CHAPTER 8 EVALUATION OF EXISTING ROAD CONDITION AND PRELIMINARY SELECTION OF SECTION TO BE REHABLITATED

Considering the limit of amount of the possible loan and other constraints, the three sections need to be prioritized for implementation. Selection of the section of NR 5 to be rehabilitated and the bypass to be constructed is to be made through the consultation between RGC and JICA during the project appraisal process by JICA. The task assigned to the Survey Team is to evaluate the present condition of NR 5 and show priorities of the South, Middle and North Sections for rehabilitation, as well as priorities of Battambang and Kampong Chhnang Bypasses for construction. Thus, the term 'preliminary selection' is used in this report.

This chapter discusses evaluation of the existing condition of NR 5 in order to consider the necessity and urgency of rehabilitation or improvement and construction of bypass based on the information available at the time of preparation of the Interim Report in early May 2011.

8.1 Criteria for Prioritization of Three Sections of Existing NR 5

Criteria for prioritization of the three sections (South, Middle and North) of existing NR 5 are proposed as described in Table 8.1-1.

Table 8.1-1 Criteria for Prioritization

Criteria	Description	Reason
Traffic Demand/ Traffic Congestion	Existing or anticipated traffic congestion	Smooth traffic is the most important reason for road improvement.
Existing Road Condition	・ Existing conditions of geometric structure, pavement and other road facilities ・ Condition inundation/flood	Bad condition of existing road hampers smooth and safe transportation.
Difficulty/Easiness of Implementation	・ Land acquisition/relocation (acceptance by stakeholders) ・ Difficult technical/ engineering problem	Negative factors need to be taken into consideration.
Relation with Other Project	・ Improvement by other project ・ Modification in timing of implementation etc. to cope with other relevant projects, if any	Existing road conditions and/or other criteria are influenced.

Table 8.1-1 briefly explains the reason for proposing each criterion. These reasons are further explained below:

(i) Traffic Condition

One of the main objectives of rehabilitation/improvement of NR 5 is to avoid traffic congestion, especially congestion in the near future, and secure smooth and safe traffic, which in turn, contribute to socio-economic development of region and whole nation.

(ii) Existing Road Condition

Existing road condition is taken into consideration to identify problems which is hampering, or is anticipated to hamper in the future, smooth and safe traffic.

(iii) Relation with Other Project

As described in Chapter 4, several repair/maintenance works are being, or have been, implemented on the South Section. Improvement of pavement executed shortly after completion of these repair/maintenance works is considered as ‘double investment’ and should be avoided. Also, execution some other projects may interfere execution of this Project.

8.2 Evaluation of Existing Road Condition

The situation of NR 5 is evaluated considering the criteria for prioritization as sited above. Followings are evaluation of existing NR 5.

8.2.1 Traffic Condition

The results of the future traffic forecast as described in Chapter 6, the traffic congestion is anticipated in the future at the locations listed below:

Table 8.2-1 Summary of Anticipated Traffic Congestion

Year	Location	Station No.	Description of Congestion
By 2021	South Section (Prek Kdam)	1	・VCR in peak hour approaches 0.8 and congestion is anticipated in peak hour. ・Daily traffic volume exceeds 20,000 PCU and congestion is anticipated substantial periods of day time.
	Middle Section (South end of Battambang City)	6	・Daily traffic volume exceeds 25,000 PCU and congestion is anticipated substantial periods of day time.
	North Section	7, 8	・VCR in peak hour exceeds 0.85 and congestion is anticipated in peak hour.
By 2030	South Section	1	・Daily traffic volume exceeds 28,000 PCU and severe congestion is anticipated substantial periods of day time.
		2	・Daily traffic volume exceeds 21,000 PCU and congestion is anticipated substantial periods of day time.
	Middle Section (South end of Battambang City)	6	・Daily traffic volume exceeds 36,000 PCU and traffic is paralyzed.
	North Section	7, 8	・Daily traffic volume approaches 25,000 PCU and congestion is anticipated substantial periods of day time.

It should be noted that the location of No. 6 is in the southern suburbs of Battambang City and thus, it coincides with the boundary between the Middle Section and North Section. It should also be noted that Counting Station No.6 is located in the southern suburbs of Battambang City, and thus, the traffic volume at this location includes short-trip traffic as substantial portion.

8.2.2 Existing Road Condition

(1) Geometric Structure/Road Width

The horizontal and vertical alignments of existing NR 5 are generous in general, although there are some sections with substandard sharp curves. This situation is common to the three sections (North, Middle and South Sections).

On the other hand, the widths of the North Section (Battambang – Sri Sophorn) and Kampong Chhnang – Thlea Ma'Am Section of the South Section are 7.7 to 7.8 meters and considered to be insufficient for 4-wheel vehicles to overtake motorcycles. (Please see Subsection 3.1.2.)

In view of increasing traffic volume, both in 4-wheel vehicles and motorcycles, separation of sow vehicles (motorcycles) and fast-going vehicles (4-wheel vehicles) is essential for enabling smooth and safe traffic.

From this viewpoint, widening of the North Section and South Section is more urgent than that of Middle Section considering that the road width of Middle Section is 10.4m. However this does not mean the width of Middle Section is sufficient. Rather, widening of the Middle Section is also necessary especially for traffic safety.

(2) Pavement Condition

Pavement conditions are generally acceptable, although many defects such as depression and cracks are actually observed. However this does not necessarily mean that the strength of the existing pavement is sufficient. Rather, the strength of existing pavement, in general, is not sufficient to support the increasing traffic volume, especially that of heavy vehicles. Also, frequent inundation and subsequent reduction in bearing capacities of the pavement/subgrade is accelerating the deterioration of the pavement.

Although the pavement is maintained in a acceptable condition owing to the strenuous effort of MPWT and Provincial DPWTs, such maintenance will become heavy burden in the near future in many ways such as budget requirements, workload of contacting and supervision of maintenance works and traffic management during the implementation of maintenance works.

This situation is more or less same among the North, Middle and South Sections.

(3) Bridge Condition

As discussed in Chapter 3, twelve bridges need to be replaced for various reasons. Table 8.2-2 shows the number of bridges which need to be replaced. Replacement of bridges requires relatively large cost and thus, the number of bridges which need replacement is taken in to consideration in evaluation of priority.

Table 8.2-2 Number of Bridge Which Need to be Replaced

Section	South	Middle	North
No. of Bridges to be Replaced	6	4	2

(4) Inundation

The results of the survey on inundation are summarized in Table 8.2-3.

Table 8.2-3 Summary of Survey Result of Inundation

Section	South			Middle	North
Location (KP)	40.6, 42.7, 57.6	45.7	55, 58.8, 90, 106.1	155	341.7 - 360
Water Depth	10 – 30cm	30cm	1 -5 cm	5cm	20 – 30cm
Frequency	1/ Every Yr.	1/ Every Yr.	1/ Every Yr.	1/ Every Yr.	2010 only
Duration	1 day – 2 weeks	1 month	1 – 2 days	3 days	2 days – 1 month

The severest inundation is that of KP 45.7. According to the local residents, the inundation started after a training center had been constructed nearby NR 5. Malfunction of side ditch is suspected as the cause of the inundation. If this is the case, the inundation may be mitigated by recovering the function of the side ditch.

Inundation of the North Section happened only once in year 2010. Some special cause is suspected.

8.2.3 Summary of Evaluation

The evaluations described above are summarized in the table below:

Table 8.2-4 Summary of Evaluation

	North Section	Middle Section	South Section
Geometric Structure	Narrow width	Narrow width in Pursat – Thlea Ma'Am	Width is generally OK
Pavement	Insufficient strength with weakening due to inundation on several sections		
No. of Bridges to be Replaced	2	4	6
Traffic Congestion	・Congestion by 2021 (in the south end of Battambang City) ・Congestion by 2021 for whole North Section	Congestion is not anticipated before 2030, except near the boundary with North Section (in the southern suburbs of Battambang City)	Congestion in peak hour anticipated near Prek Kdam by 2021
Inundation	・Only in year 2010	Only light inundation at limited location	Severe inundation is occurring at KP 45.7, but may be mitigated by improvement of side ditch

8.3 Preliminary Selection of Section to be Rehabilitated

8.3.1 Comparative Evaluation of Priority

(1) Prioritization of South, Middle and North Sections of Existing NR 5

Table 8.3-1 shows the application of the priority criteria stated in Subsection 8.1 above. It should be noted that the number of houses or families and area of land acquisition was not known at the time of this evaluation was made (August 2011), and thus, cannot be evaluated.

As indicated in Table 8.3-1, **the North Section is evaluated to have the highest priority** for rehabilitation.

Table 8.3-1 Priority of Three Sections of Existing NR 5

Criteria	Evaluation and Reason		
	North Section	Middle Section	South Section
Traffic Demand/ Traffic Congestion	◎ ・ Congestion by 2021	△ ・ Some congestion is anticipated by 2030	○ ・ Congestion on the south end (Prek Kdam) by 2021
Existing Road Condition	○ ・ Narrow width ・ Insufficient pavement strength ・ Some sharp curves ・ Inundation	△ ・ Insufficient pavement strength	○ ・ Narrow width on Pursat – Thlea Ma'Am section ・ Insufficient pavement strength ・ Inundation
Influence of Other Project	○ Nothing particular	○ Nothing particular	× ・ Existing serious pavement defects are to be repaired in RAMP: Large-scale rehabilitation in the next few years becomes 'double investment'. ・ There is a possibility that Chinese government improves/ widens the section near Prek Kdam.
Overall Evaluation of Urgency	Very High	Medium	Very High: Considering that various repair/maintenance works are being implemented, the priority is evaluated next to North Section.

8.4 Further Discussion on the Selection of Section to be Improved

Initial selection of priority section was made by the time of preparation of Interim Report in May 2011. In September – October 2011, severe flood/inundation occurred in many places in Cambodia and several sections of the South Section were damaged, giving rise to discussion on the priority. This section is added to further discuss the issue of priority, focusing on the priorities of the North Section and South Section.

Although the discussion here focuses on the improvement of the North and South Sections, it is implicitly assumed in the following discussions that improvement of the Middle Section be implemented in the future, considering that the entire length of NR 5 needs to be improved because of the importance of NR 5 as an international and national arterial road.

8.4.1 Strategy for Improvement

There are a few strategies which are commonly considered in planning of road network development:

(1) Continuity with already-improved section

Experience in Japan shows that road improvement give larger impact to traffic if the improved section is continuous, rather than fragmented, and connected to a large city. From this viewpoint, two scenarios for improvement of NR 5 are possible:

(i) Start from Phnom Penh: This is the most straightforward policy in view of the above.
(ii) Start from Sri Sophorn: In view of increasing international traffic between Cambodia and Thailand, as well as the fact that Sri Sophorn – Poipet Section has been already improved, this scenario is also justifiable. Especially, if seen from the viewpoint of Thai drivers, improvement of the North Section will give an impression of ‘continuity’.

Further, it is recommended that improvement of the Middle Section be implemented without time lag from improvement of the North Section and South Section to maintain ‘continuity’ over the whole section of NR 5.

(2) Traffic demand versus development effect

When multiple number of road projects are planned and priority of implementation is discussed, there are two main opinions:

(i) Economic effect: Road improvement projects, like any other type development project, give large impact to the local/regional economy. In many countries, public works are used as a tool to stimulate regional economy and national economy. From this viewpoint, a road project implemented in less developed region is given higher priority than those implemented in developed region such as Phnom Penh and its surroundings.

(ii) Traffic demand: On the other hand, there is an opinion that road improvement needs to be implemented to cope with the traffic demand and thus, should be started from the section with high traffic demand. From this viewpoint, the South Section should be given higher priority than the North Section.

The above two opinions are considering completely different effect of road projects and it is difficult to decide which is more important. However, one thing may be said in case of NR 5:

Most congested section of NR 5 is Phnom Penh – Prek Kdam. Severe traffic congestions are occurring every day on this section, especially near Phnom Penh. Basic solution to this congestion is widening of Prek Kdam – Phnom Penh Section and development of alternative routes such as NR 51 – NR 42 route and Kop Slov Dike Road. Without such improvements, simple widening of the South Section will amplify the congestion on Prek Kdam – Phnom Penh Section.

Actually it is very difficult to show the difference of priority between the North Section and South Section in a strictly quantitative manner. The JICA Team compared several factors and evaluated that the priority of North Section is higher than that of South Section as explained in the previous section. But this is relative comparison between North Section and South Section. It should be noted that the necessity for improvement is also very high in both of South and North Sections.

8.4.2 Timing of Implementation of Improvement

Timing of implementation of In usual road planning, capacity of the road is planned so that the planned traffic volume is around 65% of the capacity or less to ensure smooth traffic flow. Usually 20,000 pcu is considered to be the capacity of opposed 2-lane road. Thus, opposed 2-lane roads need to be widened before traffic volume reach to around 13,000 pcu to ensure smooth traffic.

As explained in Chapter 13, completion of improvement works are estimated in year 2017, if the civil works are to be started in year 2015 (see Table 13.3-1). Traffic volume on the North Section (Station No. 8) is estimated to reach 13,000 pcu around year 2017, coinciding with the expected completion year of the Project.

Table 8.4-1 Traffic Volume on the North Section

Year	2011	2016	2017 (Interpolated)	2021	2030
Traffic Volume (pcu)	8,453	12,356	13,447	17,812	25,540

Thus, it is justified to start the civil works for improvement of the North Section in year 2015, and a loan is extended to the Project of improvement of the North Section.

8.5 Necessity and Prioritization of Bypasses

8.5.1 Necessity and Priorities of Battambang Bypasses and Kampong Chhnang Bypass

(1) Necessity of Bypass in General

The main reasons for constructing a bypass are as described below:

- Common textbooks on road network planning state that through traffic should be guided, as much as possible, to detour the urbanized area. This is necessary to avoid traffic congestion, traffic accidents and deterioration of living environment (noise and air quality).
- Even without serious traffic congestion in urbanized area, travel speed of vehicles becomes slower in urbanized area due to traffic lights and other causes. This situation will cause considerable time loss of long trip and cause unnecessary transport cost.
- Also, a street would become excessively wide if it is to cater both intra-urban traffic and through traffic. An excessively wide street would separate the communities on the both sides of the street and hamper sound social and economic activities.
- Quite often, bypass becomes the outer boundary of the city in the long future. Properly planned bypass can help desirable form of urban development.

(2) Necessity of Battambang Bypass

Construction of bypass around the city of Battambang is considered to be necessary for the following reasons:

- Traffic volume in the city of Battambang is very large and is expected to further increase in the near future. Actually, DPWT Battambang is implementing widening of streets in the city area. However, widening of streets cannot be regarded as a good measure for mitigating traffic congestion in the city, considering the reasons for the necessity of bypass as sited above.
- Traffic volumes on NR 5 in the outskirts of the urbanized area of Battambang City are forecasted to exceed the capacity of a 2-lane road by year 2021. To secure smooth traffic flow (V/C <0.65), Battambang Bypass becomes necessary before 2016.

Table 8.5-1 Future Traffic Volume in the Outskirt of Battambang City

Location	Traffic Volume	2016	2021	2030
Southern Outskirt (Sta. 6)	Traffic Volume	17,556	25,625	36,834
	V/C*	0.878	1.28	1.84
Northern Outskirt (Sta. 7)	Traffic Volume	13,545	20,090	29,464
	V/C*	0.68	1.00	1.47

*Ratio of traffic volume to capacity of road section: Full capacity of 2-lane road (20,000 pcu/day) is assumed. V/C larger than 0.65 is not desirable from viewpoint of smooth traffic.

(3) Necessity of Kampong Chhnang Bypass

Reasons explaining necessity of a bypass as described in (1) above can be applied also to Kamong Chhnang Bypass. Thus, Kampong Chhnang Bypass is necessary. However, the forecasted traffic volume around Kampong Chhnang City is smaller than that around Battambang and estimated to exceed the capacity of a 2-lane road around year 2030. To secure smooth traffic flow, Kampong Chhnang Bypass becomes necessary around year 2020.

Table 8.5-2 Future Traffic Volume in the Outskirt of Kamopong Chhnang City

Location	Traffic Volume	2016	2021	2030
Southern Outskirt (Sta. 2)	Traffic Volume	11,519	15,735	21,164
	V/C*	0.58	0.79	1.058
Northern Outskirt (Sta. 3)	Traffic Volume	10,001	13,775	18,947
	V/C*	0.50	0.69	0.95

*Ratio of traffic volume to capacity of road section: Full capacity of 2-lane road (20,000 pcu/day) is assumed. V/C larger than 0.7 is not desirable from viewpoint of smooth traffic.

(4) Comparison of Priority Between Battambang Bypass and Kampong Chhnang Bypass

The priorities between Battambang Bypass and Kampong Chinanng Bypass are compared as described below:

- Traffic volume around Battambang City is larger than that around Kampong Chhnang City.
- Especially the traffic volume in the southern suburbs of Battambang City is the largest among those forecasted at eight locations, and is anticipated to greatly exceed the capacity of the road by 2021.
- If the North Section is to be rehabilitated, supervision of construction of Battambang Bypass is easier than that of Kampong Chhnang Bypass because it is adjacent to the North Section.

Based on the above consideration, **Battambang Bypass is evaluated to have higher priority.**

The final decision of the section to be rehabilitated, as well as the bypass to be constructed, is to be made during the process of appraisal of the Project where RGC and JICA Appraisal Mission will consult.

The above opinion of the Survey Team on the priorities was explained in the 1st Steering Committee held on 12 May 2011 and accepted by the Committee. Upon return to Tokyo after the 1st Steering Committee, the Survey Team explained to JICA the above priorities and JICA accepted the Team's explanation. With these consent of RGC and JICA, the Survey Team focused on the North Section and Battambang Bypass.

(5) Necessity of Sri Sophorn Bypass

Sri Sophorn Bypass was initially proposed by Province of Banteay Meanchey. The main reason of this proposal was to avoid relocation of large number of houses and people which would become necessary if the North Section would be widened to 4-lane up to the intersection with NR 6.

DPWT of Banteay Meahchey also explains that the number of heavy truck coming from Thai border and pass through the city of Sri Sophorn has been increasing especially during night. This is causing noise and vibration during night, as well as hazardous situation for traffic accident.

These are typical reasons necessitating construction of bypass, rather than widening of existing streets in the city, as explained before.

Further, the traffic volume on Sri Sophorn Bypass is estimated to be considerably large and is comparable to that on Battambang Bypass.

Table 8.5-3 Traffic Volume on Sri Sophorn Bypass and Battambang Bypass

City	Section	2011	2016	2021	2030
Sri Sophorn	Bypass	3,940	5,563	7,632	10,281
	Inner city	4,505	6,546	9,482	13,284
Battambang	Bypass	3,831	5,450	7,840	11,799
	Inner city	6,886	10,161	15,495	22,136

Thus, construction of Sri Sophorn Bypass is judged to be justified.

CHAPTER 9 PLANNING OF BYPASS ROUTE

9.1 Planning of Battambang Bypass

Based on the agreement for this Survey between RGC and JICA, the priorities of Kampong Chhnang Bypass and Battambang Bypass were studied in the 1st Stage Survey. According to the results of traffic demand forecasts and other data, it was concluded that Battambang Bypass has a higher priority than Kampong Chhnang Bypass and it was accepted by the Steering Committee that this Survey focuses on Battambang Bypass. Also, necessity of Battambang Bypass was explained in Subsection 8.5.1.

9.2 Alternatives

(1) Alternative Routes Proposed by DPWT Battambang

Prior to the commencement of this Survey, DPWT Battambang already proposals for the bypass route as shown in Figure 9.1-1 by the blue lines. These proposed routes are planned along the existing roads. The main features of the alternative routes proposed by DPWT Battambang are as follows:

(i) Bypass is constructed by widening the existing road/streets.
(ii) Thus, the residents along the bypass benefit.
(iii) Legally, the land used for the existing roads need not to be acquired. Thus, acquisition is needed only for the land taken for widening.
(iv) The subgrade of the existing roads/streets has been compacted during the long period that these roads/streets have been used. Thus, compaction is not required.

(2) Alternative Routes Proposed by JICA Team

The JICA Team proposed three other alternative routes as shown by the red lines in Figure 9.2-1. The alternative routes proposed by the JICA Team are to traverse mainly agricultural land and minimize the number of houses or other buildings to be relocated. The main features of the alternative routes proposed by the JICA Team are follows:

(i) Minimize relocation of houses and other buildings.
(ii) To fully achieve the function of bypass which is to allow the through traffic detour the urbanized area and sustain this function as long as possible.
(iii) The bypass practically defines the boundary of future urbanized area. Thus the route is selected so that sufficient space be provided for future development of Battambang City

Advantages and disadvantages of these alternatives are compared in Table 9.2-1.

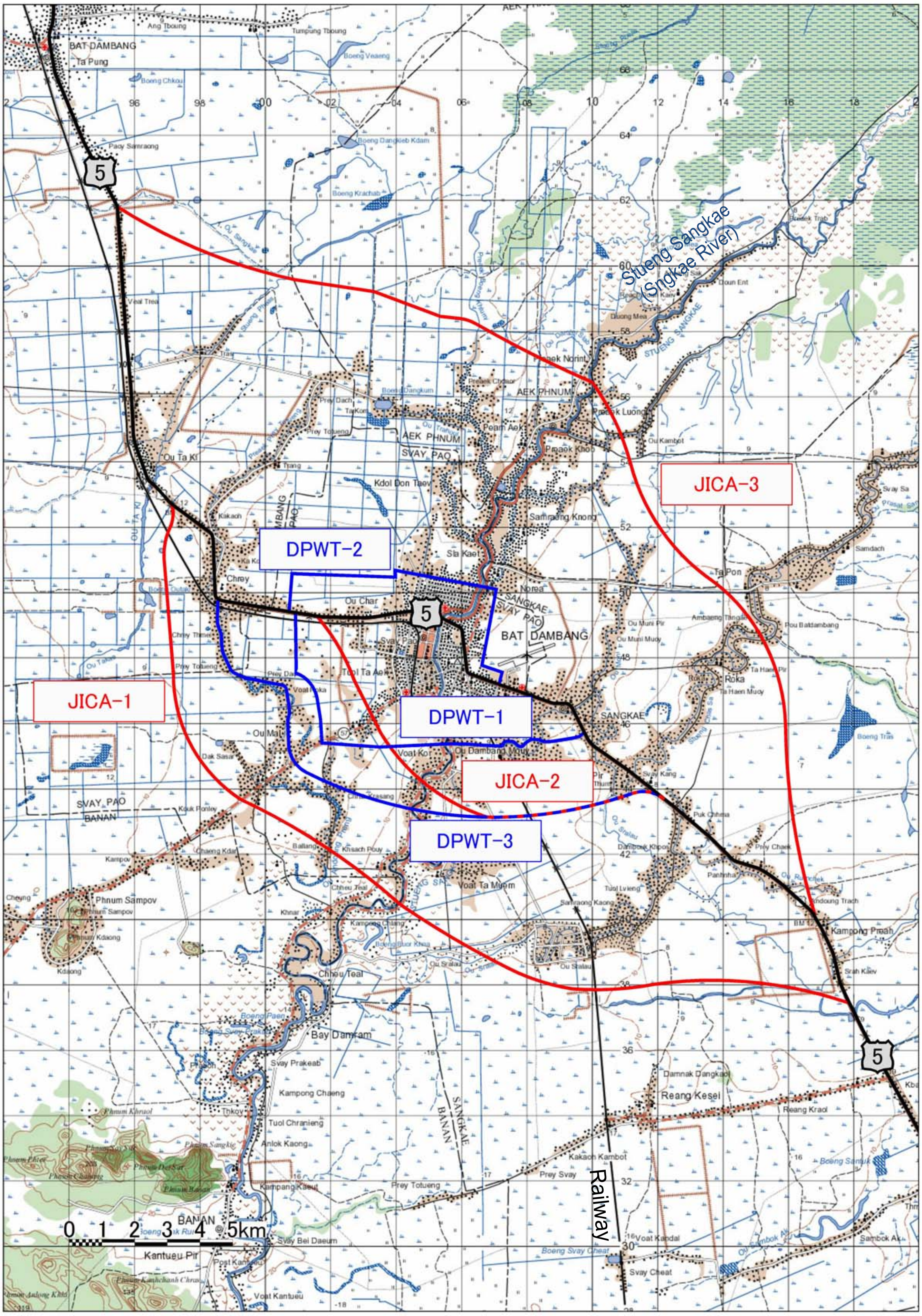


Figure 9.2-1 Alternative Routes of Battambang Bypass

Table 9.2-1 Comparison of Alternatives of Battambang Bypass Routes

Alternative	Length (km)	Estimated No. of Relocated House/Bldg.*	Advantage	Disadvantage
DPWT-1	13	180	✓ Owners of properties (houses and/or land) want the road in front of their properties be improved. Thus, this alternative is welcomed by these people.	✓ Large number of houses/buildings need to be relocated. ✓ Through traffic still passes through urbanized areas resulting in increase of traffic congestion and traffic accidents. ✓ Horizontal alignment is not smooth and prospects of traffic congestion and traffic accidents are considered to be more than those in JICA-1 to JICA-3.
DPWT-2	11	400	✓ Same as above	✓ Same as above
DPWT-3	18	360	✓ Same as above	✓ Large number of houses/buildings need to be relocated. ✓ Through traffic enters urbanized area resulting in increase of traffic congestion and traffic accident.
JICA-1	30	80	✓ The basic function of bypass road which is to allow through traffic to bypass the urbanized area is well achieved. ✓ The route is remote from the urbanized area and the above function of bypass will be maintained in future.	✓ Route is longer than JICA-2 resulting in larger project cost. ✓ Considerable area of agricultural land is lost.
JICA-2	14	70	✓ The basic function of bypass road which is to let through traffic bypass the urbanized area is well achieved.	✓ As the urbanized area will expand in future, the 'function as bypass' will be lost or reduced. ✓ Considerable area of agricultural land is lost, although

			✓ Shortest among the alternatives proposed by JICA Team resulting in the minimum project cost.	smaller than that in JICA-1,
JICA-3	34	50	✓ The basic function of bypass road which is to let through traffic bypass the urbanized area is well achieved. ✓ Estimated number of houses/buildings to be demolished is the least among the alternatives.	✓ Traverses the vicinity of the conservation area of Tonle Sap Lake. Thus, some impact on the natural environment may occur. ✓ There is a possibility that the highway embankment will disturb the hydrological environment of Tonle Sap Lake and/or its vicinity. ✓ Length traversing soft ground area and the total route is the longest among the alternative routes resulting in the largest project cost.

*The number of demolished house/building is based on the preliminary survey conducted in the early stage of this Survey when required ROW is not fixed. Thus, the numbers shown here are subject to change in the future depending on the detailed design of the road and detailed survey on the houses/building which need to be demolished.

9.3 Preliminary Selection of Optimum Route

A stakeholder meeting was held on 19 May 2011, with the participation of 14 people including three representatives from MPWT and chaired by H.E. Vice Governor of Battambang Province. Route of the bypass was one of the main subjects for discussion at the meeting. The comment of H.E. Governor of Battambang Province made at the meeting was that Alternative JICA-3 is the most preferable from the viewpoint of future development of Battambang City. However, the MPWT staff and their consultant explained that Alternative JICA-3 traverses the designated conservation area of Tonle Sap Lake and its vicinity and there is a possibility of adverse impact on the natural environment. The MPWT staff and their consultant also explained that Alternative JICA-3 passes through a soft ground area and the construction cost may be higher than the other alternatives proposed by JICA Team.

After discussion among the participants, as well as upon communication to H.E. Governor through the Chairperson (H.E Vice Governor), the following order of preference was concluded:

- 1st preference: JICA-1
- 2nd preference: JICA-2

9.4 Adjustment of Alignment

(1) Fine adjustment of JICA-1 alignment

Prior to the departure from Japan for the 2nd Stage Survey, the JICA Team undertook a fine adjustment of the JICA-1 alignment to reduce the numbers of houses/buildings to be demolished. This adjustment was done with the use of 1:2000 scale satellite images. The adjusted routes are shown in Figure 9.4-1.

JICA-1A1:
Shift the alignment at Point-A to make the crossing angle with the existing road and residential area on the both sides of the road as close to a right angle as possible to shorten the length of the section traversing the residential area and reduce the number of houses/buildings to be demolished.

JICA-1A2:

Shift the section between Steung Sangkae and the railroad to the southwest direction to cross the residential area along the existing local road at a point away from urbanized area where the houses/buildings are assumed to be sparsely distributed. The JICA Team visited the site of Battambang Bypass on 23 and 24 June 2011 to observe the actual situation of houses/building located along the proposed route of bypass. The JICA Team also met the Director of DPWT

Battambang, on 23 June 2011, to confirm that JICA-1 is the 1st choice of Battambang Province and this was confirmed.

After the meeting with the Director of DPWT Battambang, the JICA Team visited the sites of the above two alternatives, and concluded that JICA-A2 is more preferable than JICA-1A1 because of the smoothness of horizontal alignment and smce there is very little difference in number of houses/buildings to be demolished.

(2) Comment by H.E. Governor of Battambang Province

While the JICA Team was visiting the site, a further comment from H.E. Governor was transmitted to the JICA team indicating that the governe prefers the bypass route to be located not too far from the urbanized area was transmitted to the JICA Team.

(3) New alignments

Upon receipt of the above comment by the Governor, the JICA Team reexamined the alignment of JICA-1 and found two possible new alignments as shown in Figure 9.4-1 as JICA-1B and JICA-1C.

Among these two new alignments, JICA-1B is evaluated to be less advantageous than JICA-1A and JICA-1C for the following reason:

- The location of the intersection with the existing NR 5 to the south of Battambang City is the same as that of JICA-1C.The refore the effect on traffic flow is the same as JICA-1C (less than that of JICA-1A), while the route is longer than JICA-1C resulting in higher construction cost than JICA-1C.

Thus, JICA-1B is discarded at this stage and JICA-1A and JICA-1C are compared. Advantages and disadvantages of these two alternatives are summarized in Table 9.4-1.

(4) Selection of JICA-1C

As a whole, JICA-1A is preferable from the view point traffic flow bypassing the urbanized area of Battambang while JICA-1C is preferable from the view point of the traffic starting from or arriving in the urbanized area of Battambang. These features can be said only when the two alternatives are compared with each other and neither of them has a serious disadvantage as a bypass in view of the flow of traffic or future development of Battambang City.

Finally, the JICA Team recommended the JICA-1C route as the best choice to mto consideration the opinion of HE Governor of Battambang. MPWT consulted DPWT of Battambang on the selection of the bypass route and concluded that JICA-1C is also the most preferable.

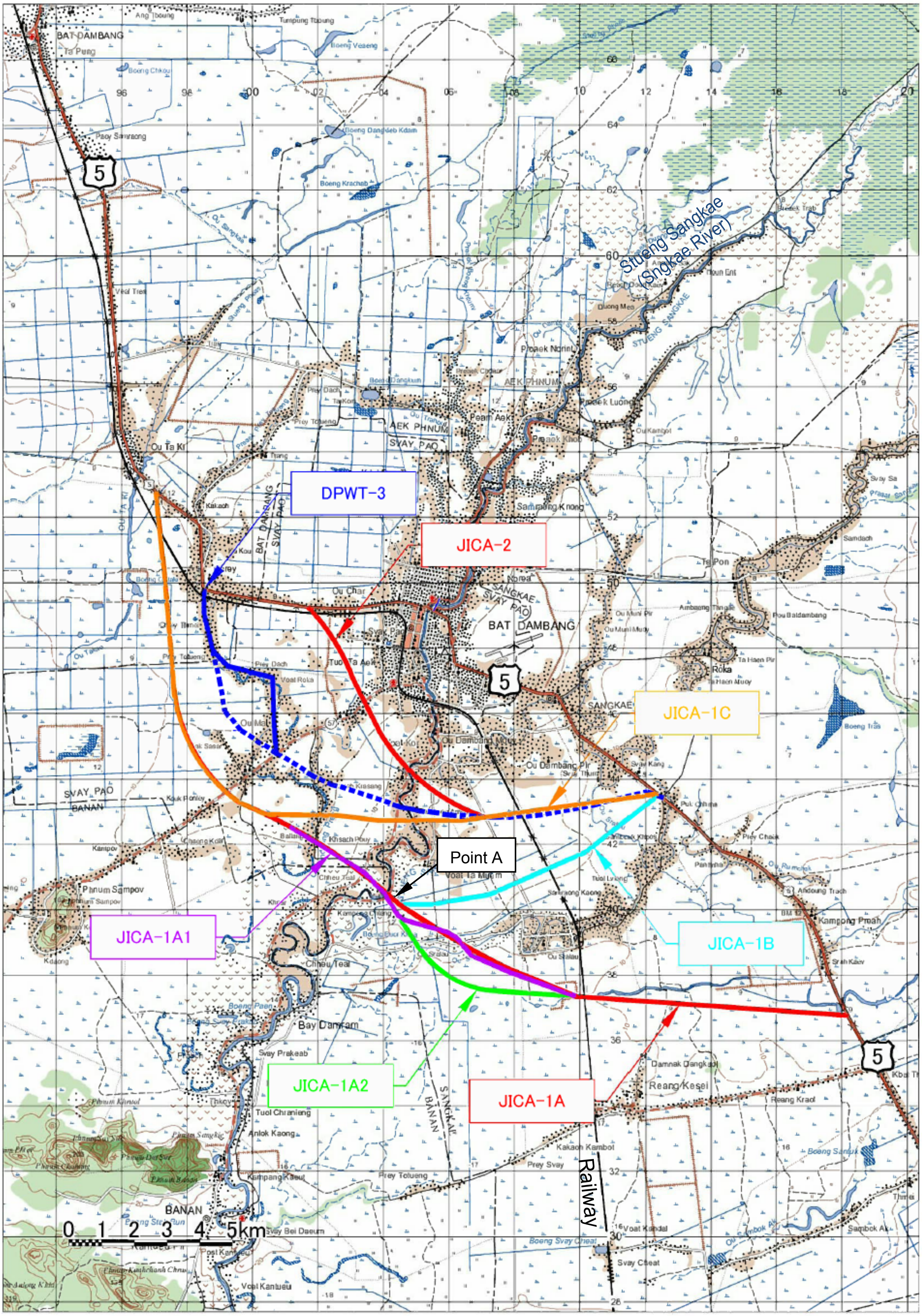


Figure 9.4-1 Adjustment of Alignment

Table 9.4-1 Comparison of JICA-1A and JICA-1C

Alternative	Length	Advantage	Disadvantage
JICA-1A	30 km	✓ Widening of Battambang City – Ou Sanda (KP 273) is not necessary. ✓ Travel distance between Sri Sophorn and Phnom Penh is shorter than that of JICA-1C. ✓ The function of bypass (smooth traffic) will be maintained in the long term. ✓ There is sufficient space for expansion of Battambang City in the long term.	✓ South connection point with existing NR 5 is far from existing urbanized area of Battambang City. ✓ Thus, this may have less desirable influence on the expansion of Battambang City in the short term or medium term. ✓ Higher construction cost
JICA-1C	23 km	✓ South connection point with existing NR 5 is near to the existing urbanized area of Battambang City ✓ Thus, this will contribute to expansion of Battambang City in short term or medium term. ✓ Lower construction cost	✓ Widening of Puk Chhma (KP 280) – Ou Sanda (KP 273) will be necessary in future. ✓ Travel distance between Sri Sophorn and Phnom Penh becomes longer than that of JICA-1A. ✓ The long term., urbanized area of Battambang will expand and the function of bypass (smooth traffic) will be reduced. ✓ The long term, expansion of Battambang City will be limited to the bypass.

- JICA-1A is preferable from viewpoint of long distance traffic and city development in the long term.
- JICA-1C is preferable from viewpoint of traffic around Battambang City and medium-term city development.
- Differences of advantages and disadvantages between the two alternatives are not large.
- Thus, both alternatives are technically feasible plans.

9.5 Planning of Sri Sophorn Bypass

During the Second Steering Committee held on 30 August 2011, the Cambodian side requested JICA to add study on the construction of Sri Sophorn Bypass to the scope of the Project. Construction of Sri Sophorn Bypass can reduce the traffic in the urbanized area of Sri Sophorn City and widening of the existing NR 5 can be minimal. Decrease in the required ROW for widening is expected to substantially decrease the number of houses and households that will be affected. After several discussions among RGC and JICA, JICA agreed to the proposal and added study of Sri Sophorn Bypass to the scope of work of the JICA Team. Necessity of Sri Sophorn Bypass is also explained in Subsection 8.5.1.

9.5.1 Alternatives

(1) Routes Proposed by DPWT Banteay Meanchey

The plan of DPWT Banteay Meanchey was to construct the bypass connecting western suburbs of Sri Sophorn City with the existing NR 5 south of Sri Sophorn city at the location where the existing NR 5 turns to the North coming from the town of Mongkol Borei. (See Figure 9.5-1.)

(2) Alternative Routes Proposed by the JICA Team

While the route proposed by DPWT Banteay Meanchey is reasonable, the JICA Team considered it preferable to extend the bypass to the south of the town of Mongkol Borei. This proposal was made to minimize the necessity of widening of existing NR 5 in the town of Mongkol Borei.

Based on the above consideration, the JICA Team proposed 4 alternatives as shown in Figure 9.5-1. Advantage and disadvantage of these 4 alternatives, as well as the alternative proposed by DPWT Banteay Meanchey are compared in Table 9.5-1. After consultation among MPWT, DPWT Banteay Meanchey and the JICA Team, it was agreed that JICA-3 be adopted.

9.6 Regulation on Disorderly Development of Lands Along Bypasses

Battambang Bypass and Sri Sophorn Bypass are to be constructed to let the trough traffic detour the urbanized areas of the two cities and shorten the travel time of vehicles. To maintain the function of bypass, disorderly development of the land along the bypass needs to be regulated. This is particularly necessary in Cambodia where many factories and other industrial facilities are newly built along an road shortly after it is improved.

Also, conservation of agricultural land is important issue in view of the fact that the Project Area is one of the main production area of rice in Cambodia.

Table 9.5-1 Comparison of Alternatives of Sri Sophorn Bypass

Alternative	Length (km)	No. of Relocated Houses/Bldg.	Advantage	Disadvantage
DPWT	8.6	Less than 20	Short route and minimum construction cost	Traffic needs to pass through city of Mongkol Borei (Ruessei Kraok)
JICA-1	8.7	No substantial difference with the case of Alternative of 'DPWT'	Same as DPWT. Avoids irrigation channel and does not need a bridge to cross the channel.	Same as above.
JICA-2	13.7		Through traffic can bypass both Sri Sophorn and Mongkol Borei.	Bypass can connect to NR 5 only at the both ends of the bypass.
JICA-3	13.4		Same as above Can connect to NR 5 at a location midway between Sri Sophorn and Mongkol Borei through the existing local road.	Alignment is winding
JICA-4	13.3		If the fund is not sufficient, the section to bypass Mongkol Borei can be constructed later.	There will be an intersection at a location midway between Sri Sophorn and Mongkol Borei which reduces the travel speed.

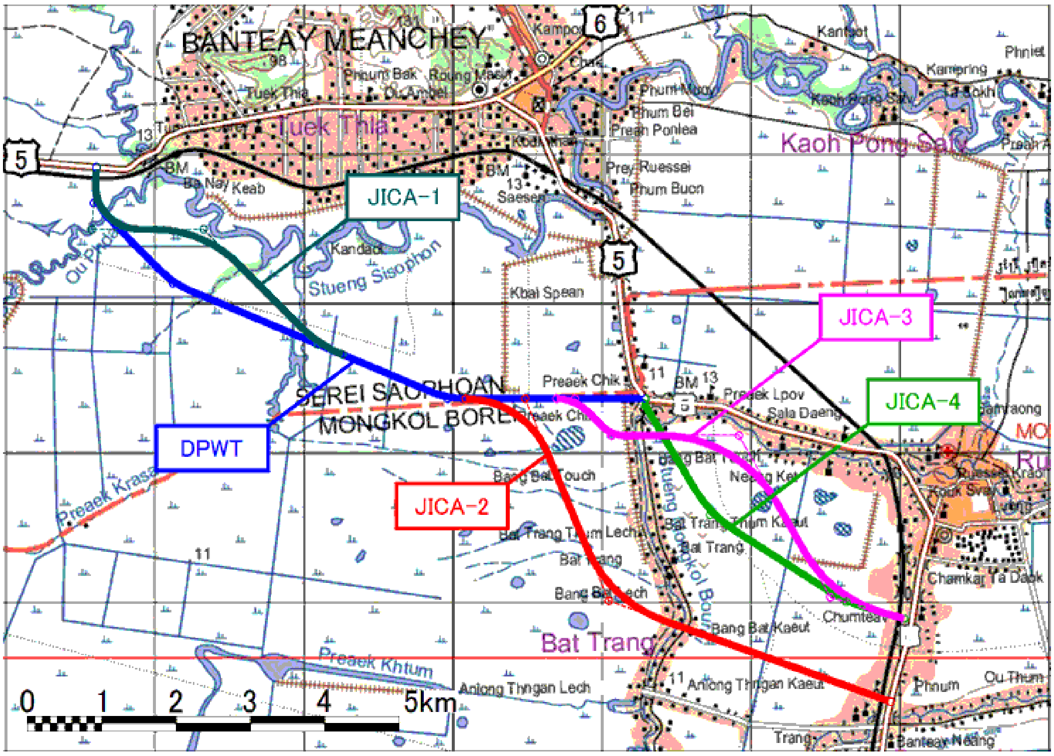


Figure 9.5-1 Alternatives of Route of Sri Sophorn Bypass

CHAPTER 10 HIGHWAY DESIGN

Improvement of the North Section of existing NR 5 and construction of Battambang Bypass and Sri Sophorn Bypass were selected as the components of the Project in Chapter 8. This chapter describes the preliminary design of these improvement/construction.

10.1 Basic Design Policy

Before actual preliminary design is conducted, basic policy for design and existing conditions corresponding to the said design item are discussed.

10.1.1 Horizontal Alignment

The horizontal alignment of North Section of NR 5 is composed of long straights and some curved sections. These curved sections may need improvement if the existing alignment does not satisfy the requirements of the design criteria.

(1) Applicable Design Criteria

NR 5 is designated as Class I road of Asian Highway Network. Thus, it is desirable to satisfy the design criteria of Asian Highway Class I road. At the same time, NR 5 is an arterial national road of Cambodia and it needs to satisfy the Road Design Standard of Cambodia. Table 10.1-1 compares the design criteria of Asian Highway Class I and Road Design Standard of Cambodia. The table also shows the criteria recommended for the Project. These recommended criteria have been discussed in outline between MPWT and JICA Team.

Table 10.1-1 Comparison of Design Speed and Criteria

Standard	Asian Highway	Cambodian Standard		Recommended	
Road Class	Class I	R5 (Rural)	U5 (Urban)	Rural	Urban
Design Speed	100 km/h (Flat)	100 km/h (flat)	50 km/h (type3)	100 km/h	50 km/h
Min. Curve Radius (Superelevation)	350 m (10%)	415 m (6%)	90 m (6%)	350 m (10%)	80 m (10%)

(2) Existing Conditions of Horizontal Alignment of North Section

Table 10.1-2 shows the existing curved sections of the North Section. There are 39 curved sections along the North Section, from KP 301 in Battambang City to the roundabout intersection (KP 360+620) with NR 6 in Sri Sophorn City. Twenty (20) curved sections are located after KP 350. In particular, there are many curves in the city area of Sri Sophorn. Straight line is widely adopted in other parts of the North Section.

At present, the speed limit on NR 5 is 60 km/h in the ordinary (rural) sections and 40 km/h in the town areas. There are road signs giving speed limits installed at the entrance and exit points of the town areas in Battambang Province as listed below:

- Battambang City (KP 285+720 ~ KP 296+030)
- Chreg Commune (KP 298+370 ~ KP 299+410)
- Otaki Commune (KP 306+030 ~ KP 306+410)
- Taporg Commune (KP 316+900 ~ KP 318+910)

However, there are no road signs giving speed limits for town areas in Banteay Meanchey Province. Therefore, 3 sections are provisionally assumed to be town areas in Banteay Meanchey Province, based on the observation of the site condition by the JICA Team:

- Brosat Commune (KP 339+380 ~ KP 339+800)
- Russey Krork Commune (KP 350+400 ~ KP 351+000)
- Ambel Commune (KP 357+610 ~ 360+620)

As for the curves on the rural sections, the curve radii are generally small and some of them do not satisfy the requirements of the design criteria of the Project, and improvement of horizontal alignment will be required to satisfy design criteria.

Table 10.1-2 Curved Sections on North Section

No.	KP of IP	Curve Radias	Land**	Criteria	No.	KP of IP	Curve Radias	Land	Criteria
1	301+003	150	R	small	21	351+455	170	R	small
2	302+656	760	R	OK	22	351+525	200	R	small
3	303+333	1040	R	OK	23	351+797	250	R	small
4	303+592	250	R	small	24	352+481	1100	R	OK
5	304+582	470	R	OK	25	353+721	1010	R	OK
6	304+897	430	R	OK	26	354+392	250	R	small
7	311+910	690	R	OK	27	355+485	110	R	small
8	312+135	270	R	small	28	355+767	210	R	small
9	316+535	1050	R	OK	29	357+228	950	R	OK
10	317+801	230	T	OK	30	357+685	170	T	OK
11	318+228	230	T	OK	31	358+139	220	T	OK
12	318+786	290	R	small	32	358+139	180	T	OK
13	319+372	250	R	small	33	358+416	200	T	OK
14	334+996	310	R	small	34	358+547	230	T	OK
15	339+108	290	R	small	35	359+041	140	T	OK
16	339+108	330	T	OK	36	359+742	100	T	OK
17	339+935	200	R	small	37	359+795	60	T	small
18	340+590	500	R	small	38	359+850	230	T	OK
19	342+531	700	R	OK	39	360+016	70	T	small
20	350+732	160	T	OK					

*intersecting point (of the extensions the straight lines tangent to the said curve) **Land T: Town, R:Rurul

10.1.2 Vertical Alignment and Height of Road Surface

(1) Basic Design Policy

Maximum grade of 4.0% is adopted for the vertical alignment, considering the design criteria of Asian Highway and Cambodian Standard. The North Section traverses generally flat plain, and slope sections exist only in the approach sections of the bridges. Where the bridges will be improved and the surface of bridge will be raised as discussed in Chapter 11, the approach sections will also be improved together with the construction of structures. Figure 10.1-1 shows schematic illustration of an approach section of bridge.

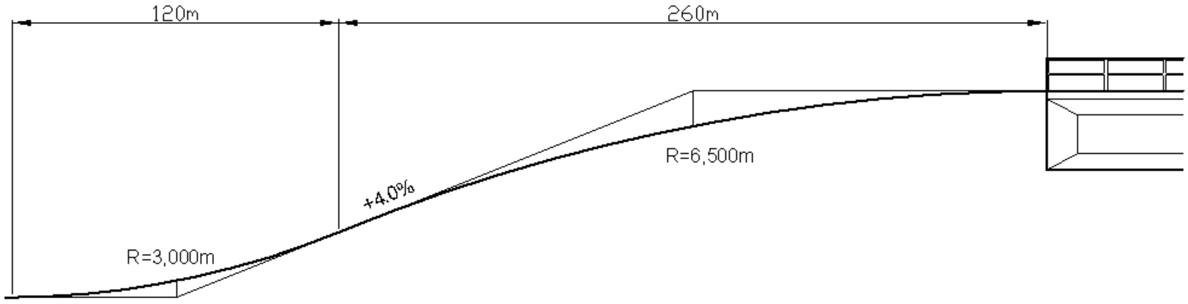


Figure 10.1-1 Vertical Curve at Bridge Approach

Where the surface of the bridge will remain as the existing condition, the existing vertical alignment shall be examined based on the above-mentioned criteria, and improved as necessary.

The height of road surface needs to be raised so that the pavement structure will not be submerged. In general, the bottom of pavement structure shall be 50 cm higher than flood water level to protect the pavement. Also height of road surface needs to be raised to prevent the inundation and/or overflow during flood.

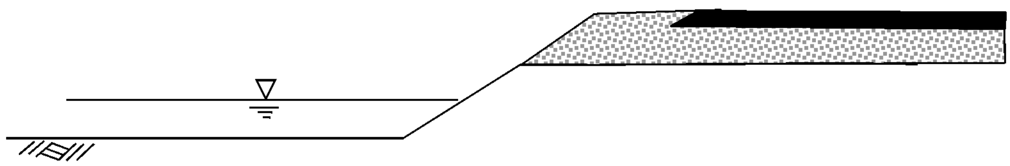


Figure 10.1-2 Schematic Illustration of Minimum Height of Pavement Structure

The Battambang Bypass and Sri Sophorn Bypass are to traverse paddy fields which are submerged during flood season. The height of road surface shall be sufficiently higher than the water level in flood season. It is also necessary to install cross drainage structures over a few hundred meters intervals and the height of embankment shall be designed so that sufficient depth of cover is provided to the culverts.

(2) Existing Condition

The vertical alignment on the North Section is generally flat, except in the approach sections of bridges. At some of the approach sections of bridges, the vertical curves are substandard, resulting in insufficient sight distance. It is necessary to improve the approach section properly in accordance with the adopted design speed.

According to the results of interviews at flood sections as described in Chapter 6, the section between KP 351 and KP 360 has been inundated only in October 2010. The depth of inundation varied between 15 cm and 30 cm, and the road became impassable during this flood. There is information that this inundation may be attributed to the collapse of a dam in Thailand.

The local residents near KP 344 say that overflow occurs every year at several locations. The depth of water is 1 ~ 2 centimeters only and duration is usually less than 1 day. Raising of road surface and installation of additional culvert for equalizing the water level on both sides of the road may be necessary. This will be a subject for in the detailed design stage.

10.1.3 Cross Section

(1) Basic Design Policy

Table 10.1-3 shows the road cross section design criteria to be applied.

Table 10.1-3 Comparison of Design Criteria

Items	Asian Highway	Cambodian Standard		Recommend
Road Class	Class I	R5 (Rural)	U5 (Urban)	
Lane Width	3.50 m	3.50 m		3.50 m
Shoulder Width	3.00 m (Flat)	3.00 m (Flat)	2.50 m (Type3)	3.00 m
Median Strip	3.00 m (Flat)	4.0~12.0 m (Flat)	2.0~4.0 m (Type3)	0.5~3.0 m
Cross Slope	2.0% (AC)	2.5~3.0% (AC)		2.0%
Shoulder Slope	3.0~6.0%	3~4% (sealed)	3%	
Vertical Clearance	4.5 m			4.5 m

The lane widths and shoulder widths of Asian Highway and Cambodian Standard are the same. The shoulder is proposed to be covered with DBST to provide the space for the bicycles and pedestrians. Low speed traffic also can use the shoulder if pedestrians or non-motorized traffic is not using it.

Regarding the median strip, MPWT’s preference is not to install the mount-up type divider because the traffic is forced to stay in lanes in one direction and access to/from the facilities located on the other road side is hindered. The wider median will be installed only in the rural areas, while narrow median will be adopted in the urbanized areas. Chatter bars will be installed at the center of narrow median to clear the centerline and to prevent traffic running accidentally the opposite lane.

(2) Existing Condition

The present cross section of the North Section is composed of undivided 2-lane carriageway and shoulders except for a few hundreds meter-long stretch in Battambang and Sri Sophorn, where divided 4-lane carriageway was constructed. The average width of pavement is 7.8 meter. The width of lane is not sufficient for 4-wheeled vehicles to overtake slow traffic, and these vehicles are frequently forced to enter the lane in the opposite direction. The typical cross section of existing road is shown in Figure 10.1-3.

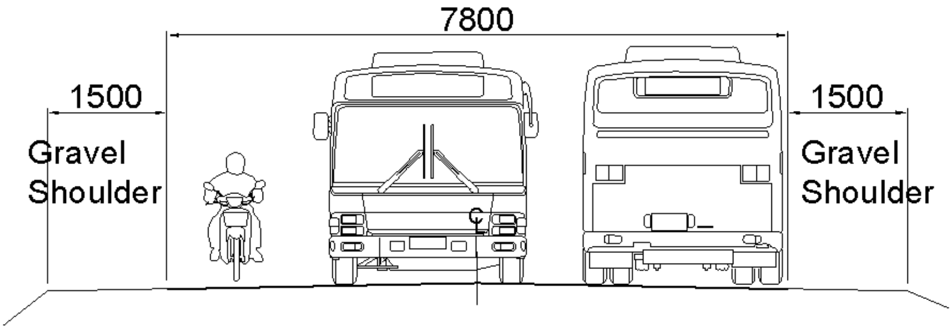


Figure 10.1-3 Typical Cross Section of North Section

10.2 Preliminary Design of North Section

10.2.1 Roadside Land Use

Road structure, such as typical cross section, is adjusted considering roadside condition. The land use of roadside of NR 5 is classified into three categories; urbanized, suburban and rural. Table 10.2-1 and Figure 10.2-1 summarizes the roadside land use of NR 5.

Table 10.2-1 Classification of Roadside Land Use

Rural Area W = 23 m			Suburban Area W = 20.5 m		
Start	End	Length (m)	Start	End	Length (m)
301+200	303+400	2,200	300+000	301+200	1,200
306+300	308+400	2,100	303+400	306+100	2,700
320+800	324+000	3,200	308+400	317+200	8,800
327+700	328+600	900	318+300	320+800	2,500
331+800	332+700	900	324+000	327+700	3,700
342+900	343+800	900	328+600	331+800	3,200
345+500	347+300	1,800	332+700	335+300	2,600
356+100	357+200	1,100	335+600	339+400	3,800
Urbanized Area W = 25.5 m			339+700	342+100	2,400
Start	End	Length (m)	342+300	342+900	600
306+100	306+300	200	343+800	345+500	1,700
317+200	318+300	1,100	347+400	347+600	200
335+300	335+600	300	347+700	350+400	2,700
339+400	339+700	300	350+800	356+100	5,300
342+100	342+300	200	357+200	358+400	1,200
347+300	347+400	100			
347+600	347+700	100			
350+400	350+800	400			
358+400	360+000	1,600			

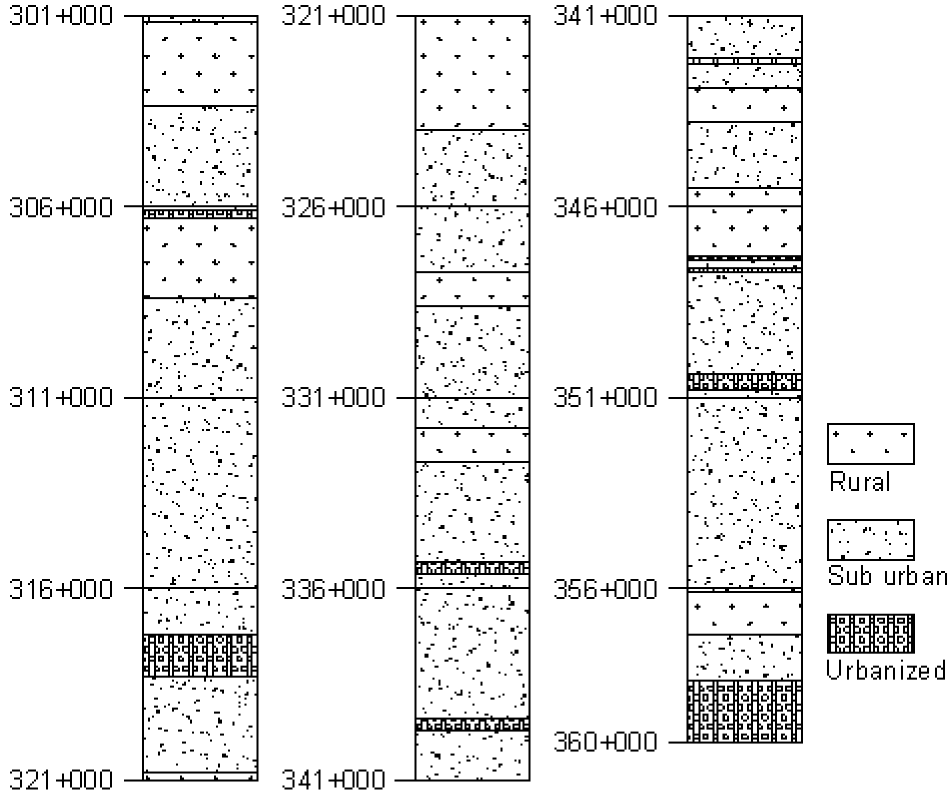


Figure 10.2-1 Straight Diagram of Roadside Land Use

10.2.2 Typical Cross Section

(1) Basic Consideration

In studying the typical cross section most suitable to the condition of the North Section and bypasses around Batttambang and Sri Sophorn, the following aspects are taken into consideration.

(i) Estimated Traffic Volume

Table 10.2-2 shows the estimated future traffic volume on the North Section. The number of lanes shall to be selected to provide sufficient capacity to cater to the estimated traffic volume.

Table 10.2-2 Estimated Traffic Volume

Counting Station No.	Location of Counting Station	Traffic Volume (pcu)	
		Year 2021	Year 2030
8	Provincial boundary between Battambang and Steung Meanchey Provinces (Between KP 332 and 333)	17,812	25,540

In addition to the data at Counting Station No. 8, traffic volume at Counting Station No. 7 has been estimates as explained in Section 6.4. However, Counting Station No. 7 is located in the northwestern suburbs of Battambang City. Thus, traffic volume passing this location is considered to contain a considerable portion of short trips with journeys in and around Battambang City area. On the other hand, Counting Station No. 8 is located far from Battambang City or Sri Sophorn City, and thus, the traffic volume at this location is considered to represent the traffic condition of the entire North Section. Therefore, the estimated traffic volumes at Counting Station No. 8 are used in the following discussion.

(ii) Capacity of 4-Lane Road

The Road Structure Ordinance of Japan stipulates that National Roads with expected traffic volume equal to, or larger than, 20,000 veh (pcu)/day be planned as 4-lane roads. 4-lane rural roads are considered to accommodate traffic volumes up to 30,000 pcu/day with reasonable smoothness. Thus, 4-lane is preferable from the traffic viewpoint.

(iii) Possibility of Opposed 2-Lane with Motorcycle Lanes from View Point of Traffic Capacity

Although it is not internationally common, a cross section of “opposed 2-lane with motorcycle lanes” is often adopted in Cambodia. Typical examples of this cross section are seen in Phnom Penh – Neak Loueng Section of NR 1 (Japanese Grant Aid Project) and NR 5 and NR 6 between Siem Riap and Poipet (ADB loan project). In these cases, paved shoulder can accommodate motorcycle traffic. In case of Phnom Penh – Neak Loueng Section of R 1, the width of motorcycle lane is 2.5 meter.

Estimation of traffic capacity for such cross section is difficult because there are no measured data for such cross sections, especially for the traffic condition with high percentage of motorcycle. By adopting conservative assumptions, the “allowable traffic volume” for this cross section can be estimated as follows:

Opposed 2-lane:	9,000 pcu/day/2-lane (based on Road Structure Ordinance of Japan)
Motorcycle lane:	11,000 pcu/day/lane x 0.7 = 7,700 pcu/day/lane
	For both direction: 7,700 x 2 = 15,400 pcu/day/lane
Total:	24, 400 pcu/day/2-direction

Thus, this cross section (opposed 2-lane + MC lanes) can accommodate the estimated traffic volume of year 2021 (17,812 pcu/day), but may not be sufficient for the traffic volume of year 2030 (25,540 pcu/day). Therefore, if the cross section of “opposed 2-lane + MC lane” will adopted, further widening will become necessary before year 2030.

(iv) Role of NR 5

As discussed in Section 3.2, NR 5 is given a very important role in the road network of both Cambodia and GMS. To fulfill this important role, the whole section of NR 5 needs to be widened to 4-lane. In addition NR 1 and NR 4 need also to be widened to 4-lane considering that these highways are vital infrastructure components if Cambodia is to be modernized.

In that sense, the section between Poipet and Sri Sophorn needs to be widened to 4-lane in the near future, or high-standard trunk road needs to be constructed, as proposed in JICA M/P Study.

(v) Traffic Safety

Traffic safety is another aspect that needs to be considered in planning of arterial highways. Accident rate of NR 5 is the highest among the single-digit national highways.

Table 10.2-3 Traffic Accident of Single-Digit National Highways

Road No.		1	2	3	4	5	6	7
Length	(km)	184	144	202	229	431	412	463
2009	No.	277	218	130	260	741	455	284
	/km	1.505	1.513	0.644	1.135	1.719	1.104	0.613
2010	No.	222	207	139	235	750	435	318
	/km	1.206	1.438	0.688	1.026	1.740	1.056	0.689
Total	No.	499	425	269	495	1,491	890	602
Average	/km	1.356	1.476	0.666	1.081	1.730	1.080	0.650

Source: Road Accident Data by National Police Commission Department, Ministry of Interior

Nation-wide data show a high percentage of accidents involving motorcycles as shown in Table below:

Table 10.2-4 Vehicle Types Involved in Traffic Accidents

		All Accident	MC Involved	MC vs MC	MC vs Small Car
2009	No.	8,560	7,318	3,085	2,063
	%	100	85.5	36.0	24.1
2010	No.	8,232	7,226	2,823,	2,084
	%	100	87.8	34.3	25.3
Total	No.	16,792	14,544	5,908	4,147
Average	%	100	31.3	35.2	24.7

Source: Road Accident Data by National Police Commission Department, Ministry of Interior

Although there is no detailed data on the cause or mode of traffic accidents which enable further analysis, there is a possibility that mixture of slow traffic and high-speed traffic is one of the main causes of high accident rate on NR 5. If this is the case, clear separation of slow traffic and high-speed traffic by providing 4 lanes can reduce the risk of traffic accidents.

(vi) Technical Discussion between MPWT and JICA Team

The team undertook technical discussions with MPWT officials on the recommended road cross section. Basically it was agreed to adopt a 4-lane road design. The summary of the discussion is shown below.

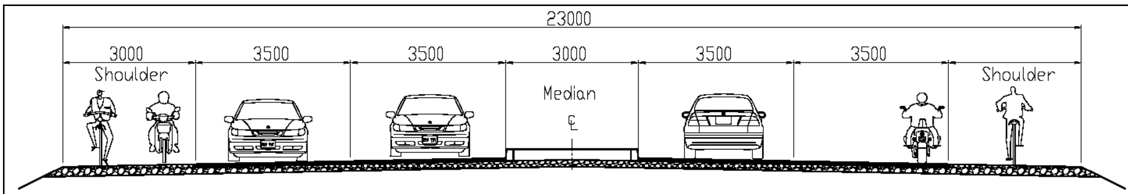
- NR 5 is Asian Highway No.1 and it shall satisfy international standards.
- In the alternatives, only the 4-lane option conforms to Asian Highway Standard.
- Initially, MPWT favored 4-lane +MC lane. However, this option may be too costly.
- 2-lane +MC lane option is not preferable from viewpoint of separation of 4-wheel vehicles and MCs.
- Thus, 4-lane option is the most favored option.
- MC may occupy the outside lane and mix with high speed traffic
- Space for exclusive use of MC should be provided.
- The pavement shall be extended to the shoulder to provide the space for MCs.
- The width of pariment extension shall be 1.5 m (same as Sri Sophorn ~ Thai border section)
- 2-lane+MC (A) option shall be also studied as the reserve option.

(2) Cross Section Alternatives

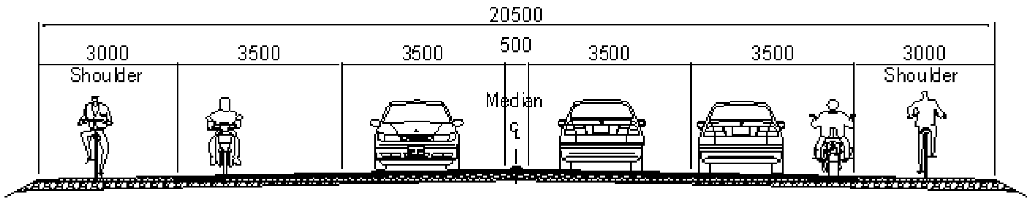
Considering the aspects as explained above, three cross section alternatives for rural area and suburban area are proposed. As reference, cross section of Asian Highway is also shown.

(i) Cross Section for Rural Area

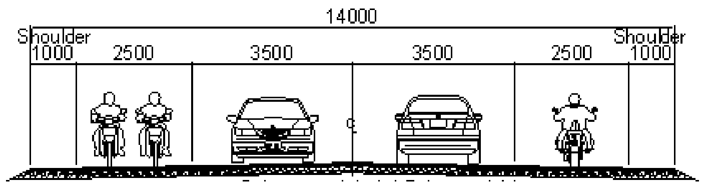
Three alternatives of cross section for rural area as shown in Figure 10.2-2 are assumed and compared.



Alternative R-1: Cross Section of Asian Highway



Alternative R-2: 4-Lane with Narrow Median and 3-Meter Shoulder



Alternative R-3: Opposed 2-Lane + MC Lane

Figure 10.2-2 Alternatives of Cross Section for Rural and Suburban Areas

The merits and demerits of these alternatives are summarized in the Table 10.2-5.

Table 10.2-5 Merits and Demerits of Cross Section Alternatives for Rural/Suburban Area

Alternative	R-1	R-2	R-3
Asian Highway Standard	Satisfied	Partially Satisfied	Not Satisfied
Design Criteria	Satisfied	Satisfied	2.5 m width of MC lane is substandard
Traffic Capacity	Sufficient for Long Term	Sufficient up to 2030	Insufficient before Year 2030
Overtaking by 4-Wheeled Vehicles	Safe for all types of traffic	Safe overtaking by 4-wheeled vehicle is possible	Overtaking by 4-wheeled vehicle needs to be carefully negotiated
Safety of MC & Slow Traffic (ST)	MC & ST can use outside lane and can be safely overtaken by high speed traffic	Same to R-1	Better than current situation but to less extent than in R-1 and R-2
Reguired Additional Right of Way	Large	Medium	Small
Separation of Community	Large	Medium	Small
Project Cost	High	Medium	Low

As can be seen in the above table, Alternative R-1 is most preferable from the viewpoint of safe and smooth traffic. Thus, this alternative is most recommendable. However, Alternative R-2 may be adopted if there is a constraint in available fond for construction. Alternative R-3 is least preferable and should be adopted only in the case when adoption of R-1 or R-2 is not possible.

In conclusion, Alternative R-2 is recommended considering cost and traffic capacity. It should be noted that widening into R-1 cross section should be retained as the ultimate plan to enable development of the Asian Highway Network as essential infrastructure for strengthening regional cooperation in the GMS.

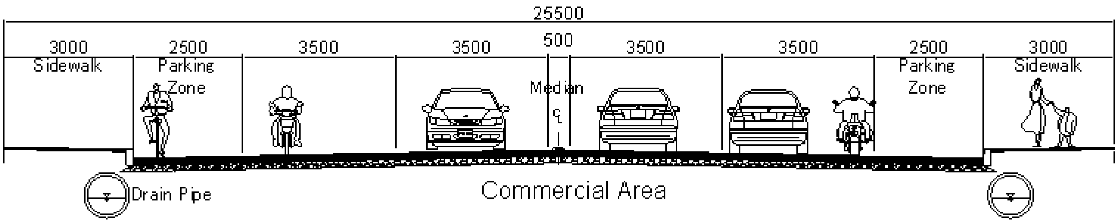
Figure 10.2-3 Perspective Drawing of NR 5 with R-2 Cross Section

(ii) Cross section for urbanized or commercial area

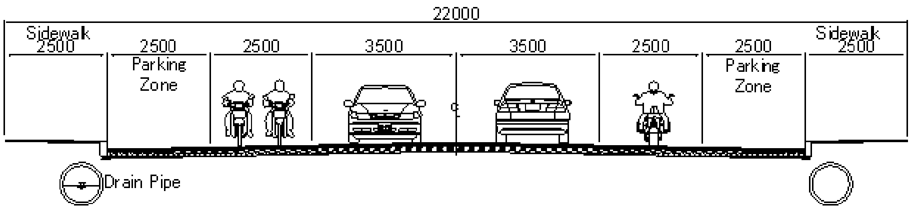
In case of the cross section for urbanized area, different considerations from those for rural/suburban areas are needed:

- Low speed regulation is imposed. Thus, travel speed of vehicles become lower.
- Less attention is needed for overtaking and separation of community. Also, design standards of Asian Highway cannot be applied.
- Traffic volume of motorcycles, moto-rumok and other slow-speed vehicles may be larger than those in rural areas because this slow-speed traffic tends to have origin or destination of trips in urbanized areas.
- There are commercial activities on the both sides of the road and vehicles often turn to the left to go to the shops etc. located on the other side of the road. Thus, median division should not be of raised structure type.
- Space for road side parking should be provided to prevent parked vehicles blocking the traffic.

Considering these facts, two cross section alternatives are proposed.



Alternative U-1: 4-Lane with Parking Space and Sidewalk



Alternative U-2: 2-Lane + MC with Parking Space and Sidewalk on Both Sides

Figure 10.2-4 Alternatives of Cross Section for Urbanized Area

The merits and demerits of these alternatives are summarized in the Table 10.2-6.

Table 10.2-6 Feature of Cross Section Alternatives for Urbanized Area

Alternative	U-1	U-2
Traffic Capacity	Sufficient	Insufficient before Year 2030
Roadside Parking Space	Provided	Provided
Land Acquisition	Large	Medium
Project Cost	High	Medium
Asian Highway Standard	Partially Satisfied	Not Satisfied
Design Criteria	Satisfied	2.5 m width of MC lane is substandard
Traffic Capacity	Sufficient up to 2030	Insufficient before Year 2030
Overtaking by 4- Wheeled Vehicles	Overtaking in urbanized section is not taken into consideration	Overtaking in urbanized section is not taken into consideration
Safety of MC & Slow Traffic (ST)	MC & ST can use outside lane and can be safely overtaken by high speed traffic	Better than current situation but to less extent than in U-1
Reguired Additional Right of Way	Large	Medium
Separation of Community	Large	Medium
Project Cost	Large	Medium

For urbanized areas, Alternative U-1 is preferable and recommended.

As shown in the above, the technically preferable cross section requires larger cost, not with standing the problem of social impact of land acquisition and resettlement. Thus, final decision for adoption of the cross section type needs to be made after diligent discussion on the available fund.

10.2.3 Horizontal Alignment

The design speed of 100 km/h is adopted for general sections and that of 50 km/h is adopted for urban sections. There are some sharp curve sections, the where the existing curve radii are less than the required minimum value. In accordance with design criteria, substandard curve sections shall be improved to ensure a safe traffic environment.

Table 10.2-7 shows the elements of curve sections with substandard curve radii and distances of centerline shift for the improvement of curve radii. Schemes of major improvements of curve sections are shown in Figures 10.2-5 to 10.2-7.

Table 10.2-7 Element of Curves to Be Improved

IP	KP of IP	Land	Radii of Curve		Center Shift
			Existing	Proposed	
1	301+003*	Rural	150	350	23.3
4	303+592	Rural	250	350	1.8
8	312+135	Rural	270	350	0.8
13	319+372	Rural	250	350	1
14	334+996	Rural	310	350	1.2
15	339+108	Rural	290	350	0.9
17	339+935	Rural	200	350	3
21	351+455	Rural	170	350	0.6
22	351+525	Rural	200	350	1.2
23	351+797	Rural	250	350	11.6
26	354+392	Rural	250	350	1.8
27	355+485*	Rural	110	350	19.8
28	355+767	Rural	210	350	2.5
37	359+795	Town	60	80	0.6
39	360+016	Town	70	80	0.5

* These curve sections may not be included in the Project (see Section 10.3 & 10.4).

Figure 10.2-5 New Alignment at IP1

Figure 10.2-6 New Alignment at IP23 (KP 351 + 797)

Figure 10.2-7   New Alignment at IP27 (KP 355 + 485)

10.2.4 Vertical Alignment and Profile

The longitudinal profile of the existing road centerline was examined based on the digital map prepared for this Survey. As a result, the elevation of road surface at sections near KP 320 and KP 345 was found to be lower than 11.0 m. During flood condition interviews, the frequent inundation at KP 344 was also informed by the residents.

The actual condition of water level was confirmed through field observation during the flood season in September 2011. The water level on the paddy along those sections was observed at near the top of the subgrade course.

Considering this site condition, the road surface of the sections between KP 320~324, KP 327~328, KP 342~343 and KP 345~347 is proposed to be raised approximately 1 m from the present road surface level.

The approach of bridges shall be properly designed with appropriate vertical curve. The minimum radius of vertical curve is 6,500 m for crest curve and 3,000 m for sag curve and the minimum length of vertical curve is 85 m at design speed 100 km/h (see Figure 10.1-1).

10.2.5 Intersection

There are two major intersections on the North Section at NR 59 and NR 6. The geometric design of the both intersections is acceptable and only minor adjustments are required for the widening of NR 5. However, the connections with planned Battambang Bypass and Sri Sophorn Bypass necessitates construction of new intersections. Considering the prevailing practices in Cambodia and familiarity of the motorists, round-about intersections are proposed at there locations. Figure 10.2-8 shows the basic design of round-about intersection with intersection of NR 5 and bypass. A different configuration may be adopted in the detailed design stage.

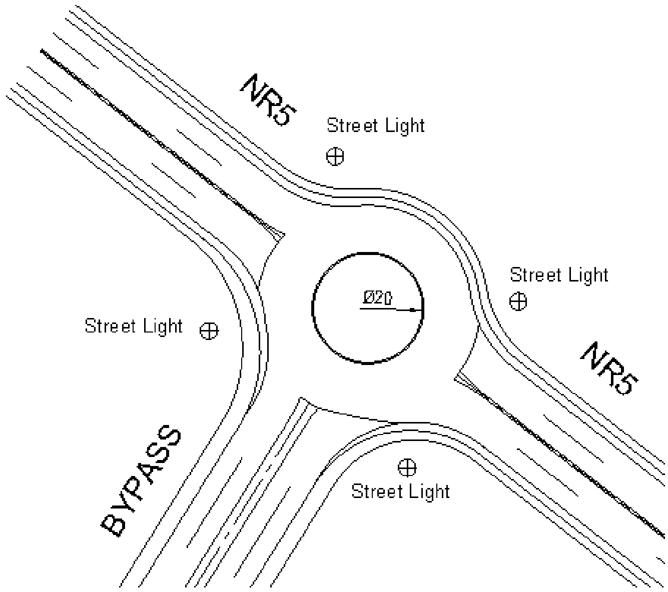


Figure 10.2-8 Intersection of NR 5 and Bypass

10.2.6 Pavement Design

Pavement structure is usually designed based on forecasted traffic load and CBR. AASHOTO's Pavement Design Manual is one of the most widely used standards of pavement design. In the design method presented in this Manual, estimated traffic volume is converted to cumulative 18-KIP equivalent single axle load (ESAL). However there are no effective data for this conversion in Cambodia.

On the other hand, the design procedure presented in the Pavement Design Guideline of Japan classifies the types of traffic depending on the share of heavy vehicles in the total traffic volume and does not require conversion to ESAL. Thus, this design method is used in this stage. The design condition as written below are used and results of design obtained are shown in Table 10.2-8:

- Design Period: 10 years
- Number of HV: 1,408 units/day direction
- Reliability: 90%
- Design CBR: 8~20
- Minimum Thickness of AC Layer: 15 cm

Table 10.2-8 Designed Pavement Structure

Section	Design CBR	Existing Layer		Additional Layer		Remarks
		Subbase	Base	Base	AC	
KP 301 ~ 306	20	20 cm	15 cm	0~10 cm	15 cm	Base for leveling
KP 306 ~ 330	8	20 cm	15 cm	0~10 cm	15 cm	Base for leveling
KP 330 ~ 340	12	20 cm	15 cm	0~10 cm	16 cm	Base for leveling
KP 340 ~ 360	8	15 cm	15 cm	10 cm	15 cm	

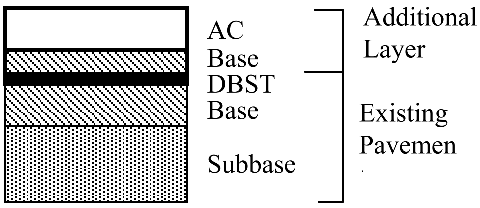


Figure 10.2-9 Pavement Structure

Existing pavement shall be utilized as a part of the pavement structure. Such an approach can reduce the construction cost and mitigate the traffic disturbance. During constructions also it can reduce industrial waste.

<u>Alternative Pavement Design</u>

In the process of appraisal of loan, alternative pavement design was discussed. The main points of discussion were;

- to change the thickness of AC layer to 10 cm so that it coincides with the thickness of AC layer in the past projects in Cambodia, and
- to save cost of pavement.

As a conclusion a pavement structure as shown in Figure 10.2-10 was adopted for the purpose of cost estimation to be used in the loan appraisal.

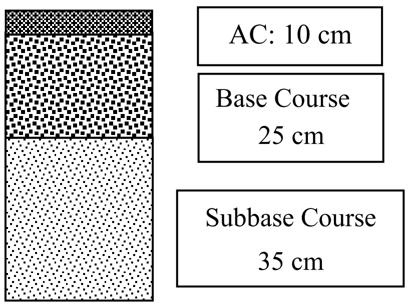


Figure 10.2-10 Alternative Pavement Structure Adopted in Loan Appraisal

This pavement structure consists of excessively thick base course and subbase course compared to the ordinary pavement. Thus, the structure of base course and subbase course needs to be reviewed and revised as necessary in the detailed design stage when more concrete data, such as axle load, will become available.

10.2.7 Drainage

Basically NR 5 is an embanked road traversing flat flood plain. However, the existing road level on some sections is lower than the roadside and rain water often remains on the shoulder and seeps into the base course and subgrade, causing reduction in bearing capacity. To solve this situation, lined ditches are proposed to be installed to drain the rain water. The schedule of lined ditch is listed in Table 10.2-9.

Table 10.2-9 Location of Lined Ditch

Lift Side			Right Side		
Start	End	Length (m)	Start	End	Length (m)
303+900	304+400	500	303+900	304+400	500
			315+100	315+400	300
316+600	317+200	600			
318+300	319+000	700	318+300	319+000	700
335+600		400	335+600	336+000	400
			343+700	344+000	300
345+000	345+300	300	345+000	345+300	300
350+800	351+400	600	350+800	351+400	600
			352+100	352+200	100
356+400	356+800	400			
357+700	357+800	100			

In urbanized areas, mounted up sidewalks are to be constructed and new drainage facilities shall be provided to drain the road surface. As shown in Figure 10.2-4, catch basins and drainpipe are to be installed under the sidewalk.

The cross drainage facilities (culverts) of NR 5 were improved by the PRRP and EFRP. No overflow caused by lack of capacity is reported for the existing facilities except for the particular flood in year 2010. In this project, all culverts are proposed to be extended to fit the widened road width and inlets and outlets. The widening of bridges is discussed in Chapter 11.

10.2.8 Appurtenance

(1) Street Lighting

The purpose of street lighting is to illuminate danger points to improve visibility at night.

- The bridges, especially where there is one bridge for each direction.
- The major intersections
- The railway crossings

(2) Railroad Crossings

A railroad line runs between Phnom Penh and Poipet generally in parallel to NR 5. There are two railroad crossings (KP 352 and KP 359) on the North Section. Currently, the railroad is not in operation. MPWT has a plan to rehabilitate the railroad and operate trains 2 times a day in the future. This proposed train operation is not considered to cause serious traffic congestion. Thus, these railroad crossing are planned as at-grade crossings. Figure 10.2-11 shows a schematic plan of the railroad crossing.

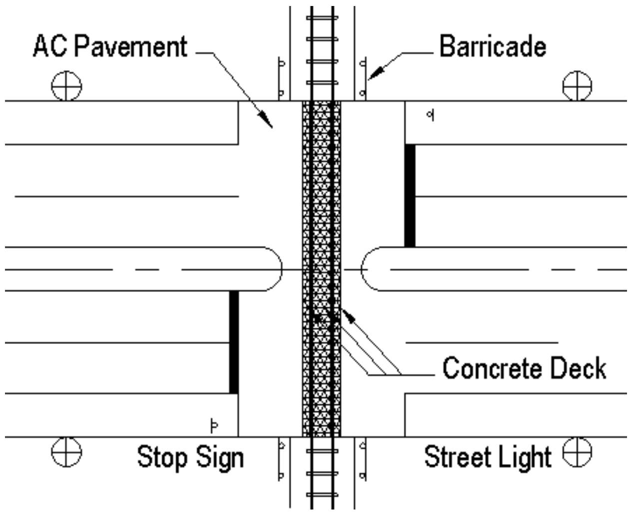


Figure 10.2-11 At Grade Railway Crossing

(3) Road Sign

Road signs are proposed to be installed as follows;

- Regulatory Signs: Stop, Speed limit, No entry, No overtaking, No U-turn, No parking etc.
- Warning Signs: Curve, Hump, Junction, Rotary, Zebra crossing zone, Railway, School, Narrow etc.
- Information Signs: Parking, Road No., Town name, Destination direction & distance etc.

10.3 Preliminary Design of Battambang Bypass

10.3.1 Typical Cross Section

After Battambang Bypass will have been constructed, the function of Asian Highway No.1 will divert to the bypass from the existing NR 5 passing through the Battambang town route. In view of the function as the international corridor, the cross section composition of ASEAN Highway No.1 should be adopted.

However, according to the traffic forecast carried out in this Survey, a 2-lane road has the capacity to accommodate the estimated traffic volume until year 2030. In view of the estimated traffic volume, staged construction will be one of the options to consider in reducing the initial investment. Figure 10.3-1 shows the proposed cross section.

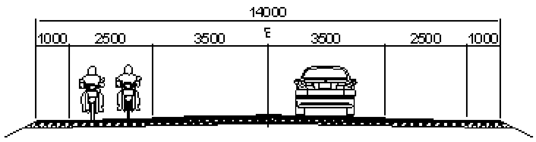


Figure 10.3-1 Cross Section of Battambang Bypass

10.3.2 Horizontal Alignment

As a result of the Study, JICA-1C route was selected as the most favorable bypass route and topographical survey was carried out along this route. During the alignment analysis, obstacles and problems were found at canal crossings, railway crossings, high voltage power towers and a rice mill factory. To avoid such obstacles, the route has been modified. The new alignment of bypass route is shown in Table 10.3-1 and Figure 10.3-2. The design speed of 100 km/h was adapted in selecting the alignment.

Table 10.3-1 IP & Element of Curves

KP	Radius (m)	Curve Length (m)	Tangent (m)
6+062	5000	675.089	338.058
8+578	5000	627.610	314.218
9+834	5000	580.138	290.395
12+697	2000	1328.221	689.646
15+453	2000	1794.383	971.467
21+228	1000	965.042	521.235
22+890	700	1245.929	864.130

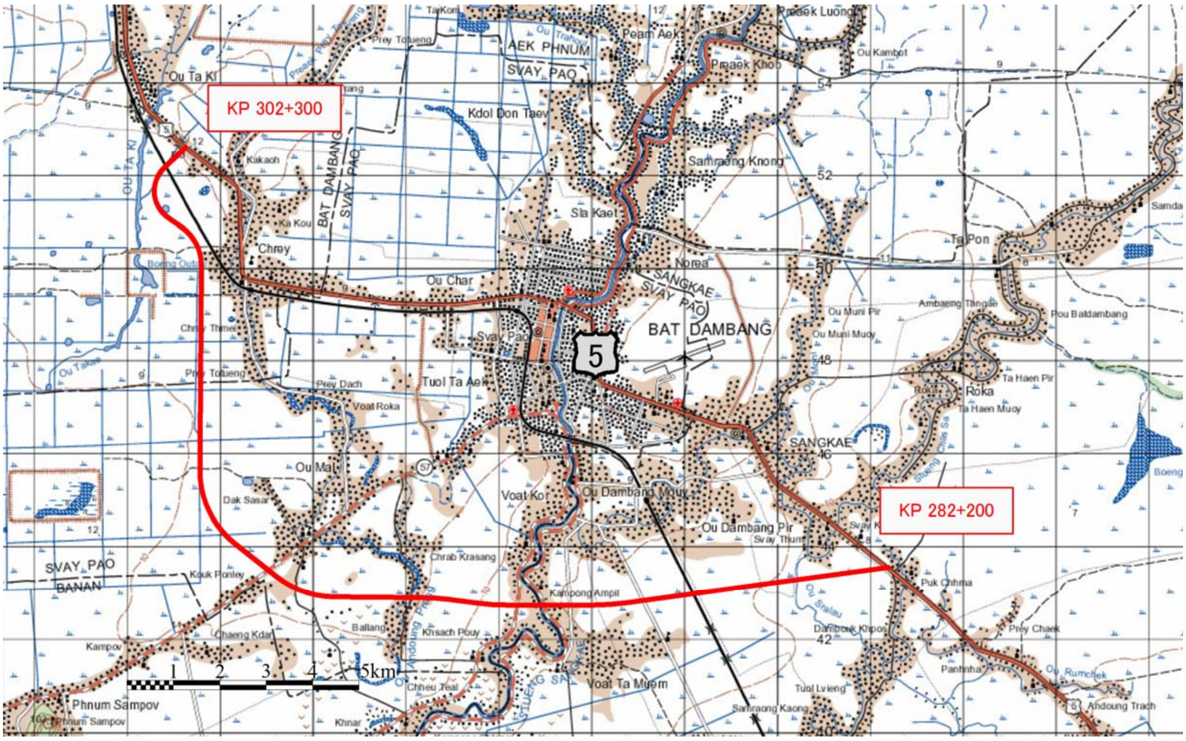


Figure 10.3-2 Alignment of Bypass Route

10.3.3 Vertical Alignment

The proposed route traverses mostly paddy areas and the land is often covered by water for cultivation of rice and/or by accumulated rain water. The embankment of the roadbed shall be sufficiently higher than usual water level of paddy and subgrade layer should be kept above the water to maintain the pavement strength.

According to the result of topographical survey, ground elevations along the route are approximately 10 ~ 12 m above sea level. While the surface levels of existing NR 5 at the starting point and end point of the bypass are 11.5 m and 11.4 m, respectively. According to DPWT officials, no flood or overflow has not been reported at these locations.

Higher embankment height is desirable from the viewpoint of flood/overflow. However, higher embankment height results in higher construction cost of embankment and grease land acquisition. Considering these, the elevation of water level is assumed at 11.5 m and embankment height is planned to be 1.5 m on average. Sufficient embankment height is also necessary to provide adequate cave for pipe culverts providing cross drainage.

10.3.4 Pavement Design

The pavement design method for the bypass is the same as that of the North Section. The design condition and the results of design are as follows:

Design Condition

- Design Period: 10 years
- Number of HV: 461 units/day direction
- Reliability: 90%
- Design CBR: 6
- Minimum Thickness of AC Layer: 10 cm

Pavement Structure

Subbase Course: 25 cm

Base Course: 15 cm

Surface Course: 10 cm

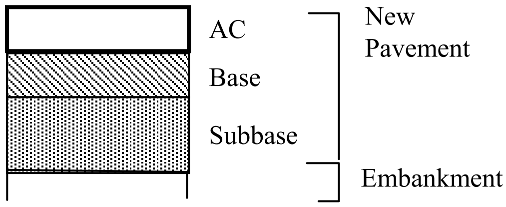


Figure 10.3-3 Pavement Structure

10.3.5 Drainage

The embankment of the bypass will behave as a dike during the flood season and block water flow. Thus, it will be necessary to install sufficient cross drainage to provide adequate cross-sectional area for discharge of flood water.

There are many channels crossing the proposed bypass route. The direction of flow is basically west to east (towards Tonle Sap Lake). Based on the result of topographical survey, cross drainage facilities are scheduled as required. For larger streams such as Sangkae River (km7+550) and the channel at (km2+020), bridges are to be constructed.

Table 10.3-2 Box Culvert Schedule

km	No. of Cell	Width	Length
00+025	3	10.2	20.5
00+270	1	3.4	20.5
03+710	2	6.6	20.5
05+335	1	3.4	20.5
06+925	2	6.6	20.5
06+935	1	3.4	20.5
09+570	1	3.4	20.5
11+440	2	6.6	20.5
11+465	2	6.6	20.5
13+470	2	6.6	20.5
14+400	3	10.2	20.5
16+620	2	6.6	20.5
17+730	1	3.4	20.5
18+245	2	6.6	20.5
19+770	3	10.2	20.5
19+795	3	10.2	20.5
21+325	2	6.6	20.5
22+960	1	3.4	20.5

(1) Box culverts are installed at comparatively wider channels. The box culvert schedule is shown in Table 10.3-2.
(2) Pipe culverts are installed at small streams and also every 250 m interval. The purpose of this is to minimize the difference of the water level on the both sides of the bypass. An in-depth study shall be undertaken at the Detailed Design stage.

10.4 Preliminary Design of Sri Sophorn Bypass

10.4.1 Typical Cross Section

Following the construction of Sri Sophorn Bypass, the function of Asian Highway No.1 will transfer to the bypass from the existing NR 5 passing through the Sri Sophorn town route. In view of the function as an international corridor, the cross section composition of ASEAN Highway No.1 should be adopted.

However, according to the traffic forecast carried out in this Survey, 2-lane road has the capacity to accommodate the estimated traffic volume until year 2030. In view of the estimated traffic volume, staged construction will be one of the options to consider to reduce the initial investment. Thus, the same cross section with Battambang Bypass is adopted. Figure 10.4-1 shows the proposed cross section proposed for the initial stage.

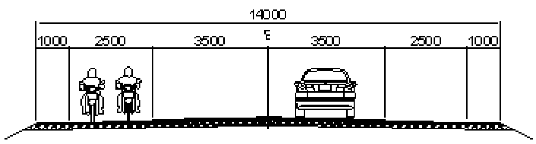


Figure 10.4-1 Cross Section of Sri Sophorn Bypass

10.4.2 Horizontal Alignment

As the result of the Study, the JICA-3 route was selected as the most favorable bypass route and topographical survey was carried out along this route. The alignment of the bypass route is shown in Table 10.4-1 and Figure 10.4-2. Design speed of 100 km/h is adapted in selecting the alignment.

Table 10.4-1 IP & Element of Curves

KP	Radius (m)	Curve Length (m)	Tangent (m)
1+034	1800	1392.751	715.181
3+458	1800	1900.375	500.000
4+975	400	314.159	284.368
5+656	600	471.238	1222.553
7+343	1200	476.384	1300.394
9+227	1800	702.800	1153.985
11+399	1600	1259.889	194.314
12+836	600	987.674	188.728

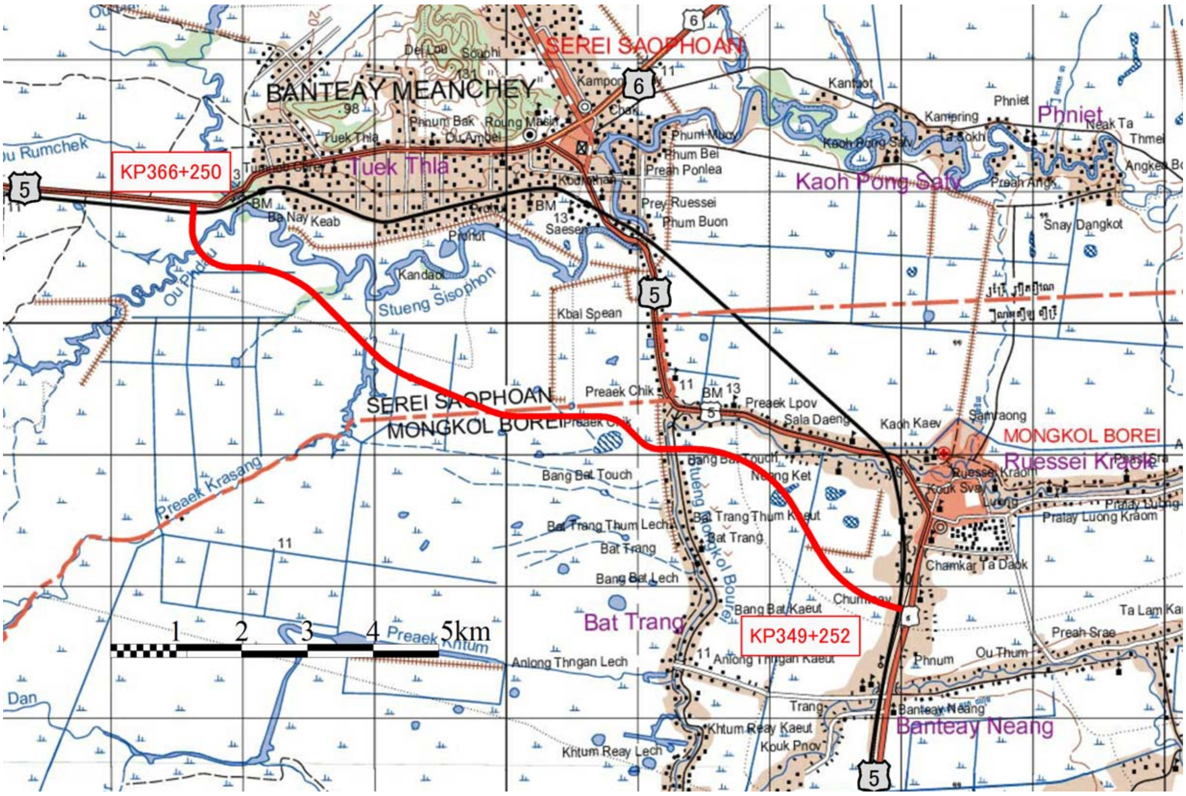


Figure 10.4-2 Alignment of Bypass Route

10.4.3 Vertical Alignment

The proposed route traverses mostly paddy areas and the land is often covered by water for cultivation of rice and/or by accumulated rain water. The embankment of the roadbed shall be sufficiently higher than usual water level of paddy and subgrade layer should be kept above the water to maintain the pavement strength.

According to the result of topographical survey, ground elevations along the route are approximately 8 ~ 9 m above sea level. While the surface levels of existing NR 5 at the starting point and end point of the bypass are 11.2 m and 12.2 m, respectively.

Higher embankment height is desirable from the viewpoint of flood/overflow. However, higher embankment height results in higher construction cost of embankment and greater land acquisition. Considering these, the elevation of water level is assumed at 11.2 m and embankment height is planned to be 2.0 m on average.

10.4.4 Pavement Design

The permit design method for the bypass is the same as that of the North Section. The design condition and the results of design are as follows:

Design Condition

- Design Period: 10 years
- Number of HV: 391 units/day direction
- Reliability: 90%
- Design CBR: 6
- Minimum Thickness of AC Layer: 10cm

Pavement Structure

Subbase Course: 25 cm

Base Course: 15 cm

Surface Course: 10 cm

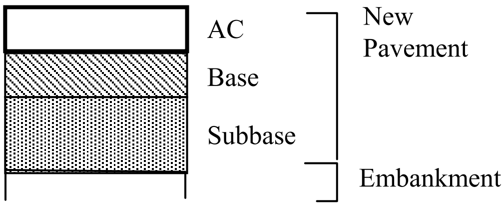


Figure 10.4-3 Pavement Structure

10.4.5 Drainage

The embankment of bypass acts as the dike during flood season and block the water flow in the roadside area. Thus, it is necessary to install sufficient cross drainage to secure the sufficient cross-sectional area for water to flow as smooth as possible.

There are many cannels crossing the proposed bypass route. The direction of flow is basically west to east (towards Tonle Sap Lake). Based on the result of topographical survey, the necessary cross drainage facilities are scheduled. For bigger streams such as the cannel (km4+620 and km12+700), bridges are to be constructed.

(1) Box culverts are installed at comparatively wider cannels. The schedule of box culvert is shown in Table 10.4-2.

(2) The pipe culverts are installed at small stream and also every 250 m interval. The purpose of this is to minimize the difference of the water level on the both sides of the bypass. The detail study shall be done at Detailed Design stage.

Table 10.4-2 Box Culvert Schedule

km	No. of Cell	Width	Length
00+015	3	10.2	14
00+135	1	3.4	14
01+530	3	10.2	14
01+970	5	17	14
02+580	5	17	14
04+370	3	10.2	14
04+780	2	6.6	14
06+220	1	3.4	14
08+170	2	6.6	14
09+360	4	13.6	14
09+500	5	17	14
09+700	2	6.6	14
10+440	2	6.6	14
10+640	5	17	14
10+680	5	17	14
11+170	2	6.6	14
11+920	1	3.4	14
13+340	1	3.4	14

10.5 Traffic Safety Measures

When a road is improved and travel speed of the vehicles increases, often traffic accidents increase. The usual types and causes of increase in traffic accidents due to road improvement are as summarized below:

Table 10.5-1 Types, Causes and Measures of Traffic Accident due to Road Improvement

Type	Cause	Measure
Vehicles collide with pedestrians or bicycles	Driver error	✓ Speed regulation ✓ Provision of rumble strip ✓ Lighting at hazardous location
	Pedestrians' misjudgment on increased vehicle speed when crossing the road	✓ Traffic safety campaign to roadside residents ✓ Provision of rumble strip near the entrance to town/ residential areas ✓ Provision of warning signs at strategic locations, such as near town, school and roadside market
Vehicles collide with other vehicle (side-to-side)	Over-speeding and driver error	✓ Speed regulation
Head-on collision	Travel on the opposite lane by mistake	✓ Provision of chatter bar on the center line
Vehicle collides with roadside obstacles	Over-speeding and driver error	✓ Install road signs & other obstacles sufficiently distant from carriageway ✓ Provision of guardrail around hazardous obstacles

Main measures are briefly explained below:

(1) Chatter bar on the center line

Raised median is preferable from the pure viewpoint of traffic safety. However, raised median has several drawbacks such as complete prohibition of overtaking on the opposed 2-lane road. Cambodian drivers usually go beyond the centerline when over taking, even on a 4-lane road since the outside lane is often occupied by motorcycles and other slow vehicles. Thus, overtaking by using the opposite lane with sufficient care needs to be accepted. Chatter bars are often installed along the road centerline to give warning to drivers when crossing the centerline, as well as to discourage drivers to cross the centerline. If the cross section of opposed 2-lane or 4-lane with narrow median is to be adopted, installation of chatter bar or road stud is proposed.

(2) Rumble strip

Rumble strip is special pavement with rough surface which cause noise when vehicle passes it. It is placed in multiple strips across the carriageway to give drivers warning. Rumble strips shall be planned at the entrance to town areas, near schools and markets, and at other strategic locations.

(3) Shoulder

Shoulder with sufficient width is expected to have the following functions:

(i) If paved, can serve as the lane for motorcycles and other slow traffic and can aid in separating this traffic from high-speed traffic.
(ii) Provide sufficient distance between the vehicles and roadside obstacles, and contribute to decrease the possibility that the vehicles will collide with obstacles.
(iii) Provide sufficient sight distance.

As discussed in Section 10.2, 3 m-wide shoulder is proposed for existing NR 5. As for the bypasses, 1.0 m-wide shoulder is proposed. The reasons for proposing 1.0 m-wide shoulder are as follows:

(i) Traffic volumes on the bypasses are smaller than that on the existing NR 5. Thus, 2.5 m-wide left lane can safely accommodate slow traffic such as motorcycles and agricultural tractors.
(iv) The bypasses traverse the areas away from the urbanized areas. Thus, traffic of slow traffic and pedestrians who needs to evacuate to shoulder is limited.

(4) Guard rail

Guard rail is proposed to be installed at the locations of hazardous roadside obstacles. Typically, guard rails shall be installed at bridge approaches.

(5) Lighting

Lighting is planned at the following locations:

- Major intersections
- Long bridges
- Railroad crossing

10.6 Summary of Proposed Design

The main points of the design of improvement of existing NR 5 and construction of the two bypasses (Battambang and Sri Sophorn) are summarized in Tables 10.6-1 to 10.6-3.

Table 10.6-1 Summary of Design of North Section of Existing NR 5

Item	Description	Remarks
Total Length	47.0 km	
Design Speed	100 km/h	
Cross Section	As shown below. Total width: 20.5 m	
Pavement Structure	AC (Binder & Surface Course) 15 cm Base Course: 15 cm Subbase Course: 20 cm	・Only base & subbase courses are executed on shoulder but AC is not executed. ・Where practical, existing base course and/or subase course is utilized.
Bridges: No. & Total Length	9 Nos. L= 83.9 m	6 brdgs. are to be widened utilizing existing structure
Others	2 Railroad Crossing	

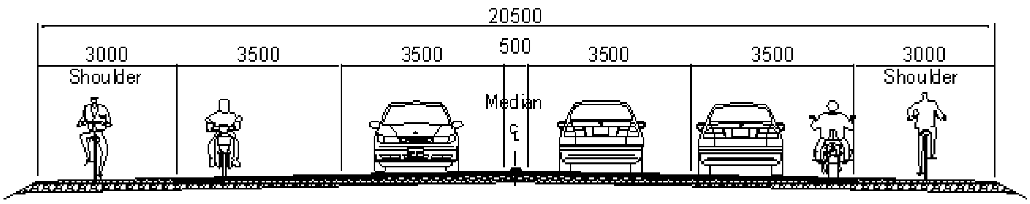


Figure 10.6-1 Typical Cross Section of North Section of Existing NR 5

Table 10.6-2 Summary of Design of Battambang Bypass

Item	Description	Remarks
Total Length	23.1 km	
Design Speed	100 km/h	
Cross Section	As shown below. Total width: 14.0 m	
Pavement Structure	AC (Binder & Surface Course) 10 m Base Course: 15 cm Subbase Course: 25 cm	Thickness of pavement is smaller than that of existing NR 5 because of less traffic volume.
Bridges: No. & Total Length	2 Nos. L = 125.0 m	2 brdgs. are newly constructed
Others	2 Railroad Crossing	

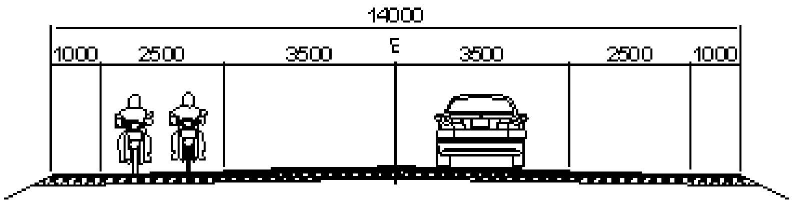


Figure 10.6-2 Typical Cross Section of Battambang Bypass

Table 10.6-3 Summary of Design of Sri Sophorn Bypass

Item	Description	Remarks
Total Length	13.1 km	
Design Speed	100 km/h	
Cross Section	As shown below. Total width: 14.0 m	
Pavement Structure	AC (Binder & Surface Course) 10 m Base Course: 15 cm Subbase Course: 25 cm	Thickness of pavement is smaller than that of existing NR 5 because of less traffic volume.
Bridges: No. & Total Length (m)	2 Nos. L = 110.0 m	2 brdgs. are newly constructed
Others	2 Railroad Crossing	

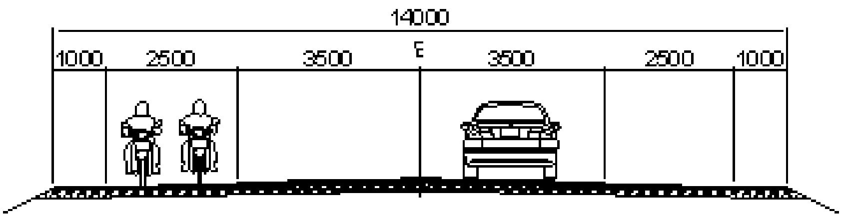


Figure 10.6-3 Typical Cross Section of Sri Sophorn Bypass

CHAPTER 11 BRIDGE PLANNING

11.1 Bridge Design Standards in Cambodia

The Cambodian Road and Bridge Design Standard and Construction Specifications were established in 1999 and are to be used for the design and construction of all new roads and bridges and related rehabilitation works in the Kingdom of Cambodia. The design standards for bridges are:

- CAM PW 04-101-99 Bridge Design Code 1996 (the Base Document)
- CAM PW 04-102-99 Amendments and additions to the Base Document and to the Commentaries on the Cambodian Bridge Design Standard.

The Base Document is in fact the Australian Bridge Design Code 1996 and associated Commentaries. (Note that in Australia and New Zealand, the Australian Bridge Design Code 1996 has now been superseded by the Australian Bridge Design Code AS5100.)

The Base Document is an International Bridge Standard making use of modern limit state design philosophy. The amendments and additions to the Base Document reflect conditions in Cambodia from the viewpoint of loading (traffic, environmental and earthquake loads), design for durability and material requirements. A comparison of nominal traffic loading for a typical 20 m span pre-stressed concrete bridge is presented below. As can be seen the total maximum traffic load effects based on the Cambodian Bridge Design Standard are reasonably comparable to both AASHTO and JRA standards.

Table 11.1-1 Comparison of Nominal Load Effects for 20m span Bridge Cambodian, AASHTO and JRA Standards

		Single lane		Standard 10m wide roadway bridge deck						
Case	**Load Standard**	**Max Shear (kN)**	**Max Moment (kN-m)**	**Impact Factor**	**No. of Lanes**	**Load Mod. Factor ***	**Total Max Shear (kN)**	**Total Max Moment (kN-m)**	**Shear Factor**	**Moment Factor**
1	CAM T44	358.3	1,639.2	0.35	3	0.80	1,161.0	5,311.0	1.00	1.00
2	CAM HLP 240	N/A	N/A	0.10	N/A	N/A	1,333.2	6,160.0	1.15	1.16
3	AASHTO LRFD HL-93	368.1	1,690.8	0.33	3	0.85	1,248.5	5,734.4	1.08	1.08
4	JRA L-Load	N/A	N/A	0.22	N/A	N/A	1,184.0	5,209.7	1.02	0.98

Note:
Case 1 & 2 : Cambodian Bridge Design Standard; Case 3 : AASHTO LRFD; Case 4 : JRA Specifications for Highway Bridges
* Load Modification Factor to account for multiple lane loading

11.1.1 Traffic Loading

The design traffic load specified in the Base Document consists of T44 Truck loading and L44 Lane loading.

The design T44 Truck load is a 44tonne vehicle with five (5) axles and with maximum axle load of 9.8 tonnes (96 kN). One design truck can occupy one standard design lane width of 3.0 m. Refer to Figure 11.1-1. L44 Lane loading shall consist of the loads shown in Figure 11.1-2. The lane loading shall be assumed uniformly distributed over a 3m Standard Design Lane. Only one tandem of concentrated loads shall be used per lane except that one additional tandem of concentrated loads of equal force shall be placed in each lane in one other span in such a position to produce maximum negative effect. L44 Lane loading does not apply for spans less than 10 m.

The Dynamic Load Allowance for T44 and L44 loadings shall be 0.35.

T44 Truck and L44 Lane loadings shall be assumed to occupy one Standard Design Lane of 3 m width.

The number of Standard Design Lanes n shall be:

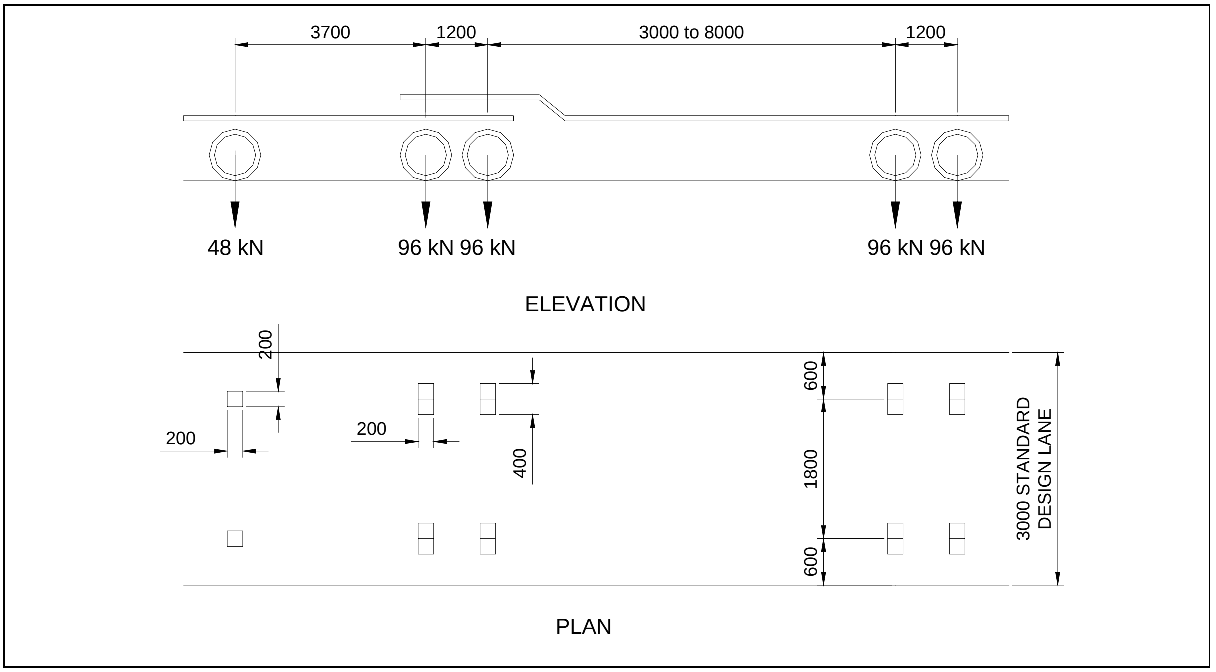
$$n = \frac{b}{3.1}$$

(rounded down to next integer)

where b = carriageway width (in meters) between traffic barriers

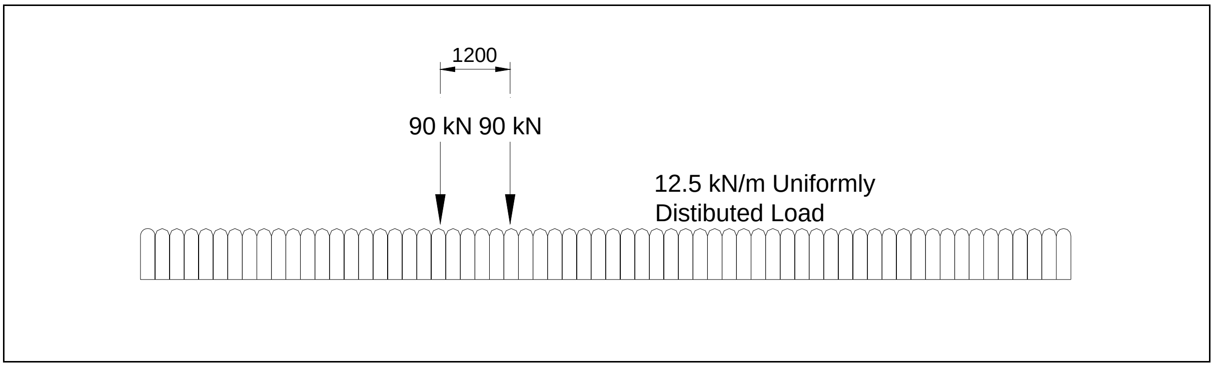
These Standard Design Lanes shall be positioned laterally on the bridge to produce the most adverse effect.

The design of bridges for the simultaneous application of road traffic loading and pedestrian loading is not required.



Source: MPWT, CAM PW 04-101-99 Bridge Design Code 1996

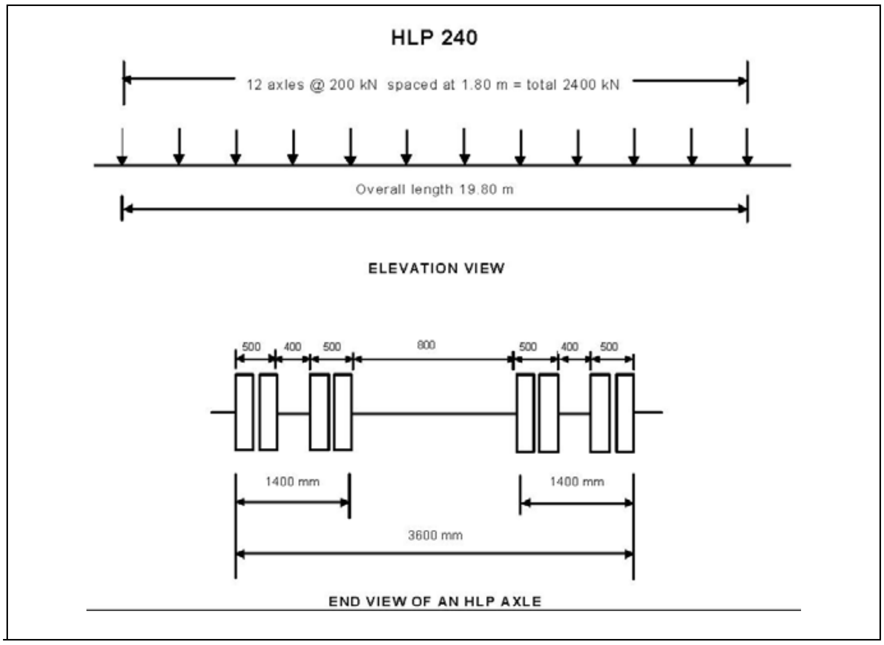
Figure 11.1-1 Design Truck Load T44



Source: MPWT, CAM PW 04-101-99 Bridge Design Code 1996

Figure 11.1-2 Design Lane Loading L44

Heavy Load Platform Loading HLP 240 shall be applied in accordance with the Cambodian Bridge Design Standard. The roads on which Heavy Load Platform Loading apply for bridge design generally will comply with design standards R6/U6, R5/U5 and R4/U4 of the Cambodian Road Design Standard Part 1 – Geometry. On this basis, bridges on National Road No. 5 will be required to support Heavy Load Platform Loading. The configuration of the HLP 240 axle loads is presented in Figure 11.1-3. Heavy Load Platform Loading HPL 240 shall be assumed to centrally occupy two (2) Standard Design Lanes. If the two Standard Design Lanes containing the Heavy Load Platform loadings are positioned such that one or more marked traffic lanes are unobstructed, then a loading of ½ of either the T44 Truck loading or L44 Lane loading shall be applied in those lanes.



Source: MPWT, CAM PW 04-101-99 Bridge Design Code 1996

Figure 11.1-3 Heavy Load Platform Loading

The load modification factors given below shall be applied to T44 Truck and L44 Lane Loading when loading Standard Design Lanes simultaneously. The modification factors shall not apply to Heavy Load Platform loadings.

Number of Standard Design Lanes Loaded	Load Modification Factor
1	1.0
2	0.9
3	0.8
4	0.7

A 70kN single dual-tyred wheel load, with a contact area of 500 mm x 200 mm, shall be applied for all deck elements for which this loading is critical. This wheel load is designated as the W7 Wheel loading.

11.2 Standard Bridges in Cambodia

Standard drawings for pipe culverts, box culverts and bridges are currently being prepared for MPWT approval under The Strengthening of Construction Quality Control Project, JICA.

With regard to bridges, plans are being prepared for carriageway widths of 7 m, 8 m, 10 m, and 12 m for the following bridge types and spans:

- RC Flat Slab (RCS) with spans of 10 m and 12 m
- RC Deck Girder (RCDG) with spans of 12 m, 15 m and 18 m
- Pre-tensioned Precast Plank hollow slab (PSC) with spans of 15 m, 18 m, 20 m and 25 m
- Post-tensioned Precast Concrete Deck Girder (PCDG) with spans of 20 m, 25 m and 30 m

The reinforced concrete flat slab (RCS) bridge is the simplest form of construction applicable to short spans and offers the largest span/depth ratio of all the options, i.e. the deck slab is minimum thickness. This type of construction will therefore have minimal impact on the road profile. The deck is simply supported on a 30 mm thick cement mortar bed and is located with dowels.

The reinforced concrete deck girder (RCDG) bridge is more economic for the longer spans in the range assigned. However this form of construction offers the smallest span/depth ratio of all the options, i.e. the deck construction is relatively deep. Such a relatively deep deck will have a significant effect on the road profile in cases where high flood level controls the deck elevation. The deck also requires the construction of diaphragms, both at the girder ends and in-span, to promote lateral load distribution. The deck is simply supported on rubber pads and is located with dowels.

The pre-tensioned precast plank hollow slab (PSC) bridge offers the advantages of precast construction, in terms of construction speed and construction quality control, and provides a large span/depth ratio for spans up to 25 m. This type of construction will therefore also have minimal impact on the road profile. The planks are pre-tensioned and incorporate voids, circular or rectilinear, to reduce weight. The planks are placed side by side to form the deck with the narrow gap filled with cement mortar. Once the mortar has gained sufficient strength, the planks are transversely post-tensioned using high tensile strength steel bars posted through holes in the planks and anchored in recesses at each side of the deck. The full depth planks do not require any in-situ concrete topping and can directly receive the pavement surfacing. The deck is simply supported on a 30 mm thick cement mortar bed and is located with dowels. This type of bridge deck has become the defector standard in Cambodia for short span bridges, with many examples already constructed ranging from 10 m span length.

The post-tensioned precast concrete deck girder (PCDG) bridge spans up to 30 m in the standard established. This type can in fact be applied to spans up to 40 m or so and is economic for the longer spans in the range assigned. The precast concrete girders again offer advantages in terms of construction speed and construction quality control. The precast girders may or may not incorporate a part of the deck slab, with the reinforced concrete deck slab either totally or partially constructed in-situ. The deck slab may feature transverse prestress. The girders also require diaphragm to promote lateral load distribution. This form of construction however has a relatively small span/depth ratio, i.e. the deck construction is relatively deep. Such a relatively deep deck will therefore have a significant effect on the road profile in cases where high flood level controls the deck elevation. The deck is simply supported on elastomeric pads and is located with dowels.

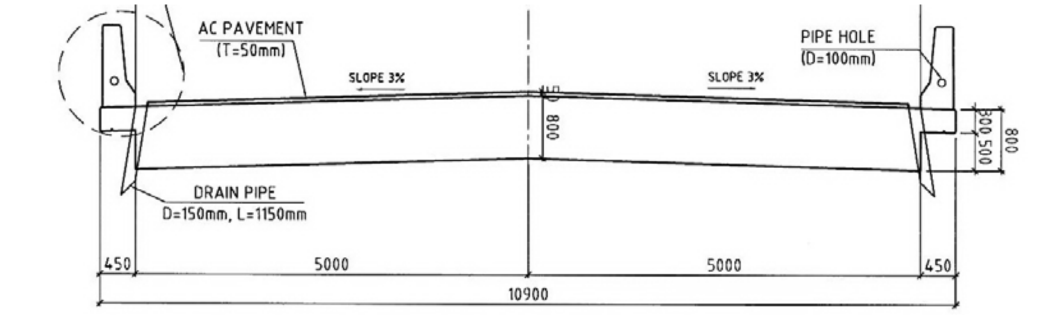
Two types of reinforced concrete abutment are featured in the standard drawings:

- Stub Type
- Cantilever Type

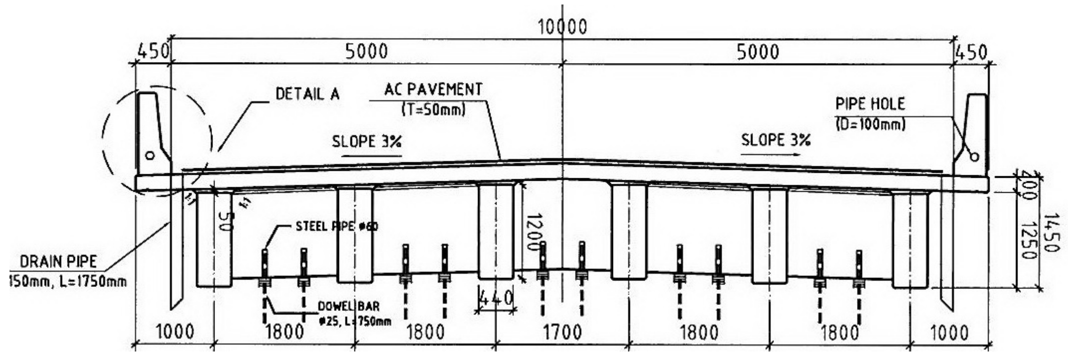
The stub type abutment features a simple coping beam, providing a bearing shelf for the deck, supported on a single row of piles, with the wing walls hung off each side. This type is suitable for all the standard deck forms where the approach embankments are relatively low and where there is no threat of local scour attack.

The cantilever abutment is a substantial structure suitable for high approach embankment situations, or deep waterway locations, and where protection to local scour attack is required. The abutment comprises of a cantilever wall, providing a bearing shelf for the deck, supported on a pile cap with multiple rows of piles. The wing walls are hung off short counterforts at each side. The abutment can support large vertical and horizontal loads.

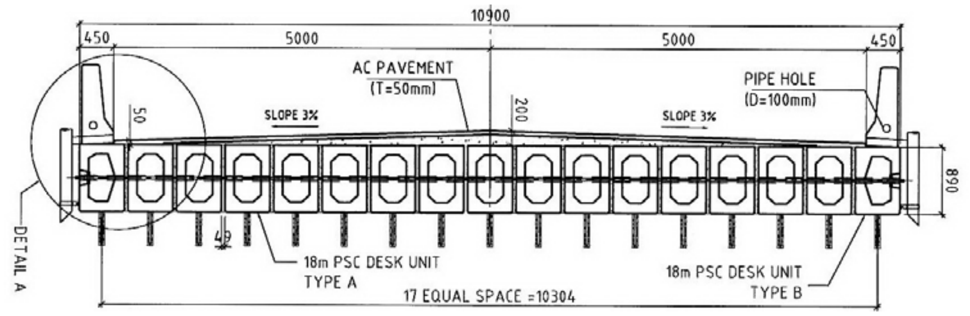
Refer to Figure 11.2-1 for typical sections of the proposed standard bridges (draft). Refer to Figure 11.2-2 for typical abutment layouts for the standard bridges. The standard bridges show a minimum freeboard of 80 cm to high water level.



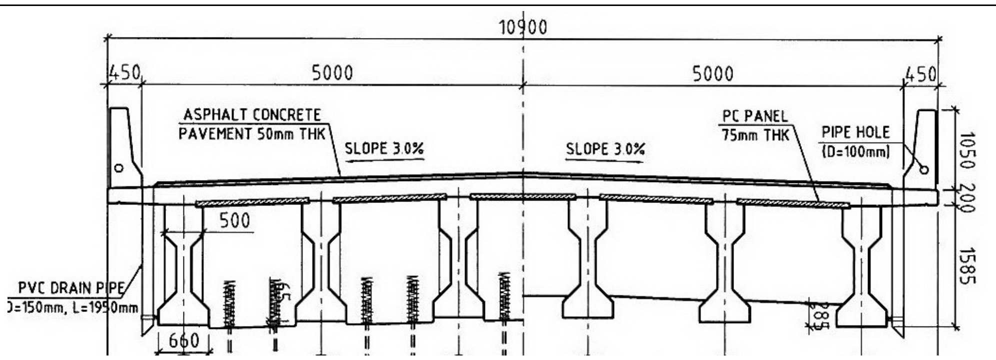
RC Flat Slab (RCS)



RC Deck Girder (RCDG)



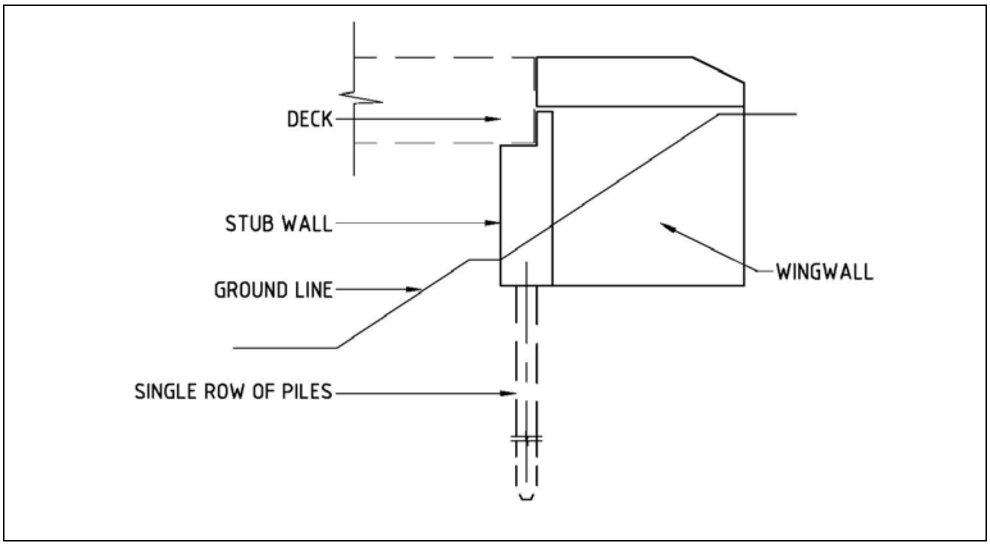
Pre-tensioned Precast Plank (PSC)



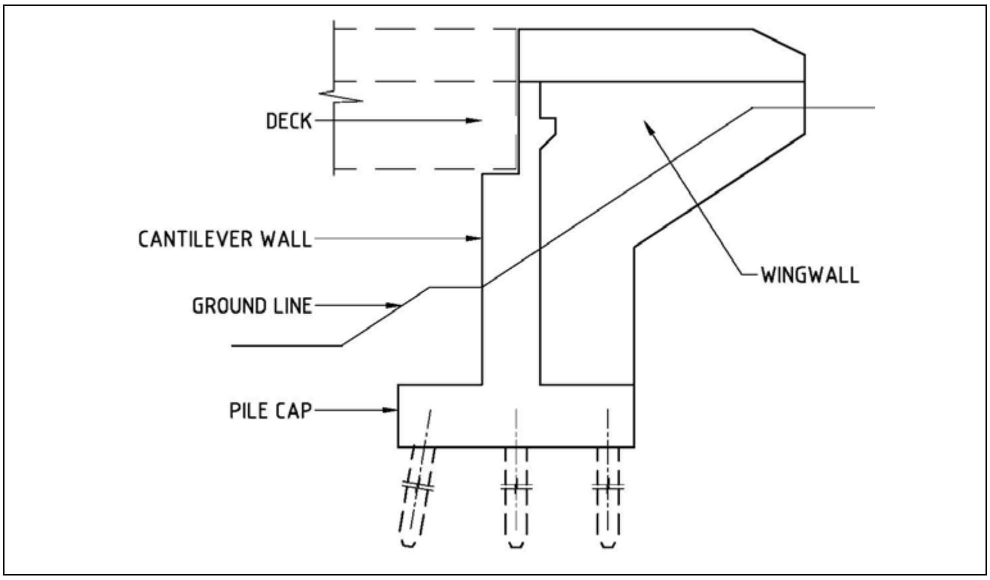
Post-tensioned Concrete Deck Girder (PCDG)

Source: MPWT, The Strengthening of Construction Quality Project, JICA

Figure 11.2-1 Standard Bridge Typical Sections for 10m wide Carriageway



Stub Type Abutment



Cantilever Type Abutment

Source: MPWT, The Strengthening of Construction Quality Project, JICA

Figure 11.2-2 Standard Bridge Abutments

11.3 Inventory of Existing Bridges on the North Section

Table 11.3-1 Inventory of Existing Bridges, North Section

1	2	3	4	5	6	7	8	9
Ref	**Code**	**KP**	**Type**	**Length**	**C/way width**	**Total Width**	**No. of spans**	**Year Built**
		(km)		(m)	(m)	(m)		
1	Br. 78	292.1	RCA	114.6	6.5	8.8	3	1962-3
2	Br. 79	303.4	IG	30.0	7.0	9.6	1	1996
3	Br. 80	304.8	Plank	20.0	10.0	10.8	1	2003
4	Br. 81	307.2	Plank	20.0	10.0	10.8	1	2003
5	Br. 82	312.1	IG	25.5	7.0	9.6	1	1996
6	Br. 83	333.8	Plank	36.0	10.0	10.8	2	2003
7	Br. 84	341.1	RCS	4.9	9.9	10.2	2	Undated
8	Br. 85	342.1	Plank	30.0	10.0	10.8	2	2003
9	Br. 86	346.1	Plank	12.0	10.0	10.8	1	2003
10	Br. 87	347.9	Plank	15.0	10.0	10.8	1	2003
11	Br. 88	349.6	Plank	10.0	10.0	10.8	1	2003
12	Br. 89	351.5	Plank	44.0	10.0	10.8	3	2003
13	Br. 90	356.1	Plank	12	10.0	10.8	1	2003
14	Br. 91	357.2	RCS	14.0	8.4	8.6	3	Undated
15	Br. 92	358.4	PCDG	81.0	10.0	10.8	3	2003

Bridge Code and Year Built from MPWT, Bridge Location National Road No. 5 & 6, 2009

Note:

1. RCA – reinforced concrete arched rib
   IG –Welded steel plate I girder with inside reinforced concrete deck slab
   Plank – precast pre-tensioned concrete plank deck
   RCS – reinforced concrete slab culvert type structure
   PCDG – pre-stressed concrete deck girder
2. Bridge length in column 5 means total bridge length between deck joints, except Br 84 which is total length of railing
3. Year of construction of Br. 78 obtained from Deputy Director of DPWT Battambang

11.4 Condition of Existing Bridges on the North Section

11.4.1 Condition of the Existing Bridge Structures

The bridges on the North Section are generally in good condition. Refer to Photos 11.4-1 and 11.4-2.

Nine (9) of the bridges constructed in 2003 under the ADB PRRP have spans lengths no greater than 20 m and feature precast concrete pre-tensioned plank decks transversely post-tensioned. Such type of construction is the most up-to-date standard bridge deck form in Cambodia for short span bridges. These bridges all feature a full 10.0 m wide carriageway, safety shape concrete barriers and stub type abutments.

Br. 78 KP 292.1

Br. 79 KP 303.4

Br. 80 KP 304.8

Br. 81 KP 307.2

Br. 82 KP 312.1

Br. 83 KP 333.8

Br. 84 KP 341.1

Br. 85 KP 342.1

Photo 11.4-1 Existing Bridges on North Section (1/2)

Br. 86　KP 346.1

Br. 87　KP 347.9

Br. 88　KP 349.6

Br. 89　KP 351.5

Br. 90　KP 356.1

Br. 91　KP 357.2

Br. 92　KP 358.4

Photo 11.4-2　Existing Bridges on North Section (2/2)

Two (2) of the bridges were constructed in 1996 under Australian fund and feature steel plate girder beams with in-situ concrete deck slabs. Close up inspection of the underside of these bridges reveal that both the structural steel and the concrete deck slab soffit are in good condition, with no rusting of the galvanized steel or spalling/scaling/cracking of the concrete. The DBST surfacing has however undergone some patch repair. The 7.0 m carriageway widths of both of these bridges is below current standard and the bridge railings are comprised of scaffolding poles fixed with clamps, considered insufficient to redirect an errant vehicle should it mount the separator curbs at the roadway edge. The abutments are probably stub type.

The existing bridge in Battambang, Br. 78, known locally as Spean Thmor Thmey, is a substantial reinforced concrete ribbed arch structure, crossing the River Sangkae over three (3) spans with a total length of 114 m. This bridge was constructed in 1962 or 1963 by local private investment, according to the Deputy Director of Battambang DPWT. Inspection from the river banks reveals a structure that is in reasonably good condition. The deck pavement is also in fair condition without obvious signs of distress. There were no reported problems raised with this bridge by DPWT following enquiries by the Study Team. The 6.5 m carriageway width of this bridge is below current standard but nevertheless is wide enough for two regular width lanes. Abutment type is unknown.

The existing bridge in Banteay Meanchey, Br. 92, known locally as Se Sin Bridge, is a substantial prestressed concrete beam and slab structure, crossing the River Sri Sophorn over three (3) spans with a total length of 82 m. The girders are precast pre-tensioned Australian standard Super-T type girders with a girder depth of 1500 mm. This bridge was constructed in 2003 under the ADB PRRP. Inspection from the river banks reveals a structure that is in good condition. The deck pavement is also in good condition without obvious signs of distress. There were no reported problems raised with this bridge by the Director of Banteay Meanchey DPWT following enquiries by the Study Team. This bridge features a full 10.0 m wide carriageway and safety shape concrete barriers. The abutments are stub type with raked piles.

Br. 84 and Br. 91 are relatively aged structures that were not replaced under the previous improvement projects, and are both of short span culvert type construction. These structures do not have a recorded year of construction according to the MPWT document “Bridge Location on National Road No. 5 & 6”.

- Bridge Br. 84 is a reinforced concrete culvert type structure that features two small span arched openings, each 1.8 m wide and with 1.8 m clear vertical opening. The carriageway width is 9.9 m on the structure. The bridge railings are damaged and do not have the capacity to redirect errant vehicles.

- Bridge Br. 91 is a reinforced concrete culvert type structure that features three spans of 4.5 m and with 3.8 m clear vertical opening. The structure crosses an irrigation channel that was improved in 2010. The carriageway width is 8.4 m on the bridge. The structure is showing clear signs of deterioration with areas of spalled concrete and exposed reinforcement. The bridge railings are damaged and do not have the capacity to redirect errant vehicles.

It is noted from the ADB PRRP construction drawings that during the reconstruction in 2003 of Br. 89, known locally as Mongkol Borei Bridge, the existing 48 m Bailey bridge was replaced by a 43.8 m permanent concrete bridge. This shorter bridge required remedial works to the steep slope protection at the abutments in the form of rock rip-rap to the slopes, rock baskets and geo-textile at the toe of the slopes and vegetated fill surfaces. It is considered by the Study Team, following site inspection, that the 2003 bridge is in fact too short for the site, at least on the Battambang side. The rock rip rap on the Battambang side has subsided and separated from the abutment since the construction exposing the abutment piles.

11.4.2 Flood Conditions at the Existing Bridge Locations

The flood conditions at the location of the existing bridges are presented in Table 11.4-1. The flood data presented is based upon interviews with local residents and measurements made by the Study Team to high water marks on the bridge structures or adjacent structures, where still visible.

Accounts of high flood level at bridge locations north of KP 333 were dominated by references to very high flood waters that occurred in October 2010. The Director of DPWT in Banteay Meanchey informed the Study Team, at a meeting on the 22nd June at DPWT offices, that the flood waters in 2010 were caused by large run-off from the bordering provinces of Thailand. Most of the residents interviewed by the Study Team also attributed the source of the flood waters to be from Thailand. These unusually large flood waters from Thailand combined with high water conditions at the Tonle Sap Lake to create flood conditions that were the most severe in recent living memory of the local inhabitants interviewed. The flood waters from Thailand were exacerbated by a dam break.

Table 11.4-1 Flood Condition at Location of Existing Bridges, North Section

1	2	3	4	5	6	7	8	9
Ref	**Code**	**KP** (km)	**Waterway Width** (m)	**River Clearance** (m)	**Normal Flood Level** (m)	**High Flood Level** (m)	**Flood Breakout**	**Comment**
1	Br. 78	292.1	80.0	no record	no record	4.0	None	
2	Br. 79	303.4	30.0	no record	1.4	1.1	None	
3	Br. 80	304.8	20.0	3.5	3.0	1.5	None	
4	Br. 81	307.2	20.0	2.2	no record	1.2	None	Note 2
5	Br. 82	312.1	25.5	3.7	2.0	0.7	None	Note 2
6	Br. 83	333.8	36.0	4.0	1.3	0.5	None	Note 3
7	Br. 84	341.1	4.0	2.2	0.8	0.4	None	Note 4
8	Br. 85	342.1	30.0	3.5	1.0	-0.1	Yes	Note 2&5
9	Br. 86	346.1	12.0	2.2	0.8	0.3	None	
10	Br. 87	347.9	15.0	3.0	1.0	no record	None	
11	Br. 88	349.6	10.0	2.5	0.8	0.4	None	
12	Br. 89	351.5	44.0	9.0	4.0	3.0	None	Note 6
13	Br. 90	356.1	12.0	2.2	1.2	0.4	None	Note 2&7
14	Br. 91	357.2	10.0	4.1	1.4	0.8	None	Note 8
15	Br. 92	358.4	81.0	9.0	3.0	2.0	None	Note 9

Note:

1. River clearance (Col 5) and Flood Levels (Col 6 & 7) are measured below carriageway level (top of pavement)
2. Waterway dry with some ponding at date of inspection (July 2011)
3. Flood water rose to top of shoulder of approach road in 2010
4. High flood level in 2010
5. Flood 10 cm over bridge and approaches in 2010 – 1 month duration
6. High flood level in 2010. Flooding duration 15days. Flood overtopped south approach road by 0.5m adjacent to Koksvay Primary School.
7. Flood water rose to top of shoulder of approach road in 2010. Run off water from north blocked in 2011.
8. High flood level in 2010. Irrigation channel improved in 2010
9. High flood level in 2010.

11.5 Bridge Rehabilitation Plan on the North Section

The majority of the existing bridges on the North Section are in good condition given their relatively recent construction. Notwithstanding the generally good condition of the existing bridges the following deficiencies are identified:

- Existing carriageway width at Br. 78 in Battambang City is, at 6.5 m, below the required standard width of 10 m for a two (2) lane national road.
- Existing 7.0 m carriageway width at Br. 79 at KP 303.4 is less than the required standard width of 10 m for a two (2) lane national road and features inadequate railing.

- Existing 7.0 m carriageway width at Br. 82 at KP 311.9 is less than the required standard width of 10 m for a two (2) lane national road and features inadequate railing.
- Relatively old structure at Br. 84 at KP 341.1 with inadequate freeboard to maximum flood level and inadequate bridge railings.
- Failure of abutment slope protection at Br. 89 with exposed abutment piles.
- Relatively old structure at Br. 91 at KP 357.2 with inadequate freeboard to maximum flood level, areas of spalled concrete and exposed reinforcement, inadequate bridge railings and insufficient width for standard two (2) lane national road.

All the bridges, except Br. 85, are not overtopped during flood conditions. However most of the bridges do not provide adequate freeboard to maximum flood level. For at least two bridges, Br. 79 and Br. 82, the lower deck section is submerged during periods of maximum flood. Br. 85 was reported to be overtopped by 10 cm during the 2010 flood. However, given the extraordinary nature of the 2010 flood it is not proposed that any of the bridges, other than the bridges that are planned to be reconstructed, should be raised in elevation.

Given that it is proposed to bypass Battambang City it is not considered necessary to recommend any bridge widening works at Br. 78, notwithstanding that the carriageway width is substandard.

The scope of the rehabilitation of the bridges on the North Section will depend on the lane configuration adopted for the road rehabilitation i.e. full 4-Lane divided or opposed 2-Lane plus motorcycle lane. However, irrespective of the final lane configuration, the bridges identified above with deficiencies will require some form of rehabilitation.

11.5.1 Planning of Bridge Widening for 4-Lane Road

The substantial carriageway width required to accommodate a 4-Lane Road will require that all bridges on the North Section will either have to be widened or to be supplemented with an additional adjacent bridge. The bridges that have tangential road approaches are recommended to be equally widened on each side in order to maintain the tangent horizontal alignment of the existing road. Those bridges that have approaches on curved alignment are recommended to be supplemented with an additional bridge of sufficient width to provide the necessary carriageway width for 4-Lane Road. Refer to Table 11.5-1 for a summary of proposed bridge widening for 4-Lane Road.

Refer to Section 11.5.2 for details of bridge widening and Section 11.5.3 for the proposed additional bridges for 4-Lane Road.

Table 11.5-1 Summary of Bridge Widening- Full 4-Lane Design

1	2	3	4	5	6
Ref	**Code**	**KP** (km)	**Existing Type**	**Road Approach**	**4-Lane Widening Concept**
1*	Br. 78	292.1	RCA	Tangent	No widening proposed
2	Br. 79	303.4	IG	Curved	Provide additional bridge LHS
3	Br. 80	304.8	PSC	Tangent/Curved	Widen existing bridge both sides
4	Br. 81	307.2	PSC	Tangent	Widen existing bridge both sides
5	Br. 82	312.1	IG	Curved	Provide additional bridge RHS
6	Br. 83	333.8	PSC	Tangent	Widen existing bridge both sides
7	Br. 84	341.1	RCS	Tangent	Replace bridge with new structure
8	Br. 85	342.1	PSC	Tangent	Widen existing bridge both sides
9	Br. 86	346.1	PSC	Tangent	Widen existing bridge both sides
10	Br. 87	347.9	PSC	Tangent	Widen existing bridge both sides
11*	Br. 88	349.6	PSC	Tangent	Widen existing bridge both sides
12*	Br. 89	351.5	PSC	Curved	Provide additional bridge RHS
13*	Br. 90	356.1	PSC	Tangent	Widen existing bridge both sides
14*	Br. 91	357.2	RCS	Tangent	Replace bridge with new bridge
15*	Br. 92	358.4	PCDG	Curved	No widening proposed

**) These bridges are not included in the improvement project of NR 5 (See Chapter 12).*

Note:

RCA – reinforced concrete arched rib
IG –Welded steel plate I girder with in-situ reinforced concrete deck slab
PSC – precast pre-tensioned concrete plank deck
RCS– reinforced concrete slab culvert type structure
PCDG – pre-stressed concrete deck girder

11.5.2 Rehabilitation of Br. 79 & Br. 82

The two similar single span bridges constructed in 1996 with Australian funding, Br. 79 and Br. 82, feature carriageways that are only 7.0 m wide. The bridges each feature six (6) steel plate girders supporting a deck slab that is 9.6 m wide, accommodating 1.3 m wide walkways each side of the carriageway. Refer to Photo 11.5-1.

 Br. 79 KP 303.4 View on Deck	 Br. 82 KP 312.1 View on Sidewalk
 Br. 79 KP 303.4 View on Railing	 Br. 79 KP 303.4 View on Railing Attachment
 Br. 79 KP 303.4 View on Girder	 Br. 79 KP 303.4 View on K Frame

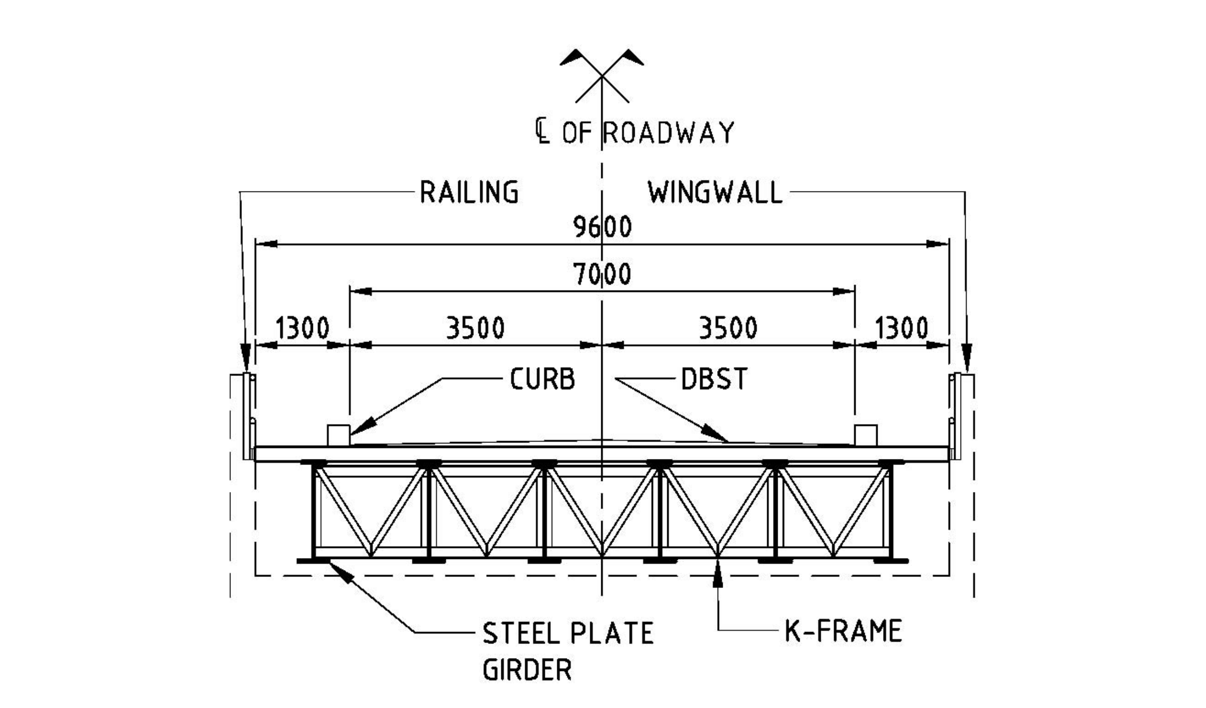
Photo 11.5-1 Existing Bridges Br. 79 and Br. 82

In the case of the 4-Lane Road rehabilitation option, it is proposed to make use of the existing structure to accommodate one of the 2-Lane carriageways and to construct an additional bridge to accommodate the other carriageway.

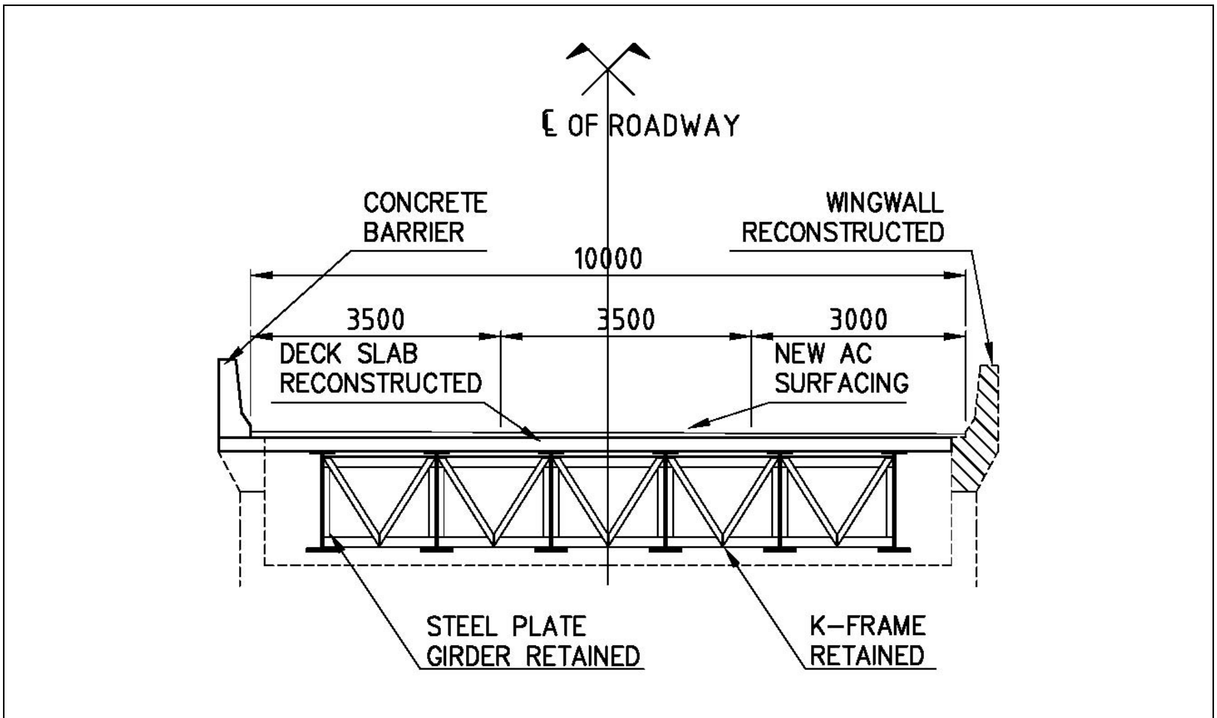
Notwithstanding that the existing bridges are in good condition, the symmetrical layout of the 7.0 m carriageway width cannot accommodate the proposed shoulder for the 4-Lane Road. In the case of adopting a 4-lane width design for the North Section, it is proposed that the deck slab is either partially demolished, or completely demolished, and new deck slab is constructed such that the 2-Lane carriageway plus shoulder can occupy a 10.0 m carriageway width. The width between the existing wing wall faces is 9.6 m and the wing wall faces are vertical. The existing wing walls will therefore be partially demolished and reconstructed with a safety shape profile to accommodate a 10 m width. The bridge railings on the deck will also be replaced with solid concrete safety shape barriers and the decks will be resurfaced with AC pavement. An analysis of the capacity of the existing steel girders will be necessary at the detailed design stage to determine if strengthening of the girders is required. Refer to Figure 11.5-1 for an outline sketch of the proposed rehabilitation.

Construction may be phased at Br. 79 and Br. 82 such that the additional bridges required for the 4-Lane Road are constructed first and put in service before the existing bridges are closed for the required rehabilitation works.

It is noted that, although flood waters do not overtop the deck, water rises above the level of the girder bottom flanges to within 100 cm and 70 cm of the top of the deck at Br. 79 and Br. 82 respectively. These bridges therefore do not provide any freeboard at all to maximum flood level and in fact the lower flanges of the girders of both bridges are submerged under such flood conditions. A freeboard clearance of 80 cm is typically required from high flood water level to the underside of the bridge deck. The bridges are therefore substandard with regard to providing adequate freeboard clearance.



a) Existing Cross-Section



b) Proposed Rehabilitation

Figure 11.5-1 Proposed Rehabilitation at Br. 79 and Br. 82 – 4-Lane Road

11.5.3 Rehabilitation of Br. 84

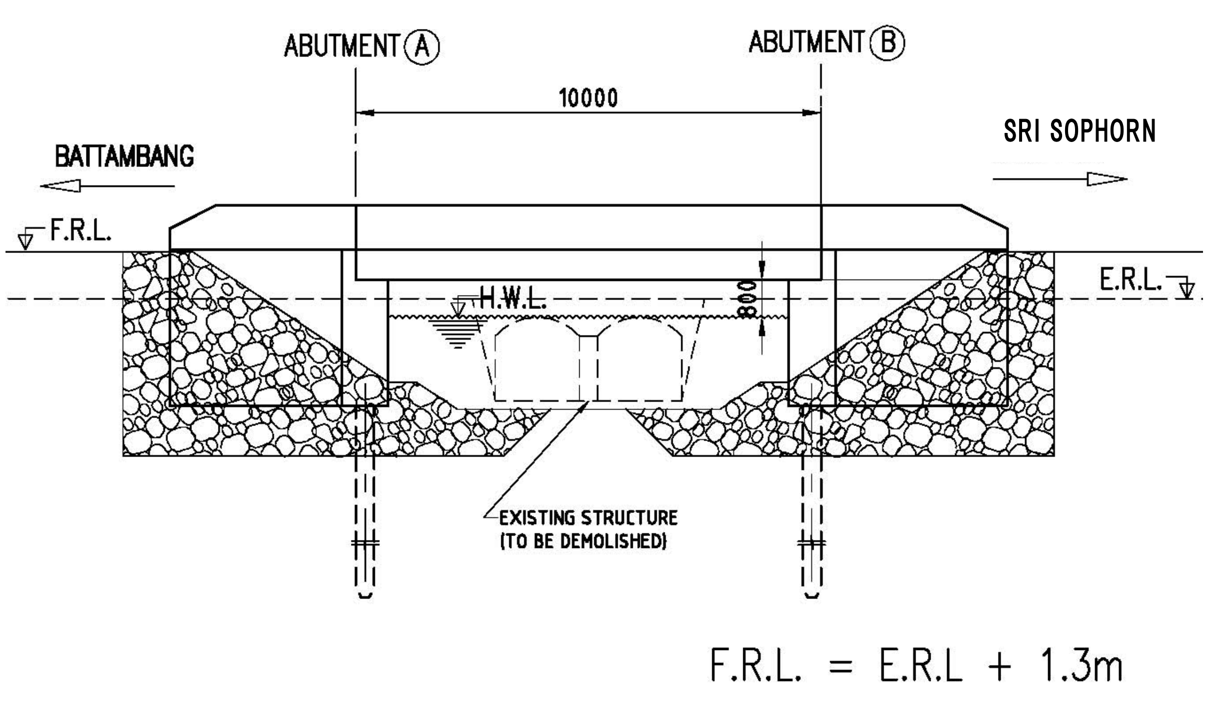
It is proposed to replace the existing structure at this location with a new 4-Lane structure. The existing structure at Br. 84 is in fact a relatively small culvert crossing a minor water channel. The maximum flood level at this location was determined from interviews with local residents during the site inspections of the Study Team. Flood waters do not overtop the structure according to accounts received but flood water level rises to within 40 cm of the road surface (in 2010). In order to protect the proposed pavement works and maintain a minimum 80 cm freeboard beneath the bridge deck surface, the profile of the road at this section must therefore be raised. Local accounts describe overtopping of the road on the approaches to the bridge structure in year 2010, although flood water depth above the road was not significant and it did not severely interrupt traffic flow with motorcycles still able to negotiate the flooded sections. Flood levels at Br. 84 were not significantly different in 2010 from other years, according to local residents.

This structure is designated by MPWT as a bridge location. Should it be the policy of MPWT to make provision for a bridge at this location, it is proposed that a minimum span length bridge is constructed. In accordance with the ongoing study, The Strengthening of Construction Quality Project, the minimum length standard bridge features a span of 10m. Either an insitu reinforced concrete slab (RCS) structure or a pre-tensioned precast concrete plank hollow slab (PSC) bridge can be recommended at this location. In drafting a structure layout for comparison purposes, an allowance of 80 cm freeboard has been made to the maximum flood water level established at this location from the accounts of local residents.

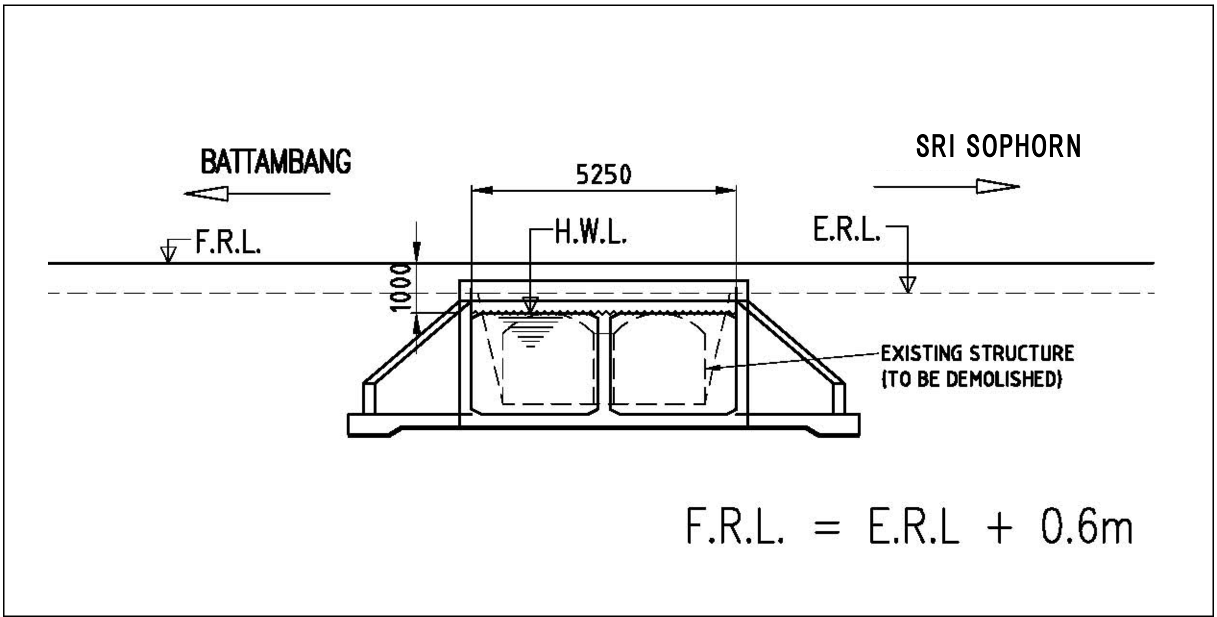
An alternative to a bridge structure at this location is a reinforced concrete culvert. The final size and configuration of the culvert should be determined at detailed design following proper hydrological and hydraulic analysis. For the purpose of illustrating a structural arrangement, a twin cell 2.5 mx2.0 m box culvert has been considered for this study. The finished road level has been set 100 cm above maximum flood level to protect the pavement.

The Study Team inspected this bridge location in November 2010 during the rainy season and found that the water level in the channel was very little changed from that found following inspections made during the dry season in June and July 2011. Notwithstanding the extraordinary food conditions encountered in 2010, it is therefore recommended that a box culvert structure is constructed at this location to replace the existing structure.

Refer to Figure 11.5-2 for elevations on the proposed alternatives.



a) RCS Bridge Alternative



b) Box Culvert Alternative (Recommended)

Note: H.W.L = High Water Level : F.R.L. = Finished Road Level : E.R.L. = Existing Road Level

Figure 11.5-2 Elevations on Structure Alternatives for Br. 84

11.5.4 Rehabilitation of Br. 89

(This bridge is not included in the project sections as described in Chapter 12.)

Location of this bridge is out of proposed project section because of diverting to Sri Sophorn Bypass.

At Br. 89, known locally as Mongkol Borei Bridge, it is proposed to retain the existing structure and to provide an additional bridge to accommodate the 4-Lane Road.

The rock rip rap on the Battambang side of Br. 89 has subsided and separated from the abutment since construction, exposing the abutment piles. The rip rap on this side is not grouted but is instead retained within a wire mesh. The grouted rip rap on the Sri Sophorn side is constructed on a less steep slope and is in reasonable condition.

From the brief inspection undertaken by the Study Team it appears that the steep rip rap slope at the Battambang abutment has suffered a local failure on the upstream side, resulting in loss of support and settlement of the soil beneath the abutment coping, exposing the piles. Refer to Photo 11.5-2.

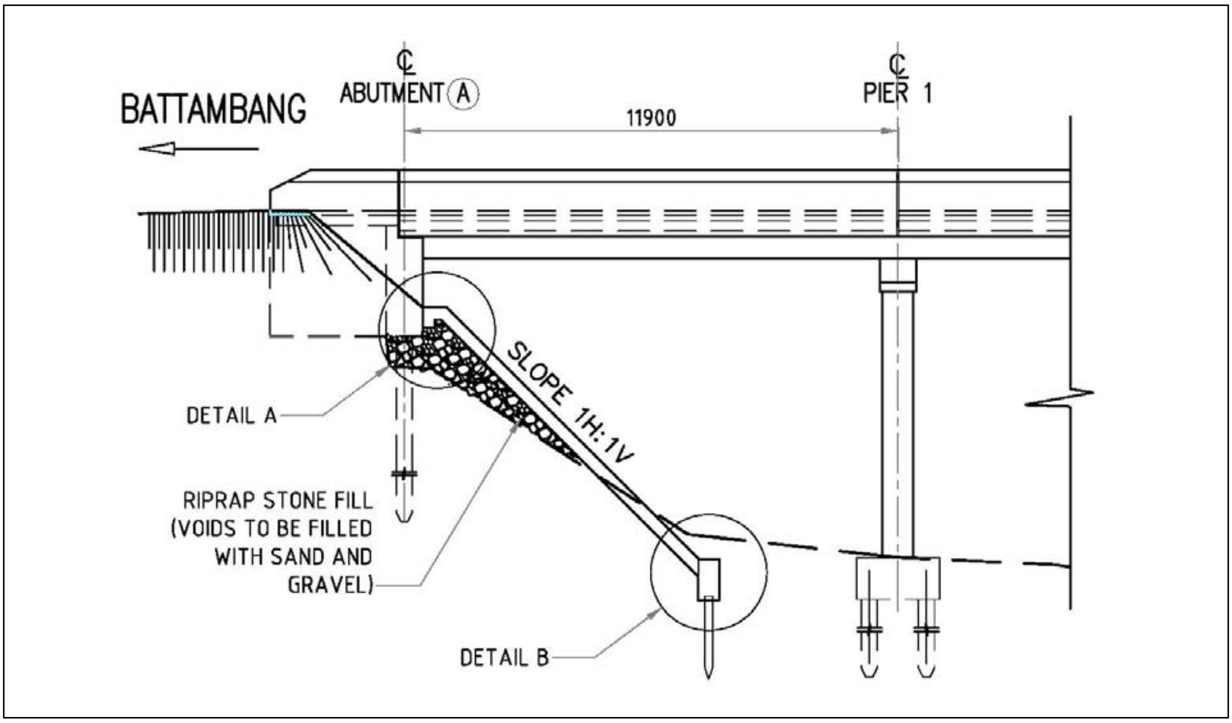
The following rehabilitation works are proposed for the rip rap protection at the Battambang abutment:

- Remove the existing wire mesh covering and the rock rip rap.
- Expose the length of the abutment coping to determine the full extent of the subsided slope.
- Remove any loose soils from beneath the abutment coping around the exposed piles to suitable depth and compact in-situ soils with hand held vibratory plate compactor as necessary.
- Trim the exposed slope and compact with hand held vibratory plate compactor as necessary, fill any subsided area with rock rip rap and fill any small voids with sand and gravel.
- Fill the voids beneath the abutment coping with rock rip rap, any small voids to be filled with sand and gravel.
- Construct a reinforced concrete curtain wall at the toe of the slope supported on timber piles.
- Fix a rebar mat over the entire slope, fix suitable weep hole pipes and cast a concrete slab slope protection to be contiguous with the abutment structure and monolithic with the curtain wall.

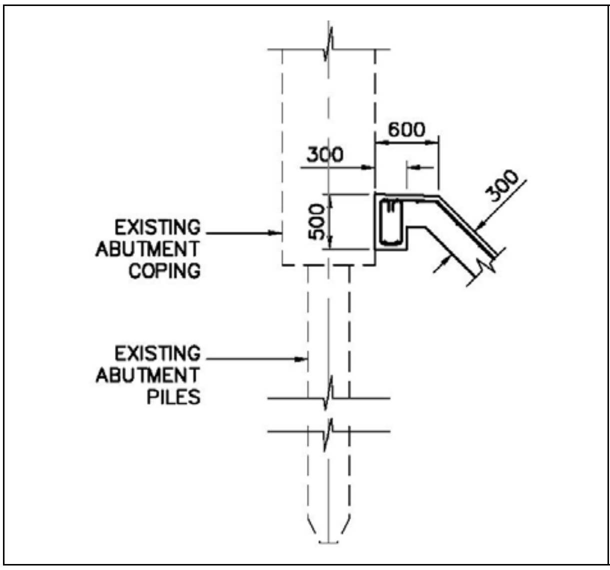
Refer to Figure 11.5-3 for details of the proposed rehabilitation at Br. 89.

 View on Battambang Abutment showing slope failure into the river	 View on Rip Rap at Battambang Abutment (loose rocks retained in wire mesh)
 View on Sri Sophorn Abutment	 View on Grouted Rip Rap at Sri Sophorn Abutment
 View on Exposed Piles at Battambang Abutment Upstream side	 View on Separated Riprap at Battambang Abutment Wing Wall Upstream side

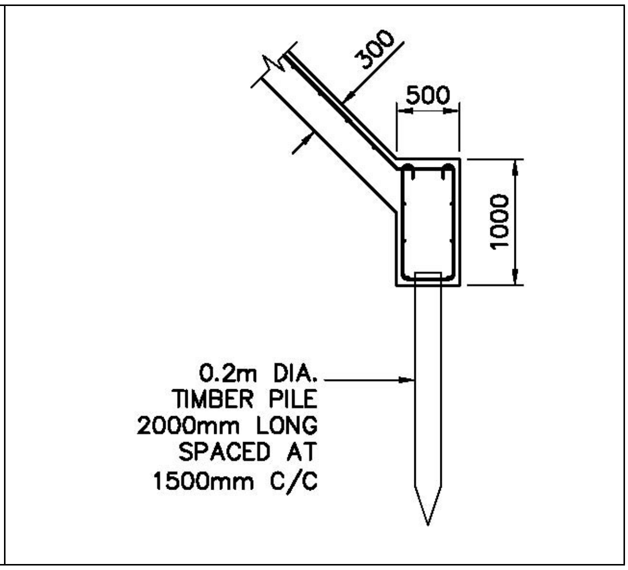
Photo 11.5-2 Existing Bridge Br. 89 KP 351.5 (Mongkol Borei Bridge)



a) Elevation on Battambang Abutment



b) Detail A



c) Detail B

Figure 11.5-3 Proposed Rehabilitation at Br. 89

11.5.5 Rehabilitation of Br. 91

(These bridges are not included in the improvement project of NR 5 (See Chapter 12).)

Location of this bridge is out of proposed project section because of diverting to Sri Sophorn Bypass.

Bridger Br. 91 is a reinforced concrete culvert type structure that features three spans of 4.5 m and 3.8 m clear vertical opening. The total length of the bridge is 14.0 m. The carriageway width is 8.4 m on the bridge. The structure is showing clear signs of deterioration with areas of spalled concrete and exposed reinforcement. The bridge railings are damaged and do not have the capacity to redirect errant vehicles.

Given the aged and deteriorated condition of the structure and inadequate carriageway width, it is proposed that this structure is replaced with a new 4-Lane bridge. In consideration of the relatively small size of the existing bridge, and the modest waterway crossed, it is proposed that the new bridge will be constructed at the same position as the existing bridge with provision made during construction for a detour road with temporary bridge. The length of the existing structure and the configuration of the waterway, with no flood water breakout reported at this location, favors a new bridge with a total deck length of 20 m.

Refer to Table 11.5-2 for an outline comparative study of alternatives for consideration. Given that the cost differences for such small span structures are not likely to be substantial, only broad cost considerations have been included in the comparative analysis. The types of construction identified, for both bridge deck and abutment layout, were selected from the standard bridges established by the MPWT, The Strengthening of Construction Quality Project, JICA.

Refer to Figure 11.5-4 for elevations on the proposed alternatives.

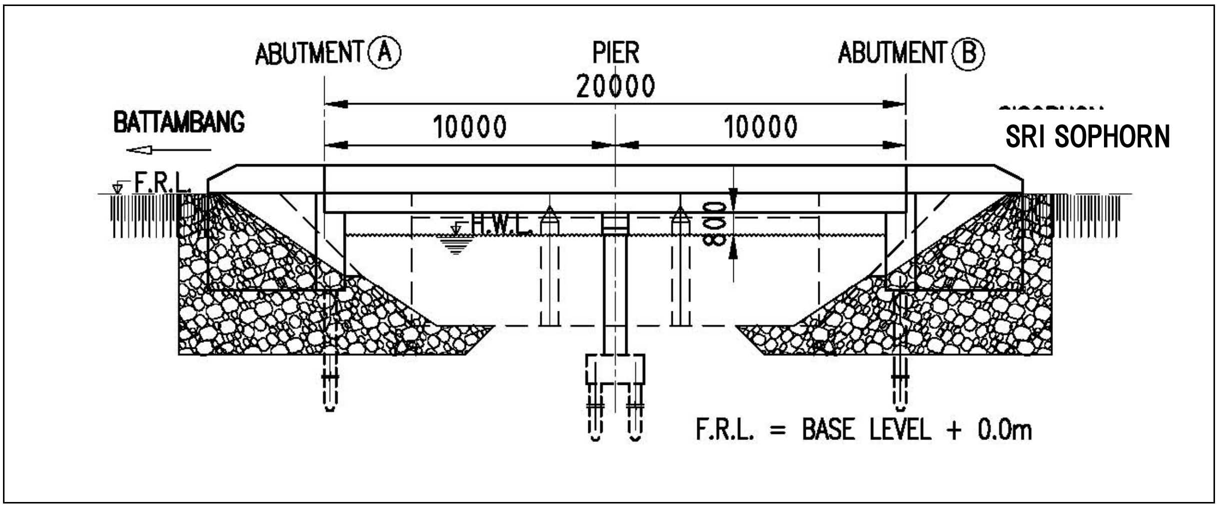
All alternatives are set to give a deck elevation no less than that of the existing road and such to provide at least 80 cm freeboard to design high water level. For the purposes of this study, and in the absence of any detailed hydrological or hydraulic analysis, design high water is set to the normal flood water level according to the findings of the site inspection. The extraordinary 2010 flood water level will not be considered. The design high water level to be adopted for the detailed design will require to be established from detailed hydrological and hydraulic analysis.

Table 11.5-2 Comparative Study of Alternatives for Br. 91

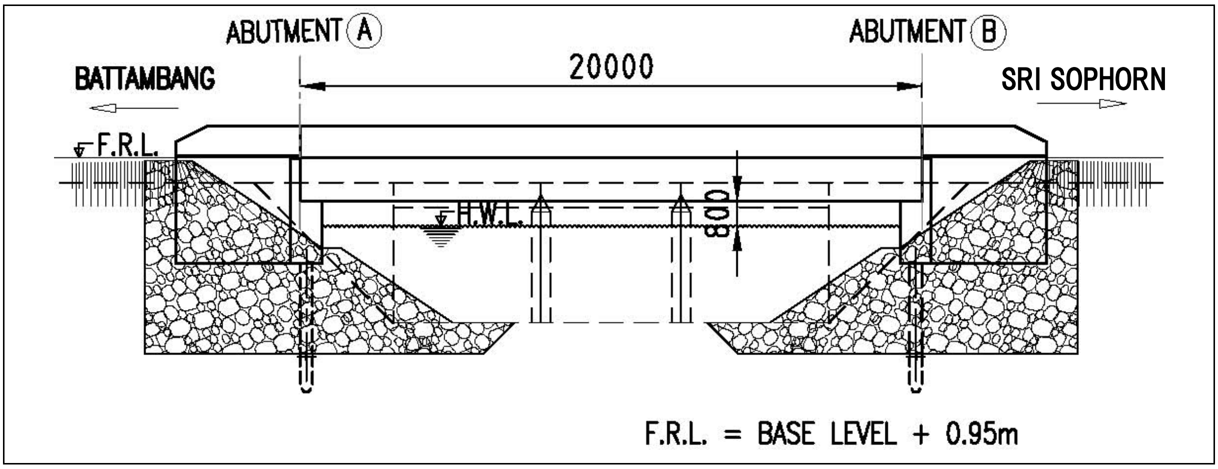
1	2	3	4	5	6
Bridge Type	**Total Length** (m)	**No. of Spans**	**Advantages**	**Disadvantages**	**Comment**
RCS	20	2	• Shallowest depth of deck • Simplest form of construction • No deck diaphragms required • No transverse prestress required • Minimal impact on road profile	• Pier construction required in waterway • Shoring required for in-situ deck construction • Longest construction period • Least economic given the additional foundation costs	2nd Rank
RCDG	20	1	• No pier required • No transverse prestress required • Most economic for the selected span	• Greatest depth of deck • Maximum impact on road profile • Deck diaphragms required • Shoring required for in-situ deck construction • Non standard length (see note 2)	3rd Rank
PSC	20	1	• No pier required • No shoring required for precast deck construction • Relatively shallow depth of deck • Moderate impact on road profile • Shortest construction period • Precasting will promote good quality of concrete finish to the deck	• Transverse prestress required	1st Rank

Note:

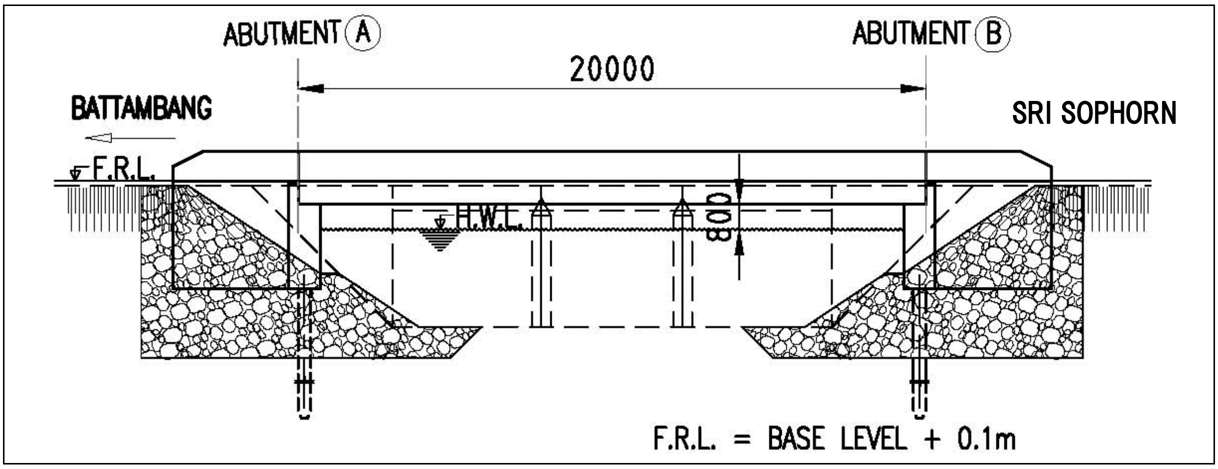
1. Bridge Type:
   RCS – Reinforced Concrete Flat Slab
   RCDG – Reinforced Concrete Deck Girder
   PSC – Pre-tensioned Precast Plank (hollow slab)
2. Standard span lengths are set at 12 m, 15 m and 18 m for RCDG bridges according to *MPWT, The Strengthening of Construction Quality Project, JICA.* Span lengths up to 24m are however standard for RCDG bridges in other countries (Philippines)



a) RCS Alternative



b) RCDG Alternative



c) PSC Alternative

Figure 11.5-4 Elevation on Bridge Alternatives for Br. 91

Note:

1. H.W.L = High Water Level : F.R.L. = Finished Road Level
2. Base Level = F.R.L. for the RCS alternative assuming H.W.L. controls the design and not existing road level.

11.6 Planning of Bridge Widening for 2-Lane Road

The option to provide an opposed 2-Lane Road with 2.5 m wide motorcycle lanes and shoulders will require 14 m wide bridge decks. In this case, the additional bridges proposed for the 4-Lane Road at Br. 79, 82 and 89 cannot be justified. All bridges will therefore be widened or replaced as the case requires.

Refer to Table 11.5-3 for a summary of proposed bridge widening for 2-Lane Road.

Table 11.5-3 Summary of Bridge Widening- 2-Lane Design

1	2	3	4	5	6
Ref	**Code**	**KP** (km)	**Existing Type**	**Road Approach**	**2-Lane Widening Concept**
1*	Br. 78	292.1	RCA	Tangent	No widening proposed
2	Br. 79	303.4	IG	Curved	Widen existing bridge LHS
3	Br. 80	304.8	PSC	Tangent/Curved	Widen existing bridge both sides
4	Br. 81	307.2	PSC	Tangent	Widen existing bridge both sides
5	Br. 82	312.1	IG	Curved	Widen existing bridge RHS
6	Br. 83	333.8	PSC	Tangent	Widen existing bridge both sides
7	Br. 84	341.1	RCS	Tangent	Replace bridge with new structure
8	Br. 85	342.1	PSC	Tangent	Widen existing bridge both sides
9	Br. 86	346.1	PSC	Tangent	Widen existing bridge both sides
10	Br. 87	347.9	PSC	Tangent	Widen existing bridge both sides
11*	Br. 88	349.6	PSC	Tangent	Widen existing bridge both sides
12*	Br. 89	351.5	PSC	Curved	Widen existing bridge RHS
13*	Br. 90	356.1	PSC	Tangent	Widen existing bridge both sides
14*	Br. 91	357.2	RCS	Tangent	Replace bridge with new bridge
15*	Br. 92	358.4	PCDG	Curved	No widening proposed

**) These bridges are not included in the improvement project of NR 5 (See Chapter 12).*

Note:

1. RCA – reinforced concrete arched rib
   IG – Welded steel plate I girder with in-situ reinforced concrete deck slab
   PSC – precast pre-tensioned concrete plank deck
   RCS – reinforced concrete slab culvert type structure
   PCDG – pre-stressed concrete deck girder

11.7 Details of Bridge Widening for 4-Lane Road

Widening of existing bridge by adding deck slab and beam, as necessary, is proposed not only for 2-lane bridges but also for 4-lane bridges. As explained later, substructure may also be widened. Such widening of bridge requires less cost because it does not demolish the existing structure but effectively utilize it. On the other hand, this method requires high-level engineering skill in execution.

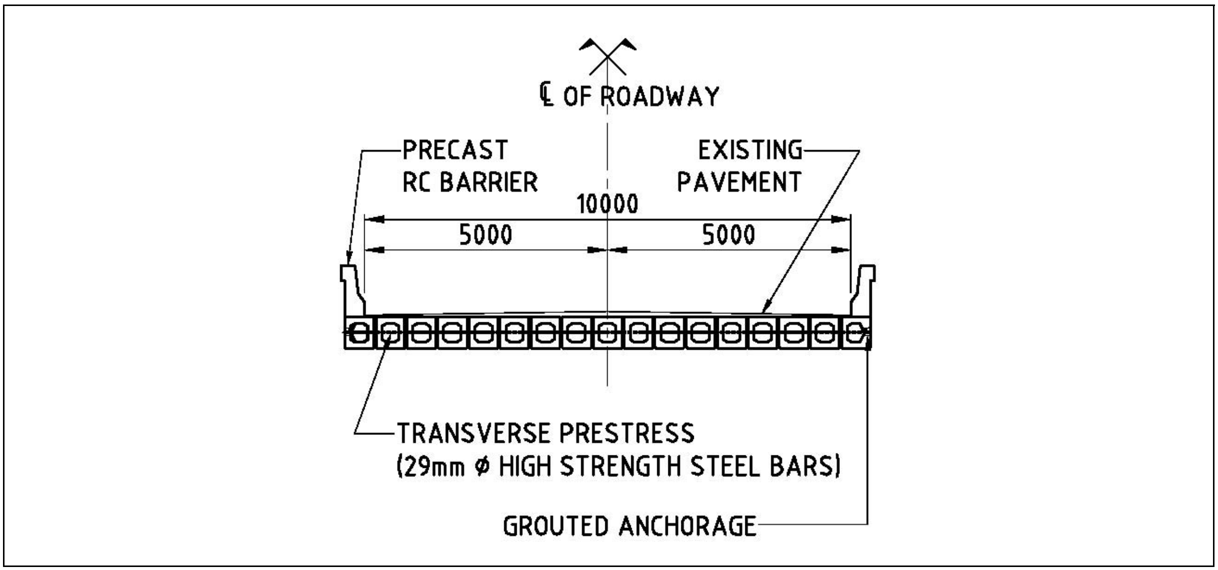
This method has been practically adopted in some developed countries including Japan. On the other hand, there has been no such case in Cambodia. Thus, this Project (widening of NR 5) will become the pilot case for this method in Cambodia.

Adoption of this method requires employment of consultant(s) and contractor(s) who have sufficient experience in this method. Once this method is successfully introduced and disseminated in Cambodia, it will substantially reduce the cost of bridge widening which is foreseen in the future as further strengthening of the function of road network will become necessary to accommodate increased traffic demand which will, in turn, support future socio-economic development.

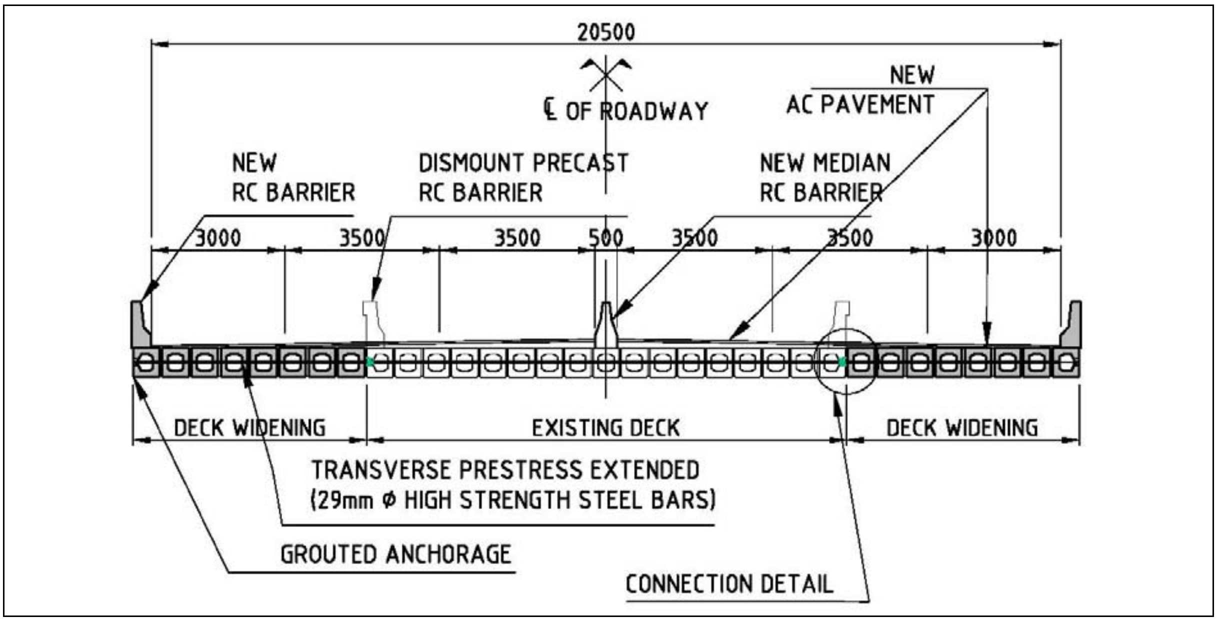
It can be seen from the Table 11.5-1 that all the bridges that are proposed to be widened feature PSC decks. The deck widening concept will therefore be substantially the same for all affected bridges. The deck widening concept will make use of similar section PSC units placed on extended substructure and transversely pre-stressed to the existing units of the deck. Refer to Figure 11.7-1 for a typical cross-section of a widened bridge and Figure 11.7-2 for deck widening details.

Two options are presented to achieve the extension of the transverse pre-stress for the PSC decks. Option 1 proposes to break out the cement mortar at each anchorage recess and to use couplers to extend the pre-stressing bars. Option 2 provides a separate anchorage plate to be attached at each pre-stress location with anchor bolts epoxy grouted into drilled holes. Option 1, using couplers, may not be practicable as the length of existing threaded bar protruding beyond the anchor nut at each anchorage may not be long enough to develop sufficient pre-stress force (350 kN) with the coupler (extended length bars would have been used during construction to enable the pre-stressing operations and then cut back near the anchor nut) or the thread may have been damaged. A trial application of this technique is recommended prior to implementation should this option be selected. Option 2 does not require the breaking out of the cement mortar in the existing anchorage recess. However this option requires the careful location of the drilled holes for the epoxy grouted anchor bolts particularly for the very shallow 10 m span units, in order not to damage the pre-stressing strands in the units.

Refer to Figure 11.7-3 for a typical cross-section of pier widening (example at Br. 85 shown) and abutment widening (stub abutments). Refer to Figure 11.7-4 for details of the widening at a stub abutment.

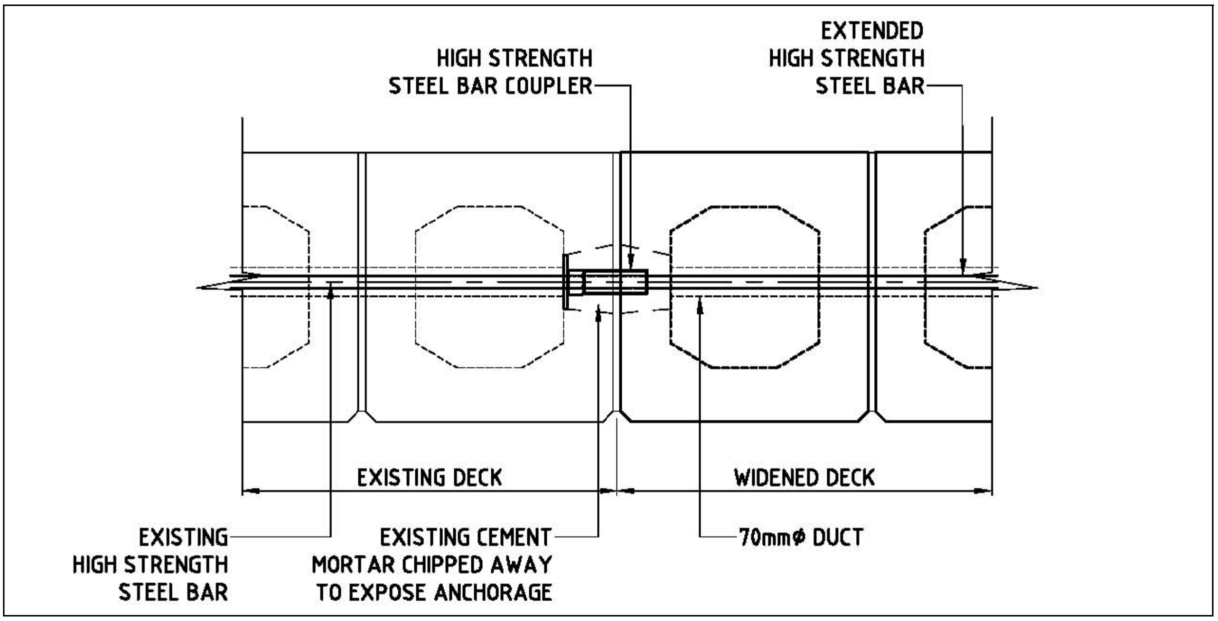


a) Typical Existing Condition of PSC Deck

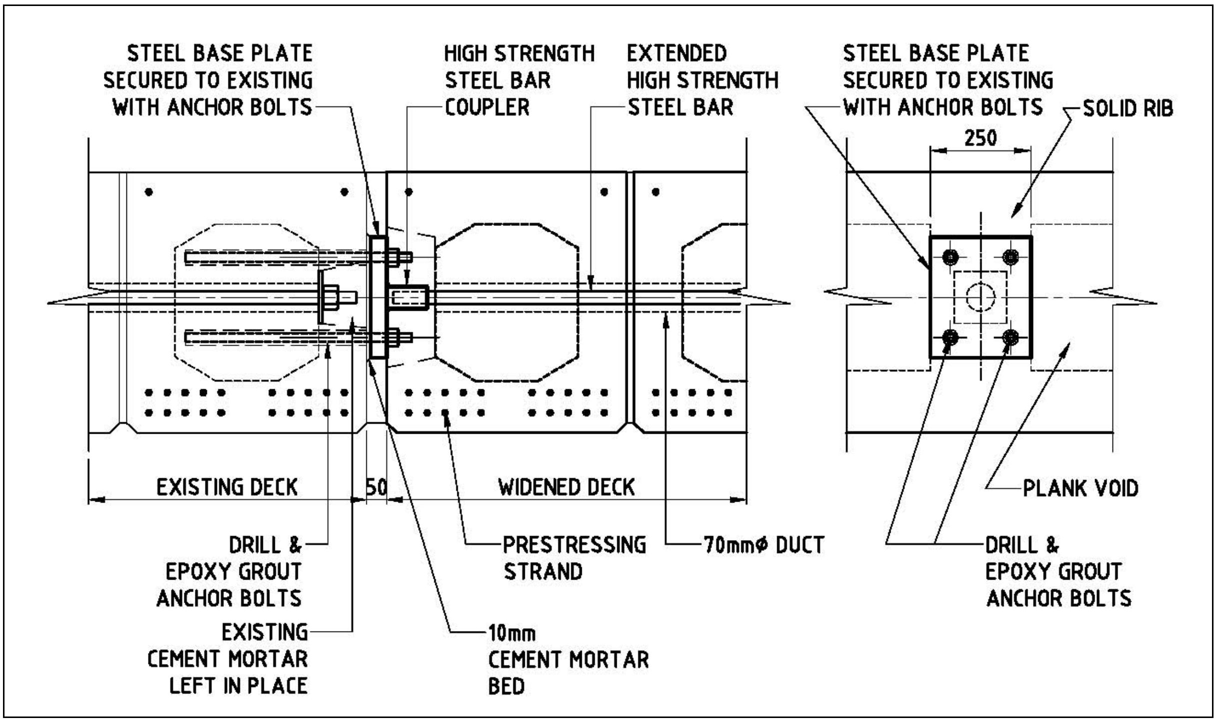


b) Bridge Widening Concept

Figure 11.7-1 Typical Cross-Sections of Widened Bridge for Full 4-Lane

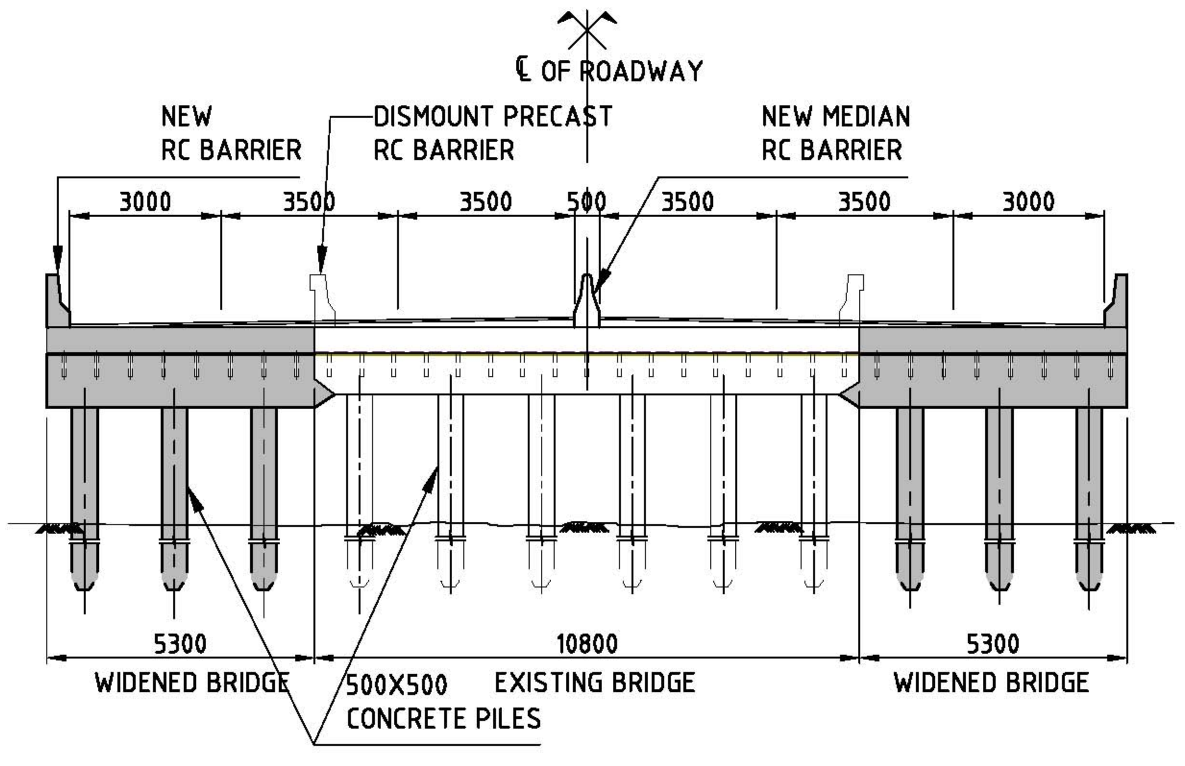


a) OPTION 1 Transverse pre-stress extended with couplers

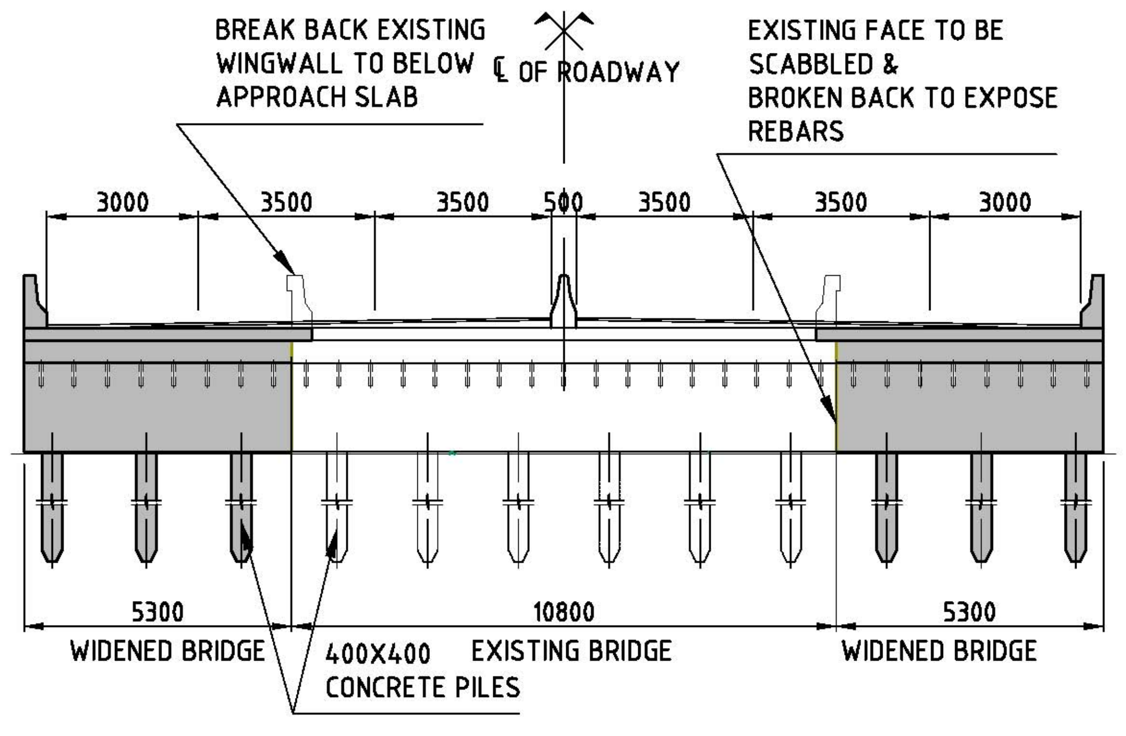


b) OPTION 2 Transverse pre-stress extended with additional base plate anchorage

Figure 11.7-2 Deck Widening Connection Details for Full 4-Lane



a) Pier Widening



b) Abutment Widening

Figure 11.7-3 Typical Cross-Sections of Substructure Widening for Full 4-Lane

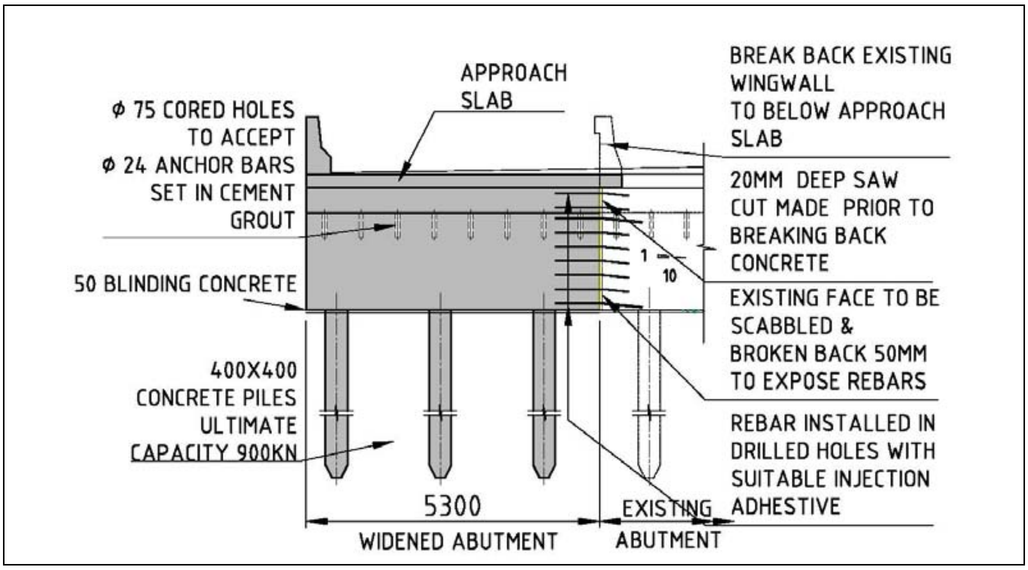


Figure 11.7-4 Abutment Widening Connection Detail for Full 4-Lane

11.8 Additional/Replacement Bridges Required for 4-Lane Road

In accordance with the bridge rehabilitation plan (Section 12.5) the preliminary design of the additional/replacement bridges proposed on the North Section of NR 5 for a 4-Lane Road is presented in Table 11.8-1.

Refer to Figure 11.8-1 for a typical cross-section showing layout of the additional bridge.

The bridge deck types for the additional bridges will be selected from the standard bridge types presented in Section 11.2. Both bridge deck type and substructure layout will be selected to be consistent with the existing bridge construction wherever possible. Bridge length typically will be established based upon the topography and waterway configuration at the locations adjacent to the existing bridges. Given the terrain the additional bridge length will typically be the same as the existing adjacent bridge. In some cases, such as at Br. 89, bridge length will be increased to avoid problems with slope stability at the abutments.

Table 11.8-1 Preliminary Design of Additional/Replacement Bridges on NR 5 - Full 4-Lane Design

1	2	3	4	5	6	7	8
Ref	**Code**	**KP**	**Type**	**Number of Spans**	**Length**	**Span Length**	**Width**
		(km)			(m)	(m)	(m)
1	Br. 79	303.4	PCDG	1	30.0	30.0	10.0
2	Br. 82	312.1	PCDG	1	25.5	25.5	10.0
3	Br. 84	341.1	RCBC	1	5.0	2 x 2.5	Width to suit 4 lane road
4*	Br. 89	351.5	PSC	3	50.0	15 - 20 – 15	10.0
6*	Br. 91	357.2	PSC	1	20.0	20.0	2 x 10.0

**) These bridges are not included in the improvement project of NR 5 (See Chapter 12).*

Note:

PSC – precast pre-tensioned concrete plank deck
PCDG – pre-stressed concrete deck girder'
RCBC – reinforced concrete box culvert

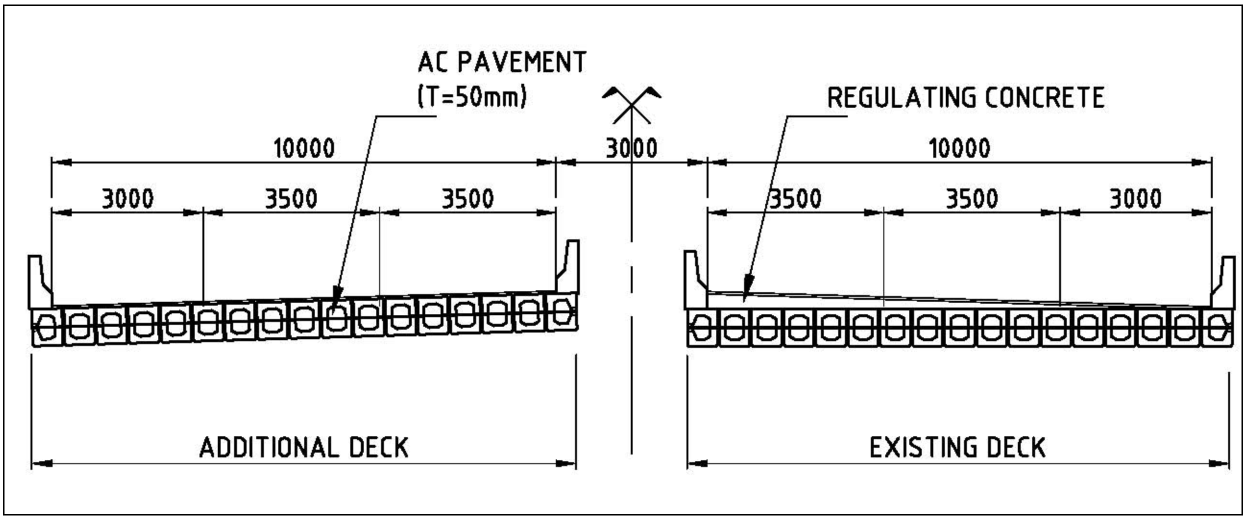


Figure 11.8-1 Typical Cross-Sections of Additional Bridge Deck for Full 4-Lane

11.8.1 Preliminary Design of Substructure

Bridge substructure layout has been selected to be consistent with the existing bridge construction and adopting standard arrangements wherever possible.

Additional bridges, new bridges or replacement bridges will feature standard stub or cantilever type abutments, and standard column type piers.

For all bridges, standard driven precast concrete driven piles are typically proposed, adopting the standard 40 cm x 40 cm section for abutments and pier pile caps, and 50 cm x 50 cm section for pier pile bents.

Pile lengths for each bridge location have been established based upon the geotechnical investigation undertaken for this study and with reference to CAM PW 04-101-99 Bridge Design Code.

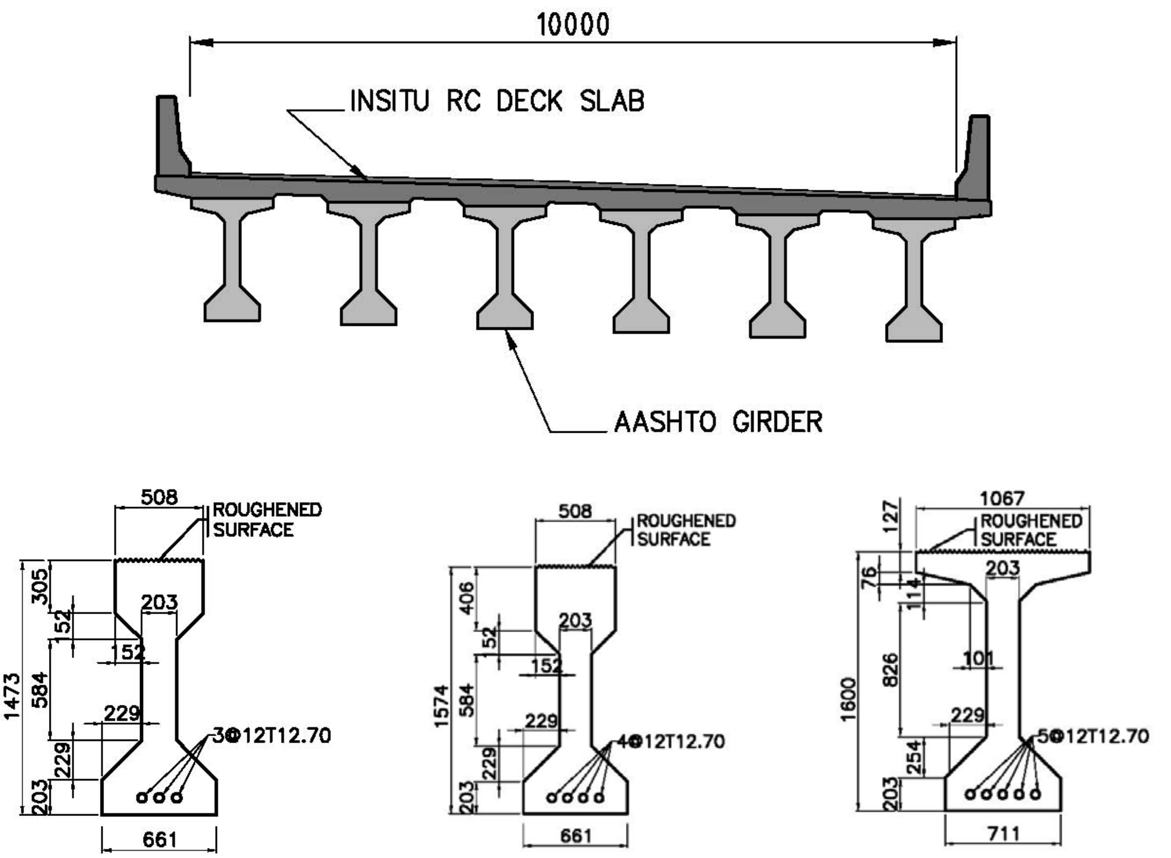
Numbers of piles at each bridge location have been determined based on calculations of design dead load and live load reactions. Calculations of design load reactions have been made with reference to CAM PW 04-101-99 Bridge Design Code.

11.8.2 Preliminary Design of Superstructure

The replacement bridge proposed for Br. 89, the additional bridge at Br. 91 on NR 5 and one (1) bridge on the proposed Battambang Bypass, Br. BB1, feature standard PSC decks.

Three (3) bridges on National Road No. 5 and one (1) bridge on the proposed Battambang Bypass, Br. BB2, are proposed to feature pre-stressed concrete deck girder (PCDG) bridges. The girder selected for these bridges is the AASHTO standard girder type. Refer to Figure 11.11-2 for the arrangement of typical AASHTO girder sections. Six (6) girders are proposed for each 10 m wide deck to be consistent with the standard set under the ongoing Strengthening of Construction Quality Project.

Outline checks have been undertaken to confirm that the girders can support HLP 240 loading, with limits on tensile stress for pre-stressed concrete taken from CAM PW 04-101-99 Bridge Design Code 1996 (the Base Document).



AASHTO Type 4A
Span Length 25m

AASHTO Type 4B
Span Length 30m

AASHTO Type 5
Span Length 35m

Figure 11.8-2 Typical AASHTO Girder Deck and Sections

AASHTO type girders have been selected given that they incorporate a reinforced concrete deck slab that can be made continuous for live load at pier supports. The girders are designed as simply supported for dead and live load, and the slab is designed to be continuous across the pier. This arrangement has already been incorporated into bridges in Cambodia, specifically at Thuok Thla Bridge on National Road 5, located just west of Banteay Meanchey. The advantage of this arrangement is that it eliminates expansion joints and bearings at the piers effectively making the bridge "maintenance free" at these locations. Additionally the monolithic arrangement provides a very robust connection between the deck and the pier head to resist applied longitudinal and transverse forces and also the deck slab continuity promotes a smooth ride profile over the pier for passing traffic.

A typical; arrangement of AASHTO girders made continuous at piers is illustrated in Figure 11.8-3.

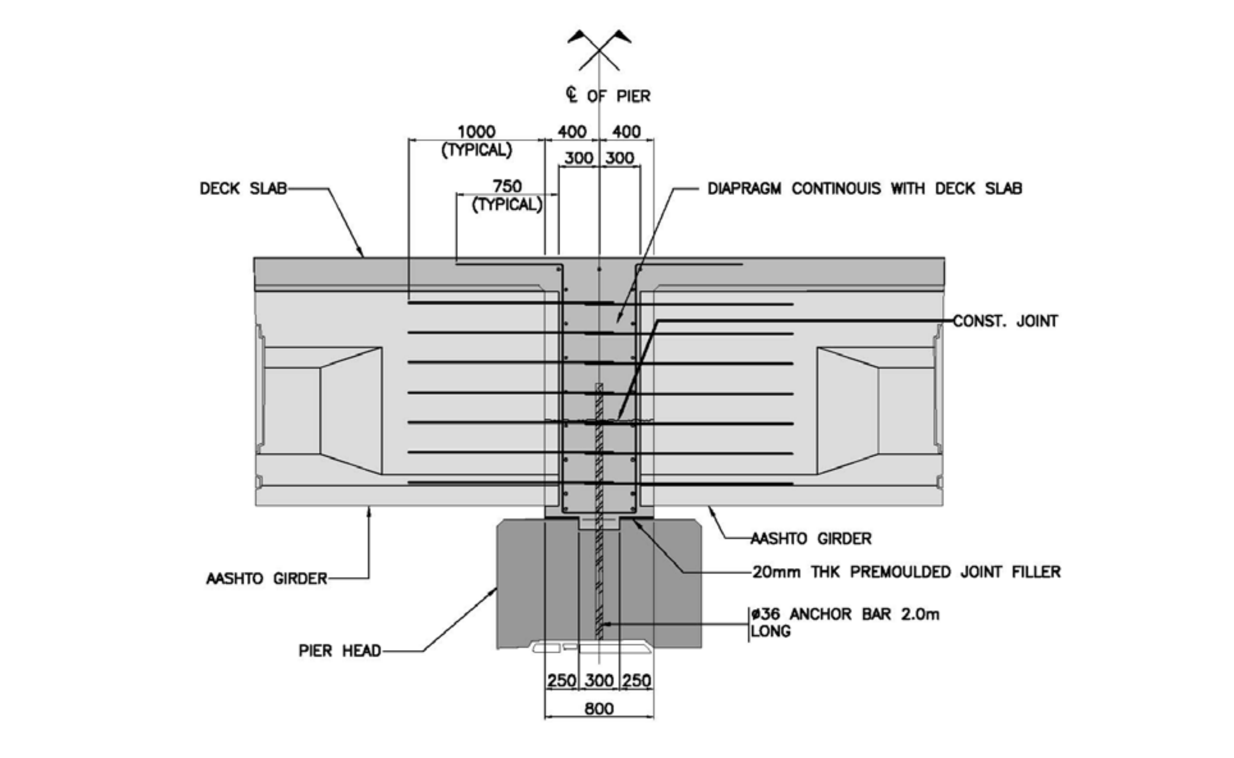


Figure 11.8-3 AASHTO Girder Made Continuous

11.9 Planning of Bridges on Battambang Bypass

An opposed 2-Lane Road with 2.5 m wide motorcycle lanes, requiring a 14m wide bridge deck, is proposed for Battambang Bypass. Two bridges are proposed to be constructed at km 2+020 and km 7+550 (Sangkae River) respectively.

The warrant for a bridge at km 2+020 is based on the reports of flood flow in the channel at this location from local inhabitants obtained during site inspections of the Study Team in November 2011. According to residents flood waters rises more than 2 m in the channel crossed by the bypass alignment. Based on the topographic survey a 20 m long bridge is considered sufficient to span the channel, although final bridge length will have to be determined based on a detailed hydrological/ hydraulic analysis.

The proposed bridge at km 7+550 will cross the Sangkae River. Based on the topographic survey and reports from local residents with regard to maximum flood level, a 105 m long bridge is considered sufficient to span the river, although final bridge length will have to be determined based on a detailed hydrological/ hydraulic analysis. It is also noted that local access roads run parallel with the river at each bank. These access roads can either be raised to connect with the new bypass road level or can aligned to pass beneath the bridge deck at each location, with sufficient headroom provided for the local traffic.

The preliminary design of bridges proposed for Battambang Bypass is presented in Table 11.9-1.

Table 11.9-1 Preliminary Design of Bridges on Battambang Bypass

1	2	3	4	5	6	7	8
Ref	**Code**	**KP**	**Type**	**Number of Spans**	**Length**	**Span Length**	**Width**
		(km)			(m)	(m)	(m)
1	Br. BB1	2.02	PSC	1	20.0	20.0	14.0
2	Br. BB2	7.55	PCDG	3	105.0	3 x 35.0	14.0

Note:
PSC – precast pre-tensioned concrete plank deck
PCDG – pre-stressed concrete deck girder'

11.9.1 Proposed Bridge over Sangkae River on Battambang Bypass

The proposed Battambang Bypass crosses the Sangkae River at km 7+550. The headwaters of the Sangkae River rise in the Cardamom Mountains in Pursat Province to the south west and the river flows north east into the Tonle Sap Lake passing through Battambang City.

At the time of the survey undertaken by the Study Team the river was approximately 50m wide at the crossing point with a maximum depth of 6m. According to accounts from local residents the river rises a further 5 m when it is in flood with a width in the order of 100 m and a depth of 11 m.

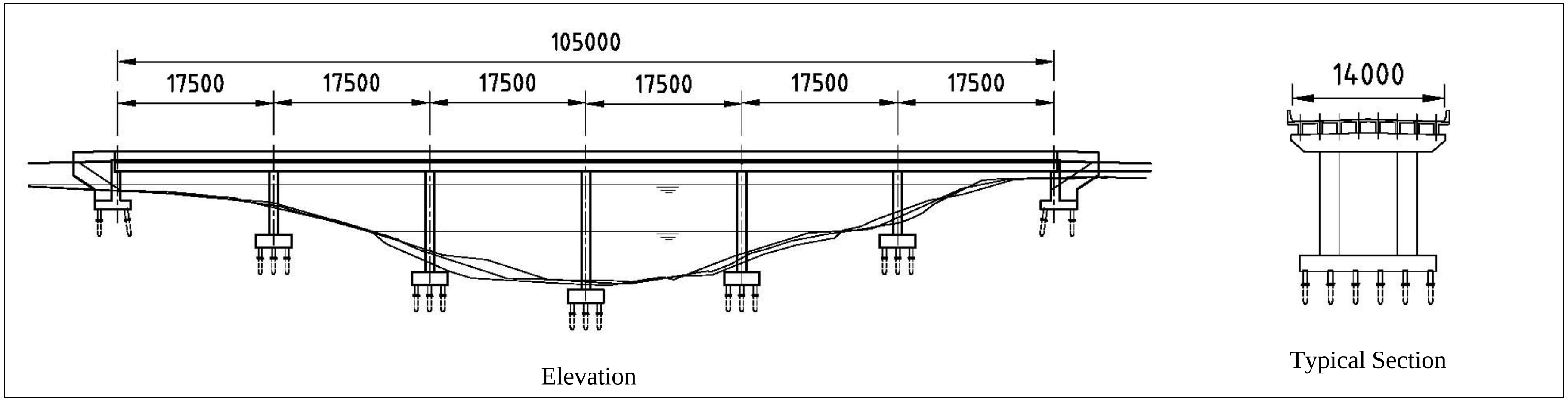
It is proposed to construct a bridge in the order of 105 m long at the crossing of the Sangkae River. Two alternative configurations for the bridge have been studied, namely a six span RCDG structure and a three span PCDG alternative. The RCDG structure is similar to Wat Kor. bridge constructed by MPWT in 2008 over the Sangkae River in Battambang City, a five span RCDG bridge with a total length of 90 m. Refer to Table 11.9-2 for an outline comparative study of the two alternatives and Figure 11.9-1 for typical elevations and sections.

Table 11.9-2 Comparative Study of Alternatives for Sangkae River Bridge

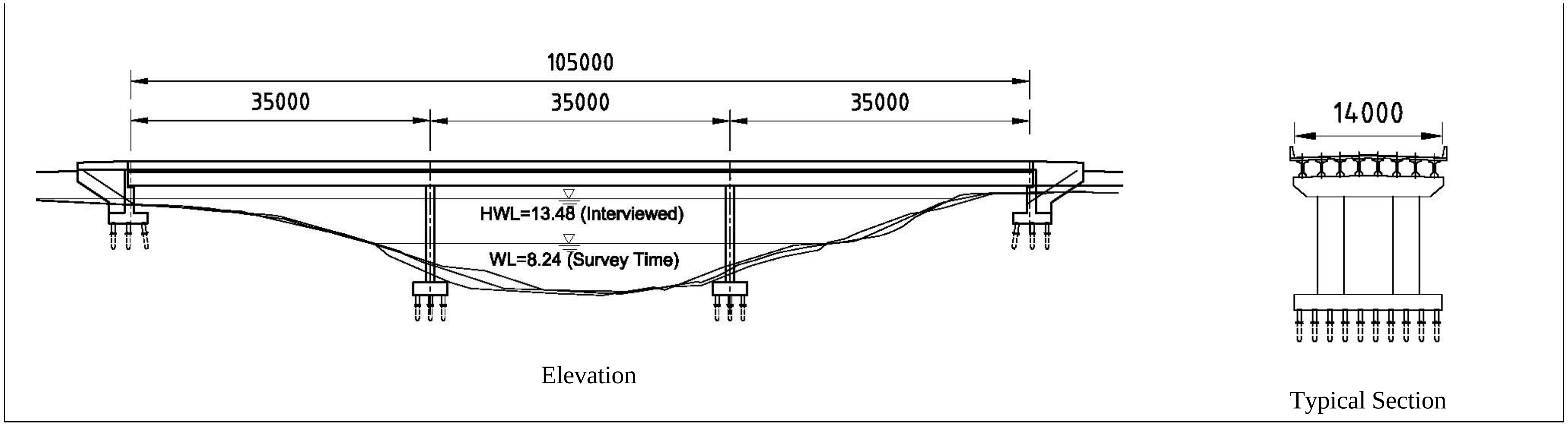
1	2	3	4	5	6
Bridge Type	**Total Length** (m)	**No. of Spans**	**Advantages**	**Disadvantages**	**Comment**
RCDG	105	6	• Simplest form of construction • Precast RC girders weigh only about 17t and can be lifted in using single small capacity cranes, without the need for launching gantries, working progressively from the river banks. • Least impact on the road profile	• Largest number of substructures to be constructed including three (3) piers required to be constructed in the river waterway • Scour hazard is greater than for the PCDG alternative • River channel is obstructed with a centrally placed pier • Longer construction period • Foundation costs are greater than for the PCDG alternative	2nd Rank
PCDG	105	3	• Only two (2) piers required in the river waterway • River channel is substantially unobstructed • Shorter construction period • Foundations pose a lower scour hazard than the RCDG alternative • Girders provide greater support during construction to the in-situ concrete deck, requiring simpler formwork than the RCDG alternative	• Girders weigh about 60t and will require a launching gantry to put in place • Greatest depth of deck • Maximum impact on road profile • Superstructure costs are greater than for the RCDG alternative	1st Rank

Note:

Bridge Type:
RCDG – Reinforced Concrete Deck Girder
PCDG – Pre-stressed Concrete Deck Girder



a) **6-Span RCDG Alternative**



b) **3-Span PCDG Alternative**

Figure 11.9-1 Elevations and Sections on Sangkae River Bridge

Alternative bridge pier configurations for the proposed Sangkae River Bridge have been briefly investigated:

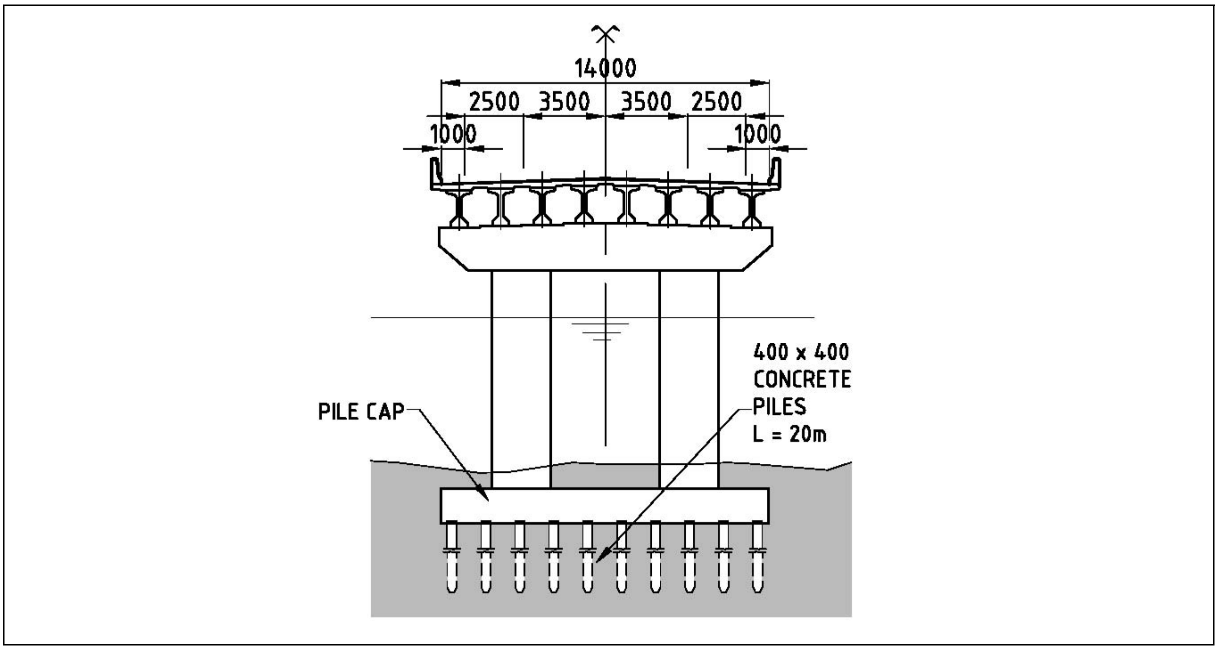
- Conventional pile cap supporting pier columns and coping beam
- Bored pile bent directly supporting a coping beam

Refer to Table 11.9-3 for an outline comparative study of the two pier design alternatives and Figure 11.9-2 for typical sections.

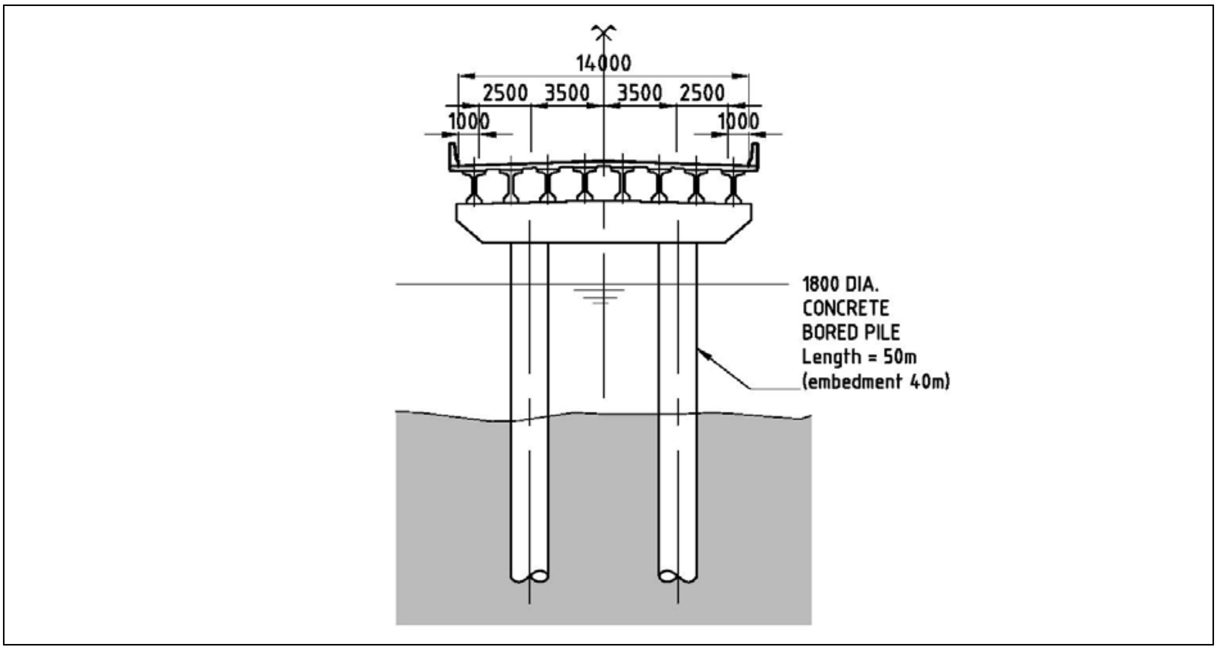
Local access roads run parallel to both of the river banks at the crossing location. Alternative arrangements should be considered in the detailed design in accommodating the access roads, either in allowing the roads to pass beneath the bridge or ramping up the side access to join the local roads to the bypass.

Table 11.9-3 Comparative Study of Alternatives Pier Designs for Sangkae River Bridge

1	4	5	6
Pier Type	**Advantages**	**Disadvantages**	**Comment**
Pile Cap	• Method recently adopted for Wat Kor bridge across Sangkae River • Precast driven RC piles can be used to maximize construction quality and minimize construction risk • Relatively short pile lengths required (approx. 20 m) • Regular construction equipment and methods can be adopted • Very robust in supporting bridge loads and in resisting lateral forces • Pile cap and multiple pile arrangement can tolerate a degree of scouring of the mud-line below the cap without overloading the piles	• Pile caps require cofferdams for construction • Large number of relatively small capacity piles to install • Pile cap construction requires longer construction period than pile bent • Scour hazard is greater than for the pile bent alternative	1st Rank
Bored Pile Bent	• No pile caps required thereby dispensing with need for cofferdams • Shorter construction period • Foundations pose a lower scour hazard than the pile cap alternative	• Larger capacity construction equipment required for the large diameter bored piles • Specialist construction techniques required using bentonite slurry/ reverse circulation methods/ and temporary steel casings that are sensitive to soil conditions and involve more construction risk • Greater environmental hazard during construction particularly with spillage of drilling slurry • Relatively long pile lengths required (approx.. 40 m embedment) • Structure configuration less robust in supporting lateral loads with greater sensitivity to depth of scour	2nd Rank



a) Pile Cap Type Pier



b) Pile Bent Type Pier

Figure 11.9-2 Typical AASHTO Girder Deck and Pier Sections

11.10 Planning of Bridges on Sri Sophorn Bypass

An opposed 2-Lane Road with 1.5 m wide motorcycle lanes, requiring 14 m wide bridge decks, is proposed for Sri Sophorn Bypass. Two bridges are proposed to be constructed at km 4+620 (Mongkol Borei) and km 12+700 (Steung Touch) respectively. The bypass traverses rivers at both locations that require bridge crossings.

The proposed Mongkol Borei bridge at km 4+620 is located approximately 4.3 km upstream of Br. 89 on National Road 5. Br. 89 is a 3 span PSC bridge of total length 44 m. The proposed bridge is also located approximately 300 m upstream of an existing bridge with a total length of about 30 m.

The proposed Steung Touch bridge is located on a tributary to the Sri Sophorn River approximately 670 m from the northern connection point of Sri Sophorn Bypass to National Road 5.

The preliminary design of bridges proposed for Sri Sophorn Bypass is presented in Table 11.10-1. Bridge length and bridge spanning considerations have been driven primarily by topographic considerations with abutments located at set back positions on the river banks. The widespread flood water break out at each location will be addressed with additional flood relief culverts to be constructed at regular intervals along the alignment.

Standard precast concrete driven piles, 40 cm x 40 cm section, are proposed at all foundation locations, with length of 20 m.

Table 11.10-1 Preliminary Design of Bridges on Sri Sophorn Bypass

1	2	3	4	5	6	7	8
Ref	**Code**	**KP** (km)	**Type**	**Number of Spans**	**Length** (m)	**Span Length** (m)	**Width** (m)
1	Br. SP1	4.62	PSC	3	50.0	15-20-15	14.0
2	Br. SP2	12.70	PSC	3	60.0	3 x 20.0	14.0

Note : PSC – precast pre-tensioned concrete plank deck