200	35505	32950
11	1991	12220	1973	1816	188700	30476	28049
12	1992	12220	1644	1501	202000	27186	24814
13	1993	12220	1370	1240	212300	23810	21553
14	1994	12220	1142	1025	223200	20861	18727
15	1995	12220	951	847	232200	18085	16101
16	1996	12220	793	700	241600	15681	13845
17	1997	20720	1120	981	251500	13603	11911
18	1998	12220	550	478	261800	11800	10247
19	1999	12220	458	395	272600	10239	8818
20	2000	12220	382	326	283900	8886	7590
21	2001	12220	318	270	295700	7713	6533
22	2002	12220	265	223	308100	6697	5635
23	2003	12220	221	184	321100	5816	4845
24	2004	20720	312	258	334700	5052	4174
25	2005	12220	153	125	349000	4390	3597
26	2006	12220	128	104	363900	3814	3099
27	2007	12220	106	86	379700	3316	2673
28	2008	12220	88	71	396000	2882	2304
29	2009	12220	74	58	413300	2507	1987
30	2010	12220	61	48	425300	2150	1690
31	2011	20720	87	68	450300	1896	1478
32	2012	12220	42	33	470200	1650	1276
33	2013	12220	35	27	491000	1436	1101
		-137298	-401	-307			
TOTAL		979467	645943	638767	8640800	670714	623295

CHAPTER 8

BUDGETARY AND FINANCIAL STUDIES

CHAPTER 8
BUDGETARY AND FINANCIAL STUDIES

In this chapter, practical financial requirements of two cases of inflationary rates are calculated and the most probable construction schedule with its starting date is set.

In addition, the disbursement schedule for each year with relative proportions of foreign and local currency required during the construction period, considering the sources and terms of funding is also estimated.

8–1 ESTIMATED FINANCIAL COST

Financial cost, studied in Chapter 6, is estimated, based on mid 1981 price with no account taken of price escalation and construction starting date. However, to determine the budget and disbursement schedule to finance the project, it is necessary to consider these practical financial factors.

The total financial cost in mid 1981 price is 781.9 Million Baht, including the cost of the detail design as summarized below.

Summary Cost Table, financial mid 1981 price (Million Baht):

	Foreign Portion	Local Portion	Total
Construction Cost	252.8	253.0	505.8
Main Bridge	(137.2)	(116.8)	(254.0)
Highway Viaduct	(68.4)	(87.0)	(115.4)
Road Work	(40.8)	(44.2)	(85.0)
Railway Viaduct	(6.4)	(5.0)	(11.4)
Land Acquision	-	52.0	52.0
Compensation	35.7	71.3	107.0
Contingency	28.2	38.3	66.5
Administrative Cost	25.4	25.2	50.6
TOTAL COST	342.1	439.8	781.9

8–2 CONSTRUCTION SCHEDULE

A time schedule for project construction is provided in Construction Schedule of Chapter 5.

The most probable actual starting date of construction seems to be October 1983 with commencement of land acquisition 6 months prior to this date and completion of the project in 30 months (2 1/2 years) after the notice to commence work.

Estimation of total expense was studied, based on this schedule of construction, considering each component of the project.

8-3 FORECAST OF PRICE ESCALATION

The rate of inflation has fluctuated considerably in recent years and has shown unpredictable change within relatively short period.

As analyzed in the Feasibility Study, the rate of price escalation has been double digit since 1978 and the price escalation of construction materials has always exceeded the average rate of inflation. Considering these factors together with the information obtained through the discussions with the government officials of Thai and intensive field survey, the probable rate of increase is estimated at between 15% and 18% per annum.

8-4 ESTIMATES OF TOTAL EXPENSES

Based on paragraphs 8-1 to 8-3 mentioned above, forecast total expense is calculated as 1,223.61 Million Baht in case of 15% price escalation and 1,331.46 Million Baht in case of 18%.

The price escalation of the foreign exchange component and local currency portion were assumed to be equal with no devaluation of foreign exchange rate during the implementation period.

8-5 FOREIGN EXCHANGE COMPONENT

The cost estimates, studied in chapter 6, are broken down into foreign currency and local currency, since cost estimates are an aggregate accumulating each item after comparing price difference and quality.

The percentages of foreign exchange component and local currency portion are 44% and 56% respectively.

8-6 FINANCIAL SOURCES AND TERMS OF FUND

Local currency portion of the project cost is supposed to be financed by the Government budget. Since the Government of Thailand is strongly supporting this project, there is little doubt about the finance for local currency portion including the foreign currency component interest and amortization. Therefore, it is not necessary to consider the terms of fund.

Concerning the foreign currency portion, PWD has a plan to apply to OECF of Japan for finance of the foreign currency component of the project.

Based on the experience from the Memorial Bridge Project of 1980 and Nonthaburi, Phathumthani Bridge Project of 1981 (both financed by OECF), the terms of OECF funds will be 3.0% interest rate and 30 years amortization period with 10 years grace period and two payments a year.

8-7 BUDGETING

Maintenance cost per year, studied in the Feasibility Study, is estimated as 12.22 Million Baht for yearly maintenance and 8.5 Million Baht for periodic maintenance, each in financial terms and mid 1981 price.

Assuming 15% price escalation for the implementation period and 7.3% price escalation thereafter based on the special procurement method for maintenance, the cost stream for maintenance is as follows (in Million Baht):

1986	1987	1988	1989	1990	1991	1992	1993
10.7	22.9	24.6	26.4	28.3	30.4	55.2	35.0

*Note: 1986 is allocated only 50% of estimated yearly maintenance.

Interest payments for foreign currency component are estimated at 3% interest and the balance of the principal rounded off (in Million Baht).

1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
0.17	1.81	4.58	10.11	14.73	16.43	16.43	16.43	16.43	16.43	113.55

*Note: In 1982, 50% of the normal interest payment is calculated for the amounts spend in the initial year.

According to the terms of funding, these interest amounts will total 113.55 Million Baht by the end of 1991, in view of the 10 year grace period of the foreign loan.

Provision of local currrency protion is discussed in Section 8-8, the disbursement schedule and amortization is examined and described in detail in Section 8-9 below.

The local currency cost stream including 15% price escalation is as follows (in Million Baht).

1982	1983	1984	1985	1986	TOTAL
5.75	68.24	287.73	204.71	110.45	676.88

The case of 18% price escalation is not examined here, but it is approximately 1% higher than the case of 15% price escalation.

PWD on behalf of Government of Thailand should schedule and provide the yearly funding for the local currency portion, amortization, interest payments, and maintenance expense for the schedule as estimated above.

8–8 DISBURSEMENT SCHEDULE

The total cost, estimated above will be dispersed over the implementation period (1981 - 1985) as shown in Table 8-1 which presents data for each 15% and 18% price escalation forecasts.

unit: Million Baht
( ) = Million Yen

Table 8-1 Summary of Disbursements

Estimated Price Escalation Rate	Item		Fy 1981	Fy 1982	Fy 1983	Fy 1984	Fy 1985	TOTAL
15%	Foreign Currency Component	Administration	115.0	41.4	72.9	83.8	45.6	358.7
		Land Aq. & Compensation		461.3				461.3
		Construction			1,515.6	1,691.7	983.0	4,190.3
		Contingency		37.5	151.6	169.2	98.7	457.0
		(TOTAL in 10^6 Yen)	(115.0)	(540.2)	(1,740.1)	(1,944.7)	(1,127.3)	(5,467.3)
		TOTAL in 10^6 Baht	11.50	54.02	174.01	194.47	112.73	546.73
	Local Currency Portion	Administration	5.75	5.17	9.66	11.11	6.08	37.77
		Land Aq. & Compensation		56.60	102.73			159.33
		Construction			148.59	176.00	94.88	419.47
		Contingency		6.47	26.75	17.60	9.49	60.31
		TOTAL	5.75	68.24	287.73	204.11	110.45	676.88
	Grand Total		17.25	122.26	461.74	399.18	223.18	1,223.61
18%	Foreign Currency Component	Administration	118.0	43.3	78.4	92.5	51.3	383.5
		Land Aq. & Compensation		483.6				483.6
		Construction			1,630.3	1,867.2	1,106.1	4,603.6
		Contingency		39.3	163.1	186.8	111.1	500.3
		(TOTAL in 10^6 Yen)	(118.0)	(566.2)	(1,871.8)	(2,146.5)	(1,268.5)	(5,971.0)
		TOTAL in 10^6 Baht	11.80	56.62	187.18	214.65	126.85	597.10
	Local Currency Portion	Administration	5.90	5.42	10.39	12.26	6.84	40.81
		Land Aq. & Compensation		59.33	107.69			167.02
		Construction			159.84	194.26	106.77	460.87
		Contingency		6.78	28.77	19.43	10.68	65.66
		TOTAL	5.90	71.53	306.69	225.95	124.29	734.36
	Grand Total		17.70	128.15	493.87	440.60	251.14	1,331.46

NOTE : .... Exchange rate
10 Yen = 1 Baht

The disbursement schedule was based on the following payment factors:

I)	Land Aquisition and Compensation for factories, etc.	paid in 6 months preceding construction
II)	Construction Cost	10%, paid in one month after contract signing as mobilization
		80%, paid in monthly increments in accordance with the work completed
		10%, retention paid on issue of completion certificate
III)	Supervision Fee	paid in monthly increments over the contract period

The total cost was thus divided to conform to the payment schedule. For budgeting purposes, disbursement during the Thai Fiscal Year is required; i.e., from October 1 to September 30.

8–9 FOREIGN CURRENCY LOAN REPAYMENT SCHEDULE

Equal amortization payments were calculated based on the total principal and interest outstanding at the end of the grace period of 10 years; i.e., 6,602.8 million yen (660.28 million baht) the end of 1991.

The repayment schedule for the foreign currency component over 20 years from 1992 to 2011 is as follows:

Million Yen, (Million Baht)

1992	1993	1994	1995	1996	1997	1998	1999
582.2	518.3	508.4	498.5	488.6	478.7	468.8	458.9
(52.82)	(51.83)	(50.84)	(49.85)	(48.86)	(47.87)	(46.88)	(45.89)

2000	2001	2002	2003	2004	2005	2006	2007
449.0	439.1	429.2	419.3	409.4	399.5	389.6	379.7
(44.90)	(43.91)	(42.92)	(41.93)	(40.94)	(39.95)	(38.96)	(37.97)

2008	2009	2010	2011
369.8	359.9	349.9	340.0
(36.98)	(35.99)	(34.99)	(34.00)

It is expected that, the loan for the proposed project would be acquired from external resources, such as international loan institutions or international cooperation agencies for developing countries, in terms of U.S. Dollar or Japanese Yen.

It should be noted that, therefore, in case of devaluation of Baht during the project period, the payment in terms of Baht would increase substantially in the amount.

Although it might be unrealistic not to consider the possible case of devaluation of Baht during the period of 30 years, it had to be assumed, in the evaluation of this study, that the rate of exchange of the local currency against the international hard currencies would not be devalued during the project time.

CHAPTER 9

IMPLEMENTATION PROGRAM

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IMPLEMENTATION PROGRAM

9–1 SCHEDULE OF ACTIVITIES

The necessary activities in order to complete construction of the bridges can be categorized into the following groups :

- Detailed Designing
- Land Acquisition
- Pre-qualification of Contractors
- Tender Procedures
- Construction Work

The time allowed for each operation is shown in the overall schedule, Fig. 9-1.

It is assumed that the final detailed design will be completed by the end of September 1982.

Land acquisition is the responsibility of PWD. The engineering firm conducting the detailed design is required to furnish the right-of-way maps. These should be available during the final stage of detailed design.

Land acquisition by PWD will be able to be started in April 1982. Although the adopted alignments in this project have tried to avoid difficult areas, some purchasing problem on the Bangkok side might occur since many small pieces of land are involved.

The time estimated for pre-qualification of the main contractors is 4 months and for the completion of tender procedures, another 5 months. The construction will be able to be commenced in October 1983, which will coincide with the start of the 1983/84 Fiscal Year.

The construction schedule is shown in Fig. 5-30.

9–2 CONTRACTUAL ARRANGEMENTS

Considering the scale and complexity of the main bridge and approachs viaduct including a difficult flyover and a railway viaduct, it is desirable for the contract to be awarded by competitive tender of pre-qualified international contractors.

The important criteria used in evaluating the pre-qualification documents will be decided by PWD, but the following factors should be taken into consideration.

- Experience and past performance in similar projects
- Personnel available
- Plant and equipment available
- Financial status
- Previous experience in Thailand
- Association with local contractors

As the present project is to be externally financed, any additional requirements of the lending agency must also be considered.

It is recommended that the bridge and the approach viaducts including an interchange and a railway bridge should be tendered as one contract, so that whole responsibility for maintaining the construction program goes to one main contractor.

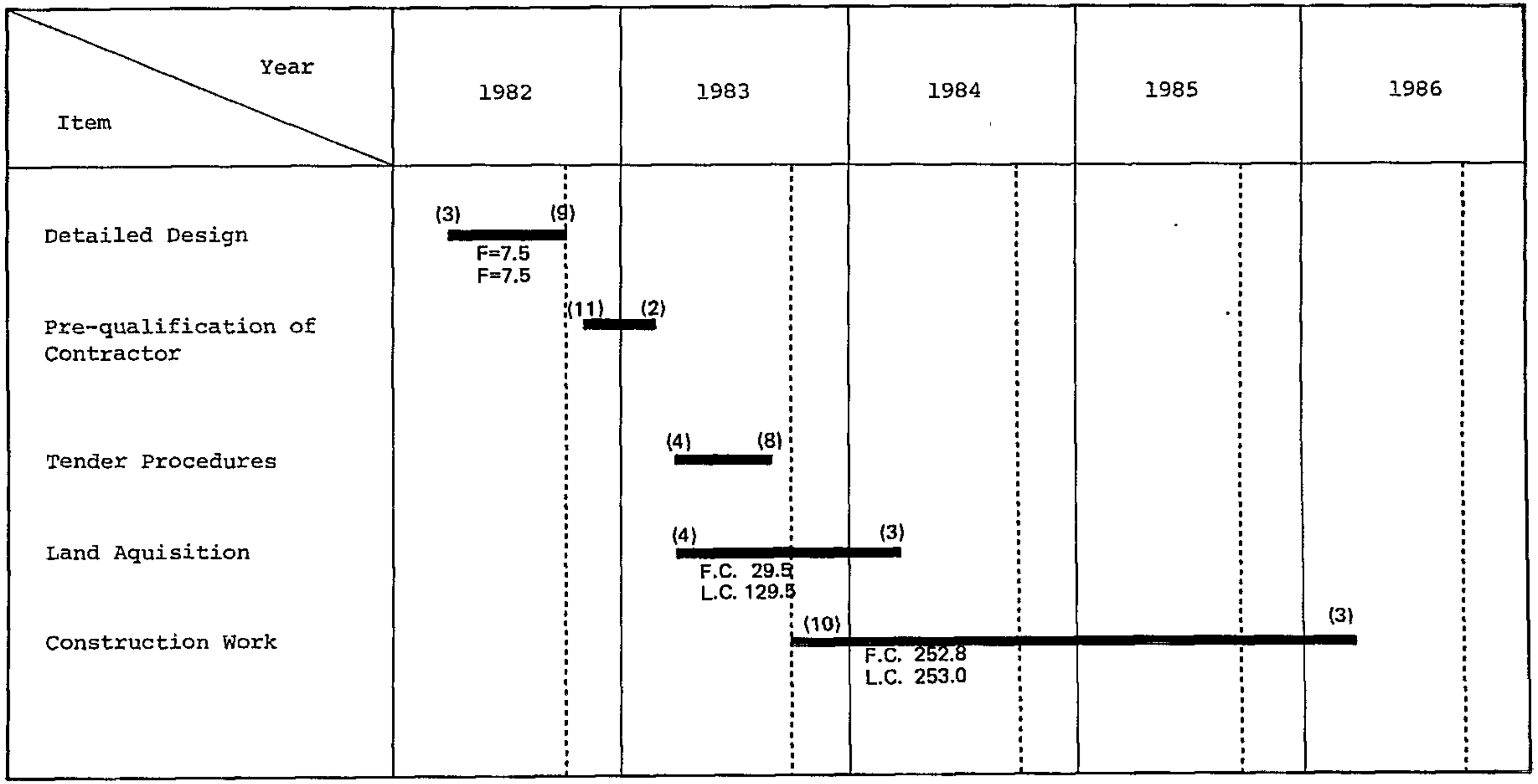
The contract should stipulate the degree of local participation required to ensure that Thai contractors fully participate in the construction.

9–3 PUBLIC FACILITIES

As the new route alignments will force the plywood factory to abandon its present premises, it would be desirable to utilize the remaining space in the area as a public park. The small areas encircled by the small trumpet interchange on the Thonburi side can be utilized as green areas.

As described previously, pedestrian walkways and staircases have been provided for the main bridge to allow direct access to the river banks. These should give convenience to the public on both sides of the river where considerable pedestrian traffic is expected.

FIG. 9–1 IMPLEMENTATION SCHEDULE



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