13.2 Pavement Design

13.2.1 Design of Asphalt Pavement

(1) Design Criteria

As explained in Chapter 11, "Design Guide for Pavement Structure" of AASHTO was used as the basis of design procedures. Other relevant standards/manuals, such as "Asphalt Pavement Manual" of Japan Road Association (JRO) and "Road Design Standard; Part II Pavement" of Cambodia were referred as appropriate.

Followings are the summary of the process of pavement design. Detailed explanation of the design is rather lengthy and, thus, given in Appendix G-3.

(2) Calculation of Required Strength of Pavement

Required strength, denoted as SN (Structure Number) is calculated by the following formula:

$$Log_{10} W_{18} = Z_R{*}S_0 + 9.36{*}\log_{10}(SN+1) - 0.20 + \frac{Log_{10}\{\triangle PSI/(4.2 - 1.5)\}}{0.40 + 1094/(SN+1)^{5.19}} + 2.32{*}\log_{10} M_R - 8.07$$

------- (Eq. 1)

Where;

- W_{18} = predicted number of 18-kip equivalent single axle load applications,
- Z_R = standard normal deviate,
- S_0 = combined standard error of the traffic prediction and performance prediction,
- $\triangle PSI$ = difference between the initial design serviceability index, p_0, and the design terminal serviceability index, p_t, and
- M_R = resilient modulus (psi) (of subgrade); calculated from CBR.

Fig. 13-2-1 shows the general flow of design of pavement.

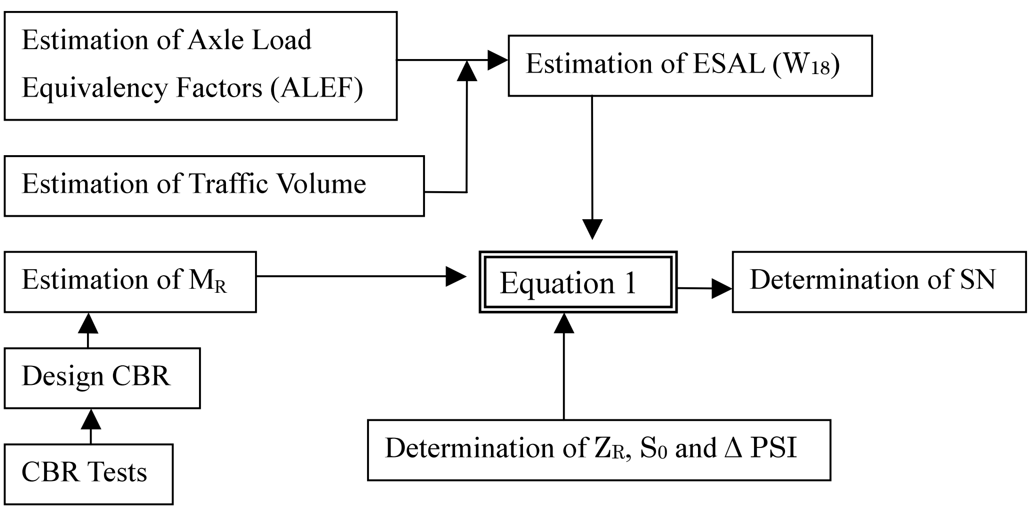


Fig. 13-2-1 General Flow of Pavement Design

(3) Design CBR

Based on the results of various test data, CBR of the existing subgrade was estimated at CBR = 2 for dry (low-water season) and CBR = 7 for high-water season. Since CBR = 2 of high-water season is very small, improvement of subgrade was examined. Preliminary cost comparison showed that chemical (lime or cement) stabilization was more expensive than placement of selected material, and, thus, chemical stabilization was not considered.

The placement of selected material as shown in Fig. 13-2-2 was assumed. The average CBR of the improved subgrade was estimated using the following formula.

$$CBR_{AVE} = [(h_1 \times CBR_1^{1/3} + h_2 \times CBR_2^{1/3} + h_3 \times CBR_3^{1/3})/100]^3$$

As a result, the following CBR values were obtained for dry season and high-water season.

Table 13-2-1 CBR of Improved Subgrade for Dry Season and High-Water Season

Season	Dry Season	High Water Season
CBR	12	7

(Rounded Value)

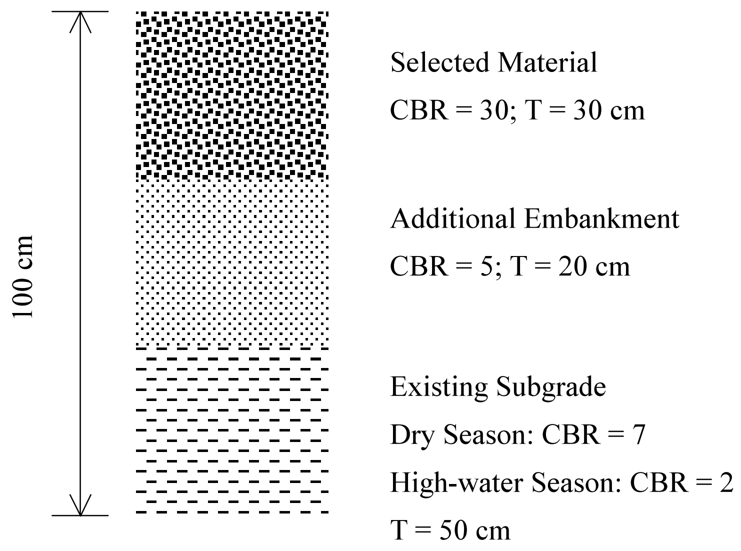


Fig. 13-2-2 Assumed Improvement of Subgrade

Since there is a wide fluctuation of CBR depending on the season, a year-round average of CBR was estimated following the procedure recommended in ASHTO Design Guide. As a result, year-round average of CBR was estimated at **CBR = 9**. This value was used for whole section of the Study Road.

Using CBR = 9, value of M_R was calculated by the following formula.

$$M_R = CBR \times 1{,}500 = 9 \times 1{,}500 = 13{,}500 \text{ (psi)}$$

This value was used in computation of SN.

(4) Estimation of Traffic Volume, Axle Load Equivalency Factor and W_{18}

Number of 18 kips single axle load application, W_{18}, was estimated from estimated traffic volume and Axle Load Equivalency Factor (ALEF).

W_{18} = Total Traffic Volume (for 10 years) x ALEF

Traffic volume forecasted in Chapter 4 was used to calculate the total traffic volume. The design life of the pavement was assumed as 10 years as the standard value stipulated in the Manual of JRO.

Values of ALEF of vehicles were estimated based on the data obtained through the "Vehicle Weight Survey" conducted in this Study (see Appendix G-2). Estimated ALEF for light vehicles and heavy vehicles are as follows:

Table 13-2-2 Estimated Values of ALEF

Vehicle Type	Light Vehicle	Heavy Vehicle
ALEF	0.00356	1.89

Using these data, the following values were obtained as the design W_{18}.

Table 13-2-3 Design W_{18} of Each Section

Section	Sta.	~	Sta.	Light Vehicle		Heavy Vehicle		Total ESAL (2 Direction)	Total ESAL (1 Direction)	Design ESAL (W_{18})
				Traffic Vol. 2006-2015	ESAL	Traffic Vol. 2006-2015	ESAL			
A	0.0	~	3.5	65.732	0.234	6.812	12.876	13.110	6.555	6.56
B	3.5	~	7.0	32.314	0.115	5.516	10.424	10.539	5.270	5.27
C	7.0	~	14.1	22.143	0.079	4.345	8.212	8.291	4.146	4.15
D	14.1	~	25.2	12.975	0.046	2.841	5.370	5.416	2.708	2.71
E	25.2	~	36.3	11.627	0.041	2.575	4.866	4.908	2.454	
F	36.3	~	46.8	10.653	0.038	2.333	4.409	4.447	2.223	2.22
G	46.8	~	55.4	10.362	0.037	2.262	4.275	4.312	2.156	

(Unit: million)

Based on the values of W_{18}, The Study road was divided into the following sections for the purpose of pavement design.

Table 13-2-4 Sections of Pavement Design and Design ESAL (W_{18})

Pavement Design Section	1	2	3	4	5
Station	Start – 3.5	3.5 - 7	7 -14	14 – 36	36 - End
Pk (MPWT)	5.6 – 9.1	9.1 – 12.6	12.6 – 19.6	19.6 – 41.6	41.6 - End
Design ESAL (W_{18})	6.56	5.27	4.15	2.71	2.22

(5) Determination of Z_R, S_0, and △PSI

Values of Z_R, S_0, and △PSI were assumed at the standard values shown in AASHTO Design Guide as follows:

Table 13-2-5 Values of Z_R, S_0, and ⊿PSI

Z_R:	- 0.674	(R = 75 %: typical value shown in AASHTO Design Guide)
S_0:	0.450	(typical value shown in AASHTO Design Guide)
⊿PSI:	1.9	(= 4.4 – 2.5: typical value shown in AASHTO Design Guide)

(6) Calculation of SN

Substituting the values described in (3) – (5) above, required SN for each section was calculated as flows. Actual computation was made by computer.

Table 13-2-6 Required SN for Each Section

Section	1	2	3	4	5
Station	Start – 3.5	3.5 - 7	7 -14	14 – 36	36 - End
Pk (MPWT)	5.6 – 9.1	9.1 – 12.6	12.6 – 19.6	19.6 – 41.6	41.6 - End
ESAL (W_{18})	6.56	5.27	4.15	2.71	2.22
CBR	9				
Calculated SN	3.345	3.231	3.111	2.906	2.815

(7) Comparison of Cost for Alternatives of Pavement Structure

Two to three alternatives were assumed for each section. These alternatives were selected to satisfy the required SN and also to satisfy the requirement for minimum thicknesses of surface course and base course. These requirements are shown in Tables 13-2-7 and 13-2-9

Table 13-2-7 Minimum Thickness of Surface Course

Class of Design Traffic Volume	Thickness (cm)
L, A	5
B	10 (5)*
C	15 (10)*
D	20 (15)*

* Thickness in ( ) can be used where the base course material is asphalt-stabilized.

The classes of traffic volumes used in the above table are as defined in the following table.

Table 13-2-8 Class of Traffic Volume (for Minimum Thickness of Surface Course)

Class of Design Traffic Volume	Traffic Volume of Heavy Vehicles (Vehicle/day/direction)
L	Less than 100
A	100 – 249
B	250 – 999
C	1,000 – 2,999
D	3,000 or more

Table 13-2-9 Minimum Thickness of Base Course and Subbase Course

Material/Construction Method	Minimum Thickness of Layer
Asphalt-stabilized	2 times of the maximum grain size and 5 cm
Other than above	3 times of the maximum grain size and 10 cm

In case of NR-1, traffic volumes of Sections 1 through 3 are categorized as Class B and those of Sections 4 and 5 are categorized as A. Accordingly, minimum thicknesses of surface course for these Sections are 10 cm and 5 cm, respectively. The structures of the alternatives for each section are shown in the table below.

Table 13-2-10 Alternatives of Pavement Structure

Section			1	2	3	4	5
Station			Start - St. 3	St. 3 - 7	St. 7 - 14	St. 14 - 36	St. 36 - End
Required SN			3.345	3.231	3.111	2.906	2.815
ALT 1	Surface	Thick. (cm)	10	10	10	5	5
		SN	1.654	1.654	1.654	0.827	0.827
	Base	Thick. (cm)	20	20	15	25	25
		SN	0.827	0.827	0.620	1.033	1.033
	Subbase	Thick. (cm)	24	21	24	29	27
		SN	0.869	0.761	0.869	1.050	0.978
	Total SN		3.350	3.241	3.143	2.911	2.838
	Total Thickness (cm)		54	51	49	59	57
ALT 2	Surface	Thick. (cm)	10	10	10	5	5
		SN	1.654	1.654	1.654	0.827	0.827
	Base	Thick. (cm)	15	15	20	20	20
		SN	0.620	0.620	0.827	0.827	0.827
	Subbase	Thick. (cm)	30	27	19	35	32
		SN	1.087	0.978	0.688	1.268	1.159
	Total SN		3.360	3.252	3.169	2.921	2.813
	Total Thickness (cm)		55	52	49	60	57
ALT 3	Surface	Thick. (cm)	10	-	-	10	10
		SN	1.654	-	-	1.654	1.654
	Base	Thick. (cm)	25	-	-	15	15
		SN	1.033	-	-	0.620	0.620
	Subbase	Thick. (cm)	19	-	-	18	15
		SN	0.688	-	-	0.652	0.543
	Total SN		3.375	-	-	2.926	2.817
	Total Thickness (cm)		54	-	-	43	40

The result of cost comparison of Alternatives is shown in the table below.

Table 13-2-11 Cost Comparison of Alternatives of Pavement Structure

Section			1	2	3	4	5
Station			Start - St. 3	St. 3 - 7	St. 7 - 14	St. 14 - 36	St. 36 - End
ALT 1	Surface	Thick. (cm)	10	10	10	5	5
		Cost*	2.067	2.067	2.067	1.000	1.000
	Base	Thick. (cm)	20	20	15	25	25
		Cost*	0.766	0.766	0.544	0.926	0.926
	Subbase	Thick. (cm)	24	21	24	29	27
		Cost*	0.813	0.727	0.813	0.956	0.898
	Total Cost*		3.646	3.560	**3.423**	**2.882**	2.824
ALT 2	Surface	Thick. (cm)	10	10	10	5	5
		Cost*	2.067	2.067	2.067	1.000	1.000
	Base	Thick. (cm)	15	15	20	20	20
		Cost*	0.544	0.544	0.766	0.766	0.766
	Subbase	Thick. (cm)	30	27	19	35	32
		Cost*	0.984	0.898	0.607	1.139	1.041
	Total Cost*		**3.595**	**3.509**	3.440	2.905	**2.808**
ALT 3	Surface	Thick. (cm)	10	-	-	10	10
		Cost*	2.067	-	-	2.067	2.067
	Base	Thick. (cm)	25	-	-	15	15
		Cost*	0.926	-	-	0.544	0.544
	Subbase	Thick. (cm)	19	-	-	18	15
		Cost*	0.607	-	-	0.578	0.493
	Total Cost*		3.600	-	-	3.190	3.104

*Unit of Cost: Cost of AC surface course = 1.000

As can be seen in the above table, the most economical Alternatives in each sections are as the following. Consequently, these Alternatives are recommended.

Section 1: Alternative 2
Section 2: Alternative 2
Section 3: Alternative 1
Section 4: Alternative 1
Section 5: Alternative 2

It is often considered in practice to adopt uniform thickness for surface course (and also for base course) for all the sections and adjust the structure number of the pavement structure by adjusting the thickness of subbase course. This practice is done for easier preparation of works and less chance of error in the actual construction work. For this reason, possibility of adopting 10 cm thick surface for Sections 4 and 5 was considered. However, the costs of pavement structure with 10 cm-thick surface course are higher than those with 5 cm-thick surface course by approximately 10 % for both Section 4 and Section 5. Therefore, adoption of 10 cm-thick surface course is not recommended for Sections 4 and 5.

Table 13-2-12 and Fig. 13-2-3 illustrates the recommended pavement structures.

Table 13-2-12 Summary of Pavement Structure

Section		1	2	3	4	5
Station		Start – 3.5	3.5 - 7	7 - 14	14 - 36	36 - End
Pk (MPWT)		5.6 – 9.1	9.1 – 12.6	12.6 – 19.6	19.6 – 41.6	41.6 - End
Pavement Type		A	B	C	D	E
Surface	Thick. (cm)	10	10	10	5	5
	SN	1.654	1.654	1.654	0.827	0.827
Base	Thick. (cm)	15	15	15	25	20
	SN	0.620	0.620	0.620	1.033	0.827
Subbase	Thick. (cm)	30	27	24	29	32
	SN	1.087	0.978	0.869	1.050	1.159
Total SN		3.360	3.252	3.143	2.911	2.813
Total Thickness (cm)		55	52	49	59	57
Required SN		3.345	3.231	3.111	2.906	2.815

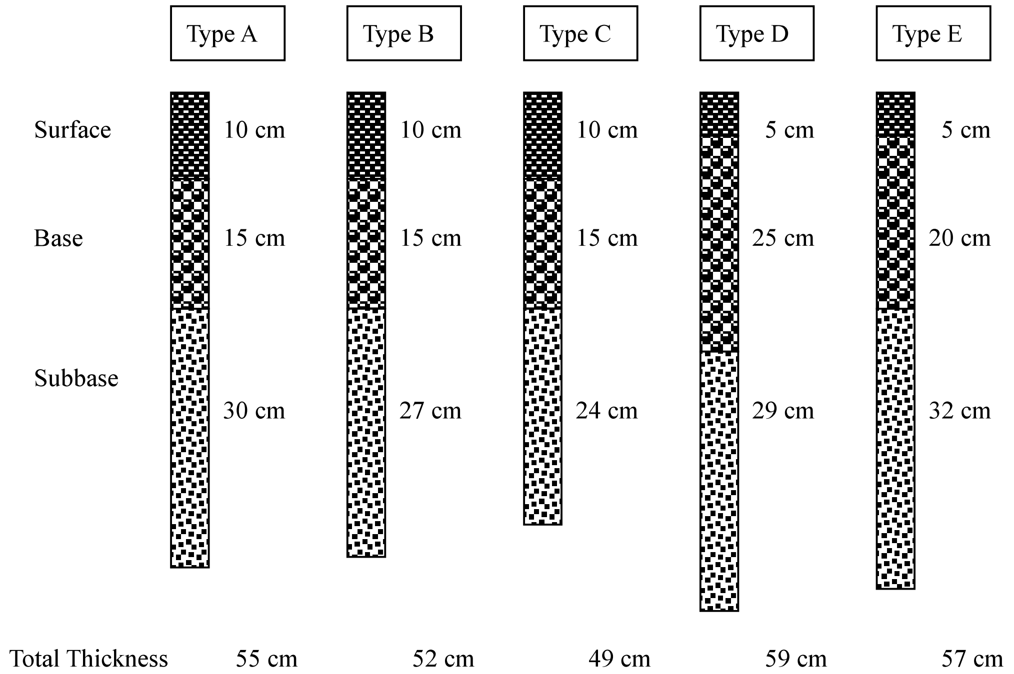
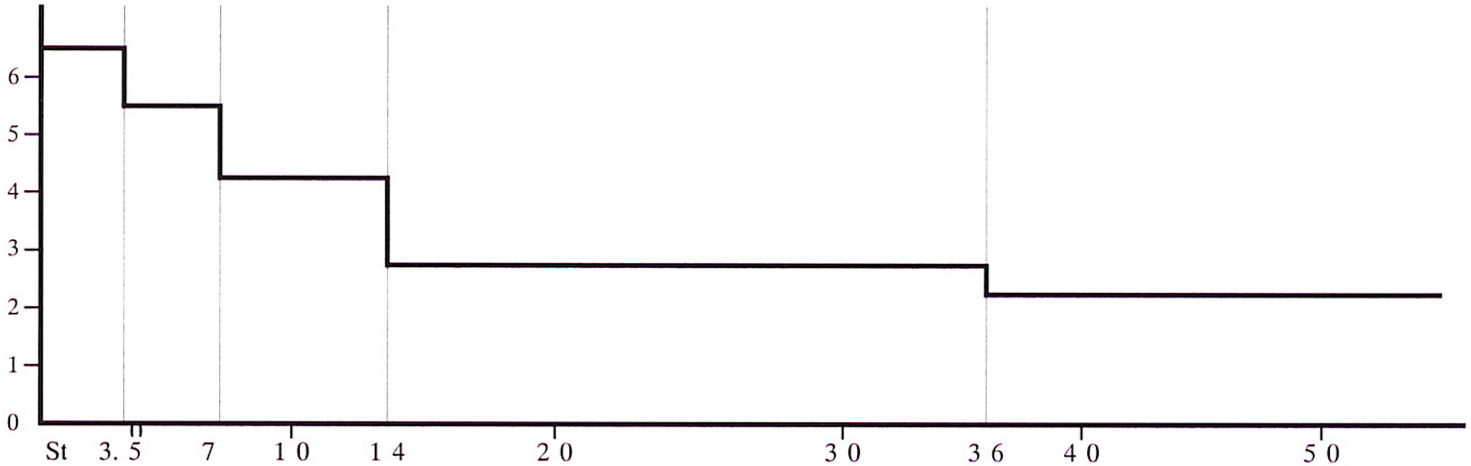


Fig. 13-2-3 Recommended Pavement Structure

(8) Summary

The assumed conditions and calculated SNs are summarized in Fig. 13-2-4.

Daily Traffic Volume (2005)					
L. V.	11,234	5,530	3,613	2,080	1,722
H. V.	1,197	969	739	482	399
ESAL (mil)	6.56	5.57	4.15	2.71	2.22



Design CBR					
Existing Embankment	CBR = 2				
Improved Subgrade	CBR = 9				
Required SN	3.345	3.231	3.111	2.906	2.815
Pavement Type	A	B	C	D	E
Anticipated SN	3.360	3.252	3.143	2.911	2.838

Fig. 13-2-4 Summary Diagram of Pavement Design

13.2.2 Consideration on Type of Pavement

Asphalt concrete (AC) pavement is recommended in this Study mainly for the following reasons.

(i) Longer life period and less maintenance cost

This is very important under present financial condition of Cambodian Government. The Government of Cambodia is currently in serious shortage of fund to carry out proper maintenance. Therefore, effort should be made to reduce maintenance cost. Because of shortage in road fund, it is also difficult to rehabilitate the damaged pavement. Therefore, life period pavement should be long enough.

(ii) To support heavy traffic

The traffic on the Study Road is heavy even among the principal national roads. To support this heavy traffic, less strong type of pavement, such as DBST is not suitable. AASHTO Design Guide stipulates that "surface treatment" be used for light traffic volume with total W_{18} less than 50,000. (The smallest W_{18} of the Study Road is more than 2 million or 40 times of this criterion.)

(iii) DBST is not suitable under rainy environment

Structure of pavement needs to be examined from two points; distribution of load and durability against climate. One of the important functions of surface course is to block the water to penetrate into base course and subbase course. The treated surface of DBST is not dense and not thick enough to sufficiently block the rain water. Accordingly, rain water penetrates into base course and other materials reducing the bearing capacities of these materials. Therefore, DBST is not suitable for the rainy environment which is the case in Cambodia.

C2 section of NR-1 is currently being improved under financial assistance of ADB. DBST is adopted as the pavement for C2 Section in accordance with the original design made in the feasibility study[1]. In the same feasibility study, AC was recommended considering heavy traffic of the C1 Section, or the Study Road.

For the same reason as described in (i) through (iii) above, ADB has changed the policy on the recommended type of pavement in Cambodia. It used to recommend DBST. However, AC is recommended for the planned project of improvement of NR-5 an NR-6 from Siem Reap to Thai border for which an ADB loan is currently being negotiated.

13.2.3 Consideration on Periodic Maintenance

(1) Present Situation of Rehabilitation and Maintenance of the Study Road

Currently, maintenance of the Study Road is poor. Rehabilitation of the Study Road was implemented from 1994 to 1996 with financial assistance by ADB. In this improvement, many sections were widened to secure necessary width for 2-lane. Single-layer

[1] TA No. 5649-REG: Greater Mekong Sub-region Infrastructure Improvement; Ho Chi Min City to Phnom Penh Highway Improvement Project, November 1997

bituminous surface treatment (SBST) was adopted for the pavement. The civil work was executed by force account.

In 1997, pot holes started to appear. However, practically no repair could be done because of lack of fund, until 2001. In 2001, urgent repair works were implemented with a fund of Cambodian Government. Total amount of actual expenditure was Riel 2.2 billion or approximately US$ 0.55 million. This amount correspond very approximately 10 % of the cost of new construction of DBST for whole section of 55 km. Since this repair works were implemented as very urgent relief, the quality of the works was not high and the area of repair was limited.

In 2002, severe pot holes are to be repaired as a part of ADB's Emergency Flood Relief Project. In the Bill of Quantity of the contract, total 2,000 m^2 of repair of pot holes and 2,000 m^2 of repair of edge break are listed for the 36 km-long section (Km 24 – 60). This corresponds approximately 2 % of the total area of pavement of this section. (Since these figures are for the original contract, they may vary depending on the actual conditions.)

Table below summarizes these maintenance works.

Table 13-2-13 Summary of Maintenance of the Study Road

Year of Implementation	Type of Works	Total Cost ($ '000)	Fund Source	Remarks
1994 - 96	Road rehabilitation	NA	ADB	Include widening
2001	Urgent repair of pavement	550	RGC*	Limited area and quality
2002	Urgent repair of pavement (Total 4,000 m^2)	(15)**	ADB	A part of "Emergency Flood Relief" Project

*RGC: The Royal Government of the Kingdom of Cambodia
** This is the figure listed in the original contract and may vary depending on the actual conditions.

In addition to the above, very minor maintenance works, such as filling soil in pot holes or placing simple warning signs, usually cut branches of tree, in front of pot holes, are done.

Of course, such situation of maintenance is considered not only undesirable but unacceptable in many other countries. However, because of severe shortage of fund, the Government of Cambodia (RGC), particularly MPWT, is forced to accept this reality.

(2) Future Prospect

As for maintenance of the Study Road, the followings are expected.

1) Reduction in maintenance cost due to adoption of AC surface

As explained in Subsection 13.2.2 above, AC surface is more durable than Bitumen Treated Surface (single layer or double layer) or Macadam type of pavement. Consequently, adoption of AC surface will substantially contribute to reduce repair works and maintenance cost.

2) Establishment of Road Maintenance Unit in MPWT

Both RGC and donors recognize importance of road maintenance. Recently, "Road Maintenance Unit" has been established to enhance the road maintenance. This is a very important step forward to improve the situation of road maintenance. When this Unit will properly function, situation of road maintenance will substantially be improved. However, it should not be forgotten that the newly established Road Maintenance Unit needs stable (reliable) budget allocation and capacity building to fulfill its responsibilities.

3) Securing the Fund

It is evident that stable supply of fund is indispensable for routine maintenance. It is expected that the capacity of tax collection will be recovered and, eventually, the revenue of the Government will increase in the future. With increased revenue, the Government will be able to allocate appropriate amount of maintenance budget.

While it is anticipated that it will take some time before the revenue of the Government will recover, it is proposed that system of collecting maintenance fee is established for the Study Road. This subject is discussed in Chapter 14.

13.2.4 Life Cycle Cost Analysis

To verify the economic justification of usage of AC pavement, life cycle costs (LCC) of AC and DBST are compared. Calculation of LCC was made for Section 5 of the Study Road as the model. The reason for this was that the estimated traffic volume of Section 5 is the smallest among those of the five sections of the Study Road, and, thus, Section 5 is considered to be most suitable for adopting DBST. Detailed explanation of LCC analysis is given in Appendix G-7.

(1) Scenario of Maintenance

Based on the observation of the actual maintenance of the Study Road and NR-4, two scenario of maintenance, "Minimum Maintenance Scenario" and "Acceptable Maintenance Scenario" were assumed, as summarized below.

Table 13-2-14 Acceptable Maintenance Scenario for DBST

Period	Maintenance Work
1st year after construction	No maintenance work
2nd – 6th year	2 % of total pavement area/year: Unit cost = $7.5/ m^2$
7th – 9th year	Rehabilitation of entire pavement, Implemented over 3 year
10th year and after	Repeat the cycle of 1st – 10th year above

Table 13-2-15 Acceptable Maintenance Scenario of AC Pavement

Period	Maintenance Work
1st – 5th year after construction	No maintenance work
6th – 10th year	Repair of pot holes etc: Cost = 0.1 % of new construction per year
11th – 13th year	Overlay implemented: Unit cost = $ 9/ m^2$
14th and after	Repeat the cycle of 1st -13th year above

The following conditions were assumed for calculation of various costs.

Table 13-2-16 Assumed Conditions of LCC Analysis

Item	Assumed Condition or Value	Remarks
Length of Road	18 km	Section 5: St. 36 - 54
Width of Pavement	7.5 m	@3.75 m x 2
Area of Pavement	135,000 m^2	
AC Pavement		
Structure	Type F	Refer Fig. 13-2-2 of Main Text
Unit Cost of New Construction	\$ 22.1/ m^2	Based on the cost estimate used in Subsection 13.2.1 of Main Text
Total Cost of New Construction	\$ 2,983,500	
Unit Cost of Overlay	\$ 9.0/ m^2	Used for budget allocation by DPWT of Phnom Penh
Total Cost of Overlay	\$ 1,215,000	
Unit Cost of Routine Maintenance	\$ 5.5/ m^2	Repair of pot holes: figure used by DPWT of Phnom Penh
DBST		
Structure	19 mm surface treatment	Base and subbase are same to AC
Unit Cost of New Construction	\$ 16.9/ m^2	Estimated for the above pavement structure
Total Cost of New Construction	\$ 2,281,500	
Unit Cost of Rehabilitation	\$ 7.5	Base course and surface reconstructed
Total Cost of Rehabilitation	\$ 1,012,500	
Unit Cost of Routine Maintenance	\$ 5.5/ m^2	Figure used for budget allocation by DPWT, Phnom Penh

The result of the calculation is summarized in the table below. As can be seen in the table above, LCC of AC is higher than that of DBST by 14 % for “Minimum Maintenance Scenario” and by 16 % for “Acceptable Maintenance Scenario”. Therefore, from economic viewpoint, DBST is desirable. However, as explained Subsection 13-2-2 above, AC pavement has many advantages over DBST which cannot be quantified and included in LCC analysis. Considering these advantages, it is recommended to adopt AC pavement.

Table 13-2-17 Summary of LCC Calculation

	LCC (\$1,000)		
	AC	DBST	AC/DBST
Minimum Maintenance	3,111	2,729	1.14
Acceptable Maintenance	3,328	2,867	1.16

13.3 Preliminary Design for Opening Structures

13.3.1 Design Concept for Opening Section

Based on the flood condition and hydraulic study, necessity of openings along the NR-1 (C-1 Section) shall be studied. The definition for openings is as follows. The bridges or culverts will be applied for the openings.

Openings by Bridge

Selecting openings at some locations, the invert level or design river bed will principally be set at the same elevation of the surrounding ground elevation, so that only flood water will go through the bridge when the flood water level become higher than the ground elevation.

Regarding the invert level or design river bed, the bridge opening will make minimum adverse impacts to agriculture in the Colmatage area where harvesting of rice in the low-lying area of should be finished by the timing of the occurrence of higher flood water level.

Shape of the opening of bridge will be set as trapezoidal section with slope of 1:1 or 1:1.5 at both sides of the opening under the appropriate protection for abutments by wet masonry or others.

Considering local scouring around the bridge piers and surrounding area, river bed protection around the bridge shall be studied.

Openings by Culverts

For the culverts, invert level will also be set at the same elevation of the surrounding ground level, so that to minimize the adverse effect to the harvesting of rice.

Utilizing the culverts for Colmatage system, invert water level will be set at the bottom elevation of the canal of Colmatage. Furthermore, inlet of the culvert will designed so that stop logs can be installed at the inlet part of the culvert.

Considering local erosion and scouring around the inlet and outlet of culverts, bank protection and protection of ground around the inlet and outlet will be provided.

13.3.2 Alternative Location and Scale for Opening Structures

(1) Basic Design Policy

In accordance with hydrological/ hydraulic studies in previous chapters, such as results of the field investigation, topographic survey, hydrological/ hydraulic analysis and geological features, proposed locations and types/ scale for opening structures shall be considered to apply along the project road NR-1, C-1 Section.

Four types for opening structures will be standardized and applied as listed in Table 13-3-1.

Table 13-3-1 Standardized Type for Opening Structures

Type No.		Scale	Consideration of Type
Type A: Bridge	A-1	Length 50m = 2@25m	Superstructure: PC- I Girder, or RC T Girder Foundation: Pile Foundation, estimated pile length 20-30m Bearing layer: depth 25-35m from ground level
	A-2	Length 75m = 3@25m	
	A-3	Length 100m= 4@25m	
	A-4	Length 150m= 6@25m	
	A-5	(Length more than 150m)	
Type B: Box Culvert	B-1	1-Cell 2.0m= 1@ 2.0*4.0-6.0m	Box Body: RC structure, only for water flow Foundation: RC pile square 30cm, l=12m*
	B-2	2-Cell 4.0m= 2@ 2.0*4.0-6.0m	
	B-3	3-Cell 6.0m= 3@ 2.0*4.0-6.0m	
Type C: Box Culvert with Gate System	C-1	1-Cell 2.0m= 1@ 2.0*4.0-6.0m	Box Body: RC structure, with simplified gate system Foundation: RC pile square 30cm, l=12m*
	C-2	2-Cell 4.0m= 2@ 2.0*4.0-6.0m	
	C-3	3-Cell 6.0m= 3@2.0*4.0-6.0m	
Type D: Pipe Culvert	D-1	1-pipe ϕ 1.0m	Pipe Body: RC pre-cast. With round concrete cover Foundation: Spread

*same length as new water gate constructed Japan Grant Aide, for NR No.1 in 2002

(2) Proposed Alternative Locations for Opening Structures (Bridges and Box Culverts)

a) Flow Section for Existing Bridges and Culverts

The flow section (area: m^2) for existing structures along the project road was investigated from field inventory survey is listed as following Table 13-3-2.

Table 13-3-2 Flow Section of Existing Structures

No.	Existing Station (Km)	Kind of Structure	Flow Section (A)
2	24+000	Steel Pipe Culvert (ϕ0.5m*1)	0.20 m^2
3	24+840	RC Pipe Culvert (ϕ1.0m*1)	0.79 m^2
4	28+450	New 3 Water Gate	42.5 m^2
5	31+120	New 3 Water Gate	42.5 m^2
8	38+923	New 3 Water Gate	42.5 m^2
9	41+040	Old 2 Water Gate	45.4 m^2
10	42+830	Bailey Bridge (99m Length)	600 m^2
11	45+776	New 3 Water Gate	42.5 m^2
12	47+967	Bailey Bridge (66m Length)	200 m^2
13	50+040	Old 3 Water Gate	25.2 m^2
Total Flow Section (Opening Section)			1,042 m^2

The river section for scale of bridge shall be determined to consider surrounding terrain and flood flow conditions.

Based on **Flood and Flood Mitigation of Chapter 9**, alternative cases are classified as A-1, A-1a, A-2, A2a, B-1 and B-2, according to the design inflow capacity from NR-1 (C1 section) to Colmatage area.

b) Scale of Proposed Alternative Bridges

From the hydrologic/ hydraulic studies, the scale of alternative project bridges is planned defining HWL. and design river section as shown in below Fig.13-3-1 and Table 13-3-3.

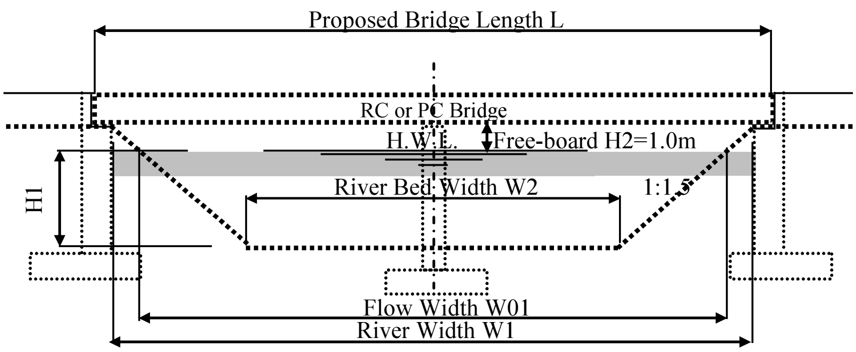


Fig. 13-3-1 Design River Section for Proposed Bridge

Table 13-3-3 Scale of Proposed Alternative Bridges

Alternatives		H1+H2	H.W.L	Design Bed	W01	W1	W2	Bridge Length (Span @)
A-1	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	143.9	146.9	130.0	150.0 (6@25.0)
	Cut-off No.2 (Km47+967)	4.30+1.00	8.28	4.30	59.9	62.9	47.0	66.0 (3@22.0)
A-1a	Cut-off No.01(Km42+400)	4.63+1.00	8.53	3.90	57.9	60.9	44.0	63.0 (3@21.0)
	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	94.9	97.9	81.0	100.0 (4@25.0)
	Cut-off No.2 (Km47+967)	4.30+1.00	8.28	4.30	59.9	62.9	47.0	66.0 (3@22.0)
A-2	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	143.9	146.9	130.0	150.0 (6@25.0)
A-2a	Cut-off No.01(Km42+400)	4.63+1.00	8.53	3.90	57.9	60.9	44.0	63.0 (3@21.0)
	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	94.9	97.9	81.0	100.0 (4@25.0)
B-1	Cut-off No.01(Km42+400)	4.63+1.00	8.53	3.90	58.9	61.9	45.0	66.0 (3@22.0)
	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	94.9	97.9	81.0	100.0 (4@25.0)
	Cut-off No.2 (Km47+967)	4.30+1.00	8.28	4.30	59.9	62.9	47.0	66.0 (3@22.0)
B-1a	Cut-off No.01(Km42+400)	4.63+1.00	8.53	3.90	85.9	88.9	72.0	92.0 (4@23.0)
	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	94.9	97.9	81.0	100.0 (4@25.0)
B-2	Cut-off No.01(Km42+400)	4.63+1.00	8.53	3.90	85.9	88.9	72.0	92.0 (4@23.0)
	Cut-off No.1 (Km42+820)	4.62+1.00	8.52	3.90	94.9	97.9	81.0	100.0 (4@25.0)

c) Scale of Proposed Culverts

The scale of box and pipe culverts is described Type B (box culvert without gate), Type C (box culvert with gate) and Type D (pipe culvert) as previous clause.

Due to flow capacity for the each alternative, the culverts are planned on the project road considering hydrological/hydraulic studies, geographical conditions and surrounding features.

13.3.3 Selection of Structural Type for Bridge and Culvert

(1) Selection of Bridge Type

In the light of present construction/ situation of the structures in Cambodia, structure types for the project shall be summarized as below considerations.

<u>Super Structure Type</u>

The general relation of superstructure type and appropriate span length with ratio of girder height and span length are shown in Table 13-3-4.

Table 13-3-4 Relation between Superstructure Type and Span Length

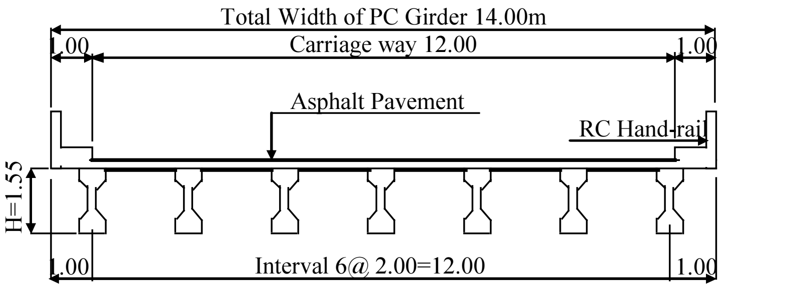
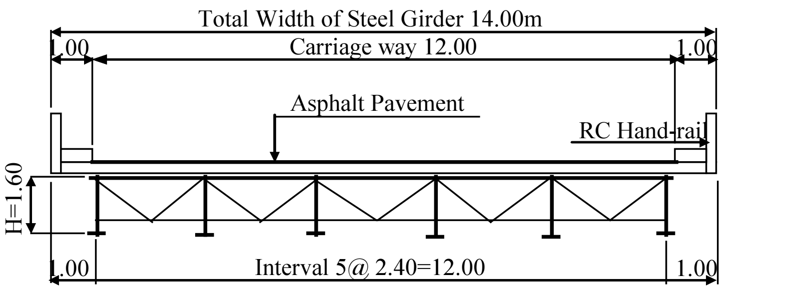
Type of Bridge		Span Length(m) 20 30 40 50	Girder height/ Length
RC Bridge	Simple Slab		1／13～17
	Simple/continuous Hollow Slab		1／17～20
	Simple/Splice/Continuous T-shape Girder		1／13～17
	Simple Box Girder		1／18
	Continuous Box Girder		1／20
PC Bridge	Simple Slab		1／18
	Simple/continuous Hollow Slab		1／18～22
	Simple T,I-shape Girder		1／15～18
	Simple/continuous Box Girder		1／18～22
Steel Bridge	Simple H-shape Beam		1／22
	Simple I-shape Girder		1／17
	Continuous I-shape Girder		1／18
	Continuous Box Girder		1／18～20

(═══ :Applied Type to the Project)

Regarding to the type of superstructure, almost of reinforced concrete (RC) and pre-stressed concrete (PC) girders were constructed in the past and at present on account of availability of materials, cost and construction method.

The steel Bridge is required long term maintenance, and higher cost than RC/PC girders. The detailed comparison between pre-stressed concrete (PC) and steel bridge for the characteristics is shown in Table 13-3-5.

Table 13-3-5 Comparison of Characteristics between PC Bridge and Steel Bridge

Case-A: PC -I Girder	
Characteristics	1 Construction Cost : Low (index 1.00) 2 Construction Period: Longer (6 months) 3 Construction Method: Girder erection, Crane (weight 36 ton/no.) 4 Maintenance: Not need 5 Materials: PC Cable/tensioning to be imported
Case B: Steel I Girder	
Characteristics	1 Construction Cost: Higher (index 1.53) 2 Construction Period: Shorter (4.5 months) 3 Construction Method: Crane, Easier to erection, Need skilled labors (Assembly) 4 Maintenance: Need repainting for long term etc, 5 Materials: All of Steel materials to be imported

The concrete bridge (RC or PC) is selected in viewpoints of characteristics of above table, especially compared construction cost and maintenance and materials.

The whole comparison for bridge type (super, sub-structure and foundation) is to be summarized as span arrangement in next clause.

<u>Substructure Type</u>

The type of substructure is selected based on the scale of superstructure (girder length, weight, etc.), the height of substructures, river section and geological conditions. The standard substructure types are shown in Table 13-3-6.

Table 13-3-6 Relation between Substructure Type and Height

Type of Abutment	Structure Height (m)			
	10	20	30	
Gravity				
Reversed T-shape				
Buttres				
Rigid Frame				
Box				

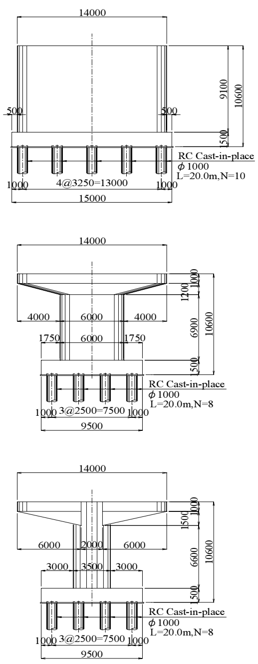
Type of Pier	Structure Height (m)			
	10	20	30	
Wall, Column				
Two-column				
Rigid Frame				

Application:

The type of abutment shall be reinforced concrete reversed T type on account of superstructure scale with 15 to 30 meters girder length, abutment height with 5 to 10 meters, economy and easier construction.

The comparison of pier types is shown in Table 13-3-7. The type of pier is selected reinforced concrete T type with elliptic column in the point of 10 to 15 meters height and river section.

Table 13-3-7 Comparison for Pier Type

		stics	Evaluation
		ıy (Index 1.35) ǐood	
		ex 1.00)	Applicable
		)1)	

Foundation Type

The standard applicable pile types are shown in Table 13-3-8. Based on the scale of superstructure, geological conditions and depth of bearing stratum, the type of foundation is to be selected.

Table 13-3-8 Foundation Pile Types

Foundation Type		Depth to Bearing Layer (m) 10 / 20 / 30 / 40	Reference
Spread Footing			
Pile Foundation	Reinforced Concrete (dia. 30-50cm)		Small/Medium Bridge
	Prestressed Concrete (dia. 50-100cm)		Medium/small Bridge
	Steel Pipe Pile (dia. 60-150cm)		Big/Medium Bridge
	Cast-in-place Concrete (dia.80-200cm)		Big/Medium Bridge
	Bearing Layer for the Project Area	20-30m under foundation. Medium silty clay layer more than N-value 27	

: Application (for box culvert: 5-15m under foundation. Silty clay layer more than N-value 5-15)

The pile length at bridge site is estimated 20 to 25 meters in depth with bearing stratum. The pile foundation shall be applied considering kinds of strata of soils, economy, easier fabrication of pile, use of country materials and piling equipment. In the recent years, cast-in-place concrete piles and pre-cast reinforced concrete pile (the dimension is 30 to 40cm) are frequently adopted for pile foundation in Cambodia.

According to the results of geological survey in the project road, bearing stratum for foundations can be seen 20 to 30 meters depth from existing ground. Almost of structures in the project site is to be pile foundation type.

The basis of bearing layer with description of strata at the bridge/gate sites is illustrated as below Fig. 13-3-2.

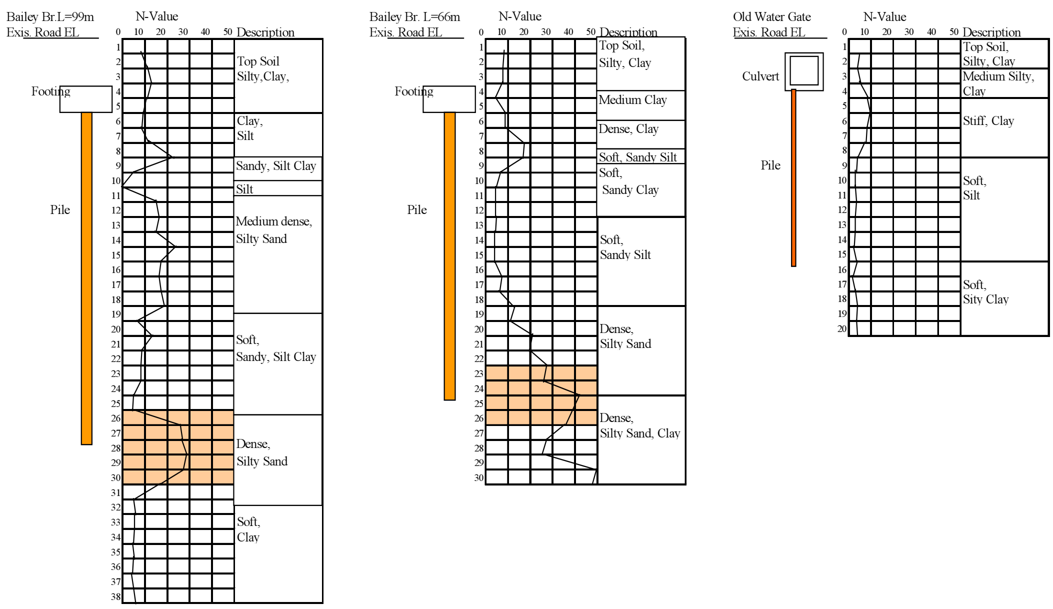


Fig. 13-3-2 Bearing Strata and Pile Length for Project Structures

The pile setting method from engineering characteristics for the large scale of bridges in the project is compared between pile driving and cast-in-place pile as shown in Table 13-3-9.

The cast-in-placed pile set method for the project bridges is selected in viewpoints of pile length and transport, geological data, scale of equipment, surrounding environment, and available materials/ construction experience in Cambodia.

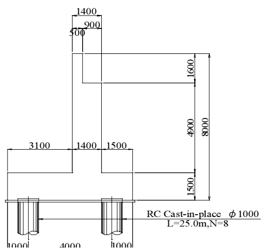
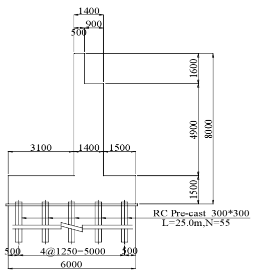
Table 13-3-9 Comparison of Pile Setting Method for Engineering Characteristics

Pile Set Method	for Pile			for Geological Condition			Surrounding Environment
	Quality Cost	Length & Transport	Equipment & Period	Strata (Intermediate)	Bearing Layer	Water Depth	
Pile Driving PC Pile (50-100cm dia.) Steel Pile (60-150cm) **for Big/Medium Bidge**	Quality: Good Cost: Fair Costly include transport for steel pile	Length: Need joints Transport: Long trip, Limit of length	Equipment: Large scale Period: Fair (need robust approach road)	for Loose silt, sand and clay: Possible	Impossible to confirm for pile tip Bearing+friction pile	No limit	Affects for vibration & noise
Cast-in-place RC Pile (80-200cm) (Earth Drill) (Reverse Circulation) **for Big/Medium Bidge**	Quality: Fair Cost: Fair	Length: Possible 45m Transport: No need	Equipment: Small scale Period: Fair	for Loose silt, sand and clay: Possible	Possible to confirm for pile tip Bearing+friction pile	Within 5m (water depth for piling)	No affects

Note: ▭ Advantage

And also, the scale, cost and pile numbers between RC cast-in-place and pre-cast piles for the abutment of bridge are computed and compared as shown in Table 13-3-10.

Table 13-3-10 Comparison for Pile Foundation Type

Type	Dimension (m)	Characteristics	Evaluation
ase A: Cast in Place Concrete Pile		1 Construction Cost: Economy (Index 1.00) 2 Construction: Easy to deep length 3 Construction Period: Shorter 4 Construction Method: Earth Drill/ Reverse circulation Drill	Applicable
		:tion Cost: Economy (Index 1.12) :tion: Difficulty to deep length :tion Period: Longer :tion Method: Driving/ Pre-boring	

From the above reasons and situations, the cast-in-place pile type shall be applied to bridges for the project.

On the other hand, pile foundation for the box culverts were applied for new water gates (JICA) on project road, with 30 cm square concrete pile of 12 meters length (interval 1.4 meters*2.3 meters). This method is an improvement of soft ground to prevent subsidence of culverts, though pile depth is not reached to bearing stratum.

Therefore, the type of pile foundation for the box culvert shall be applied with section of 30 cm square, pile length of 12 meters with interval of 2.0 meters as computed.

The setting method for pipe culvert is directly placed on layer, and/or replaced with sand compaction.

(2) Application for Bridge Type

For the cost estimation of the openings, the comparison for super structural types of bridges with large scaled characteristics such as whole construction cost, method, period, experience, availability of materials, maintenance, affect to river, aesthetic, etc. was studied as below cases 1 to 4 and shown in Table 13-3-11.

Case-1: Reinforced (RC)/Pre-stressed Concrete (PC) Bridge- Span 6@ 16.7 meters
Case-2: Pre-stressed Concrete (PC) Bridge- Span 4@ 25.0 meters
Case-3: Pre-stressed Concrete (PC) Bridge- Span 3@ 33.3 meters
Case-4: Steel I Girder Bridge- Span 4@ 25.0 meters

The appropriate standard type of large scale bridge is pre-stressed concrete I shape girder (span length @ 25 meters). The reasons are shown in Table 13-3-12.

Applicable Type for Opening Bridge:

Case-2: Super Structure: Pre-stressed Concrete (PC) I-shaped Splice Girder, Span @25 meters
Sub Structure: Reinforced Concrete (RC) Reversed T Abutment, Pier
Foundation: Cast-in-place Reinforced Concrete Pile, ϕ1.0 meter L=20-25 meters

The Girder will be spliced on the pier by RC concrete and PC cable (PC cable for crosswise). It will make the bridge surface continuous without expansion joint. Therefore bridge can be maintained easier and with less cost. Appendix C-4 shows the details of the comparison between splice girder and simple girder.

Table 13-3-11 Comparison of Span Arrangement (Bridge Length 100m)

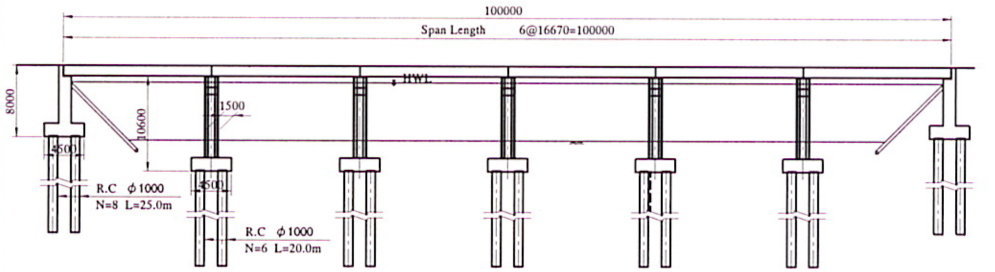
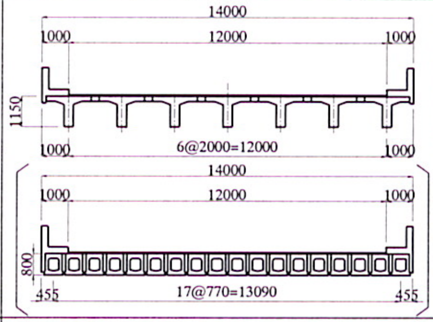
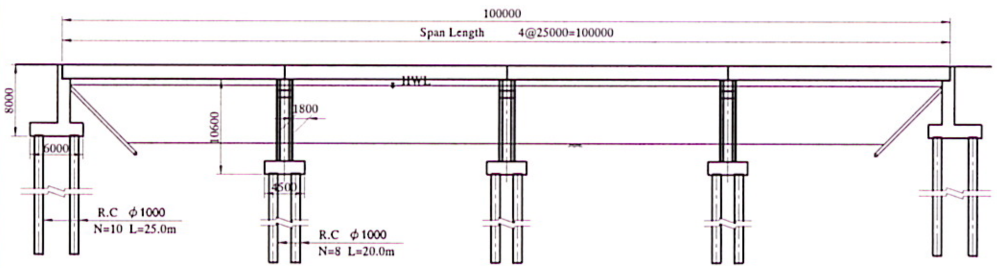
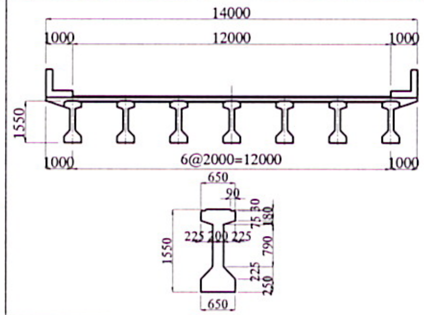
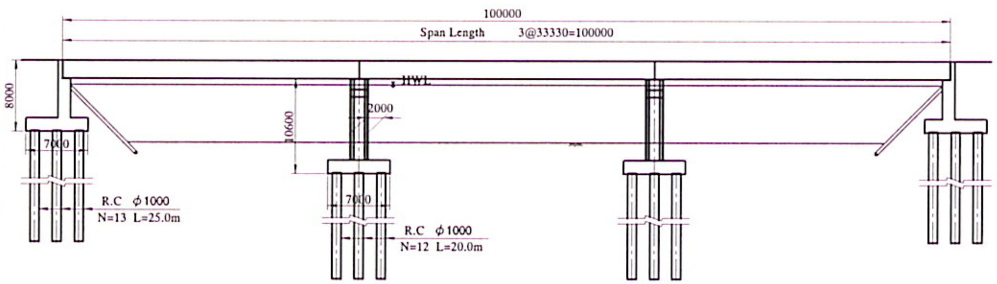
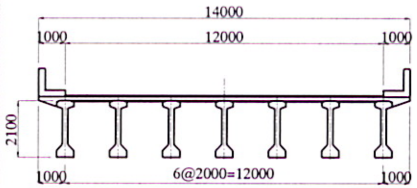
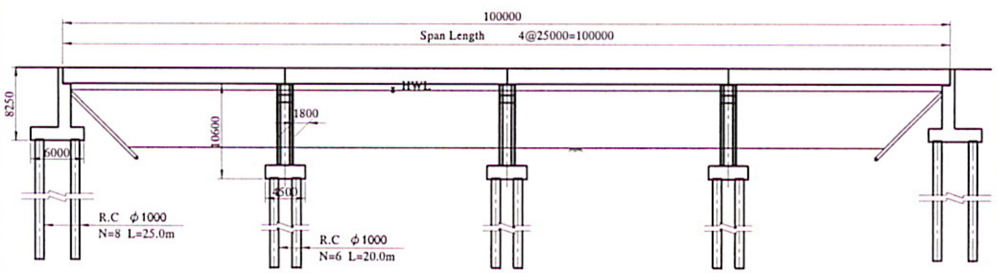
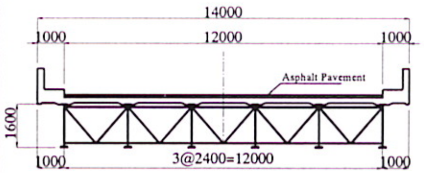
CASE & TYPE	Profile	Cross Section	Characteristics	Evaluation
CASE- 1 6 Span RC-T Girder (PC-hollow (Pretension) Girder) @16.67m			1. Construction Cost: Low (Index: 1.02) [High (Index: 1.39)] 2. Construction Period : Fair 3. Construction : Girders are constructed at site [Construction Yard]. Erection takes longest period due to high number of girders. (Weight: 29.3 [14.6] t/girder) 4. Flow Obstraction Rate by Piers: 7.5 % 5. Others :	
CASE- 2 4 Span PC-I Girder @25.00m			1. Construction Cost: Lowest (Index: 1.00) 2. Construction Period : Fair 3. Construction : Girders are constructed at site. Erection does not take long due to less number of girders. Careful work is needed in errecting girders. (Weight: 36.3 t/girder) 4. Flow Obstraction Rate by Piers: 5.4 % 5. Others :	Appllicable
CASE- 3 3 Span PC-I Girder @33.33m			1. Construction Cost : Low (Index: 1.01) 2. Construction Period : Fair 3. Construction : Girders are constructed at site. Erection takes sortest period due to least number of girders. Careful work is needed in errecting girders. (Weight: 57.5 t/girder) 4. Flow Obstraction Rate by Piers: 4.0 % 5. Others :	
CASE- 3 4 Span Steel Girder @25.00m			1. Construction Cost : Low (Index: 1.53) 2. Construction Period : Short 3. Construction : Girders are imported from Japan. Errection Girder is Necessary. Assemble work is needed at site. Construction cost is highest due to large quantity of import materials and machinary. 4. Flow Obstraction Rate by Piers: 5.4 % 5. Others :	

Table 13-3-12 Characteristics of Selected Bridge Type CASE-2

	Characteristics	Evaluation
1	Rough Construction Cost	Lowest:
2	Construction Period	Fairly Short: 17 months for all construction
3	Construction Method	Fairly Easy: Erection-girder, Girder 36.3ton/no. Experienced construction in Cambodia
4	Availability Materials	Available concrete materials, except PC wire
5	Flow Obstruction by Piers	Fairly: 5.4%, Minimum span length 20m (Japanese Standard)
6	Maintenance	No need
7	Environment	Not affects to surroundings, such as fabrication of girder, piling

(3) Application of Culvert Type

<u>Pipe Culverts</u>

There are 2 pipe culverts on project road NR-1 (C-1 section), as steel pipe culvert (diameter 0.5 meter) and concrete pipe culvert (diameter 1.0 meter). Due to over-age of materials and shortage of culvert length, both culverts shall be replaced with pre-cast reinforcing concrete (RC) pipe culverts of diameter 1.0 meter at the same locations. These locations are closed to housing area. Therefore, to minimize the construction time and to use half lane (more than 6.5 meters) of cross section for traffic flow, the pre-cast reinforcing concrete (RC) pipe culverts shall be applied with concrete lining around outside of pipes for prevention from leakage of water. The setting elevation of culverts is to be measured from topographical, surrounding features, and hydrological/hydraulic aspects.

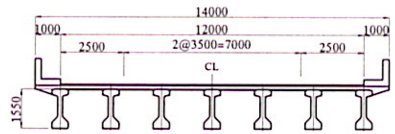
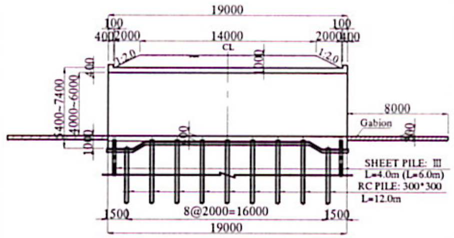
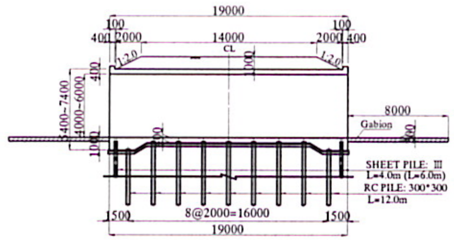
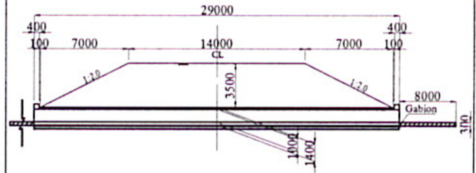
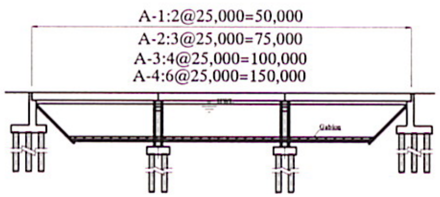
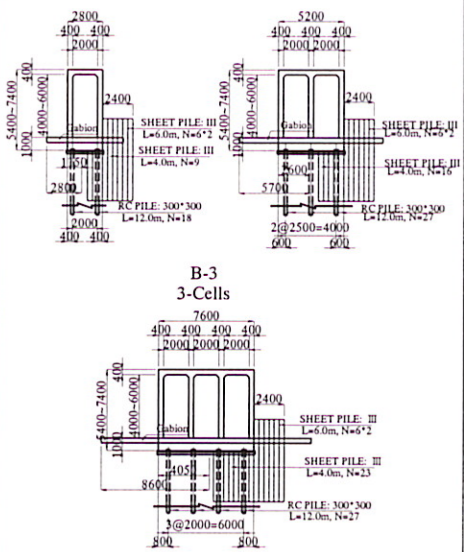
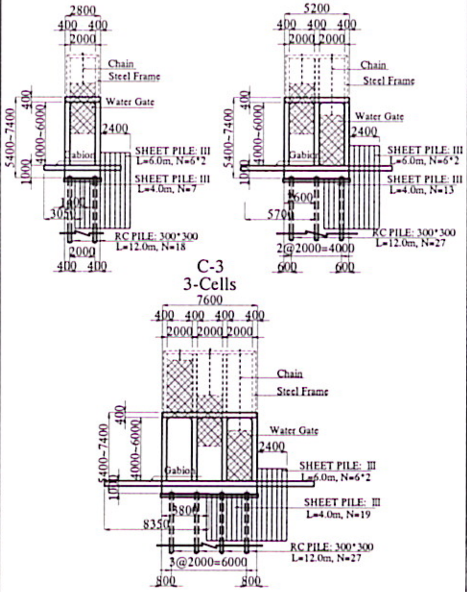
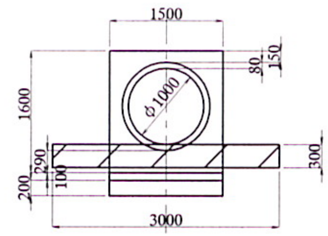
<u>Box culverts</u>

As constructed new water gates by Japan Grant Aid, reinforcing concrete (RC) box culvert type shall be applied to new and existing locations according to hydrological/hydraulic studies in this project. And also, the type with/without gate (stop log) shall be classified and designed. The pile foundation (RC square pile) for the new box culverts shall be adopted as constructed new water gates.

(4) Scale of Opening Structures for Alternative Cases

For the purpose of studying the alternative routes, the construction scales for all cases of structures as bridges and box/pipe culverts were estimated. From the construction experience and project studies, the scales of all applicable cases are estimated as shown in Table 13-3-13.

Table 13-3-13 Specification and Characteristics of Opening Structures

		Case-A Bridge	Case-B Box Culvert	Case-C Box Culvert with Watergate	Case-D Pipe Culvert
General View	Cross Section				
	Profile		B-1 1-Cell; B-2 2-Cells; B-3 3-Cells 	C-1 1-Cell; C-2 2-Cells; C-3 3-Cells 	D-3 
Characteristics		･Discharge Capacity: Large ･Construcrion Dificulties: Fair ･Construction Period: Long ･Construction Cost: High ･Effect to Flood Water level: Large ･Value as Water Resource: Large ･Agricultural Value: Large ･Environmental Aspect: Large	･Discharge Capacity: Fair ･Construcrion Dificulties: Easy ･Construction Period: Short ･Construction Cost: Low ･Effect to Flood Water level: Fair ･Value as Water Resource: Small ･Agricultural Value: Small ･Environmental Aspect: Fair	･Discharge Capacity: Controllable ･Construcrion Dificulties: Easy ･Construction Period: Short ･Construction Cost: Low ･Effect to Flood Water level: Fair ･Value as Water Resource: Large ･Agricultural Value: Large ･Environmental Aspect: Small	･Discharge Capacity: Small ･Construcrion Dificulties: Easy ･Construction Period: Shortest ･Construction Cost: Lowest ･Effect to Flood Water level: Very Small ･Value as Water Resource: Very Small ･Agricultural Value: Small ･Environmental Aspect: Small

(4) Study of Protection Method for Opening Structures Caused Floods

Gabion Mat at design river bed is proposed to protect substructures from scouring. This method is often used and has been effective in Cambodia, as constructed NR-6A, 24th , 25th , and 26th bridges.

a) Bridges

Design length of river bed protection shall be 1.5 times of the potential scouring length. Design width is calculated by the Laursen's Equation applying the assumption of the angles of sudden contraction and enlargement flow as shown in the Fig.13-3-3, below.

The angles are quoted from the report of the project of improvement of bridges on NR-6A (JICA Grant Aid Project). Horizontal angle is on the Fig. 13-3-3 and Longitudinal is 17 degrees for upstream and 14 degrees for downstream respectively.

The results of calculation for 3 cases of bridges are shown in the Table 13-3-14. The bolders with width of 10 meters in front of the protection against local scouring along the down stream end of river bed protection.

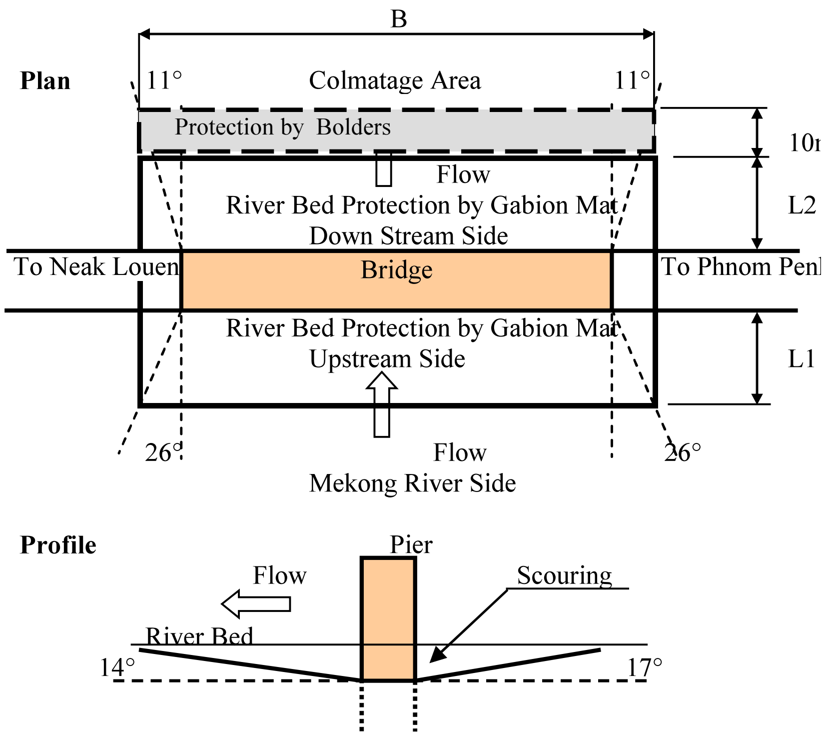


Fig. 13-3-3 Protection Area of Proposed Bridge

Table 13-3-14 List of Protection Area of Proposed Bridge

Protection Area for Opening Bridge

Bridge No.	Bridge Length (m)	Protection Length (m)		Protection Width (m)		
		Upstream L1	Downsream L2	Upstream B1	Downstream B2	**Width**
1 (Cut-off 01	66	**16.50**	**20.00**	82.10	73.78	**82.00**
2 (Cut-off 1)	100	**16.50**	**20.00**	116.10	107.78	**116.00**
3 (Cut-off 2)	66	**16.00**	**19.50**	81.61	73.58	**82.00**

b) Culvert

Design length of the river bed protection for box culverts is assumed to be more than 15 meters, and design width is assumed to be more than double size of culvert itself on both upstream and downstream. Furthermore, boulders shall be placed at down stream side for avoidance of scouring and protection of wet masonry. These hydraulic studies relating protection and scouring shall be referred in chapter 9.

c) Approach Slab for Bridge and Box Culvert

To avoid the differential settlement at approach embankment for bridge and box culvert site, approach slab with reinforcing concrete shall be placed as shown in Fig.13-3-4.

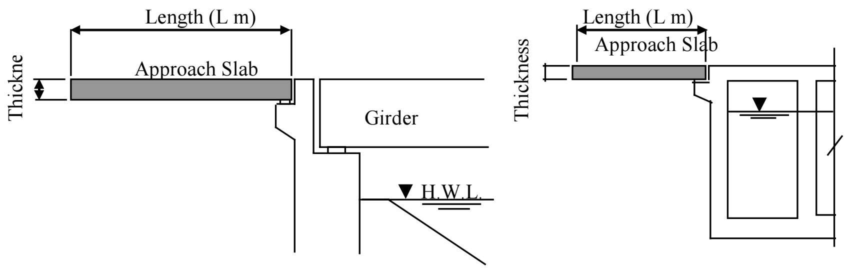


Fig. 13-3-4 Approach Slab for Bridge and Box Culvert

d) Slope Protection for Structures and Embankment

The slope protection applied wet masonry type for bridge embankment sites and eroded road embankment sites (existing Km+19) are to be stabilized against sliding and flood, and are proposed as shown below Fig. 13-3-5.

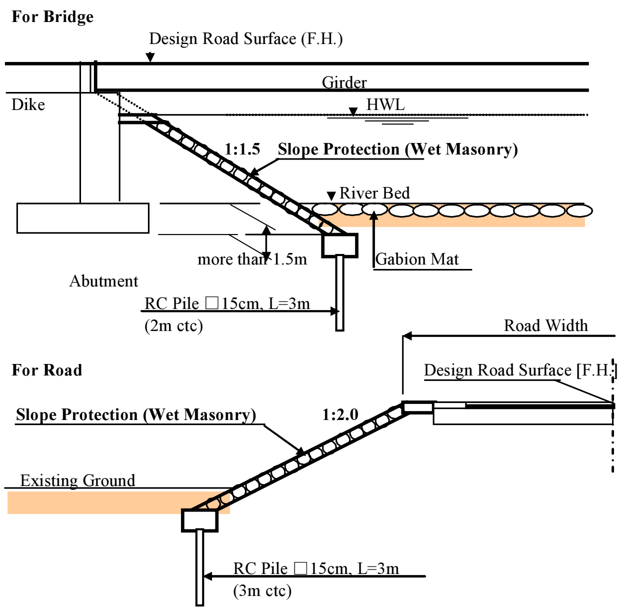


Fig. 13-3-5 Slope Protection Method for Bridge and Road

13.3.4 Preliminary Design and Drawings for Opening Structures

(1) Determination of Location and Scale for Bridges and Culverts

For the purpose of designing of opening structures as bridges and culverts including river protections on project road NR-1, design conditions in detail shall be given from results of topography, geology, hydrology, design standards and the studies. The numbers, scales and locations of structures for preliminary design stage on NR-1 in this project were selected from Chapter 12, Setting and Evaluation of Alternative Plans, as following Fig.13-3-6 and Table 13-3-15.

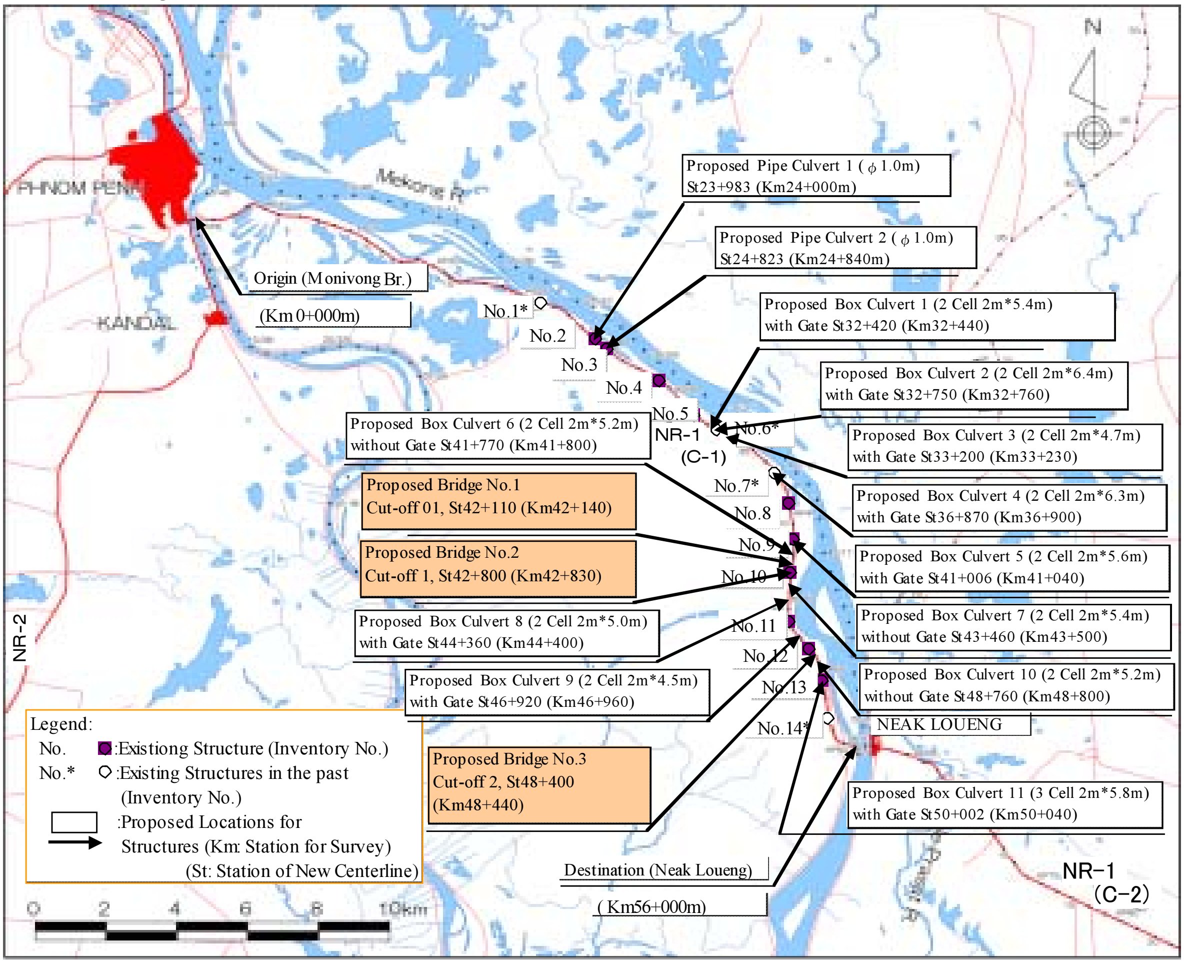


Fig. 13-3-6 Location Map of Opening Structures for Preliminary Design

Table 13-3-15 Opening Structures for Preliminary Design

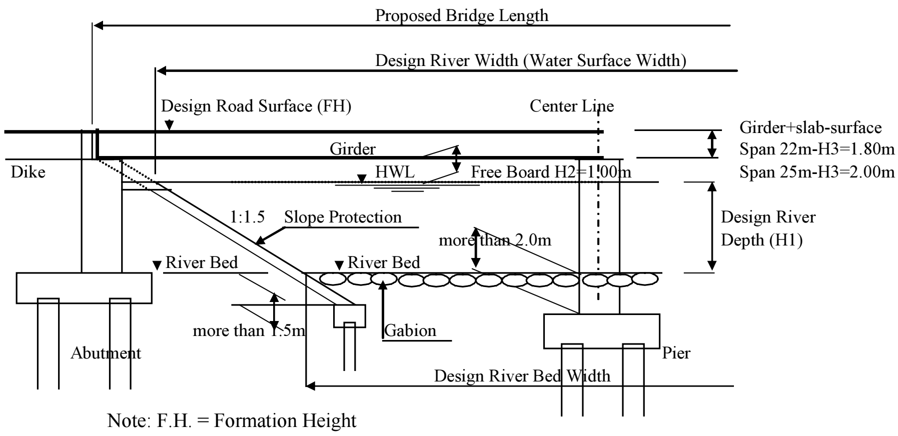
No.	St+	Km+	(Pk+)	Opening Type	Scale and Dimension	Remark
1	St 23 + 983	Km 24 + 000	(Pk 29 + 600)	RC Pipe Culvert 1	Dia. Φ＝1.0m	Replace Pipe Culvert
2	St 24 + 823	Km 24 + 840	(Pk 30 + 440)	RC Pipe Culvert 2	Dia. Φ＝1.0m	Replace Pipe Culvert
3	St 32 + 420	(Km 32 + 440)	(Pk 38 + 040)	RC Box Culvert 1	2 Cell B2.0m*H5.4m	
4	St 32 + 750	Km 32 + 760	(Pk 38 + 360)	RC Box Culvert 2	2 Cell B2.0m*H6.4m	
5	St 33 + 200	(Km 33 + 230)	(Pk 38 + 830)	RC Box Culvert 3	2 Cell B2.0m*H4.7m	
6	St 36 + 870	Km 36 + 900	(Pk 42 + 500)	RC Box Culvert 4	2 Cell B2.0m*H6.3m	
7	St 41 + 006	Km 41 + 040	(Pk 46 + 640)	RC Box Culvert 5	2 Cell B2.0m*H5.6m	Replace Prek Samrong W.G.
8	St 41 + 770	(Km 41 + 800)	(Pk 47 + 400)	RC Box Culvert 6	2 Cell B2.0m*H5.2m	
9	St 42 + 110	Km 42 + 140	(Pk 47 + 740)	PC Bridge No.1	Length 66m (3 @ 22m)	New Cut-off No.01
10	St 42 + 800	Km 42 + 830	(Pk 48 + 430)	PC Bridge No.2	Length100m(4 @ 25m)	Cut-off No.1
11	St 43 + 460	(Km 43 + 500)	(Pk 49 + 100)	RC Box Culvert 7	2 Cell B2.0m*H5.4m	
12	St 44 + 360	(Km 44 + 400)	(Pk 50 + 000)	RC Box Culvert 8	2 Cell B2.0m*H5.0m	
13	St 46 + 920	(Km 46 + 960)	(Pk 52 + 560)	RC Box Culvert 9	2 Cell B2.0m*H4.5m	
14	St 48 + 400	Km 48 + 440	(Pk 54 + 040)	PC Bridge No.3	Length 66m (3 @ 22m)	New Cut-off No.02
15	St 48 + 760	(Km 48 + 800)	(Pk 54 + 400)	RC Box Culvert 10	2 Cell B2.0m*H5.2m	
16	St 50 + 002	Km 50 + 040	(Pk 55 + 640)	RC Box Culvert 11	3 Cell B2.0m*H5.8m	Replace Kampong Phnom W.G.

Note: St = Chainage of Proposed Centerline, Km = Chainage of Present Centerline in Study Area, Pk = Chainage of NR-1 (MPWT)

a) Bridge

Considering design river condition, the scale of bridge such as bridge length, sub structures and alignment of road elevation for preliminary design shall be determined as following Fig.

13-3-7and Table 13-3-16. And also, the control points for alignment of road elevation shall be given from figure and table as below.



Note: F.H. = Formation Height

Fig. 13-3-7 Design Opening Section of Bridges

Table 13-3-16 Design of Bridges and Road Surface Elevation

No.	Chainage	Name Bridge Length	HWL	River Bed EL	H1	H2	H3	Minimum FH of Road Surface
9	**St42+110**	Cut-off No.01	8.55	3.70	4.85	1.00	1.80	11.350
	(Km42+140)	3 @ 22=66m						
	(Pk47+740)		Design River Bed Width= 48.45m			Design River Width= 63.00m		
10	**St42+800**	Cut-off No.1	8.54	3.70	4.84	1.00	2.00	11.540
	(Km42+830)	4 @ 25=100m						
	(Pk48+430)		Design River Bed Width= 82.48m			Design River Width= 97.00m		
14	**St48+400**	Cut-off No.2	8.25	3.70	4.55	1.00	1.80	11.050
	(Km48+440)	3 @ 22=66m						
	(Pk54+040)		Design River Bed Width= 49.35m			Design River Width= 63.00m		

Note: St = Chainage of Proposed Centerline, Km = Chainage of Present Centerline in Study Area, Pk = Chainage of NR-1 (MPWT)
HWL = High Water Level, EL = Elevation, FH = Formation Height

Based on the above design conditions, general views for the planned three bridges including quantities are prepared as shown in separate volume.

b) Pipe/ Box Culverts

The general views for pipe/ box culverts are prepared corresponding to topography of the planned locations, existing water ways, and surrounding environment.

Fig. 13-3-8 and Table 13-3-17 show the general condition of cover of culverts from road surface ,and control points for alignment of road elevation shall be given from figure and table as below.

Taking into the above consideration, general views including quantities were designed to standardize the types of culverts as shown in separate volume.

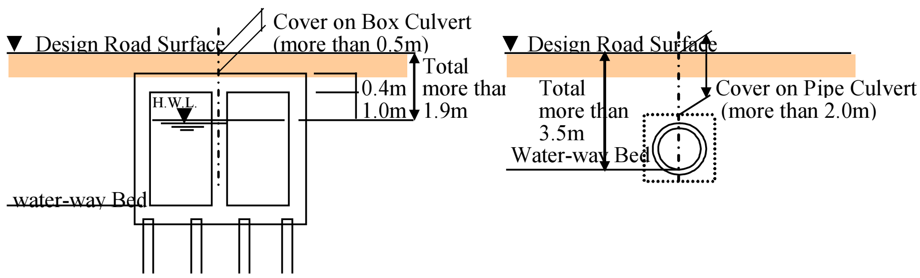


Fig. 13-3-8 Design Opening Section of Culverts

Table 13-3-17 Design of Culverts and Road Surface Elevation

No.	Chainage	Culvert Type	Dimension(Nos of Cell@ B*H)	HWL	River Bed EL	FH of Road Surface
1	St23+983 (Km24+000, Pk29+600)	Pipe 1	1 Set Dia. 1.0m	9.24	5.50	9.00 → 10.50
2	St24+823 (Km24+840, Pk30+440)	Pipe 2	1 Set Dia. 1.0m	9.21	6.00	9.50 → 10.50
3	St32+420 (Km32+440, Pk30+000)	Box (with Gate) 1	2 Cell 2.0*5.4m	8.88	4.50	10.80
4	St32+750 (Km32+760, Pk38+360)	Box (with Gate) 2	2 Cell 2.0*6.4m	8.86	3.50	10.80
5	St33+200 (Km33+230, Pk38+830)	Box (with Gate) 3	2 Cell 2.0*4.7m	8.85	5.20	10.80
6	St36+870 (Km36+900, Pk42+500)	Box (with Gate) 4	2 Cell 2.0*6.3m	8.72	3.50	10.70
7	St41+006 (Km41+040, Pk46+640)	Box (with Gate) 5	2 Cell 2.0*5.6m	8.58	4.05	10.50
8	St41+770 (Km41+800, Pk47+400)	Box 6	2 Cell 2.0*5.2m	8.55	4.40	10.50
11	St43+460 (Km43+500, Pk49+100)	Box 7	2 Cell 2.0*5.4m	8.54	4.20	10.50
12	St44+360 (Km44+400, Pk50+000)	Box (with Gate) 8	2 Cell 2.0*5.0m	8.46	4.50	10.40
13	St46+920 (Km46+960, Pk52+560)	Box (with Gate) 9	2 Cell 2.0*4.5m	8.35	4.90	10.30
15	St48+760 (Km48+800, Pk54+400)	Box 10	2 Cell 2.0*5.2m	8.25	4.10	10.20
16	St50+002 (Km50+040, Pk55+640)	Box (with Gate) 11	3 Cell 2.0*5.8m	8.15	3.40	10.10

Note: St = Chainage of Proposed Centerline, Km = Chainage of Present Centerline in Study Area, Pk = Chainage of NR-1 (MPWT)
Nos = Numbers, B = Width, H = Height, HWL = High Water Level, EL = Elevation, FH = Formation Height

(2) Preliminary Design Drawings for Opening Structures

In accordance with design criteria in previous Chapter 11, the structures of bridges and culverts were computed, drawn, and reported in attached Volume Ⅲ, "**DRAWINGS**" corresponding to the International Highway as Asian Highway A-1 Route.

The design standards shall apply Japanese Specification referring American AASHTO and Cambodian Standards.

From the design of structures, the drawings including quantities for the project were executed as shown in below Table 13-3-18.

These opening structural design drawings show with scaled 1 to 200, 500.

Table 13-3-18 Design Drawings of Opening Structures for the Project

1	General View of Bridge No.1 (Cut-Off No.01) St 42+110
2	General View of Bridge No.2 (Cut-Off No.1) St 42+800
3	General View of Bridge No.3 (Cut-Off No.2) St 48+400
4	General View of Pipe Culverts
5	General View of Box Culverts (2-cells with Watergate)
6	General View of Box Culvert 11 (with Watergate)
7	General View of Box Culverts (without Watergate)

(3) Estimated Construction Cost of Bridges and Culverts

Based on the unit costs in next section 13.4, the construction cost for the opening structures along the Project Road was extracted as shown below Table 13-3-19.

Table 13-3-19 Estimated Construction Cost of Opening Structures

Type of Openings	Name/Type Station St. (Pk)	Quantity	Cost（US$）
Bridges	Bridge No.1 (Cut-Off No.01) St (Pk): 42+110 (47+740)	924.0m^2	1,464,500
	Bridge No.2 (Cut-Off No.1) St (Pk): 42+800 (48+430)	1,400.0m^2	1,801,800
	Bridge No.3 (Cut-Off No.2) St (Pk): 48+400 (54+040)	924.0m^2	1,332,400
Pipe Culverts	RC Diameter 1.0m	2 nos.	27,200
Box Culverts With Gate	2 Cell B2.0m*H4.5-6.4m	7 nos.	1,401,600
	3 Cell B2.0m*H5.8m	1 no.	234,700
Box Culverts Without Gate	2 Cell B2.0m*H5.2, 5.4m	3 nos.	596,000

(4) Additional Survey in Design Stage

Additional geotechnical and topographic survey is necessary in design stage to have sufficient site data. As the depth of soft ground differs in the study area, close geotechnical survey should be carried out in the construction site of bridges and culverts. The details are mentioned in Appendix D-2.

13.3.5 Construction Method for Opening Structures

(1) Construction Type and the Volume

The construction for project road shall be implemented considering long distance with 56 km between Phnom Penh and Neak Loueng. Especially, the opening structures are in range of St+24 to St+51, 27 km length.

Due to location and scale (number and volume) of structures in project area, the construction method shall be studied to meet the construction sequence, period, economy and safety aspects.

The construction scale and volume for the opening structures are shown in Table 13-3-20.

Table 13-3-20　Construction Scale for the Opening Structures

Type of Openings	Name/Type Station St (Pk)	Type (Superstructure)	Quantity (Total)
Bridges	Bridge No.1 (Cut-Off No.01) St (Pk): 42+110 (47+740)	PC-I Girder	Structural Concrete Volume: (Girder): 905 m^3 (Others): 4,600 m^3 Reinforcing Steel Bar Weight: 611 t PC cable Weight: 59 m^3 Gabion Volume: 7,600 m^3 Slope Protection Area: 7,400 m^3
	Bridge No.2 (Cut-Off No.1) St (Pk): 42+800 (48+430)	PC-I Girder	
	Bridge No.3 (Cut-Off No.2) St (Pk): 48+400 (54+040)	PC-I Girder	
	Total	3	

Type of Openings	Type/Specification	Numbers	Quantity (Total)
Pipe Culverts	RC Diameter 1.0m	2	Pipe Length: 54 m Structural Concrete Volume: 98 m^3 Reinforcing Steel Bar Weight: 6 t Gabion Volume: 24 m^3 Slope Protection Area: 109 m^3
	Total	2	

Type of Openings	Type	Specification	Numbers	Quantity (Total)
Box Culverts	with Watergate	2 Cells B2.0m*H4.5-6.4m	7	Structural Concrete Volume: 4,855 m^3 Reinforcing Steel Bar Weight: 486 t Gabion Volume: 1,786 m^3 Slope Protection Area: 10,797 m^3
		3 Cells B2.0m*H3.5m	1	
	without Watergate	2 Cells B2.0m*H5.2, 5.4m	3	
	Total		11	

(2) Key Points for the Construction of Structures

Following items shall be taken into consideration for the construction of bridges and culverts.

- Construction period for the whole work on the project site is limited annually from November to July (9 months) due to the rainy weather conditions.
- From viewpoint of the long length of the Project road, the location/place of plant and base camp yard shall be considered for the construction materials, equipment, concrete and asphalt work, etc.
- In the range of project area, the borrow pit and quarry site shall be obtained to utilize the construction work.
- The construction works in the river shall be taken measures to avoid flood in the rainy season.
- During the construction work for the structures, ordinal traffic flow shall not be disturbed, even for inhabitants in the project area.
- The check/test for materials, concrete, reinforcing bar and asphalt shall be completely executed at prepared laboratory.
- Erection method by crane or launching for girders shall be selected considering existing land access, weight of girders and availability of the equipment.
- Before coming annual flood season, protection works such as wet masonry and gabion mat for opening structures shall be finished completely.

13.3.6 Maintenance Method

(1) Maintenance Works of Existing Bridges

The inspection works of existing bridges are important to improve them effectively for their serviceability and for making the improving cost less.

Example of inspection procedure of bridges is shown in flowchart of Fig. 13-3-9, to be applied.

The result of inspection for bridges shall be recorded to sheets with general view and photograph, as Inspection Form in Appendix-C, (Inventory Sheets) which were applied in this project.

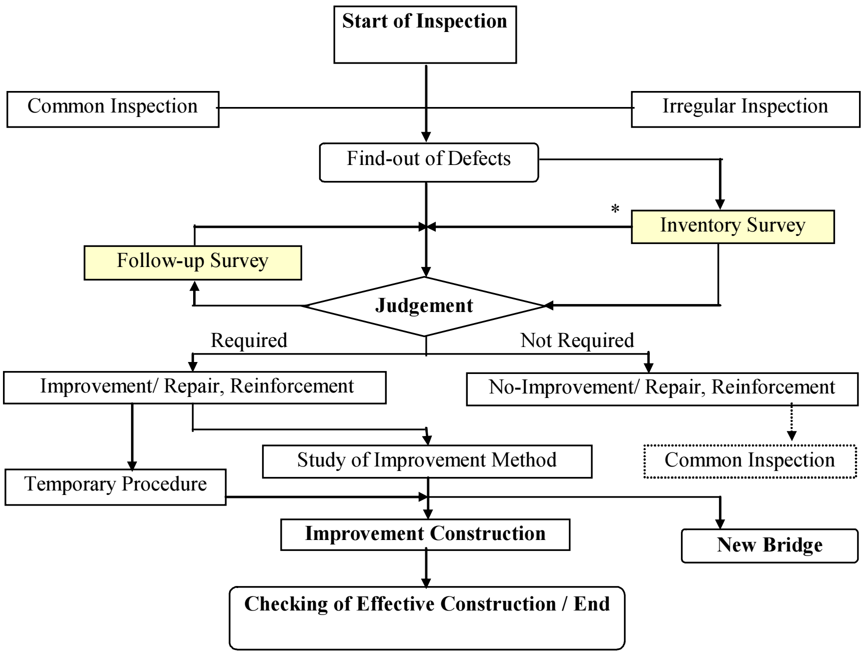


Fig. 13-3-9 Flowchart of Maintenance Method for Bridges

(2) General Evaluation and Priority of Improvement Method

As studied the soundness of the bridges in the project, general evaluation method will be proposed in Table 13-3-21, exampled for extensive bridges.

Table 13-3-21 Method of Evaluation and Soundness Degree for Existing Bridges

Evaluation Item			Rating Point (E.P.)	Bridge (E.P.)	Weight Factor(W/F)	Point (E.P.)*(W/F)
Durability	Degree of superstructure damage and defect		good to bad 1 2 3 4		0.6	
	Degree of substructure damage and defect		good to bad 1 2 3 4		0.4	
Load Capacity	Low traffic volume (heavy vehicle with axle load less than 20 ton)		1		0.3	
	High traffic volume (heavy vehicle with axle load greater than 20 ton)		3		0.3	
Function	Constructed record	Constructed after 1980 (use less than 20 years)	1		0.1	
		Constructed before 1980 (use more than 20 years)	3		0.1	
	Effective width of bridge	Sufficient width for traffic capacity	1		0.1	
		Insufficient width for traffic capacity	3		0.1	
Overall evaluation for bridge (Range of point)		A: Sound	1.5~2.5		Min. 1.5	A
		B: Fairly sound	2.5~3.5			B
		C: Unsound / Lack of safety	3.5~4.5			C
		D: Danger	4.5~5.5		Max. 5.5	D

After the overall evaluation of each existing bridge, the administrative priority for the improvement/rehabilitation shall be given as shown in Fig.13-3-10.

The implementation program for the bridge improvement/rehabilitation works will be conducted considering these evaluation methods.

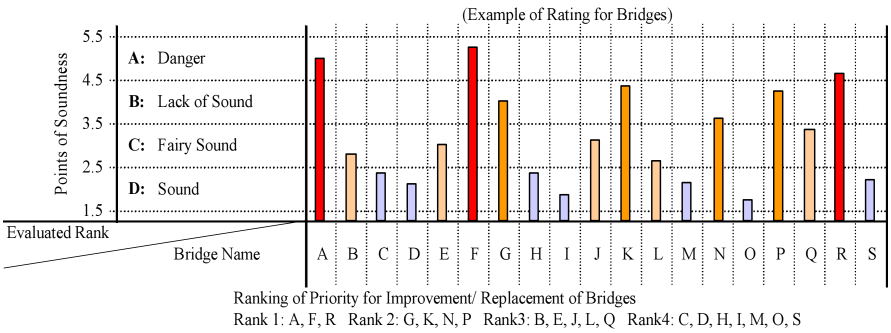


Fig. 13-3-10 Overall Evaluation and Priority of Improvement/Rehabilitation for Bridges

(3) Effective Maintenance for the Bridges

The appropriate evaluation and immediate/effective improvement/rehabilitation of the existing bridges will be extended the public serviceability and life span, as illustrated in below Fig. 13-3-11.

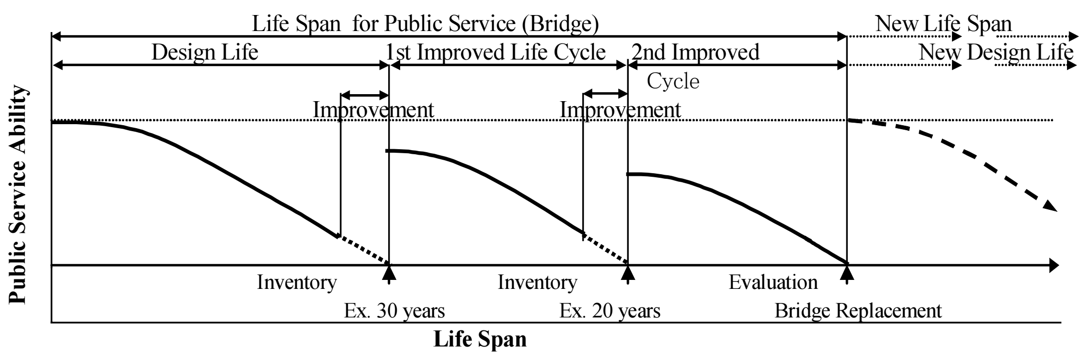


Fig.13-3-11 Relation between Appropriate Improvement and Public Serviceability (Life Span)

(4) Organization of MPWT of Cambodian Government

The Bridges and its maintenance works will be executed steady methods as mentioned above items in organized MPWT of Cambodian Government.

The organization chart of MPWT for public works including bridge and its maintenance works is shown in Fig. 13-3-12.

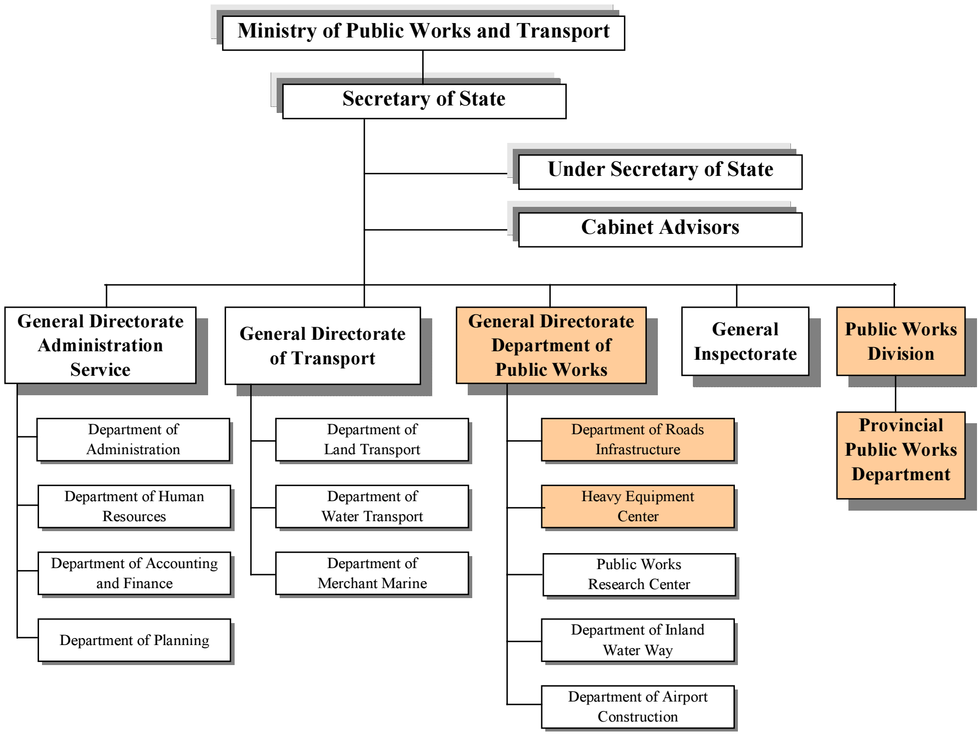


Fig. 13-3-12 Organization Chart of MPWT of Cambodian Government

(5) Example of Emergency Temporary Repair Work for Old Water Gate (Kampong Phnom Km50+040)

As the result of inventory survey for old water gate at Kampong Phnom, Km 50+040, there are defects such as holes and exposed reinforcing bars at upper reinforcing concrete slab currently. (as below photograph 13-3-3)


Existing Old Gate: Km50+040, Kampong Phnom Lied with Steel Plate on Road Surface & Slab

Although the old water gate shall be replaced in the study, the emergency temporary repair will be required, for the time being. The one of example for emergency repair method is reinforced with concrete panels after demolishing of existing pavement, as shown in below Fig. 13-3-13.

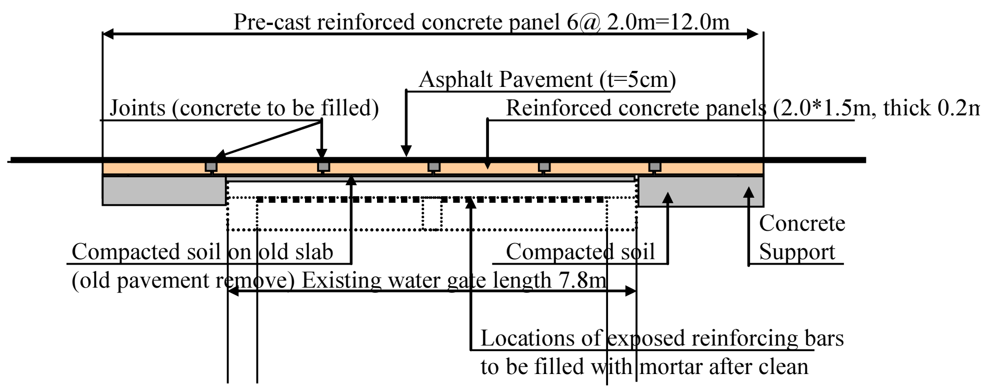


Fig.13-3-13 Example for Emergency Repair Method for Kampong Phnom Old Gate

13.4 Construction Planning and Cost Estimation

13.4.1 Construction Planning

(1) Planning of procurement and transportation

1) The procurement source

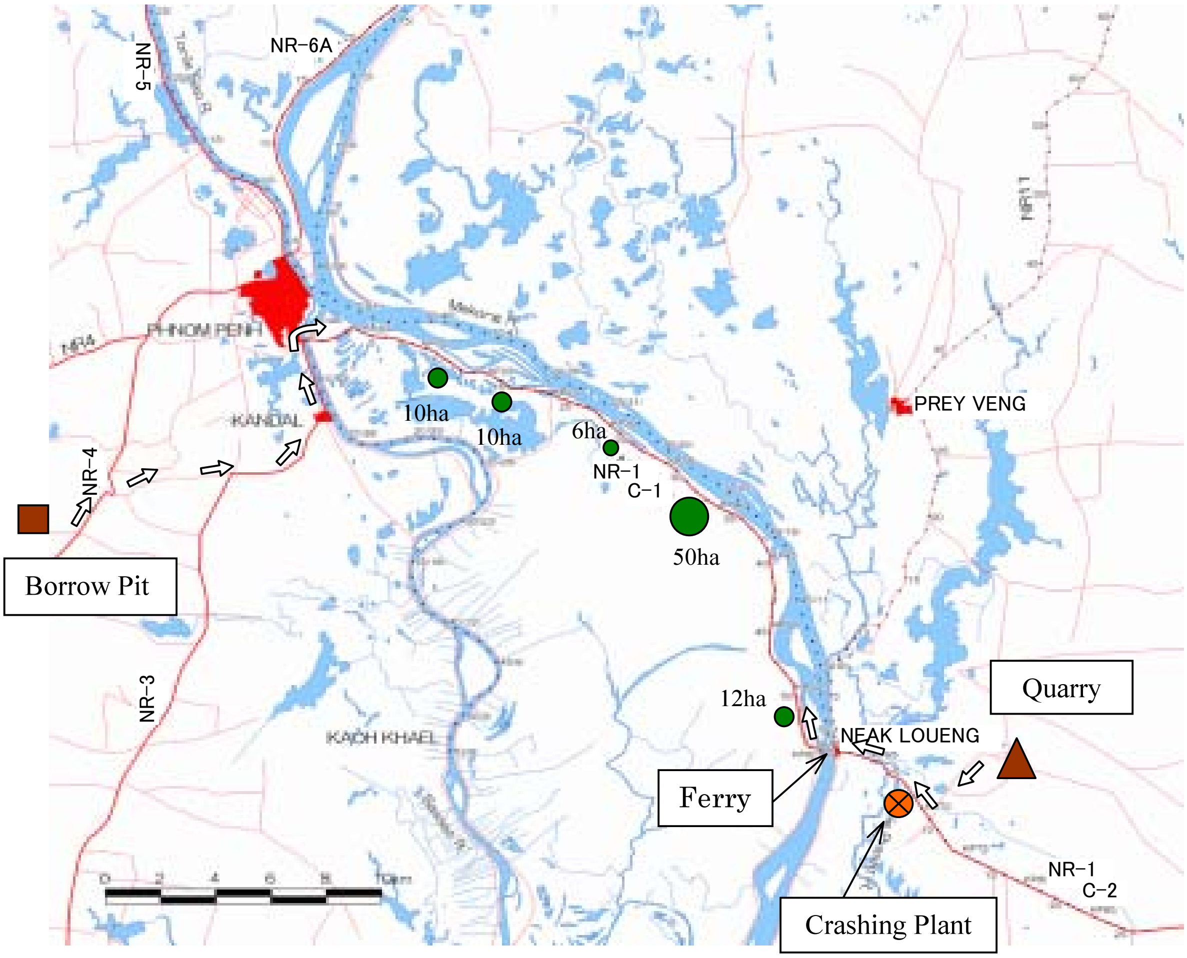
The material procurement sources for construction are shown on Table 13-4-1.

Table 13-4-1 Material Procurement Source List

Items	Procurement Source
Main construction materials	Phnom Penh
Pavement structure materials	
Sub-Grade	Borrow pit along NR-3 and quarry NR-1*
Sub-Base and Base course	Quarry along NR-1*
Bitumen	Phnom Penh
Embankment materials	Borrow Pit along NR-1
Equipments	Phnom Penh

* : The quarry along NR-1 is located at about 15 km passing the Mekong river from Neak Loueng.

The location of sources for pavement materials (Sub-Grade, Sub-Base and Base Course) and embankment material are shown in Fig.13-4-1.



Legend

: Borrow Pit for embankment material

: Borrow Pit for Sub-Grade material

: Quarry for Sub-Grade, Sub-Base, and Base course Material

Fig.13-4-1 Location of Quarry and Borrow Pit

2) Transportation

The main construction materials and equipments where are procured in Phnom Penh City is planed to transport by appropriate vehicles. The pavement materials (Sub-Grade, Sub-Base and Base course) are planed to directly transport to the site by dump truck considering hauling cost.

(2) Construction method

NR-1 is functioning as one of important trunk road in Cambodia for passage of people and transportation of local products. Therefore the construction planning should be planed to keep the existing traffic function.

1) Construction of road

<u>General</u>

The road construction is planned to keep the same function of existing roads, means two traffic lanes and space for pedestrians. The typical construction procedure (draft) in case of 14 meters road width is shown in Appendix H Construction.

The embankment and sub-grade are conducted in dry season; sub-base, base course and pavement work are conducted in rainy season considering condition of surrounding project area.

Construction of Embankment on Soft Ground

Although there is no large-scale soft ground area along the Study Road, this does not mean that there is no need for due precaution. Small-scale soft ground may be encountered anywhere which can be easily dealt with as far as appropriate construction procedures are followed.

One of the major problems encountered in construction of road embankment on soft ground is stability of embankment. Failure of embankment often occurs when speed of embankment is too high, or thickness of each spreading of soil is too large.

In the embankment works on soft ground or swampy area in Cambodia, it is often observed the soil material is dumped in thickness of more than 1 meter (Fig. 13-4-2). This does not allow necessary time for the soft soil to consolidate and increase the strength, and failure may occur. One of the common method adopted in Japan is to strictly follow the specification on spreading depth of embankment material, such as 30 cm or less, and limit the speed of embanking such as 5 cm/day (1.5 m/day) or less (Fig.13-4-3). It should be noted it is usual practice, and also is usually stipulated in the technical specifications, that the maximum spreading depth of embankment material is limited to certain value, such as 30 cm. This stipulation has to be strictly followed not only on soft ground but anywhere to secure good quality of embankment.

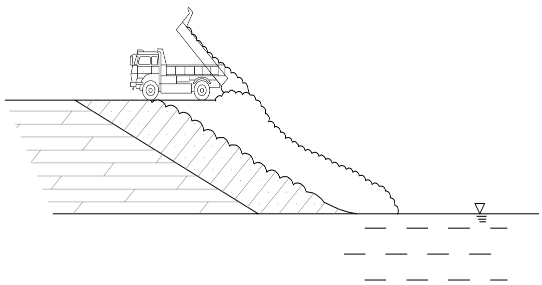


Fig. 13-4-2 Wrong Embankment Works: Thick Spreading Depth and High Speed of Embankment

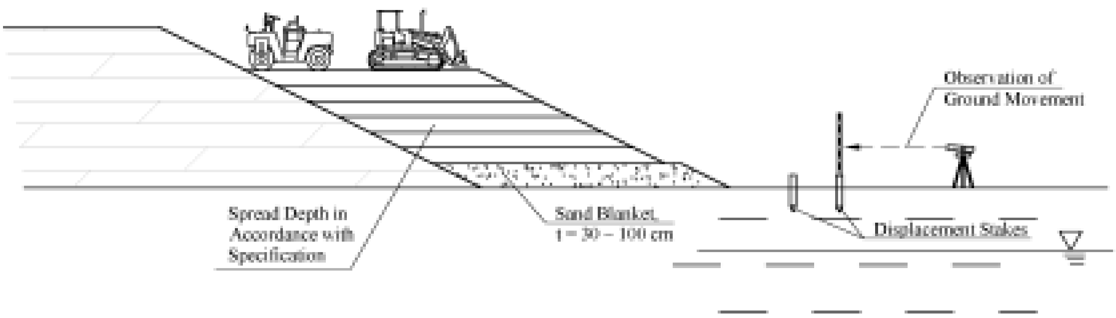


Fig. 13-4-3 Proper Embankment Works and Observation of Ground Movement

It is also a common practice to place a layer of loose, pervious sand with a thickness of 30 to 100 cm, depending on the ground condition, on the surface of soft ground, before the embanking works starts, to secure the traffic ability for the construction equipment. This layer of sand (usually called “sand blanket”) is effective to drain the water squeezes out of the soft soil and to accelerate the consolidation and, thus, increase of strength in soft soil.

Where serious problem of stability is anticipated, it is recommended to observe the movement of ground surface by surveying the movement of displacement stakes. One of the criteria for judging the critical condition is to plot the ratio of daily increment of embankment load, ⊿q, against daily increment of horizontal displacement of stakes, ⊿δ (Fig.13-4-4). Critical condition of stability of embankment can be known when the ratio ⊿q/⊿δ approaches zero.

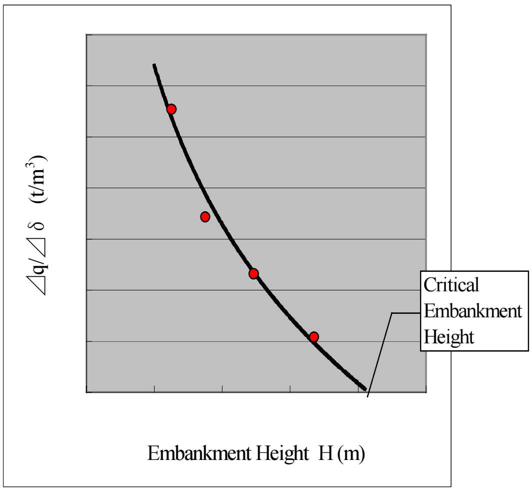


Fig. 13-4-4 ⊿q/⊿δ ~H Management

2) Construction of structure

The structures are shown in Table 13-3-12 will be planed to construct in this project. The construction of structures also should be considered to keep the function of existing road. Works mentioned below are the outline of construction of structures.

Bridges

Temporary Work

Temporary construction road and /or detour road crossing river/waterway will require.

Pile Foundation Work

Before pile driving at the position, temporary road for equipment into river shall be prepared. The piling method is earth drilling or reverse-circulation considering technical experience/ equipment type.

Substructure Work

During foundation works, embankment with soils/sheets at the position of footing will be made to avoid from water flow. Regarding to the pouring concrete for substructures, transportation of agitator truck from plant shall ensure the traveling time and interval. The curing method after poured concrete will be required, case by case.

Superstructure Work

The fabrication works (form-work, pc wire, steel bar-arrangement, pouring concrete, curing, etc.) of pre-stressed concrete girder in base camp/casting site yard shall carry out with technical force by skilled Engineer, especially pre-stressing procedure and controls.
Transportation of the girders by long-trailer to bridge site from base camp/casting yard is to be taken the safety of road.
Their qualities of pre-stressed concrete girders shall ensure by testing at laboratory.
Prior to the girder erection, the approach road shall be constructed for the transportation and setting of their girders. According to dry season or flood season, two kinds of erection method by crane and launched girder for the project bridges will be proposed.

Protection Works

To avoid the scouring of floods, protection for approach embankment and gabion for river bed at bridge site shall be constructed. The bank slope shall be kept with appropriate value, as 1(vertical): 1.5 to 2.0(horizontal).

Box Culverts Foundation Work

Before setting the RC box culvert, pile driving shall be carried out. The piling method is with diesel hammer after construction of temporary road.

Before set the culvert, leveling concrete will be laid at the location.

Concreting Works

The works of retaining walls and inlet/outlet shall be completely carried out to protect the road embankment and waterway.

Protection Works

To avoid settlement the embankment on and approach of culverts, certain compaction of back fill is required. To avoid erosion en local scouring slope will be covered with wet masonry and river bed by gabion mat.

Pipe Culverts Fabrication Work

The pipe culvert of reinforced concrete type shall be fabricated in base camp for the length with 1 meter to 2meters segments.

Setting Work

Before setting the pipe culverts, the bearing layer will be examined by the Engineer. The set of pipe culvert with lining concrete base shall be arranged at correct position.

The works of retaining walls and inlet/outlet shall be completely carried out to protect the road embankment and waterway.

Protection Works

To avoid settlement the embankment on and approach of culverts, certain compaction of back fill is required. To avoid erosion en local scouring slope will be covered with wet masonry and river bed by gabion mat.

Pipe culvert

The pipe culverts construction will be conducted as following Fig. 13-4-5, considering closed residential area.

Step1: Construct temporary traffic road with gravel surface of width 7 meters (2nd section) and set sheet pile, Excavate and install for pipe culvert for 1st section,

Step2: Re-set sheet pile and back-fill, paving work and traffic at 1st section,
inlet or outlet and protection work for 1st section,
Excavate and install pipe culvert for 2nd section,
Back-fill and paving work for 2nd section,
Inlet outlet and protection work for 2nd section

Step3: Traffic lane for both sections

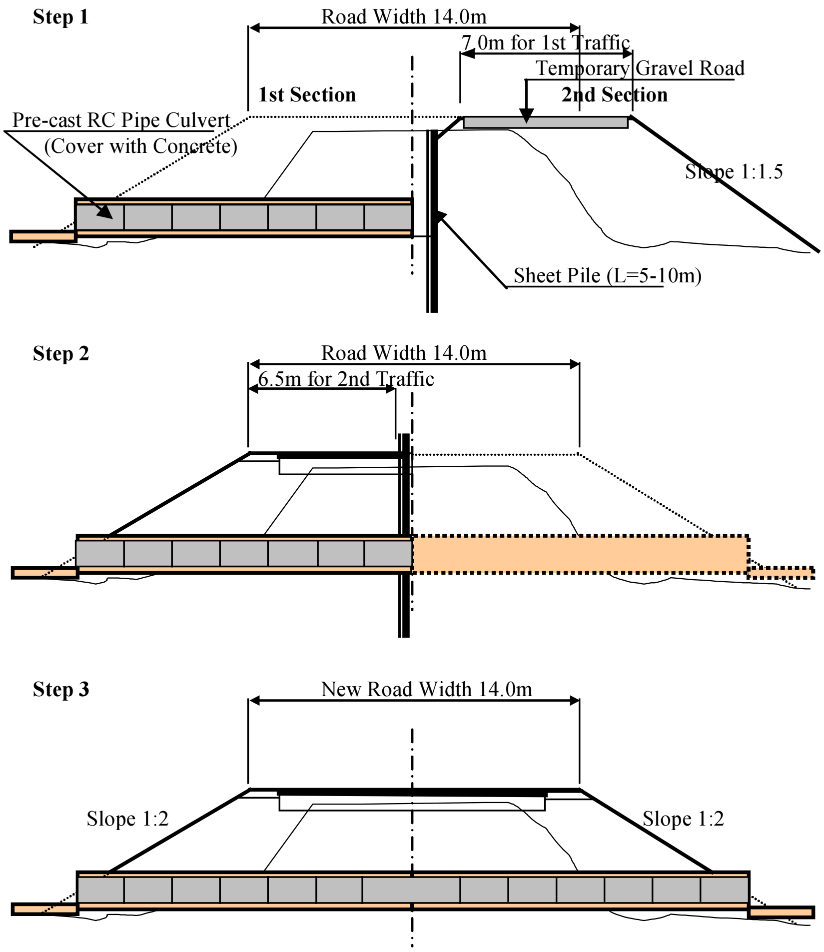


Fig. 13-4-5 Construction Sequence for Pre-cast Pipe Culvert

Box culvert

The box culvert construction is conducted in dry season with the detour road. The planning detour road is shown in Fig.13-4-6.

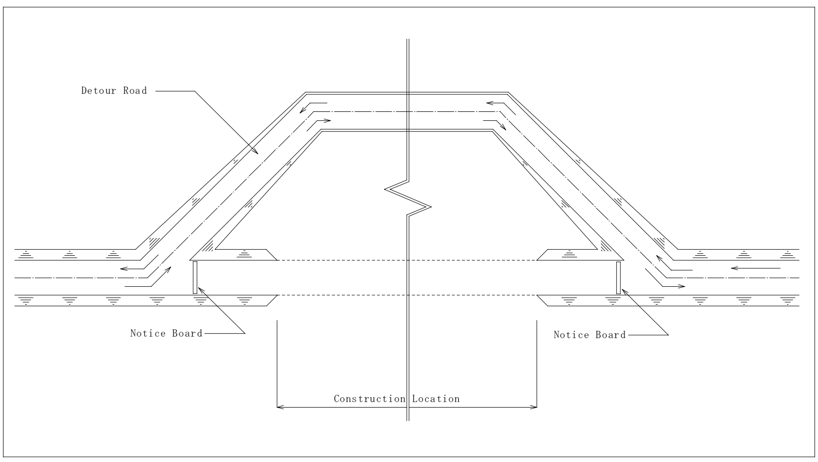


Fig.13-4-6 Detour Road for Construction of Box culvert

Cross Section is shown in the figure below;

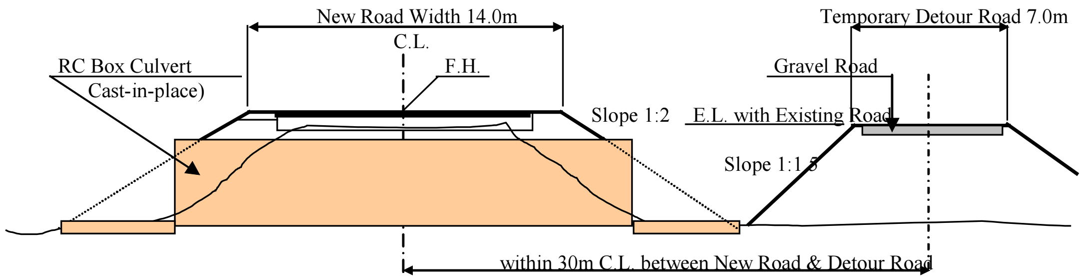


Fig. 13-4-7 Construction Method for RC Box Culvert

Bridge

- Site camp yard

  As shown in Fig. 13-4-8, exampled site camp yard for fabrication of girders, stock of materials and offices shall be planned at the appropriate location. (Exampled location: between Bridge No.1 [Cut-off No.01] and Bridge No.2 [Cut-off No.1]

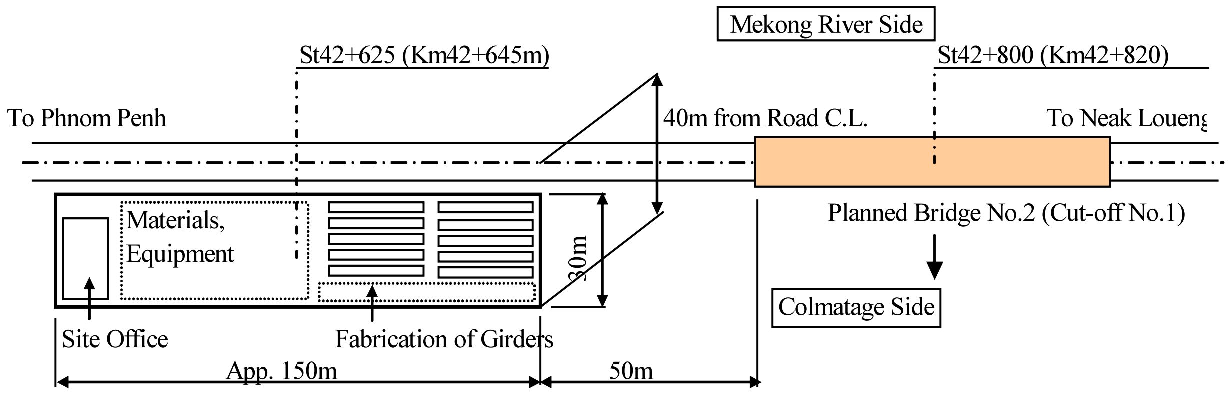


Fig. 13-4-8 Site Camp Yard for Structures

- Detour

  The detour road for the construction of new bridges is required with temporary Bailey bridge considering opening width and elevation of road surface in flood season. The construction method for bridge is shown in Fig.13-4-9, the sequence of detour road is shown in Fig.13-4-10

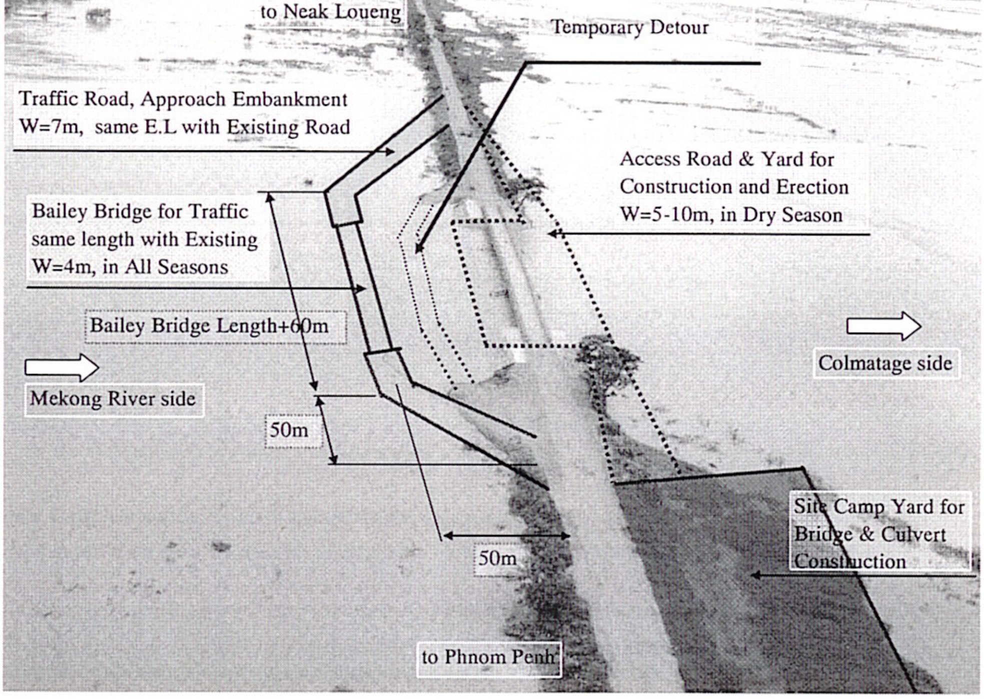


Fig. 13-4-9 Outline of Construction Method for Bridge

- Substructure, revetment and riverbed work

  The substructure, revetment and riverbed work should be completed in dry season considering a flood during rainy season. The construction sequence is shown in Fig.13-4-11.

- Superstructure work

  The PC girders for superstructure are conducted at casting yard in site camp where is installed beside of bridge site. The erection method of girders should be adopted erection girder method because of the erection work will be conducted in rainy season. The sequence of erection work is shown in Fig. 13-4-12.

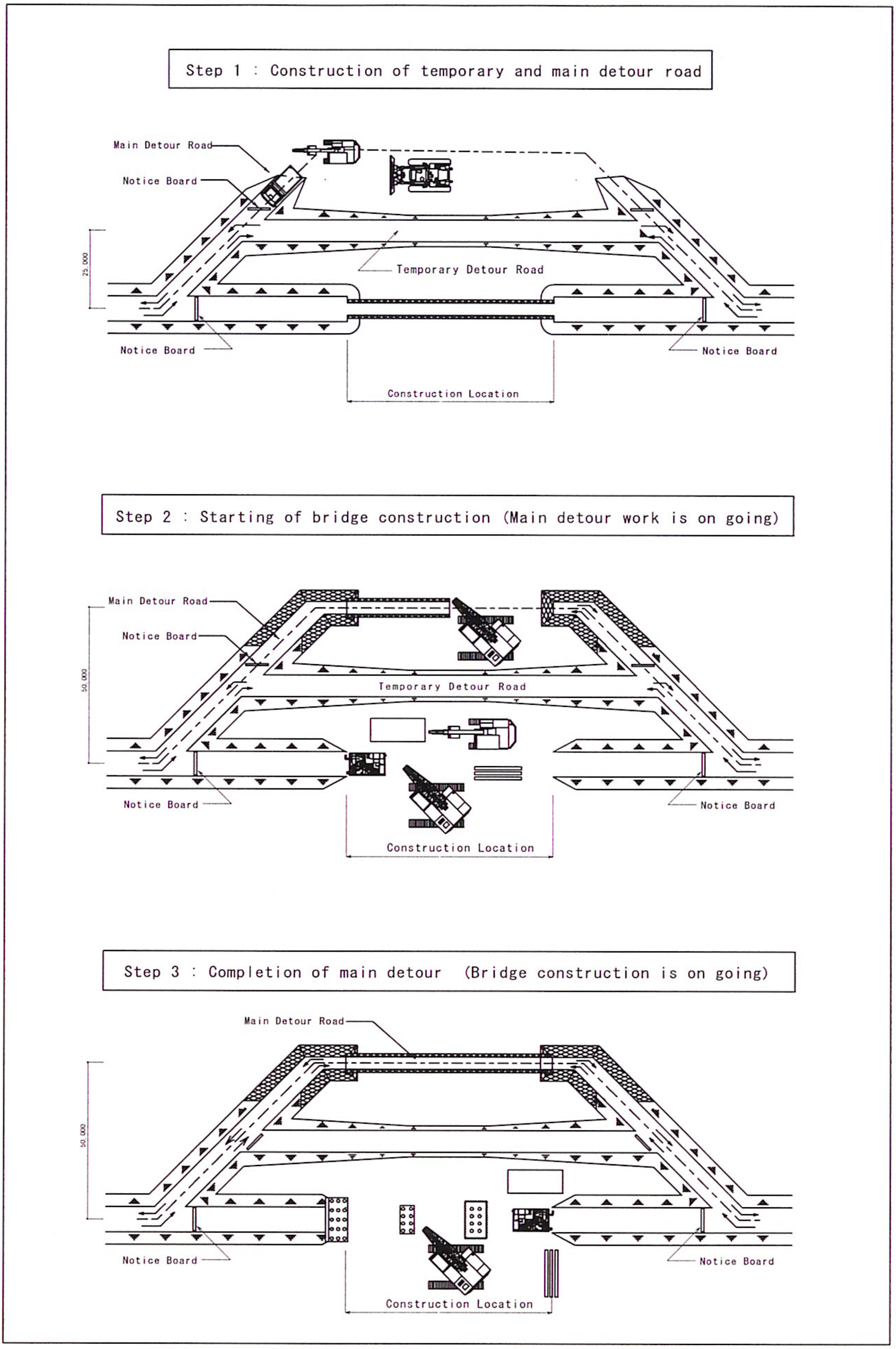


Fig.13-4-10 Construction Sequence of Detour Road for New Bridge

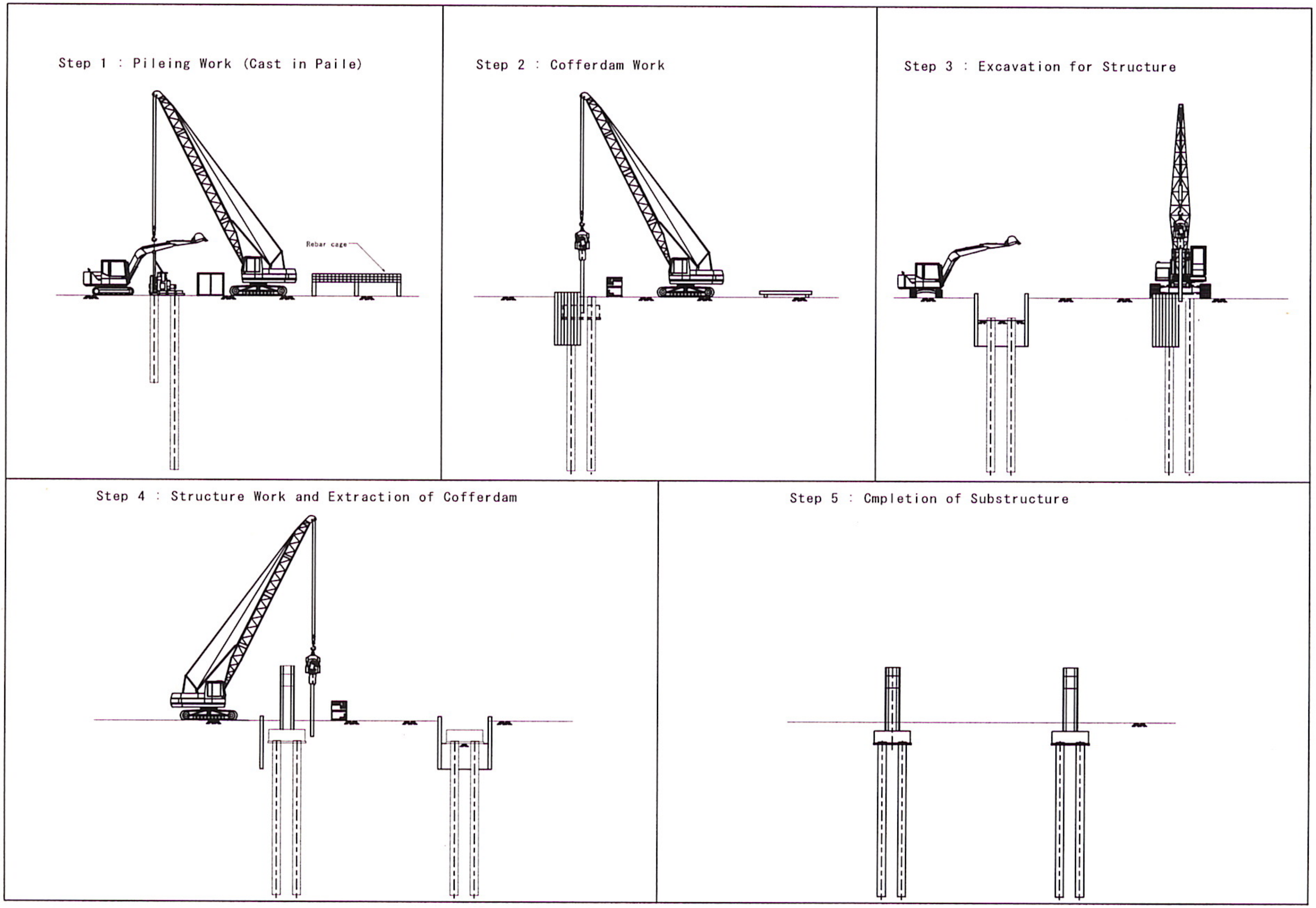


Fig.13-4-11 Construction Sequence of Substructure

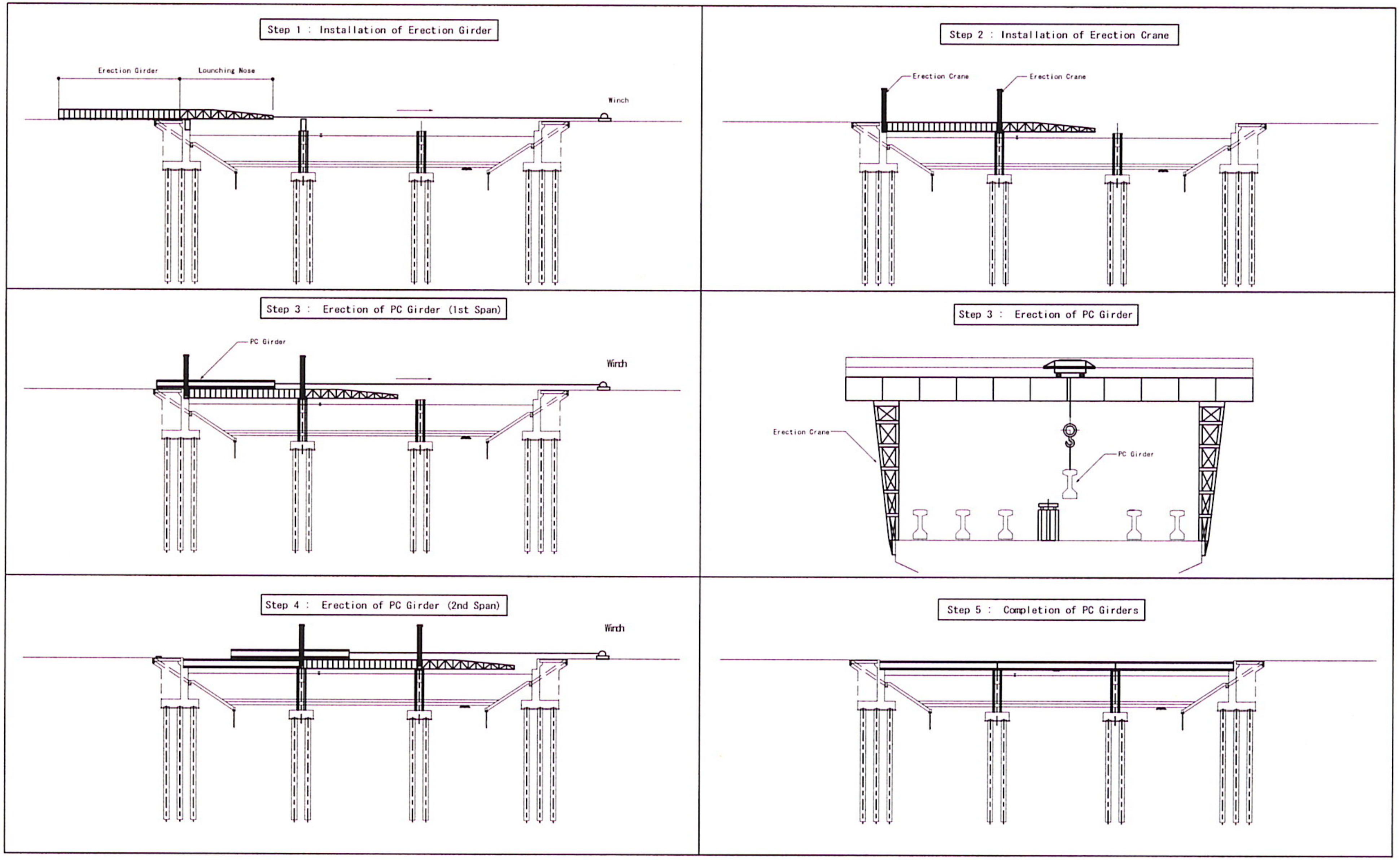


Fig.13-4-12 Construction Sequence of Erection of Girders

3) Implementation Schedule of Major Works

Considering the natural conditions, especially rainy season, structural works at site shall be estimated as working months and days.

The implementation schedule for major works are assumed according to working conditions and construction scale.

The examples of implementation schedule for culverts, bridges and road construction are shown in Table 13-4-2, Table 13-4-3 and Table 13-4-4.

Table 13-4-2 Implementation Schedule for Culvert Construction

Year	1								
Work \ Month	1	2	3	4	5	6	7	8	9
Preparation Work					(4.5 Months for Box)				
Detour Road					(3.0 Months for Pipe)				
Box-Piling									
Culvert Placing									
Rebetment Work									
Insidental Work									

Table 13-4-3 Implementation Schedule for Bridge Construction

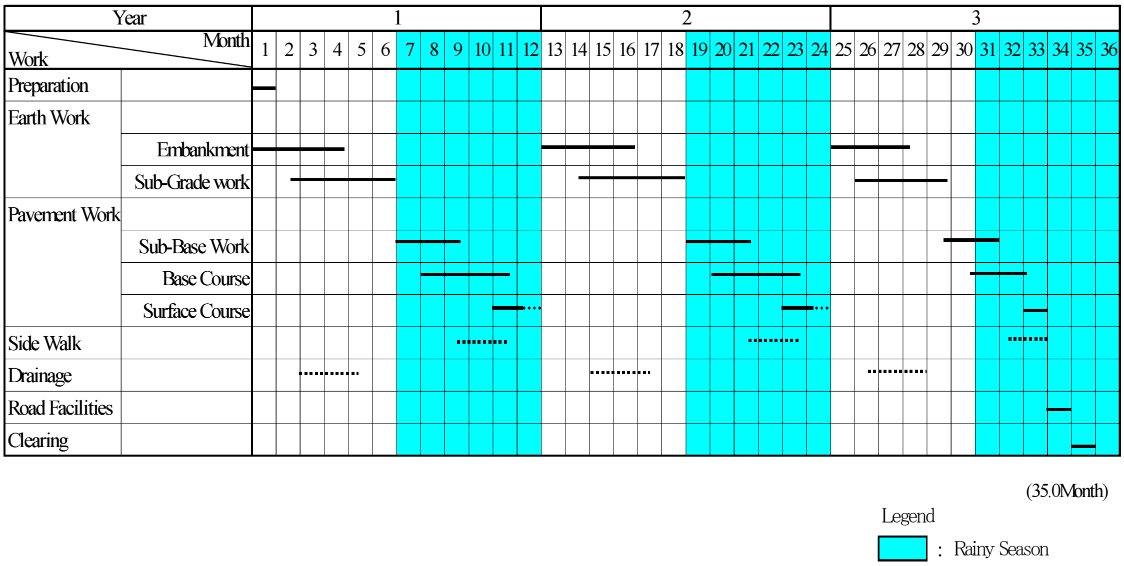
Year	1												2						
Work \ Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Preparation Work																			
Detour Road																			
Casting of Girder																			
Sub-Structure																			
Abutment 1																			
Foundation Work																			
Structure Work																			
Pier 1																			
Foundation Work																			
Structure Work																			
Pier 2																			
Foundation Work																			
Structure Work																			
Pier 3																			
Foundation Work																			
Structure Work																			
Abutment 2																			
Foundation Work																			
Structure Work																			
Super Structure																			
Election																			
Slab																			
Rebetment Work																			
River Bed Work																			
Subsidiary Work																			
Demolitin of detour																			
Cleaing																			

(18.5Month)

Legend

: Rainy Season

Table 13-4-4 Implementation Schedule for Road Construction



13.4.2 Construction Cost

<u>General</u>

The project cost was estimated in October 2002 price broke down into the foreign currency component, local currency component and taxes. The foreign component includes cost of imported materials, goods and services, wages expatriate personnel and foreign overheads and profit. The local component includes locally procured materials and supplies, local wedge, local supervision, local transport and local overheads and profit. The US$ is applied to as local currency which is daily use in Cambodia.

The following conversion rate is applied;

US$ 1.00=¥ 120.00

(1) Market price, unit cost of major construction items and analysis

For the estimation of Construction Cost, the market price survey of main construction material, labor, worker and equipment was conducted. The market price on October 2002 of main construction materials, equipments and labors in Cambodia are enumerated in Table 13-4-5 to 7.

Table 13-4-5 Unit Price of Major Construction Material

Description	Unit	Unit price US$	Source	
			Local	Import
Gasoline	L	0.58		○
Diesel	L	0.47		○
Portland Cement	t	80.0		○
Plywood (12mm) 2x2.4m	Plate	17.5		○
Timber	Cu m	290.0	○	
Pre-stress Strand	t	723.0		○
Reinforcement Bar	t	380.0		○
Bitumen 60/70	t	330.0		○
Sand	Cu m	5.0	○	
Course aggregate (M-30)	Cu m	8.0	○	
Course aggregate (C-40)	Cu m	6.5	○	
Concrete Pipe				
-ϕ600mm	m	19.0	○	
-ϕ800mm	m	34.0	○	
-ϕ1000mm	m	38.0	○	
H-Beam	t	430.0		○
Sheet Pile: Type III	t	650.0		○
Pre-cast Concrete pile -300mm x 300mm x 12m	pc	230.0	○	

Table 13-4-6 Unit Prices of Labor and Worker

Description	Unit cost (US$)	Remarks
(1) Labor		
Foreman	25.6	Daily
Common Labor	6.8	Daily
Carpenter	11.6	Daily
Rebar Worker	10.1	Daily
Operator	19.2	Daily
(2) Worker		
Civil Engineer (20years Experience)	1500	Monthly
Assistant Civil Engineer (10years Experience)	940	Monthly
Surveyor	800	Monthly
Mechanic	700	Monthly
Electrician	700	Monthly
Typist	290	Monthly
Guardsman	180	Monthly

Table 13-4-7 Unit Prices of Equipments

Description	Capacity	Unit	cost (US$)	
			Market price	RCC
Bulldozer	15t	Monthly	4,300	-
	21t	Monthly	4,800	3,700
Back Hoe	0.8m3	Monthly	4,050	2,700
Dump Truck	10t	Monthly	2,600	1,050
Vibration-roller	15t	Monthly	4,650	3,000
Tire Roller	8-20t	Monthly	3,300	-
Motor Grader	3.1m	Monthly	3,700	2,400
Water Cart	8000L	Monthly	1,700	1,050
Track Crane	15-16t	Monthly	3,900	-
	20-22t	Monthly	4,500	-
Crawler Crane	50t	Monthly	7,900	-
Trailer	40t	Monthly	3,800	3,000(30t)

*RCC: Road Construction Center (Belong to MPWT)
*The price of RCC includes cost of operator.

The MPWT implements construction and maintenance work using RCC equipments supplied by Japan's Grant Aid. The RCC equipments should be planed to apply for this project as much as possible.

(2) Construction Cost

The construction cost consists of direct cost and indirect cost, means temporary facility cost, field expenses and over head. The direct cost is estimated by unit price of major works that is enumerated in Table 13-4-8. The direct cost is enumerated in Table 13-4-9 and each indirect cost is estimated to multiply direct cost by percentage that is enumerated in Table 13-4-10.

Table 13-4-8 Unit Price of Major Works

Classification	Item	Unit	Unit Price (US$)
Earth Work	Excavation	m^3	0.8
	Removal of existing pavement	m^2	0.2
	Embankment work	m^3	0.4
	Sub-Grade work	m^3	0.6
	Trimming work of Slope	m^2	0.9
	Embankment Material (Including Hauling cost)	m^3	1.4
	Sub-grade Material (Including Hauling cost)	m^3	7.8
Pavement Work	Sub-Base	m^2	5.8
	Base Course	m^2	4.7
	Surface course (AC)	m^2	6.8
Structure Work	Structural excavation	m^3	1.6
	Back fill work	m^3	2.1
	Coffer dam work	m	4.4
	Foundation work (Rivers Circulation Method)	m	302.3
	Form work	m^2	6.0
	Rebar work	Kg	0.5
	Scaffolding work	m^2	3.7
	Supporting work	m^3	3.9
	Concrete work	m^3	38.9
	PC girder work	Nos	4,799.4
	Election of girder (Erection Girder Method)	Nos	4,418.7
	PC work	Nos	47.7
	Revetment work (Including Foundation)	m^2	99.0
Drainage Work	RC pipe installation: φ600	m	28.6
	RC pipe installation: φ400 (Including outlet structure)	m	72.6
	L-Shape ditch	m	24.6
Road Facility Work	Road making	m	0.5
	Delineator post installation	Nos	18.1

Table 13-4-9 Direct Cost for Construction

Item	Unit	Qty	Unit Price (US$)	Financial Cost (US$)	Local (US$)	Foreign (US$)	Tax (US$)
Excavation	m^3	1,539,182	0.8	1,231,300	795,900	372,800	62,600
Removal of existing pavement	m^2	333,000	0.2	66,600	43,100	20,200	3,300
Embankment work	m^3	1,233,432	0.4	493,400	318,900	149,400	25,100
Sub-Grade work	m^3	373,070	0.6	223,800	144,300	67,610	11,890
Trimming work of Slope	m^2	743,064	0.9	668,800	426,700	199,950	42,150
Embankment Material Including Hauling cost)	m^3	1,233,432	1.4	1,726,800	1,098,800	514,700	113,300
Sub-Grade Material (Including Hauling cost)	m^3	273,170	7.8	2,130,700	1,364,200	639,010	127,490
Revetment work	L.S	1	-	295,500	190,700	89,400	15,400
Planting	L.S	1	-	9,800	5,900	2,700	1,200
Miscellaneous Work	L.S	1	-	348,100	222,800	104,400	20,900
Sub-Base	m^2	754,236	5.8	4,374,600	2,772,400	1,298,700	303,500
Base Course	m^2	822,258	4.7	3,864,600	2,441,900	1,143,900	278,800
Surface course (AC)	m^2	677,400	6.8	4,606,300	2,839,300	1,330,000	437,000
Side Walk work	L.S	1	-	228,950	141,500	66,250	21,200
L=66.0m (3@22m) Width=14m	m^2	924	1,585.0	1,464,500	934,000	437,450	93,050
L=100.0m (3@25m) Width=14m	m^2	1,400	1,287.0	1,801,800	1,149,700	538,600	113,500
L=66.0m (3@22m) Width=14m	m^2	924	1,442.0	1,332,400	848,200	397,300	86,900
Pipe culvert 1.0m	L.S	1	-	27,200	17,100	8,070	2,030
Box culvert (2 cells)	Plc.	10	199,759.0	1,997,600	1,296,900	607,500	93,200
Box culvert (3 cells)	Plc.	1	234,677.0	234,700	151,900	71,100	11,700
RC pipe installation φ600	m	2,400	44.4	106,600	66,300	31,100	9,200
RC pipe installation φ400	m	1,067	72.6	77,500	48,600	22,700	6,200
L-Shape Ditch	m	6,400	24.6	157,400	99,800	46,700	10,900
Catch Basin	L.S	1	-	44,700	28,500	13,300	2,900
Road making	m	240,500	0.5	129,900	82,700	38,780	8,420
Conecting road work	m^3	39,845	8.4	334,700	202,700	94,940	37,060
Traffic Signal installation	Plc.	5	16,000	80,000	45,200	21,200	13,600
Street Light installation	Nos	496	1,000	496,000	279,200	130,800	86,000
Delineator post installation	Nos	500	18.1	9,100	5,500	2,600	1,000
Tall Gate Facility	Plc.	1	423,800	423,800	239,600	112,200	72,000
Pedestrian Bridge work	Plc.	2	52,300	104,600	66,600	31,200	6,800
Evacuation Space & Bus Bays	Plc.	1	30,200	30,200	19,800	9,300	1,100
Moto Stop	Plc.	8	2,900	23,200	15,100	7,100	1,000
Miscellaneous Work	L.S	1	-	14,500	8,900	4,130	1,470
Stock yard work	Plc.	14	3,447.0	48,300	31,900	14,900	1,500
Asphalt plant yard	Plc.	1	-	283,000	185,700	87,000	10,300

Note: Plc. Stands for places

Table.13-4-10 Items of Indirect Cost and Percentage to Direct Cost

Items	Contents	Percentage to Direct cost
Temporary facility cost	・ Preparation work Survey for commencement of the works Establish of temporary field office etc. ・ Cost for safety Lane control and common safety expense ・ Cost for quality control Cost for instrument of test etc. ・ Maintenance cost for temporary field office	4% (Approximately)
Field expenses	・ Welfare expenses ・ Cost for insurance CAR insurance, Automobile insurance ・ Staff salary, Allowance and Travel expenses ・ Office supplies expenses ・ Communication expenses	17% (Approximately)
Over head	・ Over head	10% (Approximately)

13.4.2 Estimated Project Cost

(1) Consultancy Cost

The consultancy cost for detailed engineering service usually account for 3 to 5% of direct cost. The average of 4% is adopted in this study. The consultancy cost for construction supervision service which generally account for 5 to 9% though depend on the work schedule, accordingly it is estimated at 6% of direct cost in this study.

(2) Compensation Cost

The estimated compensation cost is enumerated in Table 13-4-11. The detail of compensation cost mention in section 10.

Table 13-4-11 Compensation Cost

Items	Total Cost (US$)
House & Shop	1,214,247.30
Fence	2,812,.80
Tree Plantation	146,261.50
Estimated Allowance	10,000.00
Total	**1,395,321.60**

(3) Relocation Cost for Utility

It is necessary to relocate the telegraph poles along project site and optical cable under the ground. These relocation costs are estimated in Table 13-4-12.

Table 13-4-12 Relocation Cost for Utility

Items	Unit	Qty	Unit Price (US$)	Amount (US$)
Electric Pole (small, with cable)	km	32	8,429	269728
Electric Pole (big, with cable)	km	16.5	6,929	114328.5
Optical Cable	km	56	4,840	271040
Total				655,097

(4) Survey and demolition Cost for UXO

In this study, there is no UXO which affect to construction. Areas for borrow pit for embankment material along NR-1 could be dangerous after the flood. Survey and demolition work is only needed when contractor or supervisor judges the necessity of it. Therefore, the cost will not be included for project cost.

(5) Cost on Environmental Measurement

The cost on environmental measurement is estimated in Table 13-4-13. The detail of these costs is mentioned in section 10.

Table 13-4-13 Cost on Environmental Measurement

Items	Total Cost (US$)
Monitoring Program	12,160
Resettlement Action Plan	13,700
Environmental Management Action plan	43,950
Total	**69,810**

(6) Project cost

The project cost consists of construction cost, consultancy cost, compensation cost, relocation cost for utility, Survey and demolition Cost for UXO and Cost on Environmental Measurement. The project cost is mentioned in Table 13-4-14.

Table 13-4-14 Project cost

Item	Financial Cost	Local Cost	Foreign Cost	Tax
1. Construction Cost				
1) Direct Cost				
Earth Work	7,194,800	4,611,300	2,160,170	423,330
Pavement Work	13,074,450	8,195,100	3,838,850	1,040,500
Structure Work	6,858,200	4,397,800	2,060,020	400,380
Drainage Work	386,200	243,200	113,800	29,200
Road Facility Work	1,646,000	965,300	452,250	228,450
Temporary Work	331,300	217,600	101,900	11,800
Sub Total	29,490,950	18,630,300	8,726,990	2,133,660
2) Indirect Cost				
Temporary Facility Cost	1,179,638	745,212	349,080	85,346
Field Expenses	5,013,462	3,167,151	1,483,588	362,722
Overhead	2,654,186	1,676,727	785,429	192,029
Sub Total	8,847,285	5,589,090	2,618,097	640,098
Total	38,338,235	24,219,390	11,345,087	2,773,758
2.Consultant Fee				
Detailed Engineering	1,179,638	745,212	349,080	85,346
Construction Supervision	1,769,457	1,117,818	523,619	128,020
Total	2,949,095	1,863,030	872,699	213,366
3.Compensation Cost	1,395,322	1,268,474	0	126,847
4.Relocation Cost for Utility	655,097	595,543	0	59,554
5.Survey and demolition Cost for UXO	0	0	0	0
6.Cost on Environmental Measurement	69,810	63,464	0	6,346
Ground Total	**43,408,000**	**28,010,000**	**12,218,000**	**3,180,000**

unit: US$