MINISTRY OF PUBLIC WORKS AND TRANSPORT
THE KINGDOM OF CAMBODIA

No. 01

BASIC DESIGN STUDY REPORT ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 AND 7 IN THE KINGDOM OF CAMBODIA

JANUARY 1997

JAPAN INTERNATIONAL COOPERATION AGENCY
ORIENTAL CONSULTANTS CO., LTD.

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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 Rehabilitation of National Roads Route 6 and 7 and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Cambodia a study team from June 9th , 1996 to July 18th, 1996.

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 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.

January 1997

Kimio Fujita
President
Japan International Cooperation Agency

Letter of Transmittal

We are pleased to submit to you the basic design study report on the Project for Rehabilitation of National Roads Route 6 and 7 in the Kingdom of Cambodia.

This study was conducted by Oriental Consultants Company Limited, under a contract to JICA, during the period from June 3rd, 1996 to February 10th, 1996. 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,

Kazurou Yanagida
Project manager,
Basic design study team on
the Project for Rehabilitation of
National Roads Route 6 and 7
in the Kingdom of Cambodia
Oriental Consultants Company Limited

THE BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION
OF
NATIONAL ROADS ROUTE 6 AND 7

Definition and Abbreviations

A. Authorities and Agencies

ADB	Asian Development Bank
CIDA	Canadian International Development Agency
CMAC	Cambodian Mine Action Centre.
JICA	Japan International Cooperation Agency
MPWT	Ministry of Public Works and Transport
RCC	Road Construction Centre
UNDP	United Nations Development Programme
USA/US	United States of America

B. Other Abbreviations

AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ASTM	American Society for Testing and Materials
@	At the rate
Ac	Holocene clayey soils
As	Holocene sandy soils
B	Basalt
B/D	Basic Design
BR	Bridge
BL	Bridge length
CBR	California Bearing Ratio
℄	Center Line
cm	Centimetre
cm^2	Square centimetre
Dc	Pleistocene clayey soils
D/F	Draft Final Report
Ds	Pleistocene sandy soils
$	Dollar
Ec	Young's modulus of cement
Es	Young's modulus of steel
Esp	Modulus
Ex	Existing
El	Elevation
F	Fill
g/cm3	Gram per cubic centimetre
H	Height

HWL	High water level
i	Coefficient of impact
Kg	Kilogram
Kgf/cm^2	Kilogram force per square centimetre
Kgf/mm^2	Kilogram force per square millimetre
Km	Kilometre
Km^2	Square kilometre
Km/h	Kilometre per hour
L	Length
l	Length
LWL	Low water level
m	Metre
M	Million
Mc	Mesozoic clayey souls soils
m^2	Square metre
m^3	Cubic metre
Min	Minimum
MSL	Mean sea level
N	N-value or Number of wheel load application
n	Number or Ratio of Es to Ec
%	Percent
ϕ	Diameter
P.C	Prestressed Concrete
PCU	Passenger car unit
PSI	Present serviceability index
R.C	Reinforced concrete
RN	Route number of national road
S	Scale
σck	Allowable stress of concrete
σsa	Allowable stress of steel bar
Sta/St	Station
Ta	Equivalent thickness of asphalt concrete
t	Ton or Thickness
W	Width
W.L	Water level

CONTENTS

CHAPTER 1

CHAPTER 1 BACKGROUND OF THE PROJECT

1-1 Background of the Request

After many years of civil war and isolation from the rest of the world, Cambodia returned to the international scene in 1992. However, as a result of the internal conflict lasting for more than a decade, the economy was nearly brought to ruin and the lives of many of the country's engineers and intellectual class had been taken: these two major factors have stood in the way of redeveloping the social structure which is lacking in educated and trained people needed for social stability and economic reconstruction. Among others, the road network, which supports the basic function of the movement of people as well as goods, is in urgent need of repair.

In light of these conditions, Japan has taken a leading role in the peace-making efforts in the country and has been very active in cooperating with reconstruction activities, being the leading donor of aid (as of 1993).

Furthermore, the return of stability to Cambodia is of great import to all of Southeast Asia as it is a region of great natural resource potential which has not been realized due to war and political instability. Therefore, a stable social environment in this country is a topic of great concern to all countries involved in the region. In addition, Vietnam and Laos have begun to introduce market economies which constitute yet another factor of the changing face of the region. Combined with these, historical ties and geographic location show that the entire region is closely interrelated and that a balance of economic development is in the best interests of the region. Japan is actively involved in this movement and has held the "Indochina Integral Development Forum" and other such conferences which are attended by delegates of related countries. Topics most discussed in these meetings include development of international infrastructure and human resources.

National Roads 6 and 7, which are the object of the request for a grant aid by the Cambodian government, are of particular importance as national routes. The full length of National Road Route 6 is 386 km, connecting the border of Thailand to the west and Vietnam to the east, not to mention the world-recognized ancient ruins of Angkor Wat. This is obviously an important route in the country. National Road Route 7, with a full length of 475 km, is vital for the transporting of lumber, raw rubber, and other agricultural products from the northeastern provinces as well as being a part of an international highway (Asia Highway 11) connecting Vietnam and Laos.

However, the stretch of highway between Prek Kdam and Sukun (NR 6) and extending as National Road 7 to the city of Kompong Cham on the Mekong River, suffers from deteriorating pavement conditions as well as damaged road structures such as bridges, culverts, etc., which obstruct the smooth flow of traffic. Such obstructions, among other causes, are hindering social and economic progress in the country as a whole.

The Feasibility Study on the Mekong River Bridge Construction Project carried out by JICA in the fiscal years of 1994 and 1995 determined the construction of the bridge at the city of Kompong Cham, which is to be constructed by funds from Japanese Government grant aid. However, in this plan there is no provision for an access road to National Road Route 7, the plan being to route access traffic through the city area. However, an increase in traffic volume is anticipated following the completion of the bridge; therefore degradation of the living environment through traffic accidents, noise, vibration, ect., will accompany. Therefore, it is hoped that a bypass route will be constructed to avoid with problems.

The Cambodian government has requested the Government of Japan for a grant aid for improvement of road surface and repair of road-related structures such as bridges and culverts over the 93 km stretch between Prek Kdam and Kompong Cham, and construction of an undeveloped 2.2 km bypass needed as the result of the Mekong River Bridge Construction Plan.

CHAPTER 2

CHAPTER 2 CONTENTS OF THE PROJECT

2-1 Objectives of the Project

In order to reconstruct the damaged economy and rehabilitate the society of Cambodia, it is of utmost importance to rehabilitate road transport mode, especially National Route 1-7, which is the most important mode of transport.

The objectives of the Project are to rehabilitate National Road Route 6 (Thnolkeng - Skun) and National Road Route 7 (Skun - Kampong Cham) including construction of bypass road to proposed Mekong Bridge to improve transport between Phnom Penh and Kampong Cham, which is the economic centre of northern areas, and the neighbouring region, which is a principal area for production of rice, rubber and lumber, and to contribute to the enhancement of the national economy and that of other countries of the region.

2-2 Basic Concept of the Project

2-2-1 Project Area

The original request from the Cambodian Government included the 93km stretch of road from Prek Kdam to Kompong Cham. However, because the traffic volume of the 18km stretch between Prek Kdam and Thnolkeng (the latter being the intersection of Route 6 and ex-route 6A) is considerably smaller than that of other sections and thus the economic benefit is negligible, it was concluded that it should be removed from the Project as the result of discussion with Cambodian authorities.

2-2-2 New Construction of Access Road to Mekong Bridge in Kompong Cham

Cambodian authorities made an urgent request for the construction of a new access road to Mekong Bridge and National Route 7 of the project (a distance of about 2.2km). Judging from forseeable traffic volume, it is believed that the existing city route is sufficient, but as a result of careful consideration it has been decided to undertake the construction of such a access road be undertaken for the reasons stated below.

(1) Following the construction of the Mekong Bridge, traffic volume forecasted for 2011 is 10,000 vehicles per day and 14,000 per day (including motorcycles) in 2021. Such traffic increase within the city streets will bring about the degradation of living environment through noise and traffic accidents.

(2) Both the construction of Mekong Bridge and the rehabilitation of National Routes 6 and 7 are grant aid projects by the Japanese Government. The access road going unconstructed would be inconsistent with these projects.

(3) Resettlement, the biggest problem involved in access road construction, does not

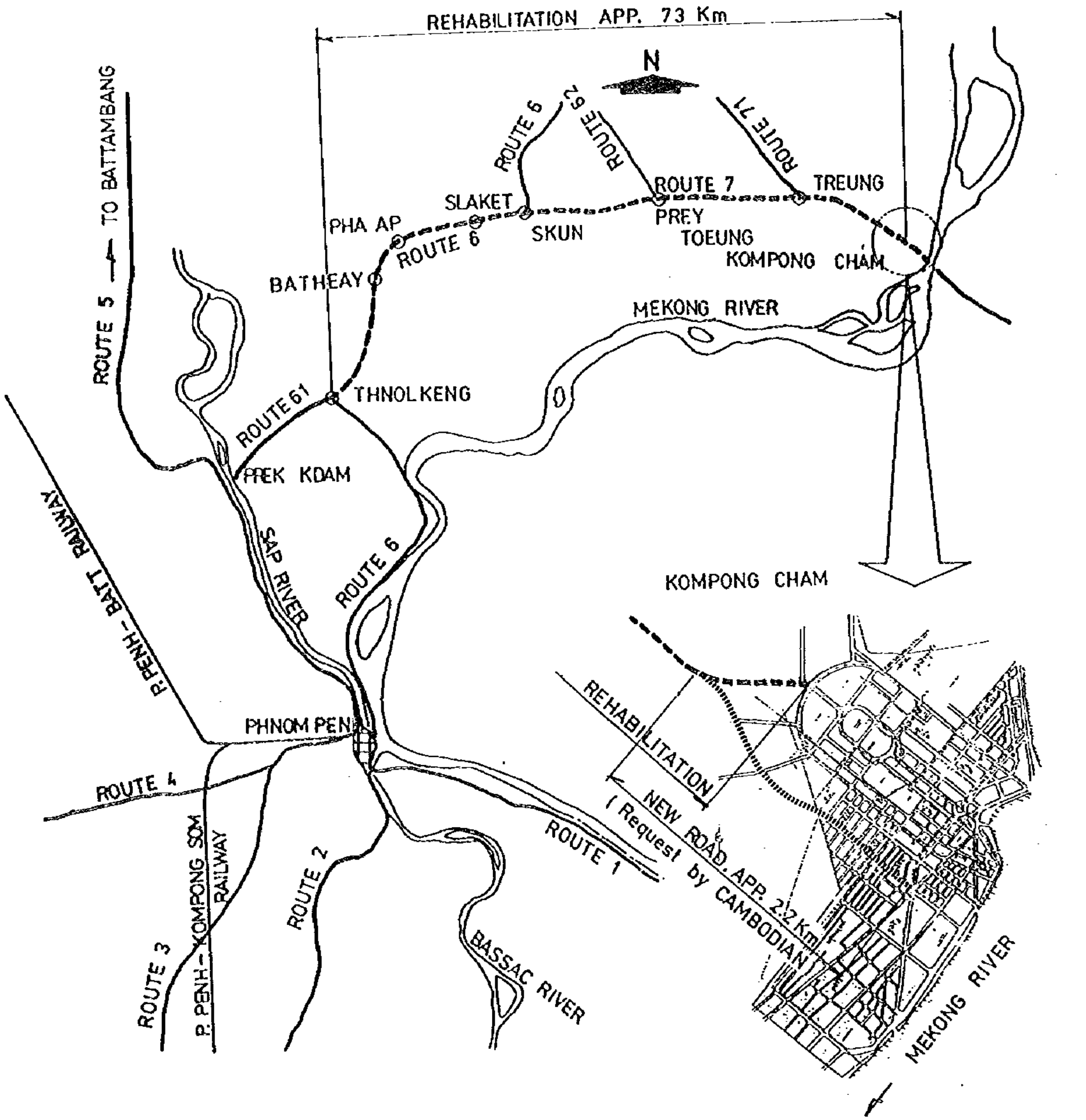


Figure 2-2-1 Project Area

appear to pose insurmountable barriers in this case, as the Cambodian Government reports that it has obtained consensus from local residents in regards to land acquisitoin in connection with the Mekong Bridge project. At present, the residents are in the process of looking for appropriate areas to resettle already.

2-2-3 Road Rehabilitation Plan

1) Composition of Rehabilitation Plan

In consideration of the standards set domestically as well as for the Asia Highway, the width of 2-lane carriageway will be the same as national Route ex-6A, that is, 7m. In view of the high ratio of two-wheel vehicles utilizing the road, a special lane will be included as a safety measure. In sections where it is assumed there will be minimal safety problem, this lane will be narrowed in order to economize on the project cost.

2) Flooding Measures

In 1996, flooding of the Mekong River, at a scale of which is said to have last occurred in 1978 (although officially unconfirmed due to absence of records from that time), caused damages such as collapse of embankment at three locations, destruction of slopes and flooding on part of the roads on the Route 6 and 7. In this basic design, we carry out an analyses of the flood and investigation of flood water level and damage this year, and necessary measures such as the raising of road level, embankment slope protection, etc., will be carefully considered as part of the plan in hopes to reduce maintenance cost as much as possible for the Cambodian side.

2-2-4 Rehabilitation Plans for Requested Bridges and Culverts

Upon surveying the present conditions of eight bridges and two culverts, concern was voiced regarding their durability in light of the fact that constant logging traffic passes over them. In all instances, the superstructures show signs of heavy damage. As for the substructures, most of them are deemed undependable as they chiefly consist of mortar-covered bricklaid structure. Since there were found no instances of sufficiently durable structures, it has been decided that all be replaced.

2-2-5 Maintenance following Rehabilitations

To the greatest possible extent, the design will be made and construction carried out to minimize future needs for maintenance. However, it is strongly recommended that at least a minimum percentage of budget be set aside for maintenance, hereafter.

2-2-6 Utilization of Road Construction Center (RCC) and Possibilities of Conducting OJT as Part of this Project

1) Utilization of RCC's Machinery and Equipment

As a result of field reconnaissance, it has been verified that there is a large amount of utilizable equipment for this project in the RCC, the use of which will take priority as a means of the most efficient utilization of the center. In this instance, however, it is necessary that handling of the income of the center, which is financially independent, be taken care of by Cambodian authorities.

2) Conducting of OJT for RCC Staff Members as a Part of the Project

Through interviews with JICA experts sent to the RCC, it was found that the degree of skill of the RCC operators and other skilled laborers is at a developing stage. However, thanks to training being conducted by these JICA experts as well as the fair amount of road repair work being conducted recently, there is a marked, if slow, trend of skills improvement.

At present, the construction market in Cambodia is favorable, but due to the limited number of sufficiently skilled laborers, many are brought in from Thailand, Vietnam, or the Phillipines. Therefore, in order to raise up skilled workers to support Cambodia's future progress, it is recommended that RCC staff as well as certain other skilled workers from Cambodia be trained in OJT as a part of this project.

2-2-7 Basic Concept of Project

As a result of reviewing the above matters, the basic concept of this project involves road rehabilitation for the 73km stretch of National Routes No. 6 and 7 between Thnolkeng and Kompong Cham as well as new construction of a 2.2km route passing through Kompong Cham city to the connecting route for the Mekong Bridge. As a result of this project, access from Phnom Penh to Siemreap and other areas in the north, and Kompong Cham and the northeast areas will be ameliorated. Moreover, the Project would enhance Cambodia's economy, improve shipping and transport standards to all areas involved, and further stabilize the living standards of local citizens. Specific contents of the project are shown below.

1) Rehabilitation of National Route 6 and 7

(1) Project Area :Thnolkeng (intersection of Route 6 and Route ex-6A) to Kompong Cham

(2) Length : 73km

(3) Contents of Rehabilitation :

① While improving the road to satisfy the geometric structure and road structure indicated below, raising of road surface and slope embankment protection will be conducted in areas with tendency to submersion in rainy season.

- Total width : 11m (outside settlements, 10m)
- Composition of width :

  0.5 m + 1.5 m + (3.5 m x 2) + 1.5 m + 0.5 m
  (protective shoulder) (two-wheeler lane) (carriageway)
- Pavement structure : asphalt concrete

② Replacement of eight (8) existing bridges and two (2) existing box culverts to an effective width of 10m to withstand passage of heavy vehicles (25-ton truck load).

③ Construction of three bridges as countermeasures against flooding.

④ Lengthening and/or reconstruction of small-to-medium size culverts in nineteen (19) locations.

⑤ Alignment improvement : 5 points between Thnolkeng and Skun

⑥ Installation of drainage facilities

Settlements Scheduled for Road Drainage Installation

Station	Place	Content	Length (m)
26+300 - 27+500	Batheay	U-shaped drainage at one side	1.2km x 1
31+700 - 31+900	Pha Ap	L-shaped drainage on both sides	0.2km x 2
44+000 - 44+150	Skun	L-shaped drainage at one side	0.15km x 1
65+800 - 66+000	Prey Toeung	L-shaped drainage on both sides	0.2km x 2

⑦ Improvement of intersection : Thnolkeng, Skun, Treung

⑧ Traffic safety facilities

- Center line on all project roads
- Outer line on the sections with 11m road width
- Guide signs at Thnolkeng, Skun and Treung
- Kilometer posts every 10km

2) New Construction of Access Road to Mekong Bridge through Kompong Cham City

(1) Project Area :Kompong Cham

(2) Length : 2.2km

(3) Road Structure :

To be constructed as a road satisfying the following geometric design and road structure.

- Design speed : 60km/hr
- Total width : 11m (outside settlements, 10m)
- Composition of width :
  0.5 m + 1.5 m + (3.5 m x 2) + 1.5 m + 0.5 m
  (protective shoulder) (two-wheeler lane) (carriageway)
- Pavement structure : asphalt concrete

2-3 Basic Design

2-3-1 Design Concept

1) Items to be Considered in Basic Design

The design policy of the basic design of the Project, as shown in the following, takes into consideration various factors. These include natural conditions, socio-economic situations, and environment. As for construction and material procurement, the scale of roads, bridges and other structures as well as hindrances in construction are considered: particularly problems of transportation of materials, machinery and labor to the construction site.

(1) The area of the project site has a long rainy season which brings flooding to the area. Road structure type, embankment, bridges and other structures must take this seasonal hazard into account. The construction schedule will also be adjusted accordingly.

(2) The project roads play a role in the development of the area north of Phnom Penh towards Kompong Cham. Logging vehicles and other heavy vehicles travel along the routes. In the future, other international traffic will be using these roads; the design specifications must be set accordingly.

(3) Most construction material is imported and available on the market. Local material where available will be used as much as possible. Quality, stable stock situation and availability have been investigated and reflected in the design; therefore, the exporting countries also vary.

(4) Construction machinery and equipment available in the country will be used, particularly from the Road Construction Center of the Department of Major Construction, Ministry of Public Works and Transport (RCC).

(5) Local technical staff, including consultants, contractors, surveyors, and those of other similar professions, have sufficient knowledge for small-scale road and bridge construction: however, they have yet to acquire experience for larger-scale construction such as are included in this project. Consequently, the project will

be designed in Japan in such a manner that Japanese engineers are directly involved in the important aspects of the construction progress.

(6) The Cambodia administration's ability of maintenance management is improving very rapidly, though financial backing is still rather weak. Maintenance-free features, with slightly higher initial cost, are to be included in the design of roads and structures.

(7) In summary to the above mentioned, due consideration is given to designs, keeping in mind that this project is a grant aid program of the Japanese Government. The project will be carried out economically, and in the shortest time possible.

In addition, an attempt is made to utilize as much as possible materials available in Cambodia, and to adopt the method of construction readily available here that meets on-site requirements. Furthermore, the dry season is to be utilized to the greatest extent possible

(8) Asphalt concrete surfacing is to be adopted having longer pavement life while the existing layers of pavement are utilized as base course where possible.

(9) The wet season is planned exclusively for the superstructure manufacturing and aggregate production while piling, foundation, substructure, embankment and pavement works are planned during the dry season. Other works such as superstructure erection and construction, base course works and others are planned according to the specification of such works.

2) Design Conditions for Road Rehabilitation

(1) Design Standard and Road Class

Basically, Japanese standards are applied to the Project, however the standards of Asian Highway and Cambodia are also taken into consideration due to the fact that the project road is the part of Asian Highway No.11

The project road will be forecasted to carry around 1,700 pcu/day in the year 2001 and 5,800 pcu/day in the year 2011, based on the analysis by the JICA Study Team. According to the Japanese standard, as a consequence, the requirement for geometric design is as follows;

Design standard	:	Japanese standard
Class	:	Equivalent to Class 2 of Type 3

(2) Geometric Design Standard

Geometric design standard for Asian Highway was reviewed by ESCAP in 1994. Table-2-3-1 shows revised geometric design standard for Class II. Asian Highway No.11 is equivalent to Class II.

Table-2-3-1 Geometric Design Standard for Asian Highway

Class of Road		Class II			
Terrain		flat	Rolling	Mountainous	Steep Slope
Design Speed (km/h)		80	60	50	40
Width	R.O.W	40			
	Lane Width	3.50			
	Shoulder	2.50		2.00	
	Median			—	
Min. Radius		210	116	80	50
Cross fall of Carriageway		2			
Cross fall of Shoulder			3-6		
Pavement Type		Asphalt / Concrete			
		10			
Maximum Gradient		4	5	6	7
Design Live Load			HS20-44		

Source: "A Study for the Development of the Asia Highway Network, Draft Report", 1994, UN ESCAP

Geometric design standard in Cambodia is shown in Table-2-3-2. The project road is equivalent to primary national road.

Table-2-3-2 Cambodian Geometric Design Standard

		Primary National Road	National Road	Provincial Road
Design speed (km/h)	Flat	80-100	60-80	60-70
	Rolling	70-90	50-70	50-60
	Mountainous	60-80	40-60	40-50
R.O.W (m)		60	50	40
Carriageway (m)		7.00	6.00	5.50
Shoulder (m)		2.00	1.50	1.50

Cross sections for other rehabilitation projects are shown in Figure 2-3-1. According to this figure, the rehabilitation project for Route 4, which is a part of Asian Highway, adopted Asian Highway standard.

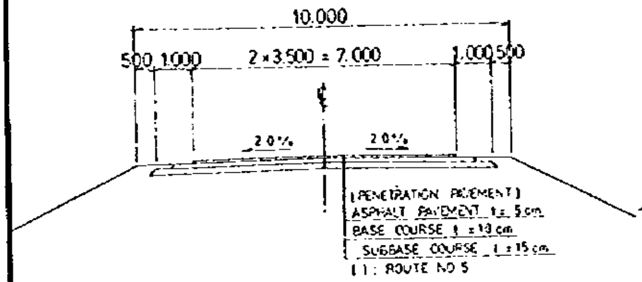
(3) Lane Width

Based on Asian Highway, Cambodian and Japanese standard and other rehabilitation projects in Cambodia, lane width of 3.5m was adopted.

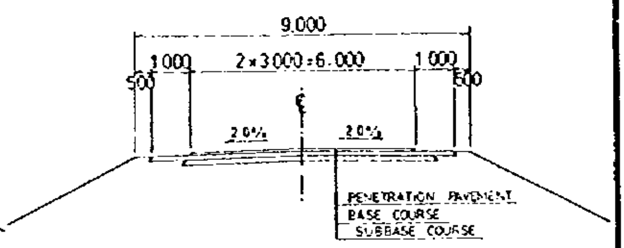
(4) Geometric Design Standard

The following geometric design standard (Japanese standard) is applied to the basic design.

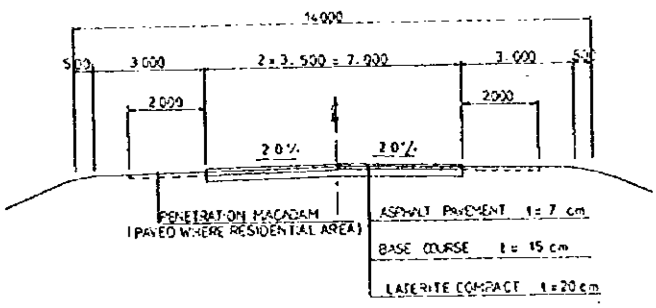
TYPICAL CROSS SECTION OF ROUTE NO.6A & NO.5

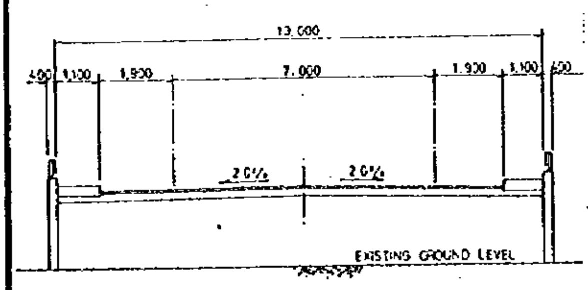


TYPICAL CROSS SECTION OF ROUTE NO. 6 (From SKUN)



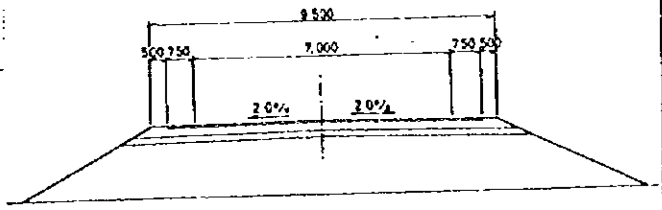
TYPICAL CROSS SECTION OF ROUTE NO.4





Typical Cross Section of Approach Road to Mekong River Bridge

(Kompong Cham)



Typical Cross Section of Approach Road to Mekong River Bridge

(East Side Of Mekong river)

THE BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 AND 7	Figure 2-3-1 Standard Cross Sections for Other Rehabilitation Projects

Table-2-3-3 Adopted Geometric Design Standard

Item	Unit	Design Standard
Design Speed	km/hour	60
Lane Width	m	3.5
Crossfall of Travelled Way	%	2
Horizontal Alignment		
Min. Radius (Absolute)	m	200 (150)
Max. Super-elevation	%	6
Min. Curve length	m	100
Vertical Alignment		
Min. Vertical Curve Radius (Crest)	m	1400
Min. Vertical Curve Radius (Sas)	m	1000
Max. Grade	%	5

(5) Composition of Road Width

① Installation of two-wheeled vehicle lanes.

As the results of traffic survey, it is observed that a high ratio of two-wheeled vehicles are utilizing the project road. From the view point of traffic safety, it is recommended that a special lane for two-wheeled vehicles should be constructed next to the carriageway on both sides.

② Composition of Road Width

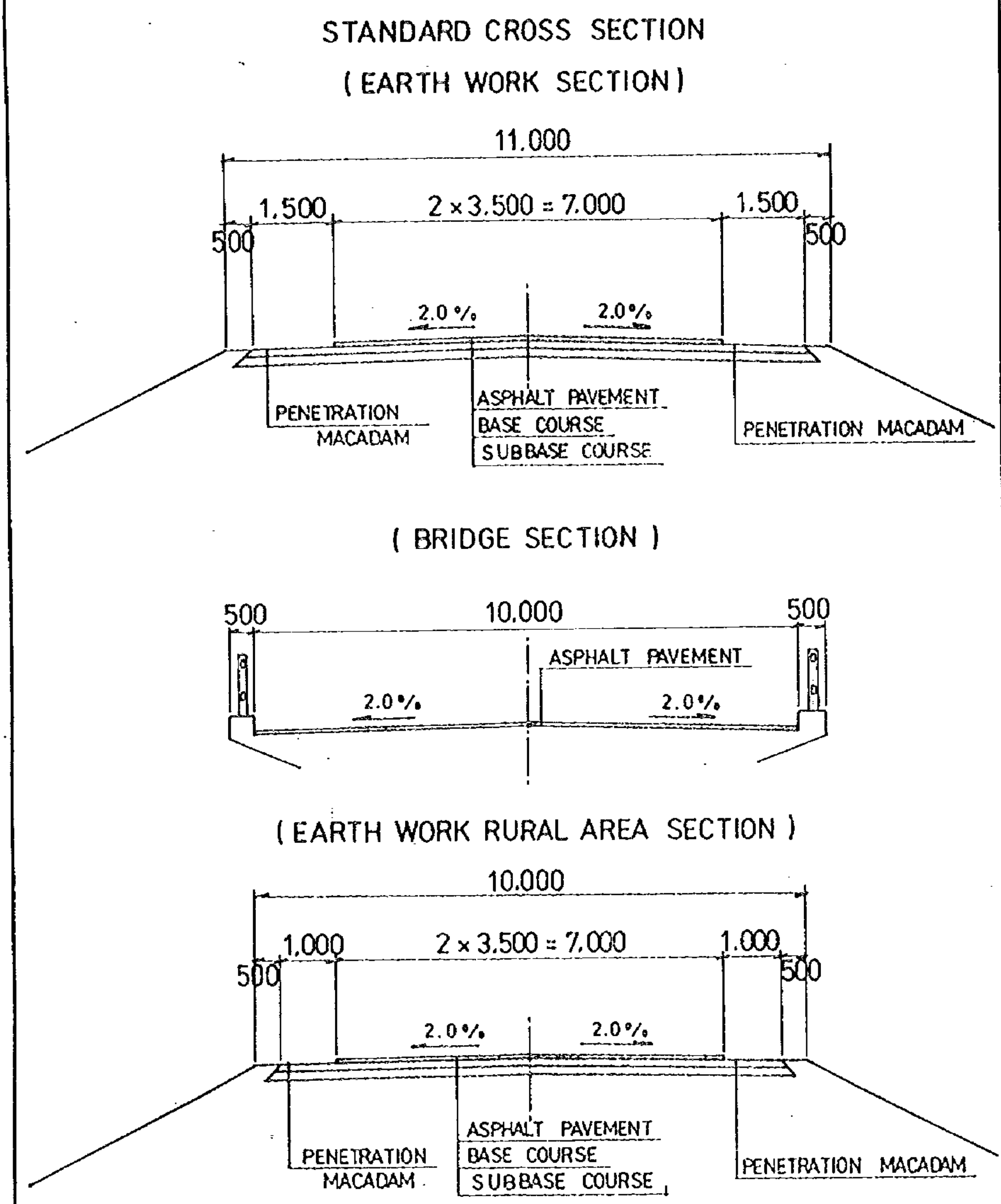
After due consideration of traffic safety, expected increase of heavy traffic, and construction cost, the following road sections were selected as shown in Figure 2.3.2.

The total width of roadway, as a standard, is 11.0 meters, which consists of the total of carriageway width (7.0 meters) and hardshoulder width (2 x 2.0 meters). However, where the conditions fall into the categories shown below, the total roadway width will be reduced to 10.0 meters; the sum of a carriageway width (7.0 meters) and hardshoulders width (2 x 1.5 meters) because of reduction of construction cost.

(1) Areas beyond towns and/or villages
(2) Areas with the small numbers of pedestrians, bicycles and motorcycles
(3) Flat areas where sufficient space is already available

For the above-mentioned selections, the consultants studied the geometric design of the existing and planned roads in Cambodia which are shown in Figure-2-3-1.

Reference was made to other national road projects, in Table-2-3-4.



BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 & 7	Figure 2-3-2 Standard Cross Sections for the Project

Table-2-3-4 Comparison of Road Section

Item	Study Routes	Routes 5 and Ex-6A	Route 4
Carriage Way	3,5m×2	3,5m×2	3,5m×2
Left Shoulder	Nil	1,0m	3.0
Lane for Motorcycles	1.5m	Nil	2.0
Protection Shoulder	0.5m	0.5m	0.5m
Total Road Width	11.0m	10.0m	14.0m

The width of road on bridge is 10m, which is same as standard road width, as shown in Figure-2-3-2 for the reasons stated below.

- A bridge can serve for more than 50 years with appropriate design, construction and maintenance. Cosequently, it is necessary to consider the future traffic situation.

- To widen a bridge is quite difficult from the viewpoint of construction, economics and structure.

3) Design Conditions for Bridges

(1) Design Standard

Existing bridges and other structures are assumed to have been constructed between the 1930s and 1950s with 10 to 13 tons loading standard. None of them are suitable to the present or foreseeable future traffic situation and must be replaced. With regards to bridge and other structures, an agreement has been reached with the DMC to apply the latest specifications for highway bridges in Japan.

These specifications, in order to increase transport capacity, correspond to the increase larger-size vehicles, which is a worldwide trend.

(2) Application of Live Load

Taking into account the international trend of increase of larger-size vehicles, Type-B live load is adopted.

(3) Loading Conditions

Design loads are classified as primary, secondary, and "others" in the specifications.

Primary loads:
The primary loads consist of
- Dead load
- Live load (Type B)

- Impact load
- Prestressed force
- Influence of creep of concrete
- Influnce of shrinkage of concrete
- Earth pressure
- Water pressure
- Buoyancy or uplift.

4) Design Standard for Earth Work and Drainage

Earth work and drainage design are also executed in accordance with Japanese design standard.

5) Pavement Design Standard

The pavement design standard of Japan Road Association is applied to the Project.

6) Materials and Basic Strength

The strength of materials which are used for the structural design is shown in the following.

(1) Concrete

(a) Compressive Strength of Cylindrical Test Specimen at 28 days after casting

PC girder	:	σ ck=350kgf/cm^2
RC girder	:	σ ck=240kgf/cm^2
RC slab, Crossbeam	:	σ ck=210kgf/cm^2
RC curb, Handrail	:	σ ck=210kgf/cm^2
Abutment, Pier, Footing	:	σ ck=210kgf/cm^2
Box culvert	:	σ ck=210kgf/cm^2
RC pile	:	σ ck=240kgf/cm^2
PC pile	:	σ ck=400kgf/cm^2

(b) Modulus of Elasticity

Compressive Strength at 28 days (kgf/cm^2)	210	240	350	400
Modules of Elasticity (kgf/cm^2)	2.3510^5	2.5010^5	2.9510^5	3.1010^5

(2) Prestressing Steel

Steel Strand 12T-12.7 mm

Ultimate strength	190 kgf/mm^2
Yield strength	160 kgf/mm^2
Relaxation ratio	5 %

Modulus of Elasticity $Esp= 2.0x10^6 kgf/cm^2$

(3) Reinforcing Steel

Grade	SD295, SD345
Yield strength	$3000 kgf/cm^2$
Modulus of Elasticity	$Esp= 2.1x10^6 kgf/cm^2$
Modulus Ratio of Elasticity at stress calculation for RC section	n=Es/Ec=15

2-3-2 Basic Design

1) Basic Policy of Road Rehabilitation Plan

The basic policy for the road rehabilitation plan is drawn out as indicated below, being based upon the results of field survey. Furthermore, present issues concerning the project area and their suggested countermeasures are shown in Table-2-3-5 (1) to (4), and the results of Basic Design is summarized in Figure-2-3-3.

(1) Alignment Improvement

Improvements will basically be carried out along the present alignment. However, there will be six curved sections whose radius will not satifsy the requirements of the 60km/hr. design speed set by the present plan.

(2) Pavement

As a result of the CBR test as the part of the pavement structure survey, the length of the project route will be divided up according to the more appropriate method indicated below.

- Additional base course + overlay
- Repaving (in cases where the road bed soil's CBR value is low.)

(3) Measures against the Degradation of Road Shoulder and Embankment

- In areas subject to submersion, road elevation will be raised above the flood level (to be ascertained by survey).

- In sections where embankment protection is required, slope treatment with clay will be conducted.

(4) Composition of Road Width

- As stated in the design standards, in areas where the separation of pedestrians from different types of vehicles is necessary, such as cities and settlements, traffic safety dictates the need for the adoption of road width of 11m, including lanes on both sides for two-wheel vehicle. In other

Table-2.3.5(1) Countermeasure to Problems on Existing Study Roads

KM Post	Existing Situation: Road Structure: High Embankment(H>3.0m)	Medium Embankment(3.0>H>1.0m)	Low Embankment(H<1.0m)	Flat	Narrow Road Width	Damaged Slope	Small Radius Curve	Land Use: Town	Village	Mix (Village & Paddy)	Paddy	Field	Mountain	Marshland	Flood Area	Remark	Measure: Draining	Raising	Slope Protecting	Widening	Improve Alignment	*Road Width	Type of Typical Cross Section	Remark	Photograph No.
0.0																•Prek Kdam									
0.5																									
1.0																									
1.5																									
2.0																									
2.5																									
3.0																									
3.5																									
4.0																									
4.5																									
5.0																									
5.5																									
6.0																									
6.5																									
7.0																									
7.5																									
8.0																•Flood depth 20cm									
8.5																									
9.0																									
9.5																									
10.0																									
10.5																									
11.0																									
11.5																									
12.0																									
12.5																									
13.0																									
13.5																									
14.0																									
14.5																									
15.0																									
15.5																									
16.0																•Intersection 6A & 6									
16.5																•No.1 box-culvert								•Replacement	
17.0																									
17.5																									
18.0																•Sharp curve									
18.5																									
19.0																									
19.5																									
20.0																									
20.5																•Flood 1 time, 20 years ago									
21.0																									
21.5																•No.2 bridge								•Replacement	
22.0																									
22.5																									
23.0																									
23.5																									
24.0																									
24.5																									
25.0																									

*1 Regarding culverts, refer to existing culverts list

*2 [shaded] = 11.0m, [blank] = 10m

Table-2.3.5(2) Countermeasure to Problems on Existing Study Roads

KM Post	Existing Situation – Road Structure: High Embankment(H>3.0m)	Medium Embankment(3.0>H>1.0m)	Low Embankment(H<1.0m)	Flat	Narrow Road Width	Damaged Slope	Small Radius Curve	Land Use: Town	Village	Mix (Village & Paddy)	Paddy	Field	Mountain	Marshland	Flood Area	Remark	Measure: Draining	Raising	Slope Protecting	Widening	Improve Alignment	*Road Width	Type of Typical Cross Section	Remark	Photograph No.
25.0																									
25.5																									
26.0																・Sharp curve									
26.5																・Sedimentation									
27.0																									
27.5																									
28.0																									
28.5																・Sharp curvo									
29.0																									
29.5																									
30.0																									
30.5																									
31.0																									
31.5																									
32.0																・Puddles of									
32.5																rainwater									
33.0																・Sharp curve									
33.5																									
34.0																									
34.5																									
35.0																									
35.5																									
36.0																									
36.5																・Sharp curve									
37.0																									
37.5																									
38.0																									
38.5																									
39.0																									
39.5																									
40.0																									
40.5																									
41.0																									
41.5																									
42.0																									
42.5																									
43.0																									
43.5																									
44.0																								・Skun	
44.5																								・Intersection 6 & 7	
45.0																・Pool									
45.5																・No.3 bridge								・Replacement	
46.0																									
46.5																・No.4 bridge								・Replacement	
47.0																									
47.5																・No.5 bridge								・Replacement	
48.0																・Flood 1 time, 20 years									
48.5																ago, depth 40 cm									
49.0																・No.6 bridge								・Replacement	
49.5																・Flood depth 40cm,									
50.0																2 times after 1990									

*1 Regarding culverts, refer to existing culverts list
*2 [shaded] = 11.0m, [blank] = 10m

Table-2.3.5(3) Countermeasure to Problems on Existing Study Roads

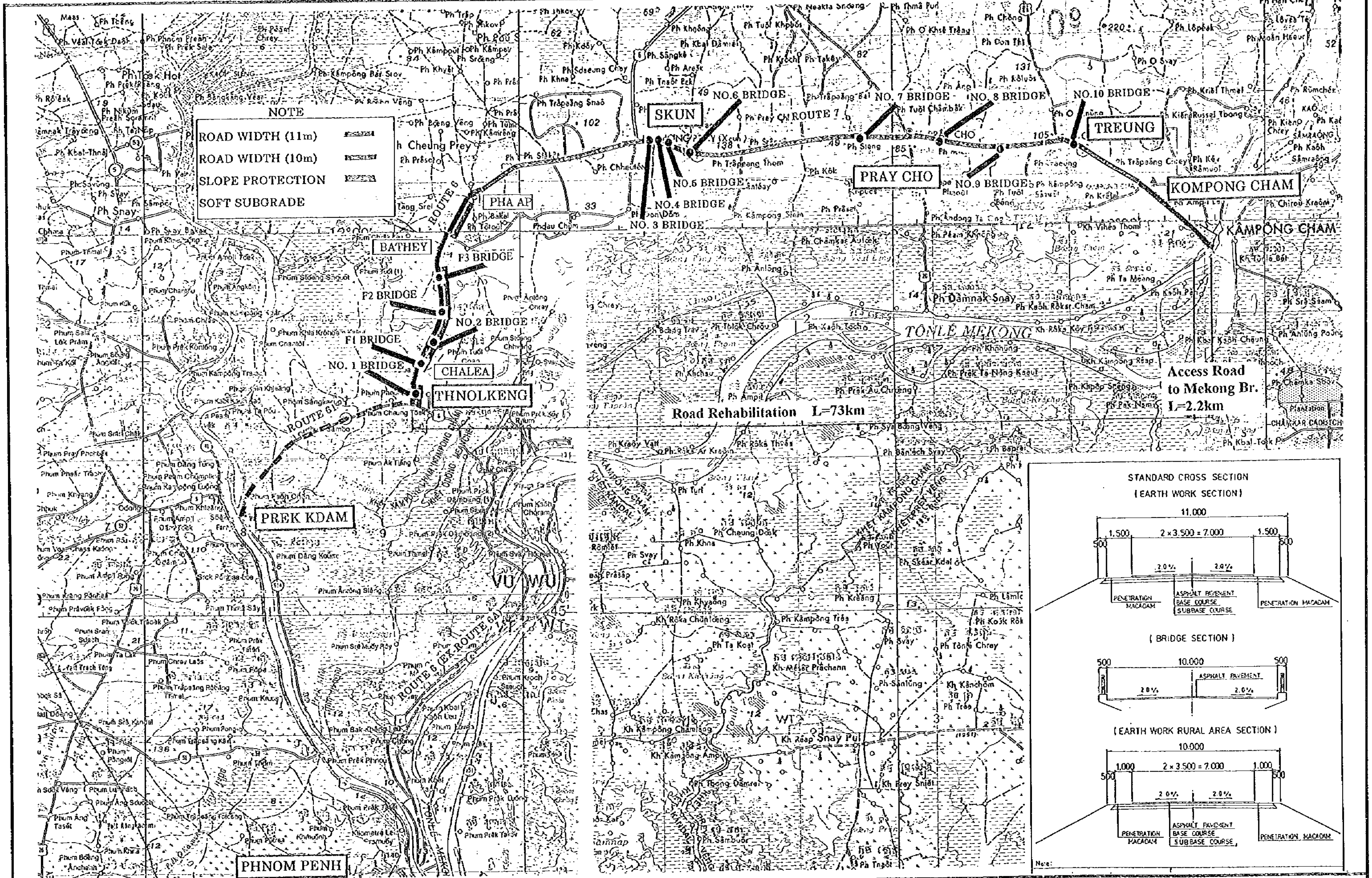
KM Post	Existing Situation: Road Structure: High Embankment(H>3.0m)	Medium Embankment(3.0>H>1.0m)	Low Embankment(H<1.0m)	Flat	Narrow Road Width	Damaged Slope	Small Radius Curve	Land Use: Town	Village	Mix (Village & Paddy)	Paddy	Field	Mountain	Marshland	Flood Area	Remark	Measure: Draining	Raising	Slope Protecting	Widening	Improve Alignment	*Road Width	Type of Typical Cross Section	Remark	Photograph No.
50.0																									
50.5																									
51.0																									
51.5																									
52.0																									
52.5																									
53.0																									
53.5																									
54.0																									
54.5																									
55.0																									
55.5																•Flood depth 40cm by rain, 5 days per year									
56.0																									
56.5																									
57.0																									
57.5																									
58.0																									
58.5																									
59.0																									
59.5																•Flood depth 5 cm by rain, every year									
60.0																									
60.5																								·Replacement	
61.0																•No.7 bridge									
61.5																									
62.0																									
62.5																									
63.0																									
63.5																									
64.0																									
64.5																									
65.0																•Flood by rain (Intersection)									
65.5																									
66.0																									
66.5																									
67.0																									
67.5																•No.8 bridge								·Replacement	
68.0																									
68.5																									
69.0																									
69.5																									
70.0																									
70.5																									
71.0																									
71.5																									
72.0																									
72.5																•No.9 bridge								·Replacement	
73.0																									
73.5																									
74.0																									
74.5																									
75.0																									

*1 Regarding culverts, refer to existing culverts list
*2 [shaded] = 11.0m, [blank] = 10m

Table-2.3.4(4) Countermeasure to Problems on Existing Study Roads

KM Post	Existing Situation																Measure								
	Road Structure							Land Use								Remark								Remark	
	High Embankment(H>3.0m)	Medium Embankment(3.0>H>1.0m)	Low Embankment(H<1.0m)	Flat	Narrow Road Width	Damaged Slope	Small Radius Curve	Town	Village	Mix (Village & Paddy)	Paddy	Field	Mountain	Marshland	Flood Area		Draining	Raising	Slope Protecting	Widening	Improve Alignment	*Road Width	Type of Typical Cross Section		Photograph No.
75.0																									
75.5																·Traeung									
76.0																·Intersection 7 & 71									
76.5																·No.10 box-culvert								·Replace to bridge	
77.0																·Flood by rain									
77.5																									
78.0																									
78.5																									
79.0																									
79.5																									
80.0																									
80.5																									
81.0																									
81.5																									
82.0																·Flood by rain									
82.5																									
83.0																									
83.5																									
84.0																									
84.5																									
85.0																									
85.5																									
86.0																									
86.5																									
87.0																									
87.5																									
88.0																							2	·Kompong Cham	
88.5																									
89.0																									
89.5																									
90.0																									

*1 Regarding culverts, refer to existing culverts list
*2 [shaded] = 11.0m, [blank box] = 10m



THE BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITAITON OF NATIONAL ROADS ROUTE 6 AND 7

Figure 2-3-3 Summary of Basic Design

sections, road width will be 10m. Precise locations of each section are indicated in Table-2-3-5 (1) to (4).

- Asphalt penetration macadam will be laid for the two-wheeler lane in order to improve running efficiency.

(5) Road Widening

- Based upon road width which has been decided upon, certain portions of the road which do not meet these standards must be widened.

- In sections where embankment is required, the most efficient method from the viewpoint of machine construction, is to conduct fill on one side of the road. However, where there are limitations in terms of land aquisition issues or resettlement, some portions will require the filling on both sides.
  The various basic cross-sections, which are presumed to be implemented along the project route, are shown in Figures-2-3-4 (1) to (3).

(6) Installation of Drainage Facilities

In places such as cities or other settled areas where the road level is low, non-draining rainwater degrades the living environment of local residents. Consequently, in such areas, drainage facilities, which will enhance road functions as well as ameliorate living conditions, will be constructed.

(7) Traffic Safety Features

At present, there are almost no center lines, crosswalks or traffic signs. Center lines will thus be included, and, in city areas, outer lines as well as guide signs, ten kilometers will be included.

2) Pavement Design

(1) Design Traffic Volume

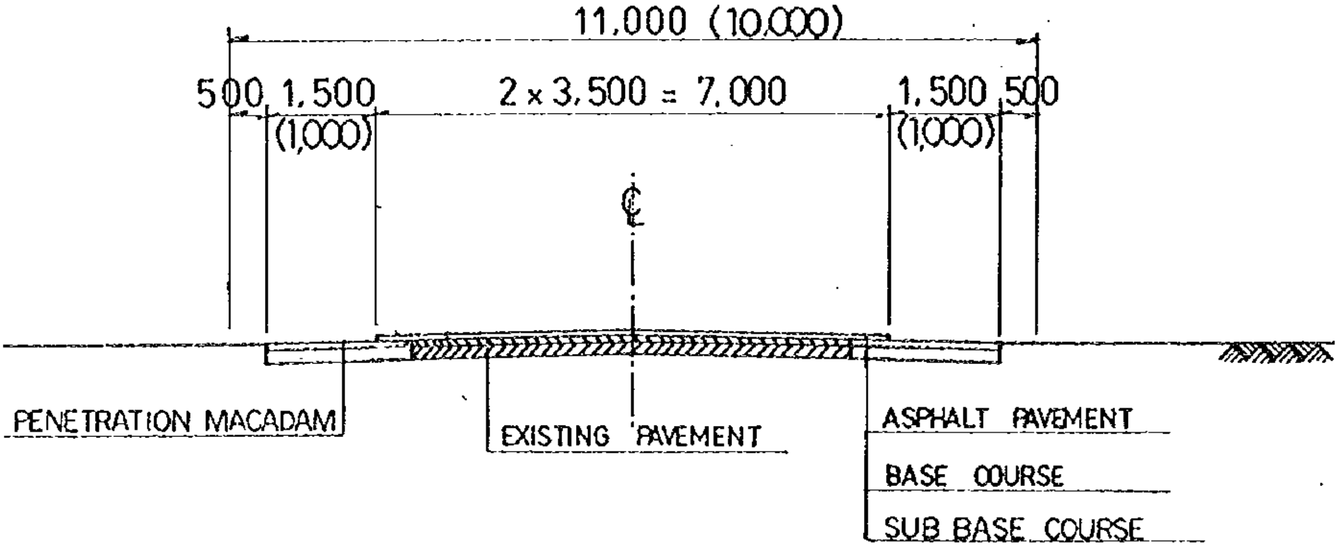
a) Section
The results of traffic survey have revealed that the traffic volume between Thnolkeng and Skun section, and Skun and Kampong Cham section significantly differs. As a consequence, pavement design should be drawn up for the two sections.

b) Design life : 5years (from 1999 to 2003)

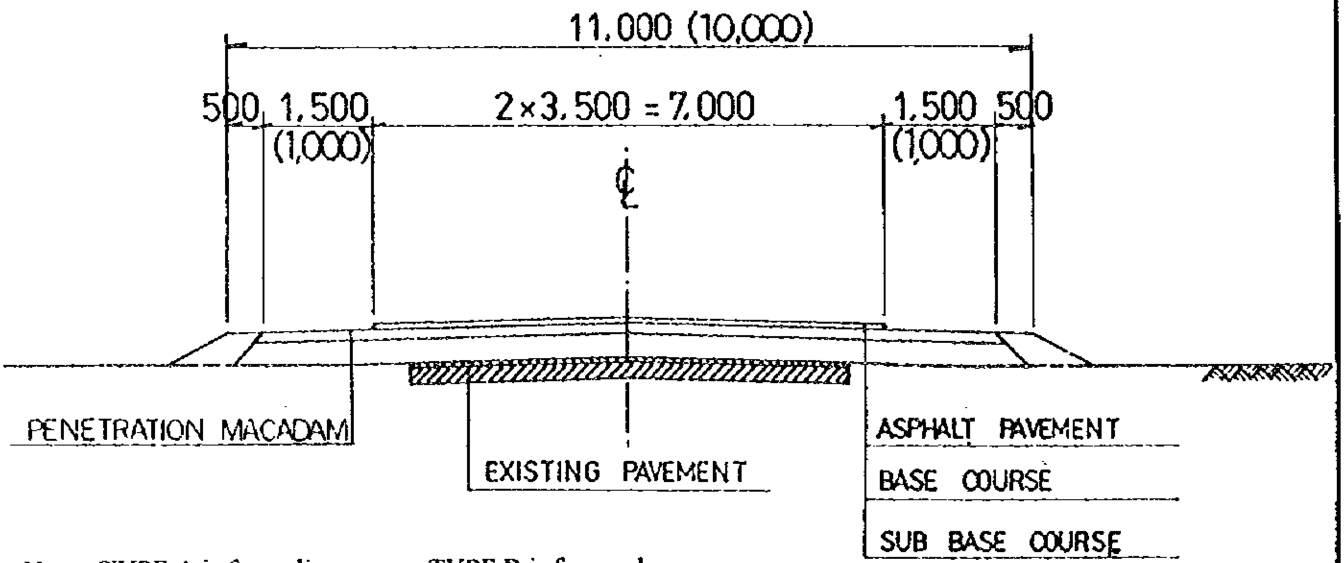
c) Average daily traffic volume of heavy vehicles

Thonkeng - Skun : 145 vehicles/day/direction
Skun - Kompong Cham : 92 vehicles/day/direction

TYPE 1 - A (1 - B) Flat Section, Overlay



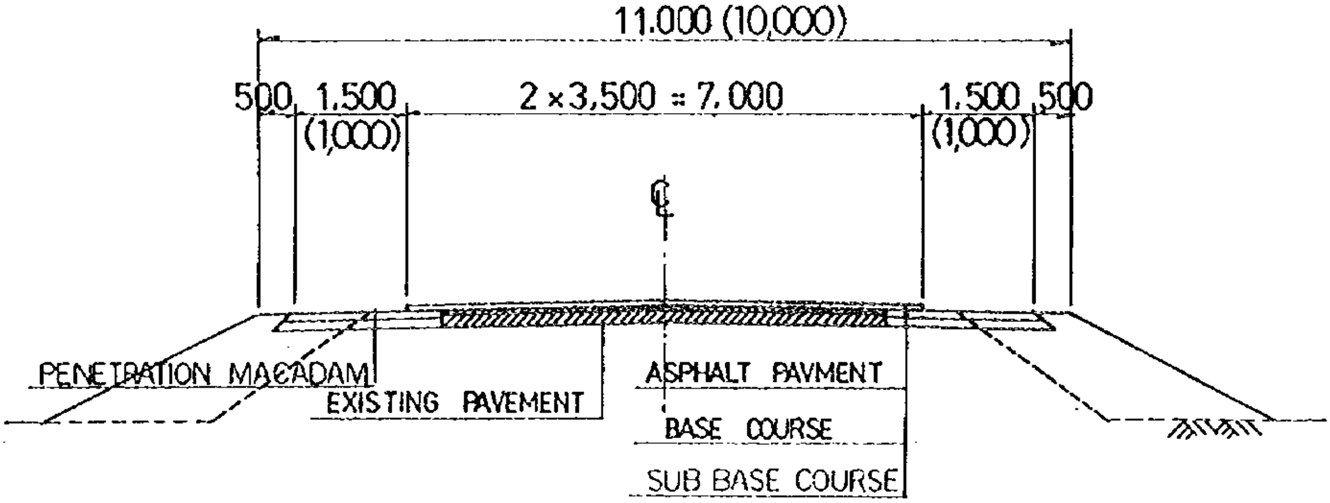
TYPE 2 - A (2 - B) Flat Section, Raising



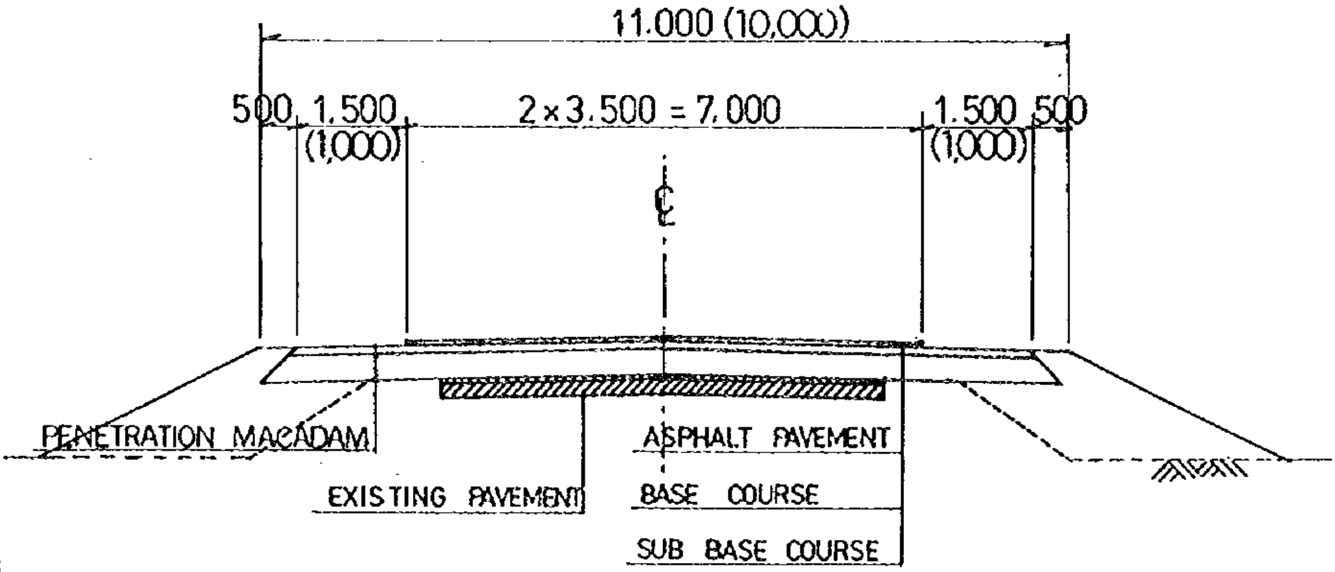
Note : TYPE A is for ordinary area, TYPE B is for rural area.
Value in parenthesis is indicated for rural area (TYPE B) measurement.

BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 & 7	Figure 2-3-4(1) **TYPICAL CROSS SECTION**

TYPE 3 - A (3 - B) Embankment Section, Overlay



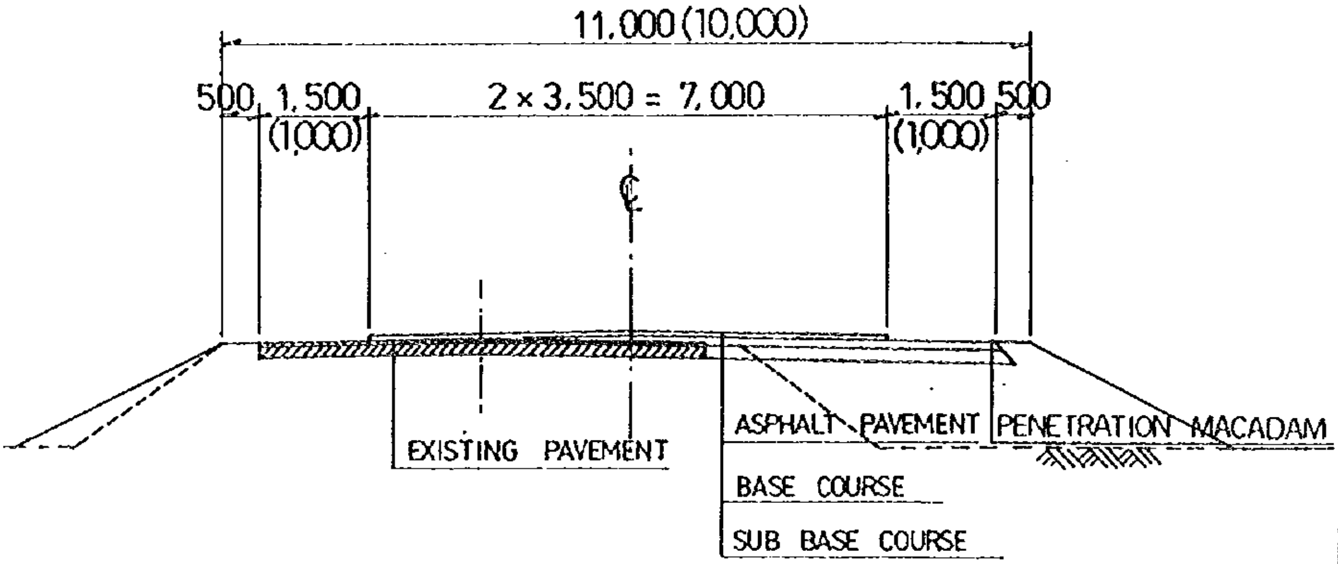
TYPE 4 - A (4 - B) Embankment Section, Raising



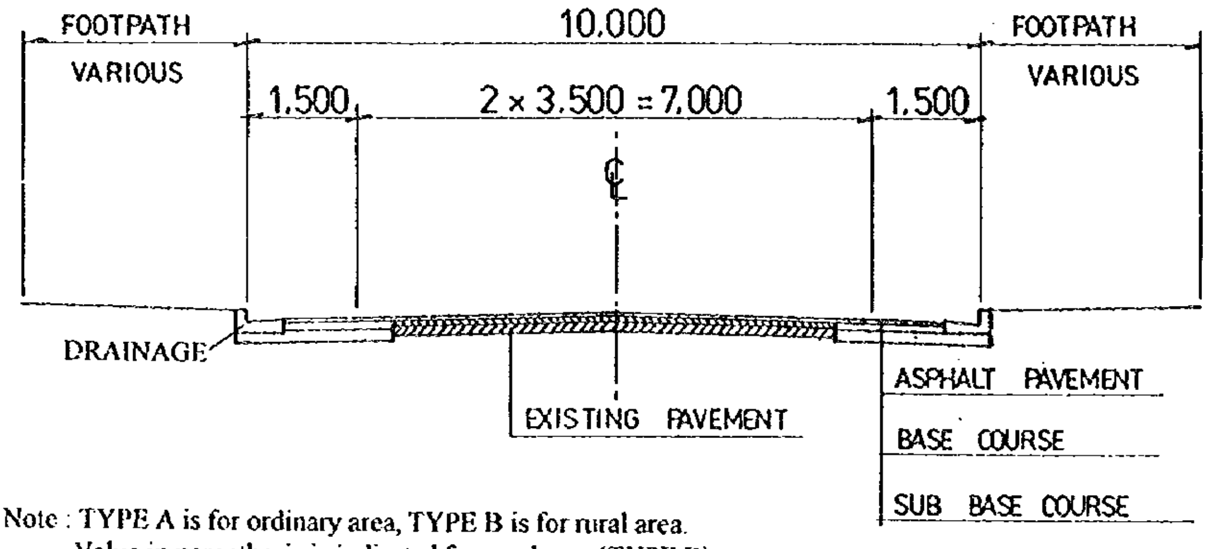
Note : TYPE A is for ordinary area, TYPE B is for rural area.
Value in parenthesis is indicated for rural area (TYPE B) measurement.

BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 & 7	Figure 2-3-4(2) TYPICAL CROSS SECTION

TYPE 5 - A (5 - B) Embankment Section (One side widening), Overlay



TYPE 6 Town Section, Overlay



Note : TYPE A is for ordinary area, TYPE B is for rural area.
Value in parenthesis is indicated for rural area (TYPE B) measurement.

BASIC DESIGN STUDY ON THE PROJECT FOR REHABILITATION OF NATIONAL ROADS ROUTE 6 & 7	Figure 2-3-4(3) **TYPICAL CROSS SECTION**

d) Growth rate of traffic volume
Based on the findings of Feasiblity Study on Construction of Mekong Bridge, 3% has been applied.

e) Composition of heavy vehicles

- Trailer trucks (full loading) 43t : 5%
- Trailer trucks 25t : 27%
  (no loading of trailer trucks, and full loading of trucks)
- Trucks (no loading) 15t : 16%
- Other heavy vehicles less than 8t : 52%

(2) Required Equivalent Asphalt Concrete Thickness (T_A)

T_A is determined based on the following equation

$$T_A = 3.84 \times N^{0.16} / CBR^{0.3}$$

Where N : Total equivalent 5-ton wheel load application in design period of n-year (wheel load/direction)
CBR: Design CBR subgrade

N is calculated by the following equations

$$N_5 = \sum_{j=1}^{13}\left[(Pj \div 5)^4 \times Nj\right]$$

Where N_5 : Total equivalent 5-ton wheel load applications per day
Pj : Representative conversion value (from Japanese standard)
Nj : Number of wheel load applications (from Japanese standard)

and $$N = \sum_{i=1}^{n}(N_5 \times 365 \times a_i)$$

Where a_i : Traffic growth rate after i-year to be applied to N_5
n : 5

From the above calculations, the following values were obtained.

Thnolkeng - Skun N=357,900
Skun -Kompong Cham N=171,600

(3) T_A and Layer Coefficients

Using the Japanese standard the following layer coefficients are obtained:

Pavement Component	Layer Coefficient
Surface and binder courses	1.25
Base course (stabilised aggregate)	0.35
Subbase course (crusher-run aggregate)	0.25

Adopted equivalent asphalt concrete thickness (T'_A) is determined by the following equation.

$$T'_A = a1 \times T1 + a2 \times T2 + a3 \times T3$$

Where a1, a2, a3 : Layer coefficients
T1, T2, T3 : Thickness of each layer in cm

(4) Minimum Thickness of Surface, Binder, Base and Sub Courses

According to the Japanese standard, the minimum thicknesses are as follows:

Pavement Component	Layer Coefficient
Total thickness of surface and binder courses	5cm
Base course	3 times of maximum aggregate size
Subbase course	3 times of maximum aggregate size

(5) Disign CBR of Subgrade

As the results of CBR test, design CBR have been determined as shown in Table-2-3-6.

Table-2-3-6 Design CBR in Each Section

Section	Results of CBR test	Design CBR
15.6 ~ 24 km	7.6	6
24 ~ 30 km	41.7	20
30 ~ 38 km	13.2	12
38 ~ 45 km	35.8	20
45 ~ 50 km	4.0	4
50 ~ 60 km	24.1, 73.6	20
60 ~ 75 km	2.7, 3.2, 2.7	2
75 ~ 87.5 km	7.1	6
87.5 ~ 90.4 km	-	8

(6) Optimum Design of Pavement Structure

The optimum design in each section is determined taking into consideration of its cost-effectiveness and the method which would facilitate the construction and maintenance. The results of consideration are shown in Table-2-3-7.

Table-2-3-7 Optimum Design of Pavement Structure

	Thnolkeng - Skun				Skun - Kompong Cham				
Section	15.6～ 24 km	24 ～ 30 km	30 ～ 38 km	38 ～ 45 km	45 ～ 50 km	50 ～ 60 km	60 ～ 75 km	75 ～ 87.5km	87.5～ 90.4km
Design CBR	6	20	12	20	4	20	2	6	6
Asphalt Concrete Surface Course	5cm	5cm	5cm	5cm	5cm	5cm	5cm	5cm	5cm
Base Course (Crushed stone) Modified CBR≧30	20cm	10cm	15cm	10cm	20cm	10cm	25cm	20cm	15cm
Subbase Couse (Crusher-run aggregate) Modified CBR≧30	25cm	15cm	20cm	15cm	25cm	10cm	35cm	20cm	20cm
Equivalent Asphalt Concrete Thickness (TA)	17.43	12.11	14.12	12.11	17.68	10.93	21.85	15.72	14.37
Adopted Equivalent Asphalt Concrete Thickness (T'A)	18.25	12.25	15.25	12.25	18.25	11.00	22.50	17.00	15.25

3) Drainage Design

(1) Small-to-medium size culverts

As a result of field survey, a total of 28 small-to-medium size culverts were found crossing under the project route. A detailed survey to confirm the basic structure, purpose, and present utilization was thereby conducted; the results are shown in Table-2-3-8. Almost all of these culverts are used either for irrigation or drainage purposes. Judged as a necessary structure, the present situation of the and/or lengthening measures are to be carried in conjunction with the road rehabilitation. Inprovement policies are shown in Table-2-3-8.

(2) Installation of drainage facilities along the road in the city area

The field study has revealed that, where the project route goes through cities and other settlements, level of the road is lower than the surrounding area. In many areas, this causes large undrained puddles of water to remain for several days following a rain, and has been further observed to be detrimental to the residents' living environment. This is due to the lack of drainage facilities along the route. Accordingly road rehabilitation in the settled areas will include the installation of drainage facilities which will improve the living conditions of local residents. Basic ideas of the design of drainage facilities to be installed in settlements are shown in Table-2-3-9.

Table-2-3-8 Existing Culverts and Countermeasure for Improvement

No	Station	Type	Sectional Form			Residential	Purpose	Conditions	Countermeasure
			Section (m)	L (m)	Overburden, t (m)				
1	27+200	Arch	W=1.0, H=0.8	9.1	0.6	Housing	Drainage	- Insufficient length - Overflow	Reconstruction of box culvert
2	31+000	Arch	W=1.0, H=0.8	13.7	1.6	Paddy	Irrigation	- Choked	Cleaning
3	31+800	Pipe	0.65	11.0	0.9	Housing	Drainage	- Insufficient section	Reconstruction of pipe culvert
4	34+300	Box	W=1.0, H=0.8	7.0	0.2	Paddy	Irrigation	- Insufficient length - Damaged	Reconstruction of box culvert
5	37+200	Pipe	0.65	11.0	1.4	Paddy	Irrigation		Not required
6	38+500	Box	W=1.0, H=0.8	7.0	0.3	Paddy	Irrigation	- Insufficient length - Damaged	Reconstruction on improvement of box culvert
7	43+800	Box	W=1.0, H=0.8	7.1	0.3	Housing	Drainage	- Insufficient length - Damaged	Reconstruction on improvement of box culvert
8	53+600	Pipe	0.65	7.3	0.4	Paddy	Irrigation	- Insufficient length - Choked	Extension of pipe Cleaning
9	54+200	Pipe	0.65	7.3	0.4	Paddy	Irrigation	- Insufficient length - Settled	Reconstruction of pipe culvert
10	54+300	Pipe	0.65	15.6	1.2	Paddy	Irrigation		Not required
11	56+100	Pipe	0.55	8.1	0.6	Paddy	Irrigation	- Insufficient length - Constructed with brick	Reconstruction of pipe culvert
12	56+800	Pipe	0.65	15.6	1.0	Paddy	Irrigation		Not required
13	58+600	Pipe	0.65	9.0	1.1	Paddy	Irrigation	- Insufficient length - Destroyed intake	Reconstruction of pipe culvert
14	73+800	Pipe	0.65	7.5	0.5	Paddy	Irrigation	- Insufficient length - Destroyed intake	Reconstruction of pipe culvert
15	75+900	Pipe	20.45	12.6	0.8	Paddy	Irrigation		Not required
16	77+000	Pipe	0.65	15.2	1.2	Paddy	Irrigation		Not required
17	78+300	Pipe	0.65	13.0	1.4	Paddy	Irrigation		Not required
18	80+400	Pipe	20.45	8.3	0.5	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
19	80+600	Pipe	0.65	8.3	0.4	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
20	80+800	Pipe	0.65	8.2	0.4	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
21	81+800	Pipe	0.65	8.2	0.4	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
22	81+400	Pipe	0.65	8.2	0.4	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
23	82+100	Pipe	0.65	8.2	0.7	Paddy	Irrigation	- Insufficient length	Extension of pipe culvert
24	82+400	Pipe	0.40	8.3	0.6	Paddy	Irrigation	- Insufficient length - Settled	Reconstruction of pipe culvert
25	83+100	Pipe	0.65	8.2	0.6	Paddy	Irrigation	- Insufficient length - Overflow	Reconstruction of pipe culvert
26	84+700	Box	W=4.0, H=1.0	12.2	0.7	Paddy	Irrigation		Not required
27	86+500	Pipe	20.40	8.2	0.6	Paddy	Irrigation	- Insufficient length - Settlement	Reconstruction of pipe culvert
28	87+000	Pipe	21.00	12.2	0.7	Housing	Drainage		Not required

Table-2-3-9 Settlements Scheduled for Road Drainage Installation

Station	Name of Town	Content	Length (m)
26+300 - 27+500	Batheay	U-shaped drainage at one side	1.2km x 1
31+700 - 31+900	Pha Ap	L-shaped drainage at one side	0.2km x 1
44+000 - 44+150	Skun	L-shaped drainage at one side	0.15km x 1
65+800 - 66+000	Pray Toeung	L-shaped drainage at both sides	0.20km x 2

(3)Installation of New Culverts

As a result of survey, it is considered that around sta. 59km + 700 submersion, which occurs in times of heavy rains, is caused by the lack of culverts. A new culvert will be installed here, as shown in Table-2-3-10.

Table-2-3-10 Location of New Culvert

No.	Station	Type	Sectional Form			Pourpose
			Section (m)	L (m)	Overburden (m)	
1	59+700	pipe	0.65	12.0	0.8	drainage

4) Embankment Slope Protection

The 32-kilometer stretch of road between Thnolkeng and Pha Ap is of high-raised embankment structure, and the significant section of notable degradation and "dragon holes." One of the reasons for this phenomenon is that the fill material, laterite, has the high coefficient of permeability. This means that, when the rainy season comes to an end and water draws out, particles of the embankment are carried along with it, gradually weakening the overall structure. As a consequence, measures are required for embankment protection. Possible construction methods are compared in Table-2-3-11.

Table-2-3-11 : Comparison of Slope Protection Measures

Method	Characteristics	Evaluation
Grass-planting method	Most of the grass would be underwater for most of the rainy season, causing roots to rof.	×
Gentle slope method	Observing the present situation, a stable inclination would be 1:5～1:10. In order to satisfy such terms, a great amount of fill and cost would be required, also affecting greatly the ferm of construction.	△
Stone masonry protection method	The most effective in terms of protecting the submerged embankment, but due to the length required, cost and time limits should be tested.	△
Clay application method	• By applying clay materials earth, water absorption coefficients are decreased and embankment degradation is expected to be lessened. • Materials are locally available, thereby saving cost and maintenance. • Success has been proven in Bangladesh.	○

5) Construction of Access Road to Mekong Bridge

According to the Draft Final Report of "The Feasibility Study on Construction of Mekong Bridge" conducted in 1995 ～ 96, scope of the project is limited to connecting route up to the point at which it connects with the six-way intersection (rotary) in the south of Kompong Cham city. With regard to the access of National Route No.7, though a few suggestions for a bypass which detours the city area are made, there was no clear recommendation for a specific route.

Accordingly, this project will take on the construction of such an access road. The two following Alternatives are considered from the viewpoint of project cost, traffic safety, environment and convenience (See Fig. 2-3-5).

Alternative A: Construction of a new route detouring around the south side of city.
Alternative B: Use of existing city routes.

Combodian authorities are strongly in favor of Alternative A. When an official visit was made to the Governor of Kompong Cham, he also expressed strong sentiments in favor of bypass construction.

Upon comparing the two proposals, Alternative A was chosen for the reasons stated below.

(1) Following the construction of the Mekong Bridge, traffic volume forecasted for the year 2011 are 10,000 vehicles per day and 14,000 per day (including motorcycles) in the year 2021. Such traffic increase within the city streets will bring about the degradation of living environment through noise and traffic

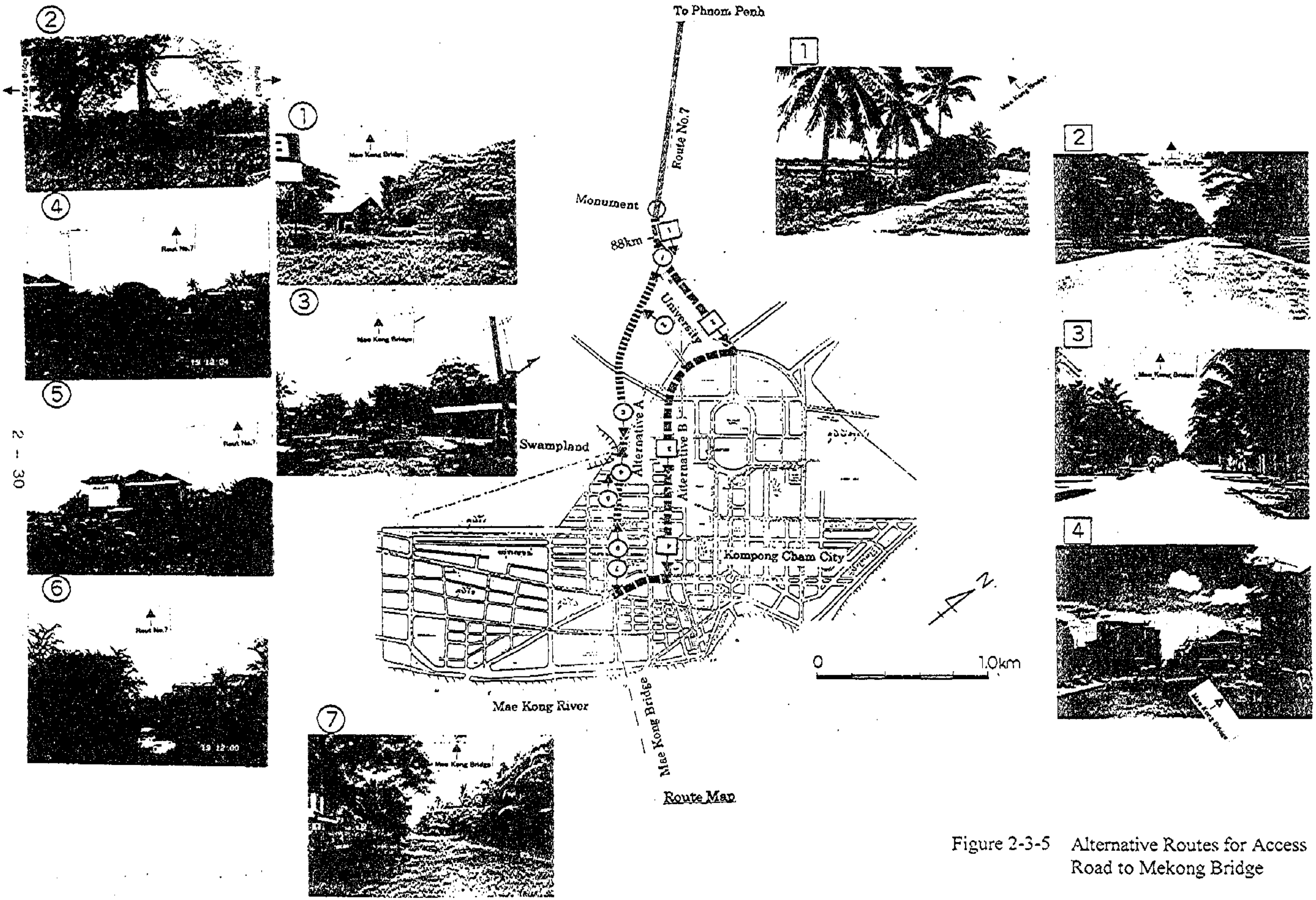


Figure 2-3-5 Alternative Routes for Access Road to Mekong Bridge

accidents.

(2) Both the construction of Mekong Bridge and rehabilitation of National Roads Route 6 and 7 are grant aid projects by the Japanese Government. The bypass going unconstructed would be inconsistent with these projects.

(3) Resettlement, the major problem involved in access road construction, does not appear to pose insurmountable barriers in this case, as the Cambodian government reports that it has obtained consensus from local residents in regards to land acquisitoin in connection with the Mekong Bridge project. At present, the residents are already in the process of looking for appropriate areas to resettle.

6) Basic Policy Regarding Rehabilitation of Bridges and Culverts in the Project

Upon conducting field survey of all bridges and culverts included in the Project, it is deemed that all need to be replaced. The findings of survey and basic policies based on them are shown in Table-2-3-12.

(1) Considerations on each bridge and culvert

a) Location

① Bridge No.2

Alternatives for the location of Bridge No.2 were compared from the point of view of construction costs (including connecting road), road alignment, constructability, construction period and considerations during rainy and dry seasons. Comparison results are shown in Table-2-3-13.

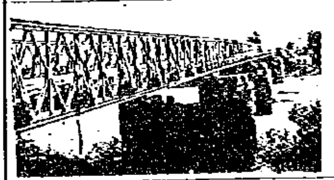
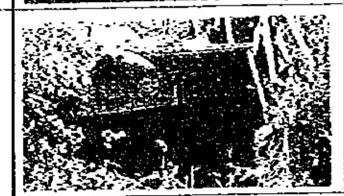
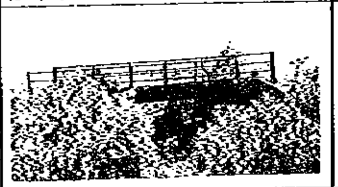
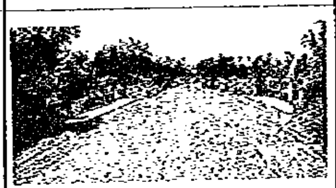
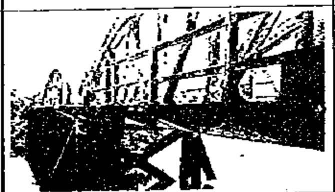
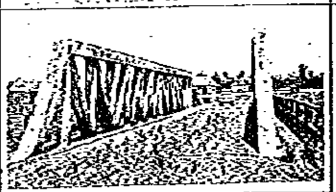
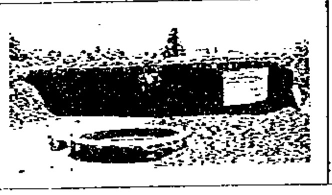
Alternative 1: Replacement of bridge in same location as existing bride.
Alternative 2: Replacement of bridge in a location which is parallel to the existing bridge.

As a result of comparison, it has found that detouring becomes somewhat complicated. Nevertheless, considering economic feasibility, difficulty of construction of a high-embankment connecting road, and the retainability of a favorable alignment, Alternative 1 was selected.

② Bridge Nos. 3, 4, 5, 7, 9, 10

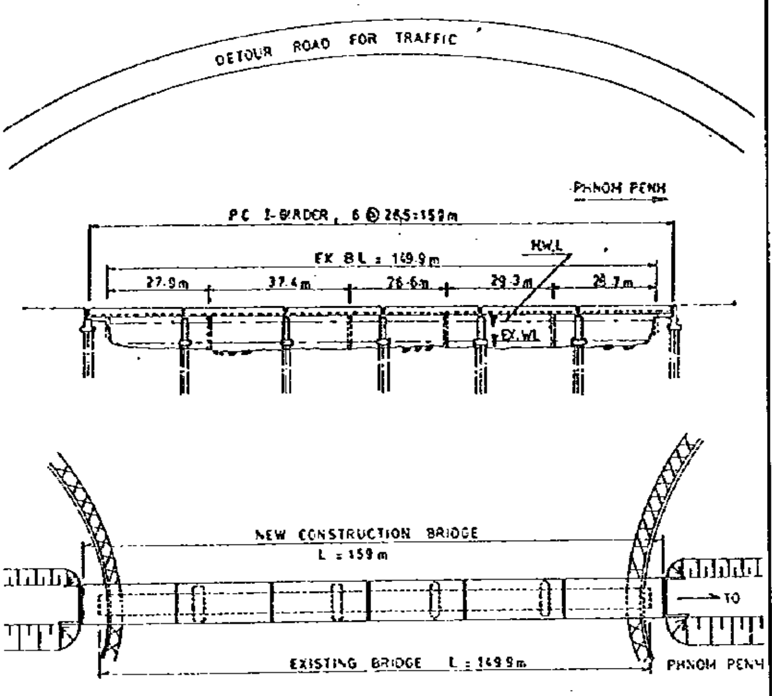
Since favorable alignment can be retained and, in these locations, there is practically no water under them during the dry season, detour routes are easily obtained. Accordingly these bridges will be replaced at the same location as present.

Table 2-3-11 Outline of Rehabilitation Plan for Bridges and Culverts

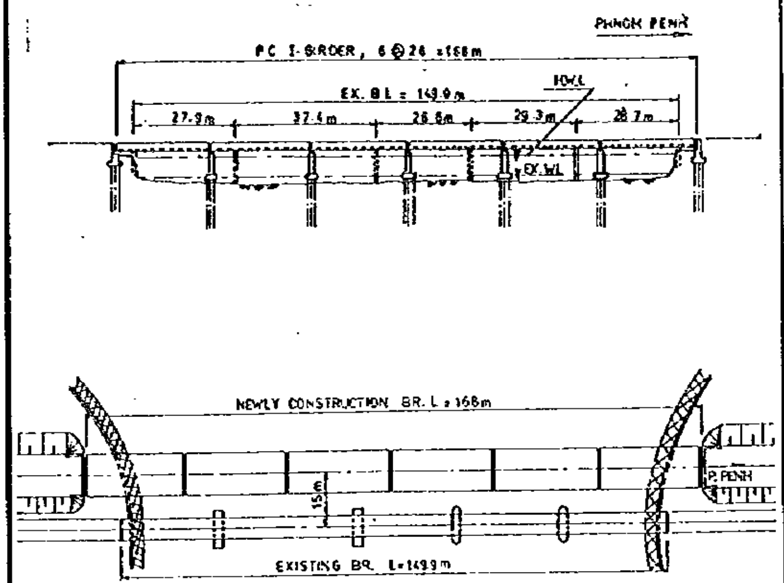
No	Photo	Current Situation	Comments	Countermeasures
1		Structural Type : Box Culvert Length: 18 m Width : 0.9m	- It is found that water flow (discharge) capacity is insufficient. - Slope failure observed around the culvert.	- Replacement to new culvert at the same location. - Cross section of 5mx2.5m is applied because to ensure water flow capacity - Raise road level
2		Structural Type : Bridge Length: 149.5m Span: 25mx2+30m+25mx2 Effective Width : 4.5m Superstructure: Bailey Type Substructure: RC Wall Type	- Longest bridge of the project. - Temporary superstructure of single-car width. - Substructures seriously damaged by shells - The only reliable route during rainy season.	- Replacement with new bridge at the same location to keep smooth road alignment and avoid new approach road construction. - Bridge surface level to be risen up about 2m as measure against flooding. - Bridge length will be slightly longer as new abutment is set back from existing one. - New piers are set between existing ones
3		Structural Type : Bridge Length: 9.1m Span: 1m+7.1m+1m Effective Width : 6.8m(0.9+5+0.9) Superstructure: RC Slab Substructure: Pier: RC Wall Type	- Assumed to have low loading capacity constructed in the 1950s. - Railing is broken at one side. - Settlement of backfill of abutment and loss of materials by erosion.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season). - Bridge length will be the same as there is sufficient water flow capacity. - In order to keep free board from flooding level, bridge surface will be risen up about 1m
4		Structural Type : Bridge Length: 9.0m Span: 9.0m Effective Width : 4.2m Superstructure: Steel I-Beam (Temporary) Substructure: Gravity wall	- Temporary superstructure of single-car width. - Surface of the bridge is seriously deteriorated. - There is no water in dry season.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season) - Bridge length will be the same as there is sufficient water flow capacity. - In order to keep free board from flooding level, bridge surface will be risen up about 1m
5		Structural Type : Bridge Length: 10.7m Span: 10.7m Effective Width : 6.8m(0.9+5+0.9) Superstructure: RC Slab Substructure: Gravity wall	- Assumed to have low loading capacity constructed in the 1950s. - Railing is damaged at one side. - Settlement of backfill of abutment and loss of materials by erosion.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season). - Bridge length will be the same as there is sufficient water flow capacity. - In order to keep free board from flooding level, bridge surface will be risen up about 1m
6		Structural Type : Bridge Length: 41.5m Span: 20.75m+20.75m Effective Width : 7.4m(1.2+5+1.2) Superstructure: RC Arch Substructure: Pier: RC rigid frame	- Some parts of superstructure and railing are damaged. - Assumed to have low loading capacity constructed in the 1950s. - Water depth is about 1m in dry season	- Replacement with new one 15m to the south. Existing bridge will be used as a detour road during construction. - Bridge length will be the same as there is sufficient water flow capacity. - In order to keep free board from flooding level, bridge surface will be risen up about 1m.
7		Structural Type : Bridge Length: 10m Span: 10m Effective Width : 4.5m Superstructure: Steel I-beam (Temporary) Substructure: Pier: RC Wall Type	- Temporary superstructure of single-car width. - Surface of the bridge is seriously deteriorated. - There is no water in dry season.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season) - Bridge length will be the same as there is sufficient water flow capacity. - In order to keep free board from flooding level, bridge surface will be risen up about 1m.
8		Structural Type : Bridge Length: 35.8m Span: 8.0m+20.8m+8.0m Effective Width : 7.6m(1.1+5.4+1.1) Superstructure: RC Truss Substructure: Pier: RC wall	- Some parts of superstructure and railing are damaged. - Assumed to have low loading capacity constructed in the 1950s. - Water depth is about 1.5m in dry season	- Replacement with new one 15m to the south. Existing bridge will be used as a detour road during construction - Bridge length will be the same as there is sufficient water flow capacity - In order to keep free board from flooding level, bridge surface will be risen up about 1m.
9		Structural Type : Bridge Length: 18.3m Span: 6.1mx3 Effective Width : 4.5m Superstructure: Bailey Type Substructure: Pile bent	- Temporary superstructure of single-car width. - Surface of the bridge is seriously deteriorated. - Water flow passes over the connecting road in times of heavy rain due to insufficient water flow capacity.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season). - Bridge length should be longer to ensure sufficient water flow capacity - In order to keep free board from flooding level, bridge surface will be risen up about 2m.
10		Structural Type : Bridge Length: 11.0m Span: 5.5mx2 Effective Width : 7.0m Superstructure: RC slab Substructure: Gravity wall Type	- This bridge is assumed to have low loading capacity because of shallow slab depth. - Some parts are damaged.	- Replacement with new bridge at the same location for ease in detouring (small amount of water in dry season). - In order to keep free board from flooding level, bridge surface will be risen up about 2m.

Tablel 2-3-13 Comparison of Bridge Location for No 2 Bridge

General View



Alternative 1 (The same position as existing bridge)		
Construction Step	First Period	1. Arrangement of detour, construction of temporary access and banking. 2. Removal of existing superstructure (Bailey bridge), demolition of substructure. 3. Piling work. 4. Construction of substructure. 5. Raising and widening of existing road. 6. Erection of temporary bridge (Bailey bridge) on the newly constructed substructure.
	Rainy Season	7. Fabrication of patching and coating main girder
	Second Period	8. Arrangement of detour and temporary access. 9. Removal of temporary bridge (Bailey bridge). 10. Erection of P.C main girder. 11. Deck slab work. 12. Bridge surface work.
Merits and Demerits		1. Traffic diversion will be required twice. 2. Erection and removal of temporary bridge (Bailey bridge) are required during the first and second periods respectively. 3. Requires raising and widening work for improvement of existing road.
Evaluation		○



Alternative 2 (The side position of existing bridge)		
Construction Step	First Period	1. Arrangement and construction of temporary access and banking. 2. Pilling work. 3. Construction of substructure. 4. Embankment work for diversion of existing road.
	Rainy Season	5. Fabrication of P.C main girder.
	Second Period	6. Arrangement of temporary access for construction. 7. Erection of P.C main girder. 8. Deck slab work. 9. Bridge surface work. 10. Removal and demolition of existing bridge.
Merits and Demerits		1. Detour for existing traffic during new bridge construction not necessary. 2. Embankment work required for diversion of existing road (about 400m). 3. New bridge length is about 10m longer than that of Alternative 1. 4. Because of 2 and 3 above, construction cost should be higher compared with Alternative 1.
Evaluation		△

③ Bridge Nos. 6, 8

Both of these bridges are located in the center of an S-shaped curve. Furthermore, the water level in the river during the dry season is 1.0 to 1.5m. Considering the need of drainage facilities appropriate to the bridge's waterflow cross-section, the scale and cost of detour route construction would be massive. Consequently, a new bridge will be constructed approximately 15m south of the present bridge, where the alignment can be easily changed and the old bridge can be used as detour route during constructions.

b) Bridge length

Bridge length depends upon upstream and downstream river width, capacity of water flow, amount of scouring at abutment, position of pre-existing abutment, etc. With the exception of Bridge No.2, there are no problems regarding present bridge lengths, and as a consequence there will be little or no change.

As for Bridge No.2, the bridge length will be extended 9m to make a total length of 159m. This is due to the existence of a pre-existing abutment which would be highly difficult to remove, and the fact that a new abutment also needs to be put up.

c) Span Arrangement

① Bridge No.2

As old existing piers which are seriously damaged, cannot be re-used for new bridge, the new piers are constructed between the existing ones with the same span pitch in consideration of shortening the construction period and facilitating construction.

② Bridge Nos. 3, 4, 5, 7, 10

Since these bridges are rather short (9.0 ~ 11.0m), they will be designed as single-span bridges.

③ Bridge Nos. 6, 8

Since these two bridges are rather long (No.6=38m, No.8=42m), it is judged that it will be more economical to construct them with bridge supports and shorter spans from the point of view of the cost of the entire bridge. 2-span and 3-span alternatives were considered and the 3-span alternative has been adopted for its superior structural and economical factors. (See Table-2-3-14 to 15)

Table 2-3-14 Comparison of No.6 Bridge Type

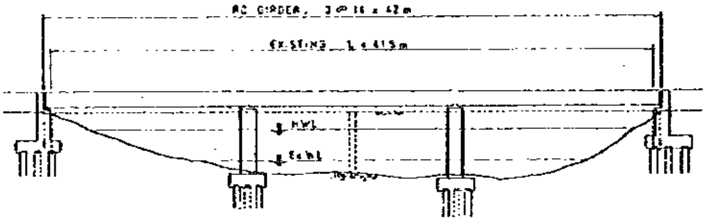
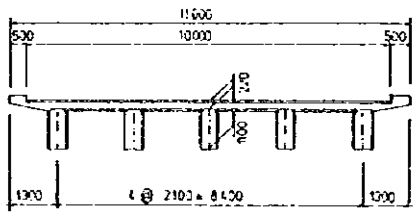
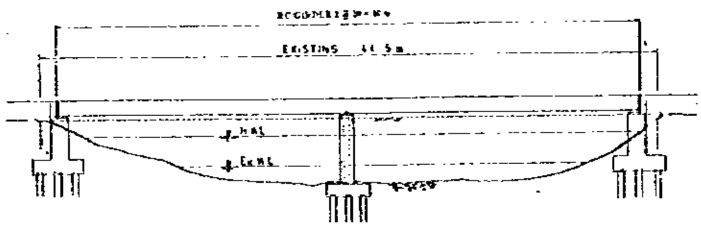
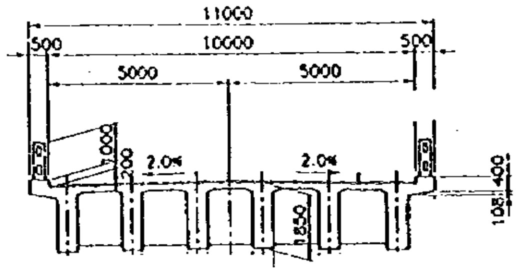
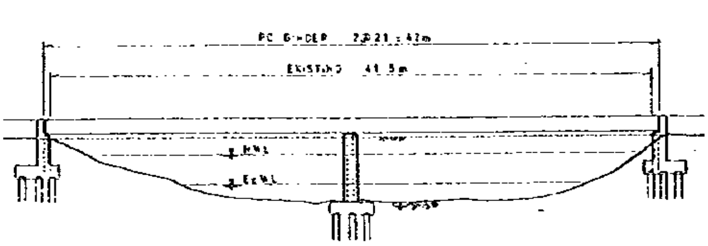
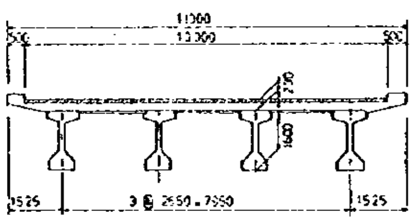
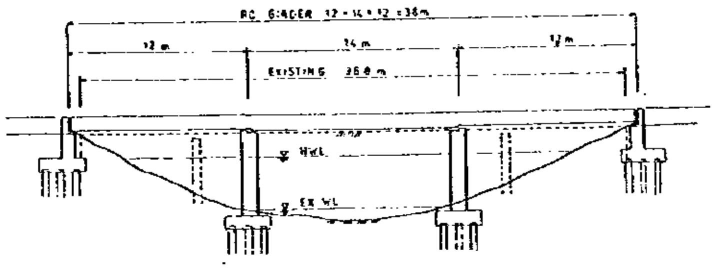
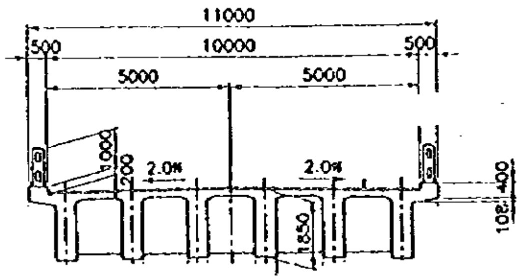
General View		
	Alternative 1 : RC3 span Continuous T-Girder	
	Structure	- In consideration of proper span for RCT-girder and maintenance cost, 3 span continuous type is applied. - Compared with 2 span type, obstruction by piers of the sectional area of the river and a number of piers increase. - The balance of bending moment is better compared with 2 span type.
	Construction	- Cast-in-place RC T-section type girder produced on staging. - Temporary filling for working space in the riverbed shall be made during the dry season, when the water depth goes down to as shallow as 0.5m-1.0m. - All construction materials are available in Cambodia.
	Cost	1.0
	Maintenance	○
	Evaluation	○
	Alternative 2 : RC 2 span Continuous T-Girder	
	Structure	- In consideration of limit span for RC-T girder and decreasing the number of piers, 2 span type with shorter bridge length (40m) is applied. - Larger abutment is required because of shifting riverside. - This type is not economical because span length is close to limit as a RC T-girder.
	Construction	- Cast-in-place RC-T girder produced on staging. - Larger scale of staging is required because of heavy dead load. - Construction is executed in dry season because water level rises in the rainy season. - All construction materials are available in Cambodia
	Cost	1.06
	Maintenance	○
	Evaluation	△
	Alternative 3 : PC 2 span continuous I girder	
	Structure	- In consideration of proper span for PC I-girder, and maintenance cost, 2 span continuous type is applied. - The balance of bending moment is inferior compared with 3 span type because of larger negative bending moment on the pier.
	Construction	- PC girder which are divided into 3 blocks are fabricated in Phnom Penh by using high strength concrete supplied from concrete plant. These blocks are transported to the site and set by erection girder. - Shorter construction period is possible because girder fabrication can be executed in the rainy season. - PC steel wire is necessary to be imported.
	Cost	1.20
	Maintenance	◎
	Evaluation	△

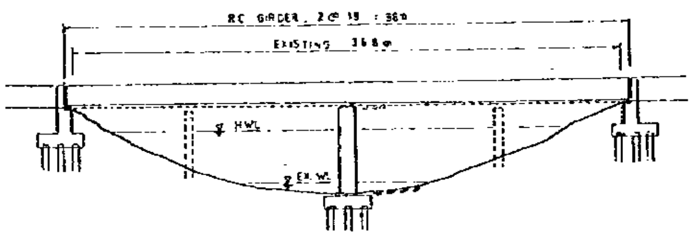
Table 2-3-15 Comparison of No.8 Bridge Type

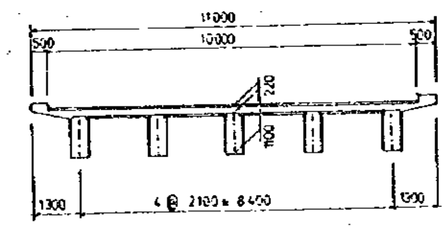
General View





	Alternative 1 : RC 3 span Continuous T-Girder
Structure	- In consideration of proper span for RC T-girder, and maintenance cost, 3 span continuous type is applied. - Compared with 2 span type, obstruction by piers of the sectional area of the river and a number of piers increase. - Proper span balance leads to good balance of bending moment.
Construction	- Cast-in-place RC T-section type girder produced on staging. - Temporary filling for working space in the riverbed shall be made during the dry season, when the water depth goes down to as shallow as 0.5m-1.0m. - All construction materials are available in Cambodia.
Maintenance	○
Cost	1.0
Evaluation	○





	Alternative 2 : RC 2 span Continuous T-Girder
Structure	- In consideration of limit span for RC-T girder and decreasing the number of piers, 2 span type is applied. - The balance of bending moment is not better because of larger negative moment on the pier. - This span length is close to limit as a RC-T girder, so this type is not economical.
Construction	- Cast-in-place RC-T girder produced on staging. - Larger scale of staging is required because of heavy dead load. - Construction is executed in dry season because water level rises in rainy season. - All construction materials are available in Cambodia.
Maintenance	○
Cost	1.06
Evaluation	△

④ Bridge No.9

The findings of flood survey have indicated that approach roads on both sides of the bridge were submerged, due to the lack of the bridge's capacity of water flow, following heavy rainfall. In order to remedy this problem, the bottom of the bridge will be raised, and the bridge itself will be redesigned from a three-span to single-span bridge.

d) Design Flood Level and Freeboard

Design flood level is set based upon the results of flood survey. Since there are no records of floods or flood level, survey was carried out through interviews and obsevation of terrain marked by former flooding. 0.5m was added to the flood level which could be surmised through these methods, to obtain the design flood level.

As for freeboard from flood water level, according to the Japanese standard of river control, a bridge of 10m should have that of 0.6m. For Bridge Nos.2, 6 and 8, 1.0m will be assigned.

e) Superstrucure Type

① Selection of superstructure basic type

In order to decide whether any of the project bridges' superstructure ought to be concrete or steel, the following points must be taken into consideration:

- Ease of construction and economic aspects of total bridge cost including substructure and foundation
- Whether or not the type is easy to maintain and/or cost effective
- How the bridge is to be used, and potential of transfer of skills in Cambodia.

Since the span length of the project bridges is 10m to 30m and the depth to the bearing layer is less than 20m, though inferior in the aspect of dead load, concrete bridge would be favorable, judging from precious experience, in terms of its cost-effectiveness in both construction and maintenance. As a consequence, from the aspect of previous performance and of technical transfer in Cambodia, concrete bridges generally are chosen in order to facilitate bridge construction.

However, since (1) the span length of Bridge No.2 is considerably long (20 to 30m), (2) there is a significant water level even during the dry season, and (3) at present there are no 100-ton class cranes, which are needed for the construction of concrete bridges, in Cambodia, steel bridges are also considered in comparison.

② Review of superstructure types

As a result of reviewing bridge length and span arrangement, project bridges are divided into two groups; That is, those with maximum span length of 10m and those of 20 to 30m.

The general relationship between span length and bridge type is shown in Table-2-3-16. In this table, bridge types applicable to the two groups are indicated in Table-2-3-17.

Table-2-3-16 Standard Spans for Various Types of Bridges

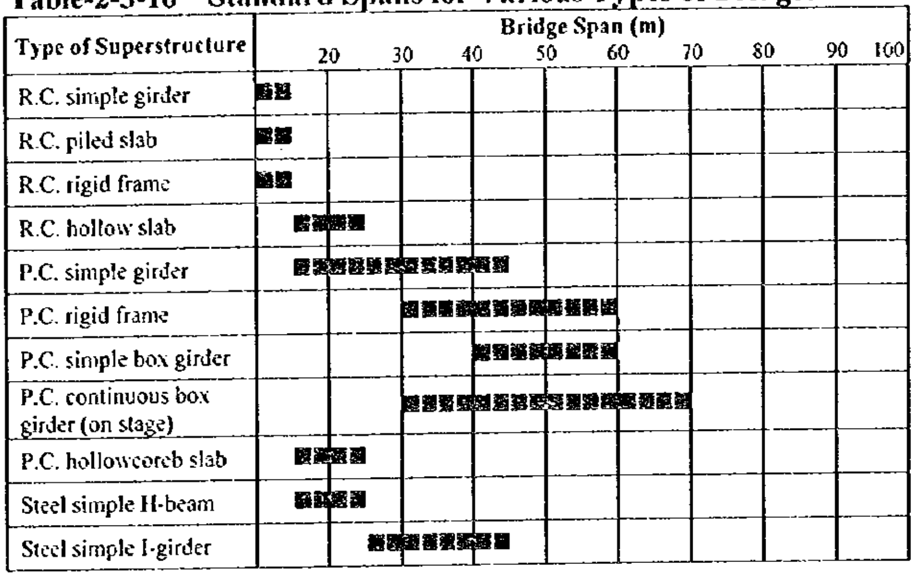


Table-2-3-17 Bridge Types Applied to Project Bridges

Applied span length	Bridge type	Appropriate bridge type
10m	Concrete bridge Culvert	RC Slab Type, RC T-girder Type
20～30m	Concrete bridge	RC Hollow Type, PC Hollow Type RC T-girder Type, PC I-girder Type
	Steel bridge	H-Beam Type, Plate Girder Type

A comparison of superstructure types of each bridge was conducted based on Table-2-3-18 to 20. Furthermore, if applied span is less than 10m, box culvert becomes a candidate of comparison as a structure type, so bridge and box culvert types have been compared together. For the results, see Table-2-3-21.

③ Reduction of maintenance through structure-type

As a way of reducing maintenance in RC bridges of more than two spans, the continuous girder method (which does not require the often-damaged expansion joints) is adopted.

Table 2-3-18 Comparison of Superstructure Type for No. 2 Bridge

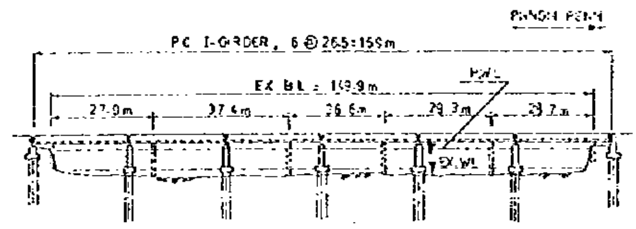
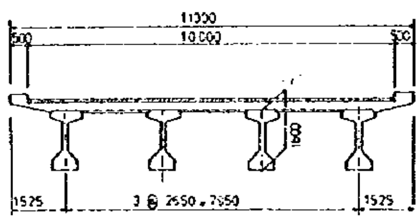
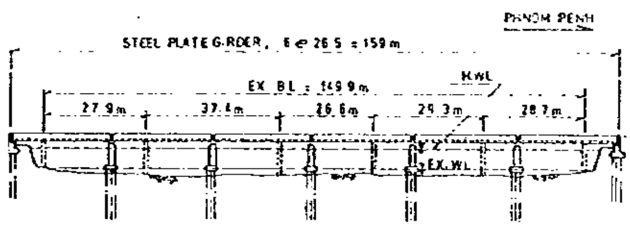
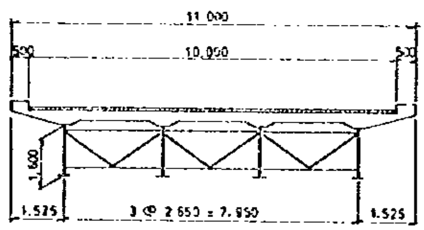
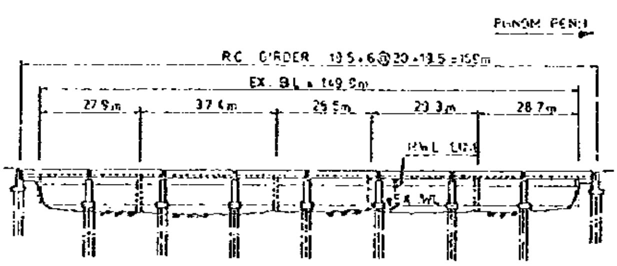
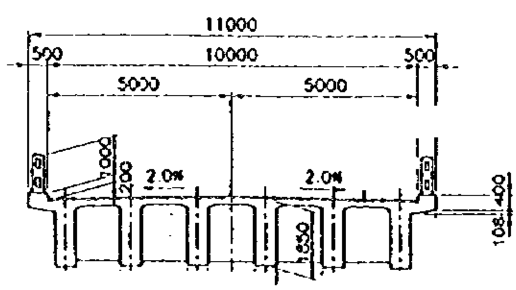
General View		Alternative 1 : 6 Span PC Continuous I-Girder
	Structure	- 6-span continuous girder bridge. - Resistance to live loads with composite section of I-shaped main girders and RC slab. - Compose continuous girder by connecting each girder end at piers to leave out expansion joint except at abutments.
	Construction	- Main girders are manufactured while the substructures are being constructed. This construction method reduces the construction period compared with Alternative 3.
	Cost	○
	Maintenance	- Easy because of concrete structure.
	Evaluation	○
		Alternative 2 : 6 Span Steel Simple Plate Girder
	Structure	- Resistance to live loads with composite section of plate girder and RC slab.
	Construction	- As the main girders are of shop fabrication, the site work will be reduced so the construction period at site is the shortest. - Main girders and accessories are imported.
	Cost	○
	Maintenance	- Re-painting is required.
	Evaluation	△
		Alternative 3 : 8 Span RC Simple T-Girder
	Structure	- As the girder length is near the upper limit for application of RC girder, the section of main girder becomes larger. - The number of pier increase comparing with the Alternative 1 and 2. - Because of the above reason and construction condition mentioned below, Alternative 3 may be most expensive.
	Construction	- Because of cast-in-place RC type girder constructed on staging, necessary to secure reliable foundation with banking and filling. - Construction of superstructure must follow that of substructure, since every member is cast-in-place. So, it takes longer construction period. - It is difficult to complete superstructure work in one dry season.
	Cost	△
	Maintenance	- Easy because of concrete structure.
	Evaluation	△

Table 2-3-19 Comparison of Superstructure Type for NO. 3,4,5,7,10 Bridges

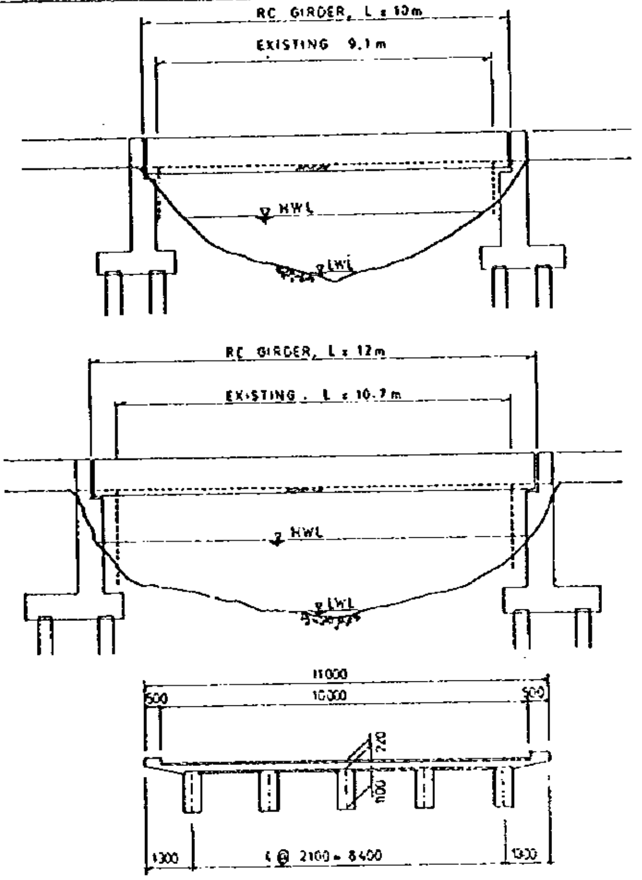
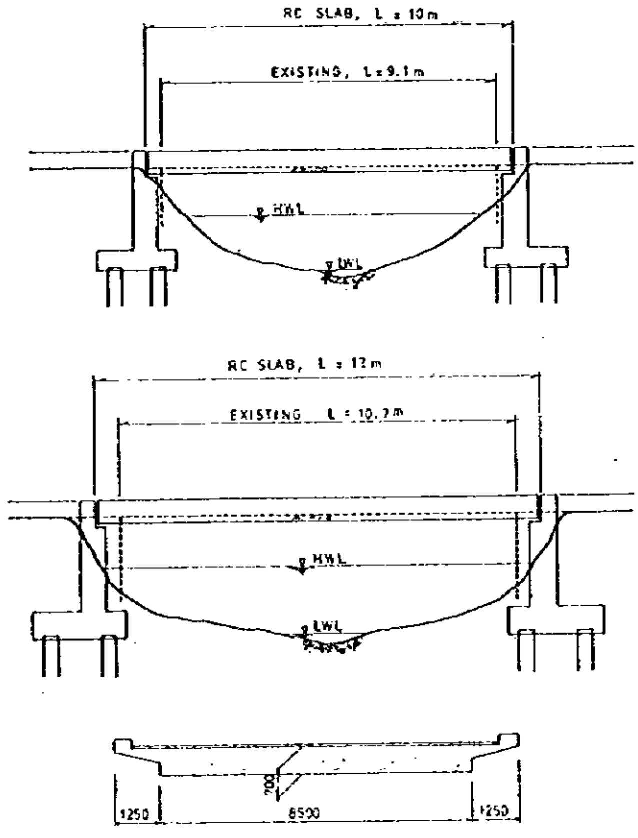
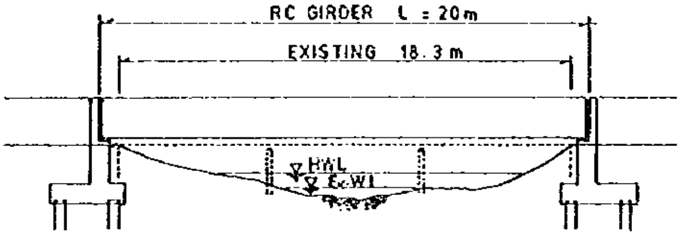
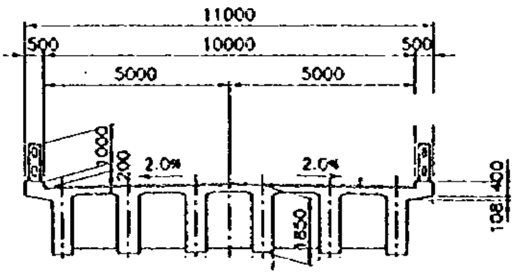
General View	Alternative 1 : RC Simple T-girder	
	Structure	- Cast-in-place RC T-section type girder produced on staging.
	Construction	- Shallow water depth during the dry season is suitable for setting a staging form for concreting. - Temporary filling and drainage pipes may be required.
	Cost	1.0
	Evaluation	○
	Alternative 2 : RC Simple Slab	
	Structure	- Cast-in-place RC slab. - Dead weight of this type will be heavier than that of Alternative 1.
	Construction	- Shallow water depth during the dry season is suitable for setting a staging form for concreting. - Temporary filling and drainage pipes may be required.
	Cost	1.05
	Evaluation	△

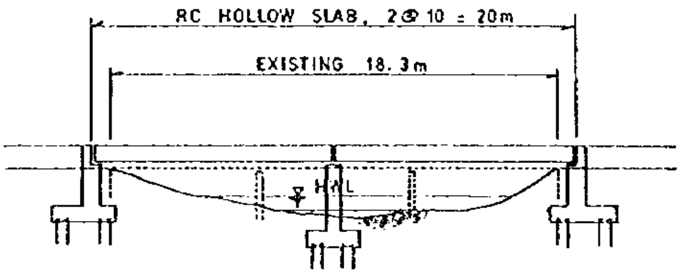
Table 2-3-20 Comparison of Superstructure Type for No.9 Bridge

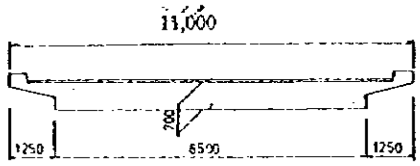
General View





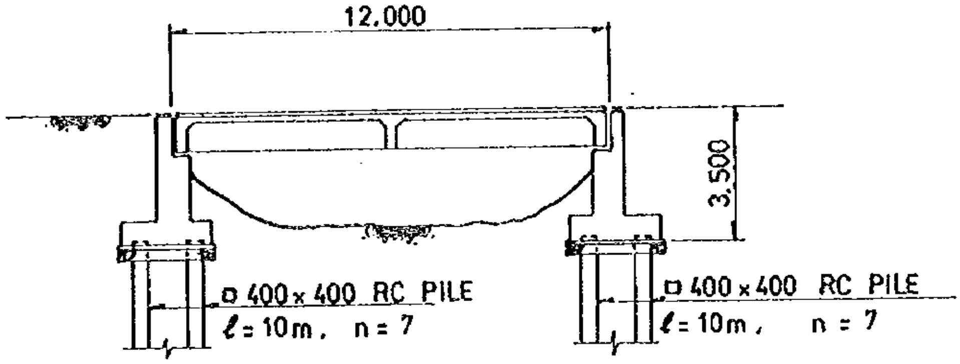
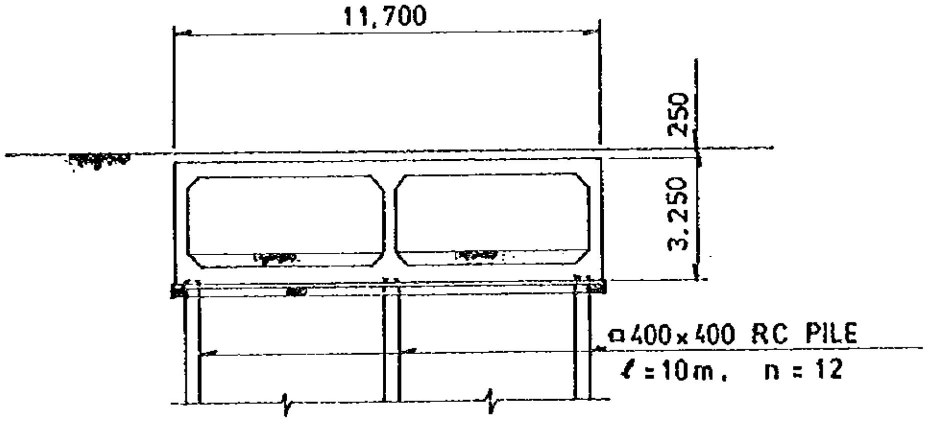
	Alternative 1 : RC Simple T-girder
Structure	- In order to secure water flow capacity, this bridge is planned without pier. - Cast-in-place RC T-section girder produced on staging. - As span length is close to limit as a RC T-girder, superstructure cost is not economical, but total cost unaffected because of spread foundation.
Construction	- Temporary filling for working space in the riverbed shall be made during the dry season, when the water depth goes down to as shallow as 0.5 - 1.0m. - Drainage pipes will be laid underneath the filling. Sub- and superstructure can be easily executed on the temporary dry working space.
Economic	1.0
Evaluation	○





	Alternative 2 : 2 Span RC Continuous Slab
Structure	- Cast-in-place RC slab produced on staging - Pier obstructs the water flow at flooding.
Construction	- Shallow water depth during the dry season is suitable for setting a staging from concreting. - Temporary filling and drainage pipes may be required.
Economic	1.0
Evaluation	△

Table 2-3-21 Comparison of Box Curvert and Bridge

	Alternative 1: Bridge (R.C Simple T-Beam)
General View	
Structure	-A small number of piles is necessary for abutment because allotment height is low and bending moment on the pile is also small.
Cost	1.0
Evaluation	○
	Alternative : Two Cell Box Culvert
General View	
Structure	-A section of box cullvert is not economical because a ratio of section width by height is large. -Concrete volume of this type is larger than bridge type, because base slab is necessary.
Cost	1.1
Evaluation	△

For Bridge No.2 (PC bridge), conventional continuity reinforcement method, which articulates simple girders following installation, is also adopted as it does not require the use of expansion joints.

f) Substructure Type

① Selection of substructure type

The following points were considered in the selection of substructure type

- A point in the river which is as straight as possible is selected for crossing site, and bridge axis is designed perpendicular to the flow of water. Furthermore, consideration is made for the prevention of scouring and protective measures in the area of abutment.

- Abutments and piers are to be of a structure safe in instance of flodding, with pier footing of a sufficient depth and appropriate for the speed of flow and soil type of riverbed.

- The most suitable substructure type will be selected in accordance with the required structure height, since the substructure and structure height are in close relationship with each other.

② Bridge No.2

With regard to Bridge No.2, since the water level at the bridge is 1.0m to 1.5m even during the dry season, temporary work for substructure must be minimized in terms of construction cost. In addition, because the detour route constructed with a Bailey Bridge last year is practically in original condition and hereby little scouring is anticipated, it is expected that the construction cost can be minimized. Based upon these facts, the three types of substructure shown below were examined by comparison to find the most cost-productive alternative. (See Table-2-3-22)

Alternative-1: Multi-pile foundation
Alternative-2: Pile-bent type
Alternative-3: Buried footing

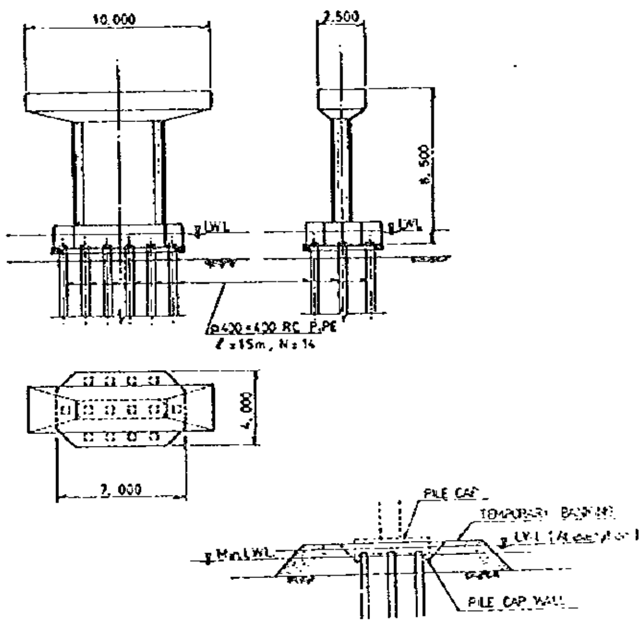
As a result of comparison, Alternative-1 was selected considering its economic feasibility, efficiency in construction, and small amount of scouring.

③ Other bridges

For comparison of abutments and piers for bridges other than No.2, see Table-2-3-23 and 24.

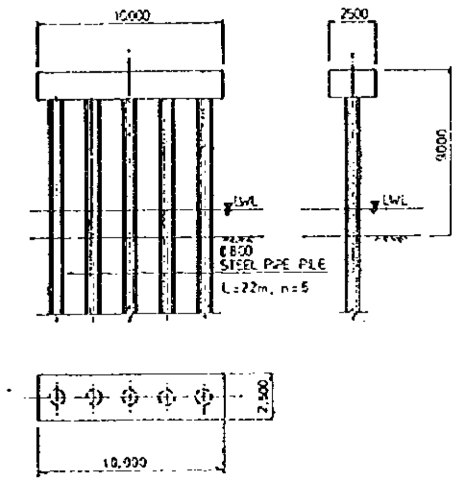
Table 2-3-22 Comparison of Bridge Location for No.2 Bridge

Alternative 1 (The same position of existing bridge)



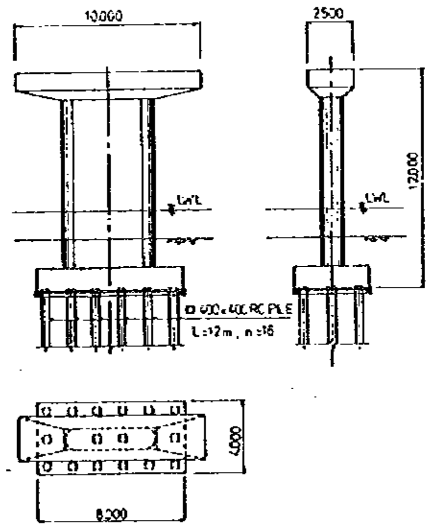
Item	Alternative 1 (The same position of existing bridge)
Structure	- This design is adopted for piers in the river with comparatively deep water depth without temporary cofferdam. - After connection of each pile head with pile cap, the pier is built on the pile cap. - As the water depth at dry season is 1.5m, open cut excavation method for pile-cap work is applied after temporary banking around substructure to protect construction site from flooding. - In order to keep the working ground dry, dewatering work by submersible pumps, should be executed and bottom level of the pile-caps located under the Min. L.W.L. not to have the pier head exposed.
Cost	1.0
Evaluation	○

Alternative 2 : Pile Bent Type



Item	Alternative 2 : Pile Bent Type
Structure	- This design is adopted for piers in the river without temporary cofferdam. Superstructure is placed on the pile-cap connecting each pile head. - The pile foundation rigidity to the longitudinal direction to the bridge axis is not strong because of high projection of piles. - Large displacement is reduced by introducing large piles which require a large pile driver.
Cost	1.3
Evaluation	△

Alternative 3 : Footing Type



Item	Alternative 3 : Footing Type
Structure	- This design is adopted for piers in the river with rapid flow and scouring. - In case of deep water, large-scaled temporary island with double cofferdam is required, and causing deterioration of workability because of increase of temporary support like struts and wales.
Cost	1.7
Evaluation	△

Table 2-3-23 Comparison of Abutment Type

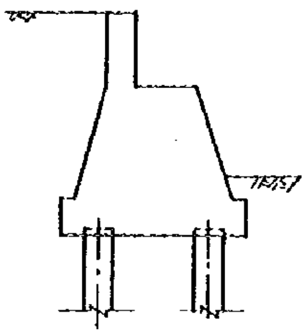
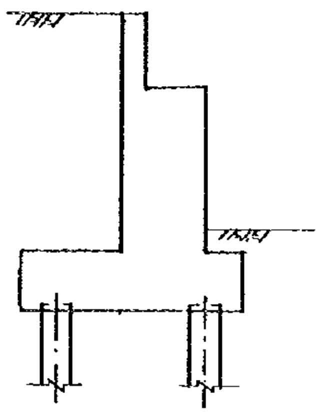
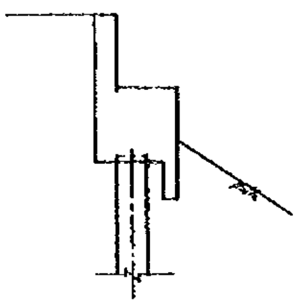
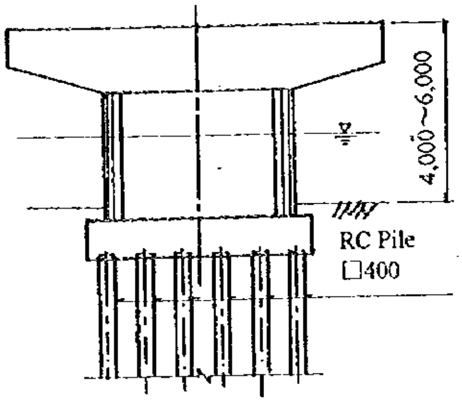
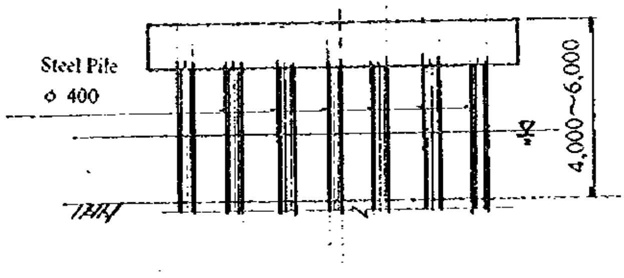
General View	Alternative 1 :Gravity Type	
	Structure	- This type is applied to an abutment less than 3m in height and when stable ground exists. - As plane concrete is used excepting parapet, construction is easier. - Weight of abutment increases as the height is greater and is not economical.
	Evaluation	- This type is adapted to No.7, 8 bridges which have lower height and No.9 bridge which has spread foundation on rock.
	Alternative 2 : Reversed-T Type	
	Structure	- This type is applied to the abutment with about 4m to 12m in height. - This type is economical due to weight filling used as a couture weight and less abutment weight. - Construction work is a little harder because of reinforced concrete.
	Evaluation	- This type is adapted to No. 2, 3, 4, 5, 6 bridge which are more than 3m in height and pile foundation.
	Alternative 3 : Pilebent Type	
	Structure	- This type is economical because of small volume of concrete, and is applied to the place where the front side of the abutment does not suffer erosion. - When the front side of the abutment suffers erosion, slope protection such as masonry wall is required and becomes less economical.
	Evaluation	- As every abutment suffers erosion, this type is not applied.

Table 2-3-24 **Comparison of Pier Type**

General View	**Alternative 1 : T shaped Type**	
	Structure	- This type is applied to the pier in the river with stable water flow. This type is economical compared with wall-type because of small concrete volume. - This type is superior to pilebent type as this type does not obstruct water flow. - Supporting is required for beam concrete work. - All materials are available in Cambodia.
	Cost	1.0
	Evaluation	○
	Alternative 2 : Pilebent Type	
	Structure	- This type is built to connect with pile cap after pile driving. - Construction work is easier, not requiring excavation and cofferdam. - Steel pile is applied as pier height is taller. - When there is water flow, this type leads to scouring around pier. - Steel piles are imported.
	Cost	1.05
	Evaluation	△

g) Foundation Structure Type

With the exception of Bridge No.9, the exposed geological layer of the project area is chiefly 10 to 20m of an eroded belt of Mesozoic clay layers; consequently, pile-type foundation is to be adopted.

As shown in Table-2-3-25 there are a variety of pile types such as RC pile, PC piles, Steel pipe, and cast-in-place concrete piles. RC square piles have been selected for the reasons stated below.

① Pile length is shorter, therefore economical.
② Intermediate stratum is of evenly-textured clay, therefore no fear of cracking while pile is being driven
③ Bridges are of small scale; number of piles is small
④ Widely used throughout Cambodia

Most commonly used square piles are 400x400mm in dimension. These will be used for project sites.

Table-2-3-25 Characteristics of Potential Pile Types

Pile type	Sphere of pile length	Supply route	Characteristics
RC pile	approx.30m	Domestically manufacturable	- Driving method is expected, and this type is appropriate for softer upper stratum with supporting stratum of less than 30m. - Applied in situations where lighter vertical and horizontal loads are already in effect. - Economic for short spans.
PC pile	approx.30m	Imported from Thailand, Singapore or Japan	- Driving method is expected, and this type is appropriate for softer upper stratum with supporting stratum of less than 30m. - Applied in situations where lighter vertical and horizontal loads are already in effect. - Economic for short spans. - Greater strength compared to RC pile; less cracking and other damage during installation.
Steel pipe pile	15m to 60m	Imported from Thailand, Singapore or Japan	- Most applicable in cases of long piles, welding makes for fewer problems with joints. - Most effective in situations of heavier vertical and horizontal load. - Less economical
Cast-on-site pile	15m to 60m		- Applicable in cases of long piles as there are no problems with joints. - Most effective in situations of heavier vertical and horizontal load. - Less economical in shorter-span bridges.

7) Bridge Construction Methods

(1) Bridge No.2

As a result of careful review, the following methods are to be adopted in regards to bridge construction and manufacturing of PC-I girder. (L=26.5m)

Girder manufacture:	To be manufactured from concrete supplied by a concrete mixing plant as one girder divided into three blocks manufactured at a girder manufacturing yard in the vicinity of Phnom Penh.
Transport of girder:	Since transport routes are not in good condition, reinforced concrete girders can be damaged by vibration en route. To avoid this, each block girder will be bound with PC steel wire and carried to construction site by trailer.
Temporary installation:	Construction is to be executed by a temporarily installed girder after putting together the three girder blocks and tensing it into one girder with PC steel.

This method has been adopted for the following reasons:

- PC girders require a high degree of concrete strength for durability; in the case of a portable on-site mixer, good mix quality is difficult to maintain. Furthermore, as it takes two hours by car from Phnom Penh to the site, the quality maintenance of mixed concrete transported by agitator-body truck becomes rather difficult, and use with retarder is undependable.
- Considerations were made in regards to staging erection method (amount required for the manufacture of one main girder) + girder method transverse, but staging cannot be constructed until the water level drops, thus causing tight constraints on the construction schedule, therefore not adopted.

(2) Other bridges (RC-T girder)

RC-T girders do not require as much strength as PC girders. Accordingly, a portable concrete mixer would supply a sufficient quality of concrete on site. For this reason, cast-in-place concrete method is practical. In addition, because (1) freeboard is 4m and less, (2) the girder is comparatively light, and (3) there is no need to use heavy machinery such as cranes, staging construction method is adopted.

8) Countermeasure for Flooding

(1) Flood Analysis Study

The flood of the Mekong River in 1996 recorded a water level of +15.18 on September 29 , which is the highest recorded water level at Kompong Cham city in histroy, which was covered with about 1m of water. Moreover, the flood caused great damage on the project road, such as collapse of embankment at three locations, partial inundation, and erosion of embankment slope.

Based on the flood damage of the Mekong River this year, it was decided to conduct flood analysis study in the Basic Design in order to improve the safety of the project road structure against floods of a scale similar to this flood.

(2) Objectives of Flood Analysis Study

The objectives of the analysis are to determine the design flood level for the study section on the National Roads Routes 6 and 7, where the countermeasures for flooding are applied, and the scale of necessary drainage structure to prevent collapse of road.

(3) Selection of Analysis Method

In consideration of topographic conditions in the basin of the Mekong River, types of hydrological data, time and cost required for analysis, a tank model was chosen as a flood analysis method.

The tank model is analyzed by the following assumption;

(a) Qk, the volume of inflow at Kompong Cham located upstream on the Mekong River, flows into the study section and Qp, the volume of outflow at Phnom Penh located downstream on the Mekong River and Qd, the volume of outflow from drainage structure on Route 6 and Ex-6A, outflows.
(b) In cases where the water level at Kompong Cham is more than 6 m and Qk exceeds Qp, the flow inundates around the Mekong River.

The model is the method to trace the change of this flood water depth hour by hour. A model shows this in Figure 2-3-6 and 2-3-7.

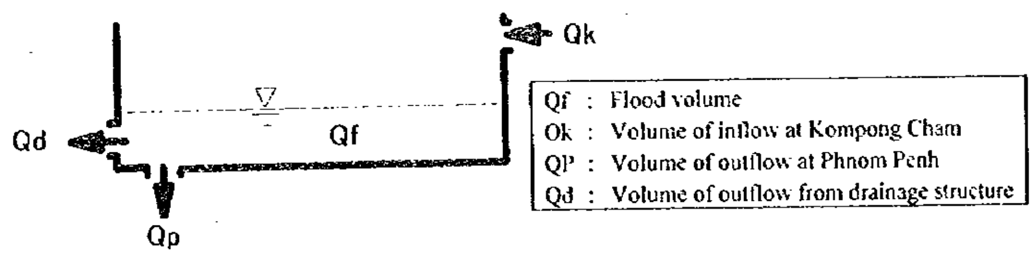


Figure 2-3-6 Tank model

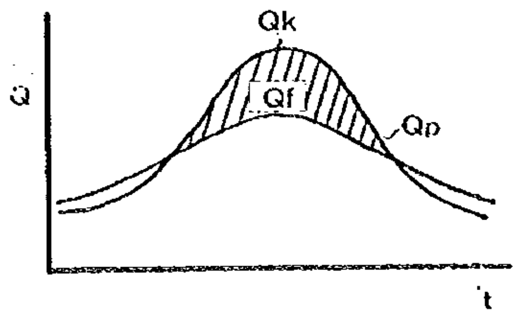


Figure 2-3-7 Volume of Flood Flow

(4) Analysis Cases

Analysis cases by using the tank model are as follows;

Case-1: Reappearance of the flood in 1991, 1994,1995 and 1996
Case-2: Without collapse of the road by using 1996 data
Case-3: Installation of new drainage structures by using 1996 data

(5) Results of Analysis

The results of the analysis are shown in Figure 3-3-8.
A water depth calculated as a result of the analysis means the following;

> In this model, as the water depth of the tank is assumed to change equally, the water depth calculated is not relevant to actual water level. Though, in case a difference of water depth between each year's data is compared, it can be thought that its difference corresponds to actual difference of water levels. Consequently, this value of water depth can be used by combining the flood water levels observed at the site and can suppose the water level at various times for which data is available. In addition, these values of water depth can be used to study the scale of necessary drainage structure.

(Case-1)

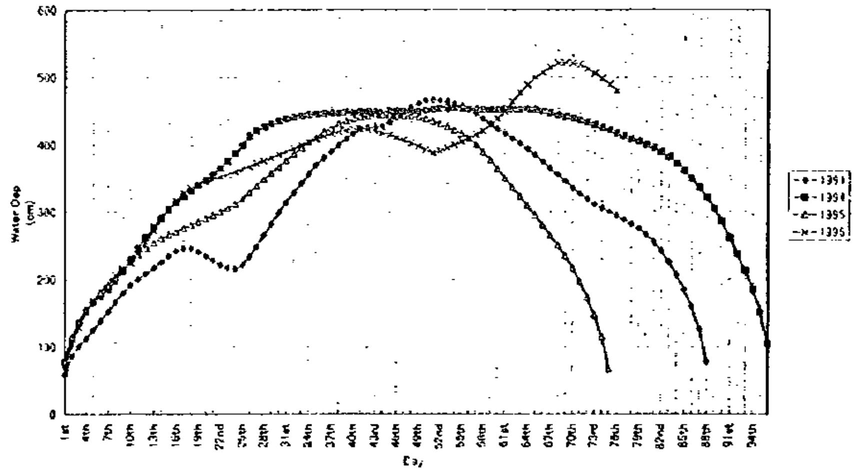
- It is found that the water depth calculated by 1996 data is the maximum and indicates a similar trend of water level of the Mekong River at Kompong Cham. The differences of the calculated water depth each year correspond to results of the flood water level investigated at the site.
- It is found that change pattern of the calculated water depth is different every year as is the water level of the Mekong River.

(Case-2)

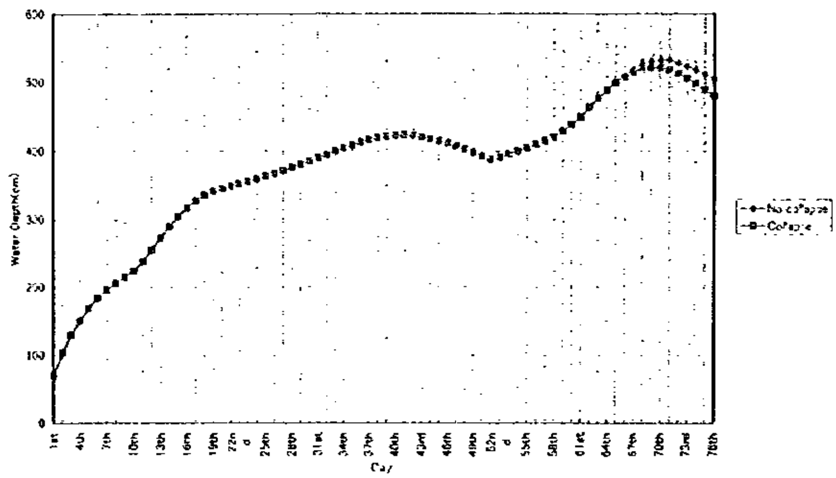
- It is assumed that flood water level has not risen since September 29 because the volume of outflow from the Mekong River increased due to collapse of the road. According to the results of analysis, it is supposed that the flood water level would have risen 22 more centimeters had the road not collapsed.

(Case-3)

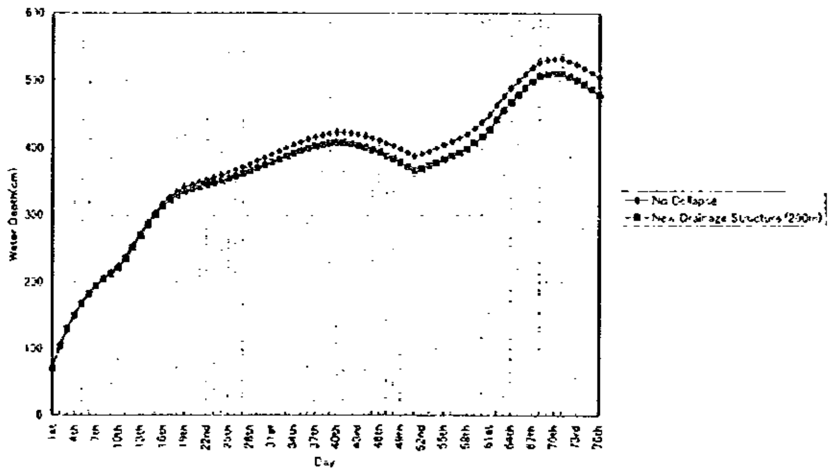
- In order to keep the flood water level under +10.5m, the level which caused collapse of the road last year, the installation of new drainage with about 200m in section width is required, based on the results of analysis.



Case-1 Reappearance of the Flood (1991, 1994, 1995, 1996)



Case-2 Without collapse of the Road by using 1996 data



Case-3 Installation of New Drainage Structures by using 1996 data

Figure 2-3-8 Results of Analysis

(6) Basic Policy for Countermeasure for Flooding of the Mekong River

① Road section requiring countermeasures for flooding

Taking into consideration the flood damage, existing road surface level, and the location of Route 6 in regards to flow of the Mekong River, the section between Thnolkeng and Bathey is located at a right angle to flow of the Mekong River with lower road surface level than other sections on the Route 6 and 7. Consequently, countermeasures for flooding based on the flood analysis are applied to this section.

② Design flood water level

It is assumed that the chances of a flood of the scale of that of 1996 occurring will be once or less every 50 years according to the results of investigation. On the other hand, there is also the opinion that a flood inflicting a similar amout of damage occurred in 1987, though officially unrecorded; therefore the chances may be higher, according to a JICA expert. According to the analysis of the " Final Report of Irrigation Rehabilitation Study in Cambodia-1994-", which was analyzed by water level record between 1960 and 1992, with no observation record between 1975 and 1980, the flood of 1996 may have about a 200-year return period at Kompong Cham and about a 100-year return period at Phnom Penh. In addition, the analysis of the report shows that the flood level at each year return period shows little change in case of exceeding 50 year return period. Consequently, it is assumed that possibility of the scale of the flood exceeding the 1996 flood is small.

Based on the above consideration, the design flood level is determined based on the 1996 flood data and its level adds +10.50m,the flood water level at the study section by the results of investigation, adding water level of 0.3m which would have occurred if the road had not collapsed.

Design Flood Water Level : +10.80m

③ Concept of Planned Road Level

The study route, which is a part of the National Roads Route 6 and 7, is an important route connecting Phnom Penh with Kompong Cham of the center of northeast area in Cambodia and is also a part of the Asian Highway No.11. Consequently, the study route aims to be a road with sufficient height not to be inundated in order to ensure a passable road through out the year. In addition, it is required to set the design flood water level below the bottom of subbase in order to keep the road surface stable.

Planned Road Level : +11.30
(Design Flood Water Level (+10.80)+thickness of pavement, base coarse and subbase (total 0.5m)

④ Installation of New Drainage Structure

In order to attain road structure without inundation, it must be considered that the flood level has a possibility to exceed the maximum flood level of the 1996 flood. Consequently, new drainage structures are placed for the following reasons;

- To lower the flood water level and water pressure to embankment
- To prevent houses near the study route from being inundated
- To prevent downstream area and road from being inundated

As the Route Ex-6A did not sustain great damage by the 1996 flood, a scale of the new drainage structure is determined not to exceed +10.50, which is the flood water level at the collapse of the road. Bridge type is adopted as a type of drainage structure because a bridge can sustain larger flow capacity than any other drainage structure types.

⑤ Strengthening and Protection of the Embankment

Filling for widening is conducted with selection of appropriate materials and compacted sufficiently. In general, the existing road is widened on the Mekong River side and clay treatment is conducted on the slope in order to prevent flood water from penetrating the embankment. In addition, mat gabions are placed around the bridge area to prevent embankment from erosion because flow under the bridge will be more rapid than usual in time of flood.

(7) Project Countermeasures for Flooding

① Study of Countermeasures for Flooding

Alternatives based on the basic policy of countermeasures for flooding are shown in Table 2-3-26.

② Location and Scale of Drainage Structures

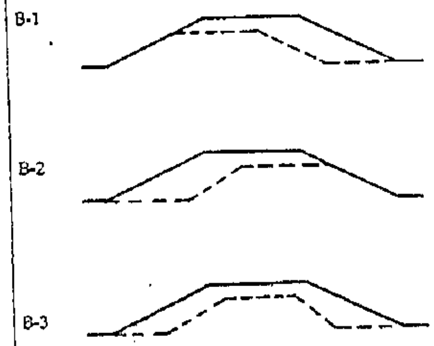
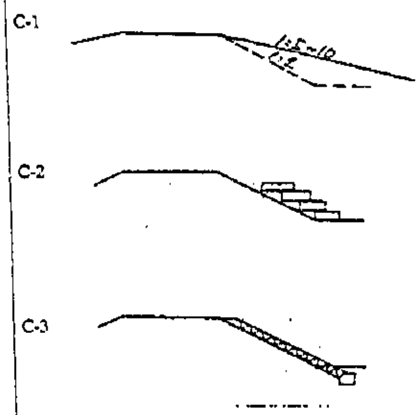
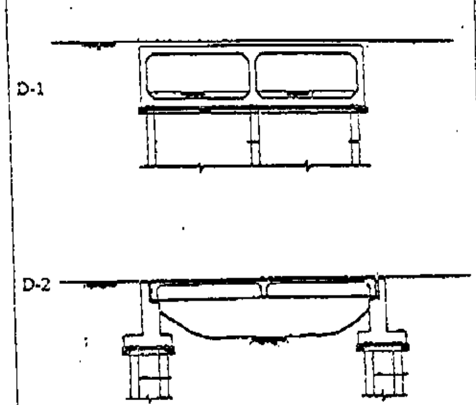
Bridges as new drainage structures are planned at the following four locations in consideration of existing drainage structures;

- Collapsed sections (three locations)
- Point receiving greatest water pressure due to topographical aspects(one location)

Bridge type is adopted as a new drainage structure. Bridge length is 54m to ensure 50m of drain width as total of 200m of drain width is required according to the results of flood analysis.

RC T-girder type is adopted as a bridge type in consideration of economics and 3-span, span length 18m, is also adopted in consideration of economical span length for RC T-girder type.

Table 2-3-26 Study on Countermeasures for Flooding

	Alternative-A: Rise of Road Level	Alternative B: Selection of Filling Materials and Location of Widening	Alternative-C: Slope Protection	Alternative-D: Installation of New Drainage Structure
Sketch				
Outline	• This is a plan to raise the road level up to prevent the flood from inundating the road which deteriorates pavement and slopes. Road level is planned at flood water level of 1996 plus 0.5m, which is thickness of sub-base and asphalt pavement.	• The following two items are considered for embanking; ① Selection of appropriate materials with low coefficient of penetration ② Study on widening method The most appropriate widening method is adopted in consideration of damage from the flood. B-1: Widening toward the Mekong River side B-2: Widening toward the Tonle Sap side B-3: Widening of both sides	• In order to prevent slopes from erosion, Alternatives for slope protection except clay treatment method are shown below; C-1: Adoption of gentle slope C-2: Installation of gabions C-3: Installation of masonry wall	• New drainage structures are required on the study route to lower the flood water level and lighten water pressure to embankment. Alternatives for drainage structure are shown as follows: D-1: Box culvert D-2: Bridge
Characteristics	• Maintenance cost lowered as a result of less deterioration from half of inundation. • As the flood level will raise with the road level, potential water pressure to the embankment will also increase.	• As a flood water level of the Mekong side is higher than that of the Tonle Sap side, penetration of water from the Mekong side is greater and sustains damages on the slopes. In order to prevent this, it is advisable to widen toward the Mekong side and compact sufficiently with appropriate materials. • Both-side widening is inferior from viewpoint of machinery construction because of narrow widening of 4m.	• Adoption of gentle slope leads to large amount of filling materials and is inferior form viewpoint of economics. • Gabions plan is economical compared with masonry wall and is easy to repair. In addition, gabions can correspond to terrain.	• Box culvert is superior from viewpoint of economics due to small drain width. • Bridge passes larger volume of flood water than box culvert and can keep smooth flow.
Evaluation	○	① ○ ② B-1 and B-2 are selected in consideration of ease of construction.	Adoption of Alternative C-2	Bridge alternative is adopted.
Comments	• Existing roads are improved as year-round traffic routes. • Maintenance cost lowered as a result of less deterioration from half of inundation. • In order to lighten increase of water pressure to embankment as the rise of the road level, new drainage structures are placed.	① adoption at construction time ② Both alternatives are applied to the following sections; B-1: Section of road inundation sustaining great damages on the slopes but where is observed embankment materials of better quality. (Thnolekeng - No.2 Bridge) B-2: Section where one of the causes of collapse is assumed to be filling materials with high coefficient of penetration. (No.2 Bridge- Bathey)	• Gabions are installed at the place around new drainage structures where will be an increase of velocity of the flood flow.	• Necessary scale of bridges are planned at collapsed sections in order to ensure smooth flood flow. • New bridges are required to include the function of drainage control for irrigation of adjacent rice paddies.
Location	Sta.15+600 ~ Sta.26+000	Sta.15+600 ~ Sta.26+000	Around new drainage structures	Br.: Sta.16+656, Sta.19+500, Sta.22+500, Sta.25+326

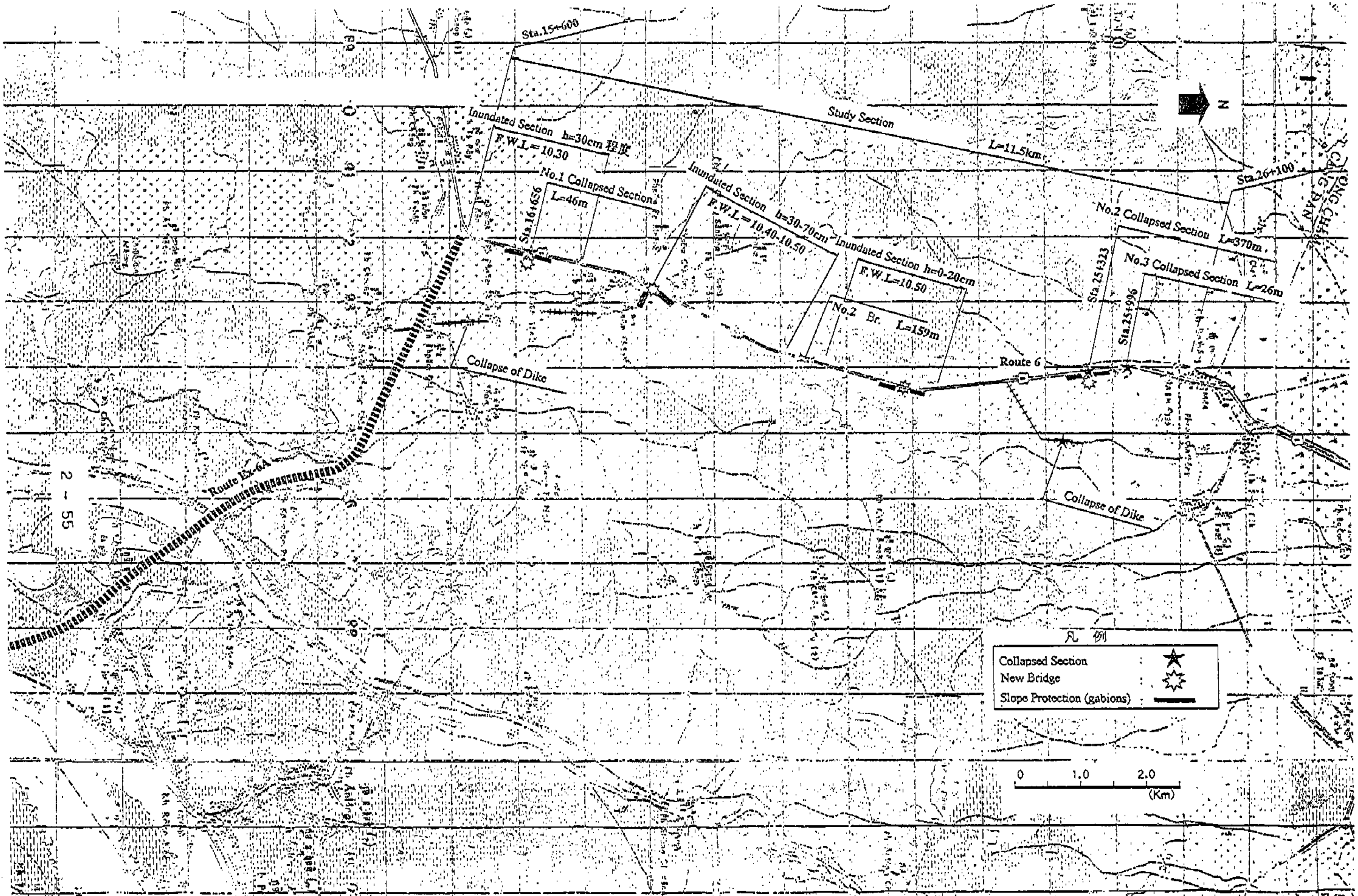


Figure 2-3-9 Damages from 1996 Flood and Countermeasure

9) Basic Design Drawings

For purpose of determining the basic amounts of construction materials, etc., formulating a construction schedule and estimating construction cost; basic design drawings for road improvement and structural improvements (bridges, culvert) were put together. Basic design drawings for the Road Improvement Plan (location map, standard Cross Sections, plan and profile culvert structure diagram) are shown in Figure 2-3-10 to 46 at the end of the Report. Basic design drawings for principal structure improvement (bridges, etc.,) are shown in Figure 2-3-47 to 58.

10) Outline of Project Cost

Principal project costs estimated according to the basic design drawings are shown below:

① Road Improvement
- Widening, raising, bank protection, overlay, etc. L=73km
- Improvements of existing small to medium culverts =19 locations

② New construction of Mekong Bridge connecting road L=2.2km

③ Replacement of principal structures
- Bridges (9) L=313m
- Box culvert one location

④ New bridges construction at three locations (L=162m)

⑤ Quantity of principal materials

Road

Material	Unit	Rehabilitation	Access Road	Total
Embankment material	m^3	635,246	53,593	688,839
Sub base coarse	m^3	196,050	5,235	202,085
Base coarse	m^3	117,285	3,807	121,092
Asphalt pavement	m^2	505,050	18,550	523,600
Bank protection work	m^2	104,903	-	104,903

Principal Structures

Material	Unit	Superstructure	Substructure	Total
Concrete	m^3	2,136.2	3,408.0	5,544.0
Reinforcement bar	t	651.0	259.0	910.0
PC steel wire	t	26.7	-	26.7
RC Pile (square 400 × 400)	m	-	7,695.0	7,695.0