NO. 56

THE KINGDOM OF THAILAND

The Feasibility Study on

THE RAMA VI BRIDGE CONSTRUCTION PROJECT

SUMMARY REPORT

MARCH 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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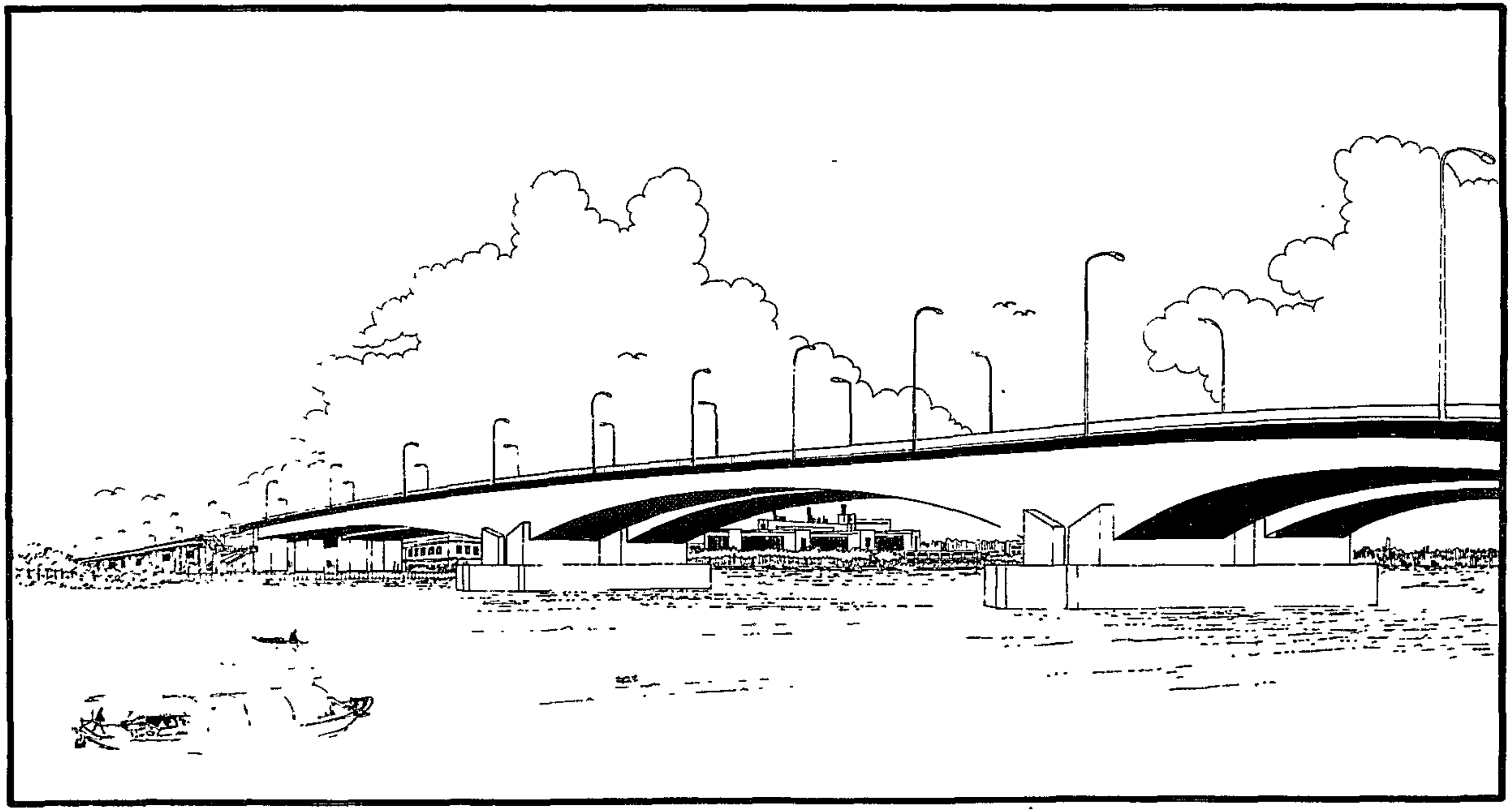

THE NEW RAMA VI BRIDGE – PERSPECTIVE VIEW

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SUMMARY

I. Background

In view of the rapid increase of traffic on the Middle Ring Road which has been constructed more than half of the whole route encircling around the Bangkok Metropolitan Area, the Public Works Department (PWD) of the Government of Thailand made a request in July 1980, to the Government of Japan to conduct a feasibility study on constructing a new bridge in the vicinity of the existing RAMA VI Bridge.

In response to the request, the Japanese Government decided to cooperate with the Government of Thailand and entrusted the Japan International Cooperation Agency (JICA) with dispatching a preliminary survey team led by Dr. Hirohiko Tada in March 1981 to Bangkok to formulate the scope of work for the New RAMA VI Bridge Construction Project.

As a result, an agreement was set forth between both the Thai and Japanese Government and the Feasibility Study for the said project was commenced in Thailand for 11 months starting May 1981 by the JICA Study Team headed by Mr. Terukazu Endo.

II. The Study

The study was made up of two phases: the first Phase I Study as a feasibility study and the second Phase II Study as a preliminary design of the proposed bridge.

The Phase I Study, (Feasibility Study) including traffic surveys, future traffic forecast, socio-economic studies, outline design of bridge and roads together with a tentative evaluation of the project, started in June 1981 and was carried out until September 1981 for 3 months, and a draft final report was submitted to PWD.

The report included a conclusion that the study project was to be highly feasible, from both technical and economic points of view.

After reviewing the Draft Final Report in Phase I, PWD issued a comment for the report giving an approval for further study, by determining a route alignment and a bridge type as the optimum design alternatives. The Final Report in Phase I (Feasibility Study) was prepared and submitted to PWD in December 1981.

The Phase II Study included topographic and soil surveys, the Preliminary Design of the bridge and roads and final evaluation of the study. The Study has been conducted from October 1981 to December 1981 and more elaborate design and accurate cost estimates of the project were obtained. The technical data collected from surveys and analyses in the Preliminary Design all have verified the previously established design factors to be correct and appropriate. Except for only a few minor alternations of the designs, no major problem occurred during the Phase II Study.

The Draft Final Report in Phase II (Preliminary Design) was prepared in December 1981 and submitted to PWD. The Final Report in Phase II was to be finalised by the JICA Study Team which returned to Japan in December 1981.

This report constitues the Summary Report for both Phase I and II Studies and is to be submitted to PWD in March 1982 together with the Final Report in Phase II.

III Conclusions

The Total Cost

The total construction cost has been estimated to 782 millon Baht (mid 1981 price), a cost breakdown of which is shown as follows:

(Unit: 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)	(155.4)
Road Work	(40.8)	(44.2)	(85.0)
Railway Viaduct	(6.4)	(5.0)	(11.4)
Land Acquisition	-	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

The percentage of the foreign and local currency portions to the total cost is 44% for the foreign portion and 56% for the local portion.

The same percentages against the total of construction cost excluding those of land aquisition and compensation are almost 50% and 50% (252.8 and 253 million Baht).

NPV and IRR

In order to determine the viability of the project, the Net Present Value and Internal Rate of Return have been calculated in the final evaluation, using the same benefit values studied in the Phase I Study.

Net Present Value (NPV) 659.7 million Baht

Internal Rate of Return (IRR) 20.6%

The resulting indices above both exceed the necessary threshold value for construction project in Thailand by wide margin thus verifying the feasibility of the project.

However, in case the present trend of inflation in Thailand would prevail for the next 5 years, the total disbursement expected for an assumed construction period of

30 months starting from autumn 1983, would amount up to 1,224 million Baht in the case of 15% inflation and 1,331 million Baht in 18% inflation.

It is strongly recommended, therefore, to commence the construction of this project in an earlier possible time.

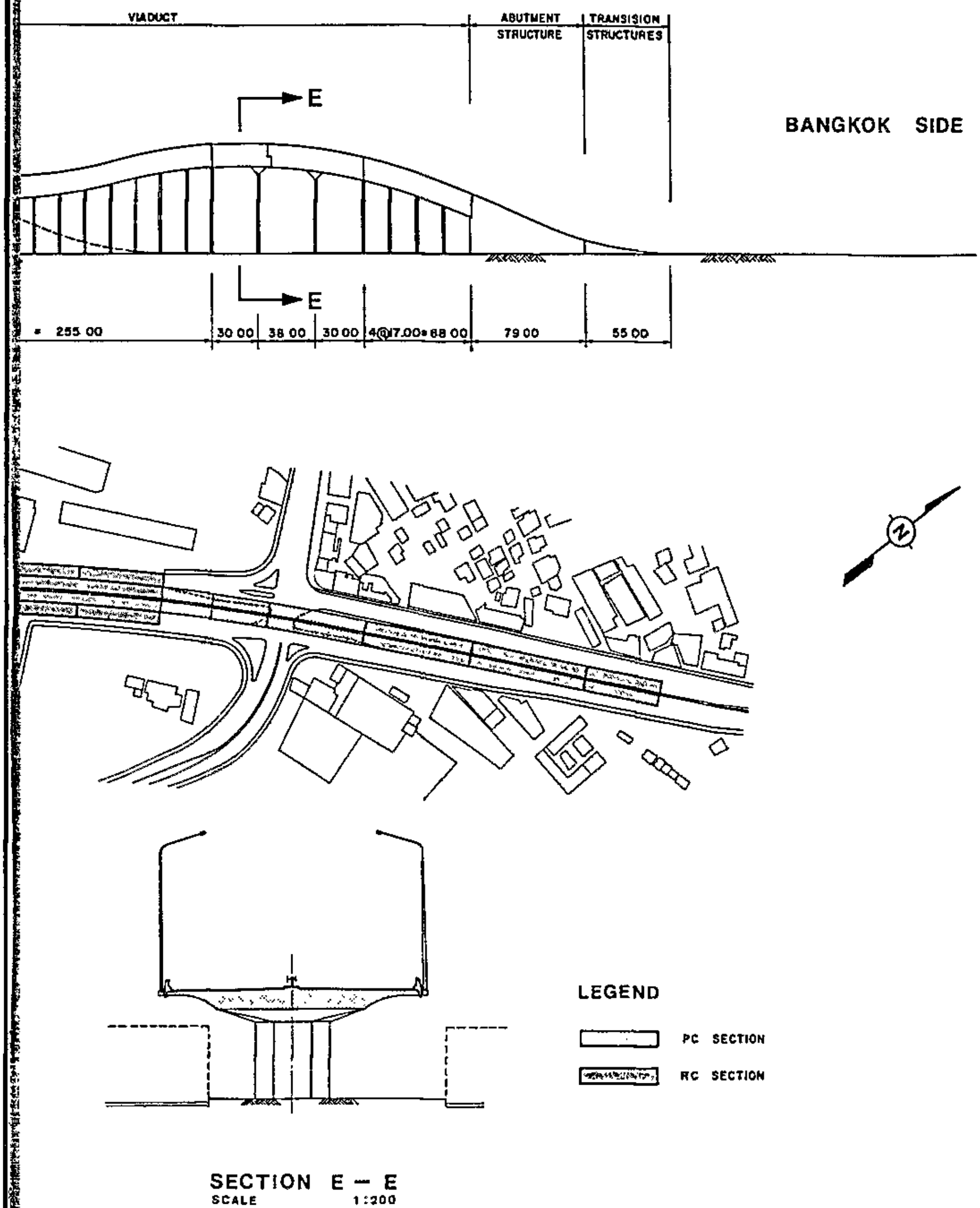

Fig. 1 BRIDGE – PLAN AND ELEVATION

PRELIMINARY ONLY
REDUCED TO HALF SCALE

KINGDOM OF THAILAND
MINISTRY OF INTERIOR-PUBLIC WORKS DEPARTMENT

THE FEASIBILITY STUDY
ON THE RAMA VI BRIDGE CONSTRUCTION PROJECT

BRIDGE – PLAN AND ELEVATION

JAPAN INTERNATIONAL COOPERATION AGENCY

DESIGNED	
DRAWN	
CHECKED	
SCALE	AS SHOWN
DATE	DEC 1981
SUBMITTED BY	PROJECT MANAGER
DRAWING NO	10

REVISION	DATE	CHECKED

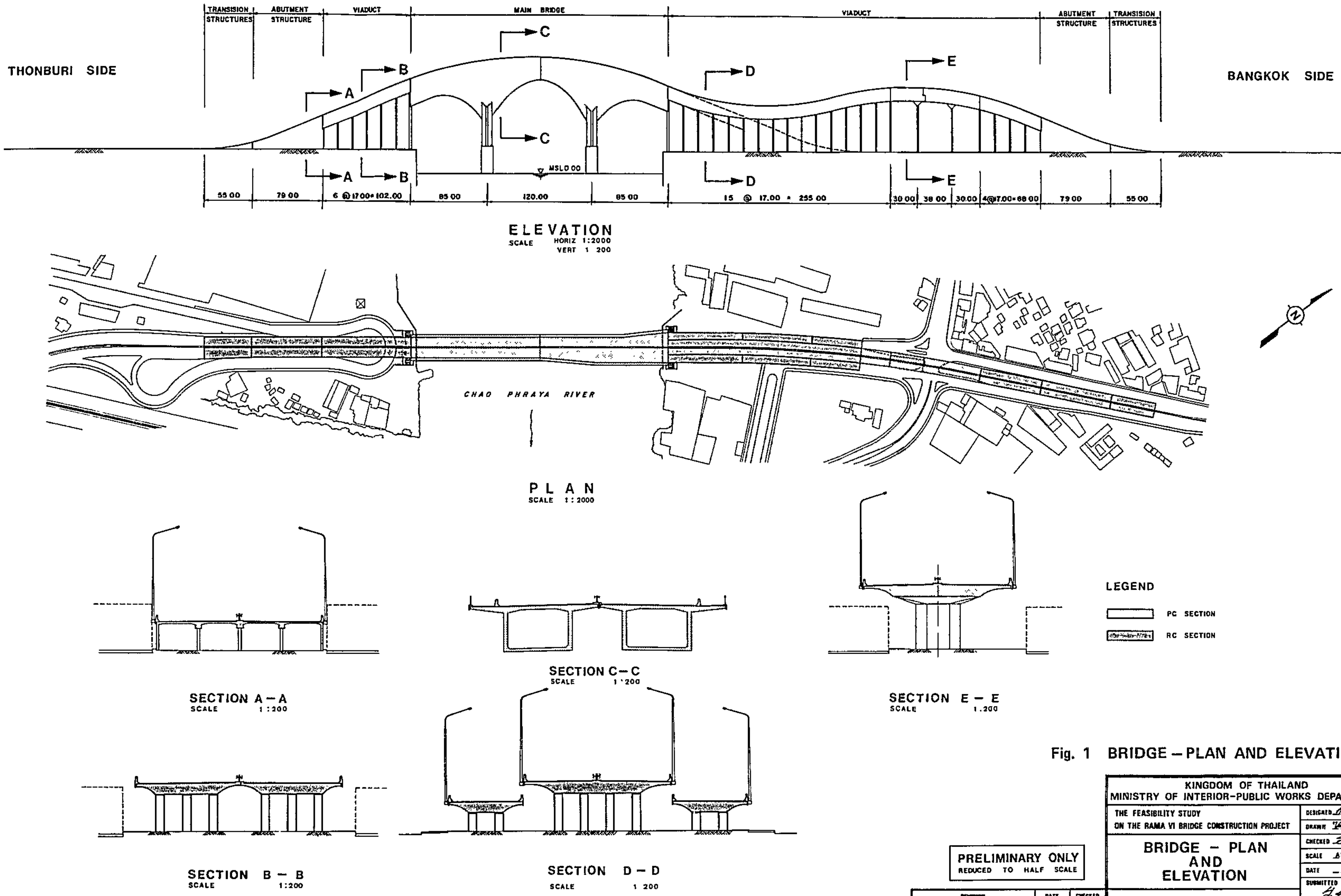

Fig. 1 BRIDGE – PLAN AND ELEVATION

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THE FEASIBILITY STUDY ON THE RAMA VI BRIDGE CONSTRUCTION PROJECT

BRIDGE – PLAN AND ELEVATION

JAPAN INTERNATIONAL COOPERATION AGENCY

DESIGNED	A. Chida
DRAWN	
CHECKED	
SCALE	AS SHOWN
DATE	DEC 1981
SUBMITTED BY	PROJECT MANAGER
DRAWING NO	10

REVISIONS	DATE	CHECKED

IV. Traffic Forecast

The location of the proposed RAMA VI Bridge constitutes one of the most vital points of the Middle Ring Road (MRR), namely, a crossing of the Chao Phraya River.

The MRR plays a very important role of circumferential urban highway together with the Outer Ring Road (ORR) in the Greater Bangkok Metropolitan Area and the planning and construction of both the networks has been expedited in recent years. The time of completion of the ORR, however, has not been set definitely and, at the present, is only expected at some time between 1985 and 1995.

The future traffic for the MRR will be affected substantially by the existence of the ORR. The forecast traffic volume for the New RAMA VI Bridge, therefore, will widely vary due to the availability of the ORR in each specific forecast year.

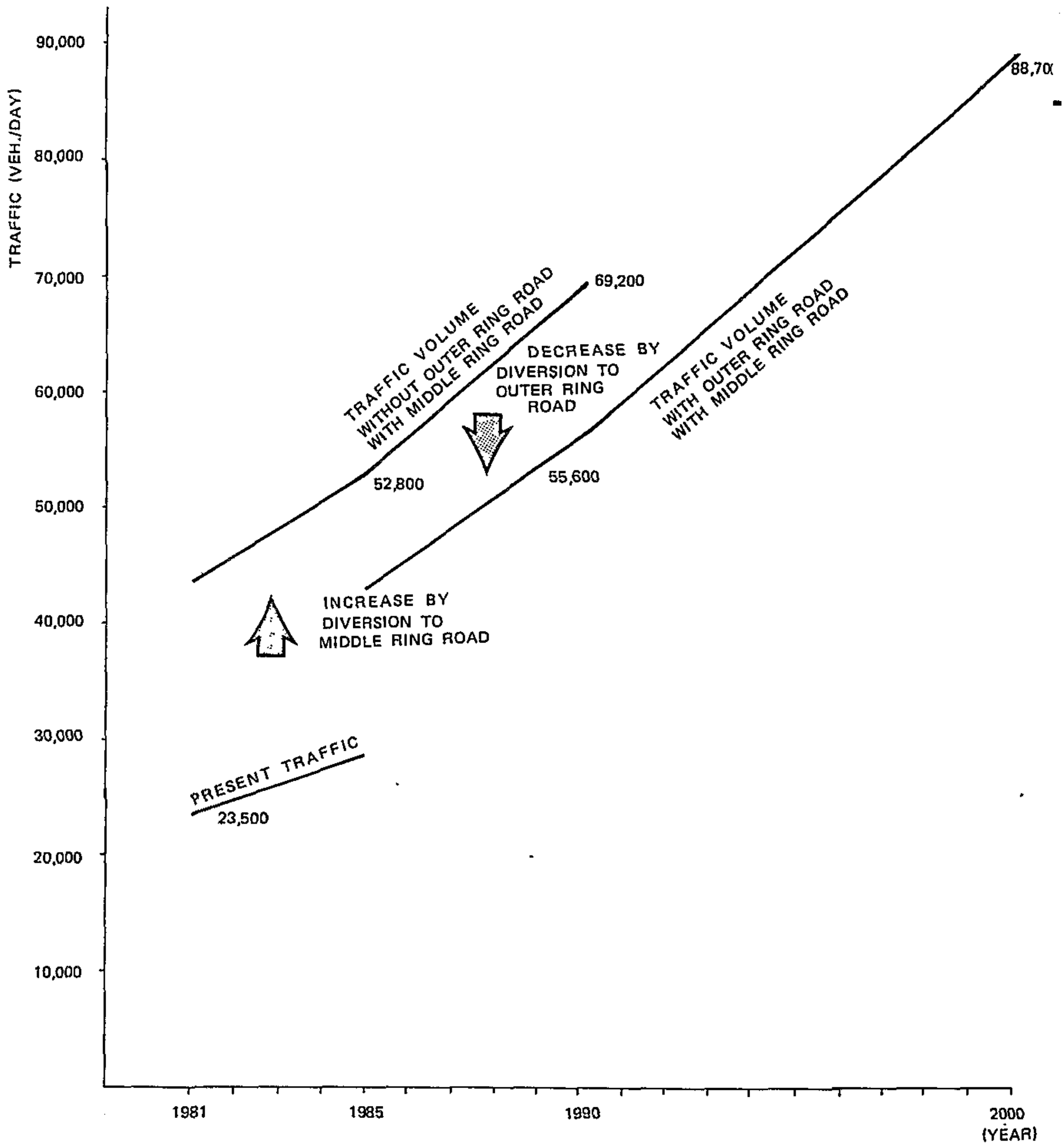
Assuming the ORR could be on service in a certain year between 1985 and 1995, the forecast traffic for the new RAMA VI Bridge would be anticipated, in both the case with completed ORR and the case without ORR, as:

Year	Forecast Traffic (veh/day)	
	w/o ORR	w/ORR
1985	52,800	-
1990	69,200	55,600
2000	-	88,700

Since the design service level C of AASHTO for a bridge on the Chao Phraya River can be generally assumed as 13,000 veh/day/lane, the design capacity for a 4-lane bridge is 52,000 veh/day and that of 6-lane bridge is 78,000 veh/day respectively.

Hence, in the year 2000, the New RAMA VI Bridge traffic will exceed the 6-lane bridge design capacity and almost reach at its critical situation similar to the present Memorial Bridge. After studying possibility of stage construction of a 4-lane bridge, it has been concluded that a 6-lane dual carriageway bridge could be regarded as the most appropriate and economical solution and has been adopted for the design of the New RAMA VI Bridge.

Fig. 2 INCREASE AND DECREASE TREND OF THE RAMA VI BRIDGE TRAFFIC



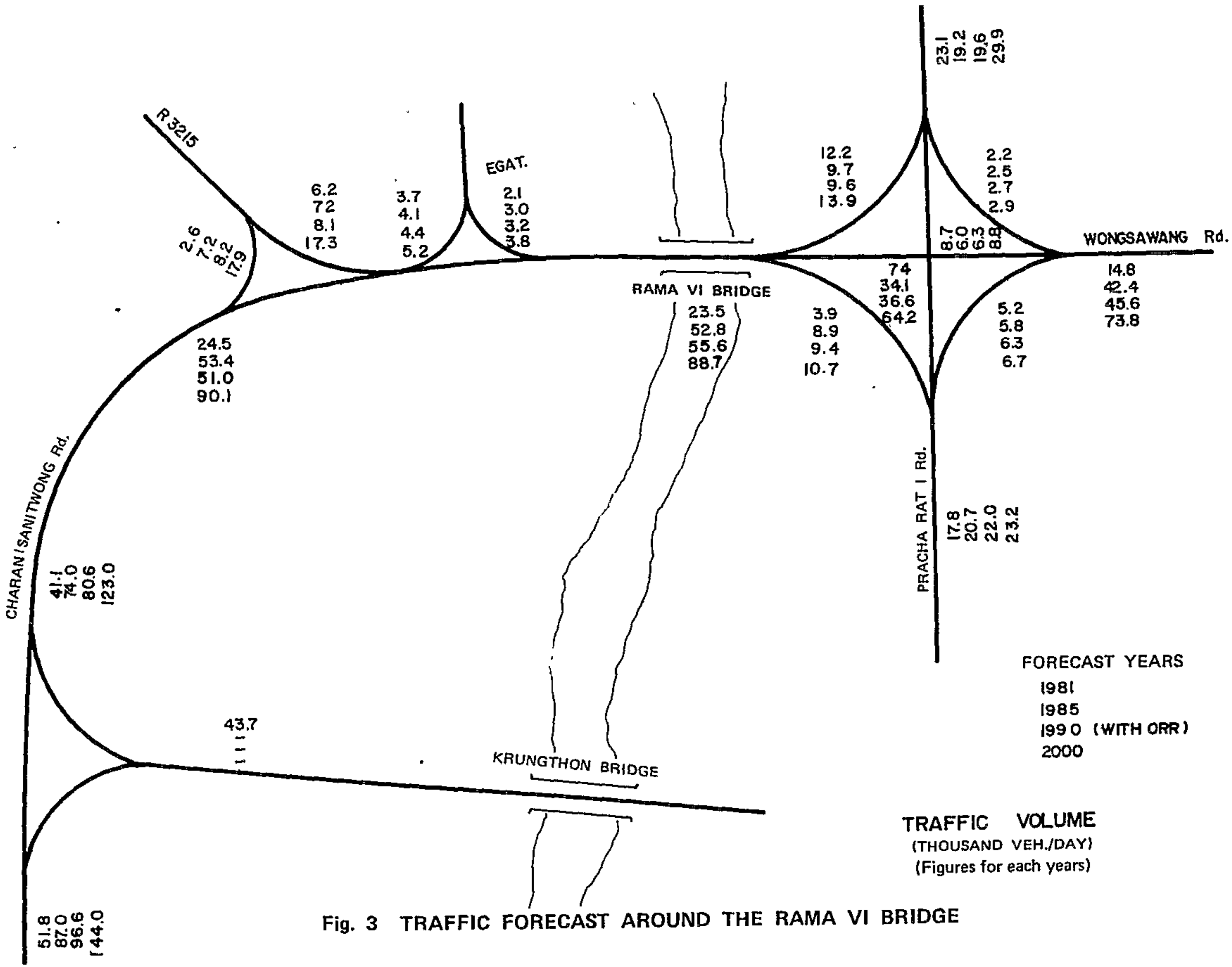


Fig. 3 TRAFFIC FORECAST AROUND THE RAMA VI BRIDGE

V. Selection of the Route Alignment

The environmental conditions around the present RAMA VI Bridge are so complicated and densely developed with schools, factories, commercial and residential areas, that it has been very difficult to select the optimal route alignment, both horizontally and vertically, for the proposed bridge and its approaches, without accompanying some degrees of disadvantages.

Five different route alternatives have been proposed at the first stage of the Phase I Study and thoroughly compared in terms of technical and economical advantages and disadvantages. Each scheme for the alternatives except "widening of the exsisting bridge" is shown in Figs. 4 to 7 respectively.

Two of the south route plans and one for north route plan have been discarded due to various reasons ranging from higher costs, sharp right-angled curve in alignment, difficult compensation problems involved, crossing through swampy low-land area, poor traffic capacities at intersections, etc., and the Alternative III has been chosen as the most favorable route after slight modifications.

After discusions with the Thai committee, the Alternative III modified has been selected and finally approved in the letter of intention issued on 1st of October 1981 by PWD.

The adopted alignment runs through the north side of the existing RAMA VI Bridge and provides a straight alignment for the main bridge. On the Bangkok side, the main roadway goes over the Pibul Songkhram-Wongsawang intersection via flyover structure.

In order to descend to the surface level of the intersection at a smooth gradient, unusual widening of the Bangkok side span of the main bridge has been inevitable in design in order to provide necessary acceleration and deceleration lanes.

Since the Bangkok side flyover passes through the congested commercial area, special considerations have been applied as to achieve good appearance for the design of flyover piers and bottom views of slabs and girders.

On the Thonburi side, an initial design of intersections at grade was discarded and a small scale trumpet-shaped interchange has been installed in order to provide more smooth flows for the future traffic.

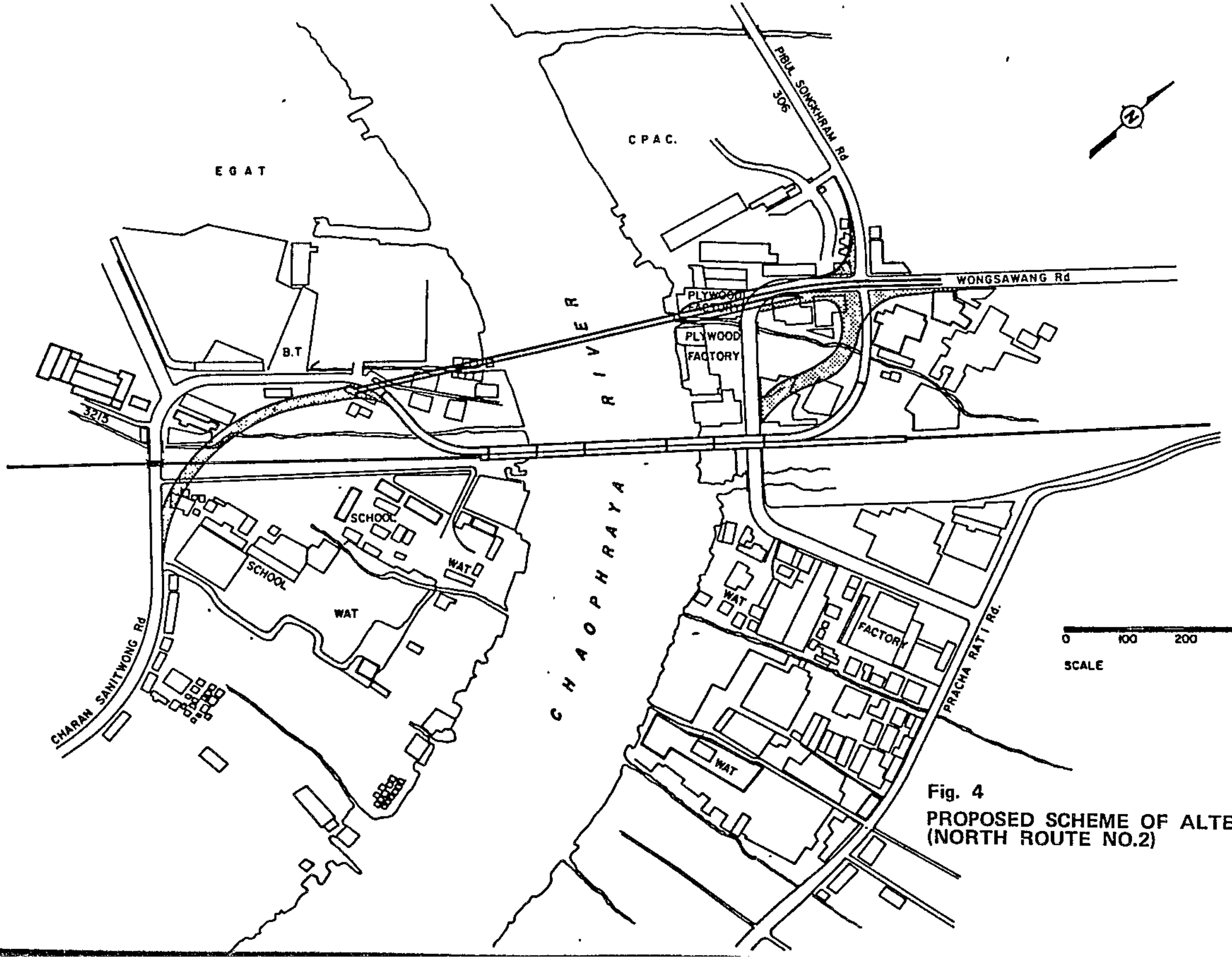


Fig. 4
PROPOSED SCHEME OF ALTERNATIVE III
(NORTH ROUTE NO.2)

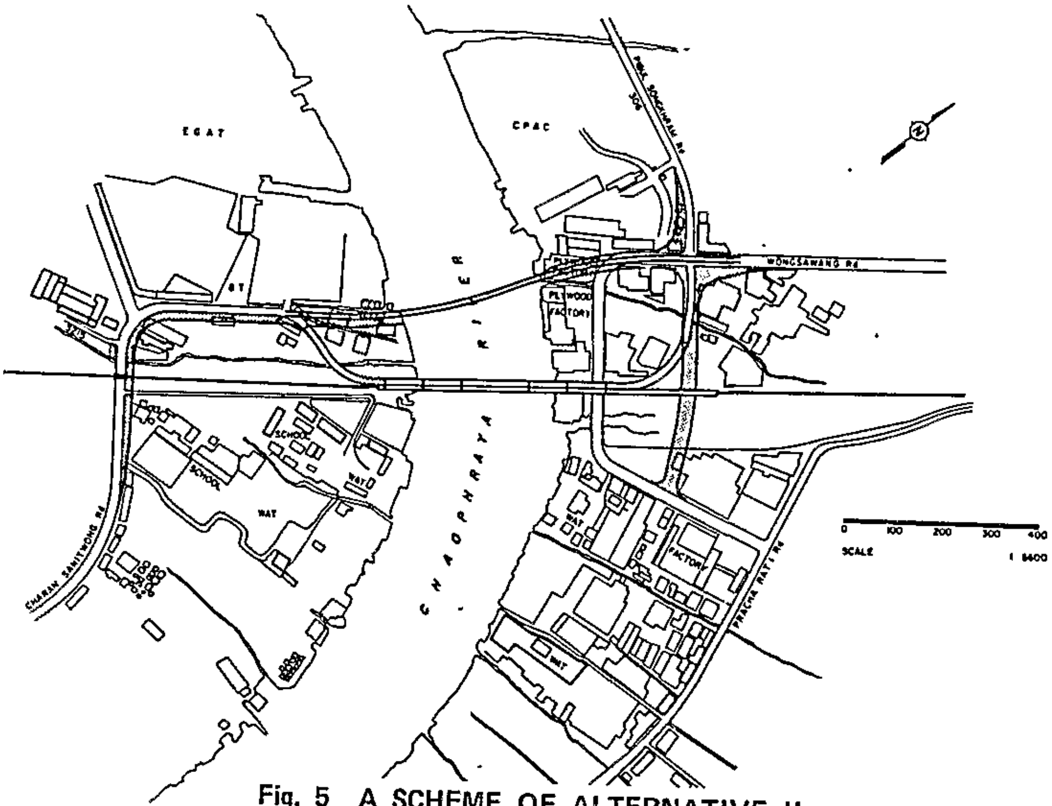


Fig. 5 A SCHEME OF ALTERNATIVE II (NORTH ROUTE NO. 1)

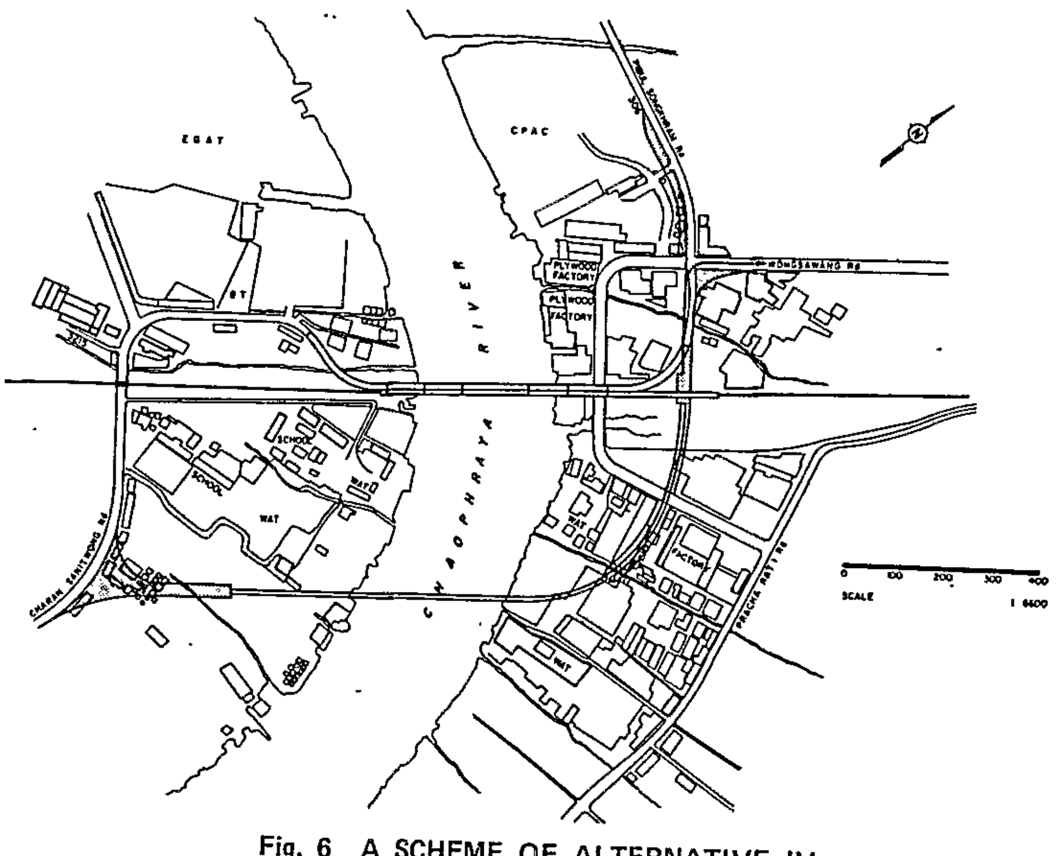


Fig. 6 A SCHEME OF ALTERNATIVE IV (SOUTH ROUTE NO. 1)

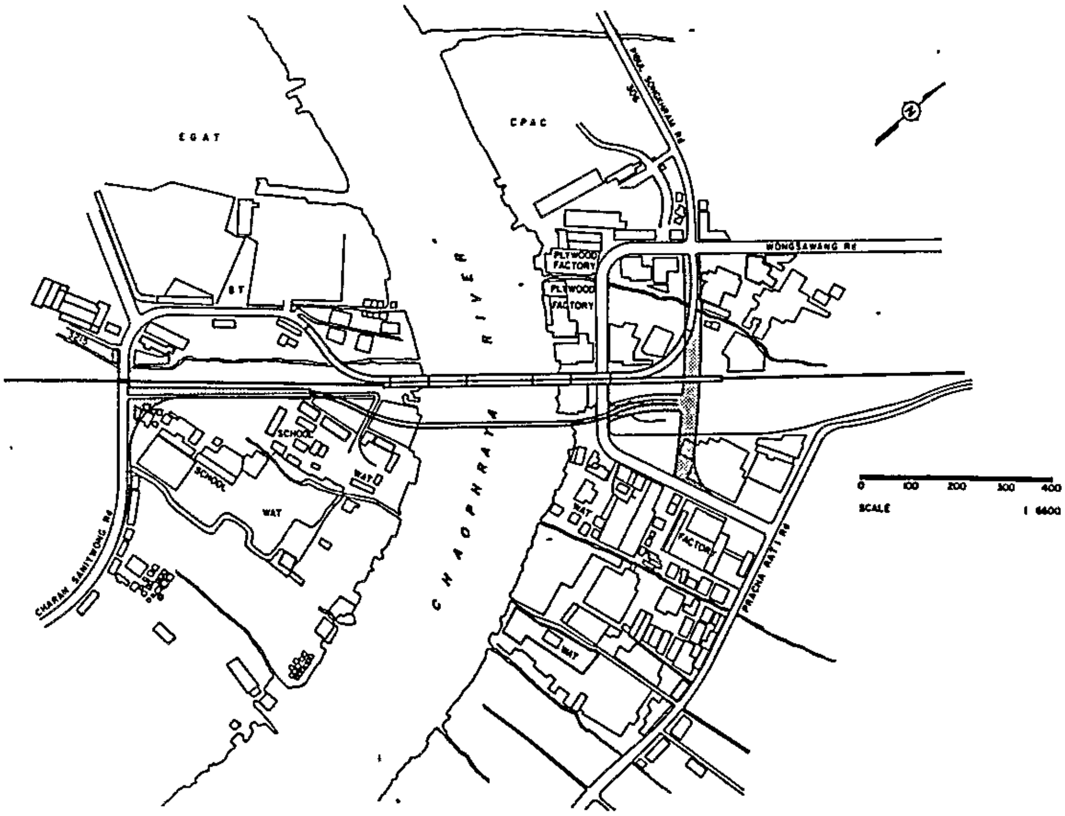


Fig. 7 A SCHEME OF ALTERNATIVE V
(SOUTH ROUTE NO. 2)

VI. Design Standards

Designing of the main bridge and its approaches and connecting roads has been carried out twice: an outline design in the Phase I Study and an preliminary design in the Phase II Study.

For the design of the main bridge, the standard specifications of AASHTO have been applied and for road design; "A Policy on Geometric Design of Urban Highways" of AASHTO has been used.

As for live loadings in structural design, however, BS 5400 of the British Standard of Steel, concrete and Composite Bridges has been specifically adopted in order to comform with the actual heavy trucks observed in the Bangkok area. The numbers of units of HB loading is 45. Other loads are in accordance with AASHTO specifications.

VII. Basic Design Factors

The typical cross sections of the bridge and roads are shown in Fig. 8.

Basic design factors adopted in design are:

<u>Roads</u>

Basic numbers of lane	:	6 lanes
Road width	:	30 - 50 meters
Minimum radius	:	270 meters
Maximum gradient	:	4%
Minimum sight distance	:	75 meters

<u>Main Bridge</u>

Total length w/approaches	:	1,100 meters
Total length of the Main Bridge	:	290 meters
Typical width of the Main Bridge	:	29.3 meters (6 lanes)
Structural type	:	Prestressed concrete box girder rigidly fixed to the pier

Span arrangement	:	85 + 120 + 85 meters

Substructure

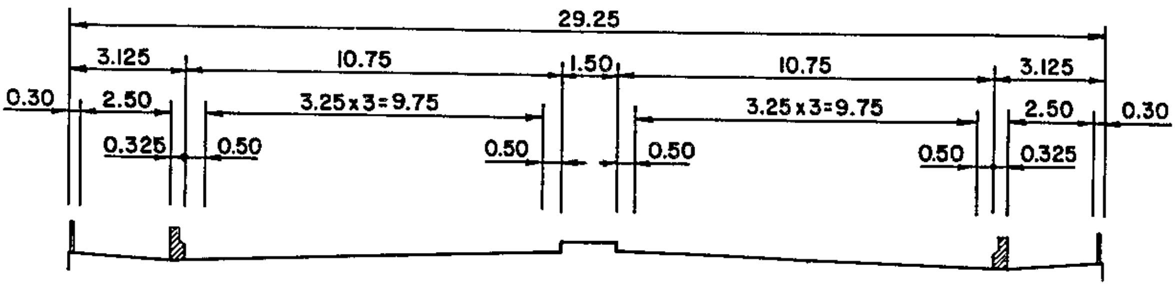
Foundations	:	In-situ concrete piles driven by reverse circulation drilling.

Approach Viaducts and Flyover

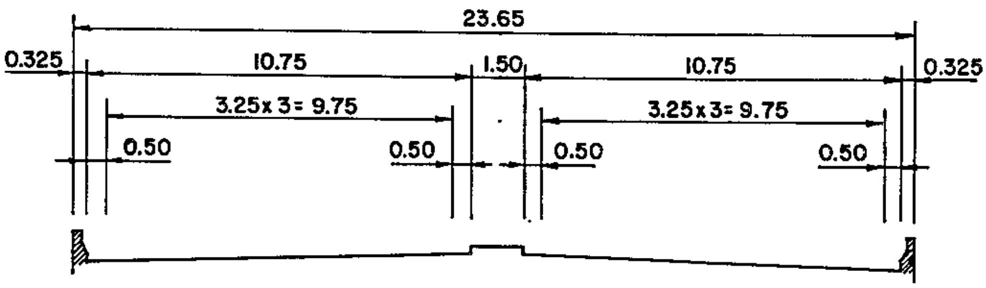
Bangkok side	:	1-leg mushroom type prestressed concrete structure
Other sections	:	Reinforced concrete unvoided slab structure. 16 - 18 meter spans.

Railway Viaduct

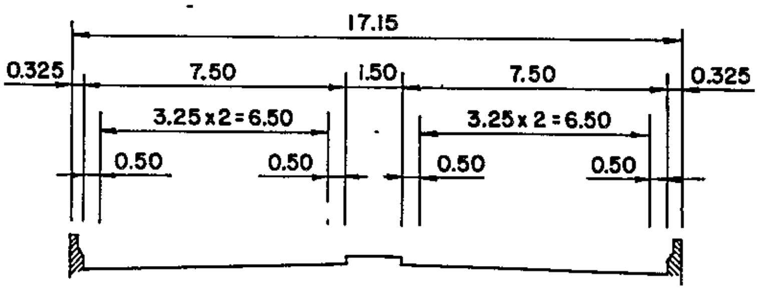
Structural type	:	A steel through type girder bridge.



a) ON CHAO PHRAYA RIVER



b) ON LAND AT THONBURI SIDE



c) AT THE INTERSECTION OF BANGKOK SIDE

Fig. 8 TYPICAL CROSS SECTIONS ON BRIDGE AND ROADS

VIII. Bridge Design

The basic design factors of the bridges determined in the outline design of the Phase I Study have been scrutinized again in the Preliminary Design of the Phase II Study. Recheckings have been made as to the control points and the span arrangements of the main bridge and approaches, using maps of 1/1,000 scale produced by topographic surveys in the Phase II Study.

Foundations

The driven length into earth of both driven piles on shore and those of reverse circulation drilled piles have been studied in the Preliminary Design of the Phase II Study using geological soil survey data. The both values, assumed in the outline design of Phase I Study, MSL-20 meters for the former and MSL-45 meters for the latter have been reconfirmed as appropriate.

Span Arrangement

The selected Alternative III route has set the horizontal alignment of the main bridge as a straight line not parallel with the existing RAMA VI Bridge, with the total length of 290 meters.

As the locations of both the bridges come upon a curved section of the river, navigational passage of long convoys of barges dragged by a tugboat would not coincide with the center of the stream. Hence, a horizontal clearance of 70 meters, instead of the 60 meter minimum requirement, has been regarded as necessary. With the total length of 290 meters and a navigational clearance of 70 meters set as design conditions, only three alternatives in terms of span arrangement could be conceived for designing a prestressed concrete bridge.

Alternative I:	290 m = 44 + 61 + 80 + 61 + 44	5 spans
Alternative II:	290 m = 60 + 85 + 85 + 60	4 spans
Alternative III:	290 m = 85 + 120 +85	3 spans

Alternative II has been simply discarded due to its defect for navigational difficulties for a long convoy of barges.

After Alternative II and III have been studied in full details, Alternative III was selected as a more preferable tion because of its aesthetical and navigational advantages in spite of its slightly higher cost. The conformity with the 3-span arrangement of the present RAMA VI Bridge was regarded as the priority factor.

Structural Type

In the case of prestressed concrete bridge with a span length of up to 150-160 meters, it is generally recognized that a box-girder bridge type by cantilevering method is recommendable due to its lower cost and simpler construction procedures.

In this project, a bridge type having shallower depth has been considered as a more attractive design. With thinner girder it will become possible either to built shorter rampways achieving lower costs or to lessen vertical gradient of ramps and improve vertical alignment as well. Another restrictions have been caused from the critical clearances for underpassing through a railway viaduct and necessary clearance for the two khlongs on Thonburi side.

Two structural types, namely, a cable-stayed concrete girder type and a concrete sail type were added for the further study as possible alternatives in the stage of outline design of the Phase I Study.

Results of a detailed comparison study showed that construction cost for each type of the three different types of bridge only slightly differed at the level of 800 million Baht, and advantages and disadvantages for each type were also similar in an overall evaluation.

The concrete sail type has been first rejected due to its peculiar shape and unpleasant impacts for drivers in spite of its lower cost.

At the joint Committee of the Thai Government and JICA held in September 1981, the remaining the alternatives of the box-girder type and the cable-stayed type in their order have been recommended and left for the final decision in the hand of PWD.

One of important reasons for recommending the conventional box-girder type bridge has been the asymmetrical cross section of the bridge in the Bangkok side caused by the installation of speed changing lanes besides roadways, because a cable-stayed type bridge is not regarded as a preferable solution for asymmetrical changing width of a bridge.

The final decision was thus made in the letter of intent issued on 1st of October 1981 by PWD to the effect that PWD considered the box-girder bridge with cantilevering method as the most favorable design and that some special considerations had to be taken concerning the appearance of the bridge.

Once the box-girder structure had been adopted, the further checks had been made as to the choice of box-girder structure: a) Continuous girders which have better trafficability for travelling vehicles, or b) Continuous T-shaped frame connected by sliding hinges in the central span, which is more economical and easier to construct.

As the result, the latter type with central hinges has been selected mainly because the design speed of travelling vehicles will not exceed 60 km/h and cause no trafficability inconvenience.

As the width of the main bridge varies from the minimum of 29.3 meters to the maximum of 36.46 meters in the length of one continuous girder, this had presented a very important problem as to the configuration of girder cross sections, both in stress analyses and in construction procedures. Hence the following design factors have to be taken into considerations.

1) To design a constant cantilevered length for slabs in order to attain good aesthetical appearances.
2) To avoid sudden changes in the girder cross section in a length of one main girder in order to attain the more smooth flow of stresses in the structures.

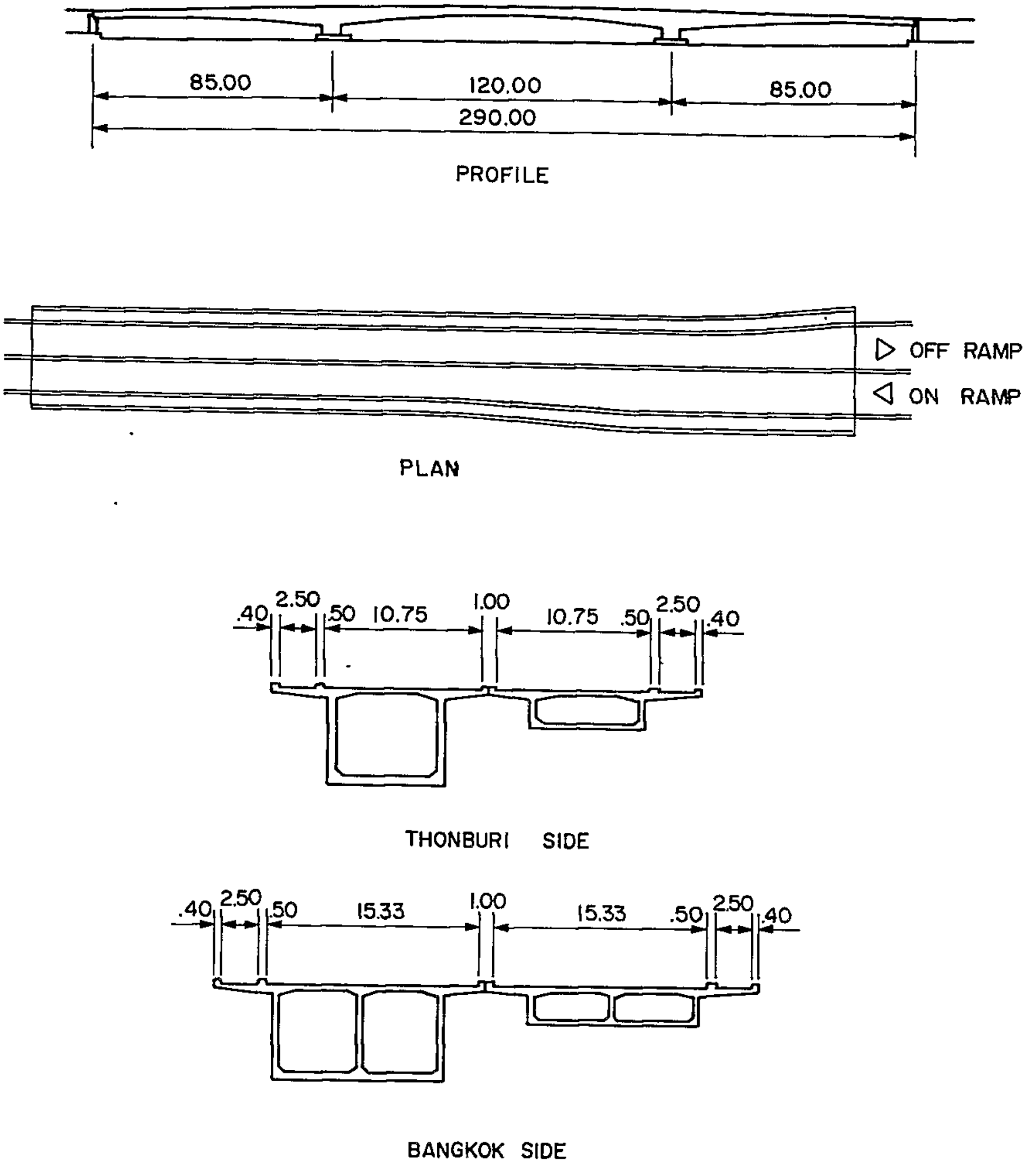


Fig. 9 CROSS SECTIONS OF BOX GIRDERS

3) To restrict the maximum clear span of carriageway slabs as not to exceed 7 meters.

As the results, a 1-cell in 1-box cross section configuration has been adopted for the Thonburi side T-frames, and a width-changeable 2-cell in 2-box cross section has been used for the Bangkok side where the bridge widths vary longitudinally.

On the basis of the above mentioned structural types, analyses have been conducted in order to determine dimensions for each girder depth and each structural member.

Upon establishing dimensions for each structure, the originally designed span arrangement had been reaffirmed as the most preferable configuration.

Appearance

Of the main bridge, the planned elevation is rather low compared with the thick girder depths at the piers. The distance between the top of pile caps and the bottom of the main girder is very small and a stubby look would resulted in case of adoptation of an ordinary upside-down T-shape pier footing.

Various designs have been studied in order to eliminate these unfavorable effects in appearance.

Approach Viaducts

The span arrangements of approach viaducts have been slightly altered in response to design changes of highways.

Although, in the outline design, voided slabs have been used for viaduct cross sections, this has been changed to the use of ordinary unvoided slabs, because the latter has been found as more economical, even for larger dead loads, after comparing form work cost and labor cost for both types.

In designing piers for the Bangkok side flyover, sleek mushroom type structures with 1-leg piers have been adopted for aesthetical reason. On the Thonburi side, ordinary multi-column type piers having 1-meter square cross section without cross beams have been used.

Railway Viaduct

The alignment for the main bridge has involved construction of a complicated case of a railway viaduct on the Thonburi side, under-crossing the existing railway line. As the SRT's future plan for double track of the present RAMA VI Bridge Railway has become materialized during the Preliminary Design stage, and SRT requested that a special consideration should be taken as to the design of the viaduct.

The proposed viaduct should be the type of structure which enables the double tracking improvement without changing the assumed distance of the double track on the present bridge.

A prestressed concrete railway bridge designed in the outline design of the Phase I Study could not be used due to its wider width between the two tracks. On this reason, the railway viaduct has been redesigned as a steel through type girder bridge in the Preliminary Design of the Phase II Study.

IX. Highways and Alignment

The Alternative III selected in the Phase I Study has been rechecked in the Preliminary Design of the Phase II Study using 1/1,000 topographic maps.

Thonburi side

The intersections at grade designed in the outline design of the Phase I Study has had problems in dealing with in-coming traffic from the bridge due to its short distance between the ends of rampway and intersections.

PWD has issued a comment to the effect that the traffic flows should be more smooth in the Thonburi intersections in view of increased traffic in the near future. In response to the request, a small scale trumpet interchange has been adopted in the Preliminary Design of the Phase II Study.

Horizontal Alignment

Based on control points established on both sides of the river, curved alignments have been adopted in the Bangkok side using R=1,500 meters, and in the Thonburi side R=270 meters and A=140 meters. On the main bridge, a straight line has been used in a skew alignment.

Longitudinal Alignment

As both the proposed bridge and the existing bridge come upon a curved section of the Chao Phraya River, it has been necessary to provide wider navigational passage under the new bridge. As a result, the maximum allowable value of 4% had to be used for the longitudinal gradient.

On the Bangkok side, the distance between the end of the on-off rampways and the Pibul-Wongsawang intersection has been so close, decelaration and acceleration lanes have to be installed besides the main bridge roadways.

The final longitudinal alignment attained for rampways has resulted in a combination curve of a sag and a crest for the Bangkok side section.

On the Thonburi side, the roadway has to under-cross a railway viaduct. The elevation of roadway has been controlled by both the vertical clearance under the railway and also by HWL of two small khlongs in the vicinity.

Traversal Cross Sections

The design standard of main roadway cross section have been based on DOH and BMA specifications, in both of which 30-meter wide right-of-way and 6-lane roadway have been specified.

In reference with both the DOH and BMA standards, the width of main roadway for the main bridge and highway sections has been determined as 3.25 meters, that of bus-stops as 2.70 meters.

Superelevation of 4% has been adopted for the interchange section in the Thonburi side in order to respond to traffic speed of 80 km/h.

Intersections

At the Bangkok side intersection, signalization will have to be installed at surface level.

After capacity checks on each direction of the intersection, numbers of lane have been determined. They vary from the maximum of 5 lanes for the RAMA VI Bridge traffic to 3 or 4 lanes for other traffic directions.

In the Thonburi side, the specially designed trumpet-shaped interchange will accommodate a smooth flow of traffic at least in the foreseeable future.

X. Construction Method and Schedule

A conventional cast-in-situ cantilevering method for prestressed concrete girder bridge has been adopted for construction method partly due to the asymmetrical cross sections of the Bangkok side span of the bridge.

The method has been practiced in many cases of bridge construction in Thailand and has been regarded as the most reliable and economical method due to its availability of materials and equipment and skilled labor as well.

The necessary construction time for the bridge and roads has been estimated to 30 months (2 1/2 years) after the issuing of the notice to proceed to contractors. Assuming land acquisition or relocations of existing facilities would take 1 year and could be overlapped by 6 months to construction time, the total completion time for the project will be 3 years.

Detailed schedule of construction is described in Fig. 10.

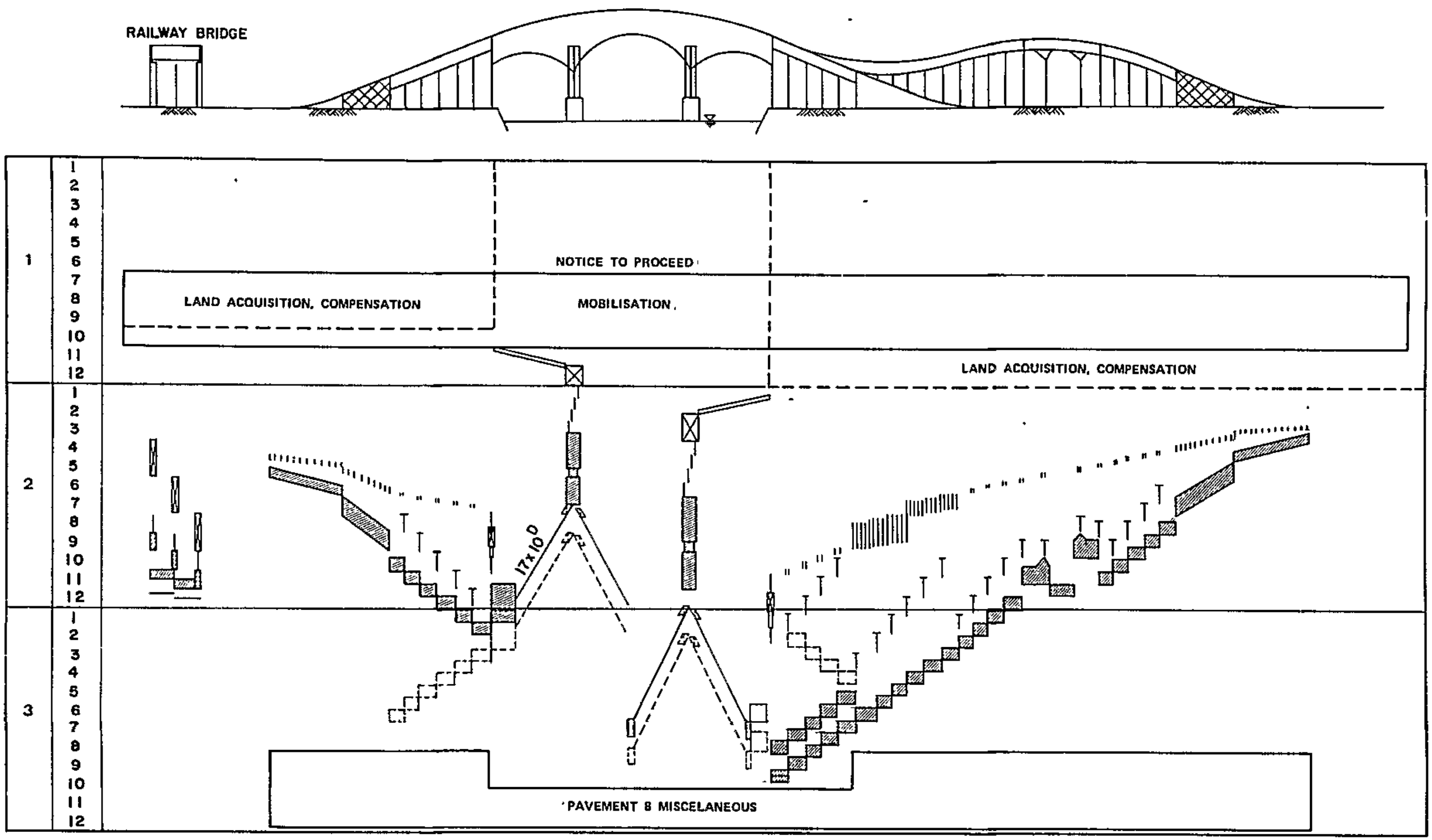


Fig. 10 CONSTRUCTION SCHEDULE

XI. Budget and Finance

In order to determine a budgetal schedule to finance the project, the following assumptions have been set:

Annual rate of inflation	:	15%
Commencement of project	:	October, 1983
Interest rate of external resource	:	3%
Grace period	:	10 years

If an assumed 15% inflation would prevail in Thailand for the next 5 years until the completion of the project, the total expenditure would amount up to 1,223.61 million Baht, of which 546.73 million Baht financed by foreign currencies and 676.88 million Baht by local currency.

Disbursement schedule of both the foreign and local components is as follows:

Year	Foreign	Local	Total
1982	11.5	5.75	17.25
1983	54.02	68.24	122.26
1984	174.01	287.73	461.74
1985	194.47	204.71	399.18
1986	112.73	110.45	223.18
Total	546.73	676.88	1,223.61

(million Baht)

The total of interest for 546.73 million Baht of foreign component will amount to 113.55 during the 10 year grace period at an assumed annual interest rate of 3%.

Thus the total amortization payments for the foreign component after the 10 year grace period including principals and interests will be 660.28 million Baht.

An implementation schedule used for the above estimation is shown in Fig. 11.

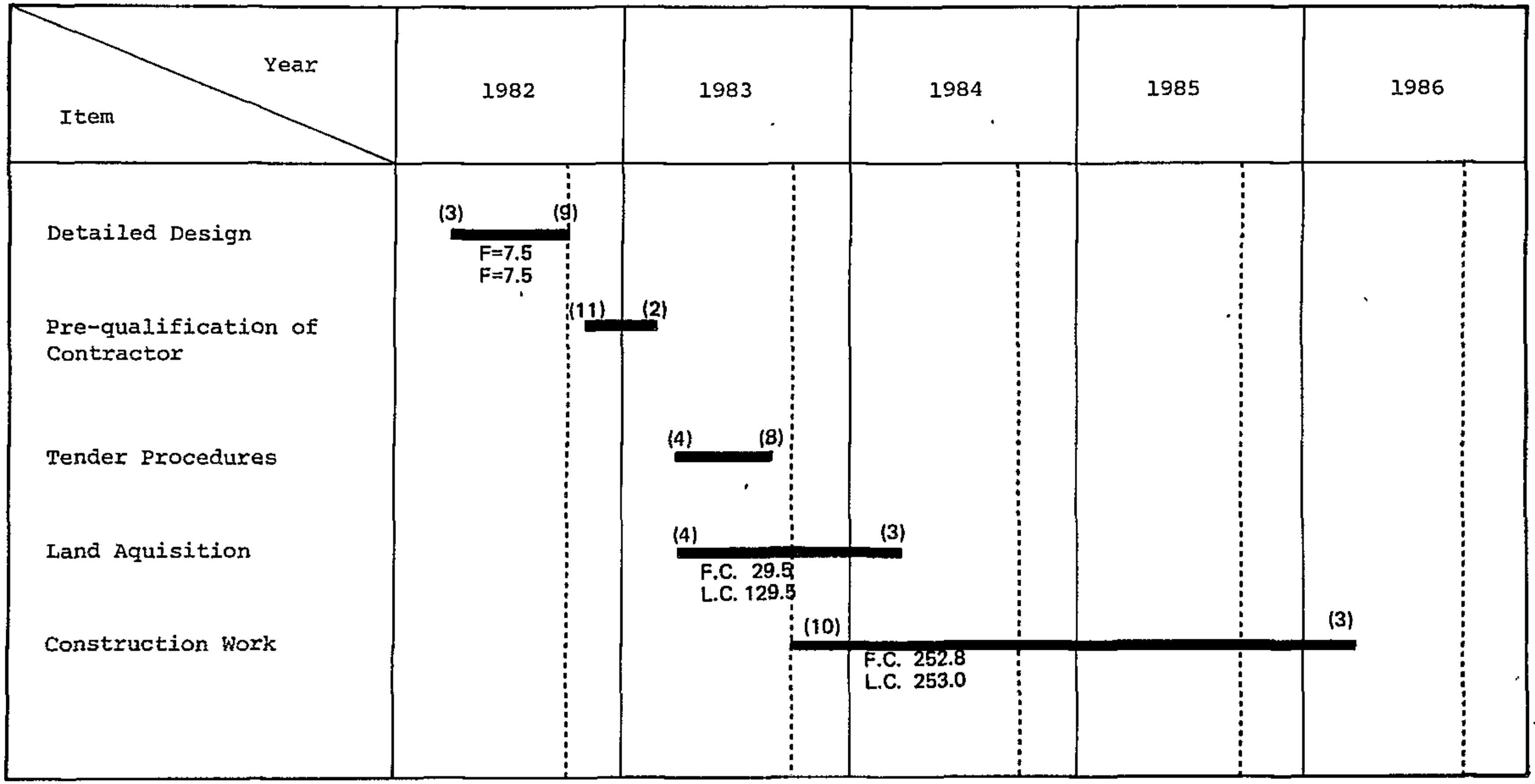


Fig. 11 IMPLEMENTATION SCHEDULE

JICA