CHAPTER 9

BRIDGE ALTERNATIVE STUDY AND SELECTION OF THE RECOMMENDED BRIDGE TYPE FOR THANH TRI BRIDGE

CHAPTER 9 BRIDGE ALTERNATIVE STUDY AND SELECTION OF THE RECOMMENDED BRIDGE TYPE FOR THANH TRI BRIDGE

9.1 Introduction

In this Chapter the recommended bridge types of the river crossing will be selected after the comparative study on the best route alternative studied in Chapter 8 Selection of the Best Alternative Route.

The bridge types for the Main bridge and Approach Bridge were preliminary selected as follows;

Main Bridge

Three superstructure types were studied for the Main Bridge, as Alternative 1,2 and 3, shown in Figure 9.1.1. In addition, preliminary cost estimate for the cable stayed with steel girder was conducted (Appendix Chapter 9).

Alternative 1 --------	PC Continuous Box Girder Bridge (Cantilever Erection Method)
Alternative 2 ---------	PC Extradosed Bridge
Alternative 3 ---------	PC cable Stayed Bridge

Pile foundation and caisson foundation types were consulted as alternative foundations.

Approach Bridge

Approach Bridge consists of Approach Bridge (1), Approach Bridge (2) and Dyke Bridge, respectively.

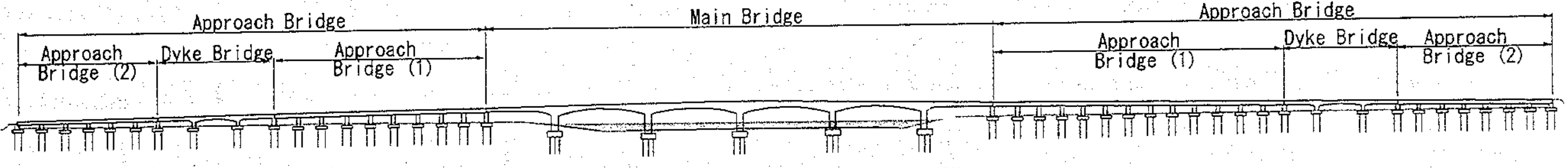
The option for the superstructure types were as follows;

(1)	Approach Bridge (1) -----	PC Continuous Box Girder Bridge
(2)	Approach Bridge (2) -----	PC Simple Girder Bridge
(3)	Dyke Bridge ------------	PC Continuous Box Girder Bridge

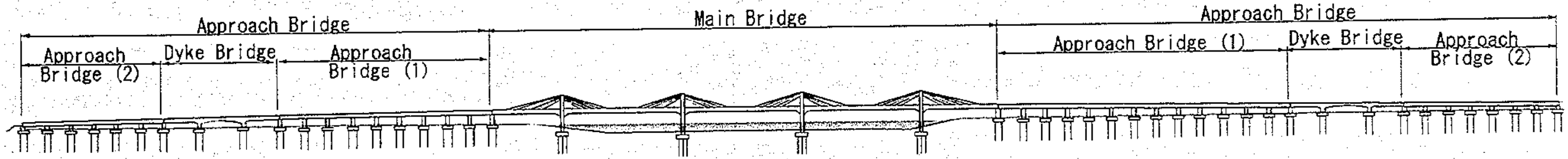
The costs comparison for the river crossing was conducted including the Main Bridge and the Approach Bridge.

The outline of the Main Bridge alternatives were shown in Figures 9.2.2, 9.3.1 and 9.4.2.

ALTERNATIVE 1: PC Continuous Box Girder Bridge



ALTERNATIVE 2: PC Extradosed Bridge



ALTERNATIVE 3: PC Cable Stayed Bridge

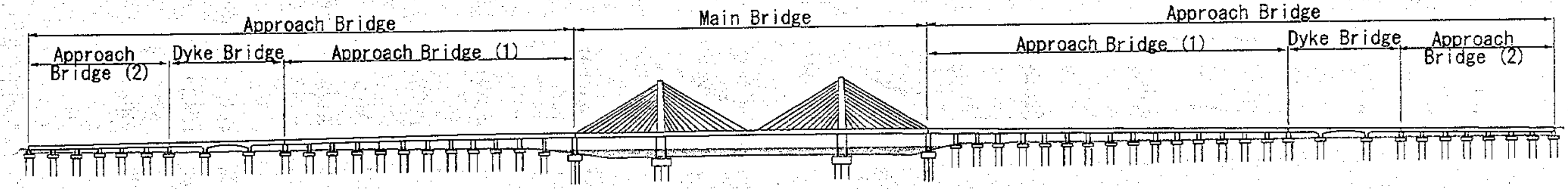


Figure 9.1.1 Definition of the River Crossing Structure

9.2 Bridge Alternative 1 (Main Bridge)

9.2.1 Superstructure

The minimum span length was selected as 130m as mentioned in Chapter 7, 7.3.2 Preliminary Selection of Bridge Type. The economically applicable span lengths of this type are generally between 35m and 170m as indicated in Figure 7.3.3.

The comparison study, 130m, 150m and 170m in span length, was conducted.

The construction costs including substructure and foundation were compared showing in Figure 9.2.1.

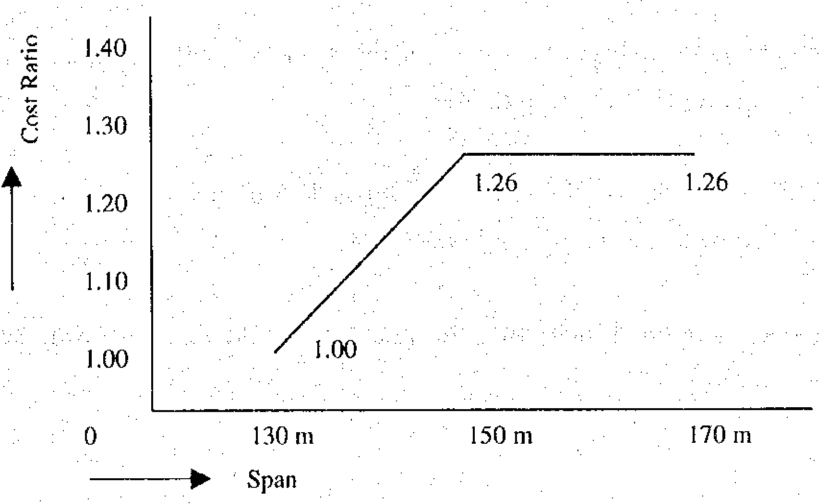


Figure 9.2.1 Cost Comparison

The optimum span was determined as 130m from Figure 9.2.2. Considering topography and hydrological data, the span arrangement and bridge length were selected as 80m + 4@130m + 80m = 680m.

9.2.2 Substructure / Foundation

(1) Pier

The Pier type for the Main Bridge was determined considering following factors:

- Piers are constructed in the normal water course of the river and the maximum depth of stream water will be up 13m in rainy season.

- Superstructure consists of PC continuous box girder (80m+4@130m+80m). Superstructure of these spans will result in large reactions. It is required for piers to have high degree of rigidity to resist impact and earthquake forces. Therefore, the Study Team has concluded to combine the foundations for both the Hanoi and Gia Lam carriageways.

- The 32.8m of bridge width will require crosshead to support the superstructure as shown in Figure 9.2.3.

- The construction of piers in the river will disturb the water flow and will cause eddies on the down stream side and consequentially scour action will occur. To minimize scour action, the pier columns will be elliptical in shape.

- The calculations show that scour of the river bed will not exceed 6m which defines the level of the foundation.

- The design force for ship/barge impart is 125 tonnes. The protection system will be considered in the detailed design.

Considering above mentioned elements, the pier type of main bridge was selected as shown in Figure 9.2.3.

(2) Foundation Type

The available option for piles were selected in chapter 7, as follows;

- Steel pipe pile	ϕ 2,000
- Cast-in-situ-concrete pile	ϕ 1,500
	ϕ 2,000
	ϕ 2,500

These types of foundations were investigated and compared including caisson foundation (steel pipe sheet pile) in Table 9.2.1. Finally, cast-in-situ concrete pile ϕ 2,000 was selected as the most suitable foundation type.

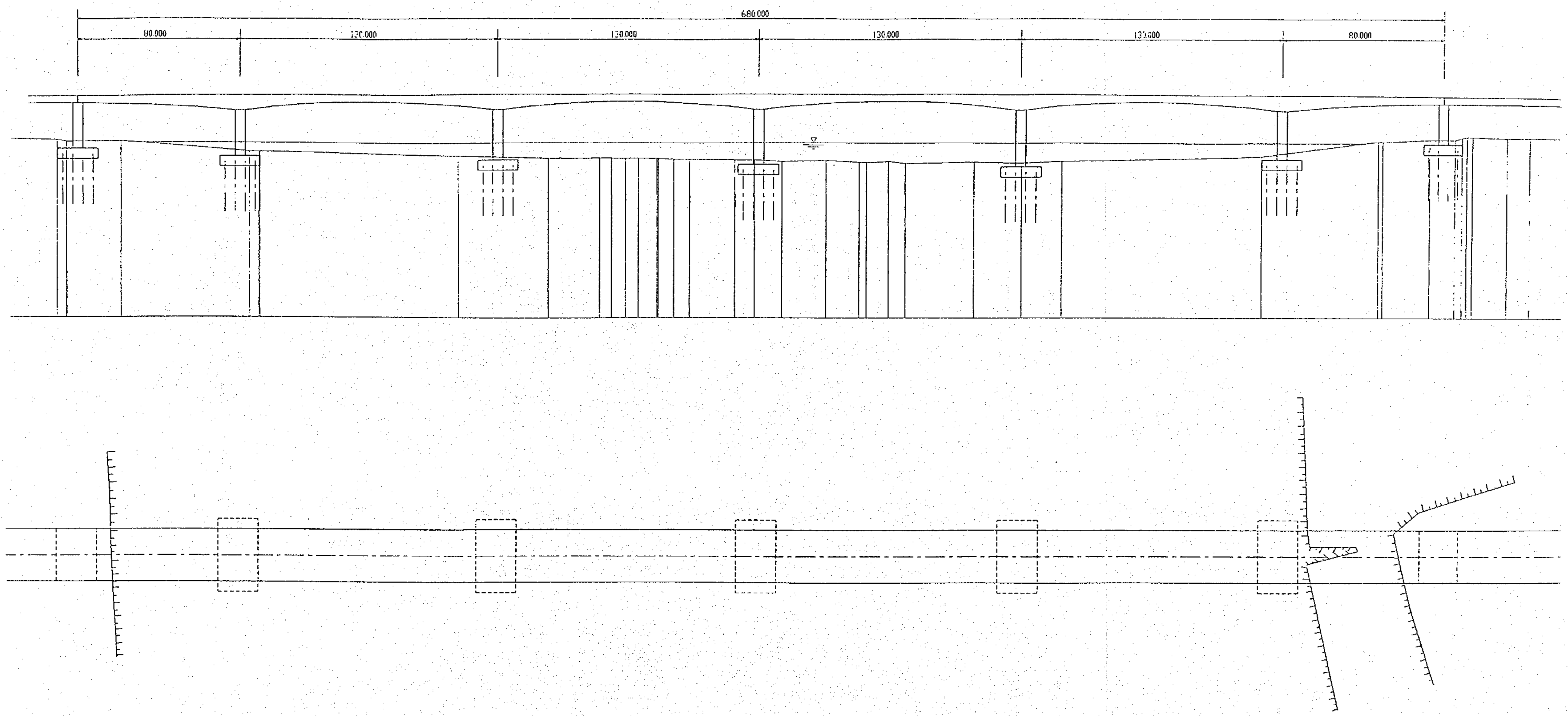


Figure 9.2.2 Alternative 1 PC Continuous Box Girder

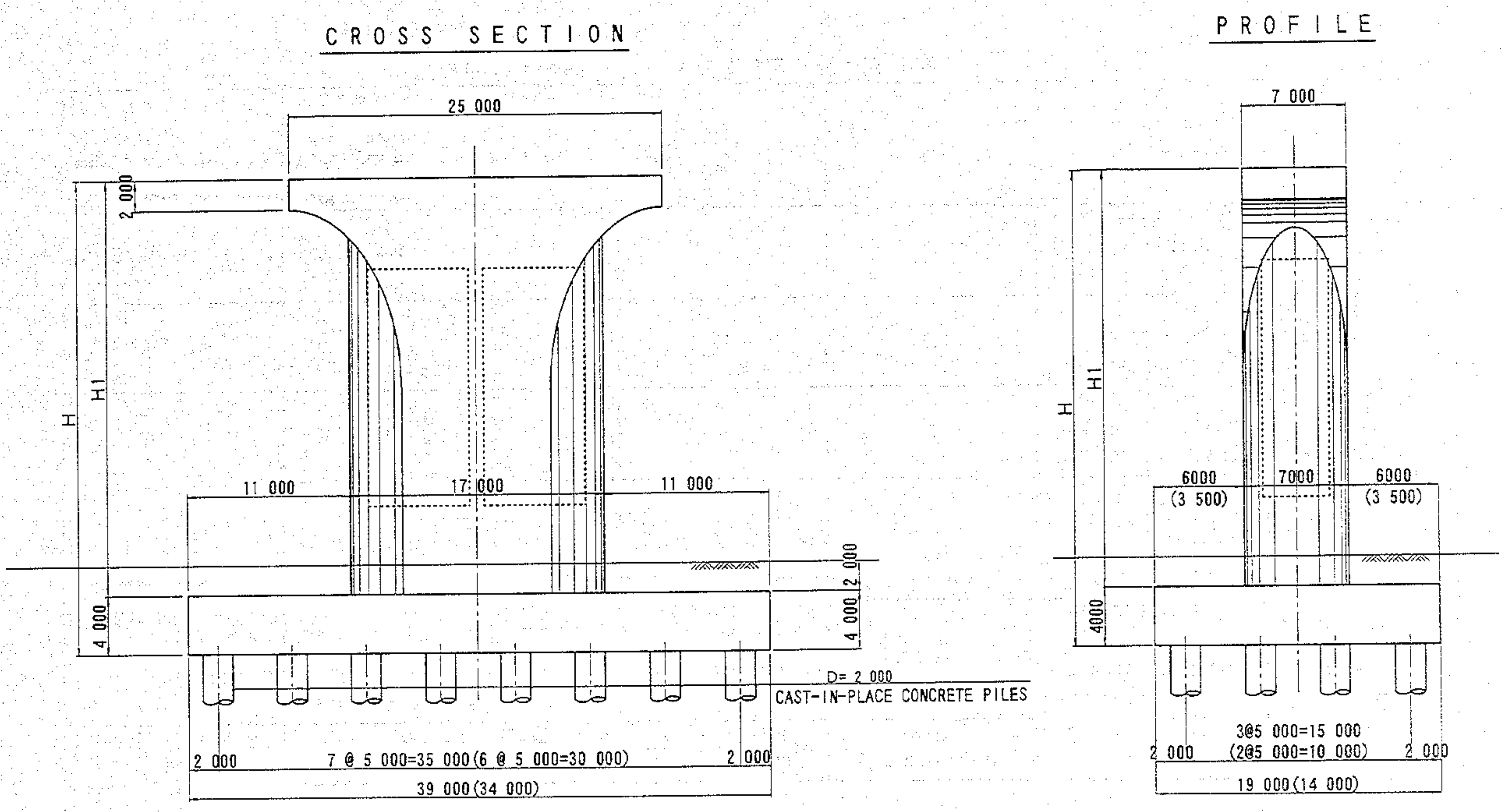


Figure 9.2.3 Substructure/Foundation

Table 9.2.1 Comparison on Foundation Type

Type of Foundation		Construction Cost	Constructability	Construction Period	Evaluation
Cast-in-situ Concrete Pile	ϕ 1500	Δ	O	Δ	- Larger number of piles required - Longer construction - Overall size of foundation of period increased
	ϕ 2000	O	O	O	- Higher rigidity than ϕ 1500 option - Most economical - Recommended foundation
	ϕ 2500	Δ	Δ	Δ	- Higher rigidity than ϕ 2000 option - Difficult to construct because of large concrete volume in each pile
Steel Pipe Pile	ϕ 2000	X	O	O	- Not economical - Material to be imported
Caisson Foundation	Size of Foundation	X	Δ	Δ	- Not economical - Long construction period - Suitable for very high loads
Permanent Steel Pipe Pile Cofferdam	Size of Foundation Steel Pile ϕ 2000	Δ	O	O	- Material to be imported

Key: O – good/low Δ - average X – high/bad

9.3 Bridge Alternative 2 (Main Bridge)

9.3.1 Superstructure

Increasing the span of Bridge Alternative 1 to a span of 180 m will necessitate a concrete box girder of 10.5 m in depth. This depth of construction may cause construction difficulties in Vietnam and the Study Team proposed to use a hybrid concrete box girder (known as 'extradose' in Japan). This bridge type incorporates low level cable stays to increase the effective section at the piers, as shown in Figure 9.3.1. Prestressed concrete extradosed bridges are normally considered in the span range of 60 m to 180 m, referring to Figure 7.3.4, which is within the span arrangement under consideration.

For this span the depth of the box girder now reduces to 9.0 m with concrete towers of 20.0 m above the deck.

9.3.2 Superstructure / Foundation

As for Bridge Alternative 1.

9.3.3 Overall Assessment

PMU Thanh Long and the Steering Committee decided to remove this alternative from the available options (higher construction cost compared with PC continuous box girder bridge).

9.4 Bridge Alternative 3 (Cable Stay Main Bridge)

9.4.1 Material Selection

Two materials types are structurally viable for cable stay bridges in the span range 200 – 350 metres, cross sections for both steel and concrete are shown in Fig 9.4.1. However, as the Study Team has previously explained the study Team considers that factors exist in Vietnam which will dictate the chosen material from an economic prospective, (Section 7.3.2 (2)). In Table 9.4.1 the Study Team has reviewed an summarised the advantages and disadvantages of the two material types for the Vietnamese conditions.

Following this review the Study Team considers that concrete will result in the most economical cable stay solution considering the construction and long term maintenance costs.

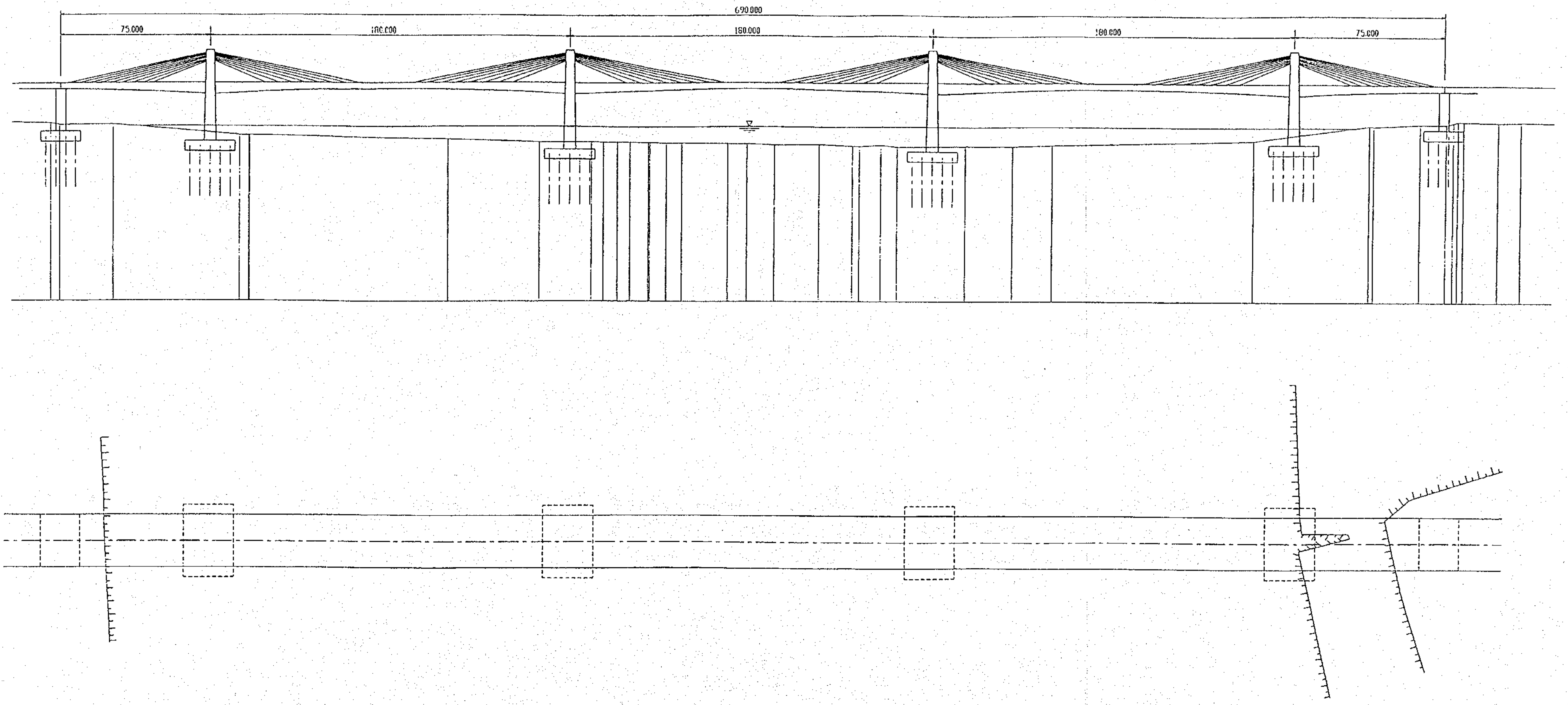
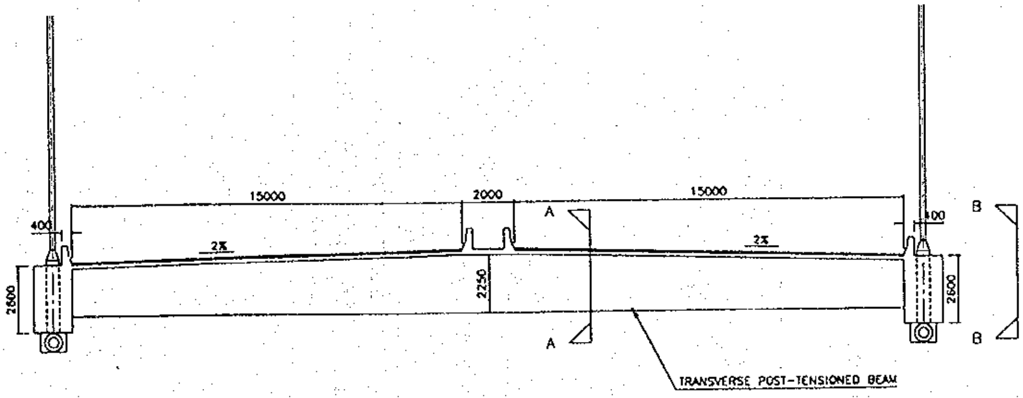
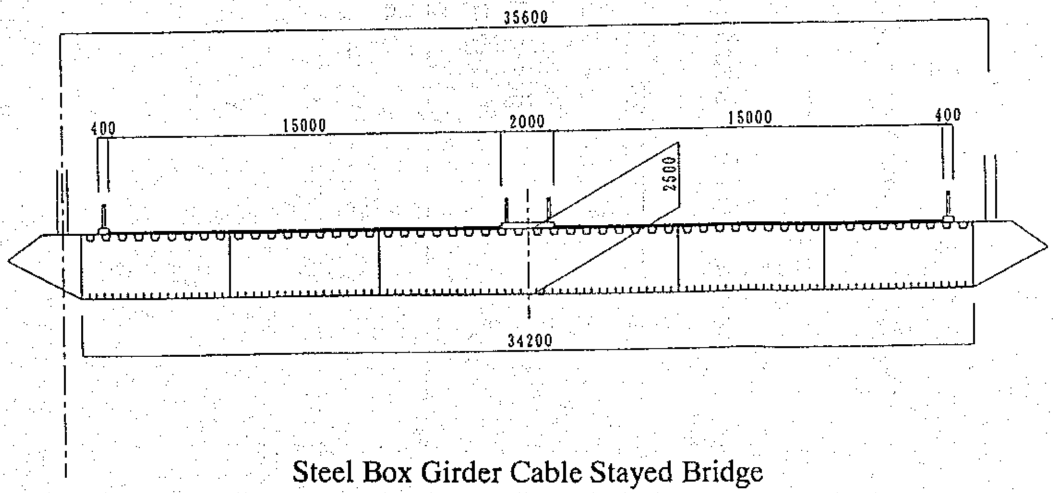


Figure 9.3.1 Alternative 2 PC Extradosed Bridge



PC Cable Stayed Bridge



Steel Box Girder Cable Stayed Bridge

Figure 9.4.1 Cross Sections of Cable Stayed Bridges

Table 9.4.1 Comparison of Materials for Cable Stay Bridges

Material	Source *	Aesthetics	Experience of Material	Protective Treatment	Maintenance and Operation
Structural Steel	Imported	Good	Insufficient experience of this material for long span bridges. Training could be instigated but will result in additional cost	Imported , training of local labour required.	High Periodic Maintenance Costs together with general costs
Concrete (prestressed or reinforced)	Local	Good	Local labour force is experienced in this material	Not Required	Low maintenance cost required throughout the design life of the bridge

* not including stay cables

9.4.2 Superstructure

Referring to Figure 7.3.4, maximum span is considered as 300 m. From aesthetic point of view, the longer span is preferable. To find the most economical central span length, the Study Team has undertaken a comparison study on the central span lengths of 200 m, 230 m, 260 m and 290 m including substructure and foundation cost.

Figure 9.4.2 shows that the 260 m of the central span is the most economical.

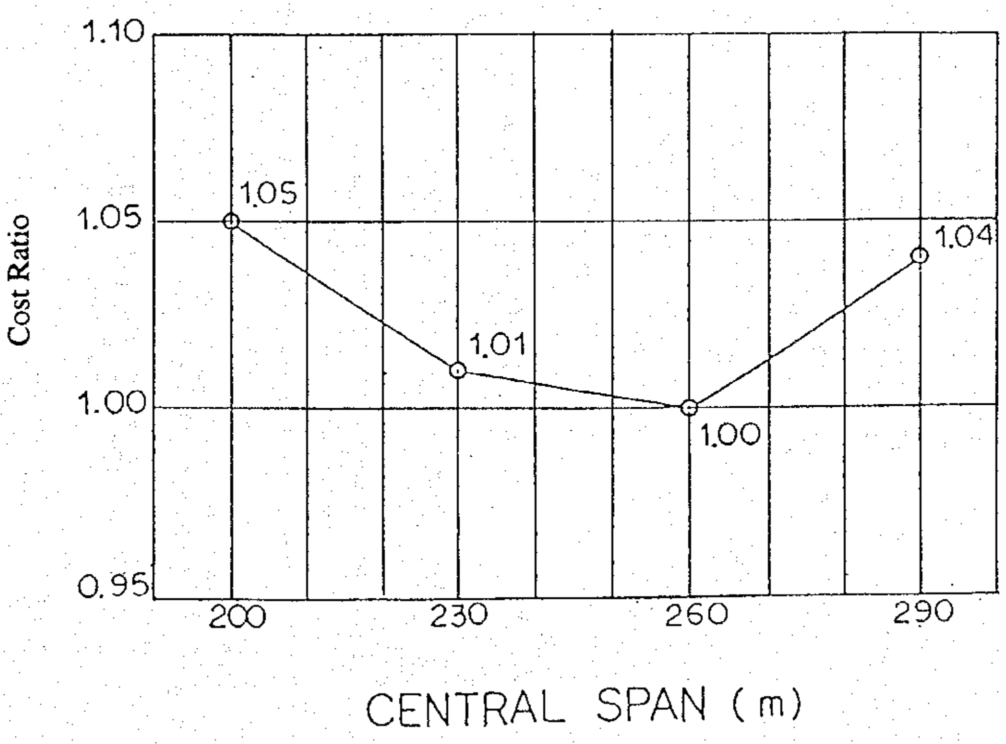


Figure 9.4.2 Comparison Study

The overall layout of the proposed bridge is shown in Figure 9.4.3. The span shown in the figure is considered to be close to the upper limit for a concrete cable stay bridge of the width of deck proposed. The height of the towers is approximately 95 metres above sea level. The height of the towers are within the limits defined by the Vietnam Aviation Dept. The technical data is shown in Appendix Chapter 9.

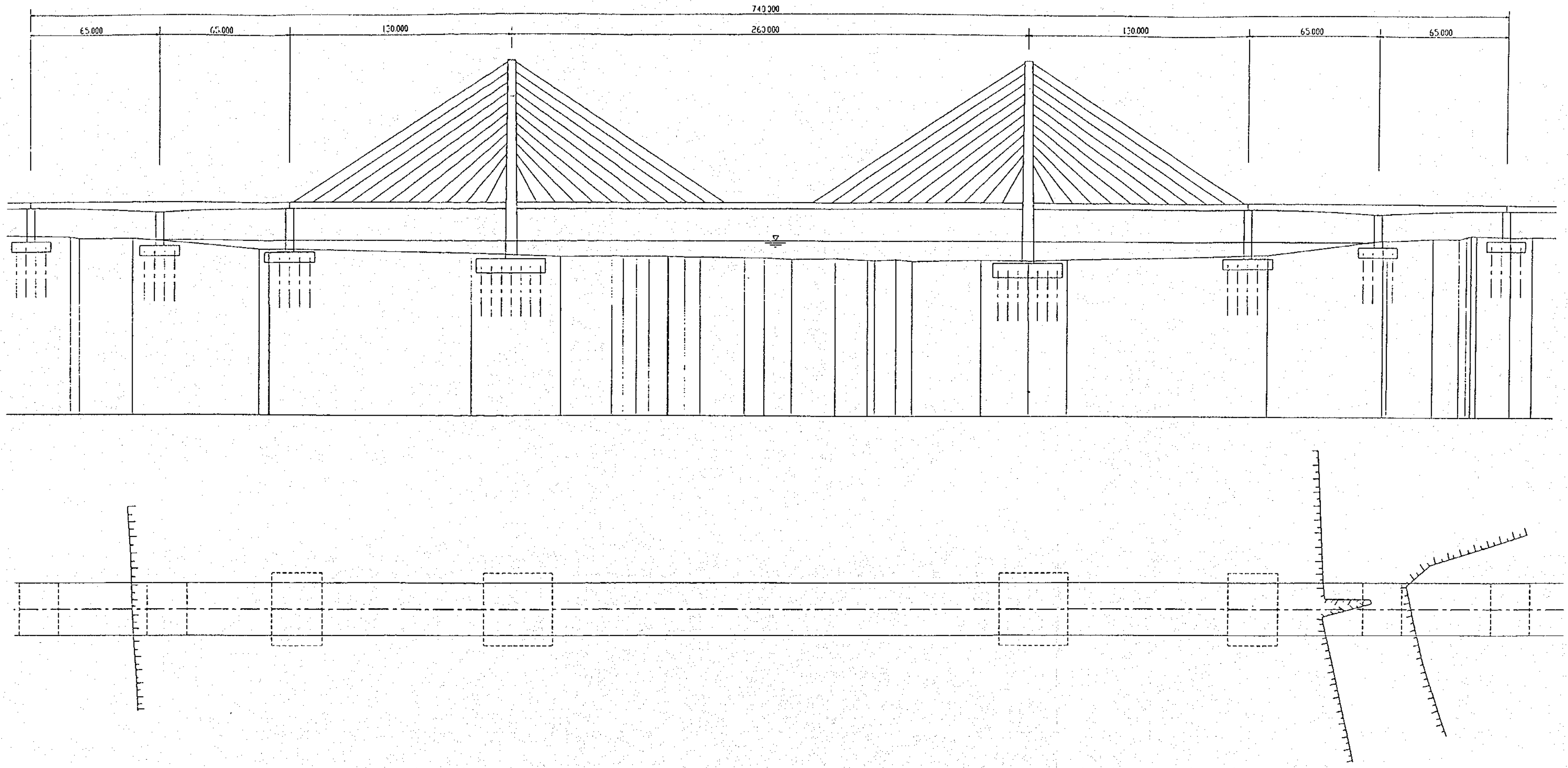


Figure 9.4.3 Alternative 3 PC Cable Stayed Bridge

9.4.3 Substructure/Foundation

As same as Bridge Alternatives 1.

9.5 Approach Bridge

(1) Superstructure

The approach bridges have been grouped in the following types.

1) Approach Bridge (1) : the bridge between the main river bridge and the dyke bridge.
2) Approach Bridge (2) : the bridge between the dyke bridge and earthworks.
3) Dyke Bridge : over the dykes.

The Study Team previously considered a number of structural forms for these bridges and after an investigation which included options such as extending the form of the main river bridge, using prestressed concrete box girder of constant depth and using precast post-tensioned concrete beams, the Study Team proposed the following arrangement:

1) Approach Bridge (1)

As mentioned in Section 9.1, PC continuous box girder bridge was adopted for Approach Bridge (1). Further study was carried out to find the most economical span arrangement. The result is shown in Figure 9.5.1. Figure 9.5.1 shows that 50 m span arrangement is the most suitable (economical) span among 30, 40, 50 and 60 m span.

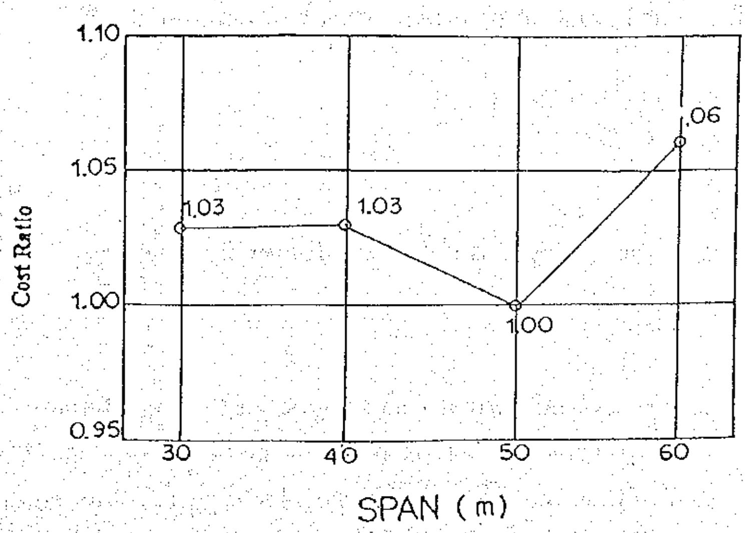


Figure 9.5.1 Comparison on Span Length

A continuous constant depth prestressed concrete box girder with a span of 50 metres for the bridge structure between the main bridge and dyke structures was used. A cross section of the bridge is shown in Figure 9.5.2 and is aesthetically compatible with the main and dyke structures. The deck can be formed by either balance cantilever or span by span techniques the latter being the most usual for this span length. In this form of construction the prestressing will be continuous with the vertical position of the cable adjusted to suit the moment condition.

2) Approach Bridge (2)

Precast beams, either simple supported or made continuous for the live load condition, with a span of 30m for the bridge structure between the dyke bridge and embankment were used. A cross section of the deck is shown in Figure 9.5.3. This type of construction has recently been used in the Hanoi region of Vietnam.

3) Dyke Bridge

Dyke authority requested that no permanent or temporary works can intrude into the dyke embankment limits. In addition, the high skew at the Thanh Tri dyke results in a span arrangement of 80+130+80. This results in a structure similar to the main river crossing. The layout of the Thanh Tri dyke bridge is shown in Figure 9.5.4. A longitudinal shift has been incorporated within the design so as to limit the length of the main span.

The Gia Lam dyke structure has a small skew angle so reducing the main span and also eliminating the need for a longitudinal shift as required in the Thanh Tri dyke structure. The layout of the bridge is shown in Figure 9.5.5.

(2) Substructure / Foundation

1) Pier

The types of piers are determined from following ideas:

a. Approach Bridge (1)

- Pier near the normal water course of the Red River are submerged in the rainy season. The type of piers shall be elliptical in shape taking into consideration the main bridge pier type to allow compatibility from an aesthetic view point.

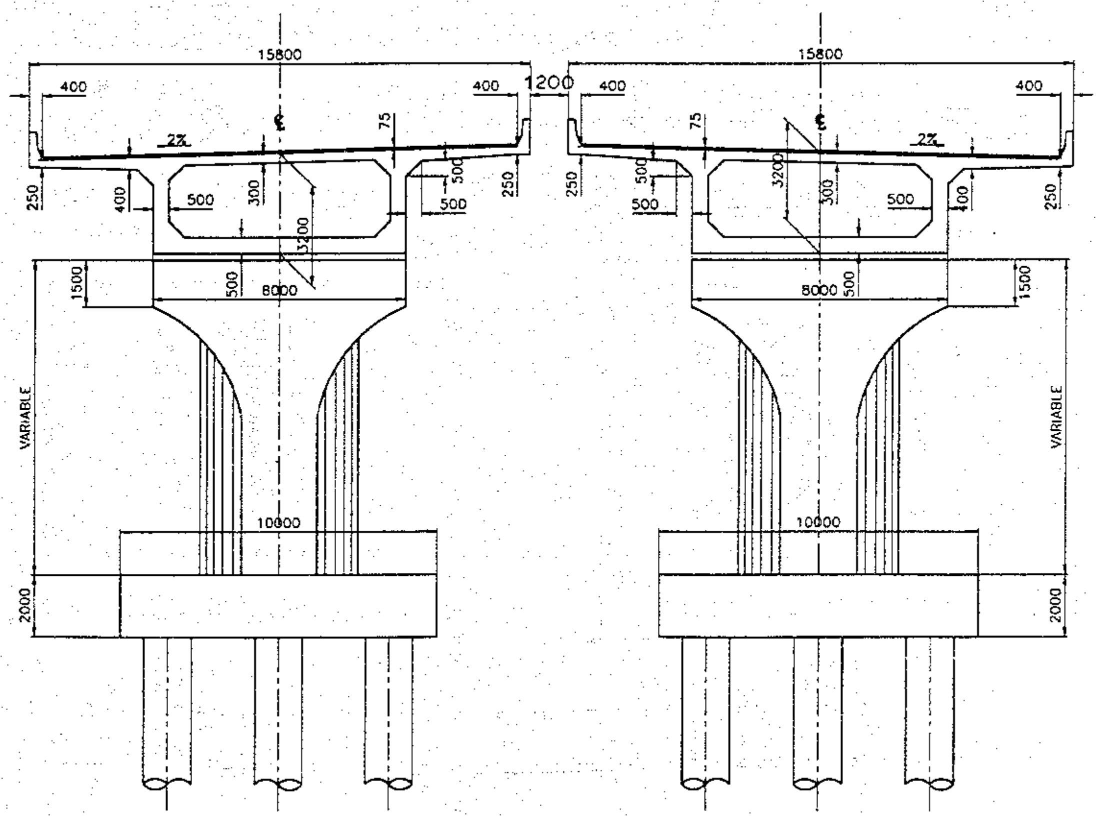


Figure 9.5.2 Cross Section, Approach Bridge (1)

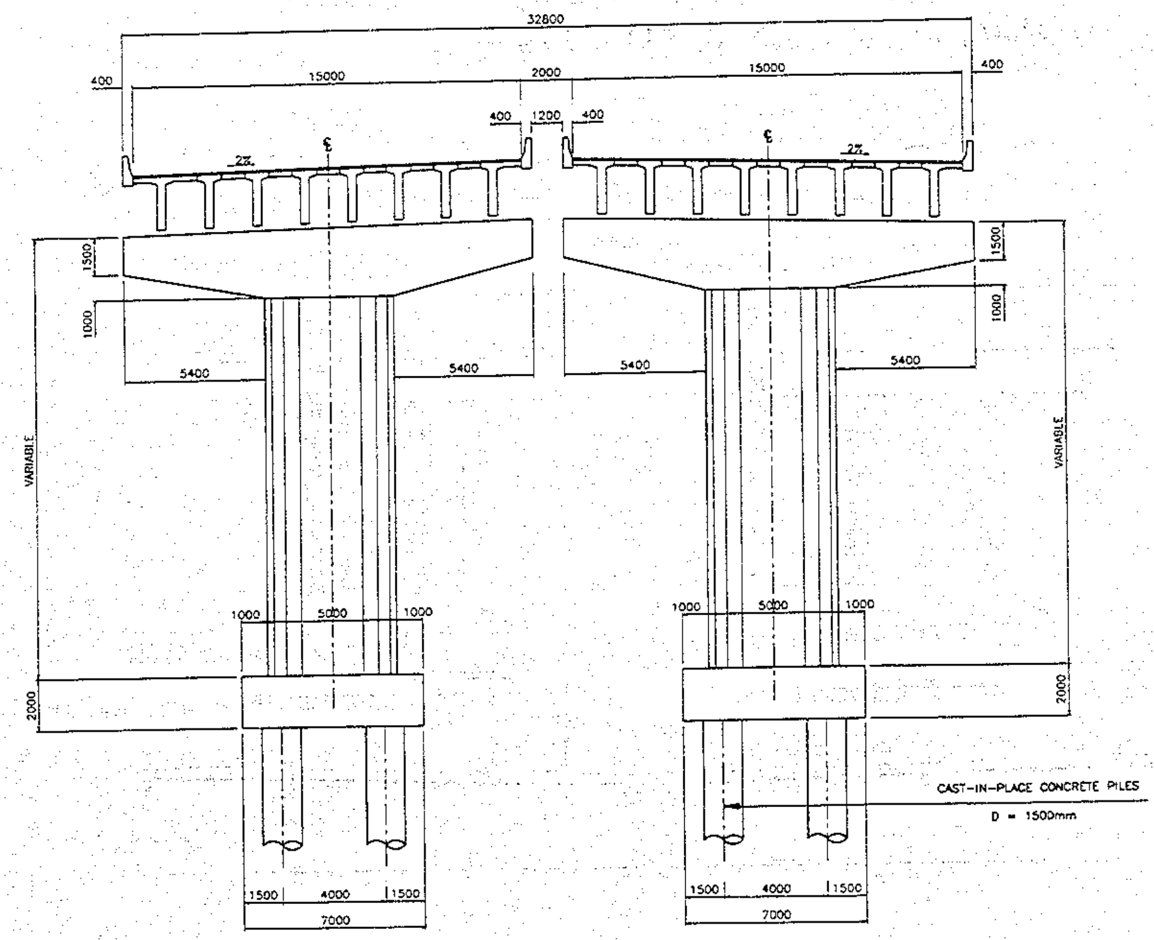


Figure 9.5.3 Cross Section, Approach Bridge (2)

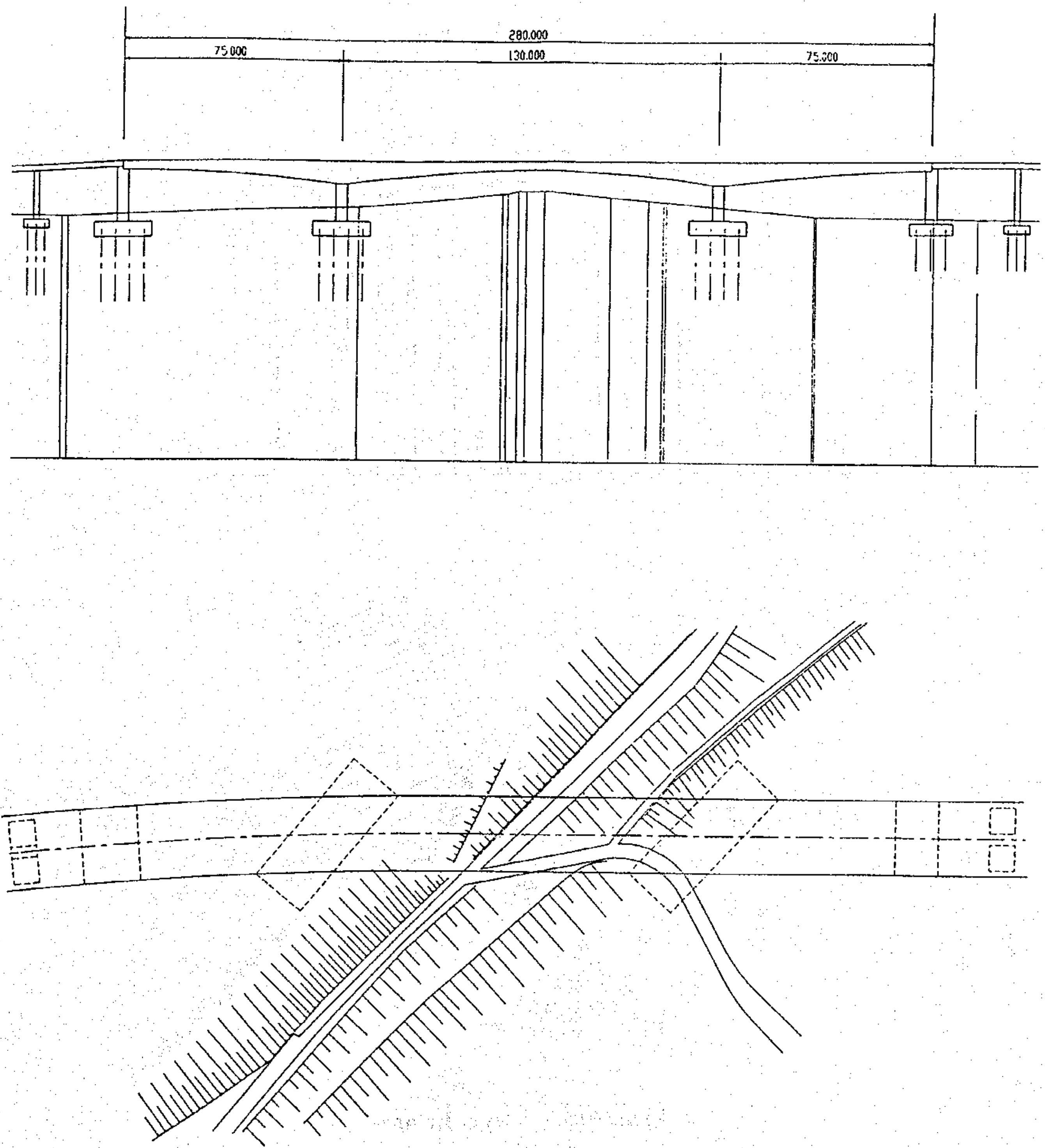


Figure 9.5.4 Dyke Bridge-1

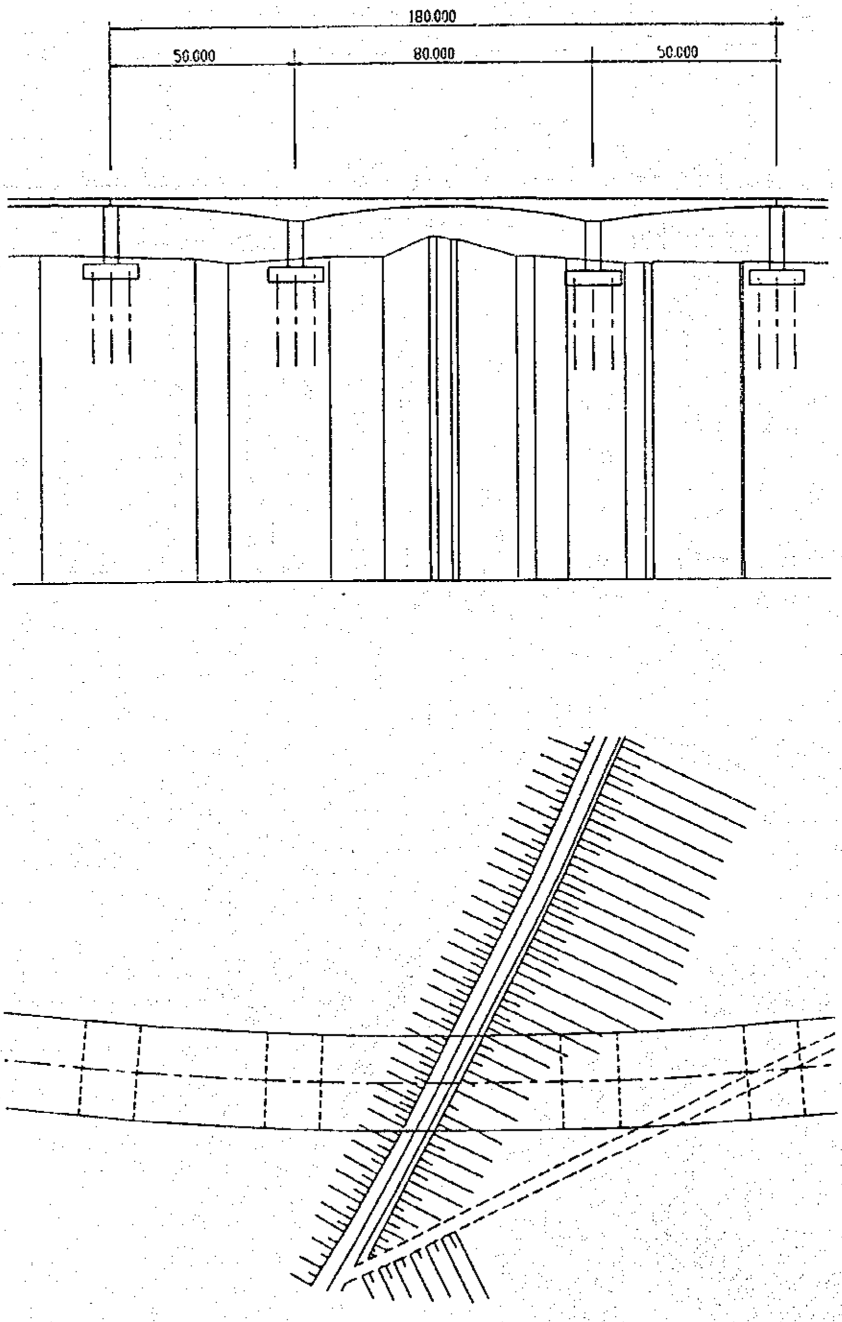


Figure 9.5.5 Dyke Bridge-2

- Selection of foundation type was investigated as same procedure as main bridge, finally the cast-in-situ concrete pile ϕ 1,500 was selected.

- Superstructure consists of PC continuous box girder (span 50 m). Comparing with Main Bridge the reactions are not as large so the scale of piers is not necessary to possess the high rigidity. Therefore, the substructure of Hanoi and Gia Lam carriageway shall be separated from the aesthetic view point.

b. Approach Bridge (2)

i. Pier

Superstructure consists of PC simple girder bridge (span = 30 m). The reactions from superstructure are further reduced than Approach Bridge (1). The Study Team proposes to use similar piers to that of Approach Bridge (1). The cross section of Approach Bridge (1) and (2) are shown in Figures 9.5.2 and 9.5.3.

ii. Abutment

Referring the results of slope and ground stability analysis in Chapter 5 the critical height of embankment is more than 10 m, however, the Study Team considers that the high embankment is not practical in the urban area and the maximum embankment height is within 6 - 7 m. The Approach Bridge (2) has been extended to achieve the maximum height of embankment. The reversed T-type abutment will be the most suitable for this project from constructability.

c. Dyke Bridge

The span arrangement of dyke bridges are as follows in the preliminary design stage.

Hanoi side	75 m + 130 m + 75 m = 280 m
Gia Lam side	50 m + 80 m + 50 m = 180 m

However, further study is required based on the topographical survey results to be conducted in the detailed design. Pier types are determined referring the results of the main bridge study.

2) Foundation

The comparison study was carried out as using the same procedure as Main Bridge. The Study Team has selected the ϕ 1,500 as the foundation for both Approach Bridge (1), Approach Bridge (2) and Dyke Bridge. The foundation loads for the Approach Bridge (2) are further reduced than Approach Bridge (1) and the option of using driven piles (40cm x 40cm) has been reviewed. This subject will be considered further at the detailed design stage but factors at present to note are:-

(a) the contractor will already have equipment on site for bored piles, changing the construction method for a short length of structure will require additional mobilisation costs.

(b) from our experience the rigidity of precast piles are less than cast-in-situ bored piles.

(c) the use of driven piles will increase the construction period as more piles are required and as a consequence a larger foundation size.

9.6 Comparison on Bridge Alternatives and Selection of the Recommended Bridge Type

9.6.1 Procedure for the Selection of Recommended Bridge Type

The selection of the recommended alternative was conducted according to the Figure 9.6.1. Procedure for the Selection of the Recommended Alternatives.

9.6.2 Selection of the Recommended Bridge Type

In step 2 of the Study Team Schedule, the design criteria and formulation of the bridge alternatives were investigated. Continuously, in step 3, the technical study and preliminary cost estimation on the bridge alternatives were conducted in Japan, then, overall evaluation on the selection was carried out.

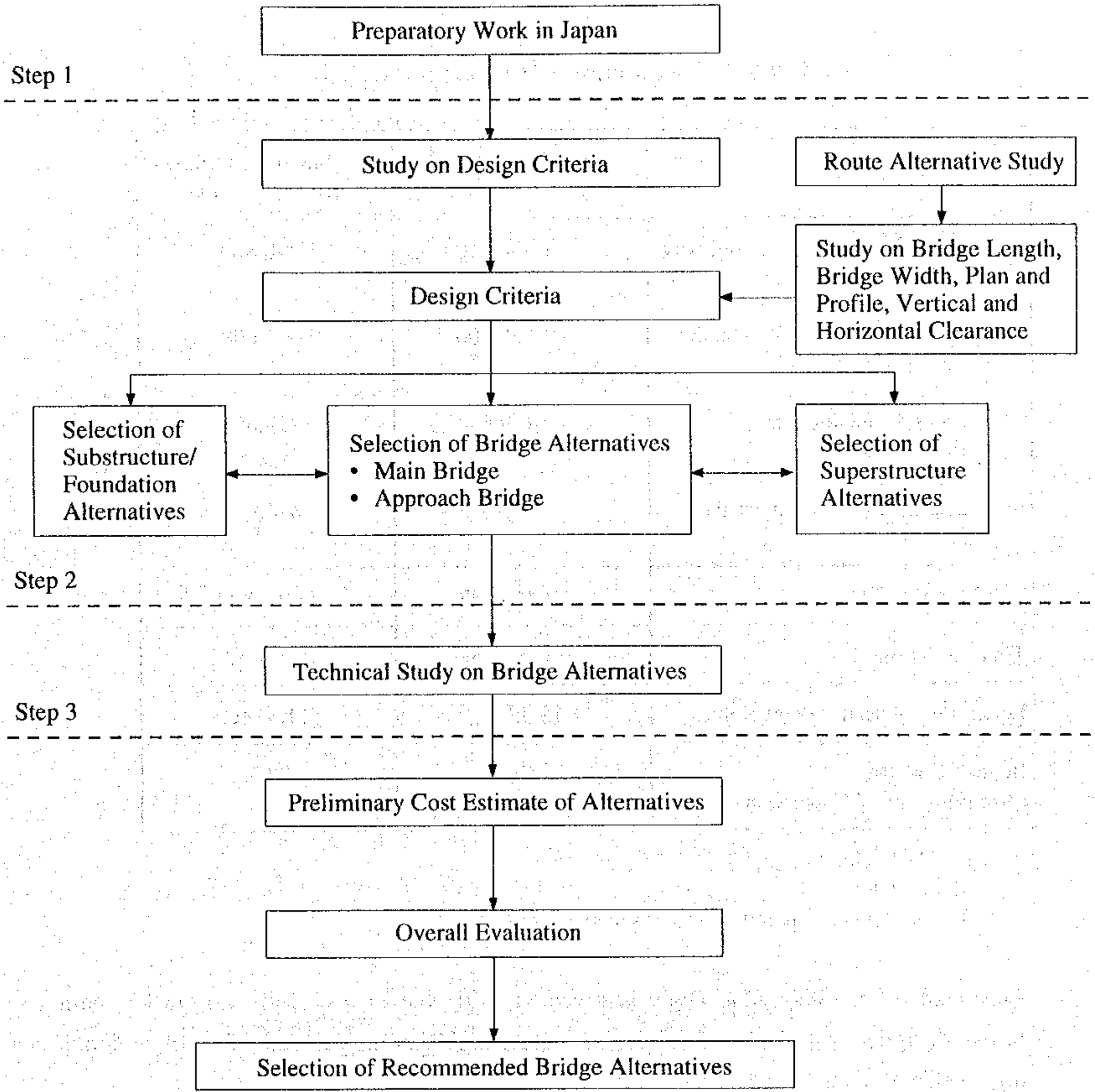


Figure 9.6.1 **Procedure for the Selection of Recommended Bridge Alternative**

Table 9.6.1 Summary of Economic Analysis

Unit of Cost: million Dong

Description	Box Girder Main Bridge Scheme	Cable Stayed Main Bridge Scheme
(1) Construction Cost of Highway and Interchanges 1)	1,390,860	1,390,860
(2) Construction Cost of Thanh Tri Bridge 2)	2,660,900	3,251,600
(3) Land Acquisition and Resettlement	129,654	129,654
(4) Engineering and Supervision (7 %)	283,623	324,972
Total Financial Cost	4,465,037	5,097,086
Total Economic Cost	3,984,452	4,546,512
Economic Internal Rate of Return	12.55 %	11.34 %
Benefit Cost Ratio (discounted at 12 % per year)	1.06	0.93

Notes: 1) Packages 2 and 3
2) Package 1
3) All costs include 10 % of physical contingency

The result of the economic analysis revealed that: the Project with box girder main bridge design is judged to be feasible, showing 12.55 % of internal rate of return which is higher than the opportunity cost of capital in Vietnam.

(2) Comparison of Short-Listed Bridge Types
(PC Continuous Box Girder Bridge and PC Cable Stayed Bridge)

1) Bridge Type Selection Method and Scoring System

Bridge type selection method followed Japanese government standard. The scoring (weighting) system is shown in Table 9.6.2.

Table 9.6.2 Scoring System in Comparison Component Evaluation

Component of Evaluation	Scoring	
	Japanese Standard	Adopted Full Score
1. Construction Cost	40 - 50	50
2. Structural Characteristics	5 - 15	10
3. Constructability	5 - 15	15
4. Aesthetics	5 - 15	15
5. Maintenance	5 - 15	10
Total	-	100

2) Scoring Method

a) Construction Cost

Superior alternative : give full score

Inferior alternative :

$$\text{full score} - \left[\frac{\text{Construction Cost of Inferior Alternative}}{\text{Construction Cost of Superior Alternative}} - 1\right] \times 50$$

b) Other Components

Good : give full score
Fair : 50 % of full score
Poor : put 0

3) Evaluation Result

The summary of evaluation result of comparison component is shown in Table 9.6.3.

4) Aesthetics of PC Cable Stayed Main Bridge

Attractiveness and Visual Balance

This bridge type will be attractive when viewed close from the river banks or boats, but maybe inconspicuous when viewed from dyke roads because of very long approach bridges.

Table 9.6.3 Comparison for Main Bridge Alternatives

Alternative	Alternative 1	Alternative 3
Main Bridge Type	PC Continuous Box Girder Bridge	PC Cable Stayed Bridge
Construction Cost	60 Million US$ (680m PC Box Girder) 50	102 Million US$ (Total Length 680m : 520m PC Cable Stayed Bridge+160m Approach Bridge) 15
Structural Characteristics	The stiffness of bridge is generally high and there is no significant problem of the wind stability. Moreover, the continuous girder has good performance for the resistance to an earthquake. 10	The stiffness of bridge is generally high but careful consideration is necessary to the wind stability and the optimum axial forces in the stay cables. 5
Constructability	Construction period in the river of the alternative 1 is longer than that of the alternative 3 as the number of substructures in the river is more. 15	Construction period in the river of the alternative 3 is shorter than that of the alternative 1 due to small number of substructures in the water. 15
Aesthetics	Well balanced views with continuing approach bridges and provides natural and graceful feelings. 8	Attractive when viewed close from flood plain or boats. However the size of main bridge is small. This situation can not be changed due to the limited height of bridge towers to meet aviation requirement. Difficult to be a symbolic structure. 15
Maintenance	Maintenance cost of the expansion joint for the alternative 1 is less than that for the alternative 3 as the number of bridge expansion joint is smaller. 10	Maintenance cost of the bridge expansion joint for the alternative 3 is slightly higher than that for the alternative 1. 10
Total Evaluation	Aesthetic impact is not so strong but superior in construction cost and structural characteristics to the alternative 3. 93	Aesthetic impact is good but construction cost is high and structural charasteristics is inferior to the alternative 1. 60
Recommended Priority	1	2

Landmark

The bridge could become an outstanding landmark, however it is doubtful that the bridge could become a symbol of the capital city of Hanoi, because of rather small scale of cable stayed bridge.

The maximum top elevation of towers is restricted within 99 m above mean sea level at Hanoi side to meet the aviation clearance requirement by Vietnam aviation department and this situation resulted present bridge design.

5) Conclusion

The priority, as a total evaluation for Alternative 1 will not be changed even if different weighting factors are adopted within Japanese standard for these five components of construction cost, structural characteristics, constructability, aesthetics and maintenance. Thus the Study Team recommends Alternative 1: PC Continuos Box Girder Bridge as the optimum bridge type.

Approach Bridge

The following bridge structures are recommended.

Superstructure

Approach Bridge (1) : PC Continuous Box Girder of Span = 50 m
Approach Bridge (2) : PC Simple T-Beam Bridge Span = 30 m
Dyke Bridge : PC Continuous Box Girder Bridge Span = 30 – 50 m

Foundation

- Cast-in-situ Concrete Pile ϕ 1,500 m

9.7 Further Studies Required in the Detailed Design Stage

Before the construction of this project, the detailed design shall be conducted after the review of the feasibility study and after the natural condition survey.

In the detailed design stage, there are many items which shall be studied in more detail in order to correspond to the detailed design purposes. The important matters to be considered in the detailed design of bridges are shown as follows:

(1) Natural Condition Survey

Topographic survey, soil investigations, hydrological survey and environmental impact survey shall be conducted.

1) Topographic Survey

Covering all of the study areas including in interchanges, flyovers and frontage roads and bridges, the topographic survey shall be carried out.

2) Soil Investigations

The soil investigations shall be conducted at the locations of all bridge, flyover and culvert sites. The boring tests shall be carried out to investigate the depths of the bearing strata of the foundations at the proposed bridge and flyover sites.

3) Hydrological Survey

It may be required to review the results of the feasibility study and conduct the hydrological surveying order to confirm the score depths and possibility of the change of normal water course at the proposed of Thanh Tri Bridge.

4) Environmental Impact Survey

It shall be required to conduct the environmental impact survey at the expecting affected sites in accordance with the Vietnam's environmental regulations. The results of the survey could be utilized for the detailed and effective environmental mitigation measures.

(2) Review of the Design Criteria

Before commencement of the detailed design, the live loads shall be reviewed to determine the scales of structures.

AASHTO HS 20-44 x 125 % can be adopted basically, however, H30 and XB 80 of Vietnamese live load codes shall be applied to the design. The loading systems shall be studied in more detail.

(3) Vertical Clearance over the Dyke Roads

In this feasibility study, the vertical clearance is 4.5 m over the dyke roads, on the assumption that the traffic vehicles can pass on the same conditions before and after the construction of Thanh Tri Bridge.

After the submission of Progress Report (2), the Study Team cooperated with PMU Thanh Long had meeting with Ministry of Agriculture and Rural Development (MARD) regarding general view (bridge planning) and MARD agreed the bridge planning including in the vertical clearance of 4.5 m.

However, when the vertical clearance over the dyke roads could be reduced from 4.5 m, the bridge lengths of Approach Bridge (2) can be shortened, as a result, the construction cost can be reduced.

The following further study was carried out:

Case 1; Vertical clearance deduction from 4.5 m to 3.0 m

The bridge evaluation over the dyke roads can be lower 1.5 m (= 4.5 m - 3.0 m) than the proposed bridge. The bridge lengths both Thanh Tri side and Gia Lam side are shorten one span = 30 m, therefore, the bridge lengths of Approach bridge (2) are shorten 60 m in total.

However, on the contrary, the embankment section is longer 60 m than the proposed plan.

Case 2; Vertical clearance deduction from 4.5 m to 2.5 m

Applying the same way of case 1, the bridge elevation is reduced 2.0 m (= 4.5 m - 2.5 m). The bridge lengths are shorten 2 span = 60 m both sides. The bridge lengths are shortened 120 m in total.

The following construction costs are changed comparing with the proposed plan.

- Decrease of Approach Bridge (2) construction cost
- Increase of embankment section construction cost
- Additional cost required due to the new detour construction cost

The results of comparison study:
The alterations of the total project cost comparing with proposed plan are as follows: The study regarding this matter shall be conducted in the detailed design.

Case 1: -0.5 %
Case 2: -1.0 %

(4) Required Coordination with Concerned Agencies

1) Ministry of Agriculture and Rural Development

Dyke Bridge at Thanh Tri side will cross the dyke with large skew angle, therefore, span length becomes extremely longer compared with right angle crossing. The possibility of the construction of foundation inside of the dykes shall be coordinated with Ministry of Agriculture and Rural Development (MARD) in order to reduce the span length.

The preliminary design of dyke bridges shall be reviewed based on the result of precise topographic survey which will be conducted in the detailed design stage. The review results shall be coordinated with MARD.

2) Vietnam National Railway

In the detailed design stage, the future railway development plan and the horizontal and vertical clearances of railway shall be reconfirmed with Vietnam National Railway.

3) Inland Waterway Bureau of Vietnam

The navigational clearance for Thanh Tri bridge shall be reconfirmed with Inland Waterway Bureau of Vietnam at the commencement of the detailed design.

CHAPTER 10

PRELIMINARY ENGINEERING DESIGN OF HIGHWAY

CHAPTER 10 PRELIMINARY ENGINEERING DESIGN OF HIGHWAY

10.1 Highway Study based on Selected Route

10.1.1 Route Description

The preferred route starts at the existing at-grade intersection of NH-1 and the existing 2 lane (6 - 8 m) road which connects the western dyke (Thanh Tri dyke road) with NH-1. The route passes along this existing road, which form the East-West trunk road network in Thanh Tri and the southern part of Hanoi. The predominate infrastructure features along this road are two ground water pumping stations, a 35 m long steel bridge and two high voltage transmission lines.

Since many housing developments are under construction in Thanh Tri district along the line of the existing road, it should be appreciated that this route may result in an increased impact to inhabitants in spite of decreasing land acquisition area. However, it is possible to relocate such affected houses adjoining the planned frontage roads, observing actual practices for NH-5 and other projects in Hanoi.

So Thuong village at Sta. 3+800 is located at the intersection with the north-south Yen So-Mai Dong road where a school and dense housing area are found in the vicinity of intersection. Before connecting to the western dyke, SHTRR is planned to deviate from the existing road and to pass between residential areas, where a church and park exist.

The route of SHTRR then runs northward along the periphery of residential area and intrudes into the premise of the cement warehouse of Chinfon factory in order to keep sufficient distance from Thanh Tri Pagoda, the newly developed residential area and school at Sta. 5+800.

SHTRR intrudes into the dense housing area at Nam Du Ha in order to keep a sufficient distance from the on-going Hanoi Water Supply and Environment Project - Stage 1 A (1997 - 1999) financed by the World Bank, the planned Ba Nhat chemical factory and the hero's cemetery of Linh Nam commune at Sta. 6+800. A viaduct is planned to minimize disruption to this housing area.

SHTRR is proposed to cross the Red River at the point of the TEDI's route. However, the route will turn towards the north 150 m from the original intersecting point with the eastern dyke to avoid the historical heritage and tombs in rice field (locally called "mo") in Gia Lam district. SHTRR then runs parallel to existing road and irrigation channel which will required relocated over a 1 km long stretch.

The route terminates at the established intersection point on NH-5 where the northern section of the New NH-1 is being implemented with assistance from the Asian Development Bank.

Total length of road between Phap Van on NH-1 and Sai Dong on NH-5 is estimated to be approximately 12.2 km, where the distance between dykes is about 2,400 m.

10.1.2 Traffic Capacity and Required Number of Lanes

(1) Methodology

The concept and methodology used for the highway capacity analysis were based on the "Highway Capacity Manual of Highway Research Board, U. S. A.". However, some adjustment was made to reflect local conditions based on the results of studies undertaken by the "Highway Research Board, Japan (Japanese Standard)", since much resemblance is found in type and size of vehicles and in operating conditions, in Vietnam and Japan.

The flow diagram in Figure 10.1.1 shows the procedure and the factors to be considered depending on the conditions of the area, type of vehicle, quality of the traffic flow and the cross section of the highway. The standard cross section which influences the capacity is shown in Figure 10.1.11.

(2) Basic Capacity (C_B)

Basic capacity in the Japanese Standard is the maximum service flow rate per lane under ideal conditions of highway and traffic flow. The ideal condition is only accomplished providing the followings are met:

- Not less than 3.5 m lane width;
- Not less than 0.75 m lateral clearance;
- Good geometric design;
- Only passenger cars running; and
- No speed limit.

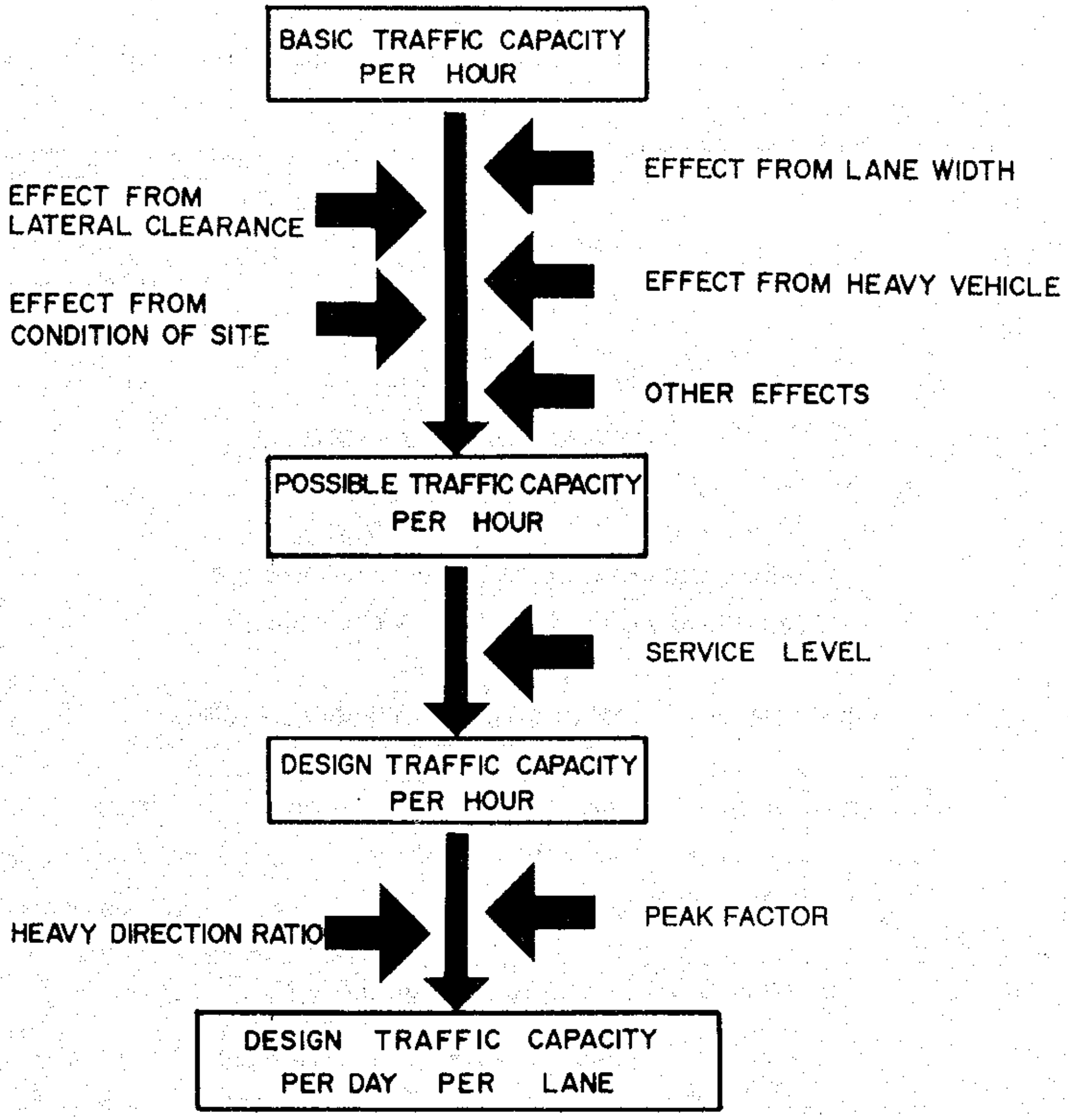


Figure 10.1.1 **Flow Diagram to Calculate Design Traffic Capacity of Multilane Highway**

2,200 CU/hr/lane is recommended for multilane highway in the Japanese Standard and this is based on data surveyed at numerous locations on the existing roads in Japan.

(3) Possible Capacity (C_L)

Actual road and traffic conditions are different from the ideal conditions. The basic capacity is adjusted using several factors which affect the capacity in order to meet the expected actual highway conditions. The factors affecting basic capacity are summarized as follows:

$$C_L = C_B \times \gamma_L \times \gamma_C \times \gamma_I \times ----$$

Where:

C_L = Possible capacity per lane (PCU/hr/lane)
C_B = Basic capacity (PCU/hr/lane) = 2,200
γ_L = Adjustment factor for restricted lane width
γ_C = Adjustment factor for restricted lateral clearance
γ_I = Adjustment factor for roadside development

1) Adjustment Factor for Restricted Lane Width ($\gamma_L = 1.00$)

In the Japanese Standard the minimum lane width for mixed traffic so as not to affect the traffic capacity, is designated to be 3.25 m. The coefficients of the effect of lane width are as shown below.

Lane Width (m)	Adjustment Index γ_L
≧3.25	1.00 (adopted)
3.00	0.94
2.75	0.88

2) Adjustment Factor for Restricted Lateral Clearance ($\gamma_C = 1.00$)

The lateral clearance is the distance between the edge of lane and obstacles such as retaining wall, electric pole, guardrail, etc.

These obstacles affect the traffic capacity if they are put within 0.75 m from the edge of the lane. The coefficients of the effect from lateral clearance are as shown in Table 10.1.1 in the case of a multilane highway (Japanese Standard).

Table 10.1.1 Adjustment Factor for Restricted Lateral Clearance

Lateral Clearance	Adjustment Index γ_C	
	Obstructions on One Side of the Roadway	Obstructions on Both Side of the Roadway
≧0.75	1.00	1.00
0.50	0.98	0.95
0.25	0.95	0.91
0.00	0.93	0.86

3) Adjustment Factor for Roadside Development ($\gamma_I = 1.00$)

No interference is expected from outside of the highway, since SHTRR is access controlled expressway type.

4) Adjustment Factor for the Effect of Trucks and Buses ($\gamma_T = 1.00$)

Heavy vehicles such as trucks and buses reduce basic traffic capacity not only by the body size but also by the reduced power to weight ratio. This results in lower vehicle speeds especially on steep and long grades.

The effect of heavy vehicles on the traffic capacity is evaluated by converting one heavy vehicle to the equivalent number of passenger cars (sedan) which give the same influence to the capacity.

Effect of trucks and buses is already considered in the conversion of actual traffic volume (vehicle/day) into passenger car unit traffic volume (PCU/day). As seen in Figure 4.5.3, a conversion factor of 2.0 is used for all trucks and buses.

The conversion factor varies depending on the categories of terrain and landuse (Japanese Standard).

Number of Lane	Conversion Rates	
	Urban Area and Flat Terrain	Mountainous Area
Multilane (Divided Highway)	2.0	3.0

Above conversion factor is applicable only for large trucks (gross weight = 8 ton and more) and buses in accordance with the Japanese Standard. The Study Team adopted the same conversion rate of 2.0 also for light trucks such as small size pick-up trucks to give a slight allowance.

5) Adjustment Factor for Driver Population ($\gamma_D = 1.00$)

In case of the rural highways which serve for weekend travelers or recreational purpose the expressways will be used less efficiently. Drivers are sometimes not familiar with the facility and must experience long drive. American Highway Capacity Manual recommends the adoption of fp = 1.00 in case of the urban highway which is mostly utilized by regular weekday drivers or commuters.

(3) Design Capacity per Hour (C_D)

Planning characteristics for the three levels of service are shown in the Japanese Standard (Table 10.1.2).

Planning level is expressed by the ratio of the traffic volume (V) and the Possible Capacity (C) - V/C.

Table 10.1.2 Planning Levels of Service

Planning Level	Adjustment Index (γ_P)	
	Rural Region	Urban Region
1	0.75	0.80
2	0.85	0.90
3	1.00	1.00

The design traffic capacity is calculated by multiplying γ_P of required planning level to the possible traffic capacity.

$$C_D = C_L \times \gamma_P = 2{,}200 \times 0.85 = 1{,}870 \text{ PCU/hr/lane}$$

The Figure 10.1.2 shows the relationship between planning level and peak hour traffic volume. Summary of the basic criteria on the traffic condition in each planning level are as follows:

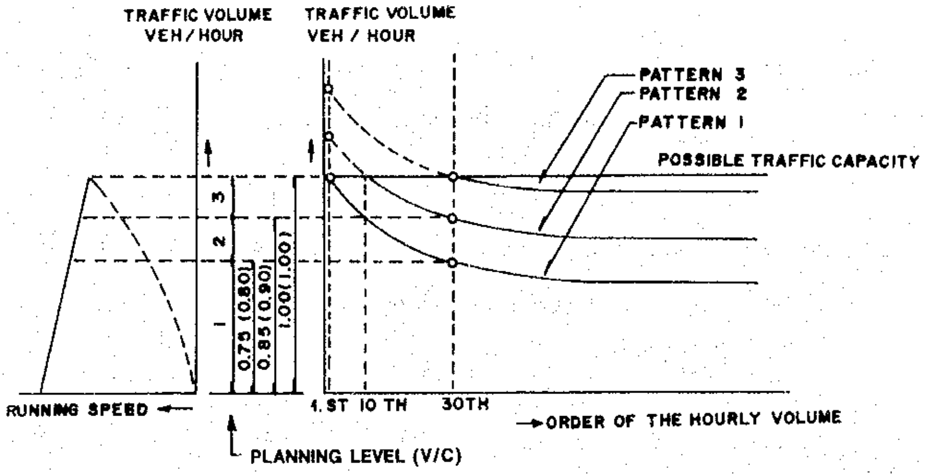


Figure 10.1.2   Planning Level and Hourly Traffic Volume

Planning level-1: At the target year of design, the annual maximum peak hour traffic volume is less than the possible capacity per hour. Vehicles in the 30th highest annual hourly volume can keep stable flow at certain speed.

Planning level-2: At the target year of design, 10th highest annual hourly traffic volume reaches possible capacity and this sometimes causes serious traffic jams during these peak 10 hours. Vehicles in the 30th highest annual hourly volume are difficult to keep uniform speeds and the speed changes at random.

Planning level-3: At the target year of design, 30th highest annual hourly traffic volume exceeds possible capacity and this causes serious traffic jams during these peak 30 hours. Vehicles in the flow of the 30th highest annual hourly volume is always forced to change speed and sometimes is forced to stop.

Even if Service level-3 is adopted, it is theoretically possible to say that during only 30 hours in 1 year (= 8,760 hours) the traffic volume exceeds possible capacity.

To consider the viability of the Project and the adoptability of stage development policy, Planning Level-2 is applied. Although an adjustment index (γ_P) of 0.90 is specified for Planning Level-2 in case of urban highways, the Study Team has been adopted more safe value of 0.85 which is compatible for rural region (refer to Table 10.2.2).

With respect to design levels of service, recommendations of AASHTO Highway Capacity Manual and the Japanese Standard are approximately comparable to the following V/S ratios.

Standard	Highway Category	V/C Ratio
AASHTO	Urban and Suburban Freeways	0.80
Highway Capacity Manual	Freeway	0.84 *
Japanese Standard	Urban Expressways	0.90 **

Note: * For level of service D; see illustration shown below.

** For Planning Level-2

Illustration Level-of-service D.

It is important to note that level of service designations and criteria are not same even in AASHTO and Highway Capacity Manual. It is observed that American standards generally apply lower ratio of V/C compared with the Japanese Standard due to the wide utilization of larger vehicles.

(4) Design Traffic Capacity per Day

1) K-Factor

The actual traffic flow on highways is not always constant but has a characteristic to change by year, season, month, day and hour depending on the nature of the highway.

Normally the 30th highest annual hourly traffic volume is applied for estimation of the capacity. The conversion factor from daily to hourly "K" is defined as the ratio of the 30th highest annual hourly traffic volume against the average annual daily traffic volume (AADT).

The K-factor is dependent on the type and density of the development environment. Highway Capacity Manual and the Japanese Standard suggest the following general average values.

Standard	Type of Environment	K-Factor
Highway Capacity Manual	Urban	0.09 - 0.10
Japanese Standard	Urban	0.076 - 0.082

The Study Team adopted 0.09 for K-factor.

2) D-Factor

Generally traffic volume is shown by total volume in two directions. However the traffic volume in each direction is not usually the same, especially in the morning and evening peak hours.

The D-factor is dependent on the type of route surveyed by the highway in question. Where local data are not available, the following general average values may be used (Highway Capacity Manual):

Type of Route	D-Factor
Urban Radial	0.55
Urban Circumferential	0.50

Adopt D-Factor = 0.55

3) Design Average Annual Daily Traffic Volume (Design AADT)

Design AADT (C_{DD}) =

$$C_D \times \frac{5{,}000}{K \times D} = 1{,}870 \times \frac{5{,}000}{9 \times 55} = 18{,}900 \text{ PCU/day/lane}$$

Where:

C_{DD} = Design capacity per day (PCU/day/lane)
C_D = Design capacity per hour (PCU/hr/lane)
K = K-factor = 9 %
D = D-factor = 55 %

4) Summary of Traffic Capacity Analysis

Table 10.1.3 shows summary of traffic capacity analysis with brief notes in each calculation steps.

The traffic demand forecast and capacity for a 4-lane traveled way is shown in Figures 10.1.3 and 10.1.4.

(5) Conclusions

1) SHTRR

The number of lanes of the through traveled way is recommended to be a total of four (4) lanes for the both of Thanh Tri and Gia Lam sections of SHTRR.

Total Capacity of 4-Lane Through Traveled Way = 18,900 x 4 =
75,600 PCU/day

This capacity contains certain allowance compared with the maximum daily traffic volume in 2010 (73,200 PCU/day).

2) Thanh Tri Bridge

The number of lanes of the through traveled way is recommended to be basically a total of six (6) lanes (motorcycle lanes separated in initial stage) for Thanh Tri Bridge.

Total Capacity of 6-Lane Bridge = 18,900 x 6 = 113,400 PCU/day

This shows that the capacity has slight allowance even if compared with daily traffic volume in 2020 (111,700 PCU/day).

3) Transition Section between 4-Lane and 6-Lane Through Traveled Ways

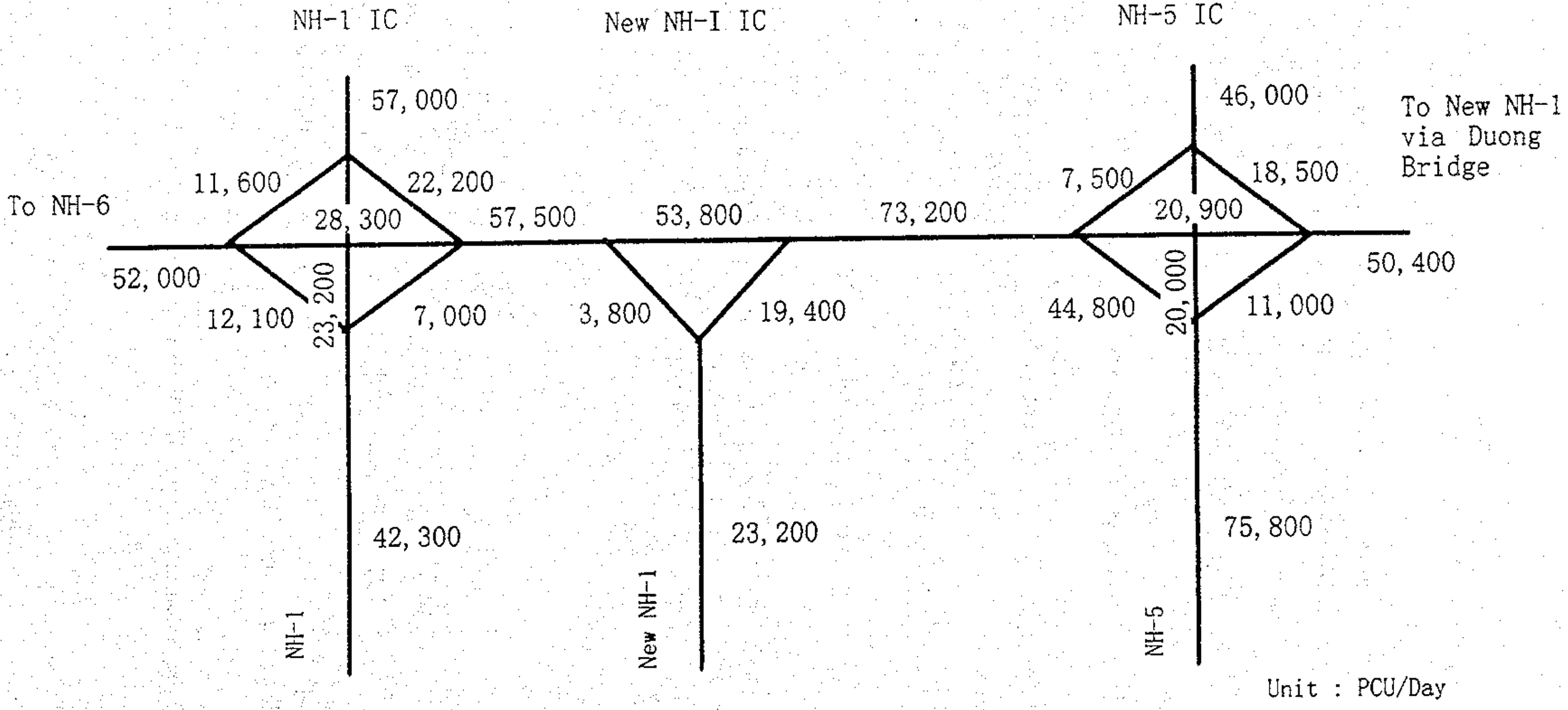
The increase in number of lanes can be made at the on and off ramps sections of dike road interchanges in the framework of detailed design. For 4 % grade (refer to footnote in Table 10.1.3), it is preferable not to adopt in 4-lane sections to obtain better vehicle maneuver freedom; therefore 6-lane through traveled way will be extended to both of the said interchanges.

Table 10.1.3 Summary of Capacity Analysis

Description		Symbol	Unit	Adopted	Remarks
Highway Type		-	-	-	Urban Expressway
Landuse/Terrain		-	-	Urban/Flat	See Note below
Design Speed		-	km/hr	100	
Lane Width		-	m	3.75	
Lateral Clearance	Outer	-	m	3.00	
	Inner	-	m	1.00	
Basic Capacity		C_B	PCU/hr/lane	2,200	Multilane highway
Adjust-ment Factors	Lane Width	γ_L	-	1.00	
	Lateral Clearance	γ_C	-	1.00	
	Roadside Development	γ_I	-	1.00	
	Large Vehicles	γ_T	-	1.00	Trucks and buses
	Driver Population	γ_D	-	1.00	
	Planning Level-2	γ_P	-	0.85	0.90 in urban region (Japanese Standard)
Possible Capacity		C_L	PCU/hr/lane	2,200	$C_L = C_B \cdot \gamma_L \cdot \gamma_C \cdot \gamma_I \cdot \gamma_T \cdot \gamma_D$
Design Capacity per Hour		C_D	PCU/hr/lane	1,870	$C_D = C_L \cdot \gamma_P$
K-Factor		K	%	9	Highway Capacity Manual
D-Factor		D	%	55	Highway Capacity Manual
Design Average Annual Daily Traffic Volume		DAADT	PCU/day/lane	18,900	Design AADT $= C_D \cdot \frac{5{,}000}{K \cdot D}$

Note: The maximum grade of 3 % has been applied for SHTRR except for the approach sections of Thanh Tri Bridge.

Location	Maximum Grade (%)	Length of Steep Grade (3 - 4 %)	
		Bridge Section (m)	Embankment Section (m)
Thanh Tri Side	4.0	250 approx.	100 approx.
Gia Lam Side	4.0	200 approx.	100 approx.



* excluding the trafic on frontage road

Figure 10.1.3 Future Traffic Demand in 2010 on SHTRR

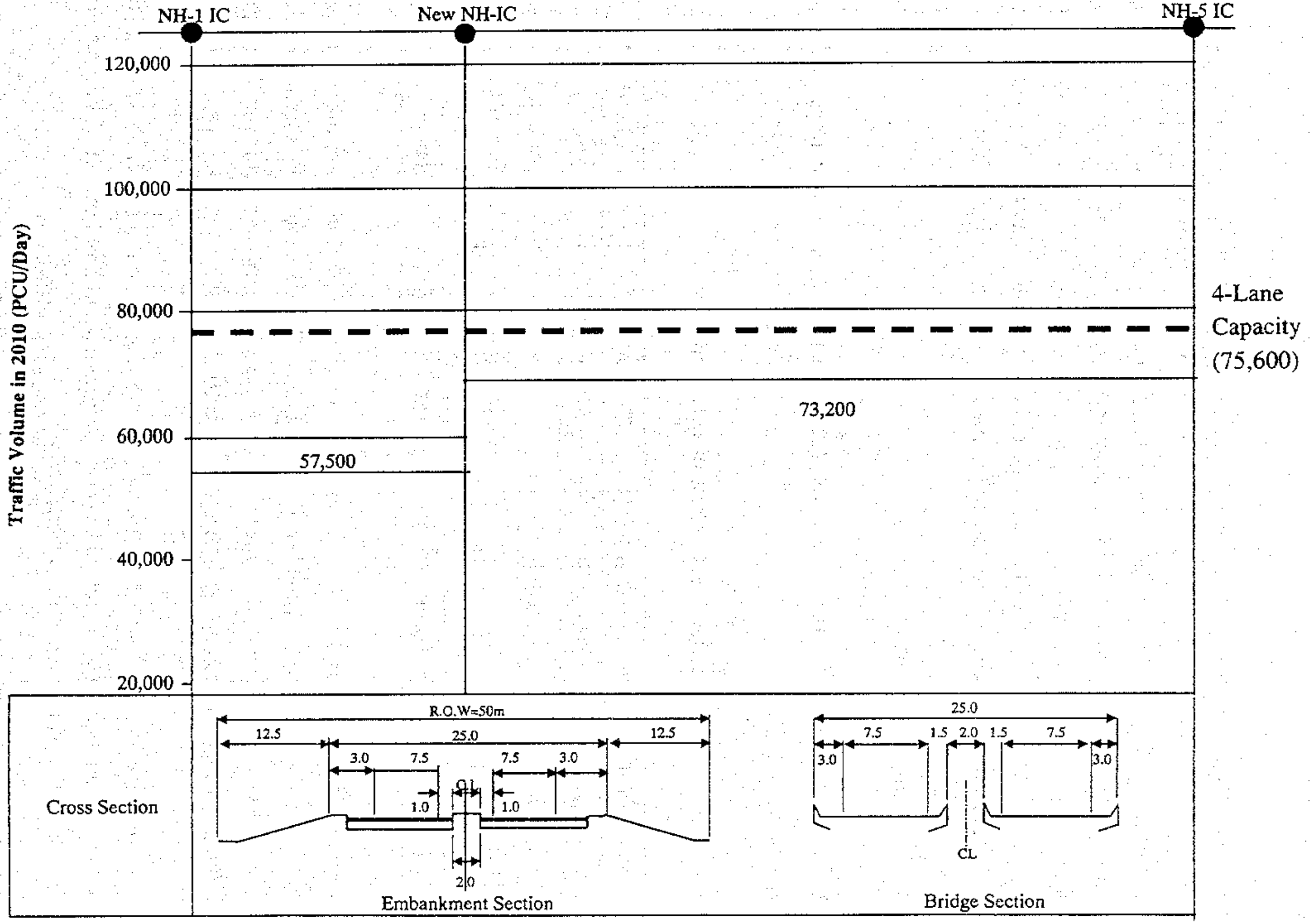


Figure 10.1.4 Future Traffic Demand and Traffic Capacity