MINISTRY OF PUBLIC WORKS AND TRANSPORT
KINGDOM OF CAMBODIA

No. 1

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR THE IMPROVEMENT OF

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ON
THE PROJECT FOR THE IMPROVEMENT
OF
NATIONAL HIGHWAY ROUTE 6
SIEM REAP SECTION
IN
THE KINGDOM OF CAMBODIA

SEPTEMBER 1999

JAPAN INTERNATIONAL COOPERATION AGENCY

KATAHIRA & ENGINEERS INTERNATIONAL

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PREFACE

In response to a request from the Royal Government of Cambodia, the Government of Japan decided to conduct a basic design study on the Project for the Improvement of National Highway Route 6 Siem Reap Section and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Cambodia a study team from April 5 to May 18, 1999.

The team held discussions with the officials concerned of the Royal Government of Cambodia, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Cambodia from August 2 to August 10, 1999 in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Royal Government of Cambodia for their close cooperation extended to the teams.

September, 1999

Kimio Fujita
President
Japan International Cooperation Agency

September, 1999

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for the Improvement of National Highway Route 6 Siem Reap Section in the Royal Government of Cambodia.

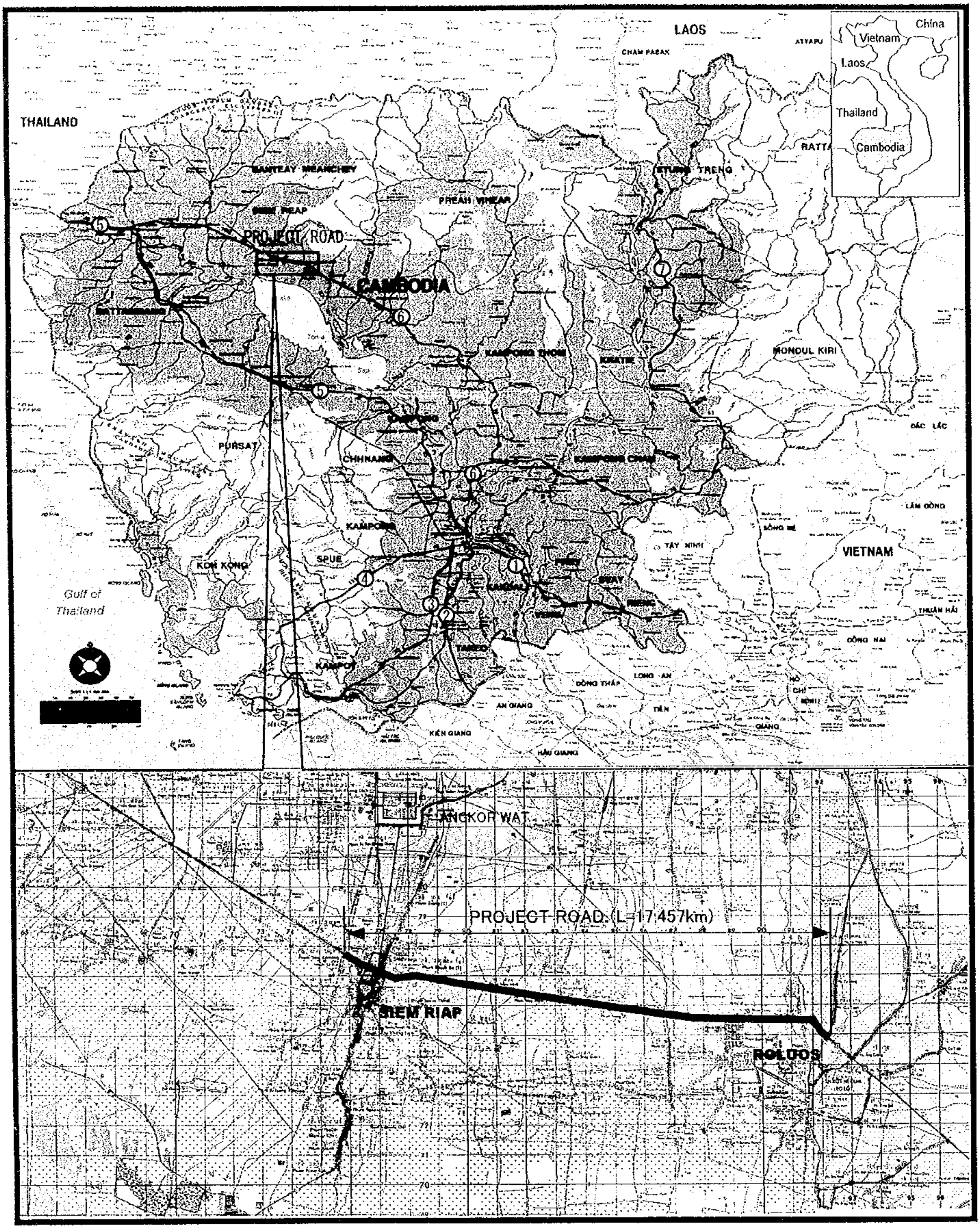
This study was conducted by Katahira & Engineers International, under a contract to JICA, during the period from March 29, 1999 to September 27, 1999. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Cambodia and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

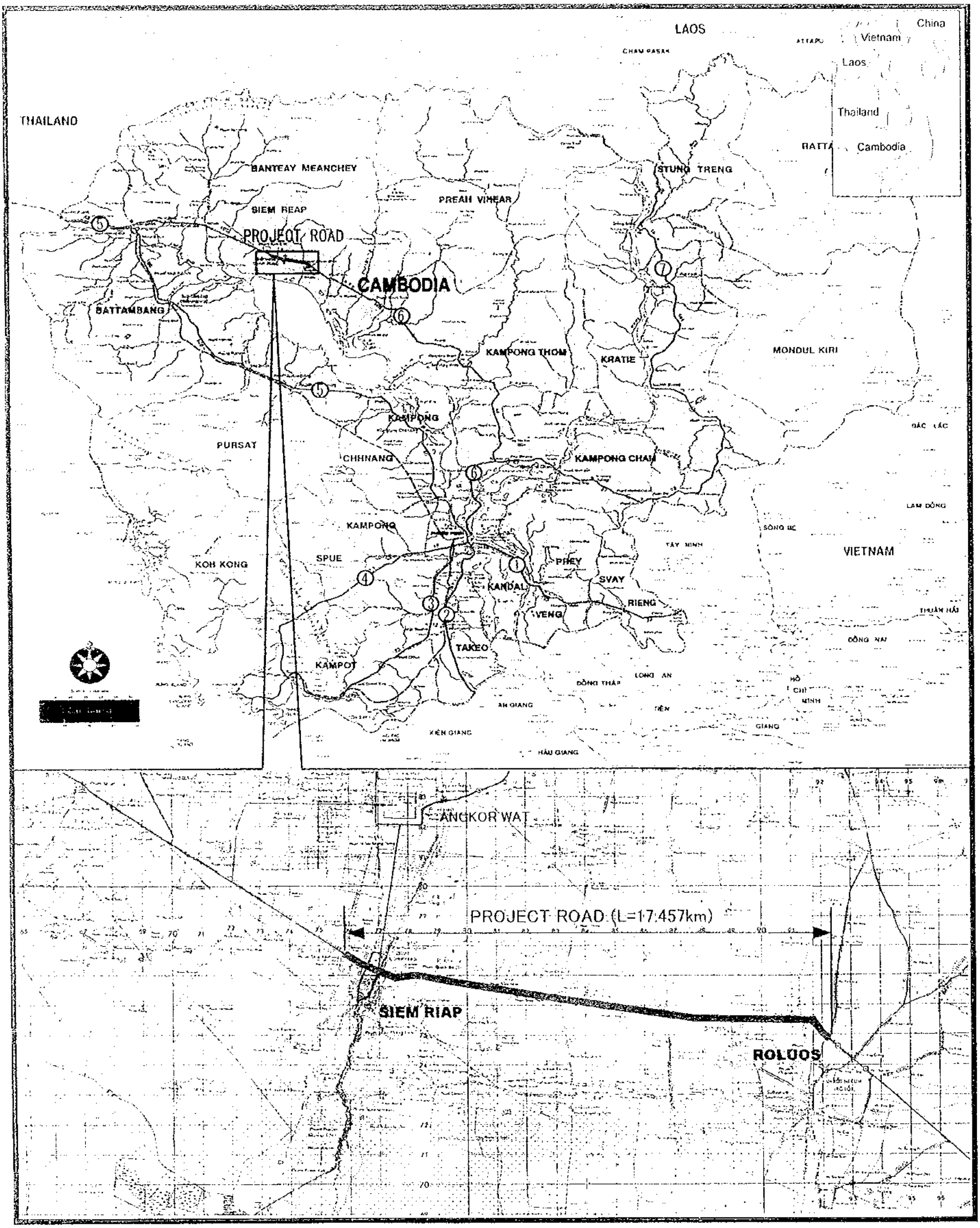
Very truly yours,

Kunihiko Sawano

Kunihiko Sawano
Project Manager,
Basic Design Study Team
on the Project for the Improvement of
National Highway Route 6 Siem Reap Section
in the Kingdom of Cambodia



LOCATION MAP



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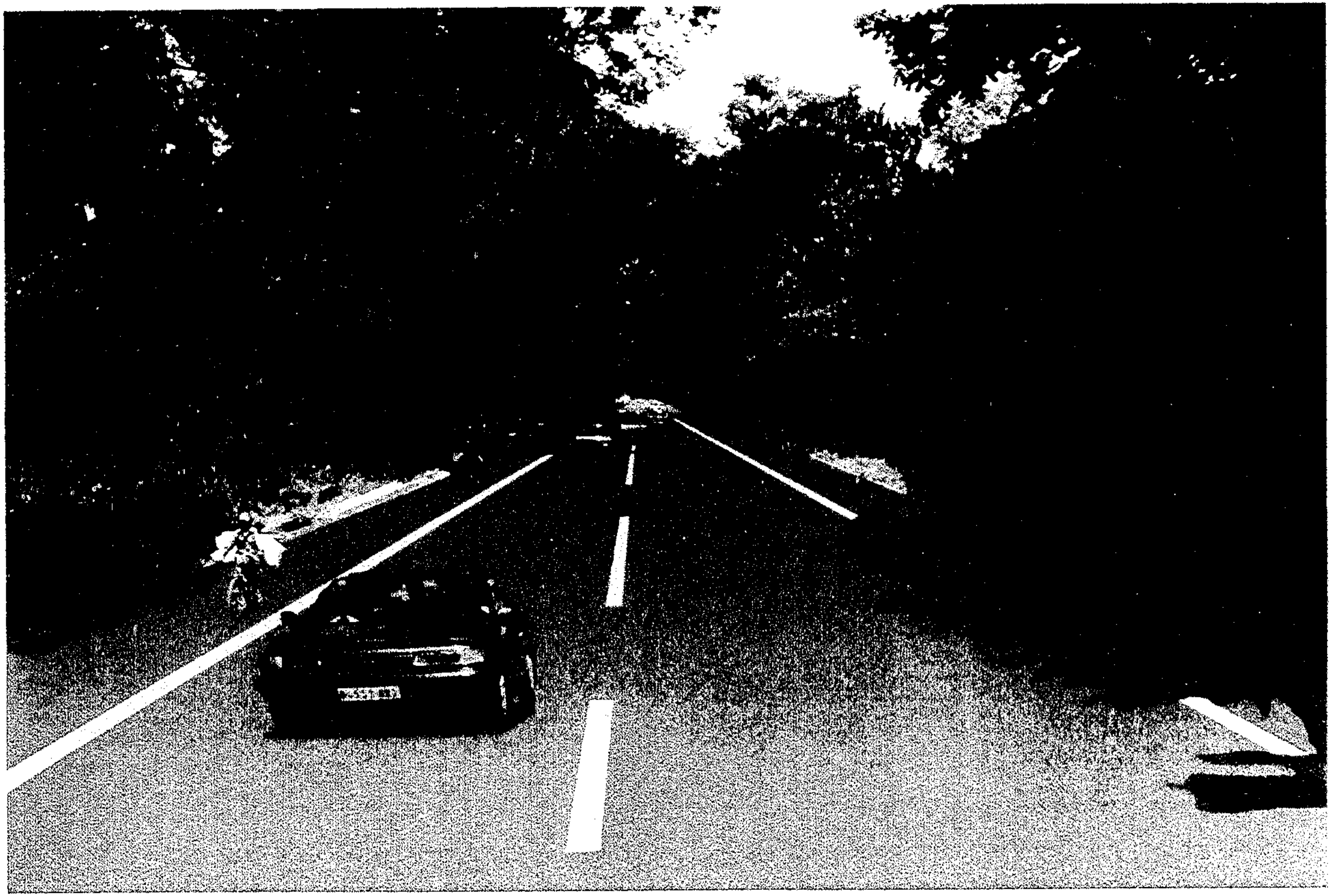
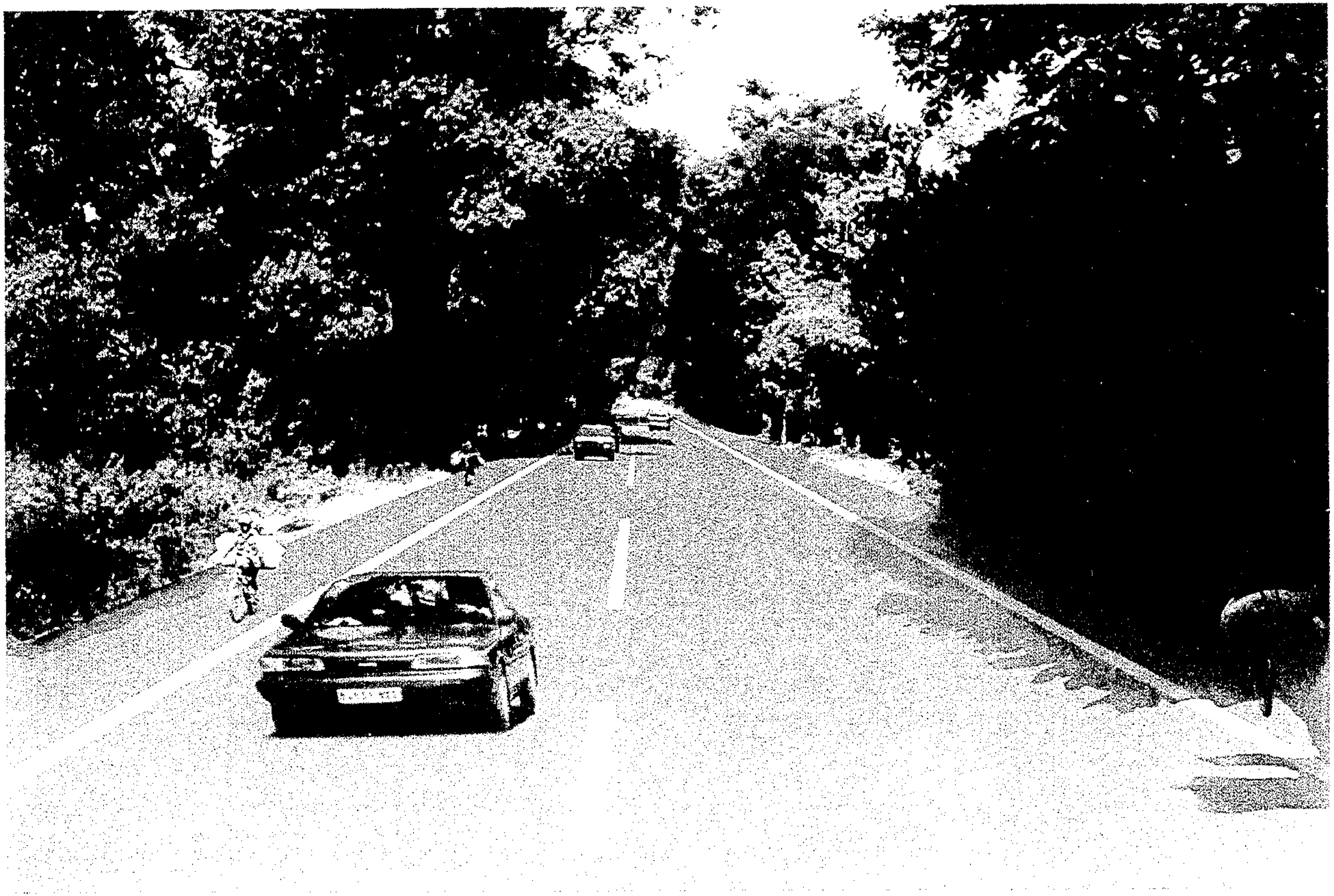


KM301+500 (Baray Bank Section)

PERSPECTIVE



KM301+500 (Baray Bank Section)

PERSPECTIVE

Abbreviation

AASHTO	:	American Association of State Highway and Transportation Officials
APSARA	:	Authority for the Protection and Management of Angkor and the Region of Siem Reap
A C	:	Asphalt Concrete
A D B	:	Asian Development Bank
C B R	:	California Bearing Ratio
CDC	:	Council for Development of Cambodia
CMAC	:	Cambodian Mine Action Centre
D B S T	:	Double Bituminous Surface Treatment
EDC	:	Electricite du Cambodge
EL	:	Elevation
E S A L	:	Equivalent Single Axle Load
MPWT	:	Ministry of Public Works and Transport
Kip	:	Kilo Pound
OJT	:	On the Job Training
PC	:	Pre-stressed Concrete
R C	:	Reinforced Concrete
RCC	:	Road Construction Center
S N	:	Structural Number
U X O	:	Unexploded Ordnance
WB	:	World Bank

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CHAPTER 1 BACKGROUND OF THE PROJECT

Transport facilities in the Kingdom of Cambodia are composed of roads, railways, air transport, sea transport and inland waterways, of which road transport is the only mode with nationwide coverage and carries more than 90% of the total volume of transport.

A central focus of the First Socioeconomic Development Plan 1996 - 2000 is to improve rural living standards by promoting rural development. A basic requirement of the rural development is the rehabilitation and development of the road network, both the rehabilitation and substantial improvement of the primary road network and the extension of secondary and feeder roads. In line with this policy, the Government with external assistance has been focusing development efforts on rehabilitating the primary road network. This is still inadequate with many primary roads including National Road Route 6 being deteriorated in many portions and impassable for heavy vehicles in rainy season.

The National Road Route 6 is a primary road with a total length of about 447 km. It starts at Phnom Penh, the capital city of Cambodia and passes through Skun, Kampong Thom, Siem Reap City, then merges with the National Road Route 5 at Sisophon which is located at 49 km east of Cambodia/Thai border (see Figure 1-1).

The town of Siem Reap is the focus for the region's economy. Furthermore, the immediate proximity of the Angkor archaeological site makes it the most important pole for tourism in the country. National Road Route 6 is the only primary road accessible to the town and plays an important role as a basic infrastructure for the rehabilitation of the national economy as well as the regional development.

The sections of National Road Route 6 from Phnom Penh City to Chung Chnok (about 44 km in length) and from Chung Chnok to Skun (about 29 km) have been improved under the Japan's Grant Aid. The section from Skun to Kampong Thmor (about 50 km in length) has been rehabilitated under the assistance of the Asian Development Bank (ADB). Thus, the said sections are in good condition but the rest of the sections has been so deteriorated that ordinary road maintenance and repair works are no longer effective and requires urgent rehabilitation and/or improvement.

To cope with the above situation, the Royal Government of Cambodia made up a plan to improve / rehabilitate the section from Kampong Thmor to the boundary of Kampong Thom and Siem Reap Provinces (about 146 km) under the financial assistance of ADB and the section from the said boundary to Roluos (about 60 km) and the section from Siem Reap City to the Siem Reap Airport access road (about 5 km) under the financial assistance of the World Bank.

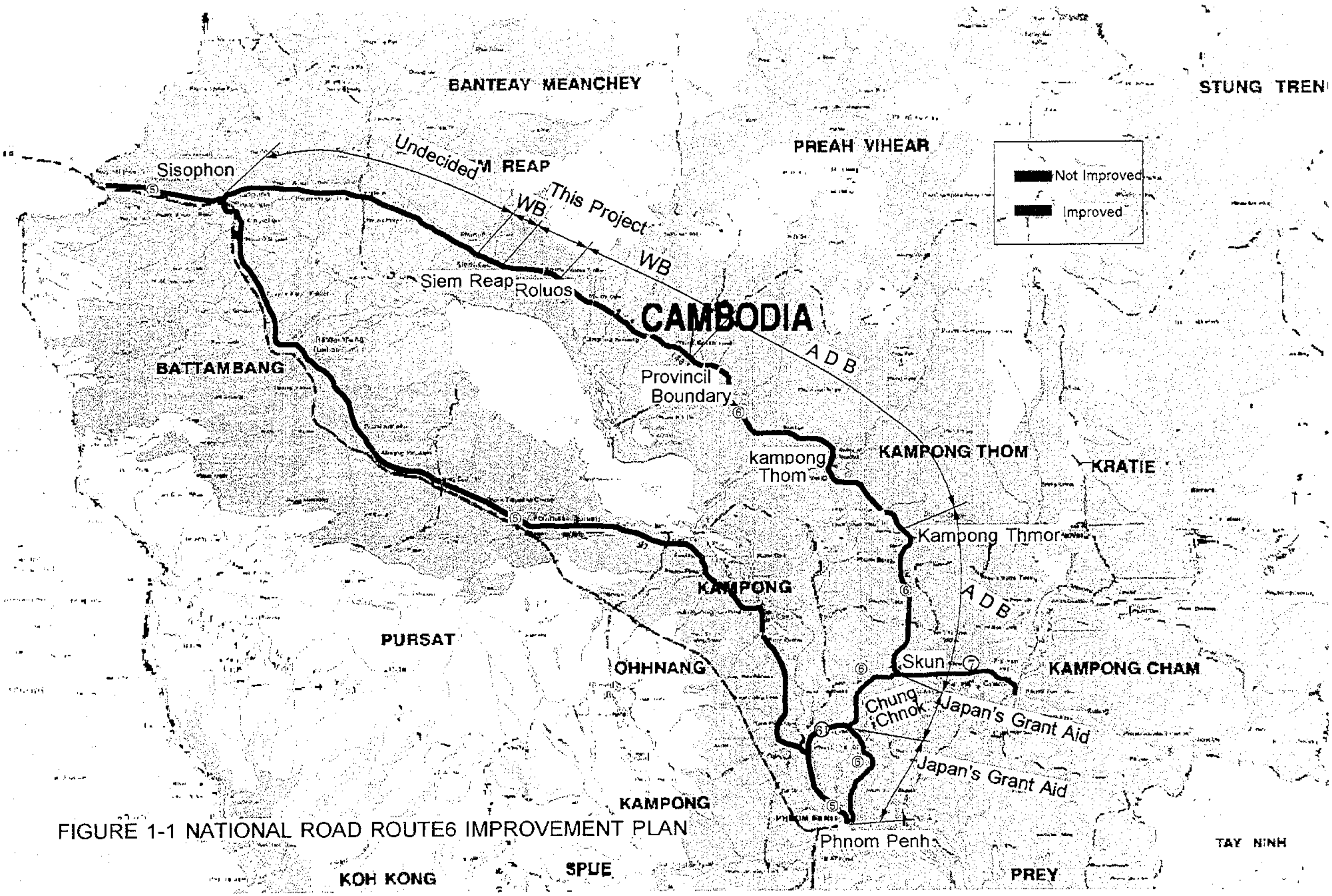


FIGURE 1-1 NATIONAL ROAD ROUTE6 IMPROVEMENT PLAN

When the 17.5 km section from Roluos to Siem Reap City is improved, the whole section of the National Road Route 6 will be improved and smooth and stable means of transport will be provided, except for the western section (about 95.5 km) of which improvement plan is not prepared yet.

In view of the above, the Royal Government of Cambodia made a request for grant aid for improvement of the section from Roluos to Siem Reap City to the Government of Japan.

Revision of the Project Section

According to the original request of the Royal Government of Cambodia, the beginning and end points of the Project were as follows:

Beginning Point	:	Km 297 + 275 (chainage from Phnom Penh City) which is located at 130m west of the intersection with Roluos Street.
End Point	:	Km 314 + 732 which is located at the center of the intersection with Phsar gne Street. (This point corresponds to Km 314+775 in the design of the World Bank section.)

An ancient bridge 43 m in length exists at the location between 762 m and 805m from the beginning point. There are nine ancient bridges in the World Bank section. The design for restoration of all ten ancient bridges is being carried out by the consulting firm employed by the World Bank. In order to reflect the design concepts to the restoration work, the construction supervision should be undertaken by those who designed. From this point of view, the restoration of the ancient bridge in the project section should be preferably included in the World Bank project. However, if only the ancient bridge is included in the World Bank project, following problems will be anticipated:

- Adjustment sections between the World Bank project and this project will increase.

- If both projects are simultaneously implemented, different contractors employed for both projects will work in the same area.

In order to avoid the above problems, a scheme was proposed to include the 850m section from the original beginning point in the World Bank project, instead, to extend this Project section for 850 m from the original end point which is presently included in the World Bank project. This scheme was agreed upon between both governments of Japan and Cambodia.

Thus, the Project section was revised as follows:

Beginning Point	:	Km 298 + 125
End Point	:	Km 315 + 625

For the additional 850 m section, the same chainage as in the design of the World Bank section was used by making a break between Km 314+732 and Km 314+775 to avoid confusion with the said design.

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 Objectives of the Project

The National Road Route 6 is a road with a length of about 447 km extending from Phnom Penh City to Sisophon. Being the only primary road in the region on the north of Tonle Sap River/Tonle Sap Lake in which Siem Reap City is situated, the road plays an important role as a basic infrastructure for the rehabilitation of the national economy as well as the regional development.

Together with the improvement plans for other sections with assistance from ADB and World Bank, the improvement of the 17.5 km section from Roluos to Siem Reap City will provide smooth and stable means of transport for the whole section of the National Road Route 6, except for the western 95.5 km section. It will contribute to the rehabilitation of the economy through savings in transport cost of passengers and goods and increase of transport capacity and reliability, and have effects of improving the information transmission speed leading to the stabilization of the people's livelihood.

Furthermore, the Project section is of distinguished importance, connecting Siem Reap City, the focus of the region's economy and base town for tourism, with Roluos, the historical town celebrated for many cultural heritages.

This Project aims to improve the Roluos-Siem Reap City section of the National Road Route 6 which is one of the priority projects of the Royal Government of Cambodia and to greatly contribute to the socio-economic development of the area.

2.2 Basic Concept of the Project

1) Existing Condition and Problems of the Project Road

Major facilities, major intersecting roads, traffic volume, road width, pavement width and condition, subgrade strength, cross drainage facilities and flood sections are shown in Figure 2.2-1. The existing conditions of bridges are shown in Table 2.2-1. Problems of the Project road are as follows:

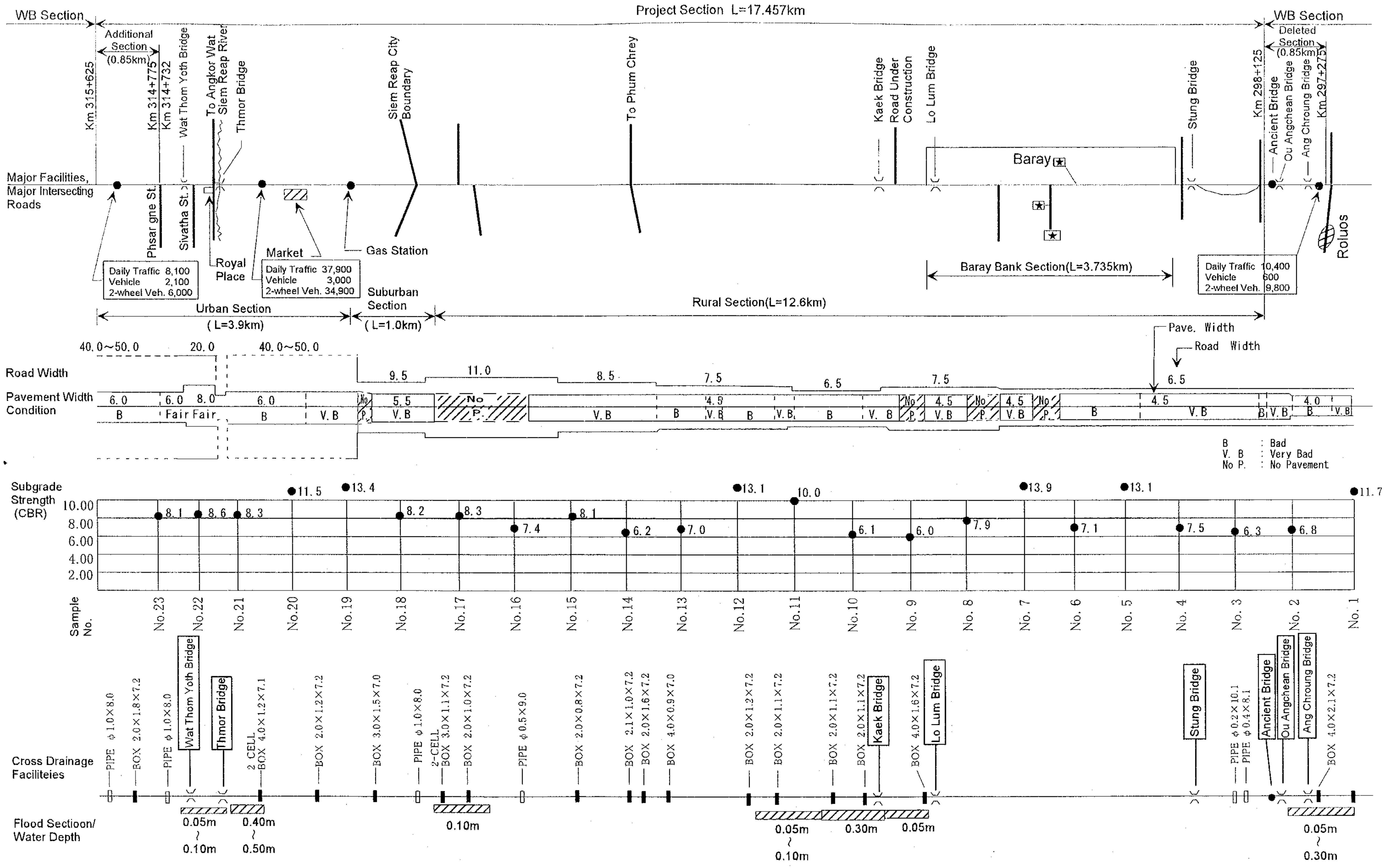


FIGURE 2.2−1 EXISTING CONDITION OF PROJECT ROAD

TABLE 2.2-1 EXISTING CONDITION OF BRIDGES

Bridge Name		Stung Br.	Lo Lum Br.	Kaek Br.	Thmor Br.	Wat Thom Yoth Br.
Bridge Length Carriageway Width Sidewalk Width		35.6m 4.0m 0.7m x 2	33.55m 4.2m -	22.0m 4.0m -	45.0m 5.0m 1.2m x 2	8.1m 6.0m 0.7m x 2
Major Deficiency	Traffic Functionality	x Lack of carriage-way width (one lane only).	x Lack of carriage-way width (one lane only).	x Lack of carriageway width (one lane only).	△ Slightly lack of carriageway width.	△ Slightly lack of carriageway width.
	Structural Strength	○ No major deficiency.	x Existing is a temporary bridge (bailey bridge).	x Existing is a temporary bridge (bailey bridge).	○ No major deficiency.	○ No major deficiency.
	River-related Condition	○	○	○	○	○
Minor Deficiency		△ Railing is partially missing. Spalling of slab concrete.	○	○	○	○
Needs of Rehabilitation		Reconstruction or widening of the existing bridge is needed due to lack of carriageway width.	Reconstruction is needed, since existing is a temporary bridge.	Reconstruction is needed, since existing is a temporary bridge.	No rehabilitation is needed. Although carriageway is not wide enough, problem of traffic function is not significant, since no large vehicles pass on it due to the Royal Palace nearby and traffic volume is not so heavy.	Such measures as provision of box culverts on both sides of the bridge is needed, as it lacks carriageway width.

- Pavement width is substandard for an arterial road. It is only 4.5m in the rural section, 5.5m in the sub-urban section and 6.0m (partially 8.0m) in the urban section. Shoulder width is narrow at 1.0 to 1.5m in the most rural section, 2.0m in the sub-urban section. Shoulders in the urban section are generally wide, but irregular in width. As the composition of motor bikes and bicycles in traffic volume is quite high (over 90%), the existing shoulder width is not enough.

- The existing pavement type is bituminous macadam. Pavement condition is very bad except 0.92 km urban section from Siem Reap River to Phsar gne Street. There are some sections where pavement is completely destroyed and removed.

- There are five bridges. The following three bridges have serious problems:

  - Stung Bridge : carriageway width is 4 m which is good for only one lane.
  - Lo Lum Bridge : temporary bridge.
  - Kaek Bridge : temporary bridge.

- There are 15 box culverts and six pipe culverts. Problems are as follows:
  - Both box and pipe culverts are short in length.
  - Upper slabs and walls of box culverts are made of reinforced concrete, but bottom slabs are made of grouted riprap, thus structurally unstable. Deterioration of box culverts such as spalling of concrete and removal of bottom slabs are progressing.
  - Most of pipe culverts are small in diameter and lack discharge capacity of storm water.

- There are four flood sections due to lack of drainage. At two flood sections in rural section, flood water overflew the roadway in 1997. Another two flood sections in urban section are flooded due to non-existence of road surface drainage, or malfunction of road surface drainage system.

2) Basic Concept of the Project

The objective of the Project is to improve the Project section of National Road Route 6 so as to assure safe and smooth traffic movement and to secure traffic function of the Project Road as an arterial road.

Taking into consideration the problems mentioned in 1) above, the basic concept of the Project is as follows:

- Road Alignment

  Road alignment does not need to be improved. However, as new pavement is in general proposed to be constructed on the existing pavement, the road elevation is slightly raised, except for the sections where the existing elevation is strategically maintained for the special reasons, e.g. existing hydrological condition shall be maintained.

- Widening

  Carriageway width of 7.0 m shall be secured. To cope with high composition of 2-wheel vehicles, effective shoulder of 1.5 m in width shall be provided in the rural sections. For the urban sections excluding the section west of Siem Reap River, 2-wheel vehicle lane of 2.5 m in width shall be provided.

- Pavement Rehabilitation

  Pavement shall be reconstructed except for the 0.92 km urban section between Siem Reap River and Phsar gne Street where the existing pavement is still in good / fair condition. AC overlay shall be applied to the said section.

- Bridge Reconstruction

  Three bridges (Stung, Lo Lum and Kaek) shall be reconstructed.

- Culvert Improvement

  All existing culverts shall be reconstructed. Additional culverts shall be provided for the flood sections in the rural area.

- New Construction of Road Surface Drainage

  Road surface drainage system shall be newly constructed except for the rural section and the 0.85 km urban section near the end of the Project Road, where natural drainage is possible due to embankment type of cross-sections.

- Safeguard Measures

  - Regarding the search of mines and UXO in the construction area, CMAC has conducted the level one survey services and reported that there are no reports or records of the casualty and no mines or UXOs were found while conducting a spot check.
  - When mines or UXO is still discovered during construction, it shall be removed by the Royal Government of Cambodia.

- Environmental Preservation

  The Project shall be implemented paying full attention to the environmental preservation, especially for archaeological remains. Excavation work in the Baray section will be carried out at the presence of APSARA staff. Construction work in other sections will be carried out also with full attention to archaeological antiques. When something antique is found, the contractor shall immediately inform APSARA thereof for proper treatment.

2.3 Basic Design

2.3.1 Design Concept

2.3.1.1 Principle Design Concept

1) Design speed shall be 60 km/hour which was determined based on the following studies and criteria:

   - National Road Route 6A Rehabilitation Project : 60 km/hour
   - National Roads Route 6 and 7 Rehabilitation Project : 60 km/hour
   - ADB Section Design : Not specified as the road alignment is designed following the existing.
   - World Bank Section Design : Not specified as the road alignment is designed following the existing.
   - Road Structure Ordinance in Japan
     Rural Section, Class 2 of Type 3 : 60 km/hour
     Urban Section, Class 1 of Type 4 : 60 km/hour

2) As the existing road alignment is good, there is no need to improve it. The existing alignment shall be followed as much as possible in order not to adversely affect accessibility to the roadsides, except for the following cases:

   - Vertical alignment of bridge approaches which is designed based on the bridge elevation. The proposed bridge approach elevation becomes generally higher than the existing road elevation.

   - New pavement is proposed to be constructed on the existing pavement, therefore, proposed road elevation is slightly raised, except for the sections where the existing road elevation is strategically maintained.

3) Sections where the existing road elevation is strategically maintained are as follows:

- Sections of which road center line elevation is 15m or below (total length is 3.0 km)

  At present, flood water during heavy rain from the upstream (or north) of the Project Road is not only discharged at bridges and culverts but also overflows at road sections with low road elevation. If road elevation is raised at the low elevation sections to prevent overflow of flood water, adverse impacts such as raising of water elevation at upstream areas, excessive water concentration at bridge and culvert openings, local water concentration at particular areas with topographical changes, etc. are expected causing such problems as changes in agricultural conditions, direct water hit to the limited areas at downstream side, scouring of road embankment slopes, etc. In order to avoid above adverse impacts and problems, existing hydrological condition shall be maintained as much as possible. According to the interview survey, the maximum flood water elevation in the past 30 years was about 14.5 m. In consideration of the interview results and local rise of water elevation due to local topographical condition, road sections of which existing road elevation is 15 m or below shall be maintained at its existing road elevation.

- Baray Section (Km 299 + 400 – Km 303 + 135, L = 3.735 km)

  The Government of Cambodia requested to maintain the existing road elevation for the baray section in order not to change hydrological and agricultural conditions.

4) Daily traffic volume is as follows:

Section	Vehicle Type	1999	2006 (5 years after completion of the Project) *
Rural	4-wheel or more 2-wheel	600 9,800	1,000 15,700
Urban (east)	4-wheel or more 2-wheel	3,000 34,900	4,800 56,000
Urban (west)	4-wheel or more 2-wheel	2,100 6,000	3,400 9,600

* Annual growth rate of 7% is assumed.

Composition of 2-wheel vehicles (motor bikes and bicycles) is quite high. Road cross sections shall be so designed that 2-wheel vehicles can be separated from other vehicles in order to assure safe and smooth traffic movement. Shoulders with an effective width of 1.5 m shall be provided for the rural section and western urban section. For the eastern urban section, 2-wheel vehicle lanes with an effective width of 2.5 m shall be provided. Both shoulders and 2-wheel vehicle lanes shall be paved.

5) Present traffic controls in front of the Royal Palace (closed to vehicular traffic) and in the section between the Royal Palace and Phsar gne Street (closed to trucks) shall be maintained.

6) Pavement design and bridge design shall reflect the fact of high composition of over-loaded trucks. Track load factor for pavement design shall be determined based on the axle load surveys conducted by ADB along the National Roads Route 5 and 6. Live load for bridge design shall increase AASHTO HS22-44 by 25%.

7) Environmental preservation shall be fully taken into consideration in the design.

   - The Project site is a famous international tourist spot and a lot of trees remain in the area, therefore, esthetic considerations shall be paid to the design. Particularly, large trees are growing along the urban section in the west of Siem Reap River and the Baray section. The design shall be so undertaken that these trees are preserved.

   - The Baray section is an archaeologically important remains. Existing condition of the section shall be maintained as much as possible. Construction work shall be carried out at the presence of APSARA staff.

   - Drainage condition of Siem Reap City urban area is not good and areas with impounding water are spotted causing insanitary conditions. Roadside drainage system shall be so planned that above problems shall be mitigated.

   - Design shall be made to minimize construction wastes.

   - Traffic safety shall be taken into consideration in the design. Following traffic safety facilities shall be provided:
     - Traffic regulatory signs
     - Road markings
     - Guardrails

8) In order for local contractors and engineers to participate in the Project, simple structures and construction methods easy in quality control shall be adopted as much as possible.

9) The design shall be so made that maintenance can be done economically and easily by the Implementing Agency.

10) Since the roadsides are flooded during the rainy season, some construction works cannot be carried out and the rate of operation decreases. The construction execution plan shall reflect such conditions.

11) A road development plan in Siem Reap City has been formulated under the assistance of the French agency for development, in which a road intersecting the Project road is included. The design of the intersecting road is under way. The adjustment with the said road shall be made as necessary in the stage of the detailed design of the Project.

2.3.1.2 Geometric Design Standards

AASHTO geometric design standards shall be basically followed. Geometric design criteria are shown in Table 2.3-1 and standard cross section elements are shown in Table 2.3-2, wherein the sectioning of the urban area is shown in Figure 2.3-1.

TABLE 2.3-1 GEOMETRIC DESIGN CRITERIA

Item	Criteria	Remarks
Design Speed	60 km/hour	
Minimum Horizontal radius	135 m	
Maximum Grade	3 %	Gentle grade is adopted in view of bicycle traffic.
Cross Fall	2 %	
Maximum Superelevation at Curve	6 %	No superelevation is provided in the urban section.

TABLE 2.3-2 STANDARD CROSS-SECTION ELEMENTS

Section	Number of Lanes	Lane Width	Shoulder / 2-wheel Vehicle Lane / Gutter Width	Sidewalk Width	Remarks
Rural Section	2	3.5m	2.0m * (Effective width=1.5m)	-	
Urban Section – 1 (including sub-urban section)	2	3.5m	2.5m	-	
Urban Section – 2	2	3.5m	0.5m	3.0m ** (Effective width = 1.5m)	Closed to traffic
Urban Section – 3	2	3.5m	1.0m	3.0m ** (Effective width = 1.5m)	Truck ban
Urban Section – 4	2	3.5m	2.0m * (Effective width = 1.5m)	-	
Bridge (rural section)	2	3.5m	1.5m	-	

Note:

* Outside 0.5m is regarded as embankment roundings.

** Tree planting strip of 1.5m in width is included.

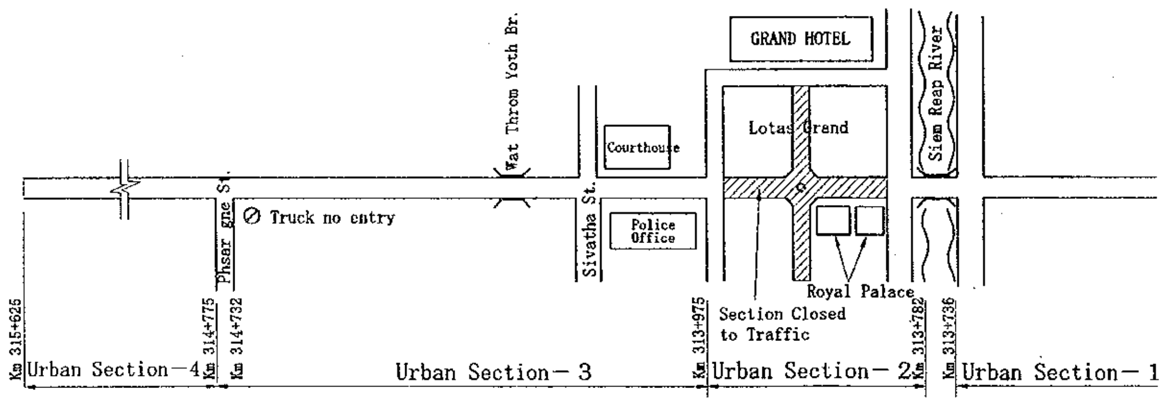


FIGURE 2.3-1 SECTIONING OF URBAN AREA

2.3.1.3 Design Concept of Pavement Rehabilitation

1) Rehabilitation Method Selection Criteria

Pavement reconstruction shall be adopted where the existing pavement falls under one of the following conditions:

- A lot of alligator cracks and potholes exist and the existing surface course needs to be replaced.
- Existing base and sub-base courses are so deteriorated that these need to be replaced in order to assure even bearing capacity.
- Pavement has been already removed.

Asphalt concrete (AC) overlay method shall be adopted for the sections other than above.

2) Pavement Type for Reconstruction

Candidate pavement types are DBST and AC. Taking into consideration the passage of considerable number of heavy loaded vehicles and minimization of maintenance requirement, AC pavement shall be selected for the Project. For DBST to have the equivalent strength to AC, more aggregates are needed resulting in being uneconomical due to hauling cost in case material source is distant. The Project is possibly in such situation.

3) Initial Performance Period

The initial performance period of the pavement shall be five years, in accordance with the criteria used in the National Road Route 6A Rehabilitation Project and the National Roads Route 6 and 7 Rehabilitation Project.

4) Design Criteria

Standards to be used	:	AASHTO Guide for Design of Pavement Structures, 1993.
Performance period	:	Five years from year 2002 to 2006.
Traffic loading	:	Number of trucks is obtained from the traffic count survey and annual growth rate of 7% is assumed. Truck load factor (number of 18-kip equivalent single axle loads per truck) is determined based on the axle load survey conducted along National Roads Route 5 and 6 by ADB. In addition, vehicles for construction of the World Bank section are taken into account.

Reliability	:	Probability that traffic loadings are not more than and pavement performance is less than predicted is assumed to be 50%.
Serviceability Criteria	:	Initial serviceability index Po = 4.2 Terminal serviceability index Pt = 2.5
Subgrade CBR	:	CBR of a design section shall be determined based on the mean value of surveyed CBR values minus standard deviation.

Material Property of Pavement Layer

- Asphalt concrete surface course : Elastic modulus = 350,000 psi
- Base Course : CBR = 80,
  Elastic modulus = 28,000 psi
- Subbase Course : CBR = 30,
  Elastic modulus = 15,000 psi

Drainage Coefficient of Base and Subbase Courses

: m = 0.90 (water removed within 3 days, duration pavement structure is exposed to moisture level approaching saturation = 60%)

2.3.1.4 Design Concept of Bridge Rehabilitation

1) Rehabilitation Method Selection Criteria

Since structural details (such as reinforcing bar arrangement and pile length) of existing bridges are unknown, it is not possible to confirm strength of bridge members and structural stability. It is, therefore, not practical to propose measures to increase bridge strength and stability, thus rehabilitation methods shall be limited to reconstruction or partial repair.

When a bridge falls under one of the following conditions, it shall be reconstructed:

- Carriageway width is not sufficient and its widening is more expensive than reconstruction.
- Substructure has been overturned, or bearing capacity is substantially insufficient and its strengthening is difficult.
- The existing bridge is a temporary one.
- The bridge opening is not sufficient to discharge flood water, and super / substructures are highly deteriorated or measures to increase bridge opening is more expensive than reconstruction.

For the following cases, partial repair shall be considered.

- Running condition is bad due to rough surface.
- Bridge surface drainage is bad.
- Railing is damaged.
- Foundations or slopes adjacent to a bridge are scoured, or would possibly be scoured.
- Carriageway width is insufficient and it can be widened economically.

2) Bridge Planning Criteria

Conditions to determine elevation, length and width are as follows:

- High water level : EL = 14.50 m (Rural Section)

  This high water elevation was estimated based on the interview survey results to have occurred during the flood in 1997, which is considered as the highest water level in the past 30 years. The hydraulic analysis resulted in the same elevation.

- Free Board : 0.6 m

  According to the interview survey, there are no big trees or similar materials flowing down under bridges, and therefore high free board is not required. In consideration of momentary raising of water due to wind waves, water swells, hydraulic jumps etc. and floating materials heights, free board shall be 0.6 m. The same value was adopted in the designs for the National Road Route 6A Rehabilitation Project and the National Roads Route 6 and 7 Rehabilitation Project.

- Distance between front faces of abutment shall not be less than that of the existing bridge.

  In principle, the distance between front faces of abutment shall be the same as the existing bridge. Where the existing abutment location is judged not appropriate from the scouring condition of bridge approaches, the abutment location shall be changed so that the bridge length is extended.

- Reduction Ratio of Cross-sectional Area of River at Bridge Site : Less than 5%

  A reduction ratio of cross-sectional area of a river at bridge site due to construction of (a) pier(s) shall be less than 5%, which is determined based on the Japan's river management criteria.

- Minimum Span Length : 10 m

  The Japan's river management criteria specify that the minimum span length shall be 12.5 m (for rivers with discharge volume less than 500 m^3/sec and river width less than 30 m). As rivers in the Project site have no defined river cross-sections, Japan's criteria could be relaxed. In view of the above, the minimum span length shall be 10m.

- Bridge Width : 10m (Carriageway Width = 7 m, Shoulder Width = 2x1.5 m)

  Carriageway and shoulder width of roadway in the rural section is 7.0 m and 2.0 m, respectively. Outside 0.5 m of shoulder is regarded as embankment roundings, thus effective width of shoulder is 1.5 m. Bridge width shall be the same as roadway width excluding embankment roundings.

3) Design Criteria

Specifications applied	:	AASHTO Standard Specifications for Highway Bridges, 1996
Live Load	:	HS 20-44 plus 25%. (in consideration of heavily loaded vehicles)

Major Materials : Concrete : σ_{ck} = 240 kgf/cm^2
Reinforcing Bar : SD295A or AASHTO Grade 40 (Yield strength = 3,000 kgf/cm^2)

2.3.1.5 Culvert Design Concept

1) Rehabilitation of Culverts

All existing culverts shall be reconstructed. As mentioned in 2.2.1), reasons of reconstruction are as follows:

- Existing culverts need to be extended in line with widening of a roadway.

- Existing box culverts are not structurally stable and deterioration of box culvert members is progressing.

- Most of pipe culverts have insufficient discharge capacity.

Type and dimension of a culvert shall be determined in consideration of the following factors:

- Discharge capacity of a culvert shall not be less than that of existing one and, if necessary, capacity shall be increased.
- It must be economical.
- It must be easy for construction.
- It must be easy for maintenance.

2) Additional Installation of Culverts

For the flood sections and their adjacent sections where the drainage is poor, additional culverts shall be installed in order to avoid water concentration at existing bridges and culverts.

Criteria to determine locations of additional culverts are as follows:

- Within the flood section, or within a section with drainage problem which was identified based on the interviews from residents and topographical characteristics.

- At the location of which ground elevation is relatively low to the adjacent area, or at the location where a waterway was made as a result of construction of an intersecting road by a side-borrow method.

- At the location where no problem is expected at the outlet side, such location as there is a pond at downstream side.

2.3.1.6 Design Concept of Road Surface Drainage

1) Type of Drainage Facility

- Rural Section

  As a road is constructed on the embankment, natural drainage shall be adopted.

- Siem Reap City Eastern Section (east of Siem Reap River)

  No mount-up sidewalks nor gutters are provided for a road, therefore, concrete side ditch with cover shall be provided at both sides of a roadway.

- Siem Reap City Western Section (from Siem Reap River to Phsar gne Street)

  Drainage facilities with catch basins and drainage pipes are existing in the section from Siem Reap River to Wat Thom Yoth Bridge, however, not functioning. No data are available on location of pipes, flow direction and location of outlet. It is considered that existing pipes might have been damaged by growing roots of roadside trees. In view of the above, new drainage facilities shall be constructed.

  As this section is provided with mount-up sidewalks, storm water is collected at catch basins and drained by pipes.

- Siem Reap City Western Section (from Phsar gne Street to the end of the Project)

  As a road is constructed on the embankment and the City Renovation Committee has a plan to rehabilitate the irrigation canal on both sides, natural drainage shall be adopted.

2) Design Discharge

Rainfall discharge estimated with the return period of three years is used as design discharge, in accordance with the Road Drainage Guideline of the Japan Road Association.

2.3.1.7 Design Concept of Other Road Facilities

1) Slope Protection

There is a possibility that flood water overflows on the roadway during heavy rains (flood section). At locations where water concentration is expected within the flood sections, slope protection shall be provided. Locations shall be at culverts and their road elevation is 14.5 m or lower. The length for slope protection shall be 20 m at each culvert.

For the rest of slopes within the flood sections, no slope protection shall be provided, as water velocity is estimated to be low, and no scouring of slopes is anticipated. (Result of hydraulic simulation of 1997 flood shows that water velocity was about 0.7 m/sec. Possibility of slope scouring is estimated to be minimal with this range of water velocity. It is supported by the fact that no slope damage within the flood sections was observed during the site investigation.)

2) Traffic Safety Facilities

From the viewpoints of traffic safety, the following facilities shall be provided:

- Traffic Regulatory Signs : Speed limit, "truck no entry" and "pedestrian crossing ahead".
- Road Markings : Road center line, carriageway outside line, and pedestrian crossing.
- Guardrail : For the bridge approaches and the sections where box culverts are installed in the urban section.

2.3.2 Basic Design

2.3.2.1 Road Design

The road design was undertaken in accordance with 2.3.1.1 Principle Design Concept and 2.3.1.2 Geometric Design Standards.

1) Horizontal Alignment

The horizontal alignment was designed following the existing alignment.

2) Vertical Alignment

The vertical alignment was designed in accordance with the design concepts as follows:

- Elevation of each bridge for reconstruction (Stung, Lo Lum and Kaek Bridges) was determined based on the high water elevation, free board and girder depth. The vertical alignment of bridge approaches was designed by adopting vertical grade of not more than 3.0%.

- For the sections of which existing road elevation is lower than 15.0m, the existing road elevation was maintained except at reconstruction bridges and their approaches.

- The existing road elevation was maintained for the Baray section.

- For the rest of above sections, the proposed road elevation was raised to the elevation which allows to construct new pavement (or to overlay) on the existing road.

Outline of the vertical alignment was summarized in Table 2.3-3.

3) Standard Road Cross-Section

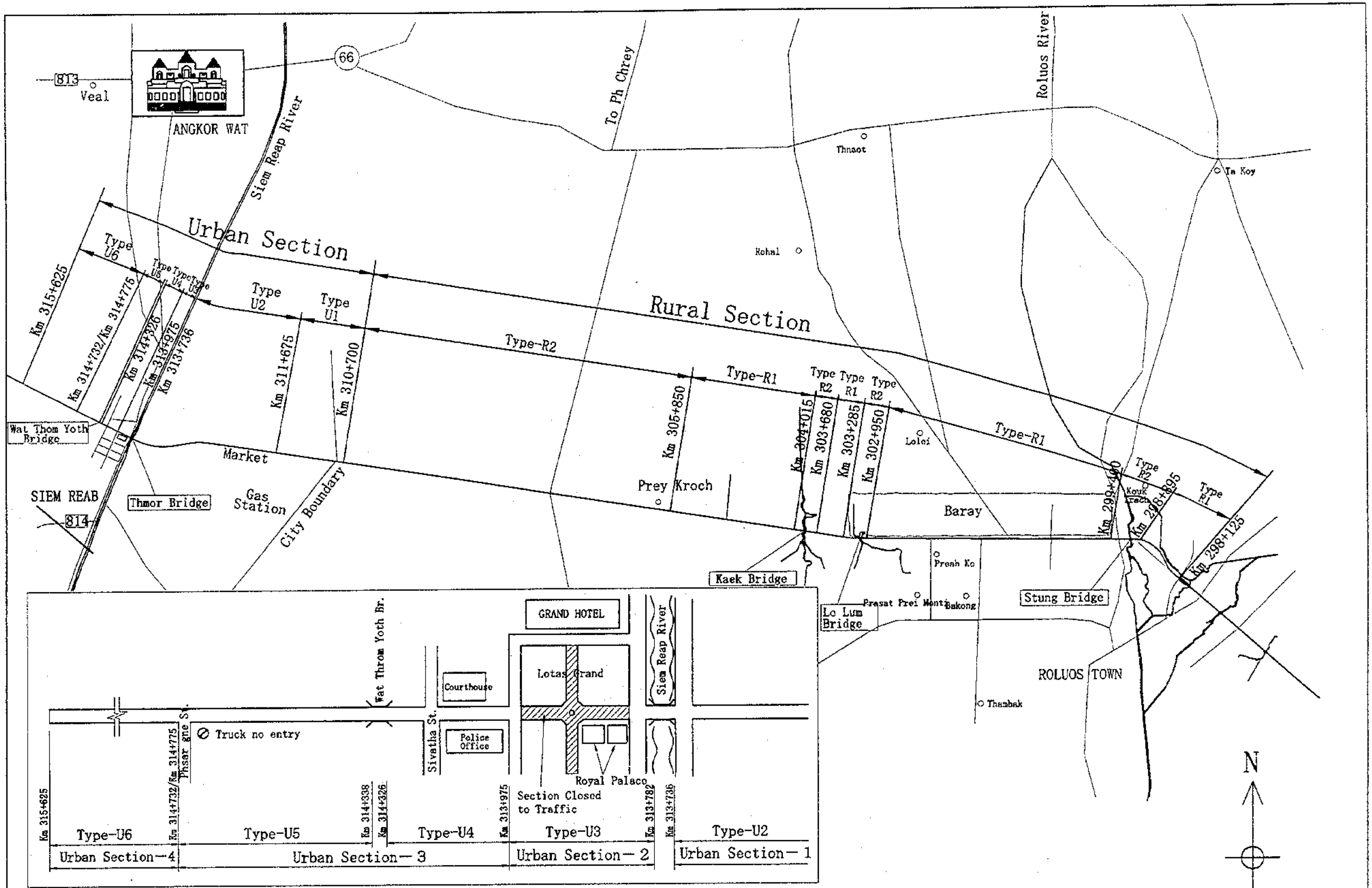
Division of road section is shown in Figure 2.3-2 and standard road cross sections by road section is shown in Figure 2.3-3.

TABLE 2.3-3 OUTLINE OF VERTICAL ALIGNMENT

Section	Outline	Remarks
Km 298 + 125 ~ Km 298 + 895	• Existing elevation maintained.	• Existing elevation is lower than 15.0m.
Km 298 + 895 ~ Km 299 + 400	• Elevation raised by 0-0.45m. • Vertical grade of east side approach :1.25% • Vertical grade of west side approach :0%	• Stung Bridge and its approaches.
Km 299 + 400 ~ Km 302 + 950	• Existing elevation maintained.	• Baray Section
Km 302 + 950 ~ Km 303 + 285	• Smoothing of existing vertical alignment (*). • Vertical grade of east side approach :1.60% • Vertical grade of west side approach :2.75%	• Lo Lum Bridge and its approaches.
Km 303 + 285 ~ Km 303 + 680	• Existing elevation maintained.	• Existing elevation is lower than 15.0m.
Km 303 + 680 ~ Km 304 + 015	• Elevation raised by 0-1.8m. • Vertical grade of east side approach :2.86% • Vertical grade of west side approach :2.88%	• Kaek Bridge and its approaches.
Km 304 + 015 ~ Km 305 + 850	• Existing elevation maintained.	• Existing elevation is lower than 15.0m.
Km 305 + 850 ~ Km 310 + 700	• Elevation raised by about 0.40m.	• Rural section.
Km 310 + 700 ~ Km 313 + 736	• Elevation raised by about 0.50m.	• Urban section.
Km 313 + 736 ~ Km 313 + 782	• Existing elevation maintained.	• Thmor Bridge
Km 313 + 782 ~ Km 314 + 700	• Elevation raised by about 0.05m.	• Overlay section in urban area.
Km 314 + 700 ~ Km 314 + 732 (**) Km 314 + 775(**)~Km 315 + 625	• Elevation raised by about 0.40m.	• Urban section.

* Original bridge was destroyed and the temporary bridge was constructed with very steep grade of about 5%.

** Km 314+732~Km 314+775 is a break section and shows the same location.



Details of Urban Section

FIGURE 2.3-2 DIVISION OF ROAD SECTION

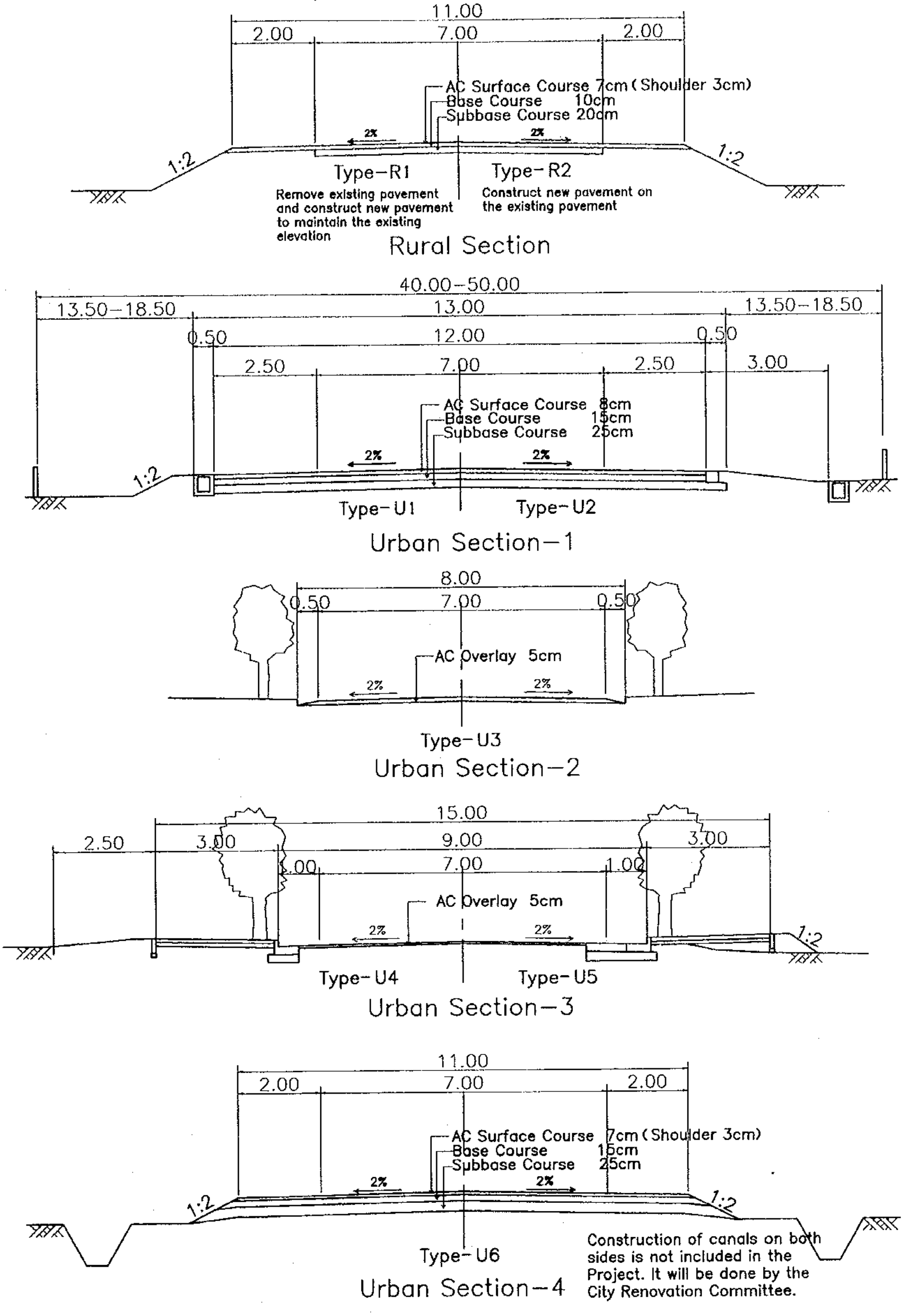


FIGURE 2.3-3 STANDARD CROSS SECTIONS

2.3.2.2 Pavement Design

In accordance with the pavement rehabilitation method selection criteria shown in 2.3.1.3, pavement rehabilitation method for each road section was selected as follows:

Rural Section	:	Reconstruction (Existing pavement seriously deteriorated)
Urban Section - 1	:	Reconstruction (Existing pavement seriously deteriorated)
Urban Section - 2	:	Overlay (Existing pavement in relatively good/fair condition)
Urban Section - 3	:	Overlay (Existing pavement in relatively good/fair condition)
Urban Section – 4	:	Reconstruction (Existing pavement seriously deteriorated)

Asphalt concrete overlay (thickness 5cm) was adopted for Urban Sections – 2 and 3 on which trucks are banned, therefore, the overlay thickness design was omitted.

Pavement thickness design for Rural Section, Urban Section - 1 and Urban Section - 4 is presented hereunder. Since aggregate material sources are located very far from the Project Site and the hauling cost of aggregates is quite high, the pavement design was focused to minimize quantities of aggregates.

1) Design Criteria

<u>Design Standards</u>

AASHTO Guide for Design of Pavement Structures 1993 was applied.

Basic Design Equation

The basic design equation for flexible pavement is as follows:

$$\log_{10}(W_{18}) = Z_R \times S_o + 9.36 \times \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(SN + 1)^{5.19}}} + 2.32 \times \log_{10}(M_R) - 8.07$$

where:

W18 = predicted number of 18-kip equivalent single axle load applications,
ZR = standard normal deviate,
So = combined standard error of the traffic prediction and performance prediction,
ΔPSI = difference between the initial design serviceability index, Po, and the design terminal serviceability index, Pt, and
M_R = resilient modulus (psi).

SN is equal to the structural number indicative of the total pavement thickness required:

$$SN = a_1D_1 + a_2D_2m_2 + a_3D_3m_3$$

Where:

a_i = i^{th} layer coefficient,
D_i = i^{th} layer thickness (inches), and
m_i = i^{th} layer drainage coefficient.

Design Criteria

Category	Value Adopted	Remarks
Design Variables		
• Initial Performance period	5 years	• 5 years from 2002 to 2006
• Traffic load	W_{18} = 0.45 x 10^6 (Rural Section) = 3.42 x 10^6 (Urban Section-1) = 1.15 x 10^6 (Urban Section-4)	• Number of trucks is based on the traffic count survey results and future traffic is estimated assuming annual traffic growth rate of 7.0%. • Truck load factor (number of 18-kip equivalent single axle loads per truck) is determined based on the axle load survey conducted along National Roads Route 5 and 6 by ADB. • Vehicles for construction of the World Bank section are additionally taken into account.
• Reliability	$Z_R = 0$ So = 0.45	• Probability that traffic loadings and pavement performance are within predicted range was set at 50%.
Performance Criteria		
• Initial serviceability index	Po = 4.2	• Based on AASHO Road Test
• Terminal serviceability index.	Pt = 2.5	• AASHTO Guide recommends 2.5 or 3.0 for arterial roads. Pt of 2.5 is apoted.
• Difference between initial and terminal serviceability indices.	ΔPSI = Po - Pt = 1.7	
Material Property		
• Effective roadbed soil resilient modulus	M_R = 8,850 psi (Rural section) = 11,850 psi (Urban Sections -1 and 4)	• M_R = 1,500 x CBR • Design CBR is determined based on the subgrade soil test results. CBR of a section is calculated as the mean value of CBR values at surveyed locations minus standard deviation (σ_{n-1}). • Design CBR is 5.9 in the Rural Section and 7.9 in the Urban Section-1. For the Urban Section-4, the same value as the Urban Section-1 is assumed.
• Pavement Layer Coefficient		
- AC surface course	a = 0.39	• Elastic Modulus E_{AC}=350,000 psi
- Granular base course	a = 0.135	• CBR=80, Elastic Modulus=28,000 psi
- Granular subbase course	a = 0.108	• CBR=30, Elastic Modulus=15,000 psi
Pavement Structural Characteristics		
• Drainage Coefficient		
- AC surface course	m = 1.0	• Normally 1.0
- Granular base course	m = 0.90	• Water removed within 3 days, duration pavement is exposed to moisture level approaching saturation is 60%.
- Granular subbase course	m = 0.90	• Same as above.

2) Traffic Load

Truck Volume

Truck volume of the opening year (year 2002) was estimated based on the traffic count survey results under the following assumptions:

- Daily Traffic Volume / 12-Hour Traffic Volume = 1.3
- Traffic Growth Rate = 7.0% per annum. (assuming nearly equal to GDP growth)

Estimated truck volumes by road section are shown in Tables 2.3-4 to 6.

TABLE 2.3-4 TRUCK VOLUME (RURAL SECTION)

Truck	Direction	1999 12-Hour Truck Volume (Survey Result) A	1999 Daily Truck Volume (A x 1.3) B	2002 Daily Truck Volume (B x 1.07^3)
2-axle Truck	To Phnom Penh	15	20	25
	To Sisophon	27	35	43
3-axle Truck	To Phnom Penh	12	16	20
	To Sisophon	12	16	20
Trailer	To Phnom Penh	9	12	15
	To Sisophon	5	7	9
Total	To Phnom Penh	36	48	60
	To Sisophon	44	58	72

TABLE 2.3-5 TRUCK VOLUME (URBAN SECTION-1)

Truck	Direction	1999 12-Hour Truck Volume (Survey Result) A	1999 Daily Truck Volume (A x 1.3) B	2002 Daily Truck Volume (B x 1.07^3)
2-axle Truck	To Phnom Penh	173	225	276
	To Sisophon	206	268	328
3-axle Truck	To Phnom Penh	72	94	115
	To Sisophon	7	9	11
Trailer	To Phnom Penh	151	20	25
	To Sisophon	13	147	180
Total	To Phnom Penh	260	339	416
	To Sisophon	326	424	519

TABLE 2.3-6 TRUCK VOLUME (URBAN SECTION-4)

Truck	Direction	1999 12-Hour Truck Volume (Survey Result) A	1999 Daily Truck Volume (A x 1.3) B	2002 Daily Truck Volume (B x 1.07^3)
2-axle Truck	To Phnom Penh	24	31	38
	To Sisophon	27	35	43
3-axle Truck	To Phnom Penh	81	105	129
	To Sisophon	29	38	47
Trailer	To Phnom Penh	10	13	16
	To Sisophon	13	17	21
Total	To Phnom Penh	115	149	183
	To Sisophon	69	90	111

Truck Load Factor

A truck load factor is defined as an average of 18-kip equivalent single axle loads (ESAL's) per truck. Total ESAL's by truck type will be obtained by multiplying a truck load factor by number of trucks by truck type. The truck load factor was determined based on the axle load survey results and the axle load equivalency factors shown in AASHTO Guide. The axle load equivalency factors vary depending on the pavement structural number (SN). SN was assumed to be 2.32 in the Rural Section, 2.91 in the Urban Section-1 and 2.76 in the Urban Section-4. Results of computation are as follows (details are shown in Tables 2.3-7 to 9):

TRUCK LOAD FACTOR

Type of Truck	Rural Section	Urban Section-1	Urban Section-4
2 - Axle Truck	1.941	1.854	1.876
3 - Axle Truck	3.005	2.832	2.876
Trailer	5.620	5.397	5.453

TABLE 2.3-7 TRUCK LOAD FACTOR (2-AXLE TRUCK)

Axle Load (ton)		18-kip Single Axle Load Equivalency Factor								
		Rural Section (SN=2.32)			Urban Section-1 (SN=2.91)			Urban Section-4 (SN=2.76)		
Front Wheel	Rear Wheel	Front Wheel	Rear Wheel	Total	Front Wheel	Rear Wheel	Total	Front Wheel	Rear Wheel	Total
2.20(S)	4.70(S)	0.008	0.122	0.130	0.008	0.133	0.141	0.008	0.130	0.138
5.60(S)	7.60(S)	0.231	0.750	0.982	0.251	0.764	1.015	0.246	0.761	1.007
6.20(S)	6.50(S)	0.339	0.406	0.745	0.362	0.430	0.793	0.357	0.424	0.781
6.00(S)	9.00(S)	0.300	1.495	1.794	0.322	1.452	1.774	0.316	1.463	1.779
4.406(S)	11.70(S)	0.097	4.609	4.706	0.105	4.228	4.333	0.103	4.325	4.427
3.70(S)	11.80(S)	0.052	4.784	4.836	0.054	4.382	4.436	0.054	4.484	4.538
3.60(S)	7.40(S)	0.047	0.674	0.721	0.049	0.692	0.741	0.049	0.687	0.736
5.30(S)	8.90(S)	0.189	1.427	1.616	0.205	1.391	1.597	0.201	1.400	1.602
Truck Load Factor				1.941			1.854			1.876

Note: (S) means Single Axle.

TABLE 2.3-8 TRUCK LOAD FACTOR (3-AXLE TRUCK)

Axle Load (ton)		18-kip Single Axle Load Equivalency Factor								
		Rural Section (SN=2.32)			Urban Section-1 (SN=2.91)			Urban Section-4 (SN=2.76)		
Front Wheel	Rear Wheel	Front Wheel	Rear Wheel	Total	Front Wheel	Rear Wheel	Total	Front Wheel	Rear Wheel	Total
3.20(S)	21.50(T)	0.031	4.381	4.411	0.031	4.085	4.116	0.031	4.160	4.191
2.70(S)	6.70(T)	0.017	0.050	0.067	0.017	0.051	0.068	0.017	0.051	0.068
5.50(S)	21.85(T)	0.216	4.696	4.913	0.235	4.364	4.598	0.230	4.448	4.678
4.80(S)	21.50(T)	0.132	4.381	4.512	0.143	4.085	4.228	0.140	4.160	4.300
5.70(S)	21.60(T)	0.247	4.469	4.716	0.267	4.163	4.430	0.262	4.240	4.503
3.40(S)	12.90(T)	0.038	0.542	0.580	0.040	0.575	0.614	0.039	0.566	0.606
3.80(S)	18.00(T)	0.057	2.058	2.115	0.060	2.006	2.066	0.059	2.019	2.078
4.40(S)	8.50(T)	0.096	0.117	0.213	0.104	0.125	0.230	0.102	0.123	0.225
4.20(S)	24.60(T)	0.081	7.909	7.991	0.087	7.188	7.275	0.086	7.371	7.457
5.60(S)	21.60(T)	0.231	4.469	4.700	0.251	4.163	4.413	0.246	4.240	4.486
5.40(S)	13.40(T)	0.202	0.627	0.829	0.220	0.660	0.880	0.215	0.652	0.867
5.40(S)	14.314(T)	0.202	0.812	1.014	0.220	0.841	1.060	0.215	0.833	1.049
Truck Load Factor				3.005			2.832			2.876

Note: (S) means Single Axle.
(T) means Tandem Axle.

TABLE 2.3-9 TRUCK LOAD FACTOR (TRAILER)

Axle Load (ton)				18-kip Single Axle Load Equivalency Factor														
				Rural Section (SN = 2.32)					Urban Section-1 (SN = 2.91)					Urban Section-4 (SN = 2.76)				
Front Wheel	Rear Wheel	Trailer Front Wheel	Trailer Rear Wheel	Front Wheel	Rear Wheel	Trailer Front Wheel	Trailer Rear Wheel	Total	Front Wheel	Rear Wheel	Trailer Front Wheel	Trailer Rear Wheel	Total	Front Wheel	Rear Wheel	Trailer Front Wheel	Trailer Rear Wheel	Total
7.050 (S)	17.650 (T)	9.200 (S)	9.250 (S)	0.557	1.896	1.639	1.677	5.769	0.579	1.858	1.583	1.618	5.637	0.573	1.868	1.597	1.633	5.671
4.550 (S)	22.100 (T)	8.350 (S)	10.250 (S)	0.108	4.936	1.097	2.595	8.736	0.118	4.575	1.090	2.443	8.226	0.115	4.667	1.092	2.481	8.355
5.400 (S)	23.350 (T)	8.350 (S)	11.800 (S)	0.202	6.283	1.097	4.784	12.367	0.220	5.763	1.090	4.382	11.455	0.215	5.896	1.092	4.484	11.686
3.950 (S)	12.400 (T)	8.300 (S)	7.000 (S)	0.065	0.466	1.070	0.542	2.144	0.070	0.498	1.065	0.564	2.196	0.068	0.490	1.066	0.558	2.183
5.700 (S)	20.500 (T)	9.700 (S)	8.500 (S)	0.247	3.570	2.051	1.181	7.048	0.267	3.364	1.955	1.167	6.753	0.262	3.416	1.979	1.170	6.828
4.800 (S)	19.250 (T)	9.600 (S)	10.200 (S)	0.132	2.730	1.963	2.541	7.365	0.143	2.612	1.876	2.394	7.025	0.140	2.642	1.898	2.432	7.112
5.500 (S)	20.600 (T)	9.650 (S)	10.100 (S)	0.216	3.645	2.006	2.436	8.304	0.235	3.432	1.915	2.300	7.881	0.230	3.486	1.938	2.334	7.989
6.000 (S)	17.950 (T)	9.100 (S)	9.500 (S)	0.300	2.035	1.565	1.878	5.777	0.322	1.984	1.516	1.799	5.621	0.316	1.997	1.528	1.819	5.661
5.150 (S)	17.500 (T)	7.050 (S)	8.700 (S)	0.170	1.830	0.557	1.299	3.856	0.185	1.797	0.579	1.275	3.836	0.181	1.805	0.573	1.281	3.841
5.050 (S)	18.300 (T)	7.900 (S)	8.800 (S)	0.158	2.206	0.876	1.362	4.603	0.172	2.140	0.884	1.332	4.528	0.169	2.157	0.882	1.340	4.547
6.400 (S)	12.700 (T)	11.000 (S)	8.800 (S)	0.383	0.511	3.518	1.362	5.774	0.407	0.543	3.265	1.332	5.547	0.401	0.535	3.330	1.340	5.605
5.600 (S)	20.500 (T)	9.850 (S)	10.100 (S)	0.231	3.570	2.189	2.436	8.425	0.251	3.364	2.078	2.300	7.993	0.246	3.416	2.106	2.334	8.103
5.300 (S)	17.850 (T)	9.900 (S)	10.100 (S)	0.189	1.988	2.236	2.436	6.848	0.205	1.941	2.121	2.300	6.567	0.201	1.953	2.150	2.334	6.638
6.200 (S)	15.700 (T)	9.650 (S)	10.350 (S)	0.339	1.173	2.006	2.706	6.224	0.362	1.186	1.915	2.542	6.005	0.357	1.183	1.938	2.583	6.061
3.900 (S)	16.400 (T)	7.300 (S)	6.100 (S)	0.062	1.404	0.638	0.319	2.424	0.066	1.403	0.657	0.342	2.468	0.065	1.403	0.652	0.336	2.457
3.400 (S)	9.400 (T)	4.400 (S)	4.300 (S)	0.038	0.168	0.096	0.089	0.391	0.040	0.182	0.104	0.095	0.421	0.039	0.178	0.102	0.094	0.413
6.400 (S)	20.300 (T)	7.400 (S)	7.000 (S)	0.383	3.422	0.674	0.542	5.020	0.407	3.232	0.692	0.564	4.894	0.401	3.280	0.687	0.558	4.926
2.400 (S)	3.800 (S)	2.100 (S)	2.100 (S)	0.011	0.057	0.007	0.007	0.081	0.011	0.060	0.007	0.007	0.084	0.011	0.059	0.007	0.007	0.084
Truck Load Factor								5.620					5.397					5.453

Note:

(S) means Single Axle

(T) means Tandem Axle

Number of 18-kip Equivalent Single Axle Load Applications (W18)

W18 was computed as shown in Tables 2.3-10 to 12.

TABLE 2.3-10 W18 (Rural Section)

Vehicle Type	Truck Load Factor	2002 Daily Traffic Volume		2002 18-kip ESAL Applications per day	
		To Phnom Penh	To Sisophon	To Phom Penh	To Sisophon
2-Axle Truck	1.941	25	43	48.5	83.5
3-Axle Truck	3.005	20	20	60.1	60.1
Trailer	5.620	15	9	84.3	50.6
Total		60	72	192.9	194.2

W18 (5 years from 2002 to 2006) $= 194.2 \times 365 \times (1+1.07+1.07^2+1.07^3+1.07^4)$
$= 0.41 \times 10^6$

TABLE 2.3-11 W18 (Urban Section-1)

Vehicle Type	Truck Load Factor	2002 Daily Traffic Volume		2002 18-kip ESAL Applications per day	
		To Phnom Penh	To Sisophon	To Phom Penh	To Sisophon
2-Axle Truck	1.854	276	328	511.7	608.1
3-Axle Truck	2.83	115	11	325.7	31.2
Trailer	5.397	25	180	134.9	971.5
Total		416	519	972.3	1,610.8

W18 (5 years from 2002 to 2006) $= 1{,}610.8 \times 365 \times (1+1.07+1.07^2+1.07^3+1.07^4)$
$= 3.38 \times 10^6$

TABLE 2.3-12 W18 (Urban Section-4)

Vehicle Type	Truck Load Factor	2002 Daily Traffic Volume		2002 18-kip ESAL Applications per day	
		To Phnom Penh	To Sisophon	To Phom Penh	To Sisophon
2-Axle Truck	1.876	38	43	71.3	80.7
3-Axle Truck	2.876	129	47	371.0	135.2
Trailer	5.453	16	21	87.2	114.5
Total		183	111	529.5	330.4

W18 (5 years from 2002 to 2006) $= 529.5 \times 365 \times (1+1.07+1.07^2+1.07^3+1.07^4)$
$= 1.11 \times 10^6$

Effect of Vehicles for Construction of World Bank Section

The following trucks/trailers were assumed to pass on the Project section after its completion:

- 3-axle truck :

Total load	180,000 t (base course aggregate 76,000 m^3, surface course aggregate 14,000 m^3, total 90,000 m^3)
Number of trucks	12,000 (15 t/truck)
Gross weight	25 t/truck (vehicle 10 t, load 15 t)
Axle load distribution	Front wheel 5 t, rear wheel 15 t

- Trailer : Total load — 10,000 t (cement)
  Number of trailers — 333 (30 t/trailer)
  Gross weight — 45 t (vehicle 15 t, load 30 t)
  Axle load distribution — Front wheel 5 t, rear wheel 20 t, trailer front and rear wheels 10 t each

Number of 18-kip equivalent single axle load applications (W18) of the above trucks/trailers was computed as shown in Table 2.3-13.

TABLE 2.3-13 W18 OF VEHICLES FOR CONSTRUCTION OF WORLD BANK SECTION

Section	Vehicle Type	18-Kip Single Axle Load Equivalency factor					Number of Vehicles	W18
		Front Wheel	Rear Wheel	Trailer Front Wheel	Trailer Rear Wheel	Total		
Rural (SN=2.32)	3-Axle truck	0.153	3.209	-	-	3.362	12,000	40,300
	Trailer	0.153	3.209	2.334	2.334	8.029	333	2,700
	Total						12,333	43,000
Urban-1 (SN=2.91)	3-Axle truck	0.166	3.041	-	-	3.207	12,000	38,500
	Trailer	0.166	3.041	2.208	2.208	7.623	333	2,500
	Total						12,333	41,000
Urban-4 (SN=2.76)	3-Axle truck	0.163	3.084	-	-	3.247	12,000	39,000
	Trailer	0163	3.084	2.240	2.240	7.726	333	2,600
	Total						12,333	41,600

W18 is approximately 0.04×10^6 for all sections.

Adding this amount, the total W18 for each section is as follows:

Rural Section $(0.41+0.04) \times 10^6 = 0.45 \times 10^6$
Urban Section-1 $(3.38+0.04) \times 10^6 = 3.42 \times 10^6$
Urban Section-4 $(1.11+0.04) \times 10^6 = 1.15 \times 10^6$

3) Roadbed Soil Resilient Modulus

Design CBR of Rural Section

CBR values of 17 locations in the rural section were as follows:

11.7, 6.8, 6.3, 7.5, 13.1, 7.1, 13.9, 7.9, 6.0, 6.1, 10.0, 13.1, 7.0, 6.2, 8.1, 7.4, 8.3.

The average of CBR values is 8.6 and the standard deviation (σ_{n-1}) is 2.7, thus design CBR is 5.9 (= 8.6-2.7). There was no extreme CBR value to be neglected.

Design CBR of Urban Section

CBR values of 4 locations in the Urban Section-1 were as follows:

8.2, 13.4, 11.5, 8.3

The average CBR value is 10.4 and the standard deviation (σ_{n-1}) is 2.5, thus design CBR is 7.9 (= 10.4 – 2.5). There was no extream CBR values to be neglected. The same design CBR value as the Urban Section-1 was assumed for the Urban Section-4.

Resilient Modulus

Resilient modulus (M_R) was computed as follows, assuming M_R = 1,500 x CBR:

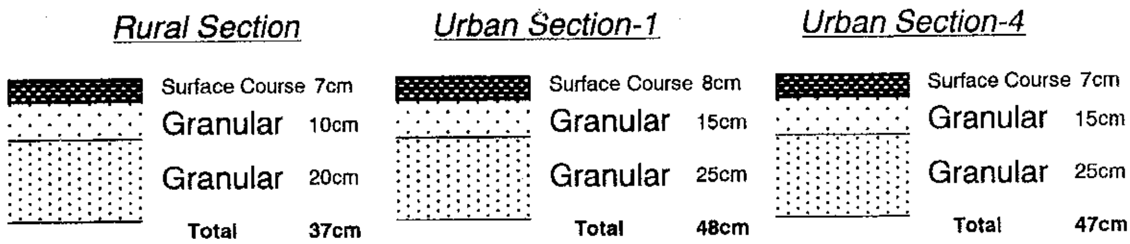
Rural Section M_R = 1,500 x 5.9 = 8,850 psi
Urban Sections-1 & 4 M_R = 1.500 x 7.9 = 11,850 psi

4) Pavement Structure

Required pavement structural number (SN) computed by applying the design variables to the basic design equation shown in 1) for each section was as follows:

Rural Section SN ≧ 2.29
Urban Section-1 SN ≧ 2.87
Urban Section-4 SN ≧ 2.39

Pavement thickness for each section was designed as follows:



SN was computed as shown in Tables 2.3-14 to 16.

TABLE 2.3-14 STRUCTURAL NUMBER (RURAL SECTION)

Pavement Layer	Layer Coefficient (a)	Layer Thickness in inch (D)	Drainage Coefficient (m)	SN = aDm
Surface Course	0.39	2.76	1.0	1.08
Granular Base Course	0.135	3.94	0.9	0.48
Granular Subbase Course	0.108	7.87	0.9	0.76
Total				2.32

TABLE 2.3-15 STRUCTURAL NUMBER (URBAN SECTION-1)

Pavement Layer	Layer Coefficient (a)	Layer Thickness in inch (D)	Drainage Coefficient (m)	SN = aDm
Surface Course	0.39	3.15	1.0	1.23
Granular Base Course	0.135	5.91	0.9	0.72
Granular Subbase Course	0.108	9.84	0.9	0.96
Total				2.91

TABLE 2.3-16 STRUCTURAL NUMBER (URBAN SECTION-4)

Pavement Layer	Layer Coefficient (a)	Layer Thickness in inch (D)	Drainage Coefficient (m)	SN = aDm
Surface Course	0.39	2.76	1.0	1.08
Granular Base Course	0.135	5.91	0.9	0.72
Granular Subbase Course	0.108	9.84	0.9	0.96
Total				2.76

SN of each section is higher than required.

2.3.2.3 Bridge Rehabilitation Design

1) Rehabilitation Method

In accordance with the bridge rehabilitation method selection criteria discussed in 2.3.1.4, the rehabilitation method of each bridge was selected as follows:

<u>Stung Bridge</u>

- Condition of the existing bridge is as follows:

  - The carriageway is narrow (4.0m).
  - Local damages and deficiencies such as damaged railings and spalling of slab concrete are found.
  - Outstanding structural defects are not observed.

- As the carriageway width is only for one lane, two schemes of reconstruction and widening were studied.

  - Reconstruction Scheme: new bridge with 10.0m width (carriageway width of 7.0m and shoulder width of 2 x 1.5m) is constructed at the same location as the existing.

  - Widening Scheme: as structural details and strength of the existing bridge were not verified, widening of the existing bridge is not recommended. Instead, the scheme to construct new one-lane bridge adjacent to the existing bridge was studied.

    Carriageway width of new bridge is planned to be 5.5m (carriageway width = 3.5m, shoulder width = 1.5m, side clearance at the opposite side of shoulder = 0.5m). Carriageway width of the existing bridge of 4.0m is not enough, but is planned to use as is.

  - Construction costs including approaches in both cases were estimated. The widening scheme was found to be slightly economical (88% of the reconstruction scheme).

- Reconstruction scheme was selected in view of the following:

  - Difference in construction cost is minimal.
  - Although the structural strength of the existing bridge is not verified, there is a possibility that it would not satisfy the present design criteria and standards, thus it might be required to be reconstructed in the future in case of the widening scheme.
  - The carriageway width of the existing bridge is insufficient (no shoulder is provided). Considering that composition of two-wheel vehicles is high and large trucks pass on the bridge, smooth

traffic flow will not be assured on the existing bridge in case of the widening scheme.

Lo Lum Bridge

- Since the existing bridge is a temporary bridge, reconstruction scheme was selected.

Kaek Bridge

- Since the existing bridge is a temporary bridge, reconstruction scheme was selected.

Thmor Bridge

- The present conditions are as follows:

  - The carriageway width is slightly insufficient (carriageway width 5.0m, sidewalks 2 x 1.2m)
  - No significant deficiency was observed and judged to be structurally sound.
  - There was no information that the flood water overflew at the bridge site, thus the bridge opening to discharge flood water is deemed sufficient.

- Although the carriageway width is slightly insufficient, traffic function of the bridge will not be seriously affected, since no large vehicles pass on the bridge and traffic volume is not high due to the traffic control in front of the Royal Palace which is located adjacent to the bridge. In view of the above, no rehabilitation was proposed for the bridge.

Wat Thom Yoth Bridge

- The present conditions are as follows:

  - The carriageway width is 6.0m and sidewalk width is 0.7m, which is not sufficient as the proposed carriageway width of this section is 9.0m and sidewalk width is 1.5m.
  - No significant deficiency was observed and judged to be structurally sound.
  - There was no flooding at the bridge site, therefore, the bridge opening is judged to be sufficient.

- The bridge was proposed to be widened by adding box culverts on the both sides of the existing bridge.

2) Basic Plan of Reconstruction Bridges

Bridge Location

The same location as the existing bridge was selected for the reconstruction bridge.

Bridge Elevation

Bridge elevation was determined by adding free board, girder depth, cross fall height and surface pavement thickness to the high water level, as shown in Table 2.3-17.

TABLE 2.3-17 BRIDGE ELEVATION

Bridge	High Water Level	Free Board	Girder Depth	Cross Fall	Surface Pavement Thickness	Bridge Elevation
Stung Br.	EL=14.50m	0.60m	1.15m	0.09m	0.05m	EL=16.39m
Lo Lum Br.	EL=14.50m	0.60m	1.15m	0.09m	0.05m	EL=16.39m
Kaek Br.	EL=14.50m	0.60m	1.15m	0.09m	0.05m	EL=16.39m

Bridge Length and Span Length

Criteria to determine bridge length and span length are as follows:

- Distance between the front faces of abutments shall not be less than that of the existing bridge.
- The minimum span length shall be 10m.
- Reduction ratio of the cross-sectional area of river at bridge site shall be less than 5%.

Bridge length and span length are summarized in Table 2.3-18.

TABLE 2.3-18 BRIDGE LENGTH AND SPAN LENGTH

Bridge	Distance between Front Faces of Abutments		Bridge Length	Span Length	Reduction Rate of Cross-sectional Area of River
	Existing	Proposed			
Stung Br.	34.0m	35.0m	36.2m	11.35m+13.00m+11.35m	4.6%
Lo Lum Br.	32.5m	35.0m	36.2m	11.35m+13.00m+11.35m	4.6%
Kaek Br.	21.0m	25.0m	26.2m	2 x 12.85m	3.2%

Bridge Width

Standard cross-section of a bridge is presented in Figure 2.3-4.

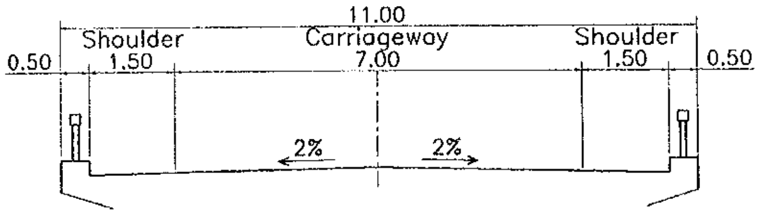


FIGURE 2.3-4 STANDARD CROSS-SECTION OF BRIDGE

3) Selection of Bridge Type

Shape of Bridge Opening

There are two schemes as follows:

- Rectangular Shape : Front faces of bridge abutments and riverbed form a rectangular shape of bridge opening. Wing walls are diagonally extended from the abutments to guide flood water to the bridge. Existing bridges are of this type of shape.

- Trapezoid Shape : Embankment slopes with slope protection work are provided in front of abutments. Bridge length of this scheme becomes longer than the other scheme in order to provide the same cross-sectional area of a river as the rectangular shape scheme.

Superstructure Type

In consideration of bridge length and minimum span length of reconstruction bridges, applicable types of superstructure are reinforced concrete girder (RC Girder), prestressed concrete girder (PC Girder) and Steel H-shaped girder (Steel H Girder).

Preliminary evaluation of superstructure types concluded that construction cost of a Steel H Girder is more expensive than other types of superstructure (1.5 to 1.6 times of RC Girder) and maintenance cost is also expensive due to required periodical paintings, therefore, Steel H Girder is not judged appropriate for the Project.

RC Girders and PC Girders are appropriate for the Project. Alternatives on the number of spans in combination with type of superstructure were studied.

Substructure Type

The inverted T type for an abutment and wall type (oval shape) for a pier was selected, as they are commonly used.

Foundation Type

RC pile which is commonly used in the country was selected for the foundation type.

Comparative Study

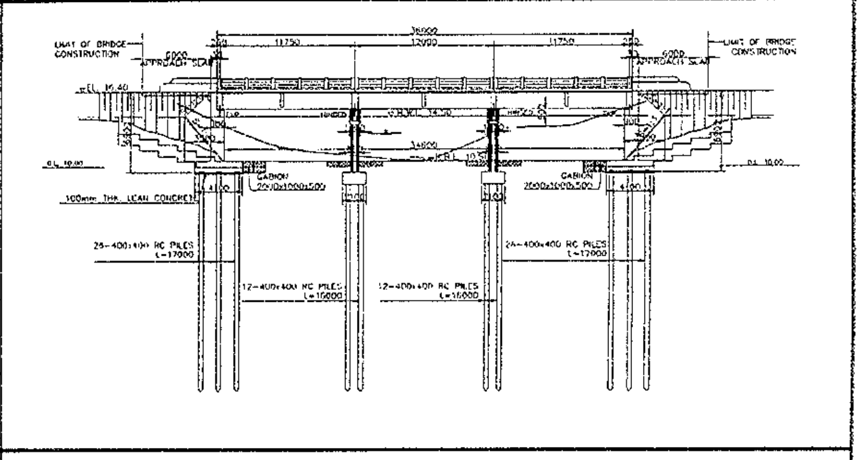
Alternatives were prepared by combining bridge opening shape alternatives (rectangular or trapezoid), superstructure type alternatives (RC Girder or PC Girder) and alternatives on number of spans (short span or long span). Results of comparative study on alternatives for reconstruction bridges are shown in Tables 2.3-19 to 21.

As a result of the comparative study, Alternative-1 (rectangular shape bridge opening, RC girder and span length of 11 to 13 m) was evaluated as the most advantageous plan from viewpoints of economical aspect, constructability and maintenance aspect.

TABLE 2.3-19 COMPARISON OF BRIDGE TYPE: STUNG BRIDGE

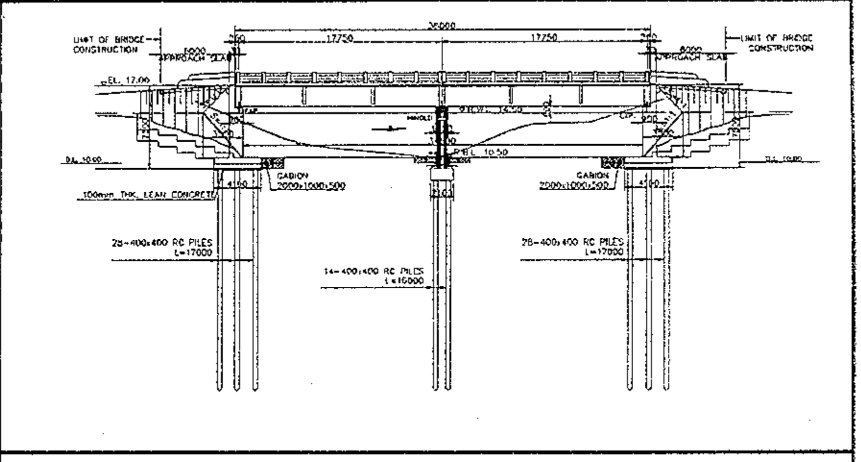
Scheme-1 : Shape of bridge opening : Rectangular
Superstructure type : 3-Span RC girder

Construction Cost	○ 1.00
Construction Period	△ Next shortest to Scheme-3 & Scheme-6.
Constructability	○ Easy, requiring no special construction equipment nor special technology.
Maintainability	○ Expects no specific problem.
Overall Evaluation	1



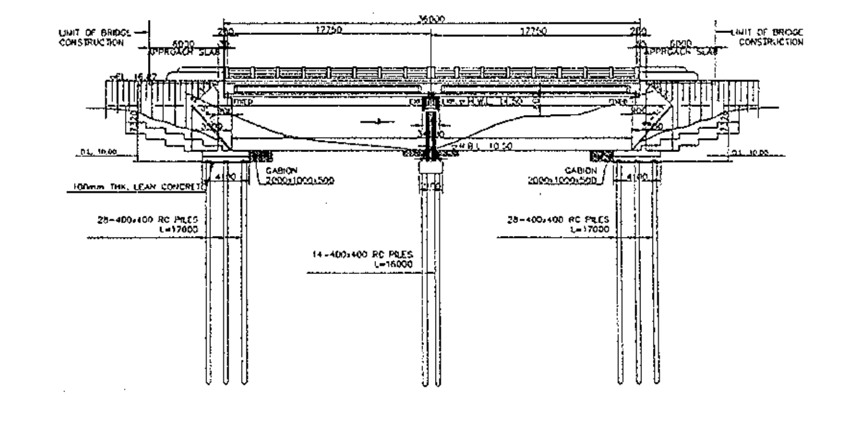
Scheme-2 : Shape of bridge opening : Rectangular
Superstructure type : 2-Span RC girder

Construction Cost	× 1.06
Construction Period	△ Next shortest to Scheme-3 & Scheme-6.
Constructability	○ Same as Scheme-1.
Maintainability	○ Expects no specific problem.
Overall Evaluation	3



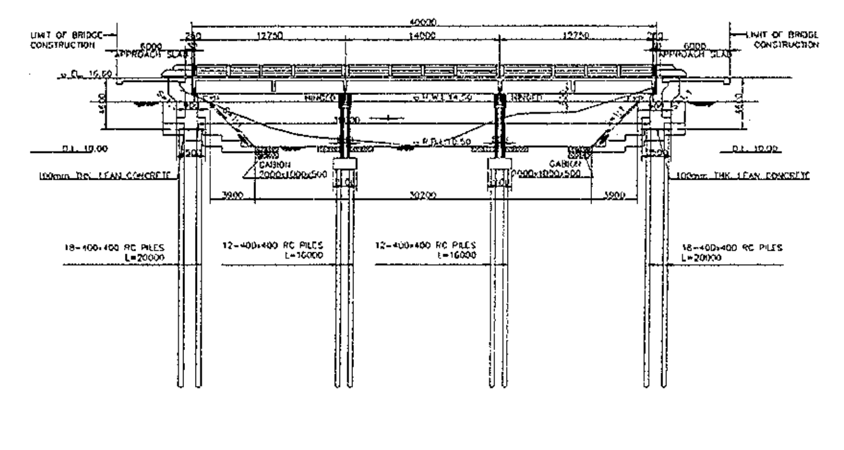
Scheme-3 : Shape of bridge opening : Rectangular
Superstructure type : 2-Span PC girder

Construction Cost	△ 1.03
Construction Period	○ Shortest, as girders can be fabricated during construction of substructure.
Constructability	× Needs high capacity crane for girder erection. If such crane is not available, needs special method such as draw erection method. Needs cautious control of prestressing.
Maintainability	○ Expects no specific problem.
Overall Evaluation	2



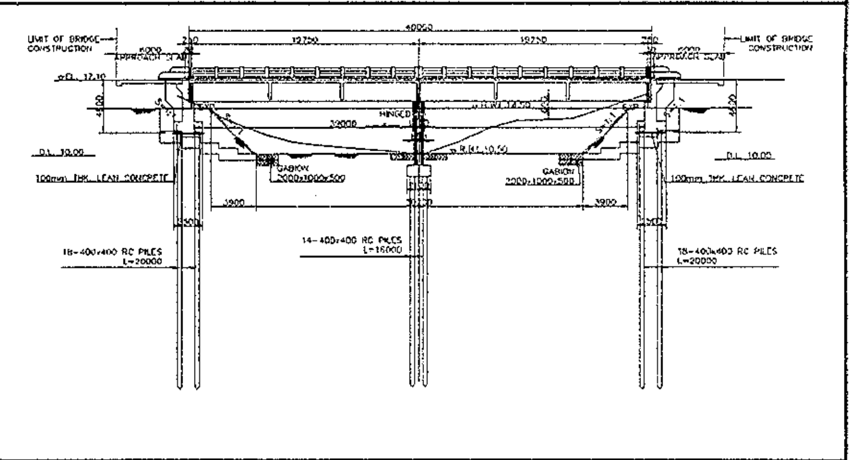
Scheme-4 : Shape of bridge opening : Trapezoid
Superstructure type : 3-Span RC girder

Construction Cost	△ 1.02
Construction Period	× Longest, requiring firstly construction of substructure, then construction of superstructure with cast-in-place concrete, and finally construction of slopes in front of abutments.
Constructability	△ Needs elaborate construction of slopes in front of abutments. Same as Scheme-1 for other matters.
Maintainability	× Possibly needs repair of slope protection in front of abutments, as the slope is apt to settle because of difficulty in its thorough compaction.
Overall Evaluation	3



Scheme-5 : Shape of bridge opening : Trapezoid
Superstructure type : 2-Span RC girder

Construction Cost	× 1.15
Construction Period	× Longest, similarly to Scheme-4.
Constructability	△ Same as Scheme-4.
Maintainability	× Same as Scheme-4.
Overall Evaluation	6



Scheme-6 : Shape of bridge opening : Trapezoid
Superstructure type : 2-Span PC girder

Construction Cost	△ 1.03
Construction Period	△ Next shortest to Scheme-3.
Constructability	× Needs elaborate construction of slopes in front of abutments. Same as Scheme-3 for other matters.
Maintainability	× Same as Scheme-4.
Overall Evaluation	3

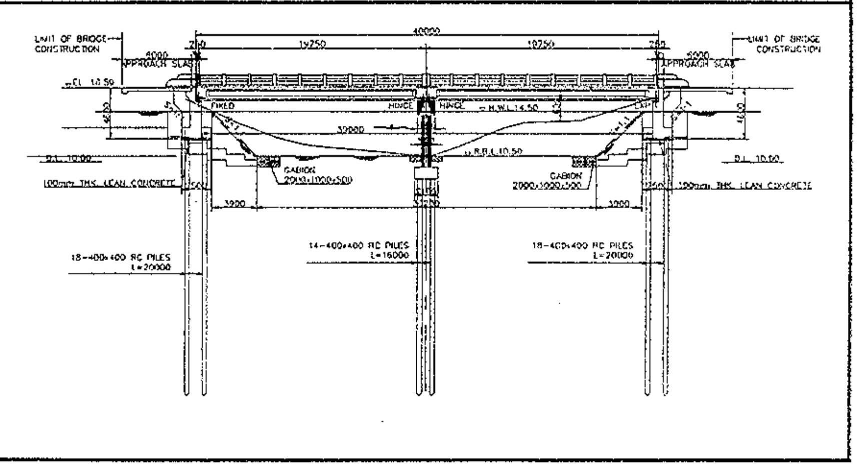
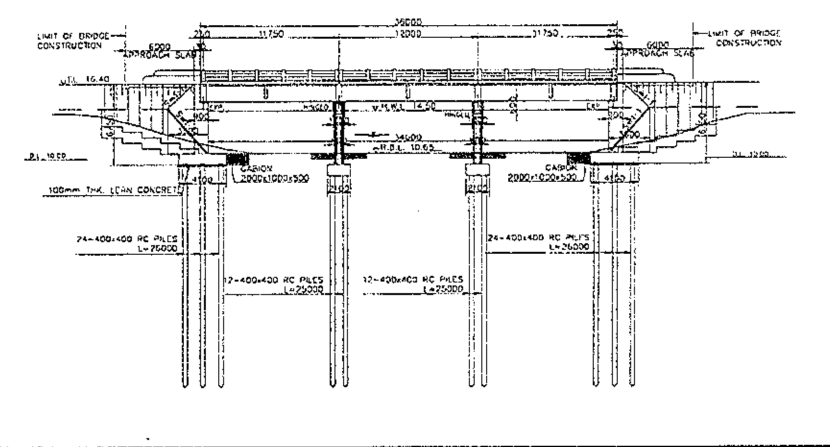


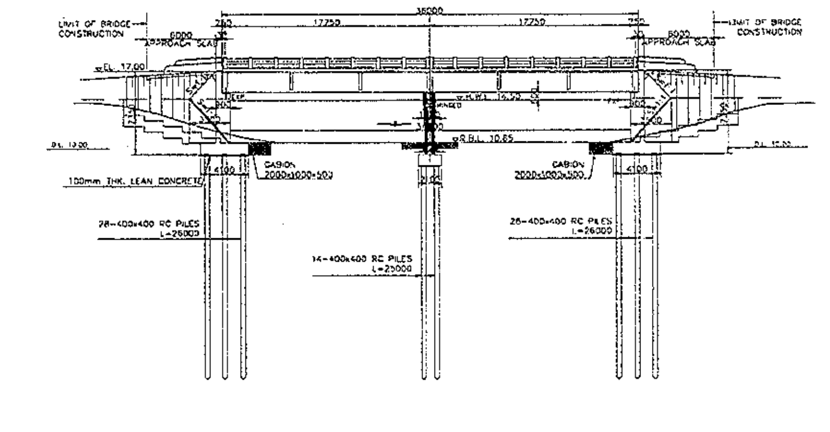
TABLE 2.3-20 COMPARISON OF BRIDGE TYPE: LO LUM BRIDGE

Scheme-1 : Shape of bridge opening : Rectangular; Superstructure type : 3-Span RC girder



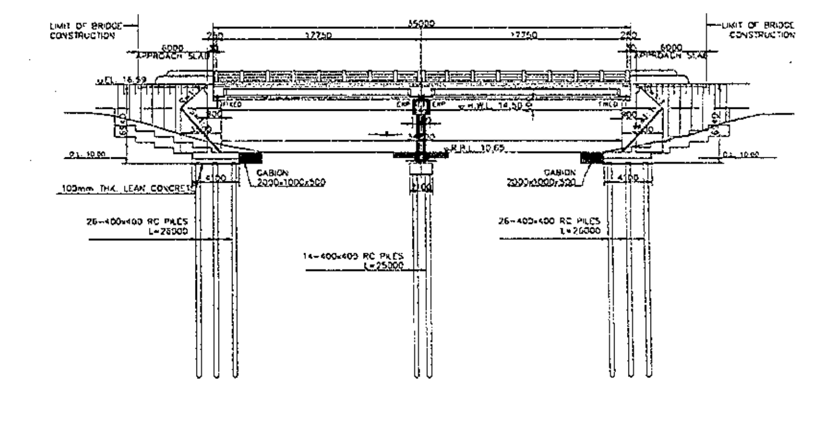
Construction Cost	○ 1.00
Construction Period	△ Next shortest to Scheme-3 & Scheme-6.
Constructability	○ Easy, requiring no special construction equipment nor special technology.
Maintainability	○ Expects no specific problem.
Overall Evaluation	1

Scheme-2 : Shape of bridge opening : Rectangular; Superstructure type : 2-Span RC girder



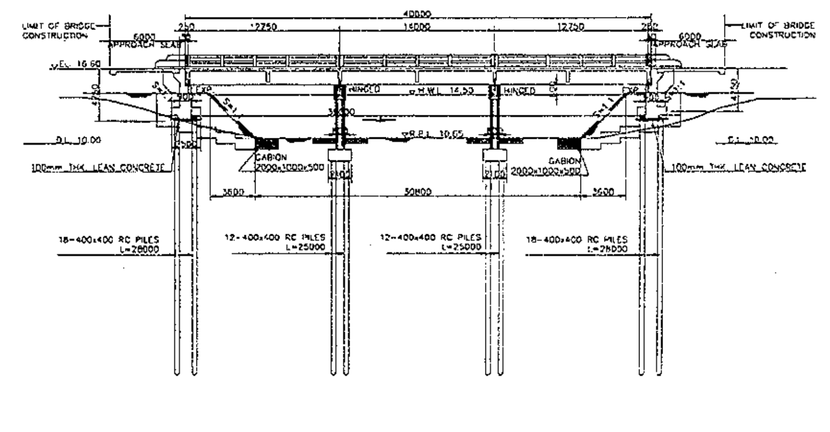
Construction Cost	× 1.07
Construction Period	△ Next shortest to Scheme-3 & Scheme-6.
Constructability	○ Same as Scheme-1.
Maintainability	○ Expects no specific problem.
Overall Evaluation	5

Scheme-3 : Shape of bridge opening : Rectangular; Superstructure type : 2-Span PC girder



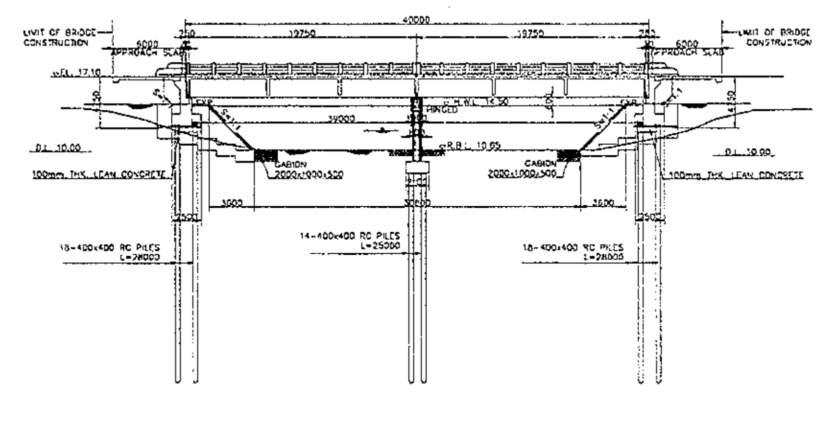
Construction Cost	△ 1.02
Construction Period	○ Shortest, as girders can be fabricated during construction of substructure.
Constructability	× Needs high capacity crane for girder erection. If such crane is not available, needs special method such as draw erection method. Needs cautious control of prestressing.
Maintainability	○ Expects no specific problem.
Overall Evaluation	2

Scheme-4 : Shape of bridge opening : Trapezoid; Superstructure type : 3-Span RC girder



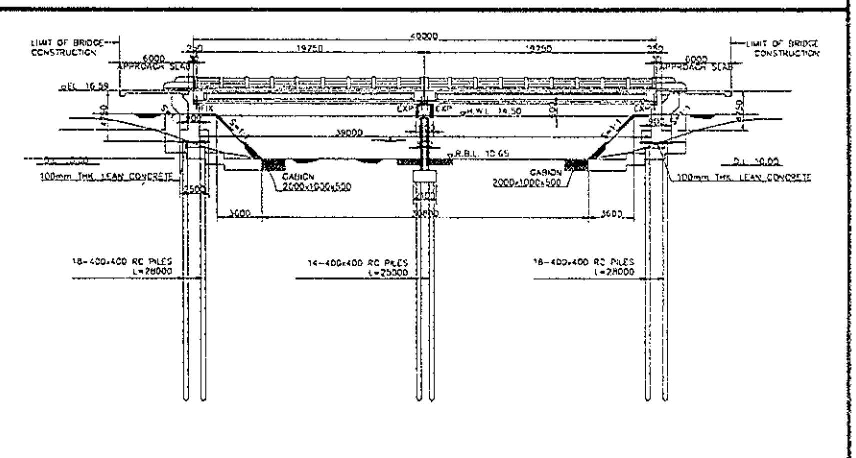
Construction Cost	△ 1.01
Construction Period	× Longest, requiring firstly construction of substructure, then construction of superstructure with cast-in-place concrete, and finally construction of slopes in front of abutments.
Constructability	△ Needs elaborate construction of slopes in front of abutments. Same as Scheme-1 for other matters.
Maintainability	× Possibly needs repair of slope protection in front of abutments, as the slope is apt to settle because of difficulty in its thorough compaction.
Overall Evaluation	3

Scheme-5 : Shape of bridge opening : Trapezoid; Superstructure type : 2-Span RC girder



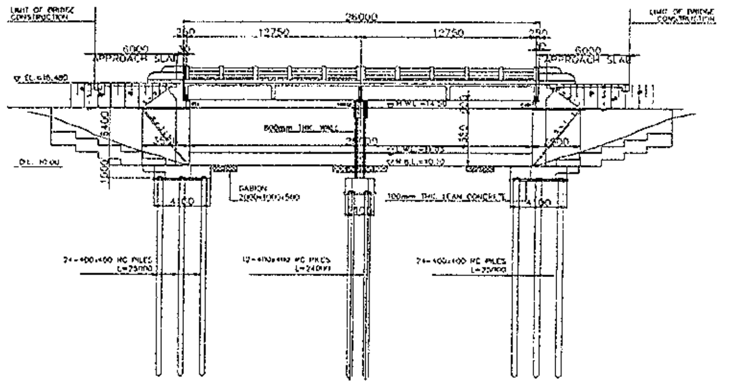
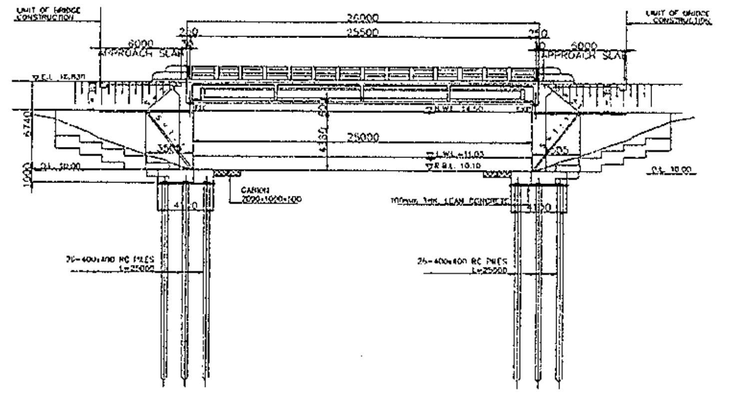
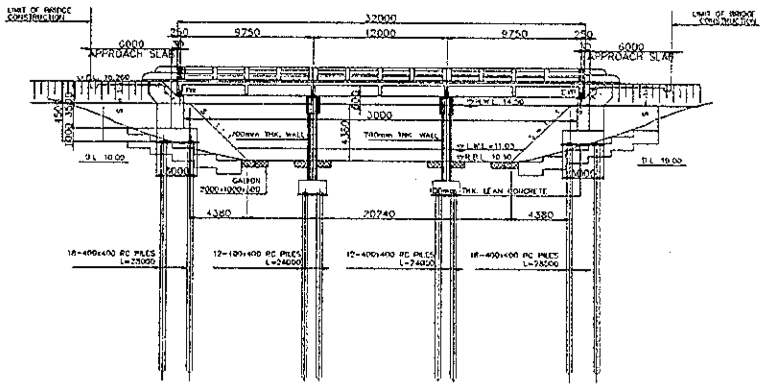
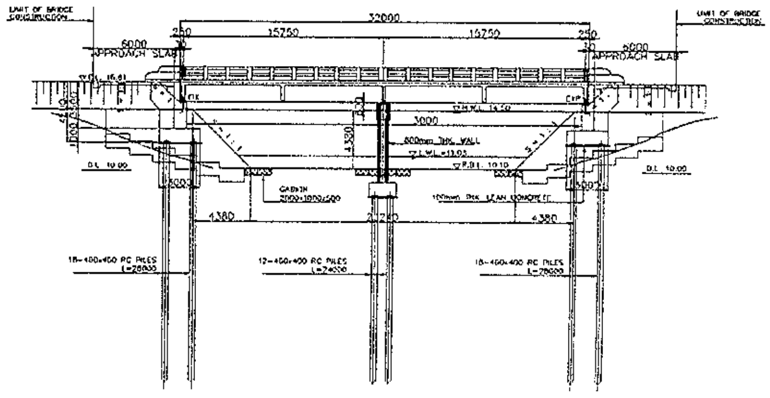
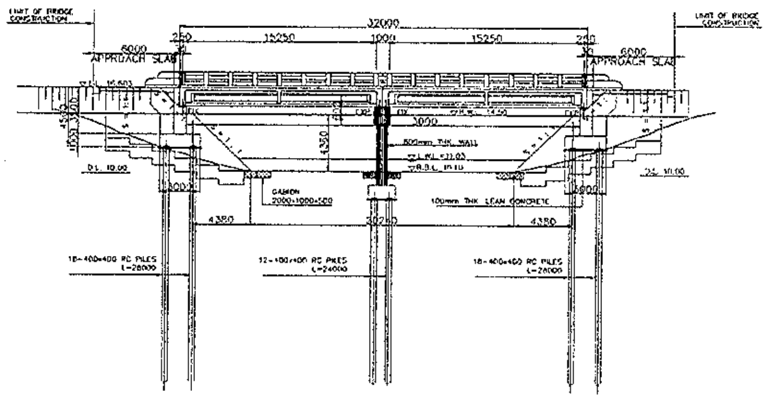
Construction Cost	× 1.12
Construction Period	× Longest, similarly to Scheme-4.
Constructability	△ Same as Scheme-4.
Maintainability	× Same as Scheme-4.
Overall Evaluation	6

Scheme-6 : Shape of bridge opening : Trapezoid; Superstructure type : 2-Span PC girder



Construction Cost	△ 1.01
Construction Period	△ Next shortest to Scheme-3.
Constructability	× Needs elaborate construction of slopes in front of abutments. Same as Scheme-3 for other matters.
Maintainability	× Same as Scheme-4.
Overall Evaluation	3

TABLE 2.3-21 COMPARISON OF BRIDGE TYPE: KAEK BRIDGE

Scheme-1 : Shape of bridge opening : Rectangular Superstructure type : 2-Span RC girder		
Construction Cost	○ 1.00	
Construction Period	△ Next shortest to Scheme-2 & Scheme-5.	
Constructability	○ Easy, requiring no special construction equipment nor special technology.	
Maintainability	○ Expects no specific problem.	
Overall Evaluation	1	
Scheme-2 : Shape of bridge opening : Rectangular Superstructure type : 1-Span PC girder		
Construction Cost	△ 1.02	
Construction Period	○ Shortest, as girders can be fabricated during construction of substructure.	
Constructability	× Needs high capacity crane for girder erection. If such crane is not available, needs special method such as draw erection method. Needs cautious control of prestrssing.	
Maintainability	○ Expects no specific problem.	
Overall Evaluation	2	
Scheme-3 : Shape of bridge opening : Trapezoid Superstructure type : 3-Span RC girder		
Construction Cost	× 1.12	
Construction Period	× Longest, requiring firstly construction of substructure, then construction of superstructure with cast-in-place concrete, and finally construction of slopes in front of abutments.	
Constructability	△ Needs elaborate construction of slopes in front of abutments. Same as Scheme-1 for other matters.	
Maintainability	× Possibly needs repair of slope protection in front of abutments, as the slope is apt to settle because of difficulty in its thorough compaction.	
Overall Evaluation	4	
Scheme-4 : Shape of bridge opening : Trapezoid Superstructure type : 2-Span RC girder		
Construction Cost	× 1.05	
Construction Period	× Longest, similarly to Scheme-3.	
Constructability	△ Same as Scheme-3.	
Maintainability	× Same as Scheme-3.	
Overall Evaluation	4	
Scheme-4 : Shape of bridge opening : Trapezoid Superstructure type : 2-Span PC girder		
Construction Cost	× 1.09	
Construction Period	△ Next shortest to Scheme-2.	
Constructability	× Needs elaborate construction of slopes in front of abutments. Same as Scheme-2 for other matters.	
Maintainability	× Same as Scheme-3.	
Overall Evaluation	3	