3.3 Bridge Design

3.3.1 Existing Bridge Conditions

The candidate bridges for Urgent Bridge Rehabilitation in the southeast block region are shown in **Figure 3.3.1**. Among these bridges, eight (8) bridges are selected for urgent bridge rehabilitation based on its poor to very poor condition. Four (4) of the proposed bridges for rehabilitation (located at NR.3, NR.7 and NR.33) are bailey bridges with either steel or timber decks. These bridges are all placed on top of old collapsed bridges so that the abutment and pier supports are mostly old substructures in poor to very poor condition.

The other four (4) bridges are located in national road NR.11 which are old Steel I-Girder bridges with timber decks. The steel I-girders are mostly corroded girders while the timber decks are mostly damaged and in very poor condition. These bridges are supported by old timber post bent piers which are in very poor conditions. The bridge in Km103+475 (NR.11) has one of the piers titling to one side due to settlement.

A summary of the bridge conditions for urgent rehabilitation is shown in **Table 3.3.1**.

Table 3.3.1 Selected Bridges for Urgent Rehabilitation

No.	Road No.	Province	Station	Bridge Description					Load Limit Posting (tons)	Overall Condition	2005 Traffic (pcu)	Remarks
				Type	Length (m)	Carriage-way Width (m)	Superstructure	Substructure				
1	3	Kandal	25 + 927	Bailey Bridge	37.0	4.5	1-span bailey bridge with steel deck	Old concrete abutment	15	Poor	3,525	Original concrete bridge washed-out by flood. Bailey bridge resting in old bridge abutment
2	3	Kampot	105 + 985	Bailey Bridge	48.0	4.2	4-span bailey bridge with steel deck	Old concrete abutment and piers	15	Poor	3,098	Bailey bridge is sitting on top of old substructures of collapsed bridge
3	7	Kratie	277 + 200	Bailey Bridge	130.0	4.5	6-span bailey bridge with timber deck	Old cocrete abutment and wall piers	15	Poor	1,076	Old bridge is concrete girder with collapsed 5th span due to overloading. The existing bailey bridge is placed on top of the old concrete superstructure
4	11	Prey Veng	84 + 900	Steel I-Girder	42.2	5.4	3-span steel I-girder bridge with timber deck	Old timber posts	15	Very Poor	1,153	Timber decks and posts for pier bents are in very poor condition
5	11	Prey Veng	88 + 094	Steel I-Girder	84.2	5.4	6-span steel I-girder bridge with timber deck	Old timber posts	15	Very Poor	826	Timber decks and posts for pier bents are in very poor condition
6	11	Prey Veng	89 + 060	Steel I-Girder	54.0	4.9	5-span steel I-girder bridge with timber deck	Old timber posts + concrete wall piers	15	Very Poor	826	Timber decks and posts for pier bents are in very poor condition
7	11	Prey Veng	103 + 475	Steel I-Girder	48.0	4.9	4-span steel I-girder bridge with timber deck	Old timber posts	15	Very Poor	826	Timber decks and posts for pier bents are in very poor condition. One of the piers is tilting and settled on one side.
8	33	Kampot	36 + 540	Bailey Bridge	30.0	4.2	1-span bailey bridge with steel deck	Old concrete abutment	5	Very Poor	419	Bridge is old and has only 5 tons capacity

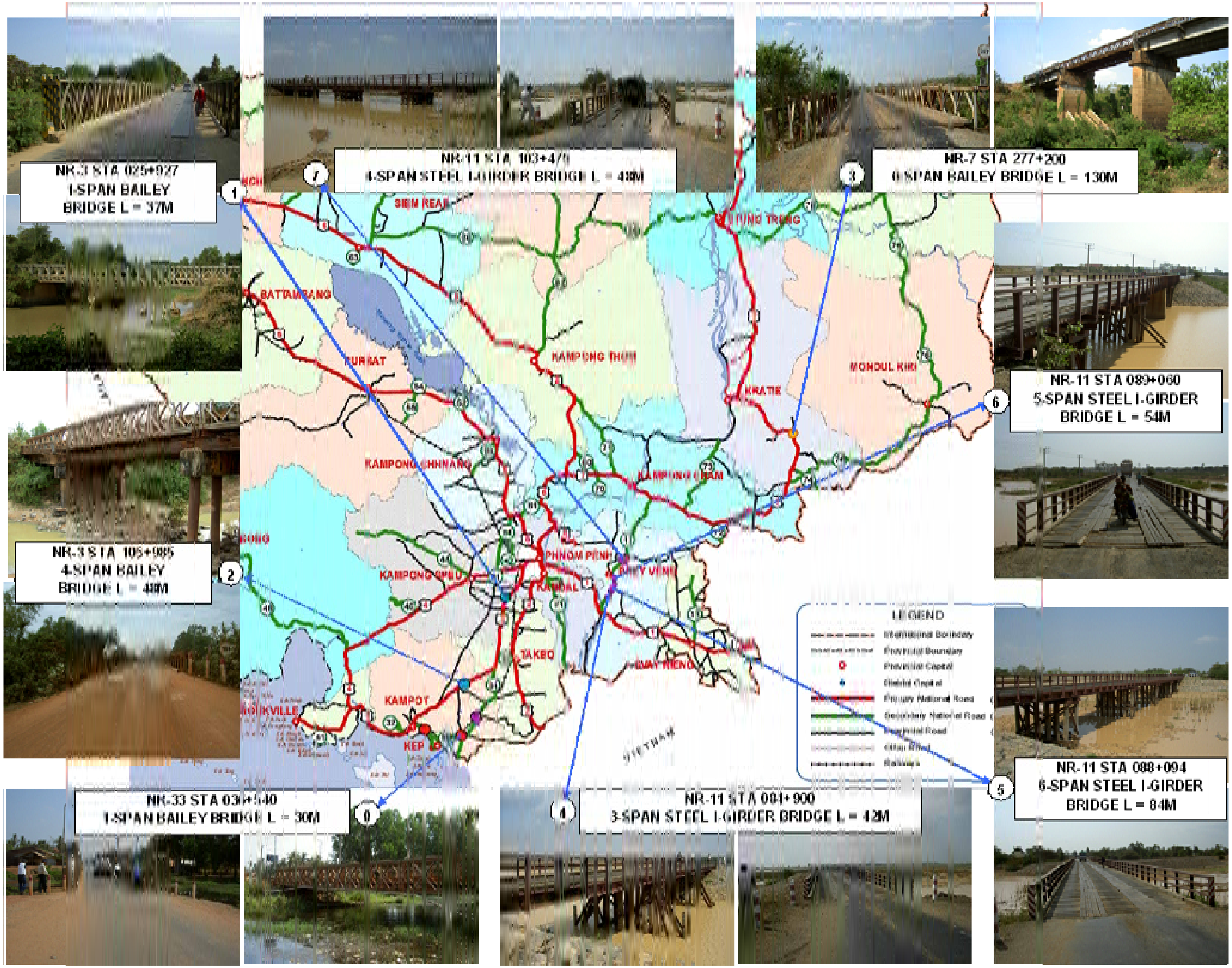


Figure 3.3.1 Candidate Bridges for Urgent Bridge Rehabilitation

1. NR.3 Km 25+927

2. NR.3 Km105+985

3. NR.7 Km 277+200

4. NR.11 Km 84+900

5. NR.11 Km 88+094

6. NR.11 Km 89+060

7. NR.11 Km 103+475

8. NR.33 Km 36+540

Photo 3.3.1 Selected Bridges and Typical Bridge Defects

The typical bridge defects as summarized in **Table 3.3.1** and illustrated in **Photo 3.3.1** includes:

- Bailey bridges supported by old piers and abutments of collapsed bridges – the integrity and structural capacity of these substructures are questionable,
- Steel I-Girder bridges are supported by timber post/pile bent piers – these piers are in very poor condition whose structural integrity is also questionable,
- Timber decks of I-Girder bridges are badly damaged and deteriorated,
- Steel decks of bailey bridges are deformed and needs proper fixing,
- Steel I-Girders are all corroded, and
- Seven bridges are posted with 15 tons load limit while one bridge is posted with 5 tons load limit – these bridges are not capable of supporting the live loading stipulated in the Cambodian Bridge Design Standard.

3.3.2 Hydrologic Analysis and River Hydraulic

The hydrological analysis was conducted mainly to derive design flood discharge at each bridge's site. To estimate the magnitude of the design flood discharge, rational method is adopted in this study.

Table 3.3.2 presents the hydraulic design data calculated for the proposed bridges.

Table 3.3.2 Hydraulic Design Data for Urgent Rehabilitation Bridges

Road No.	Bridge			Catchment Area (km^2)	Design Flood Discharge (m^3/s)	Approaching Velocity (m/s)	Design Flood Level (Elev. m)	Recommended Waterway Opening Width W_S (m)
	No.	Station (km+m)	Location					
NR.3	1	025+927	Kandal	114.6	284	3.05	12.74	53.93
NR.3	2	105+985	Kampot	256.8	238	3.2	27.50	49.37
NR.7	3	277+200	Kratie	1,000.0	1,775	3.17	58.41	134.82
NR.11	4	084+900	Prey Veng	64.2	150	1.84	7.50	39.19
NR.11	5	088+094		237.9	573	2.26	8.77	76.62
NR.11	6	089+060		184.6	454	2.84	8.15	68.15
NR.11	7	103+475		74.8	177	1.93	8.20	42.55
NR.33	8	036+540	Kampot	176.5	62	1.88	1.81	25.20

Note : 1) Based on Road Design Standard, Part 3. Drainage, CAM PW.03.103.99

2) Estimated by HEC-HMS method (C.A. > 25 km2) and verified by flood mark.

3) $W_s = CQ^{1/2}$ where C = 3.2 and Q = Design Flood Discharge (m^3/s)

3.3.3 Policy on Selection of Bridge Type

In this study, the most appropriate bridge type is selected by evaluating the various factors in bridge planning including economy, durability, vertical alignment, environmental impacts, constructability and maintainability. These factors are evaluated as follows:

- Economy : Bridge should be constructed at low cost to be cost effective. Concrete bridge structures tend to be more economical than steel structures and entails minimal maintenance cost. Concrete bridges are thus recommended for Urgent Bridge Rehabilitation.
- Durability : Bridge type should be durable to withstand contemplated design loads based on the Cambodian Bridge Design Standard. Moreover, proper type of revetment and river bed protection should be selected based on durability.
- Vertical Alignment : The bridge design profile shall be decided based on the minimum clearance for the design flood water level. However, since bridges to be constructed are located along existing road alignment, adjustment on the existing road/bridge profile should be optimized as much as possible to minimize impact to roadside structures and adjustments to approach road.
- Environmental Impacts : Impacts to environment including surrounding communities (houses, traffic, pedestrians, etc.) should be minimized by selecting the proper bridge type and technology.
- Constructability : Bridge selection should consider ease and safe construction based on available technology. Bridges located on the same alignment or near each other shall have similar structure type to minimize variation in construction requirements and methodology.
- Maintainability : The choice of material and structural elements should consider minimal maintenance requirements at low cost. Since maintenance entails cost, it is recommended to use the bridge form that will require the least maintenance – that is, concrete structure are preferred over steel structures.

(1) Substructure Types

The choice of substructure depends on the type of foundation support at site, the scale of bridge, the cost of construction and the available technology. Since most of the bridges are in rural areas, impact to environment for foundation choice is minimal. **Table 3.3.3** presents some of the typical foundation choices for the bridges.

Table 3.3.3 Foundation Choices for Bridges

	TYPE	BEARING LAYER DEPTH (m) (0 – 100)	APPLICABLE DIAMETER (m)	APPLICABLE SPANS (m) < 20	20-50	> 50	APPLICATION / ADVANTAGE
F - 1	SPREAD FOUNDATION	0, 5, 10	-	●	●	●	FOR BEARING LAYER DEPTH < 5.0M; CAN SUPPORT LARGE VERTICAL AND HORIZONTAL LOAD CAPACITY; GOOD FOR ROCKS, COHESIVE SOIL WITH N>20 OR COHESIONLESS SOIL WITH N>30
F - 2	RC DRIVEN PILE	5, 15, 25	0.3 - 0.5	●	▲	×	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 25M; GOOD FOR SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; CAN SUPPORT SMALL VERTICAL LOAD
F - 3	PC DRIVEN PILE	5, 40, 60	0.35 - 0.5	●	●	▲	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 40M; GOOD FOR SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; ORDINARY VERTICAL LOAD CAPACITY;
F - 4	STEEL H DRIVEN PILE	5, 40, 60		●	●	▲	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 40M; APPLICABLE FOR SOFT AND HARD INTERMEDIATE LAYERS; SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; LARGE VERTICAL LOAD CAPACITY; EASY TO HANDLE DUE TO LIGHTER WEIGHT
F - 5	STEEL PIPE DRIVEN PILE	5, 60	0.5 - 0.8	▲	●	●	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 60M; APPLICABLE FOR SOFT AND HARD INTERMEDIATE LAYERS; SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; LARGE VERTICAL LOAD CAPACITY; LARGER CAPACITY TO HORIZONTAL LOADS
F - 6	CAST-IN-PLACE PILE (ALL CASING METHOD)	5, 40, 60	1.0 - 1.2	▲	●	●	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 40M; GOOD FOR SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; LARGE VERTICAL & HORIZONTAL LOAD CAPACITY; GOOD FOR AREAS WITH DIFFICULTY IN STABILIZNG EXCAVATION OR SOIL LAYERS WITH FISSURES.
F - 7	CAST-IN-PLACE PILE (EARTH AUGER METHOD)	5, 25, 40	1.0 - 1.5	▲	●	▲	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 40M; GOOD FOR SOIL SUSCEPTIBLE TO LIQUEFACTION; ORDINARY VERTICAL & HORIZONTAL LOAD CAPACITY; LESS NOISE DURING CONSTRUCTION.
F - 8	CAST-IN-PLACE PILE (REVERSE CIRCULATION DRILL METHOD)	5, 15, 60	1.0 - 1.5	▲	●	●	FOR VERY SOFT SOIL WITH BEARING LAYER UNTIL 60M OR MORE; GOOD FOR SOIL SUSCEPTIBLE TO LIQUEFACTION; GROUND WATER NEAR SURFACE; LESS NOISE DURING CONSTRUCTION.

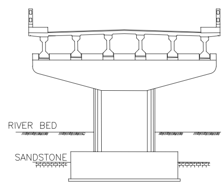
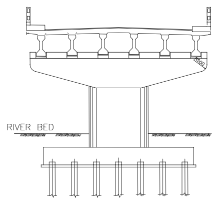
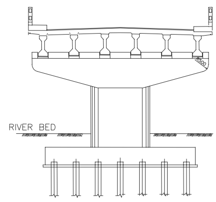
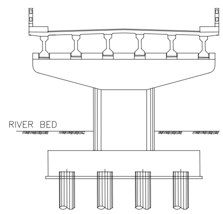
● HIGHLY APPLICABLE ▲ APPLICABLE × LESS APPLICABLE

In Cambodia, the typical foundation types for recently constructed bridges include RC or PC Driven Piles and Cast-In-Place Piles (or commonly known as bored piles). Concrete pile foundation is preferred over steel piles (H-piles of steel pipe piles) for economic consideration. In this case, for the Urgent Bridge Rehabilitation bridges, the choices for foundation type include (see comparison **Table 3.3.4**):

- Spread Foundation – for foundation on sandstone layer (depth < 5m),
- RC Driven Pile – for soft upper soil layers until 20m deep
- RC Cast-in-Place Pile – for soft upper layers deeper than 20m

The above choice is based on cost and past bridge construction experience in Cambodia. Since most bridges are in rural areas, noise produced during pile driving will not be a problem. Although RC and PC Driven piles are still applicable for longer piles (>20m), the difficulty lies in fabricating longer piles that need to be transported or lifted in place prior to driving. Moreover, splicing longer driven piles requires strict quality control. RC Cast-in-place piles are thus proposed for bearing layers deeper than 20m. This pile type is becoming widely used in Cambodia in recent bridge projects.

Table 3.3.4 Comparison of Foundation Types

Items	Pier on Spread Footing	Pier on RC Driven Piles	Pier on Steel H-Piles	Pier on RC Cast-in-Place Piles
Section		 RC Driven Piles	 Steel H Driven Piles	
Applicability	• Applicable to bearing layer less than 5m deep • Used for bearing type not susceptible to scour action	• Used for soft upper layer • Applicable to deep bearing layer • Most common type used in Cambodia • Stable to scour action	• Used for soft upper layer • Applicable to deeper bearing layer than RC driven piles • Stable to scour action	• Used for soft upper layer • Applicable to deeper bearing layer than driven piles • Becoming popular type used in Cambodia • Stable to scour action
Constructability	• Easiest construction • Need to embed footing to sandstone layer for stability	• Need crane for handling piles and for pile driving • Difficult to drive on hard intermediate layer • Difficult to handle long piles (>20m) – transportation and driving	• Need crane for handling piles and for pile driving; handling is easier than RC piles • Applicable to hard intermediate layer • Difficult to handle long piles (>20m) – transportation and driving	• Need facilities for drilling and rebar fabrication • Careful quality control required • Applicable for longer pile lengths (>20m) since piles are drilled and cast-in-place
Construction Period	• Shortest construction period	• Construction period is 90% of RC cast-in-place pile period	• Construction period is 90% of RC cast-in-place pile period	• Construction period is longer than other types
Cost	• Cheapest construction cost	• Construction cost is 70% of RC cast-in-place pile cost	• Construction cost is 120% of RC cast-in-place pile cost	• Construction cost is more expensive than other types
Environmental Impact	• Minimal environmental impact; care should be taken during excavation	• Noise and vibration produced during driving • Not recommended on urban areas	• Noise and vibration produced during driving • Not recommended on urban areas	• Requires proper measure for prevention of water pollution and disposal of waste materials
Evaluation	RECOMMENDED FOR SHALLOW HARD BEARING LAYER	RECOMMENDED FOR PILE LENGTHS LESS THAN 20M	NOT RECOMMENDED DUE TO HIGH COST	RECOMMENDED FOR PILE LENGTH GREATER THAN 20M

For RC Deck Girder or PC I-Girder Bridges with multiple spans, the pier type recommended is column type pier with thinner wall dimensions to minimize river obstruction. Moreover, since water level during ordinary time in most bridge locations are minimal (or practically none), the top of pier foundation (footing or pile cap) shall be located at least 1.0m below the river bed. Gabion mattress shall be provided to minimize local scouring on river bed.

For RC Slab Bridges with multiple spans, wall pier monolithic with superstructure is recommended since the slab bridge spans are typically shorter and requires no bearing supports.

(2) Superstructure Types

The choice of superstructure for the Urgent Bridge Rehabilitation depends on the scale of the bridge (bridge length, bridge spans, etc.) which is based on the existing topography, river discharge and maximum flood level. **Table 3.3.5** presents some of the common forms of superstructure applicable to the range of bridges in this study.

In this study, concrete bridge is preferred over steel bridge basically because:

(1) concrete bridges requires minimal maintenance compared to steel bridges,

(2) steel bridges generally cost more than concrete bridges (see **Table 3.3.6**), and

(3) past experience in bridge construction in Cambodia is directed more to concrete bridges.

A comparative study of superstructure types for the bridges in “The Project for Rehabilitation of Bridges Along the Main Trunk Roads in Cambodia” (JICA, on-going construction) was undertaken comparing concrete alternatives with steel alternatives. The results of the alternative types study indicate that concrete bridges (precast, prestressed girder type) are more applicable and cost-effective than steel bridges as summarized in **Table 3.3.6**.

For bridge spans 12m or less, cast-in-place reinforced concrete slab bridge is preferred since:

(1) it requires less structure depth and advantageous in bridge sites where the existing road vertical profile has less room for adjustment,

(2) this type has the least cost at this span range, and

(3) since the bridge scale is small, simple construction methodology using cast-in-place concrete is applicable.

For bridge spans greater than 12m until 20m, cast-in-place reinforced concrete girder bridge is preferred since this is most cost-effective at this range.

For bridge spans greater than 20m, precast prestressed I-girder is preferred since:

(1) this is cost competitive at this span range, and

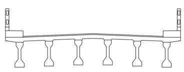
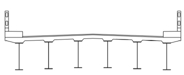
(2) construction period is shorter since the girders are precast and erected in place to support the cast-in-place deck slab.

Table 3.3.5 Typical Superstructure Choices for Bridges

TYPE	SPAN LENGTH (M) (0–70; SHORT SPAN / MEDIUM SPAN / LONG SPAN)	HEIGHT/ SPAN RATIO	CHARACTERISTICS: ADVANTAGES	CHARACTERISTICS: DISADVANTAGES
I. CONCRETE BRIDGE				
1. RC SLAB	5 – 15	1/20	SIMPLEST AND LEAST COST; CAN BE MADE CONTINUOUS WITH PIERS AND ABUTMENTS TO RESIST LATERAL LOADS; MINIMAL MAINTENANCE REQUIRED; NEAT AND SIMPLE IN APPEARANCE.	LIMITED TO SHORT SPAN RANGE; REQUIRES LONGER CONSTRUCTION TIME DUE TO FALSEWORK ASSEMBLY AND CONCRETING; DIFFICULT ON DEEP RIVERS AND HIGH PIERS
2. RC DECK GIRDER	10 – 20	1/15 - 1/18	ECONOMICAL FOR SPANS 10-20M; SUPERSTRUCTURE NORMALLY ON BEARING WITH PIERS; MINIMAL MAINTENANCE; NEAT AND SIMPLE IN APPEARANCE BUT MANY LINES ON UNDERSIDE.	ECONOMICAL UNTIL 20M RANGE; REQUIRES LONGER CONSTRUCTION TIME DUE TO FALSEWORK ASSEMBLY AND CONCRETING; DIFFICULT ON DEEP RIVERS AND HIGH PIERS; LESS AESTHETIC APPEARANCE THAN SLAB BRIDGES
3. PC I-BEAM . (AASHTO)	10 – 40	1/15 - 1/18	COMPETITIVE FOR SPANS 20-40M; GIRDERS ARE PRECAST, LIFTED IN PLACE AND DECK SLAB CAST-IN-PLACE; CONSTRUCTION PERIOD SHORTER THAN CAST-IN-PLACE TYPE; GIRDERS NORMALLY SIMPLE SPAN BUT CAN BE MADE CONTINUOUS WITH LIVE LOAD; MINIMAL MAINTENANCE;	REQUIRES SPACE FOR FABRICATION OF GIRDERS; TRANSPORTATION OF LONG SEGMENTS CAN BECOME A PROBLEM; REQUIRES CRANE FOR LIFTING PRECAST SEGMENTS; SIMPLE BUT LOOKS CLUTTERED ON UNDERSIDE DUE TO MANY LINES.
II. STEEL BRIDGE	SHORT SPAN / MEDIUM SPAN / LONG SPAN			
1. PLATE GIRDER (Composite/Non-composite)	6 – 65	1/17 - 1/22	WIDELY USED FOR SPANS UP TO 30M; STEEL GIRDER IS SIMPLY SUPPORTED BUT COMPOSITE WITH DECK SLAB; CONSTRUCTION IS FASTER THAN CAST-IN-PLACE CONCRETE; STRUCTURE IS LIGHTER THAN CONCRETE AND REQUIRES LESS SUBSTRUCTURE SUPPORT;	REQUIRES PAINTING MAINTENANCE - COST AND HAZARD NEED TO BE CONSIDERED; REQUIRES LIFTING AND TRANSPORTATION OF GIRDERS; CAREFUL QUALITY AND SAFETY CONTROL REQUIRED; MORE EXPENSIVE THAN CONCRETE; SIMILAR LOOKS WITH AASHTO GIRDER BUT MORE SLENDER.

NOTE : 1. RC is Reinforced Concrete, normally cast-in-place
2. PC is Prestressed Concrete, this can be cast-in-place or pre-cast

Table 3.3.6 Comparison Between Concrete Bridge and Steel Bridge

Superstructure Type	Cost Ratio*: Items	24m	34m	Construction Aspect	Maintenance	Evaluation
Prestressed Concrete Girder (PCDG) 	Superstructure Substructure Erection <u>Other works</u> Total	0.49 1.00 2.98 <u>1.06</u> **0.81**	0.55 0.80 3.95 <u>1.06</u> **0.85**	• Construction period is similar to steel plate girder • Construction requires heavy lifting if girders are precast • Superstructure can be cast on site by all staging method and post-tensioned; requires only medium-sized crane • Falsework should be planned carefully during rainy season	• Concrete bridge structures require minimum maintenance	• Advantageous in terms of total cost and requires minimal maintenance RECOMMENDED
Steel Plate Girder 	Superstructure Substructure Erection <u>Other works</u> Total	1.00 1.00 1.00 <u>1.00</u> **1.00**	1.20 0.80 1.00 <u>1.00</u> **1.08**	• Construction period is similar to PCDG • Construction is easier using medium-sized crane • Deck slab to be cast using suspended falsework • Requires prefabrication of steel girders and transportation to site • Area for storage of steel girders necessary and may affect traffic condition	• Steel girder requires regular inspection and maintenance • Use of atmospheric corrosion resistant steel minimizes steel maintenance but is more expensive	• More expensive than concrete bridge and requires maintenance NOT RECOMMENDED

Note: *Based on "The Project for Rehabilitation of Bridges Along the Main Trunk Roads in Cambodia" (JICA, on-going construction)

3.3.4 Bridge Planning

(1) Existing Bridge Location and River Condition

The bridges considered for Urgent Bridge Rehabilitation are part of the national roads NR.3, NR.7, NR.11 and NR.33. NR.3 and NR.33 roads were improved under the World Bank projects "Cambodia Road Rehabilitation Project (2001-2005)" and the "Flood Emergency Rehabilitation Project (2002-2004)" respectively. On the other hand, NR.7 and NR.11 were improved under the ADB projects "Primary Road Restoration Project (2000-2004)" and the "Emergency Flood Rehabilitation Project (2001-2004)" respectively. The bridges under consideration were part of these improved roads but were not improved due to financial constraints.

The locations of bridges are fixed by the existing road alignment and the condition of rivers or waterways. In all eight bridges, the bridge alignment follows the existing road alignment with bridges spanning the existing rivers or waterway opening. The rivers along NR.3, NR.33 and NR.7 are on stable locations and are not expected to migrate in the future. On the other hand, NR.11 is located in the flood plain of the Mekong river and bridges on these locations provide opening for flood discharges from the Mekong river side.

The condition of the rivers at the different bridge locations are summarized in **Table 3.3.7**.

Table 3.3.7 Existing Bridge River Condition

Bridge No.	Road No.	Station	Waterway	River Condition	Remarks
1	3	025+927	River	• The existing river opening is about 30m wide. • Flood level is about 2.02m below the deck level • River section is constricted by existing bridge. Upstream and downstream sections wider than bridge opening	• The original 2-span concrete bridge collapsed due to year 2000 flood • River section should be widened
2	3	105+985	River	• The existing river opening is about 46m wide. • Flood level is about 2.32m below the deck level • River is meandering • River section is obstructed in A2 side	• The original 4-span steel and concrete bridge collapsed due to flood • Improve river section
3	7	277+200	River	• The existing river opening is about 123m wide. • Flood level is about 4.78m below the deck level • River is meandering upstream and downstream • Scouring is observed at A2 side downstream bank. No scouring of banks noted at upstream side	• One-span of the original 6-span concrete bridge collapsed due to overloading
4	11	084+900	Flood Plain Opening	• The existing river opening is about 41m wide. • Flood level is about 1.73m below the deck level • Bridge is at Mekong river floodplain and provides opening during flood • Bridge opening is protected by gabion mattress	• The road is improved under emergency flood rehabilitation while the bridge remains temporary

Table 3.3.7 Existing Bridge River Condition (…Continued)

Bridge No.	Road No.	Station	Waterway	River Condition	Remarks
5	11	088+094	Flood Plain Opening	• The existing river opening is about 83m wide. • Flood level is about 0.75m below the deck level • Bridge is at Mekong river floodplain and provides opening during flood • Bridge opening is protected by gabion mattress and gabion guide banks are provided at both abutments	• The road is improved under emergency flood rehabilitation while the bridge remains temporary • Need to raise bridge level to provide sufficient flood freeboard
6	11	089+060	Flood Plain Opening	• The existing river opening is about 53m wide. • Flood level is about 1.30m below the deck level • Bridge is at Mekong river floodplain and provides opening during flood • Bridge opening is protected by gabion mattress	• The road is improved under emergency flood rehabilitation while the bridge remains temporary • Need to raise bridge level to provide sufficient flood freeboard
7	11	103+475	Flood Plain Opening	• The existing river opening is about 48m wide. • Flood level is about 0.59m below the deck level – flood freeboard insufficient • Bridge is at Mekong river floodplain and provides opening during flood	• The road is improved under emergency flood rehabilitation while the bridge remains temporary • Need to raise bridge level to provide sufficient flood freeboard
8	33	036+540	River	• The existing river opening is about 27m wide. • Flood level is about 1.37m below the deck level • Bridge is located in low-lying swampy area. Dam exist in the upstream side	• Bridge is located in relatively flat area

(2) Bridge Length and Span Lengths

The bridge length is decided based on the existing topography at bridge site, existing bridge lengths and condition, river design flood discharge, maximum flood water level and the condition of the river and banks.

The span length is decided based on existing span lengths, river hydraulic and expected debris flow, depth of superstructure to minimize approach road profile adjustment and depth of existing water to minimize construction of piers on river.

As a guide policy, the minimum span length is recommended to be:

i. $S \geq 20 + 0.005Q$ for $500\ m^3/s < Q \leq 2{,}000\ m^3/s$

ii. $S \geq 30 + 0.005Q$ for $Q > 2{,}000\ m^3/s$

where : S = span length in meters

Q = river discharge in m^3/s

Table 3.3.8 presents the proposed bridge length and span compared to the existing bridges. As indicated in the table, most of the bridge span lengths are increased except for 1-span bailey bridges (Bridge No.1 and No.8) where the span lengths are reduced due to small river discharge. Moreover, the bridge length of Bridge No.1 is increased to 60m since the existing bridge is observed to constrict the river section causing backwater and flood on the upstream section.

The span length of Bridge No. 7 is increased to 35m utilizing precast, prestressed girders to improve the river section opening due to large river discharge.

Table 3.3.8 Existing and Proposed Bridge Length and Spans

Bridge No.	Road No.	Station*	Existing Bridge		Discharge (m^3/s)	Min. Span Length (m)**	Proposed Bridge		Remarks
			Length (m)	Span (m)			Length (m)	Spans (m)	
1	3	025+900.000	37.0	37.0	284	-	60.6	20	Existing bridge constricts the river section, bridge length extended
2	3	105+958.442	48.0	12.0	238	-	54.6	18	Span length chosen to minimize road profile adjustment
3	7	277+129.970	130.0	21.7	1,775	28.9	140.8	35	Span length increased to 35m due to large river discharge
4	11	084+878.359	42.0	14.0	150	-	42.6	21	Span length increased to improve waterway and use similar structure type along NR.11
5	11	088+047.591	84.0	14..0	573	22.9	92.6	23	Span length increased to 23m due to waterway discharge
6	11	089+025.372	54.0	10.8	454	20.0	69.6	23	Span length made similar to bridge no. 5 since discharge is almost 500 m^3/s
7	11	103+448.058	48.0	12.0	177	-	54.6	18	Existing span length is sufficient
8	33	036+524.167	30.0	30.0	62	-	30.6	10	Span length reduced due to small river discharge and minimize road profile adjustment

Note: *Station is revised to proposed new Stationing for new bridge length.
**Based on river discharge

(3) Deck Elevation

Since the bridges are improvement of existing bridges, it is desired to keep the existing deck elevation as much as possible. However, the minimum freeboard or vertical clearance from the design flood level (DFL) to the bottom of the major structural element (girders or slab) shall be secured as discussed in the design criteria.

Since the superstructure type is governed by the span length requirements in bridges, the bridge profile is adjusted considering the depth of the superstructure and the required freeboard from the design flood level. **Table 3.3.9** presents the existing bridge elevations and the proposed bridge profile elevations based on the structure type and the minimum freeboard.

It is seen that almost all bridge elevations have to be adjusted except for Bridge No.3 at NR.7 which has sufficient clearance from the design flood based on the site topography. Minimal adjustment in bridge profile is necessary for Bridge No.8 since the bridge type (Continuous RC Slab) does not require much structure depth.

However, bridges along NR.11 have considerable deck profile elevation adjustments due to change in span length and structure type (prestressed concrete girder) and the required minimum freeboard clearance from the design flood water. A common form of structure is selected for these bridges since they lie in the same alignment and for ease of construction execution.

Table 3.3.9 Bridge Deck Profile Adjustment

Bridge No.	Road No.	Station	Existing Bridge Elev. (m)	Design Flood Level (Elev. in m)	Proposed Bridge Elev. (m)	Min. Freeboard (mm)	Remarks
1	3	025+900.000	14.767	12.740	15.400	800	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
2	3	105+958.442	29.815	27.500	30.000	800	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
3	7	277+129.970	63.186	58.410	63.250	1000	Road profile to be maintained since existing clearance from design flood is sufficient.
4	11	084+878.359	9.228	7.500	10.140	800	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
5	11	088+047.591	9.515	8.770	11.600	1000	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
6	11	089+025.372	9.452	8.150	10.800	800	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
7	11	103+448.058	8.791	8.200	10.840	800	Road profile to be raised-up to maintain minimum freeboard and accommodate new superstructure type.
8	33	036+524.167	3.174	1.810	3.600	600	Raising-up of road profile minimal due to type of superstructure.

3.3.5 Bridge Design

(1) Superstructure

As discussed earlier, the choices of superstructure type follows the requirements for bridge planning which includes span lengths and bridge lengths. **Table 3.3.10** presents the proposed superstructure type and bridge lengths for the eight bridges while **Figure 3.3.2** illustrates the basic bridge cross-sections for RC Slab, RCDG and PCDG bridges. As discussed in the design criteria, all eight bridges shall have 10m wide travel lanes (2@1.5m shoulders and 2@3.5m traffic lanes). A 1.0m wide sidewalk is provided since these bridges are located in major arterial routes.

As seen in **Table 3.3.10**, PCDG is proposed for span lengths greater than 20m which is more appropriate in terms of cost and construction. However, for national road NR.11, the structure type is standardized to prestressed precast girder (PCDG) using the same structure depth which is more advantageous during construction since the bridges are in proximity with each other.

RCDG superstructure is applied to Bridge No.2 since the span length is shorter at 18m while RC Slab is applied to Bridge No.8 which is also shorter at 10m span. These superstructure types require less structure depth than the PCDG type and will entail lesser adjustment in existing road profiles.

Table 3.3.10 Superstructure Design

Bridge No.	Road No.	Station	Bridge Length (m)	Spans (m)	Proposed Bridge Elev. (m)	Super-structure Type	Remarks
1	3	025+900.000	60.6	3 @ 20	15.40	PCDG (AASHTO Type IV)	Bridge length is increased to avoid river section constriction. PCDG is chosen to be most appropriate at this location.
2	3	105+958.442	54.6	3 @ 18	30.00	RCDG (D=1100)	Shorter span arrangement is chosen to minimize road profile adjustment which is sufficient for river discharge. RCDG is most appropriate structure type for this span.
3	7	277+129.970	140.8	4 @ 35	63.25	PCDG (AASHTO Type VI)	Longer span length arrangement is used for this bridge due to large river discharge and to minimize substructure construction. PCDG is most appropriate structure at this span range.
4	11	084+878.359	42.6	2 @ 21	10.14	PCDG (AASHTO Type IV)	Similar scale and span arrangement to other proposed bridges in NR.11 is recommended for this bridge using PCDG. This minimizes substructure construction.
5	11	088+047.591	92.6	4 @ 23	11.60	PCDG (AASHTO Type IV)	Waterway discharge requires span arrangement at 23m where PCDG is most advantageous structure type. This minimizes waterway constriction and less substructure construction.
6	11	089+025.372	69.6	3 @ 23	10.80	PCDG (AASHTO Type IV)	Waterway discharge requires span arrangement at similar to Bridge No.5 where PCDG is most advantageous structure type. This minimizes waterway constriction and less substructure construction.
7	11	103+448.058	54.6	3 @ 18	10.84	PCDG (AASHTO Type IV)	PCDG type is chosen to be of similar scale to other NR.11 proposed bridges which is advantageous during construction of these bridges.
8	33	036+524.167	30.6	3 @ 10	3.60	RC Slab (D=600)	River discharge does not require longer spans so that shorter spans at 10m is used for this bridge where RC Slab is most appropriate. The structure type chosen will require the least adjustment on existing road profile.

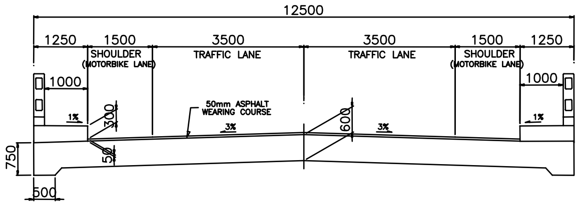
NOTE:
1. PCDG is Pre-cast Prestressed Concrete Deck Girder Bridge
2. RCDG is Reinforced Concrete Deck Girder Bridge
3. RC Slab is Reinforced Concrete Cast-in-Place Slab Bridge

(2) Substructure

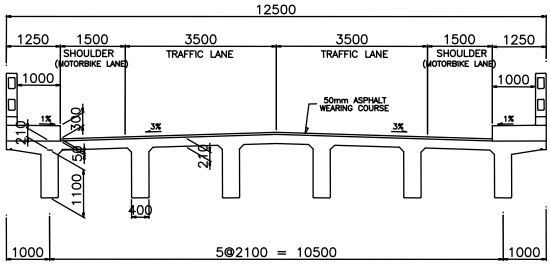
The choice of foundation system for substructure depends on the type and depth of supporting soil layer for each bridge. Spread foundation or direct bearing is used for shallow sandstone layer (depth is less than 5m) where river bed scouring does not pose any problem. This foundation type is applied to piers of Bridge No. 3 at NR.7 where geotechnical investigation reveals the presence of sandstone at shallow depth in the river.

Pile foundation is applied to the rest of the bridges since soil bearing layers are found at greater depths. Precast RC Driven Piles are applied to Bridges No. 1, 2 and 8 where bearing depths does not exceed 20m to minimize pile splicing or production of longer piles. Cast-in-place RC Piles are applied to Bridges No. 4,5,6,7 where foundation bearing depths are more than 20m.

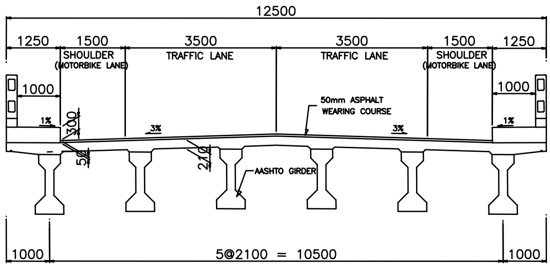
Due to the scale of Bridge No. 3 (span length is 35m), Cast-in-place RC Piles are applied to the abutments to minimize positions of pile construction works.



a. RC Slab Bridge



b. RCDG Bridge



AASHTO GIRDER TYPE	DEPTH (mm)	BRIDGE NO.
IV	1371	1,4,5,6,7
VI	1829	3

c. PCDG Bridge

Figure 3.3.2 Basic Bridge Cross-Sections

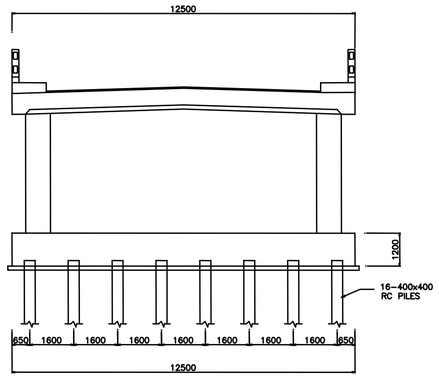
Table 3.3.11 presents the substructure types proposed for the bridges.

Table 3.3.11 Substructure Design

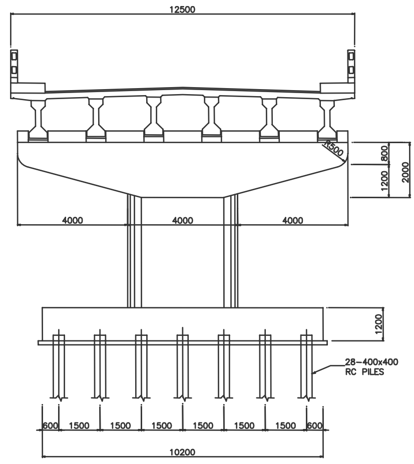
Bridge No.	Road No.	Station	Soil Condition	Pier Type (m)	Abutment Type	Foundation Type
1	3	025+900.000	Soil condition consists of loose to very dense yellow, very clayey fine to medium SAND overlying hard to very hard yellow and brown sandy CLAY.	Column Pier (1.0x4.0m)	Seat Type Cantilever	RC Driven Piles (0.4x0.4m)
2	3	105+958.442	Soil consists of medium dense brown and light gray fine to coarse SAND overlying hard to very hard yellow and gray fat CLAY	Column Pier (0.9x4.0m)	Seat Type Cantilever	RC Driven Piles (0.4x0.4m)
3	7	277+129.970	SANDSTONE is found at 9.5m below the borehole levels overlain by medium stiff to very hard CLAY at abutment A2 and medium dense to very dense SAND at abutment A1.	Column Pier (1.8x5.0m)	Seat Type Cantilever	Pier – Spread Footing; Abutment – RC CIP Piles (ϕ1.0m)
4	11	084+878.359	Medium stiff to stiff yellowish- gray CLAY with very fine sand overlies dense to very dense gray clayey SAND.	Column Pier (1.0x4.0m)	Seat Type Cantilever	RC CIP Piles (ϕ1.0m)
5	11	088+047.591	Medium stiff yellow and gray to very stiff dense yellow and brown CLAY are found to overlie very dense yellowish-brown clayey fine to coarse SAND	Column Pier (1.0x4.0m)	Seat Type Cantilever	RC CIP Piles (ϕ1.0m)
6	11	089+025.372	Soil condition is assumed to be similar to Bridge No. 5 and 6. No soil investigation was carried-out at this location	Column Pier (1.0x4.0m)	Seat Type Cantilever	RC CIP Piles (ϕ1.0m)
7	11	103+448.058	Soil consists of medium stiff to very stiff brown-gray sandy CLAY overlying medium dense to very dense yellow clayey SAND	Column Pier (1.0x4.0m)	Seat Type Cantilever	RC CIP Piles (ϕ1.0m)
8	33	036+524.167	Stiff gray and yellow lean CLAY to very stiff light-gray sandy CLAY overlies gray LIMESTONE at 15.50m below borehole level.	Wall Pier (0.6x11.0m)	Seat Type Cantilever	RC Driven Piles (0.4x0.4m)

NOTE: 1. RC CIP Piles is Reinforced Concrete Cast-in-Place Piles

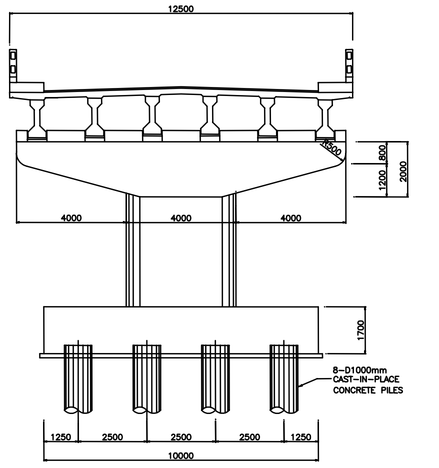
Figure 3.3.3 illustrates some of the typical substructure types applied for the proposed bridges.



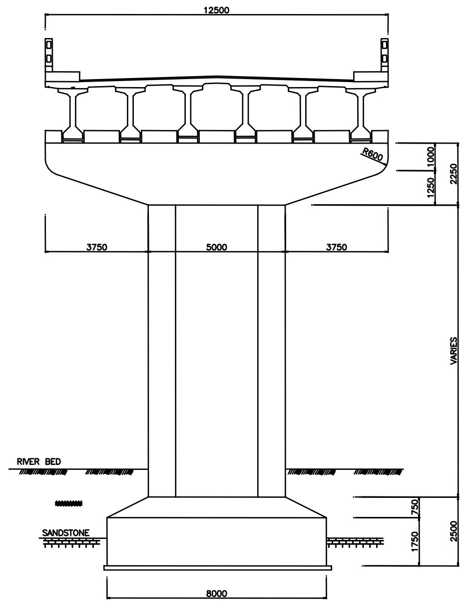
a. Wall Pier on 0.4mx0.4m RC Driven Piles



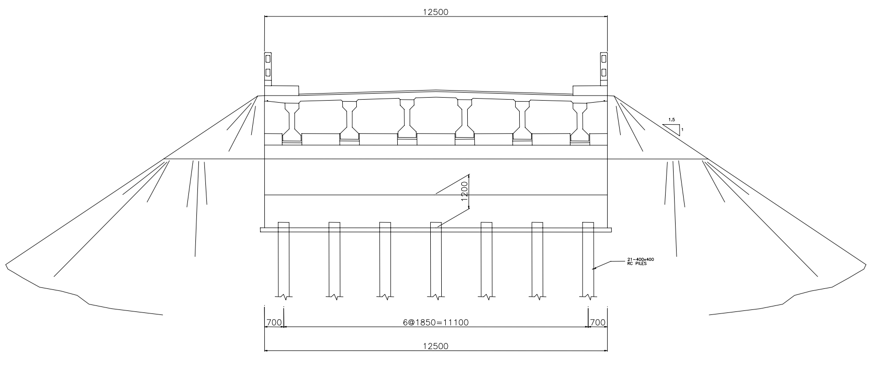
b. Column Pier on 0.4mx0.4m RC Driven Piles



c. Column Pier on ϕ1.0m RC CIP Piles



d. Column Pier on Spread Footing



e. Typical Seat Type Cantilever Abutment on 0.4mx0.4m RC Driven Piles

Figure 3.3.3 Substructure Types for Urgent Bridge Rehabilitation

(3) River Protection

In order to protect the bridge foundations and abutments against high flood flow velocities and possible scour, wet masonry protection is provided in front of and around the abutments with gabion box cut-off perimeter at the toes of the wet masonry. Moreover, the top of pier footings and pile caps are located at a minimum depth of 1.0m below the river bed with 0.5m thick gabion mattress provided at the river beds (see **Figure 3.3.4**).

For Bridge No.5, the existing gabion guide banks shall be reconstructed after completing the new PCDG bridge.

Since the meandering river at Bridge No.3 approaches the bridge at an angle with the north bank (Abutment A2 side), wet masonry revetment with gabion box at the toes is proposed to minimize river bank scouring.

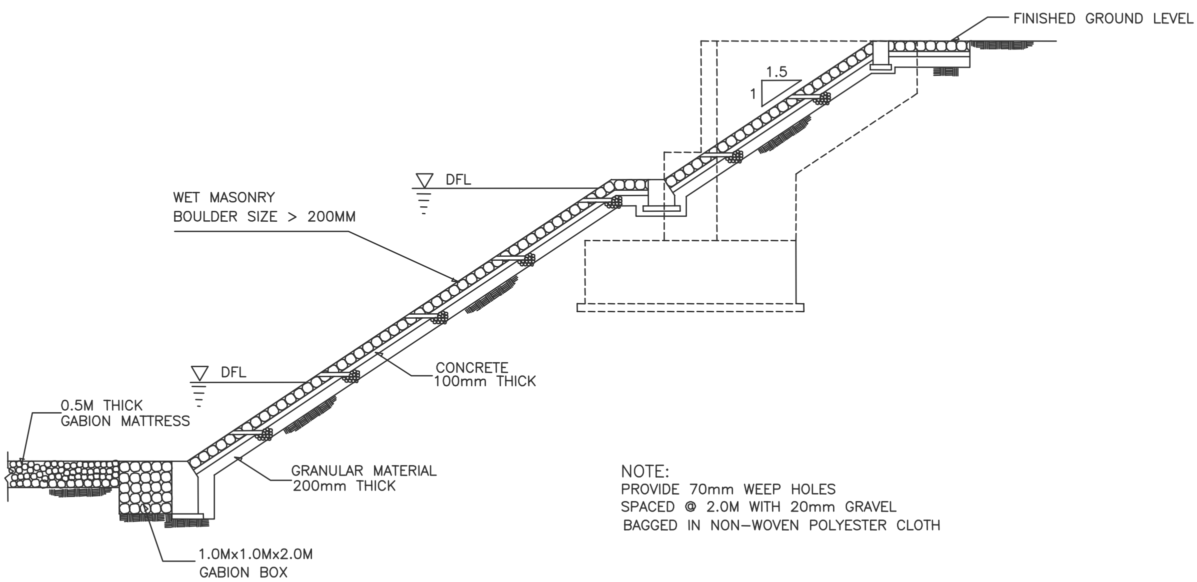


Figure 3.3.4 Typical Wet Masonry River Protection Works

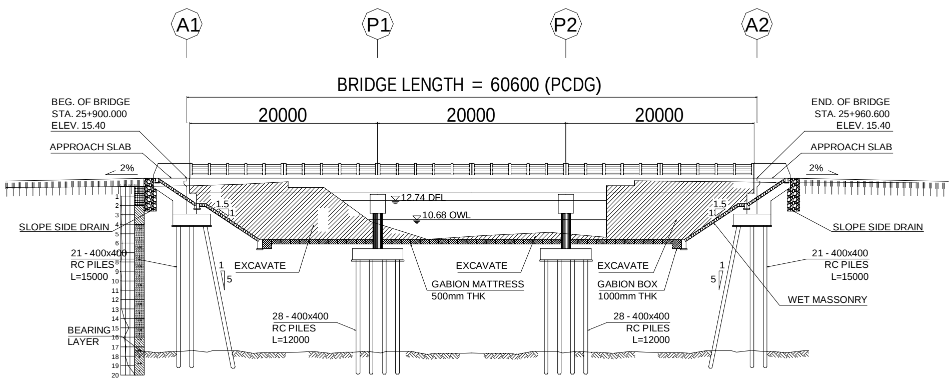
(4) Summary of Proposed Bridges

The summary of proposed bridges for Urgent Bridge Rehabilitation is presented in **Table 3.3.12** and shown in **Figure 3.3.5**.

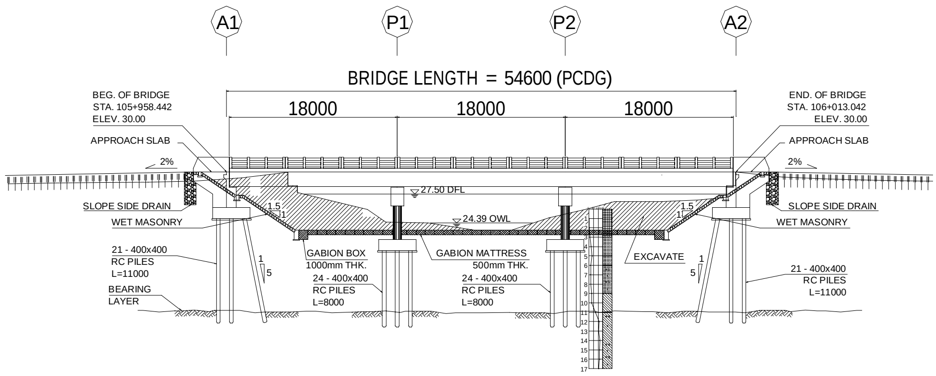
Table 3.3.12 Proposed Bridges for Urgent Bridge Rehabilitation

Bridge No.	Road No.	Station	Deck Elev. (m)	Total Length (m)	Superstructure			Substructure	
					Type	Spans (m)	Deck Width (m)	Pier	Abutment
1	NR-3	025+900.000	15.40	60.6	PCDG (AASHTO Type IV)	3 @ 20		Column Pier on RC Driven Pile (0.4x0.40m)	Seat Type Cantilever on RC Driven Pile (0.4x0.40m)
2	NR-3	105+958.442	30.00	54.6	RCDG (D=1100)	3 @ 18		Column Pier on RC Driven Pile (0.4x0.40m)	Seat Type Cantilever on RC Driven Pile (0.4x0.40m)
3	NR-7	277+129.970	63.25	140.8	PCDG (AASHTO Type VI)	4 @ 35	Sidewalk : 2@1.00	Column Pier on Spread Footing	Seat Type Cantilever on RC CIP Pile (ϕ1.0m)
4	NR-11	084+878.359	10.14	42.6	PCDG (AASHTO Type IV)	2 @ 21	Shoulder : 2@1.50	Column Pier on RC CIP Piles(ϕ1.0m)	Seat Type Cantilever on RC CIP Pile (ϕ1.0m)
5	NR-11	088+047.591	11.60	92.6	PCDG (AASHTO Type IV)	4 @ 23	Traffic Lane : 2@3.50	Column Pier on RC CIP Piles(ϕ1.0m)	Seat Type Cantilever on RC CIP Pile (ϕ1.0m)
6	NR-11	089+025.372	10.80	69.6	PCDG (AASHTO Type IV)	3 @ 23	Total : 12.00	Column Pier on RC CIP Piles(ϕ1.0m)	Seat Type Cantilever on RC CIP Pile (ϕ1.0m)
7	NR-11	103+448.058	10.84	54.6	PCDG (AASHTO Type IV)	3 @ 18		Column Pier on RC CIP Piles(ϕ1.0m)	Seat Type Cantilever on RC CIP Pile (ϕ1.0m)
8	NR-33	036+524.167	3.60	30.6	RC Slab (D=600)	3 @ 10		Wall Pier on RC Driven Pile (0.4x0.40m)	Seat Type Cantilever on RC Driven Pile (0.4x0.40m)

NOTES :
1. PCDG is Prestressed Concrete Deck Girder Bridge
2. RCDG is Reinforced Concrete Deck Girder Bridge
3. RC Slab is Reinforced Concrete Cast-in-Place Slab Bridge
4. RC CIP Pile is Reinforced Concrete Cast-in-Place Pile

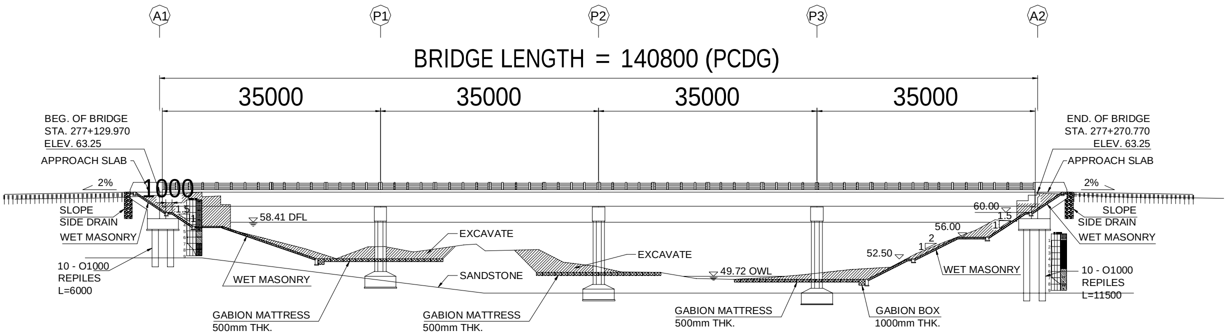


BRIDGE NO.1 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.3 (STA.25+900) BRIDGE LENGTH=60.60m

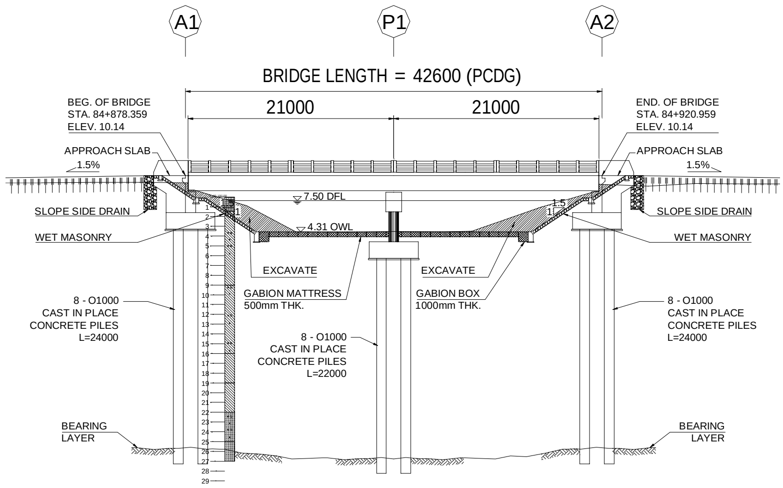


BRIDGE NO.2 REINFORCED CONCRETE DECK GIRDER BRIDGE
NR.3 (STA.105+958.442) BRIDGE LENGTH=54.60m

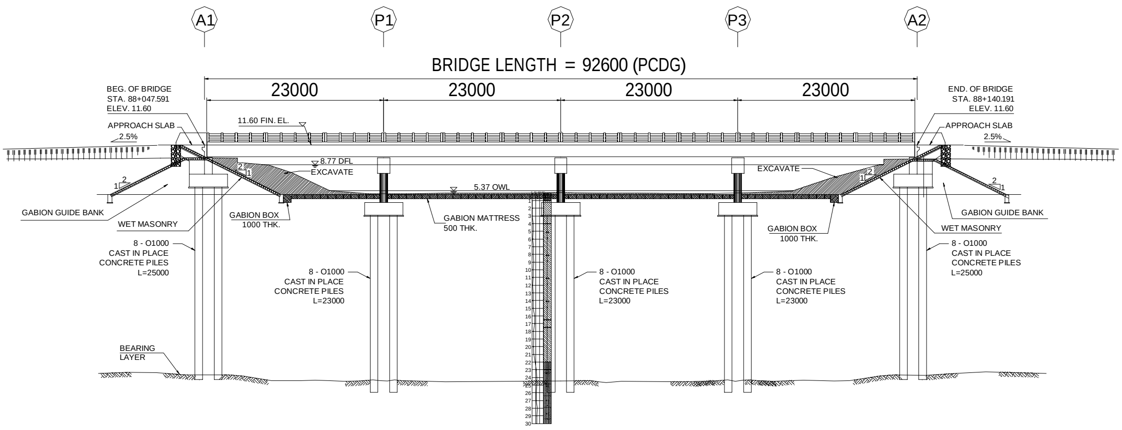
Figure 3.3.5(a) Proposed Bridges (Nos. 1 & 2)



BRIDGE NO.3 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.7 (STA.277+129.970) BRIDGE LENGTH=140.80m

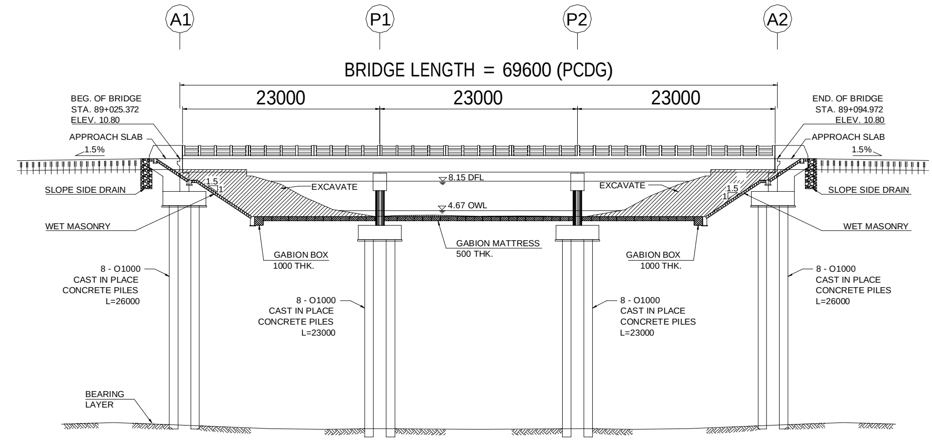


BRIDGE NO.4 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.11 (STA.84+878.359) BRIDGE LENGTH=42.60m

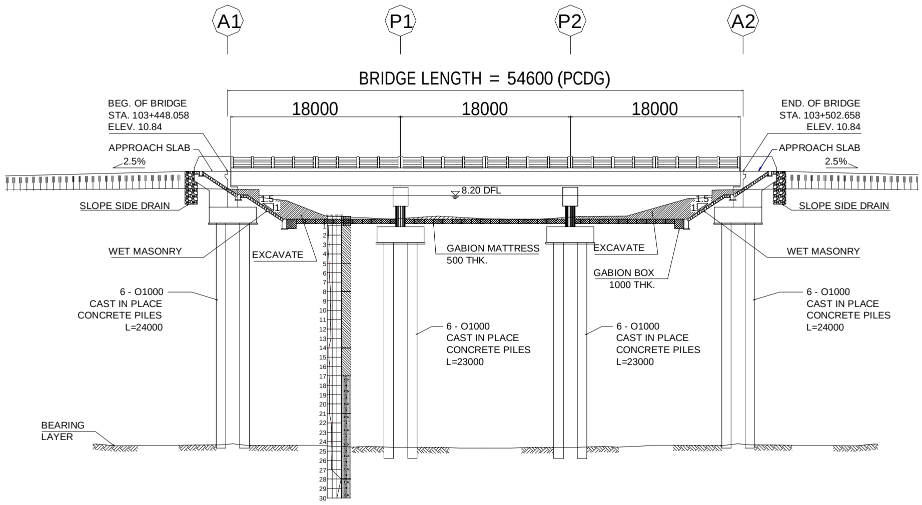


BRIDGE NO.5 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.11 (STA.88+047.591) BRIDGE LENGTH=92.60m

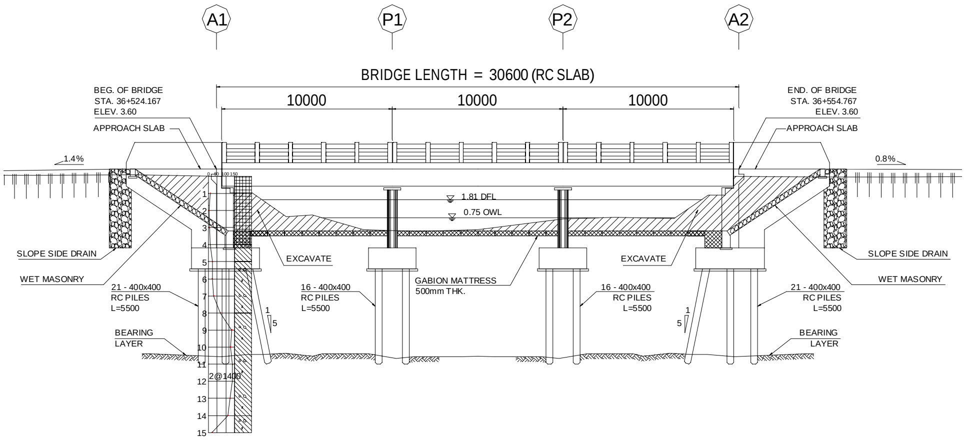
Figure 3.3.5(b) Proposed Bridges (Nos. 3, 4 & 5)



BRIDGE NO.6 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.11 (STA.89+025.372) BRIDGE LENGTH=69.60m



BRIDGE NO.7 PRESTRESSED CONCRETE DECK GIRDER BRIDGE
NR.11 (STA.103.448.058) BRIDGE LENGTH=54.60m



BRIDGE NO.8 REINFORCED CONCRETE SLAB BRIDGE
NR.33 (STA.36+524.167) BRIDGE LENGTH=30.60m

Figure 3.3.5(c) Proposed Bridges (Nos. 6, 7 & 8)

(5) Recommendations on Bridge Design

- The preliminary design for bridges on Urgent Bridge Rehabilitation is done based on the geotechnical and topographic survey conducted during the course of the study. It should be noted that the design of substructures is based on a limited number of boreholes conducted – this should be supplemented with additional boreholes during the detailed design. At least two boreholes for each bridge should be conducted to confirm the underlying bearing strata. Specifically additional boreholes at the river should be conducted at Bridge No.3 (NR.7) to determine the depth of sandstone layer. Laboratory tests on Sandstone should also be done to determine its bearing capacity.

- Preliminary hydrologic and river hydraulic analysis was conducted to determine the bridge span and length requirements. However, it is recommended that a more detailed analysis be conducted during the detailed design to verify the hydraulic design requirements at each bridge especially the bridges along the Mekong floodplain (NR.11).

- It is observed during site investigations that in most bridge locations, the collapsed members of old bridges (substructure and sometimes superstructures) are left to remain in place. This collapsed members constricts the river cross-sections and limits the river discharge capacity causing backwater and flood on the upstream side and scouring around the bridge section. When new bridges are to be reconstructed at these locations, such members that tend to constrict the river section shall be removed to improve the river section capacity.

- Although the bridges proposed under this study are concrete bridges which require minimal maintenance compared to steel bridges, a bridge maintenance system should be established to preserve its structural capacity and protect it from further deterioration. The concept of preventive maintenance for bridges is discussed in Chapter 4 of this report.