CHAPTER 6 PRELIMINARY DESIGN ON PRIORITY PROJECTS

6.1 List of Sub-Projects and Structures for Preliminary Design

The primary subprojects and their priority components are listed in Table 6.1.1. This chapter reports on the results of the preliminary design that has been conducted for each sub-project. Note that the structural comparison study for Gyaing Kawkareik Bridge was only carried out for the proposed 2-lane road. Preliminary design for Gyaing Kawkareik Bridge was conducted assuming four lanes would be constructed after the Fact-Finding Mission in December, 2014.

Table 6.1.1 List of SubProjects in the Priority Project

Subproject	Component
Sub-Project 1 Improvement of EWEC (toYangon)	Sub-Project 1-1:Replacement of Two bridges (Naung Lon Br., Gyaing Kawkareik Br.) Sub-Project 1-2: Thaton Bypass＋Replacement of Donthami Br.
Sub-Project 2 Improvement of EWEC (to Mawlamyine)	Sub-Project 2-1: Replacement of Two bridges (Gyaing Zathapyin Br., Atran Br.) Sub-Project 2-2: Kyargalay Bypass

Source: JICA Survey Team

Five major bridges and two bypasses partially making up the East-West Economic Corridor were selected as priority projects in this Study. The location of each bridge or bypass and river that each bridge crosses are listed in Table 6.1.2.

The preliminary design is being conducted based on the result of the geological survey and hydrological survey.

Table 6.1.2 The Bridges and Bypasses to be Designed

Bridge/Bypass	Road Section	River	State
Naung Lon Bridge	Thaton-Eindu	Branch of Thawmlin	Kayin
Gyaing Kawkareik Bridge	Eindu-Kawkareik	Gyaing	Kayin
Gyaing Zathapyin Bridge	Eindu-Mawlamyine	Gyaing	Mon,Kayin
Atran Bridge	Eindu-Mawlamyine	Atran	Mon
Donthami Bridge (on Thaton Bypass)	Thaton-Eindu	Donthami	Mon,Kayin
Thaton Bypass	---	---	Mon
Kyargalay Bypass	---	---	Mon, Kayin

Source: JICA Survey Team

6.2 Design Criteria and Standards

6.2.1 Design Criteria for Structural Design

Prior to the execution of the preliminary design, each design criteria was established for the design of bridges, roads and bypasses, etc. In a series of discussions between the JICA Study Team and its counterparts (MOC), each design criteria and condition such as navigation clearance, etc was determined. Those are introduced in the following sections.

(1) Design Standard

The principle design standards for bridge design that were applied are:

- ✓ AASHTO LRFD Bridge Design Specifications (2010, 5th edition)
- ✓ Specifications for Highway Bridges - Japan Road Association (JRA) (2002)

The bridge design has been conducted based on the design standards. Note that live loading is applied in accordance with AASHTO guidelines, and other design loads such as earthquake, temperature, wind, etc. are applied with modified JRA specifications considering local conditions.

(2) Dead Load

Dead loads including the weight of all components of the structure and facilities such as, utilities, pavement and future overlays are calculated based on those prescribed in AASHTO as shown in Table 6.2.1.

Table 6.2.1 Unit Weights of Bridge Materials for Dead Load Calculation

Material	Unit Weight (kN/m^3)
Steel	77.0
Plain Concrete	23.0
Reinforced Concrete	24.5
Prestressed Concrete	24.5
Asphalt mix	22.5

Source: JICA Survey Team based on ASSHTO

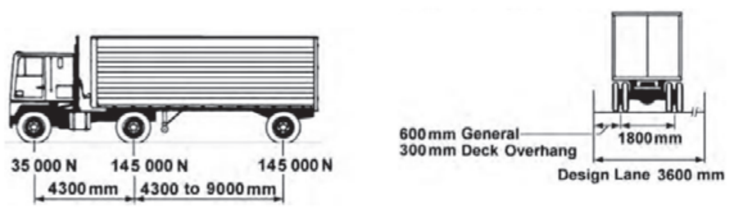
(3) Live Load

According to AASHTO LRFD, the live loads on the road bridges shall consist of;

- ✓ Design truck or design tandem, and
- ✓ Design lane load

a) Design Truck

The loading combination for spacing of wheels and axles of design vehicle specified in AASHTO LRFD is the layout given in Figure 6.2.1.



Source: ASSHTO

Figure 6.2.1 Characteristics of Design Truck (HS20-44)

b) Design Lane Load

The design lane load is a uniform linear load of 9.3 kN/m

(4) Seismic Design

Records of earthquakes that have occurred in Myanmar's recent history are shown in Table 6.2.2.

Table 6.2.2 List of Recent Earthquakes in Myanmar

Date	Location	Magnitude and/or brief description
6 Mar 1913	Bago	Shwemawdaw Pagoda lost its finial
5 Jul 1917	Bago	Shwemawdaw Pagoda fell
10 Sep 1927	Yangon	Unknown
17 Dec 1927	Yangon	M=7 RS; extended to Dedaye
8 Aug 1929	Near Taungoo	Bent railroad tracks, bridges and culverts collapsed, and loaded trucks overturned (Swa Earthquake)
5 May 1930	Near Khayan	M=7.3 RS, Imax=IX; in a zone trending north-south for 37 km south of Bago (on the Sagaing Fault line); about 500 people in Bago and about 50 people in Yangon died
3 Dec 1930	Nyaunglebin	M=7.3 RS; railroad tracks twisted (Pyu Earthquake); about 30 persons were died
27 Jan 1931	East of Indawgyi	M=7.6 RS, Imax=IX; numerous fissures and cracks (Myitkyina Earthquake)
27 Mar 1931 16 May 1931 21 May 1931	Yangon	Unknown
10 Aug 1931	Pyinmana	Unknown
12 Sep 1946	Tagaung	M=7.75 RS
16 Jul 1956	Sagaing	M=7.0 RS; Several pagodas severely damaged (40 to 50 people died)
8 Jul 1976	Bagan	M=6.8 RS; Several pagodas in Bagan Ancient City were severely damaged
22 Sep 2003	Taungdwingyi	M=6.8; RS Severe damaged to rural houses and religious building

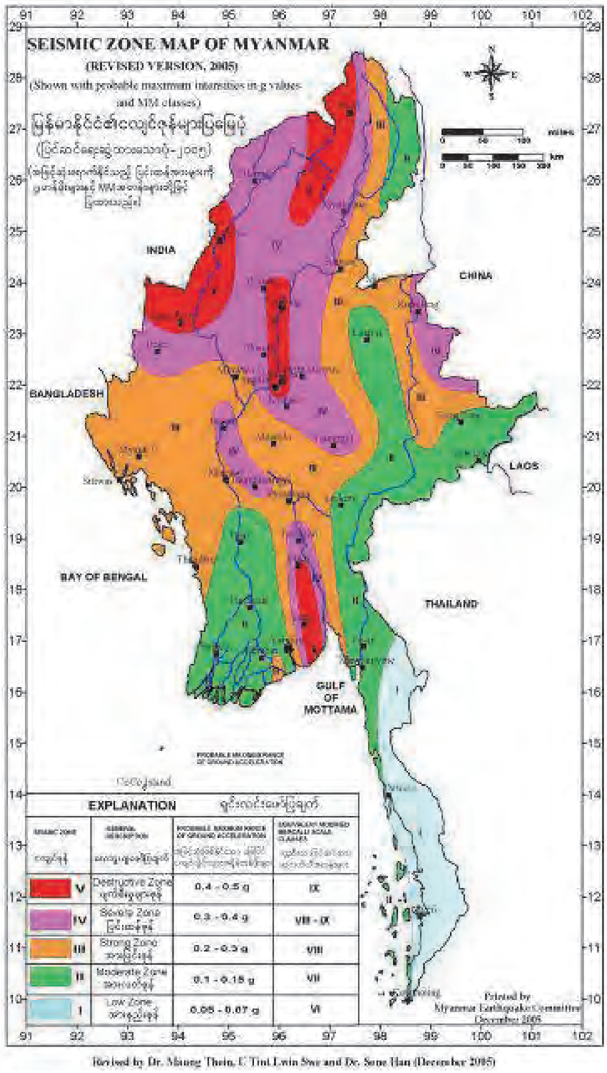
Source: JICA Survey Team based on the Data of Myanmar Geosciences Society

Most of the earthquakes occurred along the Sagaing Fault, which is Myanmar's most prominent active fault, running in the north-south direction and stretching to the Sagaing Hill.

The project sites are located near Mawlamyine in the southeast region. It is projected that the area would not be significantly affected by earthquakes. According to the Seismic Zone Map of Myanmar (See Figure 6.2.2), the ground motion near bridge sites is in the range of around 0.1-0.15 gal, which is somewhat lower than the ground motion categorized as a Level-1 Earthquake in accordance with JSHB.

In this Study, the seismic design is to be carried out using acceleration response spectra for Level-1 earthquake ground motion in accordance with JRA specifications. The verification of seismic design Level-1 is carried out using the Japanese seismic coefficient method, with $K_h = 0.2$.

When plastic behaviour of a reinforced concrete column is expected in the seismic design, structural details shall conform to JRA specification PART-V SEISMIC DESIGN in order to verify plastic deformation performance.

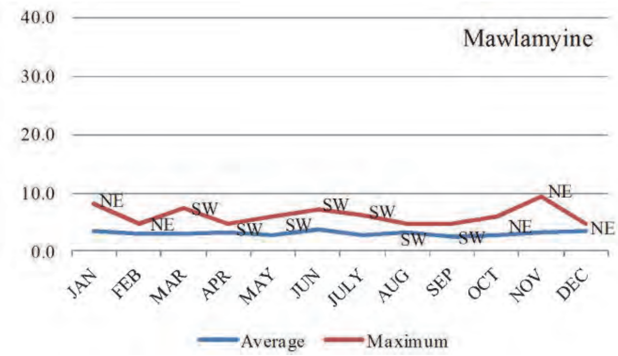


Source: Myanmar Earthquake Committee

Figure 6.2.2 Seismic Zone Map of Myanmar

(5) Wind Speed

The following figure shows the average monthly wind speed and peak daily average wind speed and for each month, as well as the wind direction with the highest frequency in each month at Mawlamyine in 2012. The wind speed in the south-west direction increases during summer. The maximum wind speed in Mawlamyine is 4-10 mph (1.8-4.5 m/s).



Source: JICA Survey Team based on DMH data

Figure 6.2.3 Wind Speed(mph) and Direction at Mawlamyine

The cyclone NARGIS with a maximum wind speed of 54m/s swept through the delta coasts of Ayeyarwady and Yangon Division on 2nd May 2008. The maximum wind speed in Yangon was 49m/s, which was almost equal to the scale of a large typhoon in Japan. The possibility of Mawlamyine being hit by similar large-scale cyclone is very high.

Therefore, the wind load on the superstructure should be applied in accordance with JRA specifications. Based on these standards, the design reference wind speed is set to 40 m/s at the height of 10m.

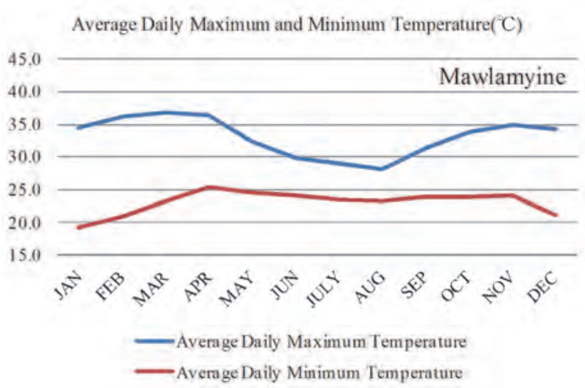
In the case of suspension bridges, cable stayed bridges and other flexible bridges, more detailed studies such as wind tunnel testing are required to examine the wind resistance of structures at the detailed design stage.

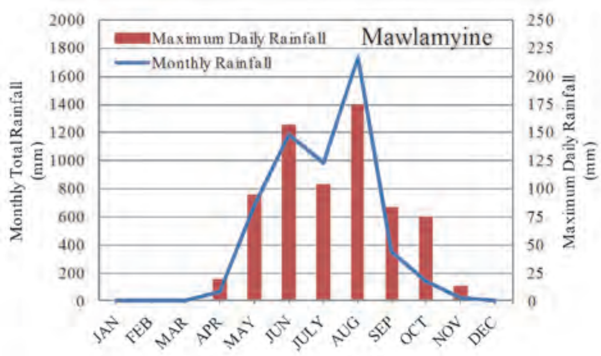
(6) Temperature and Precipitation

Average daily maximum and minimum temperatures at Mawlamyine are shown in Figure 6.2.4. Daily maximum and minimum temperatures in the Study Area are assumed to be 37°C and 19°C respectively.

The temperature range to be used in design was 15°C to 40°C with a mean of 25°C (temperature rise 10°C, temperature fall 15°C) for ordinary bridges, and 15°C to 50°C with a mean of 25°C (temperature rise 10°C, temperature fall 25°C) for steel plate decks.

As for precipitation, rainfall starts around May and intensifies during the wet season (from June to September). Average annual rainfall in Mawlamyine reaches 4,800 mm. The following figures show the temperature and annual rainfall data (2012) in Mawlamyine.





Source: JICA Survey Team based on DMH data

Figure 6.2.4 Temperature and Annual Precipitation at Mawlamyine

(7) Design Navigation Clearance

The design height of bridge depends on the design vessels navigating. Table 6.2.3 shows the required Navigation Clearance on each bridge.

Table 6.2.3 Required Navigation Clearances on Each Bridge

Bridge	Navigation Clearance	Remarks
Naung Lon	Nil	Span of existing Bridge is approximately 12.5m
Gyaing Kawkareik	Horizontal : 360 feet (110m) Vertical : 40 feet (12.2m)	Span of existing Bridge is 154m
Gyaing Zathapyin	Horizontal : 400 feet (122m) Vertical : 40 feet (12.2m)	Span of existing Bridge is 457.2m
Atran	Horizontal : 400 feet (122m) Vertical : 40 feet (12.2m)	Span of existing Bridge is 182m

Source: JICA Survey Team based on MOC data

6.2.2 Design Standard for Road Design

Design standards applied to the design of the approach roads and bypasses are as follows.

(1) Geometric Design Standard

Asian Highway Classification and Design Standards and *ASEAN Highway Standards* are applied for the section between Thaton and Kawkareik, and the section between Eindu and Mawlamyine on the East-West Economic Corridor.

Therefore, this standard is applied to the design of the approach roads for the four bridges and two bypasses. The highway classification in this section is specified for Class II (two lanes), and the terrain of the location of the four bridges is classified as level.

The geometric design standards and design values to be applied are shown in Table 6.2.4. *Design Standards For Highways (Ministry of Construction Myanmar)* and *Japan Road Structure Ordinance (2004)* were applied in cases where at the two aforementioned standards lacked clauses covering certain design issues.

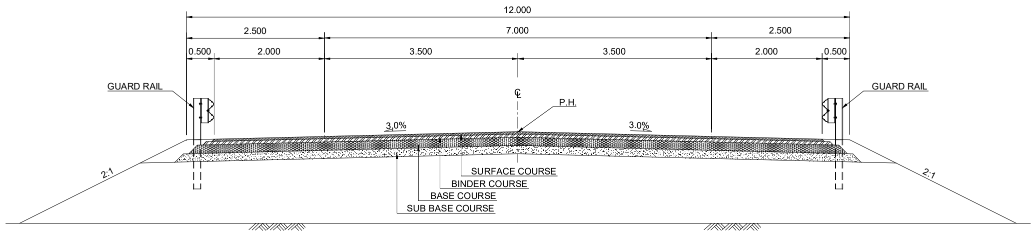
In the conference with MOC on March 12, 2014, the application of these standards was approved. The “Corridor of Impact” concept was also approved by MOC in the conference on May 15, 2014.

Table 6.2.4 Geometric Design Standard

		ASIAN HIGHWAY CLASSIFICATION AND DESIGN STANDARDS	ASEAN HIGHWAY STANDARDS	Design values to be applied
Highway Classification		Class II (2 lanes)	Class II (2 lanes)	Class II (2 lanes)
Terrain Classification		Level	Level	Level
Design Speed (km/h)		80	80-100	80
Width (m)	Right of Way	40	40-60 (Rural)	ROW:40 (4 Bridges) COI (for BP)
	Lane	3.5	3.5	3.5
	Shoulder	2.5	2.5	Without pavement: 2.5 (incl. 0.5m soft shoulder), With pavement: 0.5
	Road (Formation)	12.0	12.0	12.0
Earth Slope		—	—	1:2 (Fill)[*1] 1:1.5 (Cut)
Type of pavement		Asphalt Concrete	Asphalt Concrete	Asphalt Concrete (including hard shoulder)
Pavement Slope (%)		2	—	3[*2]
Shoulder Slope (%)		3-6	—	3 (hard shoulder)
Min.Horizontal Curve Radius		210	200	210
Max.Curve Radius with Transition Curve (m)		900 (Min.) 1800 (Desirable)	—	2000[*3]
Min.Transition Curve Length(m)		70	—	70
Max.Superelevation (%)		10 (R=210m)	10 (R=200:Rural)	10
Min. Ratio of Superelevation run off		—	—	1/150[*3]
Max.Vertical Grade (%)		4	6	4
Min.Vertical Curve Radius (m)	Crest			3000[*3]
	Sag			2000[*3]
Min.Vertical Clealance (m)		4.5	4.5	4.5
Stopping Sight Distance (m)		—	—	110[*3]
Passing Sight Distance (m)		—	—	550[*3]

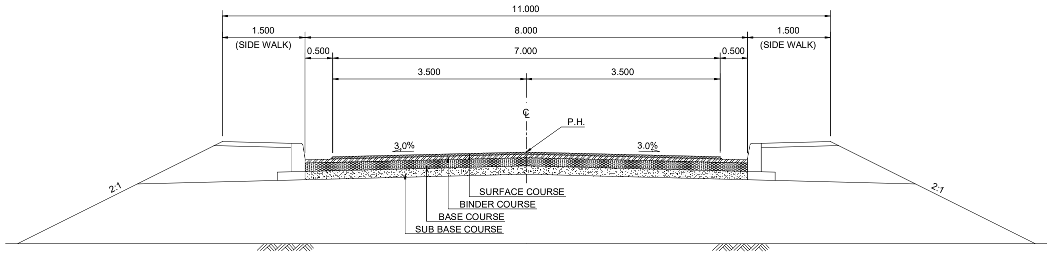
*1: GEOMETRIC DESIGN STANDARARDS FOR HIGHWAY (MOC: MYANMAR)
*2: Request from MOC
*3: Japanese Road Structure Ordinance.
Source: JICA Survey Team based on ASIAN HIGHWAY CLASSIFICATION AND DESIGN STANDARDS, GEOMETRIC DESIGN STANDARARDS FOR HIGHWAY (MOC: MYANMAR), JAPANESE ROAD STRUCTURE ORDINANCE (2004)

Typical cross sections of the embankment without and with a pavement are shown in Figure 6.2.5 and Figure 6.2.6, respectively.



Source: JICA Survey Team

Figure 6.2.5 Typical Cross Section for Earthwork Section Connecting to the Existing Road



Source: JICA Survey Team

Figure 6.2.6 Typical Cross Section for Earthwork Section Approaching to Bridge

The typical embankment section (Figure 6.2.5) is the same cross-section as used in “TA-8330 MYA: GMS East-West Economic Corridor Eindu to Kawkareik Road Improvement” implemented by ADB. In the bridge sections, 1m-wide pavement are applied to both sides of the bridges in accordance with the ASEAN Highway Standards. In addition, shoulder widths have been minimized due to economic considerations. The section approaching the bridge has a cross-section that ensures the connectivity of carriageway and pavement to the bridge section.

(2) Pavement Design Standard

AASHTO Guide for Design of Pavement Structures (1993) is used for the design of asphalt concrete pavement. It was approved at the meeting with MOC on March 12, 2014.

(3) Traffic Safety Facility Design Standard

AASHTO Roadside Design Guide (2006) is used for the design of guard rails and road markings. It was approved at the meeting with MOC on March 12, 2014.

Japanese standards such as *Standard of Installation of Guard Fences*, *Standard of Installation of Road Signs*, and *Manual of Installation of Road Markings* are applied in their respective areas.

6.3 Preliminary Study for Four Bridges

Preliminary study for four bridges (Naung Lon/Gyaing Kawkareik/Gyaing Zathapyin/Atran) is described in this section.

6.3.1 Comparative Study of Bridge Crossing Point for Four Bridges

A comparative study for the location of new bridges was executed considering technical issues such as the alignment of approach roads, construction cost, and environmental issues.

As a result of the study, the crossing points of most bridges were decided to be on the upstream side (denoted by “A Route” in the tables below) at the meeting with MOC on 26th December, 2013. For Naung Lon Bridge, B Route was re-examined in order satisfy the geometric design standards and avoid control points such as security posts in accordance with a request from MOC. Finally, B Route was selected for Naung Lon Bridge.

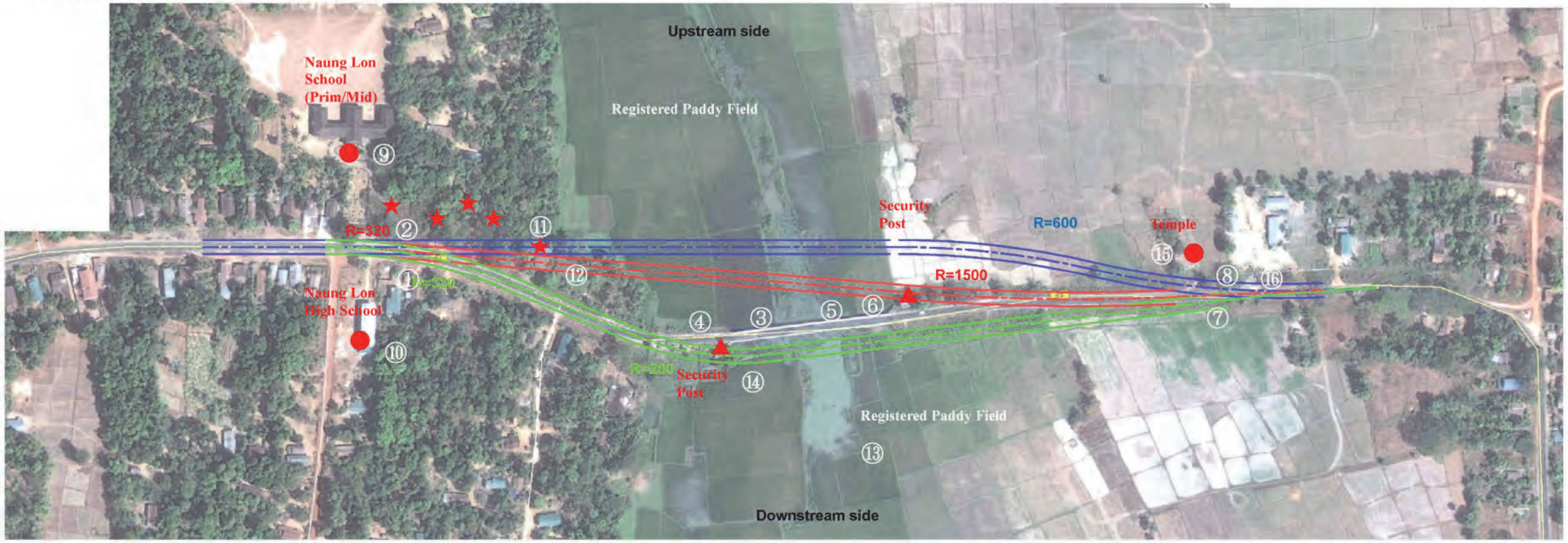
The comparative study for bridge crossing points for each of the four bridges are shown in Table 6.1.1 to Table 6.3.4. After adjusting the alignment to comply with the bridge design standards, the alignment of the approach roads was re-examined on the upstream sides based on the topographic survey conducted in this survey, considering natural and social conditions.

Table 6.3.1 Comparative Study for Bridge Crossing Points for Naung Lon Bridge (Kayin State)

Comparative Crossing Points
- **A Route**: Upstream side of the existing bridge
- **B Route**: Beside the existing bridge
- **C Route**: Downstream side of the existing bridge

Location

★Affected structure ●affected public facilities ▲ affected utilities

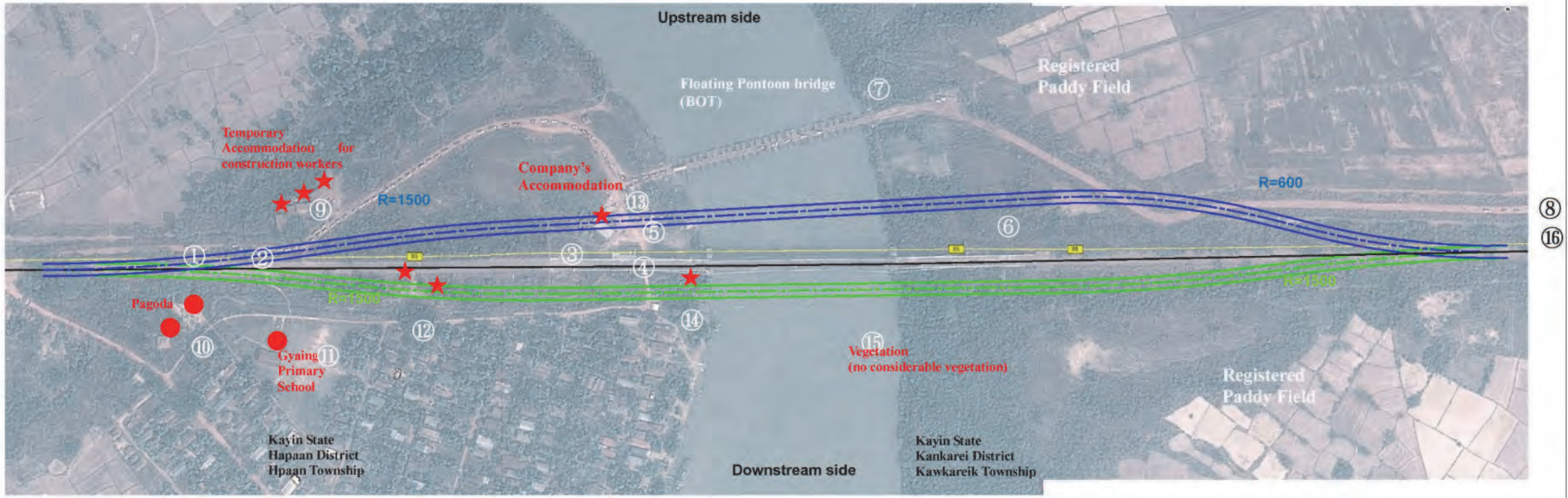


Comparative Crossing Points		A Route: Item	A Route: Assessment	A Route: Rating	B Route: Item	B Route: Assessment	B Route: Rating	C Route: Item	C Route: Assessment	C Route: Rating
Description of Alignment		The straight alignment branching out from the west side of existing road and crosses the upstream side of the existing bridge. After crossing river, it connects the existing road by applying S curve for its approaching.			The alignment branching out by applying curve (R=320) and crosses adjacent upstream of existing bridge. After the crossing river, it connects the existing road by applying one curve.			The alignment branching out nearly west side of the existing bridge crosses the river its downstream side. The alignment tracing over almost halfway of west side of existing road. After the crossing river, it connects straightly east side of existing road.		
Evaluation Criteria	Engineering Aspect	Geometry	Radius of horizontal curve: **R=600m** which secures good visibility of road user.	Good	Geometry	Radius of horizontal curve: **R=320 - 1500m** Curve length of R320m is insufficient.	Poor	Geometry	Absolute minimum radius of curve (**R=200m**) which is inserted in bridge section that is not recommendable technically.	Poor
		Cost effective	Full embankment for approach road would affect the cost. The construction could be carried out separately without detour road.	Fair	Cost effective	Slightly shorter length of approach road would reduce earthworks and land acquisition cost.	Better	Cost effective	The route through mostly over the existing road would reduce the earthworks and land acquisition cost. Need a temporary detour road during the construction.	Fair
	Environmental Aspect	Number of affected structure	Number of structure to be displaced are 1 Estimated number of affected persons are 8 *		Number of affected structure	Number of structure to be displaced are 1 Estimated number of affected persons are 8 *		Number of affected structure	Number of structure to be displaced are 0 Estimated number of affected persons are 0 *	
		Affected public facilities	None		Affected public facilities	None		Affected public facilities	None	
		Affected Utilities	None		Affected Utilities	Security Post		Affected Utilities	Security post	
EVALUATION		Recommendable			Not recommendable			Not recommendable		

*Number of affected person is based on the interview

Source : JICA Survey Team

Table 6.3.2 Comparative Study for Bridge Crossing Points for Gyaing Kawkareik Bridge (Kayin State)

Comparative Crossing Points		A Route Upstream side of the existing bridge			B Route Same as the existing bridge			C Route Downstream side of the existing bridge		
Location		★Affected structure ●affected public facilities ▲ affected utilities 								
Description of Alignment		The route branching out from the west side of exiting road by applying S curve crosses the space between pontoon bridge and upstream side of existing bridge. After the crossing river, it connects the east side of existing road by applying S curve.			The route completely traces over the exiting road and bridge.			The route branching out from the west side of existing road by applying S curve crosses the downstream side of the exiting bridge. The route passes through the village area and connects the east side of existing road by applying S curve.		
Evaluation Criteria	Engineering Aspect	Geometry	Radius of horizontal curve: **R=600 - 1500m**	Good	Geometry	Almost same exiting alignment except the adjustment of vertical profile.	Good	Geometry	Radius of horizontal curve: **R=1500m**	Good
		Cost effective	Require full embankment for the construction of the new approach road on both side of new bridge.	Fair	Cost effective	Need removal of the existing bridge and appropriate temporary detour road and bridge in addition to the existing pontoon during the construction.	Poor	Cost effective	Require full embankment for the construction of the new approach road on both side of new bridge.	Fair
	Environmental Aspect	Number of affected structure	Number of structure to be displaced are 1 Number of Estimated affected persons are 15 *		Number of affected structure	None		Number of affected structure	Number of structure to be displaced are 3 Number of Estimated affected persons are 21 *	
		Affected public facilities	None		Affected public facilities	None		Affected public facilities	None	
		Affected Utilities	None		Affected Utilities	None		Affected Utilities	None	
EVALUATION		Recommendable			Not recommendable			Not recommendable		

Source : JICA Survey Team

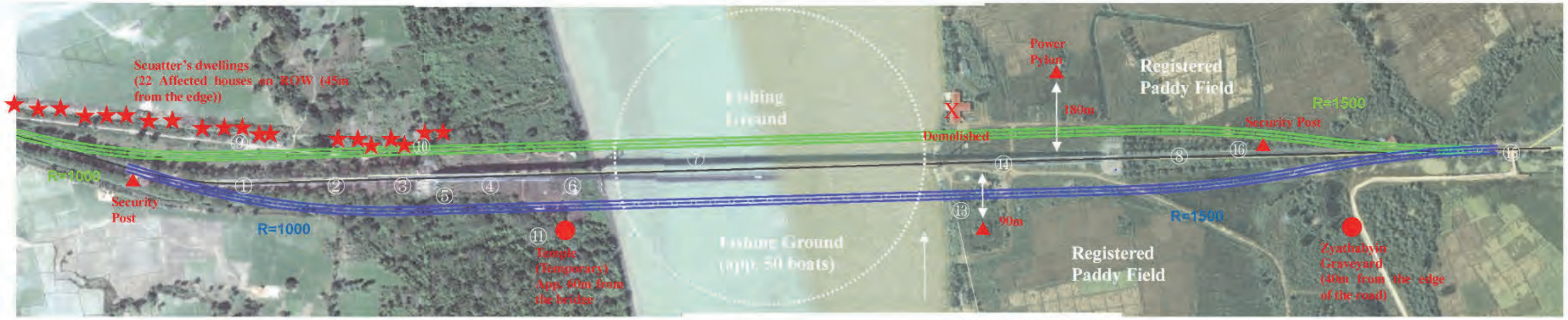
*Number of affected person is based on the interview

Table 6.3.3 Comparative Study for Bridge Crossing Points for Gyaing Zathapyin Bridge (Mon-Kayin State)

Comparative Crossing Points	A Route	B Route	C Route
	Upstream side of the existing bridge	Same as the existing bridge	Downstream side of the existing bridge

★Affected structure ●affected public facilities ▲ affected utilities

Downstream



Upstream

Mon State
Mauramyine District
Kyaikma yaw Township
Latpan village

Kain State
Hpaan District
Hpaan Township
Zarthabyin West Village

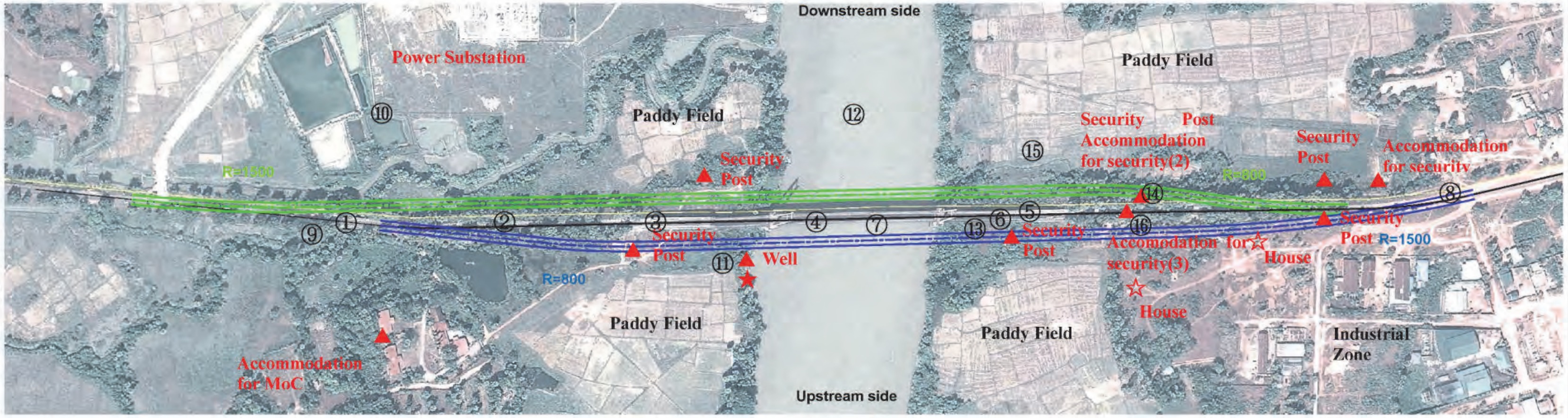
		A Route			B Route			C Route		
Description of Alignment		The route branching out from the south side of existing road by applying a simple curve crosses the upstream side of the existing bridge. After the crossing river, it connects the north side of existing road by applying S curve.			The route completely traces over the exiting road and bridge.			The route branching out from the south side of existing road by applying a simple curve crosses the upstream side of the existing bridge. After the crossing river, it connects the north side of existing road by applying S curve.		
Evaluation Criteria – Engineering Aspect	Geometry	Radius of horizontal curve: **R=1000 - 1500 m**	Good	Geometry	Almost same exiting alignment except the adjustment of vertical profile.	Good	Geometry	Radius of horizontal curve: **R=1000 - 1500 m**	Good	
	Cost effective	Require full embankment for the construction of the new approach road on both sides of new bridge.	Fair	Cost effective	Need removal of the existing bridge and appropriate temporary detour road and bridge before starting the construction.	Poor	Cost effective	Require full embankment for the construction of the new approach road on both sides of new bridge.	Fair	
Evaluation Criteria – Environmental Aspect	Number of affected structure	Number of structure to be displaced are 0 Number of Estimated affected persons are 0 *		Number of affected structure	None		Number of affected structure	Number of structure to be displaced are 22 Number of Estimated affected persons are 88 *		
	Affected public facilities	Temporary temple (60m from the existing bridge)		Affected public facilities	None		Affected public facilities	None		
	Affected Utilities	None		Affected Utilities	None		Affected Utilities	None		
EVALUATION		Recommendable			Not recommendable			Tolerable		

*Number of affected person is based on the interview

Source : JICA Survey Team

Table 6.3.4 Comparative Study for Bridge Crossing Points for Atran Bridge (Mon State)

Comparative Crossing Points		A Route			B Route			C Route		
		Upstream side of the existing bridge			Same as the existing bridge			Downstream side of the existing bridge		
Location		★Affected structure ●affected public facilities ▲ affected utilities (see map below) Mon State Mawlamyine District Mawlamyaine Township Kywe Chan Gone Quarter/ Min Ywa Village						Mon state Mawlamyine District Mawlamyaine Township Mawlamyine Industrial zone / Nyung Pinseik Village		
Description of Alignment		The route crosses branching out from the south side of existing road by applying a simple curve crosses the upstream side of the existing bridge. After the crossing river, it connects the north side of existing road by applying a simple curve.			The route completely traces over the exiting road and bridge.			The route branching out from the south side of existing road by applying S curve crosses the downstream side of the existing bridge. After the crossing river, it connects the north side of existing road by applying S curve.		
Evaluation Criteria	Engineering Aspect	Geometry	Radius of horizontal curve: **R=800 - 1500 m**	Good	Geometry	Almost same exiting alignment except the adjustment of vertical profile.	Good	Geometry	Radius of horizontal curve: **R=800 - 1500 m** Radius will continue three times	Good
		Cost effective	Require full embankment for the construction of the new approach road on left (south) side but partial embankment on right (north) bank.	Good	Cost effective	Need removal of the existing bridge and appropriate temporary detour road and bridge before starting the construction.	Poor	Cost effective	Require full embankment for the construction of the new approach road on both sides of new bridge.	Fair
	Environmental Aspect	Number of affected structure	Number of structure to be displaced are 0 Estimated affected persons are 0 *		Number of affected structure	Number of structure to be displaced are 0 Estimated number of affected persons are 0 *		Number of affected structure	Number of structure to be displaced are 0 Estimated number of affected persons are 0 *	
		Affected public facilities	None		Affected public facilities	None		Affected public facilities	None	
		Affected Utilities	None		Affected Utilities	None		Affected Utilities	None	
EVALUATION		Recommendable			Not recommendable			Not recommendable		



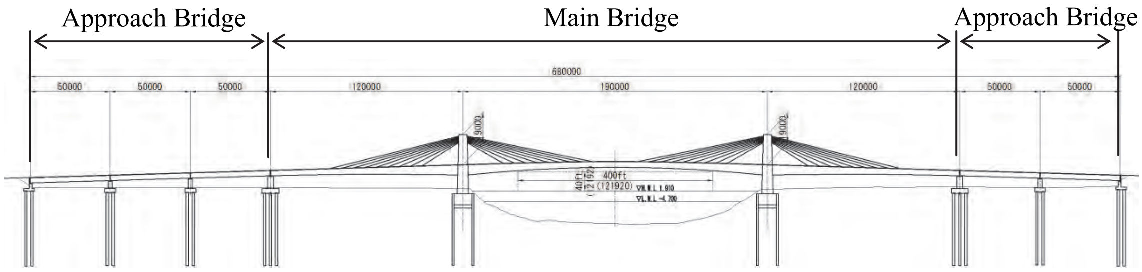
Source : JICA Survey Team

*Number of affected person is based on the interview

6.3.2 Study of Superstructure Type

After a series of discussions between the JICA Study Team and MOC, the bridge types for the four bridges (Naung Lon Bridge, Gyaing Kawkareik Bridge, Gyaing Zathapyin Bridge, and Atran Bridge) were mutually agreed upon on 14th May 2014. The Minutes of Meeting for the selected bridge types was finalized between the parties in the presence of JICA Mission on 15th May 2014.

Gyaing Kawkareik Bridge and Atran Bridge are to be composed of a main bridge and approach bridges on both sides as shown in Figure 6.3.1. The main bridge shall secure navigational clearance above the high water level (HWL) and the approach bridges shall connect the main bridge with the existing roads. The types selected the main bridges have been selected based on the engineering assessment of several criteria including span length, navigation clearance, structural stability, constructability, construction cost, maintenance, technical transfer (introduction of new technology and skills into Myanmar) and aesthetic considerations.



Source: JICA Survey Team

Figure 6.3.1 Bridge Composition

(1) Main Bridge

This section outlines (1) the process used for selection of the bridge superstructure and the criteria used for evaluation; and (2) the selections made through this process, including quantitative results of evaluation.

1) Selection Process

The selection of superstructure has been conducted through the following two steps.

- **First Selection**

Possible superstructure types are selected as candidates in consideration of the span arrangements of the existing bridge, minimum navigation clearance, and the conditions of the river and topography.

- **Second Selection**

The alternatives selected in the first stage were examined and compared using the criteria shown in Table 6.3.5.

Table 6.3.5 Evaluation Criteria of Alternative Bridge Type

	Category	Evaluation Criterion	Maximum Score (Points)
a	Technical Factors (15 points)	Structural Stability	5
b		Constructability	10
c	Economic Factors (65 points)	Construction Cost	50
d		Maintenance	15
e	Other Factors (20 points)	Environment	5
f		Landscape	5
g		Technical Transfer (New Technology)	10
Total Points			100

Source: JICA Survey Team

Table 6.3.6 shows the eligible items for each evaluation criterion and Table 6.3.7 shows the using score (point) ranking to evaluate priority.

Table 6.3.6 Eligible Items for Each Evaluation Criterion

Evaluation Criterion		Considered Items
a	Structural Stability	- Permanent Structure or Temporary structure - Earthquake Resistance and Ease of Travel
b	Constructability	- Construction Period - Ease of Erection Work - Ease of Substructure and Foundation Work
c	Construction Cost	- Construction Cost
d	Maintenance	- Concrete structure (maintenance free) or Steel structure - Ease of Inspection and Maintenance
e	Environment	- Number of affected houses - Negative impact on environment during construction
f	Landscape	- Symbol of local development and/or a landmark of the region
g	Technical Transfer (New Technology)	- Advanced technique, Useful technique or Common technique

Source: JICA Survey Team

Table 6.3.7 Scoring System for Evaluation of Alternative Bridge Type

Evaluation		a. Structural Stability	b. Constructability	c. Construction Cost	
Grade	Rate	(5)	(10)	(50)	
Good	100%	5	10	Scored by the ratio of the construction cost for the most economical alternative	
Fair	50%	3	5		
Poor	20%	1	2		
Evaluation		d. Maintenance	e. Environment	f. Landscape	g. Technical Transfer (New Technology)
Grade	Rate	(15)	(5)	(5)	(10)
Good	100%	15	5	5	Advanced technique: 10
Fair	50%	8	3	3	Useful technique: 5
Poor	20%	3	1	1	Common technique: 2

Source: JICA Survey Team

2) Evaluation Results and Recommendations

a) Naung Lon Bridge

➢ **First selection**

The existing bridge is a continuous reinforced concrete girder bridge with a span length of approximately 12.5m. The navigation clearance is not specifically required. In addition, there are no special conditions for the river or the topography. Therefore, the following four alternatives were compared.

- ✓ Alternative 1: PC-I girders (5@30m=150m)
- ✓ Alternative 2: PC Box girders (4@40m=160m)
- ✓ Alternative 3: Steel I girders (4@40m=160m)
- ✓ Alternative 4: RC girders (10@15m=150m)

- **Second selection**

The evaluation breakdown of superstructure types for Naung Lon Bridge at the second selection stage is shown in Table 6.3.8 and Table 6.3.9. Through this multi-criteria evaluation, Alternative 3: Steel-I Girder Bridge is recommended primarily because it has the most reasonable construction cost and the shortest construction period.

b) Gyaing Kawkareik Bridge

- **First selection**

The main span of the existing bridge is 154m, and the required navigation clearance is 360 feet (110m) x 40 feet (12.2m). The river depth is more than 10m.

Therefore, the following three alternatives were selected.

- ✓ Alternative 1: PC extradosed bridge (Main bridge: 100m + 160m + 100m = 360m)
- ✓ Alternative 2: PC box girder bridge (Main bridge: 90m + 130m + 90m = 310m)
- ✓ Alternative 3: Steel box girder bridge with steel slab (Main bridge: 100m + 160m + 100m = 360m)

- **Second selection**

The evaluation breakdown of superstructure types for Gyaing Kawkareik Bridge at the second selection stage is shown in Table 6.3.10 and Table 6.3.11. Alternative 1: PC extradosed bridge is recommended primarily because of its reasonable construction cost, its contribution to the landscape as a symbolic structure, and the advanced bridge techniques used in its construction.

c) Gyaing Zathapyin Bridge

- **First selection**

The main span of the existing bridge is 457.20m (no piers within the river width), the required navigation clearance is 400 feet (122m) x 40 feet (12.2m), and the river depth is more than 15m. In addition, soil investigations by the JICA survey team observed that the limestone layer underlays at very shallow depth on the river bed. (Refer to Figure 6.3.2.) With this investigation in mind, we decided to select several bridge types for which construction of piers is not required in deep areas of the river, for the following reasons:

- High risks (with regards to cost, safety and reliability) when drilling piles on limestone at a depth of 15m.
- High possibility that the stability of piles can't be secured, due to the presence of hard limestone at extremely shallow depths.
- High risks not only for drilling work of permanent structure but also for construction of a temporary jetty.

(Note that the existing bridge has no piers in deep areas of the river for similar reasons to the above.)

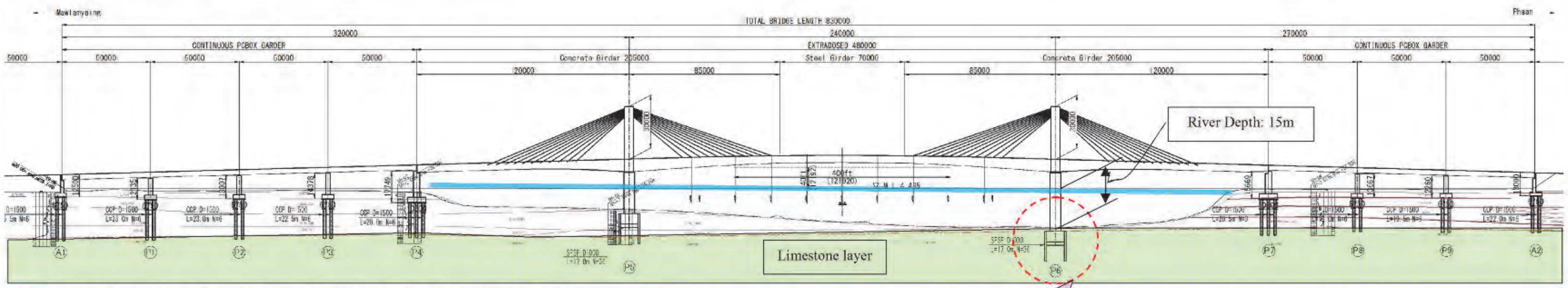
Thus, the alternatives chosen at the first selection stage are:

- ✓ Alternative 1: Steel cable-stayed bridge (210m + 460m + 210m = 880m)
- ✓ Alternative 2: Suspension bridge (210m + 460m + 210m = 880m)

- **Second selection**

The evaluation breakdown of superstructure types for Gyaing Zathapyin Bridge at the second selection stage is shown in Table 6.3.12. Alternative 1: Steel cable-stayed bridge is recommended in consideration of its reasonable construction cost, its contribution to the landscape as a symbolic structure, and the advanced bridge techniques used in its construction.

◆**In case of setting piers inside river (Ex. Hybrid Extra-dosed Bridge)**

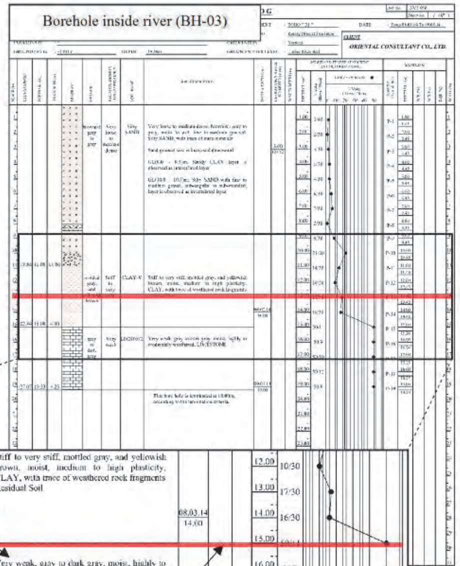


◆**Construction Possiblity of foundation on limestone based on interview of piling company**

There are very high risks for construction of foundation inside river by the following reasons.

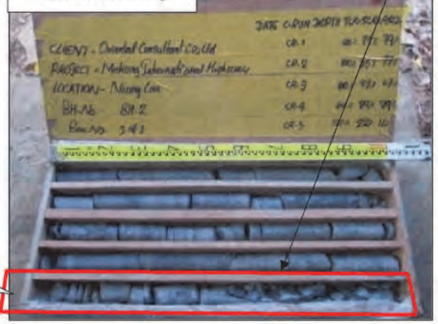
- As a general characteristic of the limestone, it is different in a property every spot and is heterogeneous. Therefore, it cannot identify the lithofacies from the result of the borlinh log.
- The limestone has many uncertain elements (ex. it is sometimes very hard to drill and sometimes can not evaluate as the supporting layer) in design stage from the inhomogeneity. Therefore, it is quite difficult to judge the possibility and/or the method of construction foundation.
- In the construction experiences in Japan, there are some examples which a large change of construction method occured based on the testing piles before the construction. In other words, the differences between design stage and construction stage may be occured in the construction of foundation on limestone.
- In addition, thare are theabove same risks for the construction of temporary jetty.

There are high risks (costly, not safety and low reliability) for the drilling piles on hard limestone with deep water.

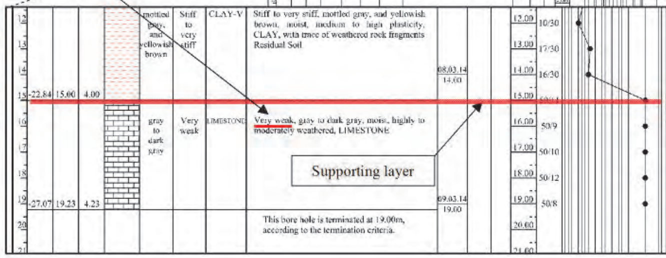


Reratively weak limestone
⇒ But it is quite difficult to grasp the chalactaristic of limestone from the core boring result with small diameter.

Phioto of core boring



The core of the limestone has few points of stick from, and understands that self-subsistence is low



Source : JICA Survey Team

Figure 6.3.2 Construction of Foundation inside River at Gyaing Zathapyin Bridge

d) Atran Bridge

- **First selection**

The main span of the existing bridge is 182m, and the required navigation clearance is 400 feet (122m) x 40 feet (12.2m). The river depth is more than 15m.

Therefore, the following four alternatives were nominated.

- ✓ Alternative 1: PC extradosed bridge (Main bridge: 120m+190m+120m=430m)
- ✓ Alternative 2: PC cable-stayed bridge (Main bridge: 120m+190m+120m=430m)
- ✓ Alternative 3: PC box girder (Main bridge: 90m+130m+90m=310m)
- ✓ Alternative 4: Steel box girder with steel slab (Main bridge: 120m + 190m + 120m = 430m)

- **Second selection**

The evaluation breakdown of superstructure types for Atran Bridge at the second selection stage is shown in Table 6.3.13 and Table 6.3.14. Alternative 1: PC extradosed bridge was chosen in consideration of its reasonable construction cost, its contribution to the landscape as a symbolic structure, and the advanced bridge techniques used in its construction.

(2) Approach Bridge

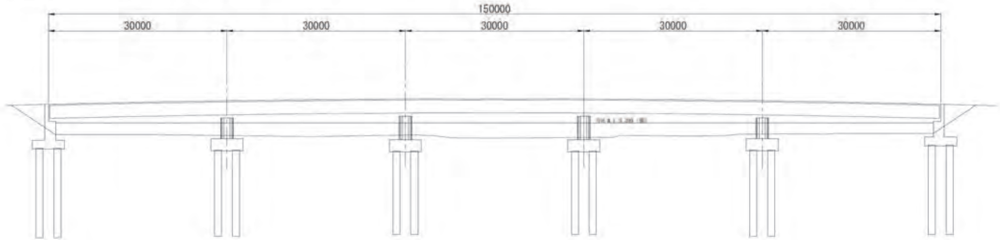
In order to keep continuity with the main bridge, the cross section of the approach bridge is designed based on the cross-section of the main bridge. Therefore, the span length of the approach bridge is set to 40-60m in consideration of girder depth restrictions, economical factors and the introduction of advanced technology in Myanmar.

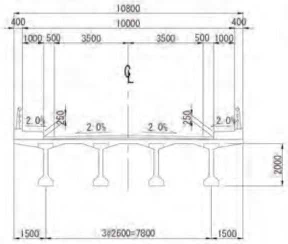
As shown in the previous section, the main superstructure of Naung Lon Bridge is Steel I Girder, the superstructure of Gyaing Zathapyin Bridge is Steel Cable-Stayed, and the superstructures of Gyaing Kawkareik Bridge and Atran Bridge are both PC extradosed (concrete). Therefore, the following types of approach bridges are selected to match with their respective main bridges:

- ✓ Naung Lon Bridge : No approach bridge
- ✓ Gyaing Kawkareik Bridge : Continuous PC Box Girder with 50m span
- ✓ Gyaing Zathapyin Bridge : No approach bridge
- ✓ Atran Bridge : Continuous PC Box Girder with 50m span

Table 6.3.8 Bridge Type Selection for Naung Lon Bridge (1/2)

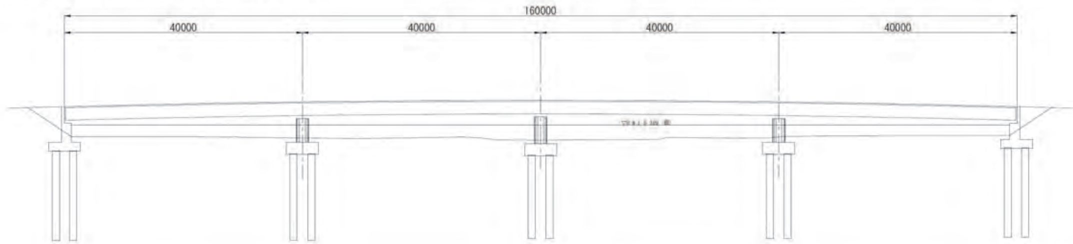
Side View	Typical Section
Alternative-1: PC-I Girder (semi-continuous) **L = 150m (5 x 30m)**	

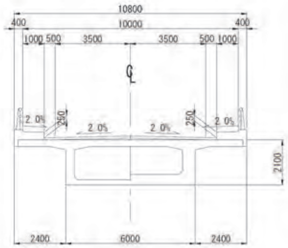




Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans by girder connection are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Heavier girders are disadvantage for erection. Construction period is approximately 13 months.	Fair	5 / 10
Economic Aspect	Construction Cost	7,933,000 USD (μ= 1.23)	----	41 / 50
	Maintenance	Maintenance for PC bridge is almost free except expansion joints and bearing shoes. Annual O&M cost is assumed as 16,730 USD.	Good	15 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of substructure and foundation in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity	----	3 / 5
	Technical Transfer	This type of girder is popular in Myanmar.	Poor	2 / 10
Evaluation		Not recommended		74 / 100

Alternative-2: Continuous PC Box Girder **L = 160m (4 x 40m)**



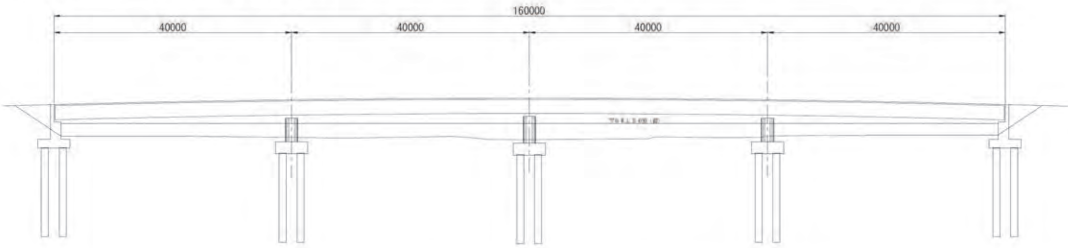


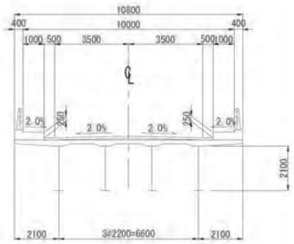
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving	Good	5 / 5
	Constructability	All-staging method is applied and disadvantage for construction safety (on soft ground). Construction period is approximately 19.5 months.	Poor	2 / 10
Economic Aspect	Construction Cost	7,804,500 USD (μ= 1.21)	----	41 / 50
	Maintenance	Maintenance for PC bridge is almost free except expansion joints and bearing shoes. Annual O&M cost is assumed as 15,610 USD.	Good	15 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of substructure and foundation in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity	----	3 / 5
	Technical Transfer	PC Box girder is still useful in Myanmar.	Fair	5 / 10
Evaluation		Not recommended		74 / 100

Source : JICA Survey Team

Table 6.3.9 Bridge Type Selection for Naung Lon Bridge (2/2)

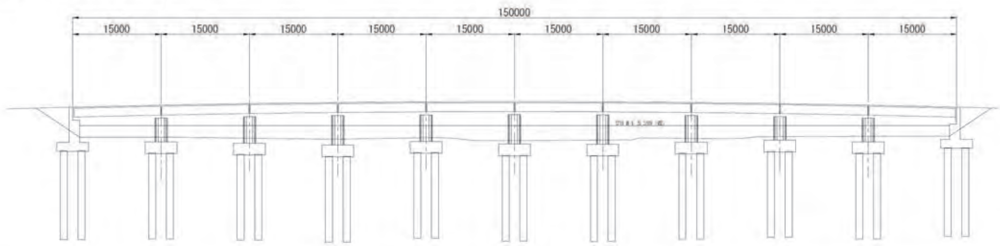
Side View	Typical Section
Alternative-3: Continuous Steel-I Girder L = 160m (4 x 40m)	

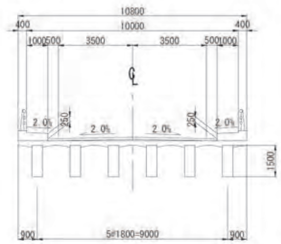




Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. Construction period is approximately 12.6 months.	Good	10 / 10
Economic Aspect	Construction Cost	6,450,000 USD (μ= 1.00)	----	50 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 25,800 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of substructure and foundation in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity.	----	3 / 5
	Technical Transfer	Weathering steel and/or thick anticorrosion painting is new technology.	Good	10 / 10
Evaluation		**Recommended**		89 / 100

Alternative-4: RC-I Girder L = 150m (10 x 15m)	

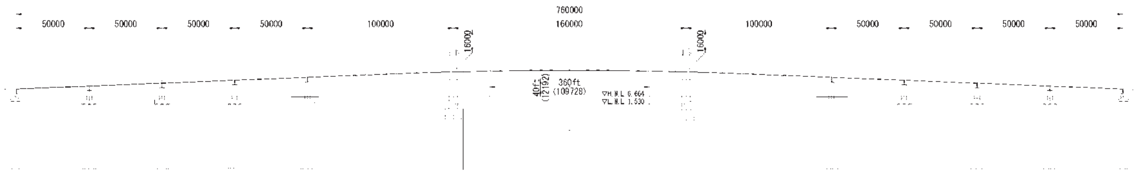
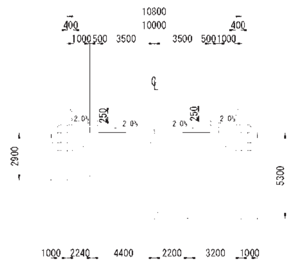




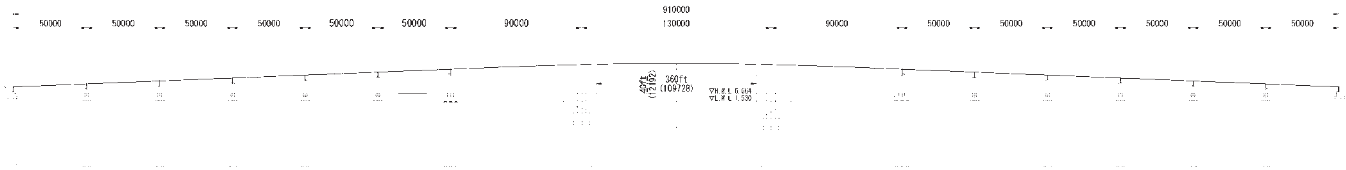
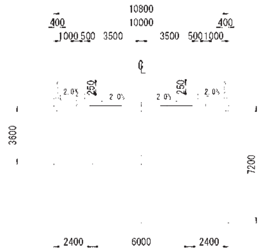
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Simple spans are disadvantage for earthquake resistance and smooth driving.	Fair	3 / 5
	Constructability	Heavier girders are disadvantage for erection. Construction period is approximately 13 months.	Fair	5 / 10
Economic Aspect	Construction Cost	8,350,000 USD (μ= 1.29 [Not economical since it is needed to construct 9piers in the river.])	----	39 / 50
	Maintenance	Rehabilitation of RC girders is required as well as bearings and expansion joints. Annual O&M cost is assumed as 15,730 USD.	Poor	5 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of substructure and foundation in the river (9piers). Due care for water pollution must be taken.	Poor	1 / 5
	Landscape	This type of bridge is relatively visual simplicity.	----	3 / 5
	Technical Transfer	This type of girder is popular in Myanmar.	Poor	2 / 10
Evaluation		Not recommended		58 / 100

Source : JICA Survey Team

Table 6.3.10 Bridge Type Selection for Gyaing Kawkareik Bridge (1/2)

Side View	Typical Section
Alternative-1: Extradosed Bridge L= 760m (4 x 50m + 100m + 160m + 100m + 4 x 50m) 	

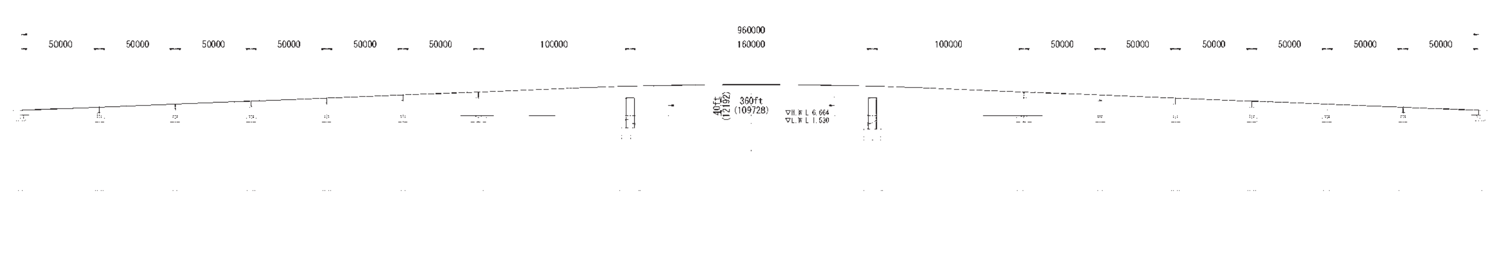
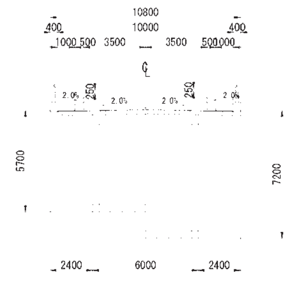
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Cantilever method is applied to girder erection. Construction of foundations and piers are advantageous since they are not constructed in the river of the dry season. Construction period is approximately 32 months (Longest).	Fair	5 / 10
Economic Aspect	Construction Cost	44,100,000 USD (μ=1.00 [Bridge length is shortest due to lower vertical alignment in accordance with lower girder depth. Generally Extradosed bridge is the most economical type for span 150-200m])	---	50 / 50
	Maintenance	Maintenance for outer-cables is required as well as expansion joints and bearings. Annual O&M cost is assumed as 132,300 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	Variable cross section and lower girder height are aesthetical. Main tower has a symbolic value and may become a landmark.	---	5 / 5
	Technical Transfer	Extradosed bridge and Steel pile sheet pile (SPSP) foundation are new technology in Myanmar.	Good	10 / 10
Evaluation		**Recommended**		88 / 100

Side View	Typical Section
Alternative-2: Continuous PC Box Girder L= 910m (6 x 50m + 90m + 130m + 90m + 6 x 50m) 	

Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Cantilever method is a reliable and safety method in the river. Construction of foundations and piers are more disadvantageous than other alternatives since they are constructed in the river. Construction period is approximately 28 month.	Fair	5 / 10
Economic Aspect	Construction Cost	56,400,000 USD (μ= 1.28 [Bridge length is longer due to higher vertical alignment in accordance with higher girder depth])	---	39 / 50
	Maintenance	Maintenance for PC bridge is almost free except expansion joints and bearing shoes. Annual O&M cost is assumed as 112,800 USD.	Good	15 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	Variable cross section is aesthetical, but inferior to extradosed bridge as a symbolic structure due to main towers.	---	3 / 5
	Technical Transfer	Steel pile sheet pile (SPSP) foundation is new technology and PC Box girder is still useful in Myanmar.	Fair	5 / 10
Evaluation		Not recommended		77 / 100

Source : JICA Survey Team

Table 6.3.11 Bridge Type Selection for Gyaing Kawkareik Bridge (2/2)

Side View	Typical Section
Alternative-3: Continuous Steel Box Girder with Steel Plate Deck **L= 960m (6 x 50m + 100m + 160m + 100m + 6 x 50m)** 	

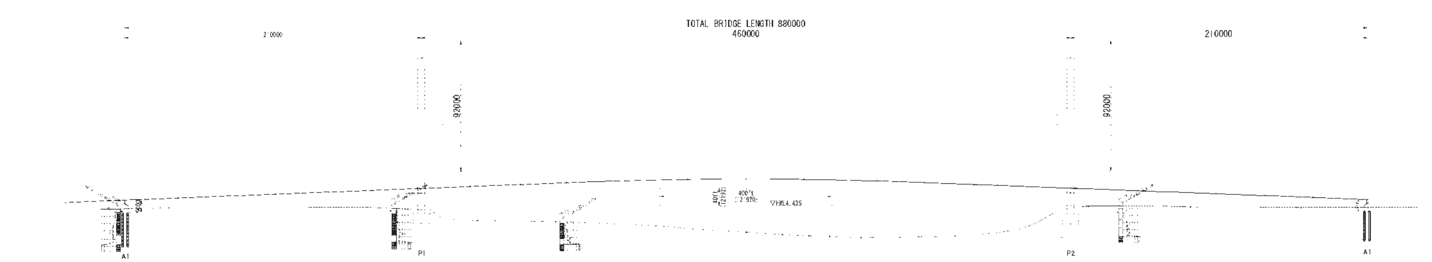
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. Construction of foundation and piers are advantageous since they are not constructed in the river of the dry season. Construction period is approximately 26 months.	Good	10 / 10
Economic Aspect	Construction Cost	55,100,000 USD (μ= 1.25 [Bridge length is longer due to higher vertical alignment in accordance with higher girder depth])	---	40 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as193,000 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	Variable cross section is aesthetical, but inferior to extradosed bridge as a symbolic structure due to main towers.	---	3 / 5
	Technical Transfer	Steel box girder with steel plate deck, weathering steel, thick anticorrosion painting and Steel Pile Sheet Pile (SPSP) are new technology in Myanmar.	Good	10 / 10
Evaluation		Not Recommended		81 / 100

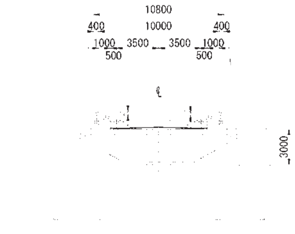
Source : JICA Survey Team

Table 6.3.12 Bridge Type Selection for Gyaing Zathapyin Bridge

Side View	Typical Section

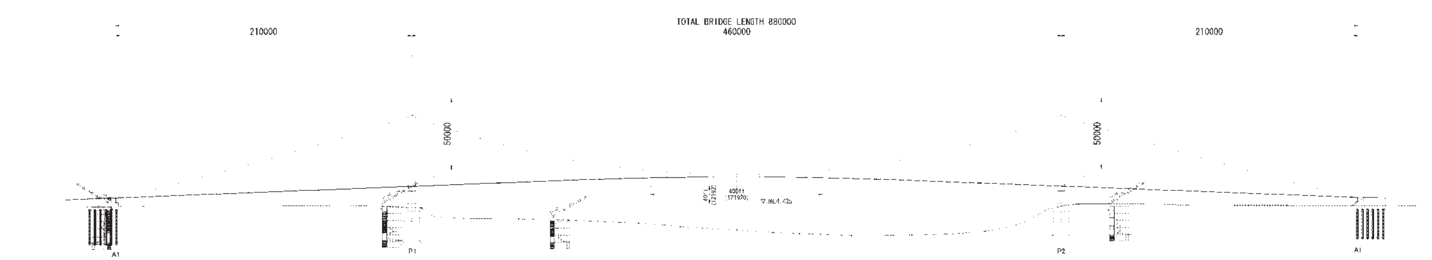
Alternative-1: Steel Cable-stayed Bridge L = 880m (210m + 460m + 210m)

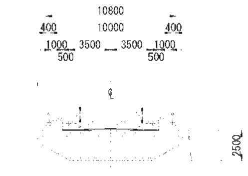




Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Steel cable stay and continuous steel box girders are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Erection of cable stay and steel bridges are performed from barge mounted crane. Construction period is approximately 43 months.	Good	10 / 10
Economic Aspect	Construction Cost	75,140,000 USD (μ= 1.00)	---	50 / 50
	Maintenance	Maintenance for stay-cables is required as well as expansion joints and bearings. Although repainting for steel girder is required in every 30 years, it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 150,280 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	Excellent view, it can be a symbolic structure due to high towers.	---	5 / 5
	Technical Transfer	Steel cable stay, box girder with steel deck slab, Steel pile sheet pile (SPSP) foundation, weathering steel and thick anticorrosion painting are new technology in Myanmar.	Good	10 / 10
Evaluation		**Recommended**		93 / 100

Alternative-2: Suspension Bridge L = 880m (210m + 460m + 210m)

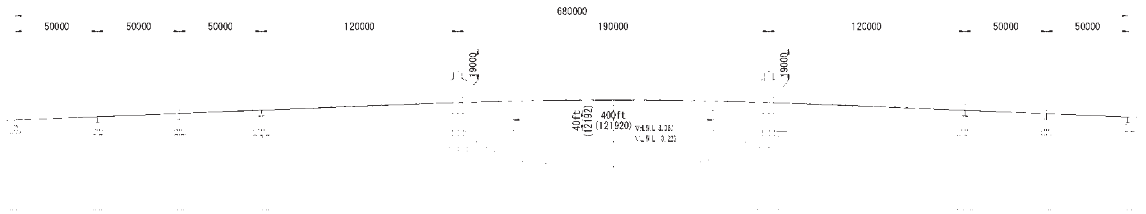
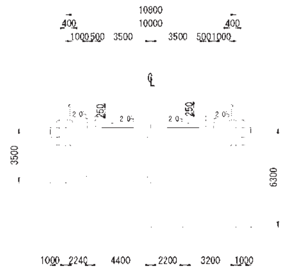




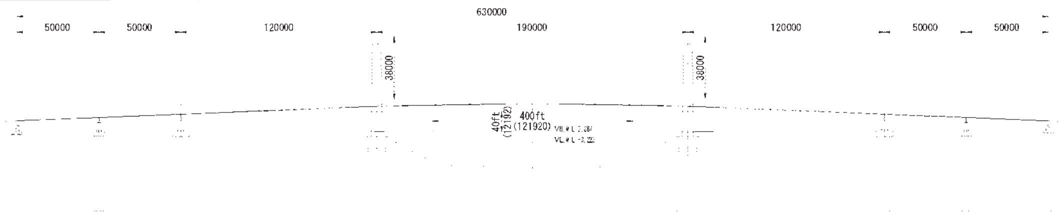
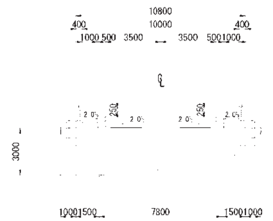
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Suspension structure with continuous steel box girder is structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Cantilever method is a reliable and safety method in the river. Construction of anchorages (A1 & A2) needs time and is required monitoring for long time after completion because they are mass concrete. Construction period is approximately is approximately 46 month.	Fair	5 / 10
Economic Aspect	Construction Cost	107,450,000 USD (μ= 1.43)	---	35 / 50
	Maintenance	Maintenance for cables is required as well as expansion joints and bearings. Although repainting for steel girder is required in every 30 years, it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. O&M cost is assumed as 214,900 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses. Negative influence on water quality to construct piers and foundations in the river.	Good	5 / 5
	Landscape	Excellent view, it can be a symbolic structure due to high towers.	---	5 / 5
	Technical Transfer	Box girder with steel deck slab, Steel pile sheet pile (SPSP) foundation, weathering steel and thick anticorrosion painting are new technology in Myanmar.	Good	10 / 10
Evaluation		Not recommended		73 / 100

Source : JICA Survey Team

Table 6.3.13 Bridge Type Selection for Atran Bridge (1/2)

Side View	Typical Section
Alternative-1: Extradosed Bridge **L= 680m (3 x 50m + 120m + 190m + 120m + 2 x 50m)** 	

Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Cantilever method is applied to girder erection. Construction of foundations and piers are advantageous since they are not constructed in the river of the dry season. Construction period is approximately 37 months (Moderate).	Fair	5 / 10
Economic Aspect	Construction Cost	40,010,000 USD (μ= 1.00 [Bridge length is shorter due to lower vertical alignment in accordance with lower girder depth. Generally Extradosed bridge is the most economical type for span 150-200m])	---	50 / 50
	Maintenance	Maintenance for outer-cables is required as well as expansion joints and bearings. Annual O&M cost is assumed as 83,800 USD.	Fair	8 / 15
Other Aspect	Environment	Almost affected houses.	Good	5 / 5
	Landscape	Extradosed bridge is excellent view, to be a symbolic structure due to main towers.	---	5 / 5
	Technical Transfer	Extradosed bridge and Steel pile sheet pile (SPSP) foundation are new technology in Myanmar.	Good	10 / 10
Evaluation		**Recommended**		88 / 100

Side View	Typical Section
Alternative-2: PC Cable Stayed Bridge **L= 630m (2 x 50m + 120m + 190m + 120m + 2 x 50m)** 	

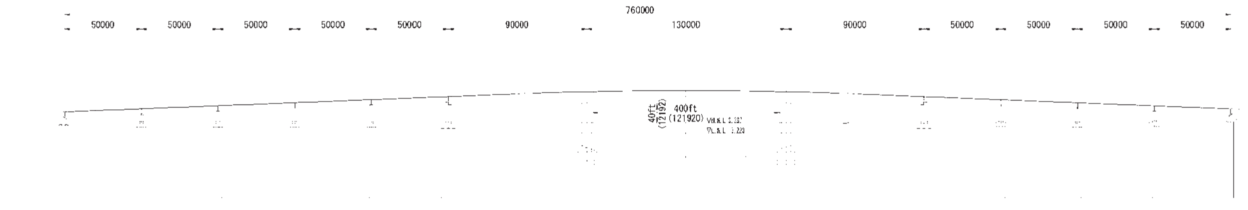
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Erection of cable stay is performed from barge mounted crane Cast-in-place concrete cantilever method is applied for girder erection. Construction period is approximately 39 months (Longest).	Fair	5 / 10
Economic Aspect	Construction Cost	46,812,000 USD (μ= 1.17 [More PC cables are needed for cable stayed bridge.])	---	43 / 50
	Maintenance	Maintenance for stay-cables is required as well as expansion joints and bearings. Annual O&M cost is assumed as 93,630 USD.	Fair	8 / 15
Other Aspect	Environment	Almost affected houses.	Good	5 / 5
	Landscape	Cable-stayed bridge is excellent view and symbolic structure due to high towers.	---	5 / 5
	Technical Transfer	Steel pile sheet pile (SPSP) foundation and PC cable-stayed Bridge are new technology in Myanmar. .	Good	10 / 10
Evaluation		Not recommended		81 / 100

Source : JICA Survey Team

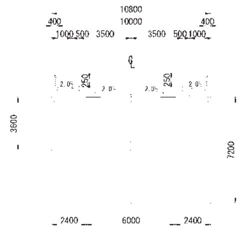
Table 6.3.14 Bridge Type Selection for Atran Bridge (2/2)

Alternative-3: Continuous PC Box Girder L = 760m (5 x 50m + 90m + 130m + 90m + 4 x 50m)

Side View

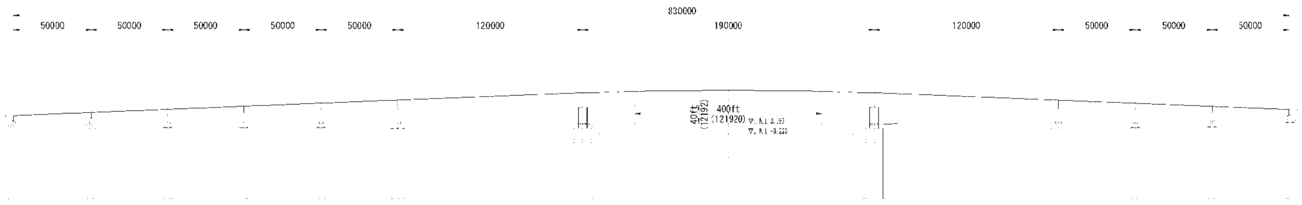


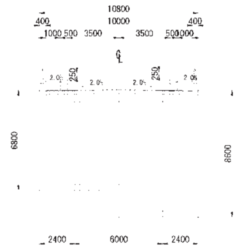
Typical Section



Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving	Good	5 / 5
	Constructability	Cantilever method is a reliable and safety method in the river. Construction of foundations and piers are more disadvantageous than other alternatives since 2 piers are constructed in the river. Construction period is approximately 35 months (Moderate).	Fair	5 / 10
Economic Aspect	Construction Cost	44,411,000 USD (μ= 1.11 [Bridge length is longer due to higher vertical alignment in accordance with higher girder depth])	---	45 / 50
	Maintenance	Maintenance for PC bridge is almost free except expansion joints and bearing shoes. Annual O&M cost is assumed as 88,830 USD.	Good	15 / 15
Other Aspect	Environment	Almost no affected houses. Negative influence on water quality to construct piers and foundations in the river.	Fair	3 / 5
	Landscape	Variable cross section is aesthetical, but inferior to cable stayed bridge and extradozed bridge as a symbolic structure.	---	3 / 5
	Technical Transfer	Steel pile sheet pile (SPSP) foundation is new technology and PC Box girder is still useful in Myanmar.	Fair	5 / 10
Evaluation		Not recommended		81 / 100

Alternative-4: Continuous Steel Box Girder with Steel Plate Deck L = 830m (5 x 50m + 120m + 190m + 120m + 3 x 50m)





Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. Construction of foundations and piers are advantageous since they are not constructed in the river. Construction period is approximately 33 months (Shortest).	Good	10 / 10
Economic Aspect	Construction Cost	47,212,000 USD (μ= 1.18 [Bridge length is longer due to higher vertical alignment in accordance with higher girder height])	---	42 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 165,250 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	Variable cross section is aesthetical, but inferior to cable stayed bridge and extradozed bridge as a symbolic structure.	---	3 / 5
	Technical Transfer	Steel pile sheet pile (SPSP) foundation , Steel box girder with steel plate deck, weathering steel and thick anticorrosion painting are new technology in Myanmar	Good	10 / 10
Evaluation		Not Recommended		83 / 100

Source : JICA Survey Team

6.3.3 Study of Foundation Type and Substructure Type

Due to different design conditions, two different foundation type studies have been conducted: one for foundations within rivers, and another for foundations on land.

(1) Foundations within river

The selection of foundation type in river shall be carefully considered taking into account specific criteria and natural conditions:

- ✓ The water depth for proposed bridge sites
- ✓ Possibility of scouring (sufficient attention must be paid to scouring)
- ✓ Supporting load of foundation
- ✓ Depth of the supporting layer

Table 6.3.15 shows the applicable foundation types.

Table 6.3.15 Applicable Foundation Types (inside River) for Gyaing Kawkareik Bridge, Gyaing Zathapyin Bridge, Atran Bridge

Criteria \ Applicable Foundation Type			Cast- in-place Concrete Pile	PHC / SC PIle	Steel Pipe Pile	Diaphragm wall	Steel pipe sheet pile	Caisson
Condition of Construction	Temporary Jetty	Depth < 5 m	△	○	○	×	○	△
		Depth > 5 m	△	△	○	×	○	△
	Environment	Vibration, Noise	○	×	×	○	△	○
		Impact on Adjacent Structure	○	×	△	○	△	△
	Loading	Normal	○	○	○	○	○	○
		Large	○	×	○	○	○	○
Ground Condition	Depth of Supporting Layer from Ground Level	< 5 m	△	×	×	×	×	×
		5 ~ 15 m	○	○	○	△	△	○
		15 ~ 25 m	○	○	○	○	○	○
		25 ~ 40 m	○	○	○	○	○	○
		40 ~ 60 m	○	△	○	○	○	○
		≥ 60 m	△	×	△	△	△	△
	Soil Condition	Clay (20 ≤ N)	○	○	○	○	○	○
		Sand/Gravel (30 ≤ N)	○	○	○	○	○	○

NOTE ○: Suitable, △: Possible, ×: Impossible

Source: JRA

Four different foundation types such as Cast-in-Place Concrete Pile (CPCP), Steel Pipe Pile (SPP), Steel Pipe Sheet Pile (SPSP) and Concrete Caisson (CC) can be applied for the foundations of Gyaing Kawkareik Bridge, Gyaing Zathapyin Bridge, and Atran Bridge in accordance with Table 6.3.15. SPSP can be used not only as a permanent foundation, but also as a temporary cofferdam during river works. The application of SPSP would therefore be more reasonable than that of SPP in terms of saving cost and shortening construction time. Hence, we can narrow down the foundation types to be compared to three (CPCP, SPSP and CC).

CPCP, as shown in Figure 6.3.3, is very common in Myanmar. However, this type tends not to be economical in large-scale bridges, since the required number of piles becomes excessive.

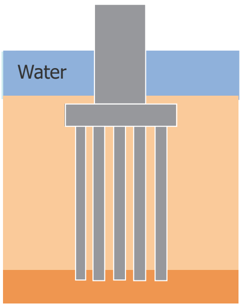
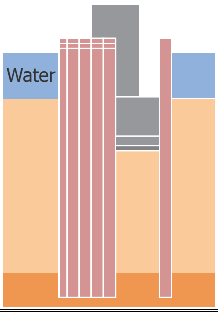
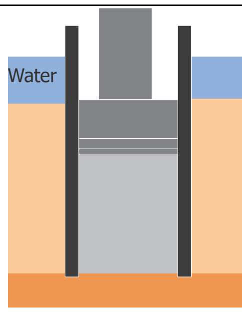
Source: JICA Survey Team

Figure 6.3.3 Foundation Type of Existing Bridges

For Gyaing Kawkareik, Gyaing Zathapyin, and Atran Bridge, the CPCP foundation, which is common in Myanmar, is not economical since i) construction period for pile cap is restricted to the dry season so that the period might be extended ii) the number of required piles is will be high due to the considerable pile length from the riverbed iii) stand pipes are necessary for the piles above the riverbed. Accordingly, the CPCP with pile-cap constructed under the riverbed is nominated to be an alternative foundation type.

Table 6.3.16 shows the general comparison of foundation types inside river, suggesting that Steel Pipe Sheet Pile (SPSP) foundations have some advantages comparatively. However, a more comprehensive comparison of the foundation types using actual dimensions and site specifications, as seen in later tables, is necessary.

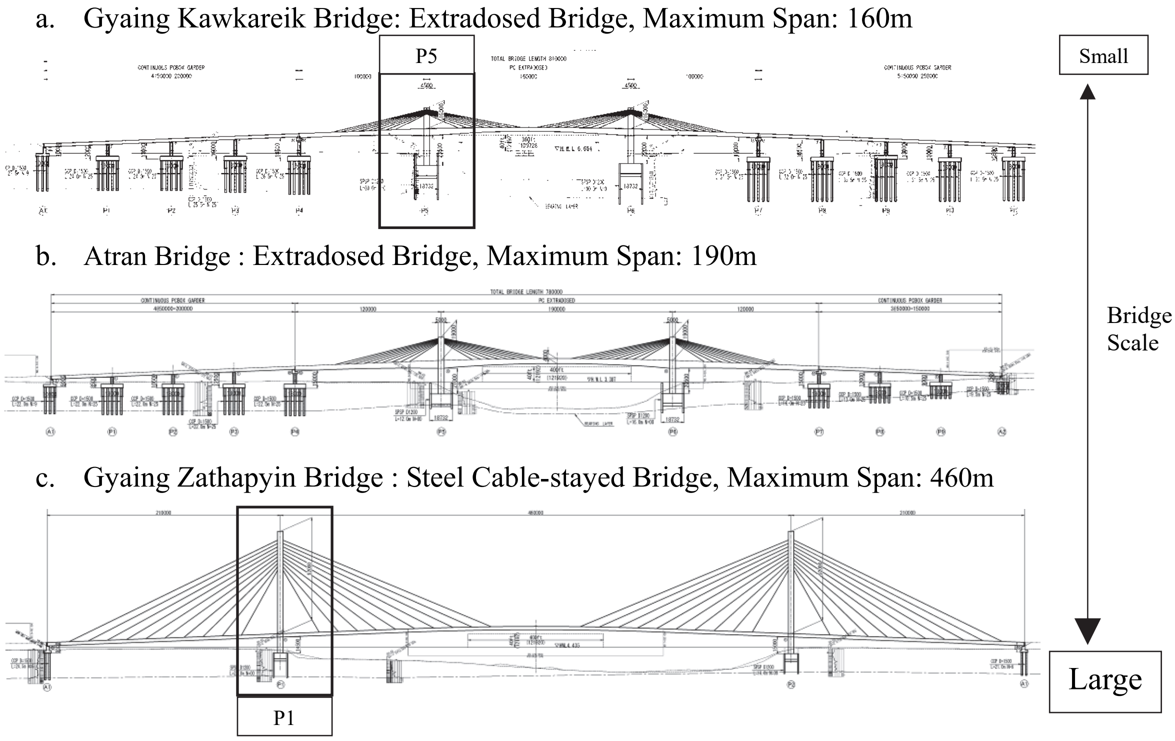
Table 6.3.16 General Comparison of Foundation Types inside River

	Cast in Place Concrete Pile	Steel Pipe Sheet Pile (SPSP)	Concrete Caisson
Foundation Type			
Workability on Water	**Inferior** -Temporary cofferdam is required separately. -Permanent casing is required. -Loading test is required.	**Superior** -Temporary cofferdam is not required separately. -Loading test is not required.	**Moderate** -Temporary cofferdam is not required separately. -Loading test is not required.
Work Period	**Moderate** - Driving of many piles takes time.	**Superior** - After driving steel pipe, construction is fast and safe.	**Moderate** -It takes time for excavation.
Against Ship Collision	**Inferior** -Because multi-pile structure.	**Superior** -Because rigid and massive structure.	
Against Scoring	**Inferior** -Because multi-pile structure.	**Superior** -Because rigid and massive structure.	
Safety of Works	**Moderate** -Temporary cofferdam is required separately.	**Superior** -Temporary cofferdam is not required separately.	
Cost	Depends on bridge scale (reaction force). When the reaction force of superstructure is large, SPSP and Caisson becomes often advantageous.		
Experience in Myanmar	**Much** - No introduction of new technology	**None** -New technology and technical transfer can be expected	**Some** - No introduction of new technology.
Evaluation	- Despite being the cheapest construction, there would be other inferior aspects. "Not Recommended"	- Despite of higher construction cost for cast in place concrete pile, there would be other superior aspects. - Technical transfer can be expected since it is the first challenge in Myanmar. "**Recommended**"	- Despite the higher construction cost for cast in place concrete pile, there would be some superior aspects. - Some inferior aspects are related to steel pipe sheet pile. "Not Recommended

Source: JICA Survey Team

Table 6.3.17 and Table 6.3.18 show respectively the results of comparative studies for three foundation types for Gyaing Kawkareik Bridge (P5) and Gyaing Zathapyin Bridge (P1).

The piers of Atran Bridge (P5 and P6) are expected to undergo a vertical load on its piers larger than that of Gyaing Kawkareik Bridge (P5) and smaller than Gyaing Zathapyin Bridge (P1) (as shown below by comparing span lengths). Hence, the selection of its foundation type can be based on the results of these two evaluations.



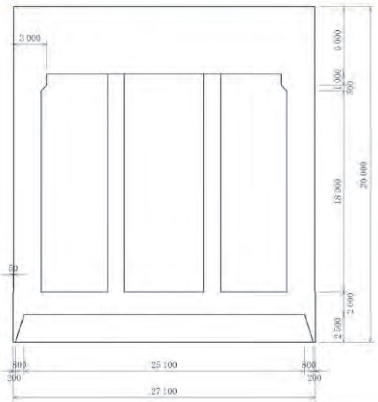
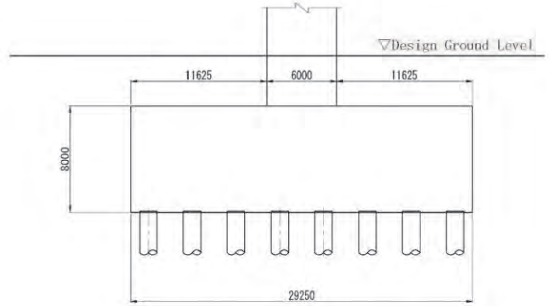
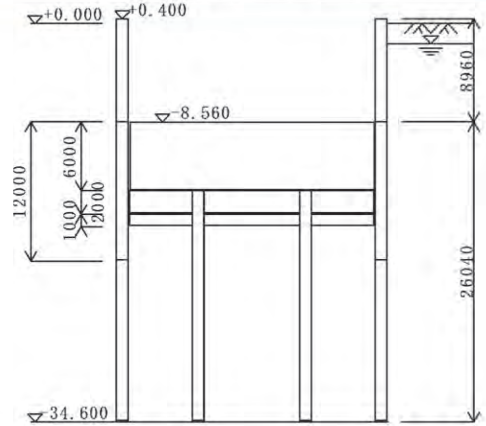
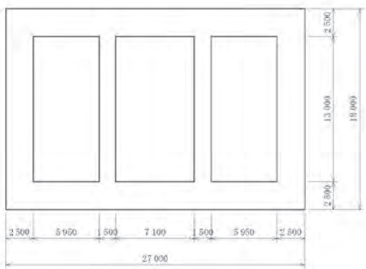
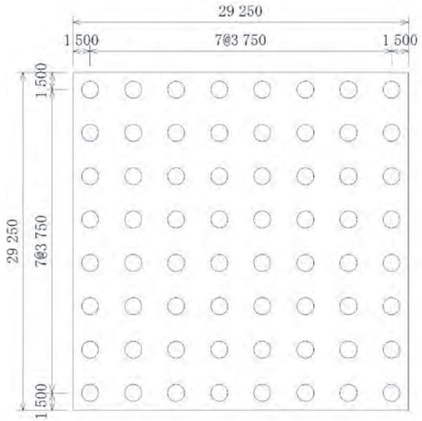
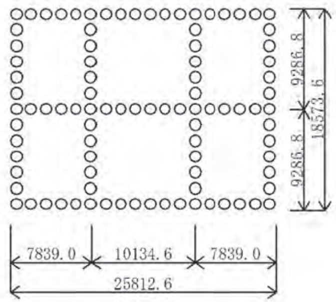
CPCP (the most common foundation type in Myanmar) can be applied as the foundation type for Naung Lon Bridge since the expected loading force is relatively small.

(2) Foundations on land

Cast-in-place concrete piled foundations were selected for the foundation types of piers and abutments on land (to be constructed on existing ground), due to their ease of constructability and procurement of materials/equipment as well as the experience in Myanmar.

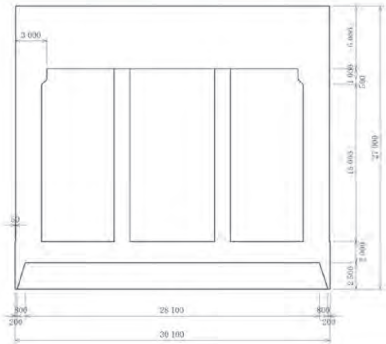
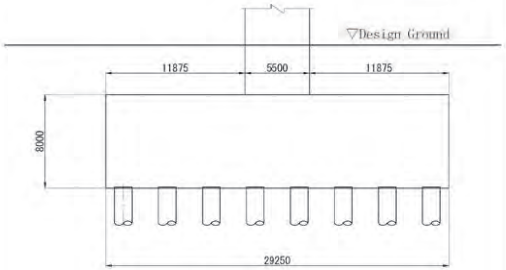
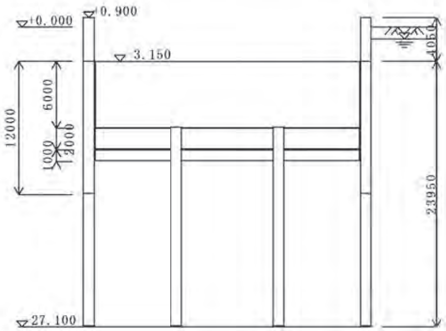
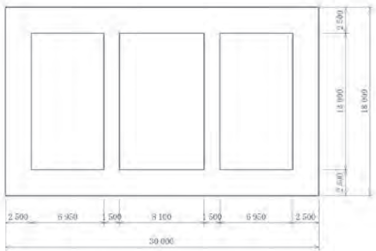
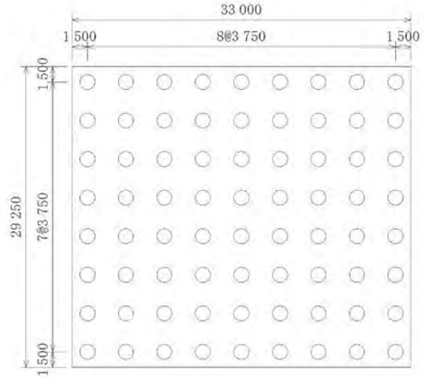
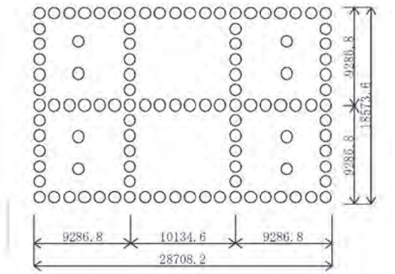
The diameter of the cast-in-place concrete pile at Gyaing Kawkareik Bridge was selected using a comparative analysis (as seen in Table 6.3.20), and this selected pile diameter is also used for other land foundations.

Table 6.3.17 Comparison of Foundation Types at Gyaing Kawkareik Bridge (P5)

		Alt-1: Neumatic Caisson	Alt-2: Cast-in-Place Concrete Pile（φ1500）	Alt-3: Steel Pipe Sheet Pile（φ1200）
Figure				
	Plan			
Shape		■Foundaion ・Neumatic Caisson, 27.0m x 18.0m x 30.0m	■Foundaion ・Cast-in-place concrete pile, φ1500-64, L=16.5m ・Pile Cap 29.25m x 29.25m x 8.00m	■Foundaion ・Steel pipe sheet pile, φ1200-94, 25.8m x 18.6m x 26.0m
Cost (ratio)		**4,014,000 USD** **(1.608)**	**4,206,000 USD** **(1.685)**	**2,496,000 USD** **(1.000)**
Evaluation		・It becomes the neumatic caisson since the width of foundation more than 18m. ・It needs large-scale facilities at the time of construction ・It inferior to SPSP in economical aspect Not Recommended	・The number of piles are so many(64piles), and it isn't realistic for construction ・The length of temporary jetty and cofferdam becomes longer than others since the width of pile-cap becomes very large ・It inferior to others in economical aspect Not Recommended	・Construction period can be shorten since it does not need a temporay cofferdam ・It superior to others in economical aspect Recommended

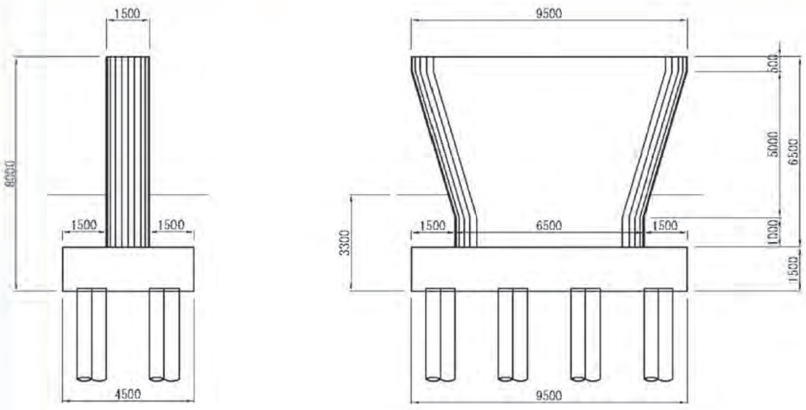
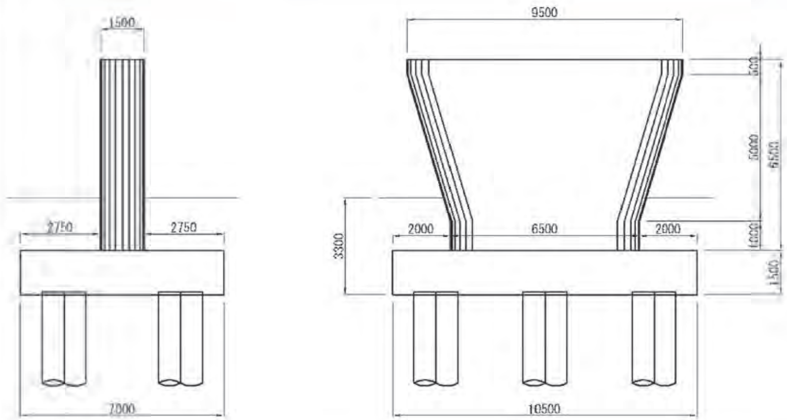
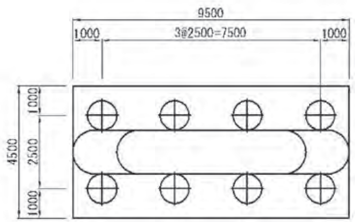
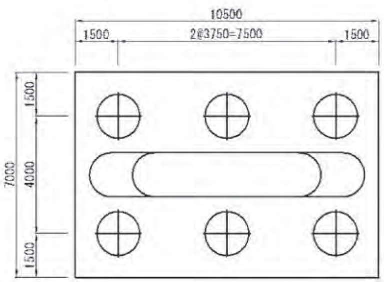
Source : JICA Survey Team

Table 6.3.18 Comparison of Foundation Types at Gyaing Zathapyin Bridge (P1)

	Alt-1: Neumatic Caisson	Alt-2: Cast-in-Place Concrete Pile（φ1500）	Alt-3: Steel Pipe Sheet Pile（φ1200）
Figure			
	Plan 	Plan 	Plan 
Shape	■Foundaion ・Pneumatic Caisson, 30.0m x 18.0m x 27.0m	■Foundaion ・Cast-in-place concrete pile, φ1500-72, L=15.5m ・Pile Cap 29.25m x 33.0m x 8.0m	■Foundaion ・Steel pipe sheet pile, φ1200-108, 28.7m x 18.6m x 24.0m
Cost (ratio)	**4,736,000 USD (1.608)**	**4,963,000 USD (1.685)**	**2,946,000 USD (1.000)**
Evaluation	・It becomes the neumatic caisson since the width of foundation more than 18m. ・It needs large-scale facilities at the time of construction ・It inferior to SPSP in economical aspect Not Recommended	・The number of piles are so many(72piles), and it isn't realistic for construction ・The length of temporary jetty and cofferdam becomes longer than others since the width of pile-cap becomes very large ・It inferior to others in economical aspect Not Recommended	・Construction period can be shorten since it does not need a temporay cofferdam ・It superior to others in economical aspect Recommended

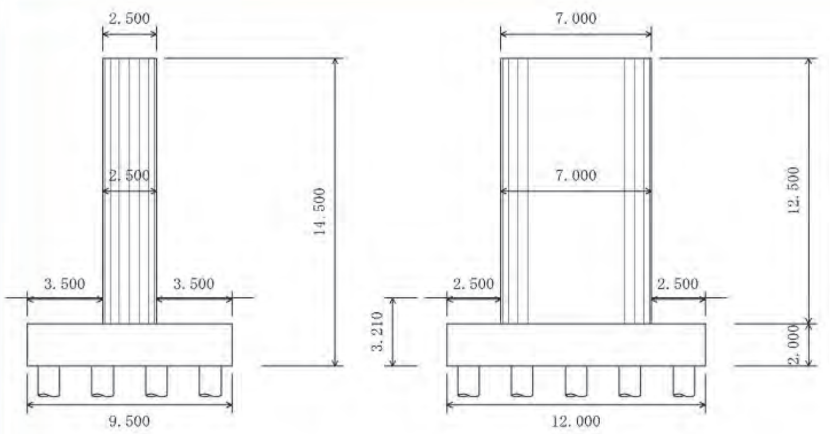
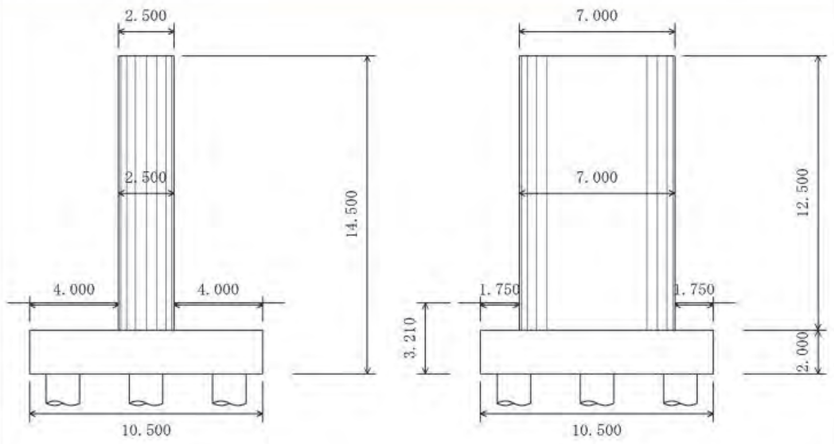
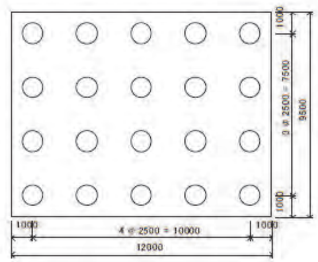
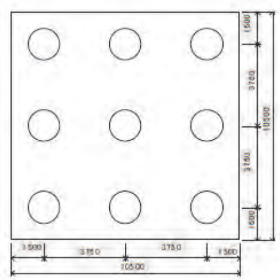
Source : JICA Survey Team

Table 6.3.19 Comparison of Diameter of Cast-in-place Concrete Pile at Naung Lon Bridge (P2)

	Alt-1: Cast-in-Place Concrete Pile (φ1000)	Alt-1: Cast-in-Place Concrete Pile (φ1500)
Figure		
		
Shape	･1000×8nos, L=27.0m	･φ1500×6nos, L=27.5m
Cost (ratio)	**135,200 USD (1.000)**	**177,400 USD (1.312)**
Evaluation	･ The size of pile cap is smaller than Alt-2, and it can mitigate negative impact on environment since the area of excavation is smaller than Alt-2 ･ It superior to Alt-2 in economical aspect Recommended	･ The size of pile cap is larger than Alt-1, and it has larger negative impact than Alt-1 on environment since the area of excavation is larger than Alt-1 ･ It inferior to Alt-1 in economical aspect Not Recommended

Source : JICA Survey Team

Table 6.3.20 Comparison of Diameter of Cast-in-place Concrete Pile at Gyaing Kawkareik Bridge (P10)

	Cast-in-Place Concrete Pile (φ1000)	Cast-in-Place Concrete Pile (φ1500)
Figure		
	Plan 	Plan 
Shape	・Cast-in-place concrete pile, φ1000, n=20, L=34.0m	・Cast-in-place concrete pile, φ1500, n=9, L=34.0m
Cost (ratio)	**327,700 USD** **(1.181)**	**277,500 USD** **(1.000)**
Evaluation	・ The size of pile cap is larger than Alt-2, and it has larger negative impact than Alt-2 on environment since the area of excavation is larger than Alt-2 ・ It inferior to Alt-2 in economical aspect Not recommended	・ The size of pile cap is smaller than Alt-1, and it can mitigate negative impact on environment since the area of excavation is smaller than Alt-1 ・ It superior to Alt-1 in economical aspect Recommended

Source : JICA Survey Team

6.4 Preliminary Design for Approach Road

6.4.1 Alignment Setting of Approach Roads

The location of new bridges was decided to be on the upstream side of the existing bridge at the meeting with MOC on 26th of December, 2013. Therefore the alignment of approach roads should be designed to connect the bridge in consideration of both natural and social condition. The design outcomes for each approach road are summarized below.

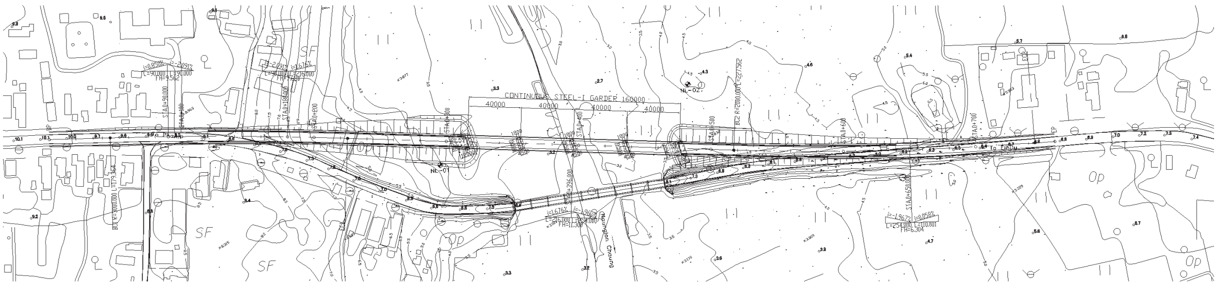
(1) Naung Lon Bridge

1) Horizontal Alignment Setting

Horizontal alignment of the approach road was determined taking into account the following condition.

- The horizontal alignment of existing road including the existing Naung Lon Bridge is adopted with an S curve. The alignment of the new road is to be connected with the existing road by using a curve with more than 2000m radius in which the transition curve can be omitted.

Horizontal alignment of the approach road is shown in Figure 6.4.1.



Source: JICA Survey Team

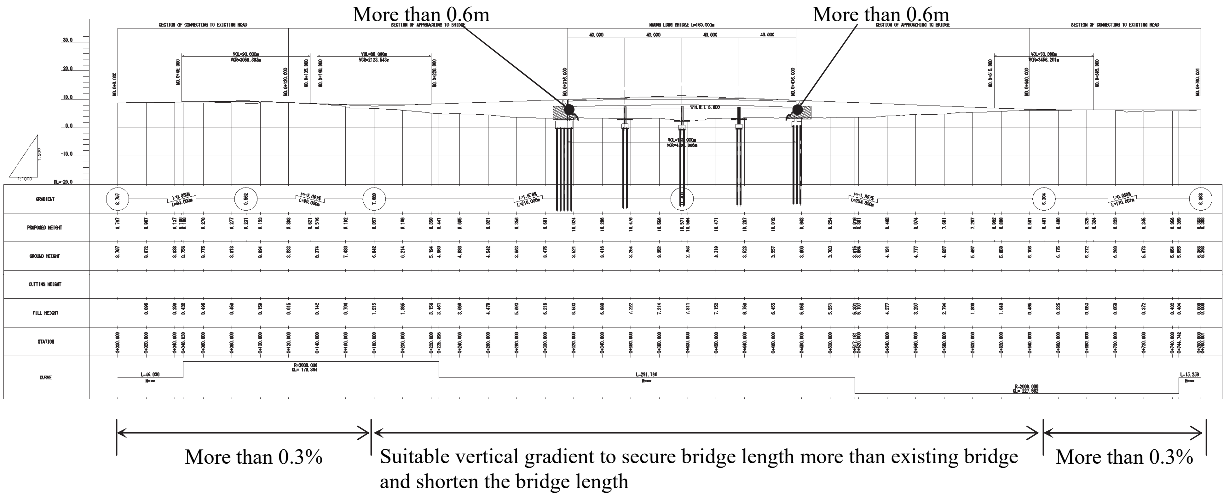
Figure 6.4.1 Horizontal Alignment of Naung Lon Bridge

2) Vertical Alignment Setting

The vertical alignment of the approach road is determined in accordance with the following conditions:

- Marginal clearance between girder bottom and H.W.L. must be more than 0.6m.
- A suitable vertical gradient must be applied to secure existing river width and to minimize the bridge length.
- A minimum vertical gradient of 0.3 % must be maintained for road drainage

Vertical alignment of the approach road is shown in Figure 6.4.2.



Source: JICA Survey Team

Figure 6.4.2 Vertical Alignment of Naung Lon Bridge

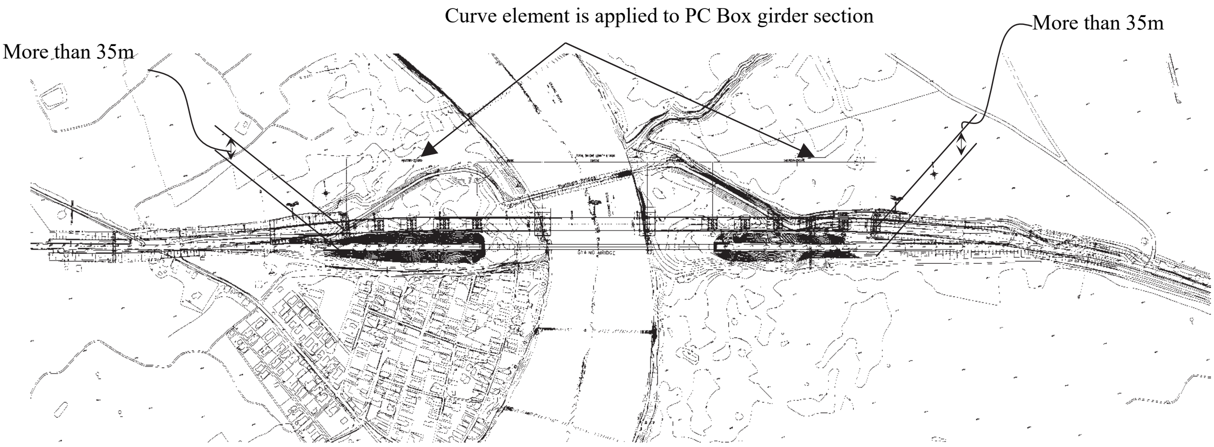
(2) Gyaing Kawkareik Bridge

1) Horizontal Alignment Setting

Horizontal alignment of the approach road is determined in accordance with the following conditions:

- The horizontal alignment of the existing road including the Gyaing Kawkareik Bridge section is R=∞ - R=700m. Therefore the alignment of the new road is connected to the existing road using an S curve with a 2000m radius at the beginning point and using a single curve with a 2000m radius at the end point.
- Extradosed is used for the main span and PC Box girders are used for the side spans. Therefore, the curve alignment is inserted in the side span sections in order to shorten the transition length of the new approach roads.
- The distance between the centre line of the existing bridges and the new bridges is set as more than 35m at the bridge ends in order to mitigate the influence of the existing road on the embankment.

Horizontal alignment of the approach road is shown in Figure 6.4.3.



Source: JICA Survey Team

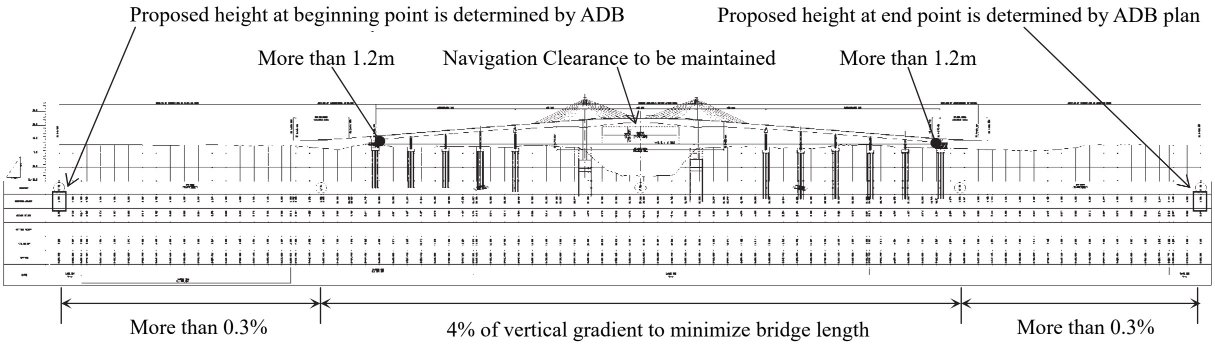
Figure 6.4.3 Horizontal Alignment of Gyaing Kawkareik Bridge

2) Vertical Alignment Setting

Vertical alignment of the approach roads is determined in accordance with the following conditions:

- In order to shorten the bridge length, the maximum vertical gradient is set to 4%.
- More than 1.2m is set for marginal clearance between girder bottom and H.W.L.
- Required navigation clearance must be maintained.
- A minimum vertical gradient of 0.3 % must be maintained for road drainage.
- It is necessary that alignment of the approach road is consistent with road improvement design by ADB (Report of FS as of July 2015). Therefore, proposed height of approach road at the end points is set as 8.15m referred from ADB design.

Vertical alignment of the approach road is shown in Figure 6.4.4.



Source: JICA Survey Team

Figure 6.4.4 Vertical Alignment of Gyaing Kawkareik Bridge

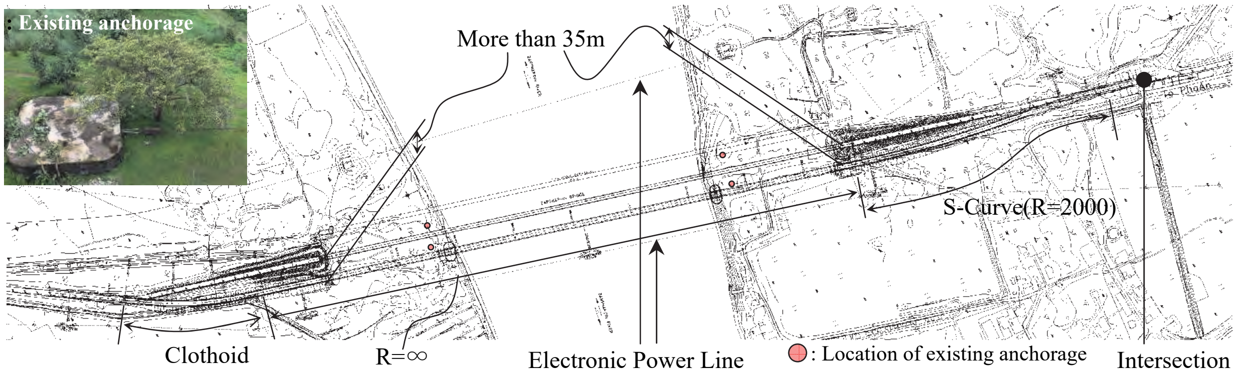
(3) Gyaing Zathapyin Bridge

1) Horizontal Alignment Setting

Horizontal alignment of the approach road is determined in accordance with the following conditions:

- Horizontal alignment of the existing road at the beginning point is R=200m-R=∞, but the distance from the end of R=200m does not satisfy the geometric standard. Therefore alignment of new road shall be connected to the existing road using a clothoid curve.
- There is an intersection approximately 500m away from the existing abutment on the right shore. Therefore the alignment of the new road is connected to the existing road using an S curve with 2000m radius in front of the intersection.
- It is desirable that the curve element is applied to earthwork sections rather than the bridge sections to allow for easy construction.
- Distance between the centre line of the existing bridge and new bridge is set as more than 35m at the bridge ends in order to mitigate influence on the embankment of the existing road.
- To secure sufficient distance from existing electronic power lines.
- To avoid existing anchorages of cable to mitigate lateral vibration.

Horizontal alignment of the approach road is shown in Figure 6.4.5.



Source: JICA Survey Team

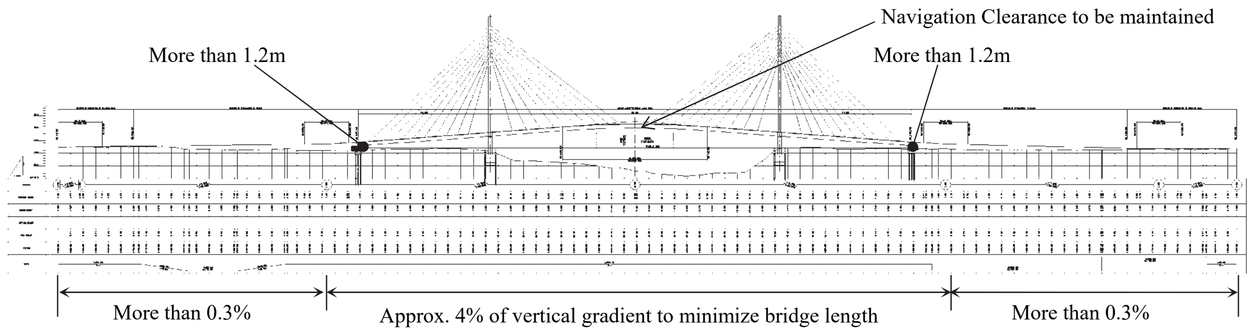
Figure 6.4.5 Horizontal Alignment of Gyaing Zathapyin Bridge

2) Vertical Alignment Setting

Vertical alignment of the approach road is determined taking into account the following conditions:

- In order to shorten the bridge length, the maximum vertical gradient is set to 4%.
- More than 1.2m is set for marginal clearance between girder bottom and H.W.L.
- Required navigation clearance must be maintained
- A minimum vertical gradient of 0.3 % must be maintained for road drainage

Vertical alignment of the approach road is shown in Figure 6.4.6.



Source: JICA Survey Team

Figure 6.4.6 Vertical Alignment of Gyaing Zathapyin Bridge

(4) Atran Bridge

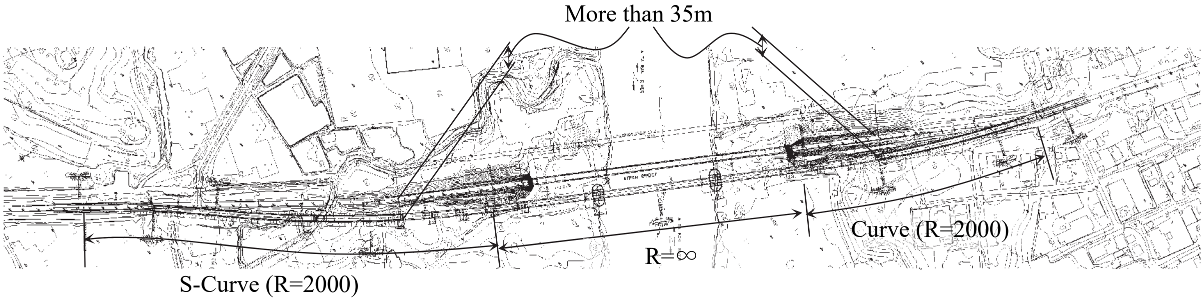
1) Horizontal Alignment Setting

Horizontal alignment of the approach road is determined taking into account the following condition:

- Horizontal alignment of the existing road is R=∞ at the beginning point and R=700m at the end point. Therefore alignment of the new road is connected to the existing road using an S curve with 2000m radius at the beginning point.
- Horizontal alignment of existing road is R=700m at the end point. Therefore the alignment of new road is connected to the existing road using a single curve with 2000m radius at the end point.
- The bridge's main span is extradosed and the side spans are PC Box girders. Therefore, the curve alignment is inserted on the side span sections in order to shorten the transition length of the new approach roads.

- Distance between the centre line of the existing bridge and the new bridge is set as more than 35m at the bridge ends in order to mitigate influence on embankment of the existing road.

Horizontal alignment of the approach road is shown in Figure 6.4.7.



Source: JICA Survey Team

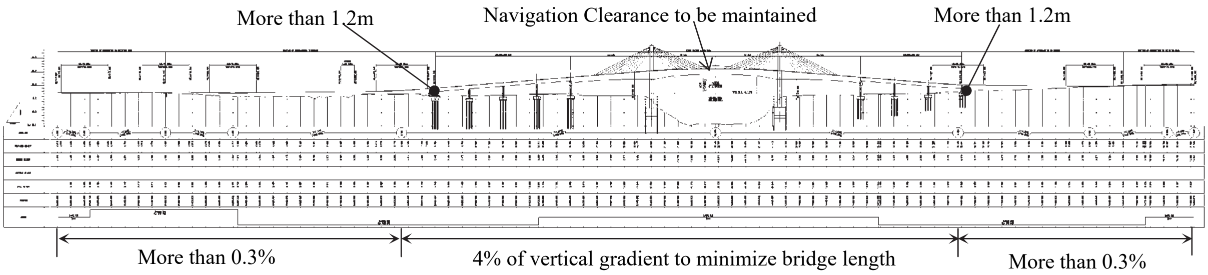
Figure 6.4.7 Horizontal Alignment of Atran Bridge

2) Vertical Alignment Setting

Vertical alignment of the approach road is determined taking into account the following condition:

- In order to shorten the bridge length, the maximum vertical gradient is set to 4%.
- More than 1.2m is set for marginal clearance between girder bottom and H.W.L.
- Required navigation clearance must be maintained.
- A minimum vertical gradient of 0.3 % must be maintained for road drainage.

Vertical alignment of the approach road is shown in Figure 6.4.8.



Source: JICA Survey Team

Figure 6.4.8 Vertical Alignment of Atran Bridge

6.4.2 Earth Work Design

(1) Embankment Structure

The structure of the approach road for four bridges is composed of embankment because the approach road runs through the river reservation. Therefore, the road structures of the section connecting to the existing road and the section approaching to bridge are as shown in Figure 6.2.5 and Figure 6.2.6.

The maximum embankment height of the four bridges are formed behind each abutment, and the height is 5.18-7.64m as shown in Table 6.4.1.

Table 6.4.1 Maximum Embankment Height of four Bridges

Bridge	Maximum Embankment Height (m)
Naung Lon	6.5
Gyaing Kawkareik	7.9
Gyaing Zathapyin	6.8
Atran	6.2

Source: JICA Survey Team

Therefore, the gradient of embankment slope is set as V:H=1:2 without the installation of a berm.

Moreover, sod strips for the protection of the slope are installed on the slope of embankment for the protection of the embankment against rain water.

The lowest formation of the new approach road is shown in Table 6.4.2. At the Naung Lon Bridge and Gyaing Zathapyin Bridge, the formation of a section connecting to the existing road is lower than HWL because the formation of the existing road is lower than HWL. Therefore, when the water level rises up to H.W.L. in the rainy season, there is a chance that the approach road could be flooded. When the existing road is improved in the future, it is preferable to raise the road formation higher than the H.W.L.

Table 6.4.2 Comparison of Minimum proposed height and H.W.L. for Four bridges

Bridge	Min elevation of Approach Road (m)	HWL (m)
Naung Lon	6.324	6.60
Gyaing Kawkareik	9.160*1	6.58
Gyaing Zathapyin	3.548	4.35
Atran	4.517	4.17

*1: Referred from "GMS East-West Economic Corridor Eindu to Kawkareik Road Improvement Project ADB
Source: JICA Survey Team

(2) Soft Soil Treatment

1) Issues and Necessity of Consideration for Soft Soil

The four target bridges are located about 150km east of Andaman Bay. The area is on the Gyaing River basin plain which has an elevation of from 2m to 10m.

According to the borehole survey results, there are weak alluvial sand or clay layers with thickness of about 15-30m. Therefore, careful consideration is required for soft soil in the sites.

The soft soil layer thicknesses in the sites are as shown in Table 6.4.3.

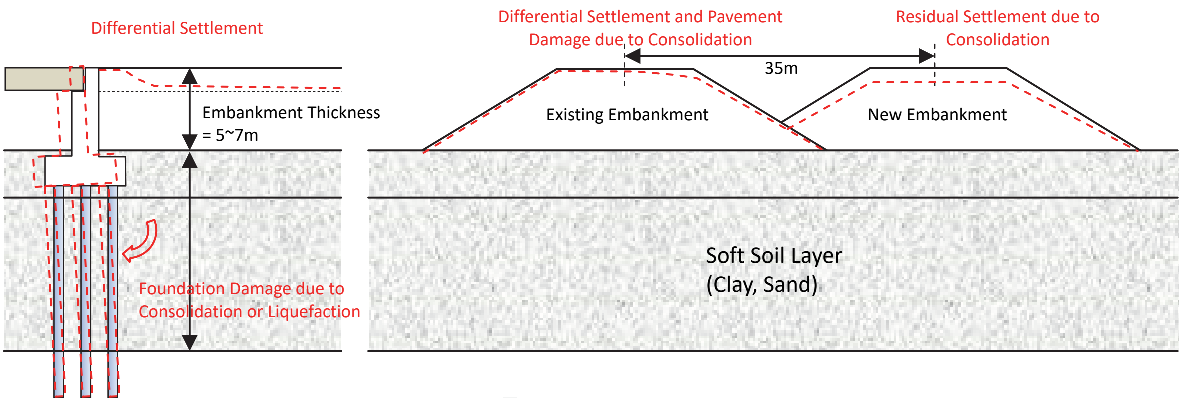
Table 6.4.3 Thickness of Soft Soil on each projected site

Bridge	Thickness of Soft Clay (m) (N<6)		Remarks
	A1 (Beginning Point side)	A2 (End Point Side)	
Naung Lon	4.0	5.0	CLAY
Gyaing Kawkareik	3.0	(3.5)*1	CLAY-I
	7.0	15.0	CLAY-II
	(2.5)*1	17.0	Sandy Clay
	10.0	32.0	Total thickness of soft soil
Gyaing Zathapyin	—	2.9	CLAY-I
	2.0	9.0	CLAY-II
	5.6	—	CLAY-III
	(10.5)*1	10.0	Sandy CLAY, Silty CLAY
	7.6	21.9	Total thickness of soft soil
Atran	2.5	-	CLAY-I
	17.5	-	CLAY-II
	20.0	0.0	Total thickness of soft soil

*1: Thickness of Soft Clay (m) (6<N)
Source: JICA Survey Team

The maximum embankment height of the new road behind the abutments is 6.2-7.9m in the basic design. Considering the embankment height and ground condition in the sites, the following issues are expected:

- Occurrence of residual settlement in the embankment section due to consolidation settlement, and differential settlement at the connection between bridge and embankment.
- Occurrence of abutment lateral movement due to consolidation settlement.
- Damage on the pavement on the existing road due to uneven settlement caused by new embankment load.
- Damage in foundation of abutment caused by the liquefaction of a weak sand layer.



Source: JICA Survey Team

Figure 6.4.9 Expected Issues due to Soft Soil Layer

2) Countermeasures

Studies on countermeasures for settlement and liquefaction prevention are required for considering the expected events. However, the cost of liquefaction countermeasures is extremely high, and hence liquefaction countermeasures are not to be employed as a basic policy for the following reasons:

- No related standard exists in Myanmar.
- Restoration of embankment structures is relatively easy.
- Careful consideration is given to conduct in-bridge foundation design against liquefaction.

As for the prevention of settlement, the study for the countermeasure is required for Gyaing Kawkareik Bridge, Gyaing Zatapyin Bridge and Atran Bridge (A1 side) where the thickness of the soft soil layer is over 5m (as listed in Table 6.4.3). Expected settlement could give a negative impact to the trafficability of new roads because residual settlement is expected to be in the range of 30cm to 100cm above soil settlement estimation using soil properties obtained from the consolidation test.

It is necessary to select appropriate soft soil treatment method. Comparison of soft soil treatment methods is demonstrated based on the useful practices in Japan or South-East Asia, as shown in Table 6.4.4.

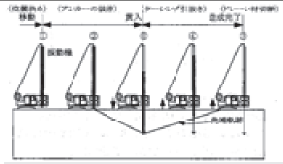
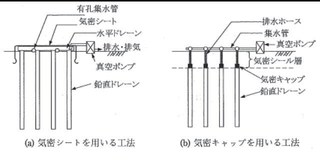
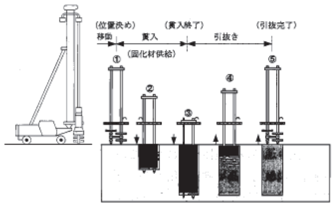
As the result of comparison, the PVD method is recommendable by the following reasons:

- Construction site space is not restricted.
- Easy to construct
- Lowest-cost

The construction process should be arranged as follow if the PVD method will be adopted for the abutment adjacent section.

1) Execute soft soil treatment (PVD)
2) Construct embankment before the abutment construction
3) Excavate after confirming the settling the subsidence
4) Construct the abutment

Table 6.4.4 Comparison of Soft Soil Treatment Method

	PVD	Vacuum consolidation method	Deep cement mixing column
General Description	 	 	 
	To install prefabricated drainage material into the ground at regular intervals. This countermeasure promotes discharge of pore water and occurrence of consolidation settlement. It is used generally and widely because it excels in cost and the workability, and quality control is also easy.	To install prefabricated drainage material into the ground at regular intervals. To connect the vacuum pump to the head of PVD, and then to allocate a membrane sheet to cover the PVD heads. This countermeasure promotes the discharge of the pore water and the occurrence of consolidation settlement by shortening the drainage length and pumping the water.	To add and mix the cement material into the ground by the specific machine in order to increase the bearing capacity. The bearing capacity of created column will be improved by about 0.2-1.0Mpa.
Technical Characteristic	+Expected consolidation settlement is large. +The residual settlement is controlled by the drain interval and the waiting period. +The stability is increased by the strength growth according to the consolidation settlement of the clay soil.	+Expected consolidation settlement is rather large. + The residual settlement is controlled by the drain interval and the waiting period. +The stability is increased by the strength growth according to the consolidation settlement of the clay soil.	+Expected consolidation settlement is little. (It depends on the improvement rate). +The residual settlement can be controlled by treatment depth and rate.
Economic Characteristic	+The maintenance cost is relatively high (dependent on the residual settlement). +The construction cost is low.	+The maintenance cost is a little high (dependent on the residual settlement). +The construction cost is moderate.	+The maintenance cost is low. +The construction cost is high.
Other Related Characteristic	+A long waiting time is required, and the construction period is long. +It is necessary to add the counterweight fill in case it is impossible to secure the stability by the strength growth of the clay soil.	The waiting period is required, but construction is comparatively fast (it is possible to make it shorter than PVD or SD methods).	+The Construction period is comparatively fast. +There is no problem excluding the ground where a special cement solidification material is needed.
Applicability	+Applicability is generally high in a usual cohesive soil ground.	+For general clay soil ground, the applicability of this method is high. +It is necessary to note have that the vacuum pressure might not been effected enough where the sand stratum with high permeability is deposited in the middle of the clay layer.	+The effect certainty and applicability is generally high. +Especially this method is suitable in case of limited ROW condition and instability condition with Vertical drain method. + It is necessary to confirm the cementation with mixing the cement material and the soil.
Evaluation	**Recommended**	Not Recommended	Not Recommended

Source: JICA Survey Team

6.4.3 Pavement Design

(1) Study of Pavement Structure

1) Basic Design Condition

At the official meeting with MOC on 12th March 2014, it was agreed that the surface layer of the pavement structure should be adopted as asphalt concrete and the thickness of the pavement structure should comply with the design specification in accordance with AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES (1993) for the project roads.

The required Structural Number (SN) can be obtained from the following equation, and the layer combination (the layer coefficient and the thickness of each layer) must satisfy the requirements of the SN.

Design life of each pavement structure is shown in Table 6.4.5.

Table 6.4.5 Performance Period for Pavement Design on Each Bridge

Bridge	Assumed Completion Year	Design Period
Naung Lon	2019	20years (2020-2039)
Gyaing Kawkareik	2021	20years (2022-2041)
Gyaing Zathapyin	2021	20years (2022-2041)
Atran	2021	20years (2022-2041)

Source: JICA Survey Team

Design condition for pavement design is summarized in Table 6.4.6.

Table 6.4.6 Basic Design condition for pavement design

Design Input Requirements			Value
1	Design Variables	Performance Period, Analysis Period	20years
		Traffic - Cumulative 18kip Equivalent Single Axle Load (ESAL)($\hat{w}_{18}$: 2 directions) -Directional Distribution Factor: D_D -Lane Distribution Factor: D_L	 - From the result of Traffic Demand Forecast - 0.5(2 Lane) - 1.0(2 lane) ,0.9(4 lane)
		Reliability(Z_R)	90% (-1.282)
		Overall Standard Deviation(S_o)	0.45 (Flexible pavement)
2	Performance Criteria	Initial Service Index (P_o)	4.2
		Terminal Serviceability (P_t)	2.5
		Design Serviceability Loss ($\Delta PSI=P_o-P_t$)	1.7
3	Material Properties	Effective Roadbed Soil Resilient Modulus, MR(psi)	1500 x CBR
		Layer Coefficient for Asphalt Concrete: a_1 Layer Coefficient for Base Course: (Crushed Stone CBR＞80), a_2 Layer Coefficient for Sub Base Course: (Gravel: CBR＞30), a_3	$a_1 = 0.42$ $a_2 = 0.14$ $a_3 = 0.11$
4	Pavement Characteristics	Drainage Coefficient for Base Course and Subbase Course: m_2, m_3	1.00

Source: JICA Survey Team

2) Traffic Volume and Equivalent Single Axle Load (ESAL)

The traffic demand forecast (AADT) classified by vehicle type for the years 2014, 2030, and 2035 is given in Table 6.4.7.

Table 6.4.7 Traffic Demand Volume Forecast for Four Bridges

Unit: vehicle/day

Bridge	Year	Passenger Cars	Buses	Trucks				Trailers	Total
				2 axles		3 axles	≧ 4 axles		
				Small	Big				
Naung Lon	2014	1,223	79	102	273	35	181	21	1,914
	2035	4,540	360	150	400	250	930	500	7,130
	2040	6,470	410	200	390	170	860	470	8,970
Gyaing Kawkareik	2014	1,120	83	125	206	14	227	19	1,794
	2035	12,260	800	1200	1970	740	1,980	1,100	20,050
	2040	20,820	1,340	1,470	2,500	840	3,160	1,480	31,610
Gyaing Zathapin, Atran	2014	760	95	118	178	9	16	0	1,176
	2035	7,080	370	1,500	2,260	680	1,350	730	13,970
	2040	12,040	790	2,260	3,470	920	2,400	1,100	22,980

Source: JICA Survey Team

Traffic volume (vehicles/day) for each design period assumed from traffic demand forecast is shown in Table 6.4.8 to Table 6.4.11.

Table 6.4.8 Traffic Volume for Pavement Design Period of Naung Lon Bridge

Units: vehicles/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧ 4 axles		
			Small	Large				
2014	1,223	79	102	273	35	181	21	1,914
2015	1,302	85	104	278	38	196	24	2,027
2016	1,386	91	106	283	42	212	28	2,148
2017	1,475	98	108	288	46	229	33	2,277
2018	1,570	105	110	293	51	247	38	2,415
2019	1,671	113	112	299	56	267	45	2,563
2020	1,779	122	114	304	61	289	52	2,721
2021	1,894	131	116	310	67	312	60	2,891
2022	2,016	141	118	316	74	338	70	3,072
2023	2,146	151	121	321	81	365	82	3,267
2024	2,284	163	123	327	89	395	95	3,475
2025	2,431	175	125	333	98	427	111	3,699
2026	2,588	188	127	339	108	461	129	3,940
2027	2,755	202	130	346	118	499	149	4,198
2028	2,932	217	132	352	130	539	174	4,476
2029	3,121	233	134	359	143	583	202	4,775
2030	3,322	251	137	365	157	630	235	5,097
2031	3,536	270	139	372	172	681	273	5,444
2032	3,764	290	142	379	189	736	318	5,818
2033	4,007	312	145	386	207	796	370	6,222
2034	4,265	335	147	393	228	860	430	6,658
2035	4,540	360	150	400	250	930	500	7,130
2036	4,873	369	159	398	231	916	494	7,441
2037	5,231	379	168	396	214	901	488	7,778
2038	5,615	389	178	394	198	887	482	8,144
2039	6,027	399	189	392	184	874	476	8,541
2040	6,470	410	200	390	170	860	470	8,970
Total (2020-2039)	**69,127**	**5,077**	**2,795**	**7,181**	**2,999**	**12,417**	**5,189**	**104,786**

Source: JICA Survey Team

Table 6.4.9 Traffic Volume for Pavement Design Period of Gyaing Kawkareik Bridge

Unit: vehicle/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧ 4 axles		
			Small	Large				
2014	1,120	83	125	206	14	227	19	1,794
2015	1,255	92	140	229	17	252	23	2,008
2016	1,407	103	155	255	20	279	28	2,248
2017	1,576	115	173	284	25	309	34	2,516
2018	1,767	128	193	316	30	343	41	2,817
2019	1,980	142	215	352	36	380	50	3,155
2020	2,219	159	239	392	43	421	61	3,534
2021	2,487	177	266	437	53	467	74	3,960
2022	2,787	197	296	486	63	518	89	4,437
2023	3,123	219	330	542	77	574	108	4,973
2024	3,500	244	367	603	93	637	131	5,576
2025	3,923	272	409	672	112	706	159	6,253
2026	4,396	303	456	748	135	783	193	7,014
2027	4,927	337	507	833	163	868	234	7,870
2028	5,522	376	565	928	197	962	284	8,834
2029	6,188	419	629	1,033	238	1,066	345	9,919
2030	6,935	466	701	1,150	288	1,182	419	11,141
2031	7,772	520	780	1,281	348	1,311	508	12,519
2032	8,710	579	869	1,427	420	1,453	616	14,073
2033	9,761	645	968	1,589	507	1,611	747	15,828
2034	10,940	718	1,078	1,769	613	1,786	907	17,810
2035	12,260	800	1,200	1,970	740	1,980	1,100	20,050
2036	13,630	887	1,250	2,066	759	2,174	1,167	21,933
2037	15,153	983	1,301	2,167	778	2,387	1,239	24,009
2038	16,846	1,090	1,355	2,273	798	2,621	1,314	26,298
2039	18,728	1,209	1,412	2,384	819	2,878	1,395	28,823
2040	20,820	1,340	1,470	2,500	840	3,160	1,480	31,610
2041	23,146	1,486	1,531	2,622	862	3,470	1,570	34,686
Total (2022-2041)	**199,066**	**13,090**	**17,475**	**29,042**	**8,850**	**32,126**	**14,006**	**313,655**

Source: JICA Survey Team

Table 6.4.10 Traffic Volume for Pavement Design Period of Gyaing Zathapyin Bridge

Unit: vehicle/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧ 4 axles		
			Small	Large				
2014	760	95	119	177	9	16	1	1,177
2015	844	101	134	200	11	20	1	1,310
2016	937	108	150	225	13	24	2	1,459
2017	1,041	115	169	253	17	30	3	1,626
2018	1,156	122	190	284	20	36	3	1,813
2019	1,283	130	214	320	25	45	5	2,022
2020	1,425	139	241	360	30	55	6	2,257
2021	1,582	148	272	405	37	68	9	2,521
2022	1,757	158	306	456	45	83	12	2,817
2023	1,951	168	344	513	56	102	16	3,151
2024	2,167	179	387	578	68	126	22	3,526
2025	2,406	191	436	650	83	154	30	3,950
2026	2,672	203	490	732	102	190	40	4,429
2027	2,967	217	552	824	125	233	55	4,972
2028	3,295	231	621	927	153	286	75	5,588

2029	3,659	246	699	1,043	187	352	102	6,288
2030	4,063	262	786	1,174	229	432	139	7,086
2031	4,512	279	885	1,321	280	531	189	7,998
2032	5,010	298	996	1,487	343	652	258	9,044
2033	5,563	317	1,121	1,674	420	801	351	10,248
2034	6,178	338	1,262	1,884	515	985	477	11,638
2035	6,860	360	1,420	2,120	630	1,210	650	13,250
2036	7,615	420	1,513	2,275	666	1,373	717	14,579
2037	8,452	490	1,612	2,442	703	1,559	790	16,050
2038	9,382	573	1,718	2,621	743	1,770	872	17,678
2039	10,414	668	1,830	2,814	785	2,009	961	19,482
2040	11,560	780	1,950	3,020	830	2,280	1,060	21,480
2041	12,832	910	2,078	3,241	877	2,588	1,169	23,695
Total (2022-2041)	**113,314**	**7,289**	**21,005**	**31,799**	**7,842**	**17,715**	**7,986**	**206,949**

Source: JICA Survey Team

Table 6.4.11 Traffic Volume for Pavement Design Period of Atran Bridge

Unit: vehicle/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧4 axles		
			Small	Large				
2014	760	95	118	178	9	16	1	1,177
2015	845	101	133	201	11	20	1	1,313
2016	940	108	150	227	14	24	2	1,465
2017	1,045	115	170	256	17	30	3	1,636
2018	1,163	123	192	289	21	37	4	1,827
2019	1,293	131	216	326	25	46	5	2,042
2020	1,438	140	244	368	31	57	7	2,284
2021	1,599	149	276	415	38	70	9	2,556
2022	1,778	159	311	469	47	87	12	2,863
2023	1,978	170	351	529	57	107	17	3,209
2024	2,200	182	396	597	71	132	23	3,600
2025	2,446	194	447	674	87	163	32	4,042
2026	2,721	207	505	760	107	202	43	4,544
2027	3,026	220	570	858	131	249	59	5,113
2028	3,365	235	643	969	161	308	81	5,761
2029	3,742	251	726	1,093	198	380	111	6,501
2030	4,162	268	819	1,234	243	470	152	7,346
2031	4,628	286	924	1,393	298	580	208	8,317
2032	5,147	305	1,043	1,572	367	716	285	9,435
2033	5,724	325	1,177	1,774	450	885	390	10,726
2034	6,366	347	1,329	2,002	553	1,093	533	12,224
2035	7,080	370	1,500	2,260	680	1,350	730	13,970
2036	7,873	431	1,628	2,462	722	1,515	792	15,424
2037	8,755	501	1,767	2,683	767	1,699	860	17,033
2038	9,736	583	1,918	2,923	815	1,907	934	18,816
2039	10,827	679	2,082	3,185	866	2,139	1,013	20,791
2040	12,040	790	2,260	3,470	920	2,400	1,100	22,980
2041	13,389	919	2,453	3,781	977	2,693	1,194	25,406
Total (2022-2041)	**116,983**	**7,421**	**22,850**	**34,687**	**8,517**	**19,075**	**8,569**	**218,102**

Source: JICA Survey Team

Cumulative 18kip equivalent single axle load (ESAL) on each bridge is shown in Table 6.4.12 to Table 6.4.15.

Table 6.4.12 ESAL 18-kip for Naung Lon Bridge

	Passenger Cars	Buses	Trucks				Trailer	Total
			2 axles		3 axles	≧4axles		
			Small	Large				
Traffic Volume (v/d) 2021-2040	69,127	5,077	2,795	7,181	2,999	12,417	5,189	
Traffic Volume (v/y) 2021-2040	25,231,174	1,853,201	1,020,118	2,621,235	1,094,814	4,532,240	1,893,966	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	25,231	1,612,285	12,445	2,568,811	1,729,806	7,160,940	2,803,070	15,912,587
$ESAL=D_D \times D_L \times \hat{w}_{18}=0.5\times1.0\times15,912,587=7,956,294$								

Source: JICA Survey Team

Table 6.4.13 ESAL 18-kip for Gyaing Kawkareik Bridge

	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧ 4 axles		
			Small	Large				
Traffic Volume (v/d) 2021-2040	199,066	13,090	17,475	29,042	8,850	32,126	14,006	
Traffic Volume (v/y) 2021-2040	72,659,143	4,777,688	6,378,257	10,600,380	3,230,135	11,726,069	5,112,371	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	72,659	4,156,589	77,815	10,388,372	5,103,614	18,527,189	7,566,309	45,892,546
$ESAL=D_D \times D_L \times \hat{w}_{18}=0.5\times0.9\times45,892,546 = 20,651,646$								

Source: JICA Survey Team

Table 6.4.14 ESAL 18-kip for Gyaing Zathapyin Bridge

	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧ 4 axles		
			Small	Large				
Traffic Volume (v/d) 2022-2041	113,314	7,289	21,005	31,799	7,842	17,715	7,986	
Traffic Volume (v/y) 2022-2041	41,359,563	2,660,479	7,666,871	11,606,491	2,862,392	6,466,004	2,914,726	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	41,360	2,314,617	93,536	11,374,361	4,522,580	10,216,287	4,313,795	32,876,536
$ESAL=D_D \times D_L \times \hat{w}_{18}=0.5\times1.0\times32,876,536= 16,438,268$								

Source: JICA Survey Team

Table 6.4.15 ESAL 18-kip for Atran Bridge

	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧4 axles		
			Small	Large				
Traffic Volume (v/d) 2022-2041	116,983	7,421	22,850	34,687	8,517	19,075	8,569	
Traffic Volume (v/y) 2022-2041	42,698,962	2,708,627	8,340,179	12,660,719	3,108,864	6,962,196	3,127,805	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	42,699	2,356,505	101,750	12,407,505	4,912,005	11,000,269	4,629,151	35,449,884
$ESAL=D_D \times D_L \times \hat{w}_{18}=0.5\times1.0\times35,449,884 = 17,724,942$								

Source: JICA Survey Team

3) CBR for Subgrade

The design CBR for subgrade on the new embankment is assumed to be 7.0%.

4) Design Structural Number (SN)

Based on the above-mentioned conditions, the design structural number (SN) is calculated using the formula below, and given for each bridge in Table 6.4.16.

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

Table 6.4.16 Design Structural Number (SN)

Bridge	Z_R	S_O	W_{18} ESAL	M_R	△PSI	SN (inch)
Naung Lon	90%	0.45	7,956,293	10,500	1.7	4.27
Gyaing Kawkareik	90%	0.45	20,651,645	10,500	1.7	4.92
Gyaing Zathapin	90%	0.45	16,438,267	10,500	1.7	4.76
Atran	90%	0.45	17,724,942	10,500	1.7	4.82

Source: JICA Survey Team

5) Determination of Structural Layer Thickness

Structural layer thickness is determined in satisfying with the conditions below.

Required Structural Number ≧ Design Structural Number

Required Structural Number SN = $a_1D_1 M_1+a_2D_2M_2+a_3D_3M_3$

where a_i: i Layer Coefficient

D_i: i Layer Thickness (inch)

M_i: i Layer Drainage Coefficient

Determined structural layer thickness is shown in Table 6.4.17.

Table 6.4.17 Structural Layer Thickness

Bridge	Design SN		Surface Course	Binder Course	Base Course	Sub Base Course	Total Thickness (cm)
			Layer Thickness(cm)				
	inch	cm	Layer Coefficient x Thickness				Required Structural Number (cm)
Naung Lon	4.27	10.84	4	6	25	30	65
			0.42 x 4 = 1.68	0.42 x 6 = 2.52	0.14 x 25 = 3.50	0.11 x 30 = 3.30	1.68 + 2.52 +3.50 + 3.3 = 11.00
Gyaing Kawkareik	4.92	12.50	4	6	30	40	80
			4 x 0.42 = 1.68	6 x 0.42 = 2.52	30 x 0.14 = 4.20	40 x 0.11 = 4.40	1.68 + 2.52 +4.20 +4.40 = 12.80
Gyaing Zathapin	4.76	12.09	4	6	30	35	75
			4 x 0.42 = 1.68	6 x 0.42 = 2.52	30 x 0.14 = 4.20	35 x 0.11 =3.85	1.68 + 2.52 +4.20 +3.85 = 12.25
Atran	4.82	12.24	4	6	30	35	75
			4 x 0.42 = 1.68	6 x 0.42 = 2.52	30 x 0.14 = 4.20	35 x 0.11 = 3.85	1.68 + 2.52 +4.20 +3.85 = 12.25

Source: JICA Survey Team

6.4.4 Drainage Design

(1) Surface Drainage

At the section of the approach roads, surface water is collected from the intake of the side ditch installed under the pavement, and the gathered water flows down to the toe of embankment slope by a vertical concrete drain (0.3mx0.3m). A catch basin (0.5m x 0.5m) is to be installed at these joints.

The vertical drain connects to the concrete U-shaped ditch (0.5m x 0.5m) which is to be installed at the toe of the embankment, and it leads the gathered water to flow out to the river. At the connecting section of the existing road, surface water is directly collected via concrete side ditches (0.3m x 0.3m) which are to be located alongside of road because there is only a small height difference between the road surface and the road side (due to the low embankment height).

6.4.5 Traffic Safety Facilities

(1) Guardrails

In order to secure traffic safety, guardrails are to be installed alongside earth shoulders at all filled sections (except at intersections and sections that require access to the roadside).

(2) Road Markings

The edge line of lanes (solid lines with width 0.15m) and road centre lines (broken lines at 5m-intervals with width 0.15m) are to be installed at earth work sections and bridge sections of the approach roads.

Pedestrian crossings (4m in width) are installed on the approach roads in the vicinity of intersections connecting to the schools. Stop lines (0.45m in width) are installed before pedestrian crossings.

(3) Traffic Signs

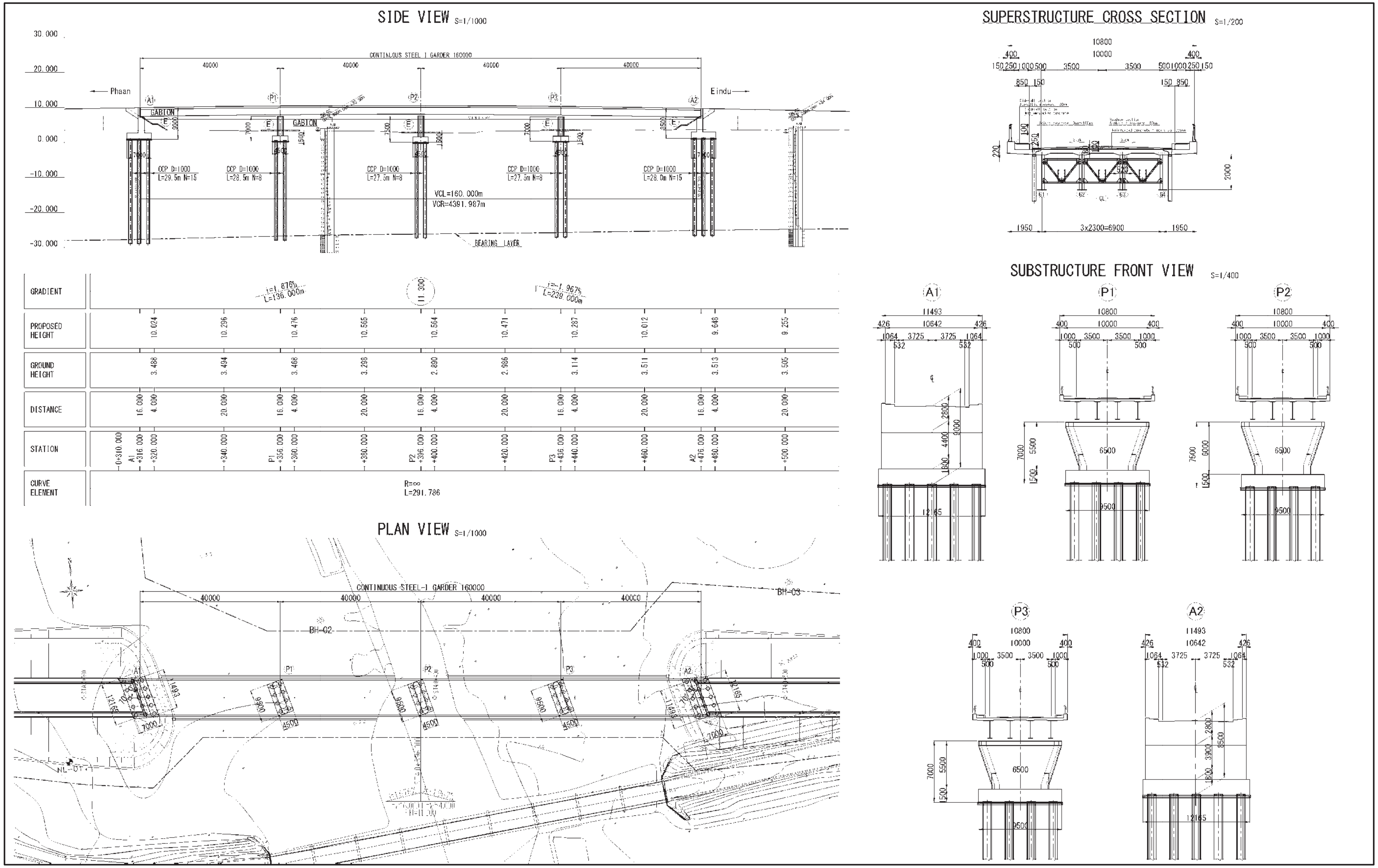
Speed control signs (80 km/h) are installed in the vicinity of the beginning point and the end point of the approach road.

6.5 Preliminary Design for Bridges

6.5.1 Introduction

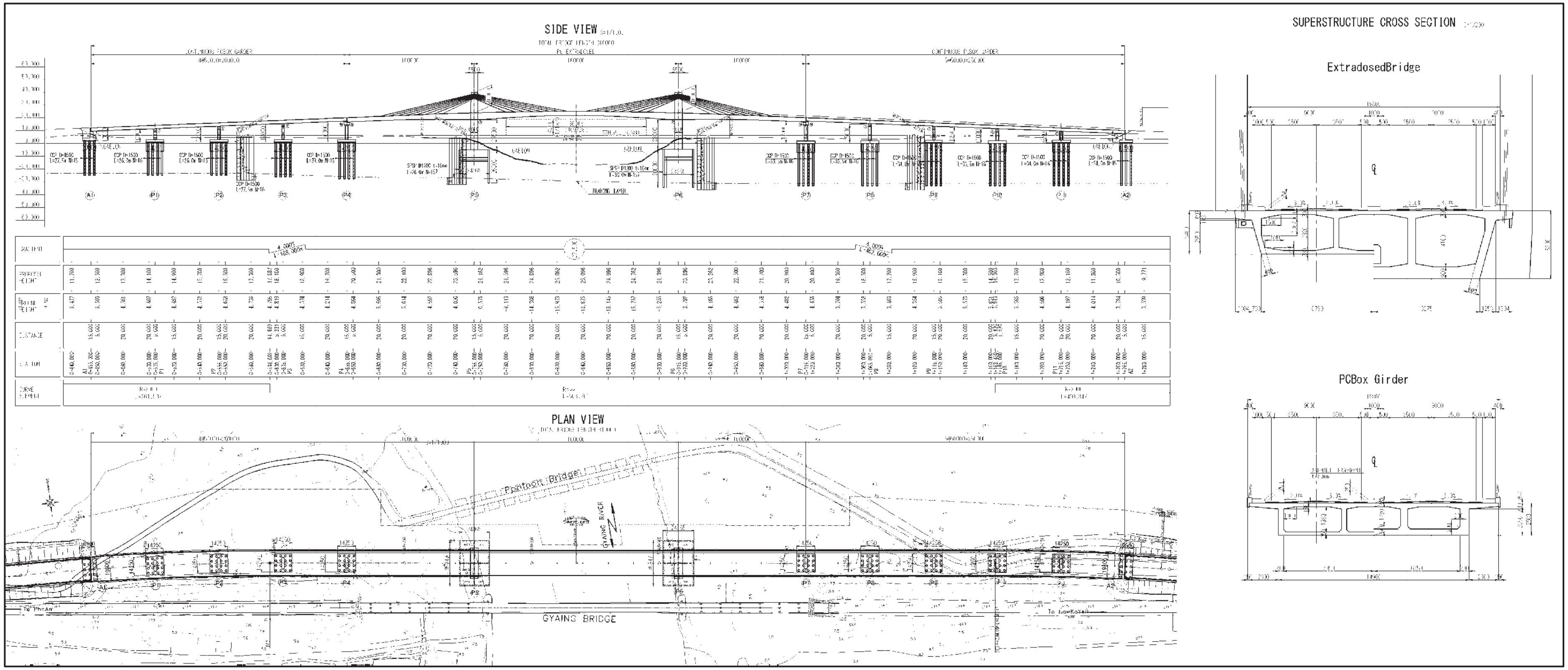
The design of bridges is preliminarily conducted for the proposed superstructure, substructure and foundation type from among the selected alternatives. The purpose of the preliminary design is to define the structural element sizes so that better estimates of cost and constructability can be obtained.

The general plan views of each bridge are shown from Figure 6.5.1 to Figure 6.5.4.



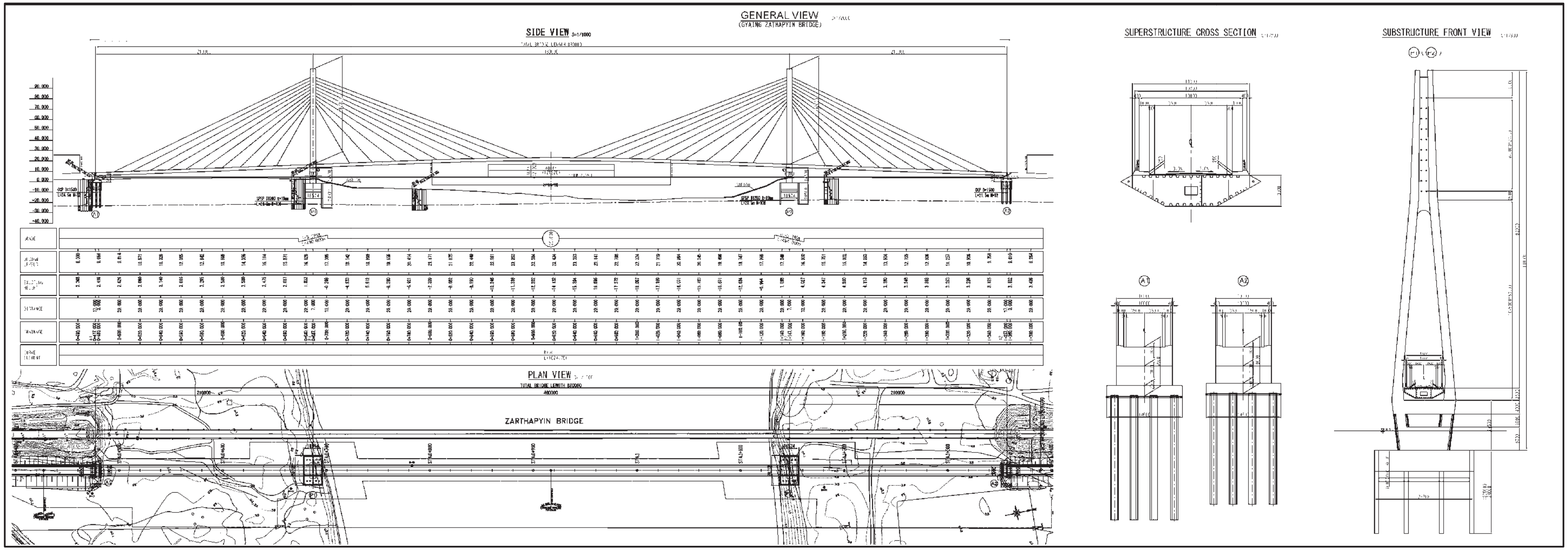
Source : JICA Survey Team

Figure 6.5.1 General View of Naung Lon Bridge



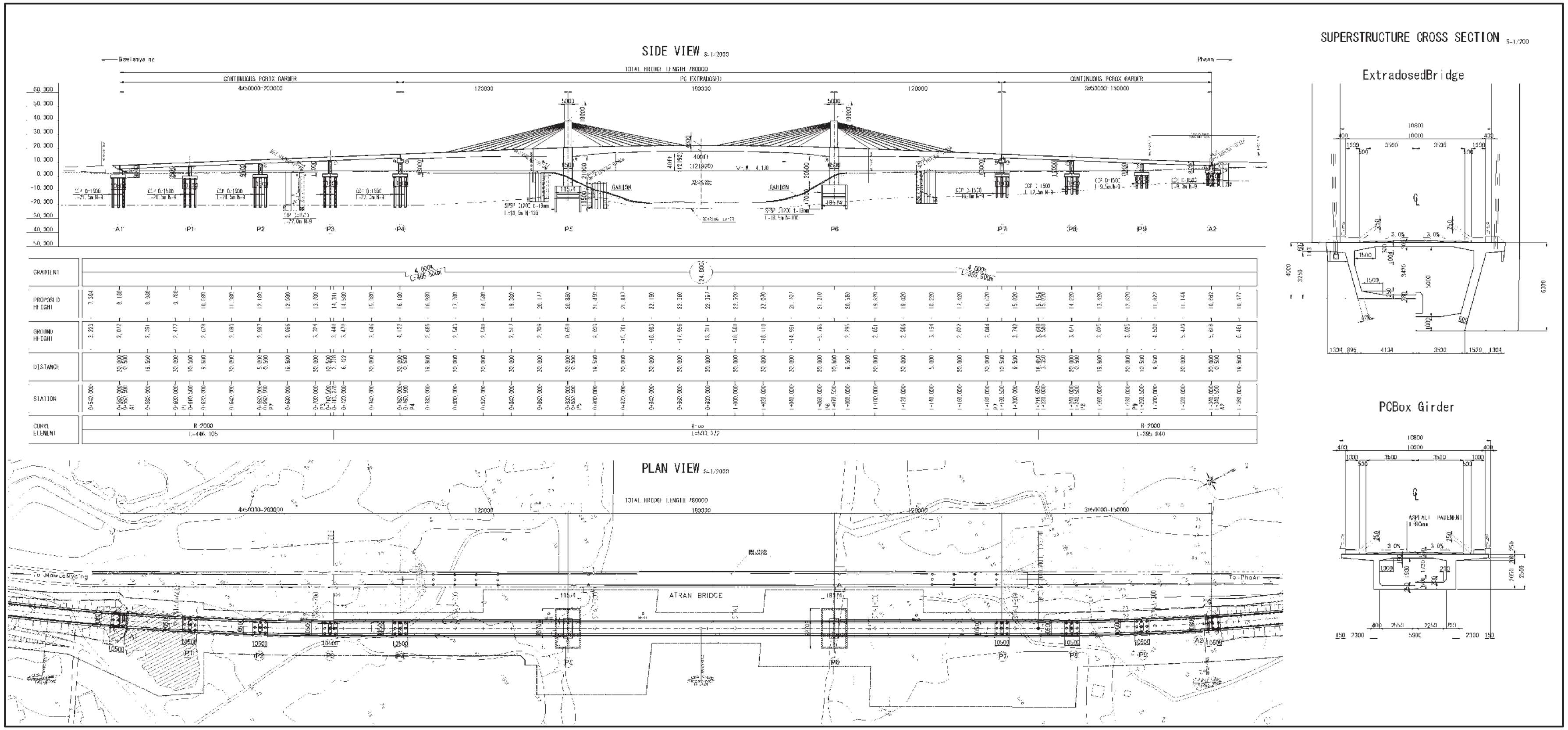
Source : JICA Survey Team

Figure 6.5.2 General View of Gyaing Kawkareik Bridge



Source : JICA Survey Team

Figure 6.5.3 General View of Gyaing Zathapyin Bridge



Source : JICA Survey Team

Figure 6.5.4 General View of Atran Bridge

6.5.2 Design of Superstructures

The recommended superstructure type for each bridge is shown in Table 6.5.1.

Table 6.5.1 Recommended Superstructure Type for four bridges

Bridge	Recommended Superstructure Type	Bridge Length (Span Arrangement)
Naung Lon	Steel-I girder	160m (4@40m)
Gyaing Kawkareik	Extradosed bridge (Main) Continuous PC Box girder(Approach)	200m/Approach + 360m/Main + 250m/Approach = 810m (4@50m + 100m + 160m + 100m + 5@50m)
Gyaing Zathapyin	Steel Cable Stayed Bridge	880m (210m + 460m + 210m)
Atran	Extradosed bridge (Main) Continuous PC Box girder(Approach)	200m/Approach + 430m/Main + 150m/Approach = 780m (4@50m + 120m + 190m + 120m + 3@50m)

Source: JICA Survey Team

(1) Continuous Steel I-Girder Bridge

For the superstructure type of Naung Lon Bridge, a continuous steel–I girder bridge, having a total length of 160m and consisting of four spans of 40m, has been recommended. The configuration of each steel element such as size and thickness are determined by structural calculation considering design loads described in 6.2. The girder configuration is shown in Figure 6.5.5.

(2) Extradosed Bridge

For Gyaing Kawkareik Bridge, we have recommended an extradosed bridge, having a total length of 360m, consisting of a main bridge with a centre span of 160m and side spans of 100m (both sides) as shown in Figure 6.5.6.

For Atran Bridge, we have recommended an extradosed bridge, having a total length of 430m, consisting of a main bridge with a centre span of 190m and side spans of 120m (both sides) as shown in Figure 6.5.7.

The properties of the main materials such as PC cables (inner and outer cables in the girder/stay cable) and reinforcements, and the configurations of the PC Box girder are determined by structural calculation considering design loads described in 6.2.

(3) Steel Cable Stayed Bridge

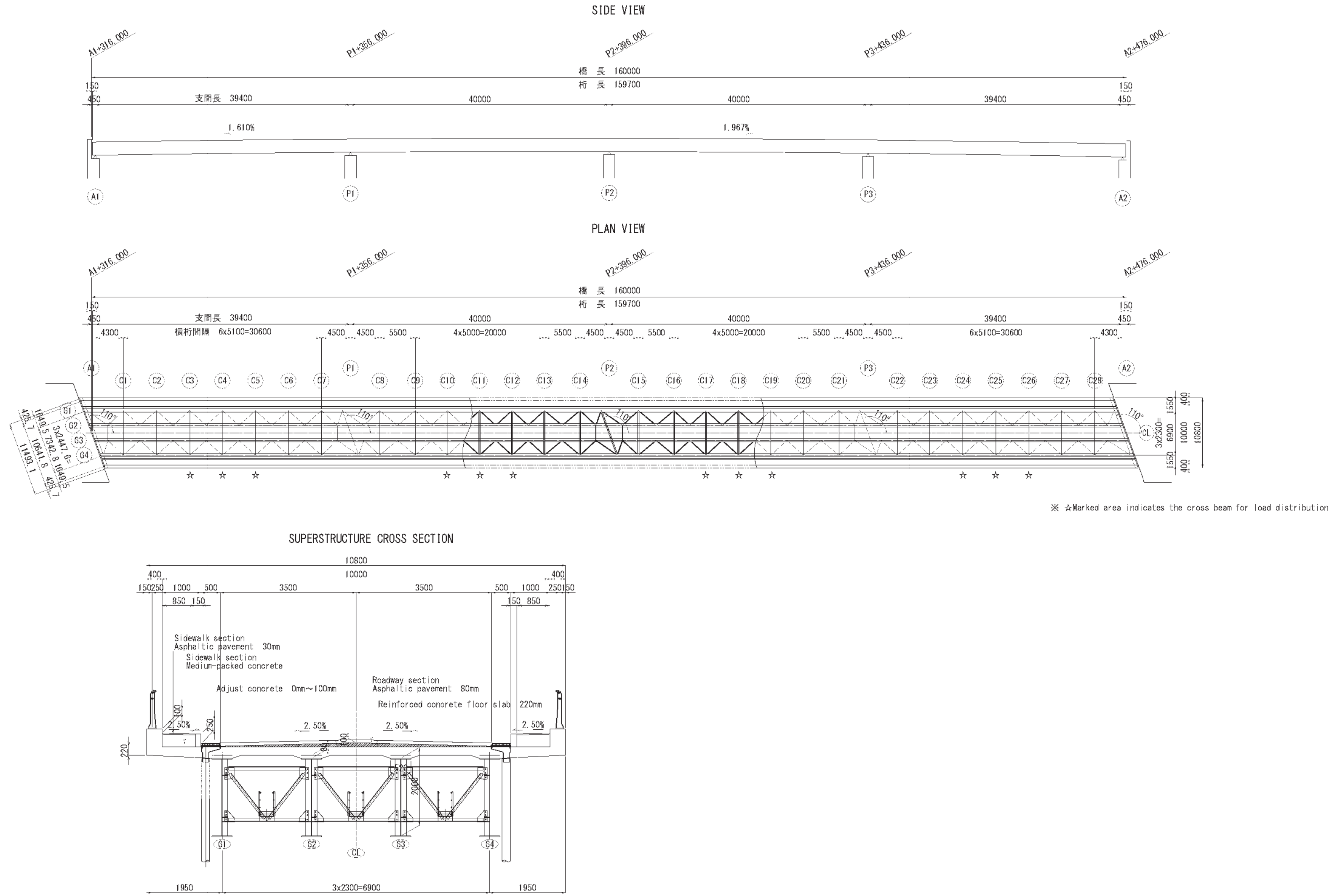
A steel cable-stayed bridge, having a total length of 880m with a centre span of 460m and side spans of 210m (both sides), is recommended for the superstructure type of Gyaing Zathapyin Bridge.

The properties of the main materials such as PC cables (inner and outer cables in the girder/stay cable) and reinforcements, and the configuration of the section are determined by structural calculation considering design loads described in 6.2. The configuration of steel cable stayed bridge is shown in Figure 6.5.8.

(4) Continuous PC Box Girder Bridge

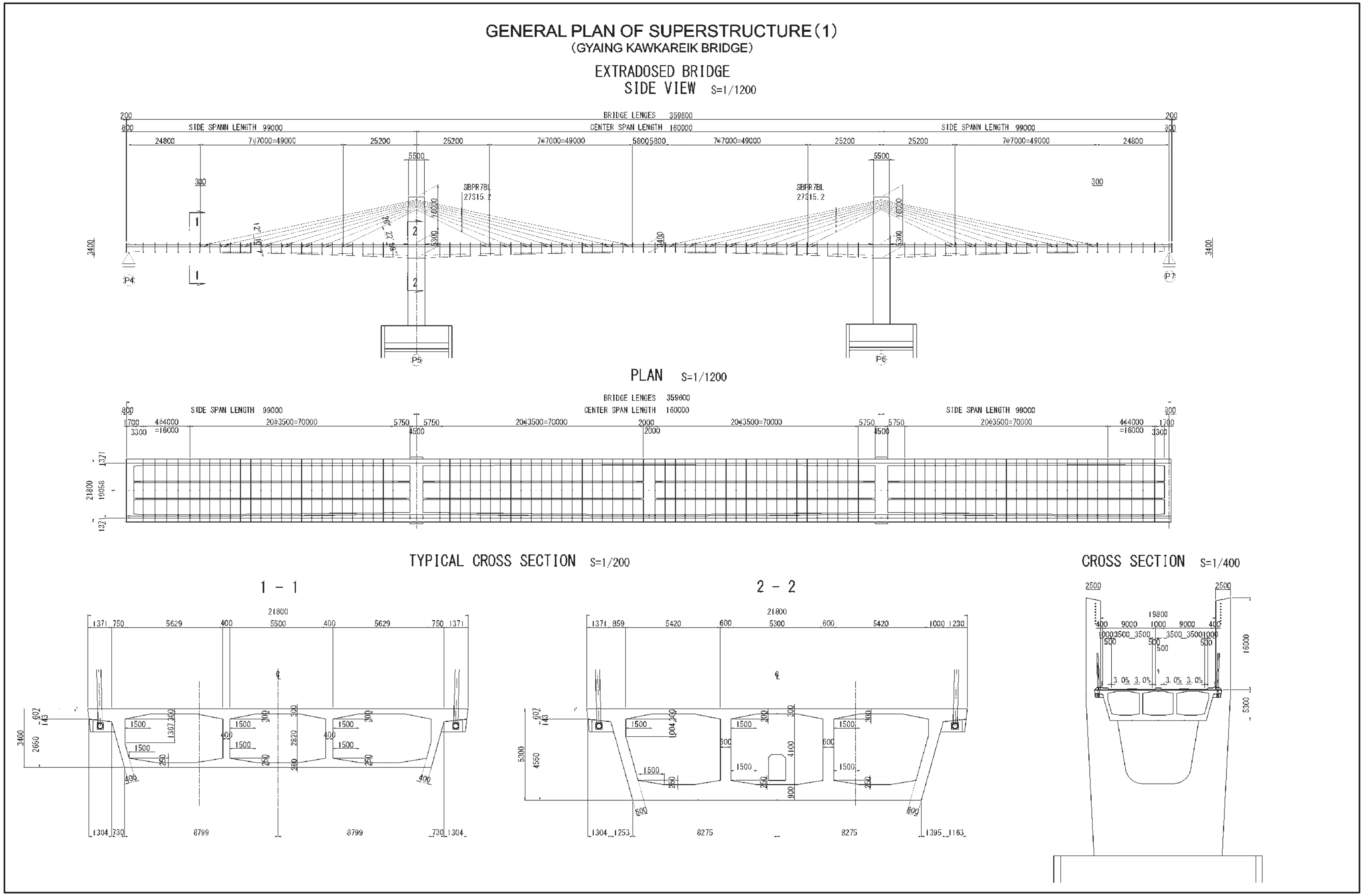
Continuous PC Box girder bridges are recommended for the approach bridges of Gyaing Kawkareik Bridge and Atran Bridge.

The properties of the main materials such as PC cables (inner and outer cables) and reinforcements, and the configuration of the section are determined by structural calculation considering design loads described in 6.2.



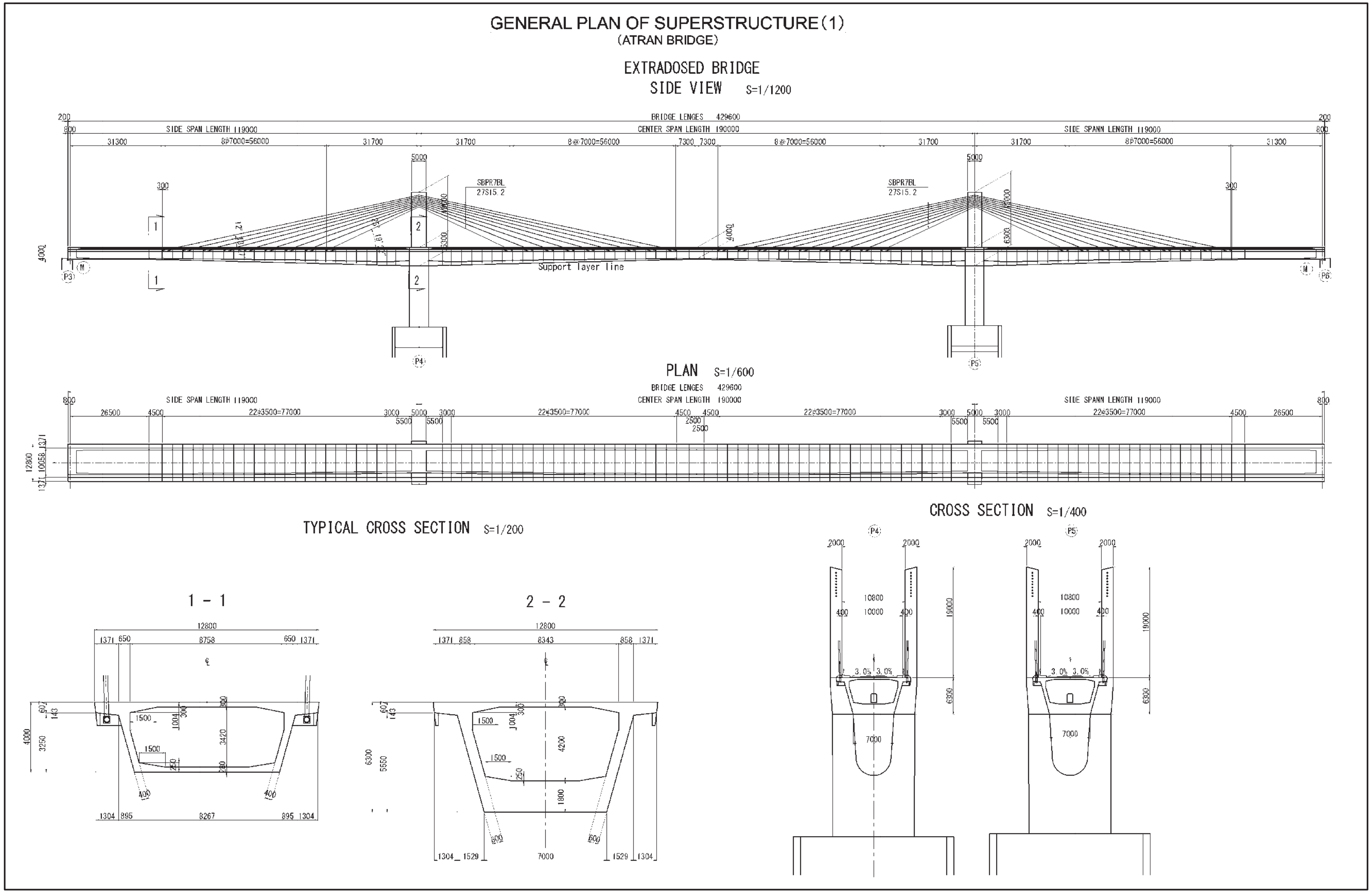
Source : JICA Survey Team

Figure 6.5.5 Configurations of Steel I-Girder (Naung Lon Bridge)



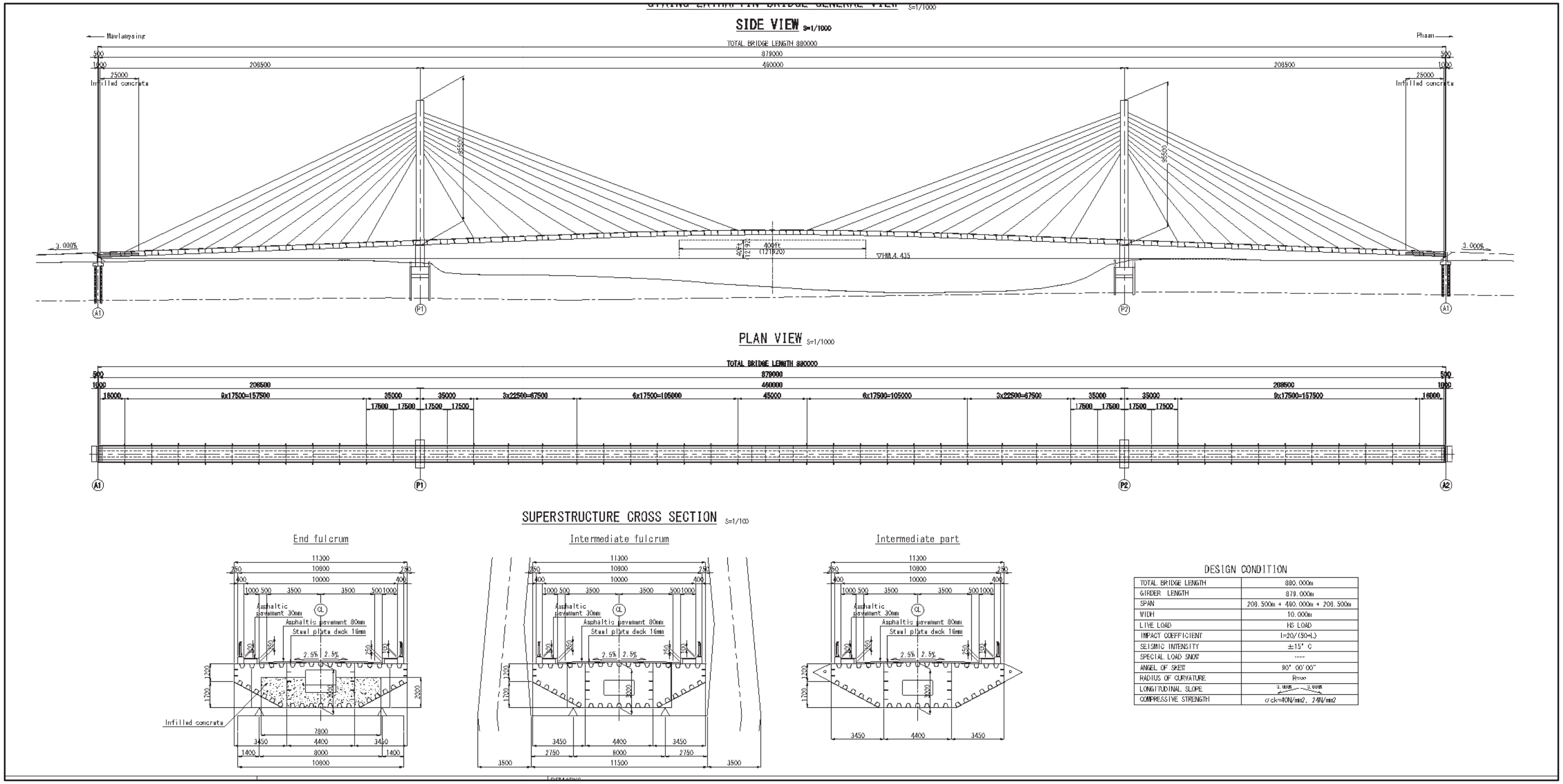
Source : JICA Survey Team

Figure 6.5.6 Configurations of Extradozed Bridge (Gyaing Kawkareik Bridge)



Source : JICA Survey Team

Figure 6.5.7 Configurations of Extradozed Bridge (Atran Bridge)

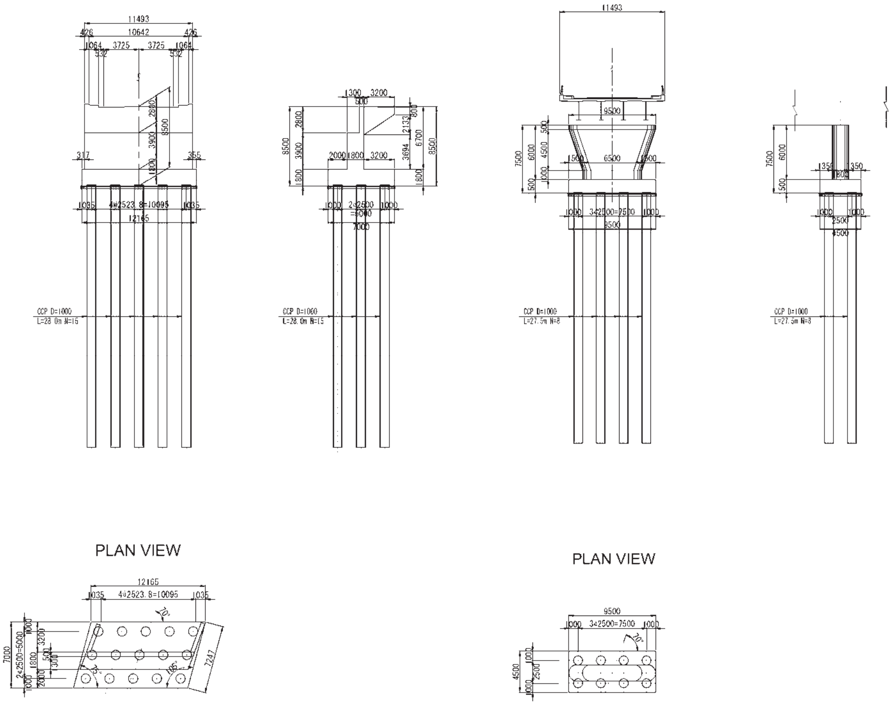


Source : JICA Survey Team

Figure 6.5.8 Configurations of Steel Cable Stayed Bridge(Gyaing Zathapyin Bridge)

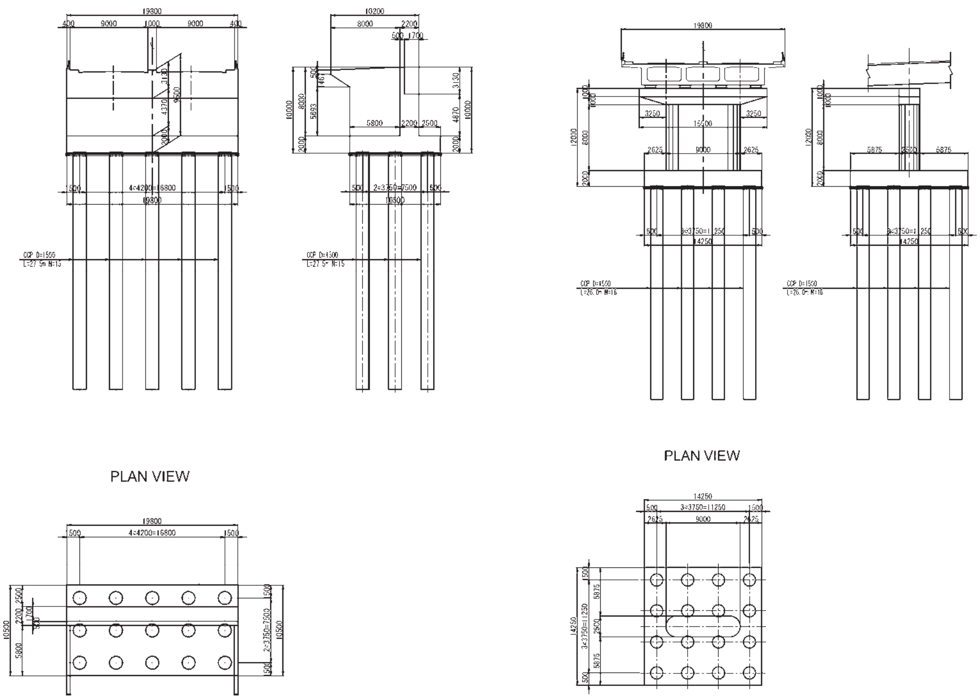
6.5.3 Design of Substructures and Foundations

The typical shapes of substructures and foundations for each bridge based on the outline design are shown in Figure 6.5.9 to Figure 6.5.14.



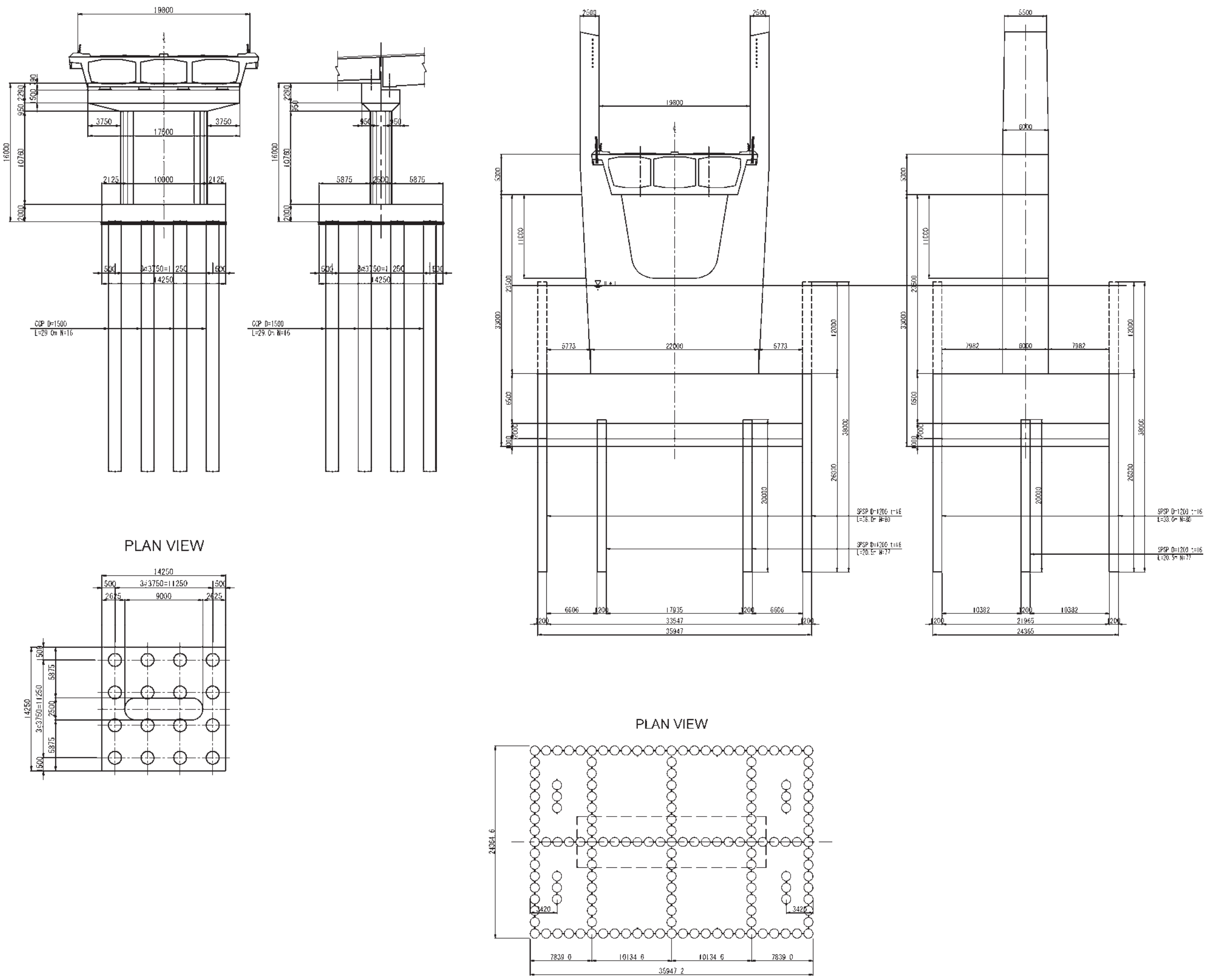
Source: JICA Survey Team

Figure 6.5.9 Typical Shape of Substructure and Foundation for Naung Lon Bridge



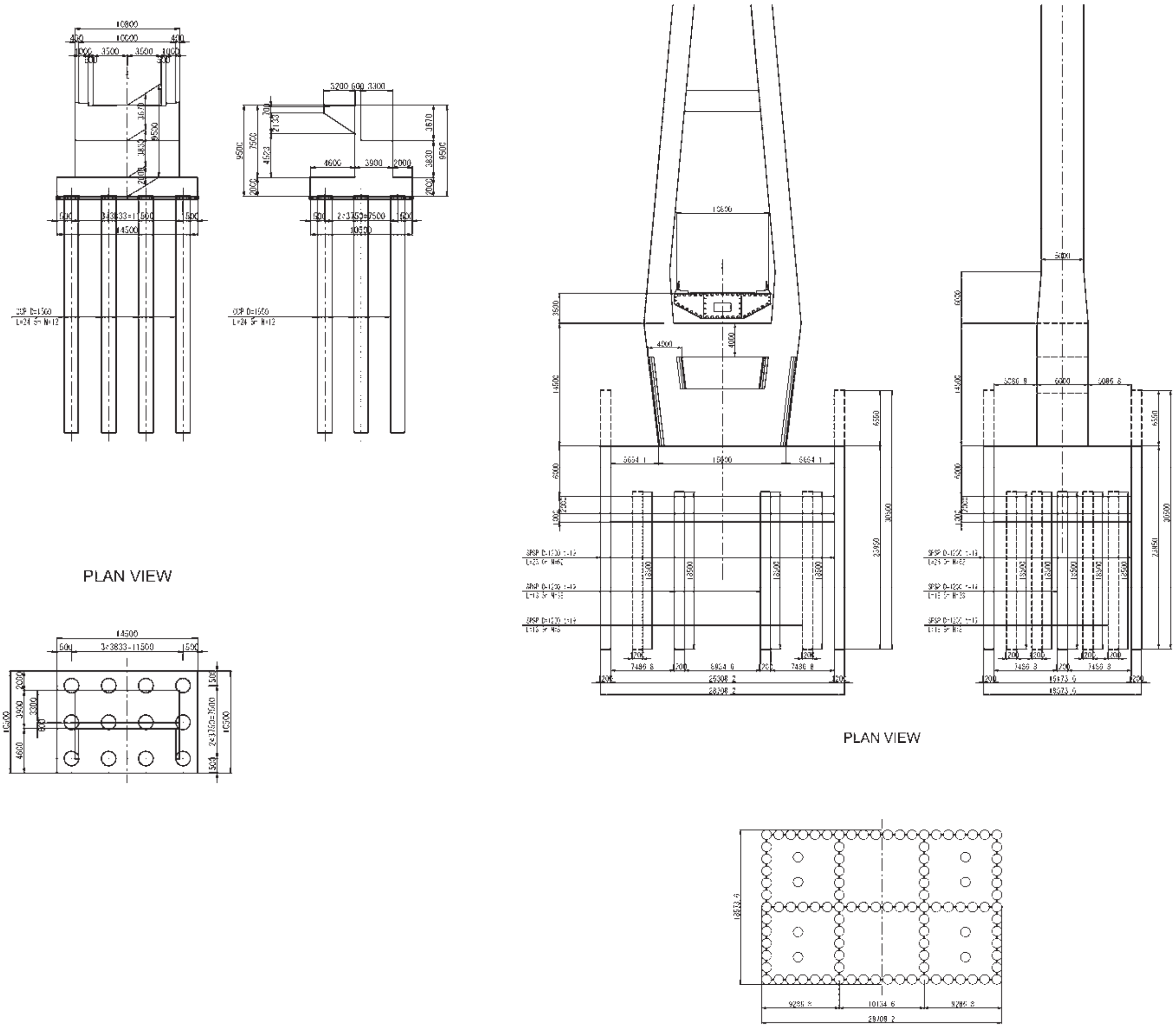
Source: JICA Survey Team

Figure 6.5.10 Typical Shape of Substructure and Foundation for Approach Bridge of Gyaing Kawkareik Bridge



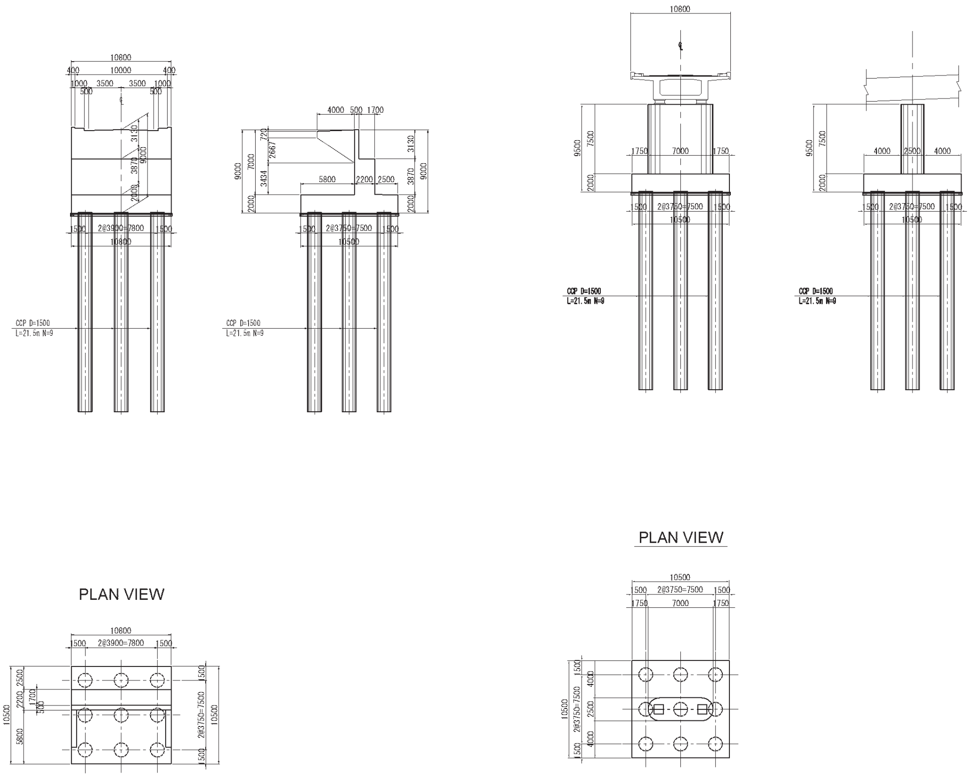
Source: JICA Survey Team

Figure 6.5.11 Typical Shape of Substructure and Foundation for Main Bridge of Gyaing Kawkareik Bridge



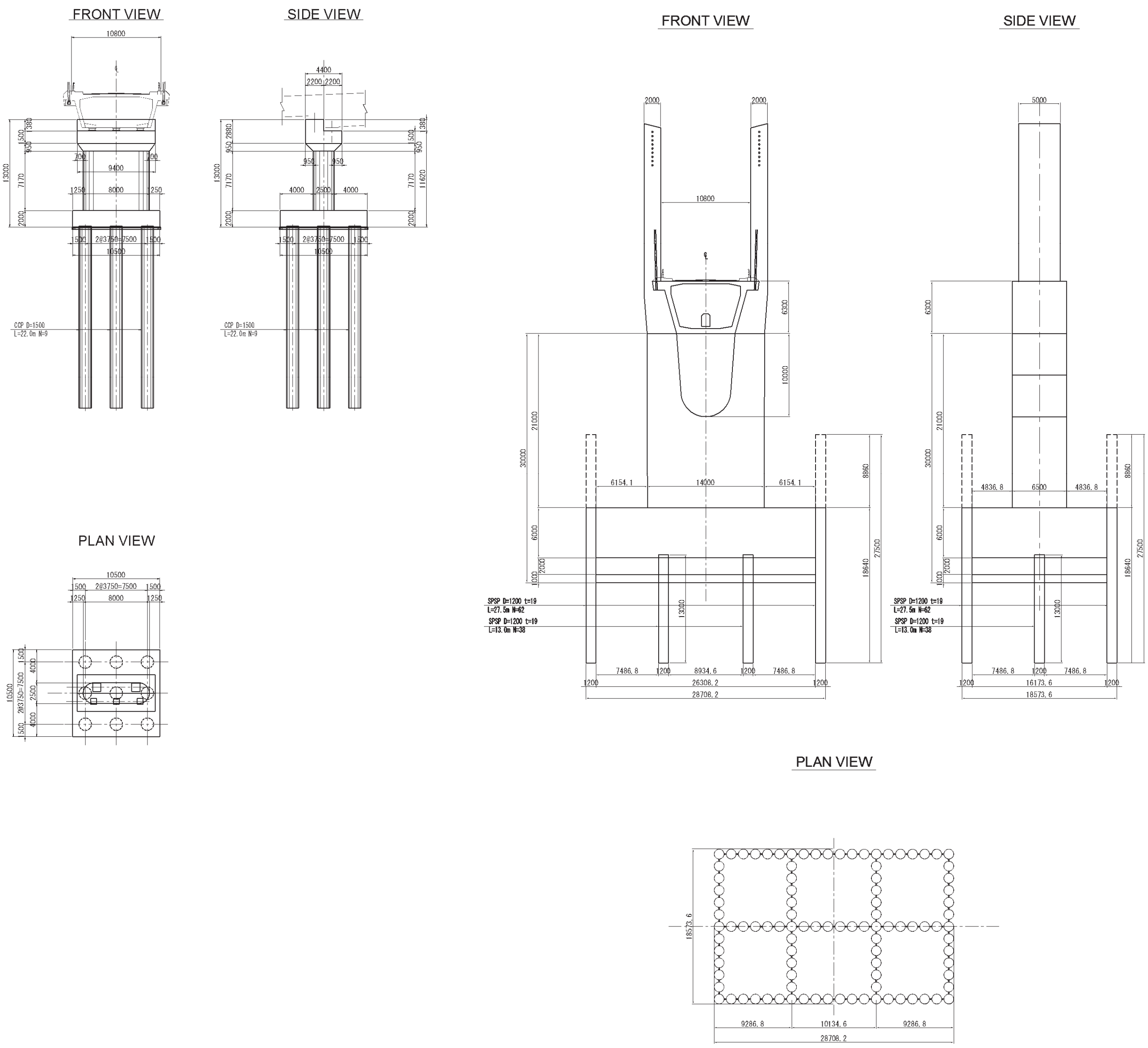
Source: JICA Survey Team

Figure 6.5.12 Typical Shape of Substructure and Foundation for Gyaing Zathapyin Bridge



Source: JICA Survey Team

Figure 6.5.13 Typical Shape of Substructure and Foundation for Approach Bridge of Atran Bridge



Source: JICA Survey Team

Figure 6.5.14 Typical Shape of Substructure and Foundation for Main Bridge of Atran Bridge

6.6 Preliminary Study for Bypass

6.6.1 Route Comparative Study

(1) Thaton Bypass

A comparative study for the alignment of Thaton BP was executed in consideration of technical issues, social impact, and safety issues.

At the meeting with MOC on 7th of July, 2014, based on the findings of the study:

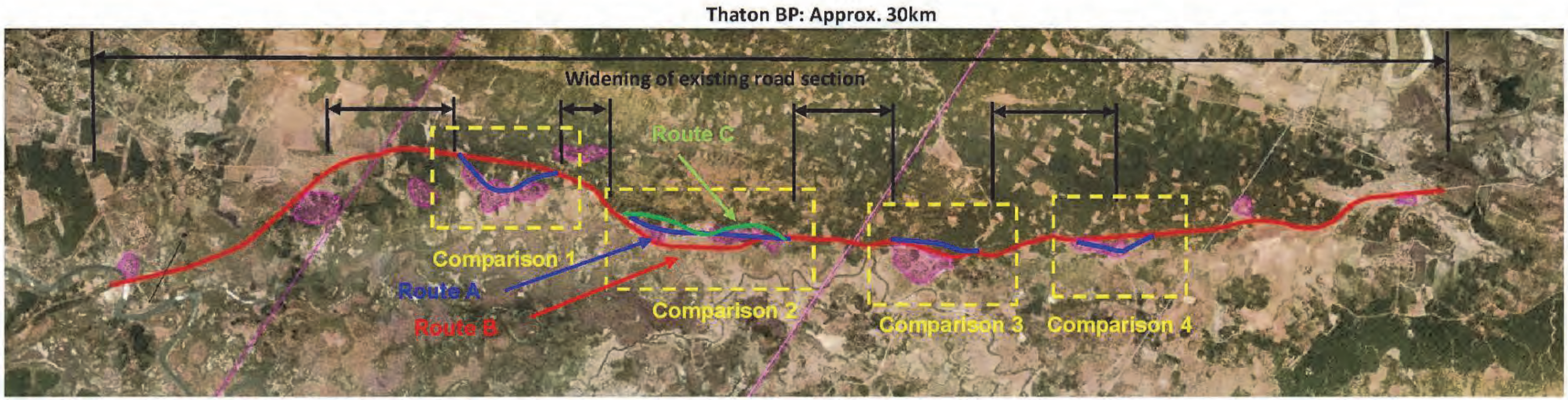
- Routes B and C were selected over Route A in order to avoid involuntary resettlement, and
- Route C was selected over Route B in order to minimize land acquisition of paddy fields (present at one section where the route passes through a mountainside town).

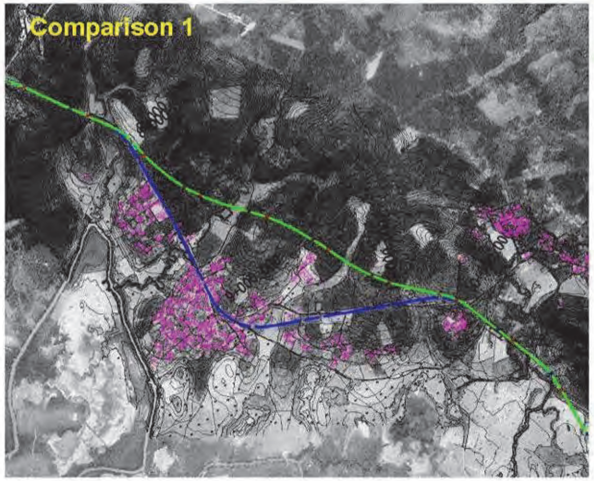
Table 6.6.1 Route Comparison

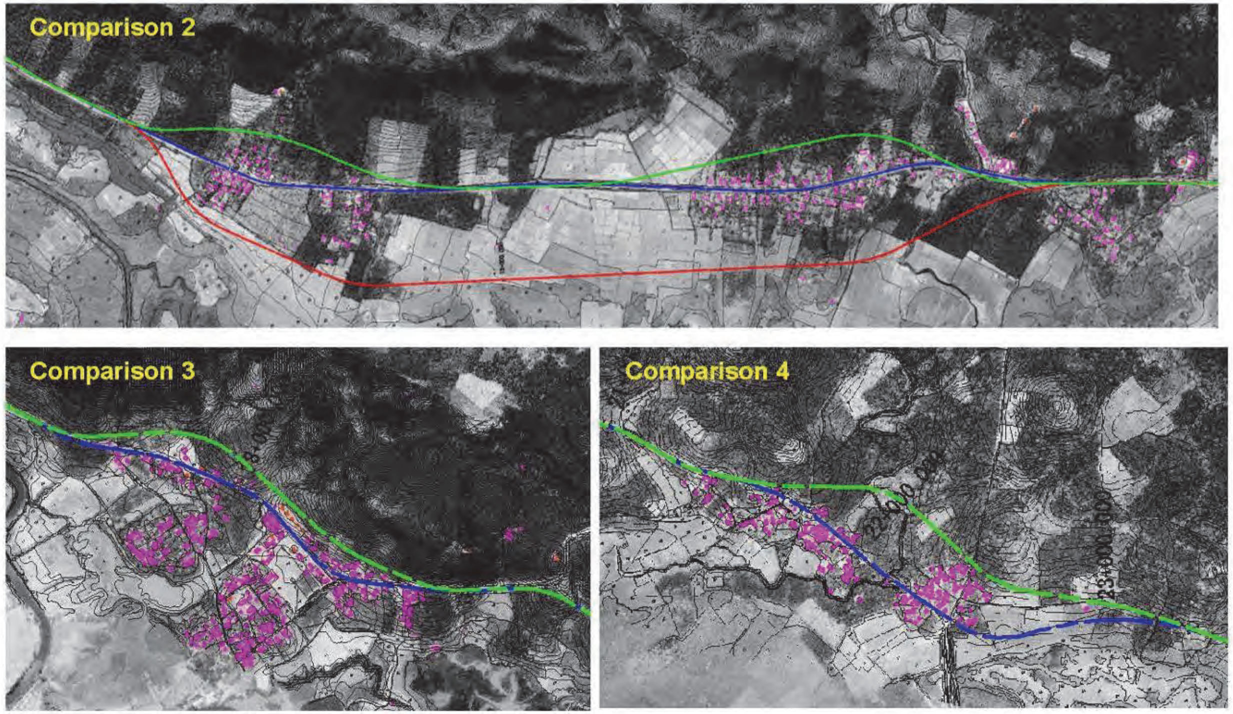
	Alternative Route A (Blue)	Alternative Route B (Red), C (Green)*
Concept of Route Setting	Mostly tracing the existing road as much as possible	Avoiding involuntary resettlement of residents
Length	Thaton BP: 28.9km (existing road: 14.3km, new road: 14.6km)	Thaton BP: 29.0km (existing road: 8.6km, new road: 20.4km)
Affected Properties	No. of Structures:34 structures (more than 200 re-settlers)	No. of Structures:17 structures (87 re-settlers)
Traffic Safety	Route crosses the community (need to appropriate traffic control)	Route away from the community (safer than route A)
Possibilities for future development	Ultimate widening of four lanes in future requires removal of many affected buildings.	Possible ultimate widening of four lanes does not require additional removal of building
Evaluation	Not Recommended	**Recommended (Route C)**

* Route C is mostly the same as Route B route passing through mountain side to minimize land acquisition of paddy field (one section).

Source: JICA Survey Team



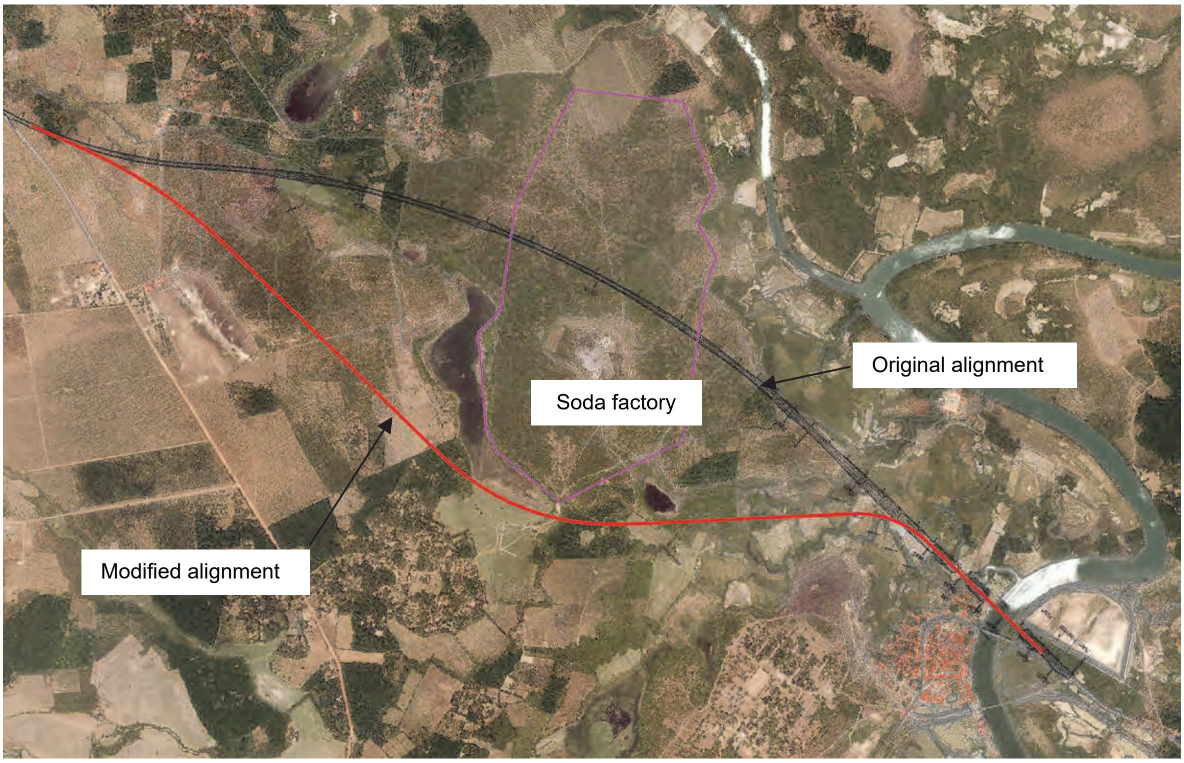




Source : JICA Survey Team

Figure 6.6.1 Comparison of route for Thaton BP

Plan of a soda factory on the original alignment became clear after the decision of alignment. The policy that Thathon BP should avoid the soda factory boundary was decided between the Minister for Ministry of Construction and the Chief Minister for Mon State, therefore the alignment was modified to avoid the soda factory as described below.



Source: JICA Survey Team

Figure 6.6.2 Modified Alignment to avoid Soda Factory

(2) Kyargalay Bypass

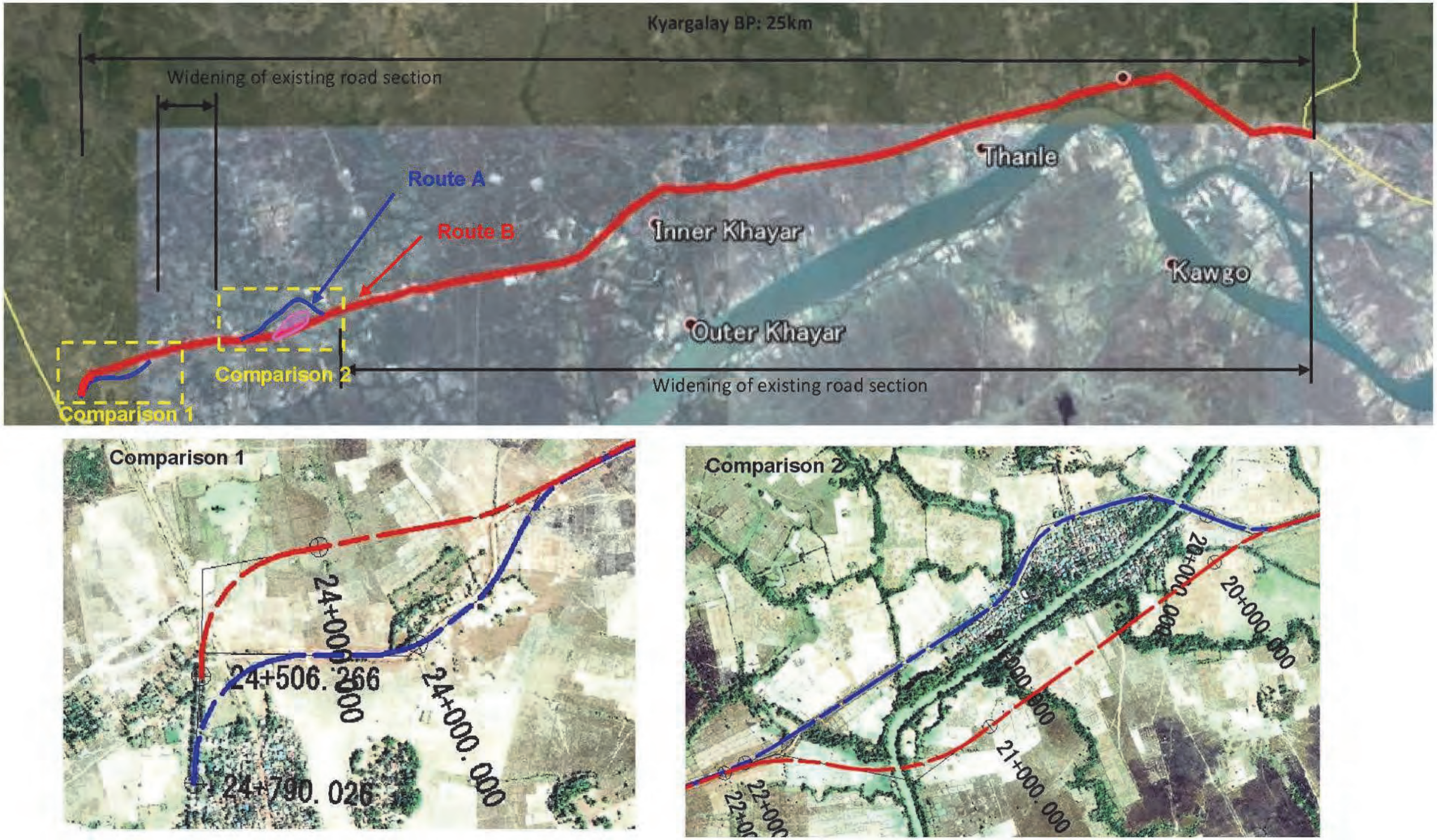
A comparative study for the alignment of Kyargalay the Bypass was executed in consideration of technical issues, social impact, and safety issues.

At the meeting with MOC on 7th of July, 2014, based on this study, B route was selected in order to avoid involuntary resettlement.

Table 6.6.2 Route Comparison

	Alternative Route A (Blue)	Alternative Route B (Red)
Concept of Route Setting	Tracing the existing road as much as possible	Avoiding involuntary resettlement of residents
Length	24.8km (existing road: 23.9km, new road: 0.9km)	24.5km (existing road: 21.4km, new road: 3.1km)
Affected Properties	21 structures + 57 structures (more than 200 re-settlers)	21 structures (104 re-settlers)
Traffic Safety	- Route crosses the community - Requires appropriate traffic control	- Route away from the community - Safer than route A
Possibilities for future development	Eventual widening into four lanes would require removal of many buildings.	Eventual widening into four lanes would not require additional removal of buildings
Evaluation	Not Recommended	**Recommended**

Source: JICA Survey Team



Source : JICA Survey Team

Figure 6.6.3 Comparison of route for Kargalay BP

(3) Study of Superstructure Type

In this section, superstructure type alternatives were studied for the bridges on the proposed bypasses.

a) Donthami Bridge

For the Donthami Bridge, a comparative study of superstructure type alternatives was conducted using the same criteria and evaluation method for the other major four bridges. (Refer to Section 6.3.2).

- **First selection**

The existing bridge is a continuous PC-I girder bridge with a span length of approximately 35m-40m. No navigation clearance is specifically required. However, the feasibility of construction of the foundation in deep water was specifically taken into consideration. Therefore, the following four alternatives were nominated:

- ✓ Alternative 1: Steel I girder (5@40m = 200m) [Two piers in the river]
- ✓ Alternative 2: Steel Box girder (64@60m = 240m) [One pier in the river]
- ✓ Alternative 3: PC Box girder (4@50m = 200m) [One pier in the river]
- ✓ Alternative 4: Steel Box girder with Steel Plate Deck (60m + 90m + 60m = 210m) [No piers in the river]

- **Second selection**

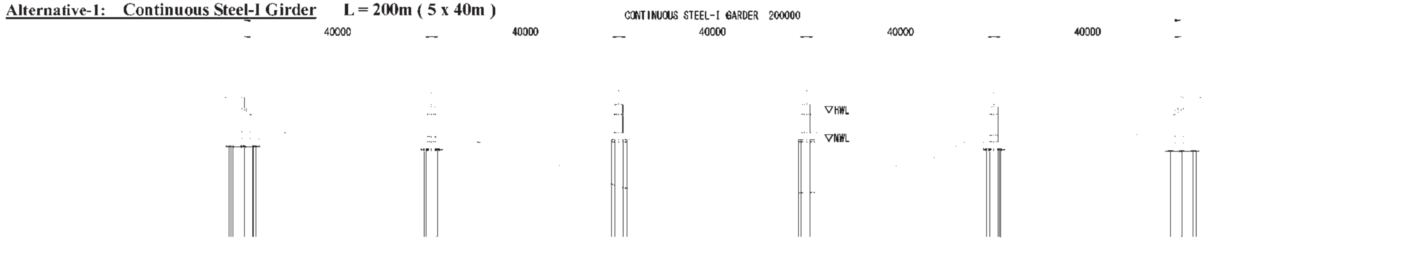
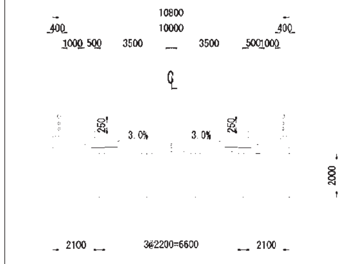
A breakdown of superstructure type evaluation for Donthami Bridge at the second selection stage is shown in Table 6.6.3 and Table 6.6.4. Alternative 1: Steel-I Girder Bridge is recommended due to its reasonable construction cost.

b) Small Bridges Along Bypass

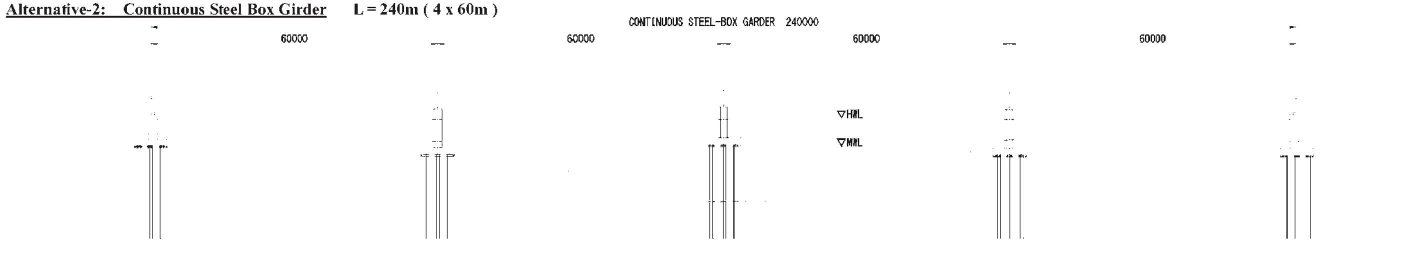
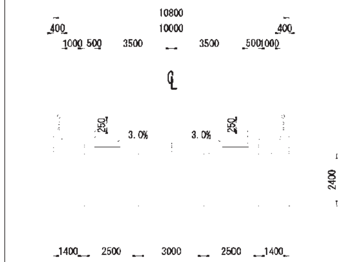
Small bridges are defined as those that must be planned along the proposed bypass at points where the bypass crosses existing creeks and rivers of a width less than 30m, where there are no special conditions of the river or the topography. The proposed span length for small bridges can be up to 30m.

The PC-I girders were selected for the superstructure type due to the ease of constructability and the ease of procurement of materials/equipment, as well as Myanmar's plentiful experience in this type of construction.

Table 6.6.3 Bridge Type Selection for Donthami Bridge (1/2)

Side View	Typical Section
Alternative-1: Continuous Steel-I Girder L = 200m (5 x 40m) 	

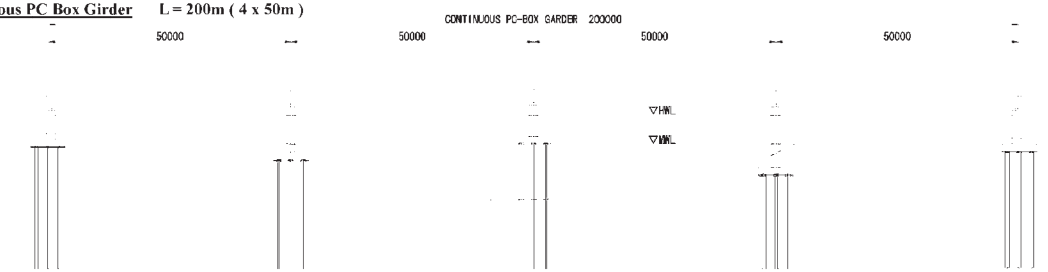
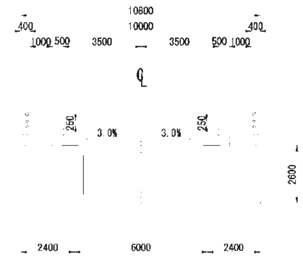
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. But Two multi-pile foundations which is applied to existing bridge can be applied inside deep river. Construction period is approximately 16 months.	Fair	5 / 10
Economic Aspect	Construction Cost	8,910,000USD (μ= 1.00)	----	50 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 31,190 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of foundations in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity.	----	3 / 5
	Technical Transfer	Weathering steel and/or thick anticorrosion painting is new technology.	Good	10 / 10
Evaluation		**Recommended**		84 / 100

Side View	Typical Section
Alternative-2: Continuous Steel Box Girder L = 240m (4 x 60m) 	

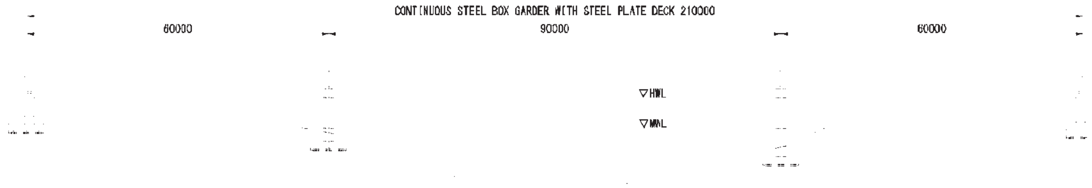
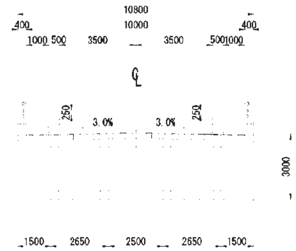
Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. A multi-pile foundation which is applied to existing bridge can be applied inside deep river. Construction period is approximately 19 months.	Fair	5 / 10
Economic Aspect	Construction Cost	11,405,000USD (μ= 1.28)	----	39 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 39,920 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of foundation in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity.	----	3 / 5
	Technical Transfer	Weathering steel and/or thick anticorrosion painting is new technology.	Good	10 / 10
Evaluation		Not recommended		73 / 100

Source : JICA Survey Team

Table 6.6.4 Bridge Type Selection for Donthami Bridge (2/2)

Side View	Typical Section
Alternative-3: Continuous PC Box Girder L = 200m (4 x 50m) 	

Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	PC slab is superior in durability. Multi-continuous spans are structurally strong for earthquake resistance and smooth driving	Good	5 / 5
	Constructability	Launching erection method is applied to be secured for construction safety on the river. A multi-pile foundation which is applied to existing bridge can be applied inside deep river. Construction period is approximately 22 months.	Fair	5 / 10
Economic Aspect	Construction Cost	11,583,000USD (μ= 1.30)	----	38 / 50
	Maintenance	Maintenance for PC bridge is almost free except expansion joints and bearing shoes. Annual O&M cost is assumed as 23,200 USD.	Good	15 / 15
Other Aspect	Environment	Almost no affected houses. Need construction of foundation in the river. Due care for water pollution must be taken.	Fair	3 / 5
	Landscape	This type of bridge is relatively visual simplicity	----	3 / 5
	Technical Transfer	PC Box girder is still useful in Myanmar.	Fair	5 / 10
Evaluation		Not recommended		74 / 100

Side View	Typical Section
Alternative-4: Continuous Steel Box Girder with Steel Plate Deck L = 210m (60m + 90m + 60m) 	

Category	Evaluation Criteria	Description	Evaluation	
Technical Aspect	Structural Stability	Multi-continuous spans are structurally strong for earthquake resistance and smooth driving.	Good	5 / 5
	Constructability	Light steel members are advantage for erection. No need to construct foundation inside river. Construction period is approximately 18 months.	Fair	10 / 10
Economic Aspect	Construction Cost	13,276,000 (μ= 1.49)	----	34 / 50
	Maintenance	Repainting on steel girder is required in every 30 years as well as bearings and expansion joints. But it can be almost maintenance free in applying weathering steel or thick anticorrosion painting. Annual O&M cost is assumed as 46,470 USD.	Fair	8 / 15
Other Aspect	Environment	Almost no affected houses.	Good	5 / 5
	Landscape	This type of bridge is relatively visual simplicity.	----	3 / 5
	Technical Transfer	Weathering steel and/or thick anticorrosion painting is new technology.	Good	10 / 10
Evaluation		Not recommended		75 / 100

Source : JICA Survey Team

(4) Study of Foundation Type

Due to different design conditions, two different foundation type studies have been conducted: one for foundations within rivers (for Donthami Bridge's inner-river pier), and another for foundations on land (all others).

a) Donthami Bridge

The selection of foundation type in a river shall be carefully considered taking into account specific criteria and natural conditions:

- ✓ The water depth for proposed bridge sites
- ✓ Possibility of scouring (sufficient attention must be paid to scouring)
- ✓ Supporting load of foundation
- ✓ Depth of the supporting layer

Table 6.6.5 shows the applicable foundation types.

Table 6.6.5 Applicable Foundation Types (inside River) for Donthami Bridge

Criteria			Cast- in-place Concrete Pile	PHC / SC PIle	Steel Pipe Pile	Diaphragm wall	Steel pipe sheet pile	Caisson
Condition of Construction	Temporary Jetty	Depth < 5 m	△	○	○	×	○	△
		Depth > 5 m	△	△	○	×	○	△
	Environment	Vibration Noise	○	×	×	○	△	○
		Impact on Adjacent Structure	○	×	△	○	△	△
	Loading	Normal	○	○	○	○	○	○
		Large	○	×	○	○	○	○
Ground Condition	Depth of Supporting Layer from Ground Level	< 5 m	△	×	×	×	×	×
		5 ~ 15 m	○	○	○	△	△	○
		15 ~ 25 m	○	○	○	○	○	○
		25 ~ 40 m	○	○	○	○	○	○
		40 ~ 60 m	○	△	○	○	○	○
		≥ 60 m	△	×	△	△	△	△
	Soil Condition	Clay (20 ≤ N)	○	○	○	○	○	○
		Sand/Gravel (30 ≤ N)	○	○	○	○	○	○

Note : ○: Suitable, △: Possible, ×: Impossible

Source: JRA

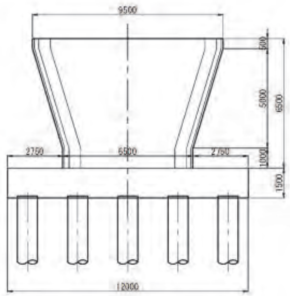
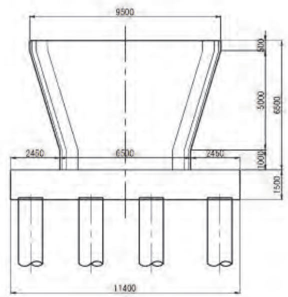
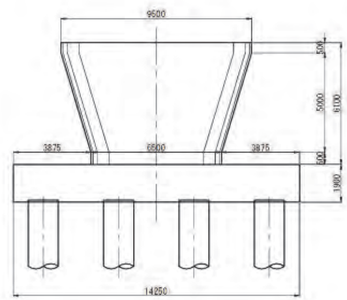
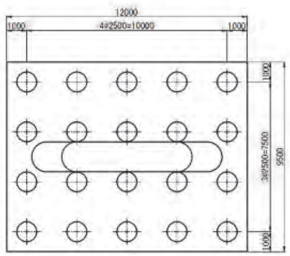
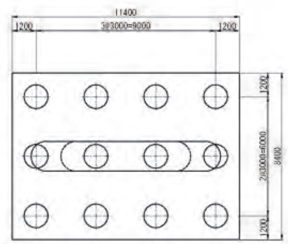
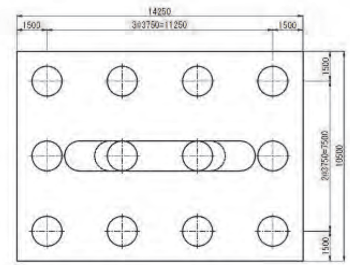
Four different foundation types such as Cast-in-Place Concrete Piles (CPCP), Steel Pipe Piles (SPP), Steel Pipe Sheet Piles (SPSP) and Concrete Caissons (CC) can be applied for the foundations of Donthami Bridge in accordance with Table 6.6.5. However, SPSP and Caisson would not be reasonable due to the bridge scale. Hence, two foundation types (Cast-in-Place Concrete Pile, Steel Pipe Pile) can be compared.

As a result of the comparative study, steel pipe piled foundations were found to be economically reasonable.

b) Small Bridge Along Bypass

Cast-in-place concrete piled foundation (CPCP) was selected for the foundation type of "small bridges" due to CPCP's constructability, the ease of procurement of required materials/equipment, and Myanmar's ample experience in CPCP construction. The pile diameter selected for Naung Lon Bridge can also be applied in this case due to the similar scale of load.

Table 6.6.6 Bridge Type Selection for Donthami Bridge (2/2)

	Alt-1 Steel pipe pile (φ1000)	Alt-2 Steel pipe pile (φ1200)	Alt-3 Cast-in-Place Concrete Pile (φ1500)
Foundation			
			
Description	■Pier Column ・1.5m x 6.5m ・Main re-bar : D29 ・Seismic time ■Foundaion ・Steel pipe pile: φ1000-20, L=45.0m,t=20mm	■Pier Column ・1.5m x 6.5m ・Main re-bar : D29 ・Seismic time ■Foundaion ・Steel pipe pile: φ1200-12, L=45.0m,t=18mm	■Pier Column ・1.5m x 6.5m ・Main re-bar : D29 ・Seismic time ■Foundaion ・Cast-in-place concrete pile: φ1500-12, L=45.5m Sheath tube: L=20m,t=15mm
Cost ratio	**767,600 USD** **(1.446)**	**530,700 USD** **(1.000)**	**637,300 USD** **(1.201)**
Evaluation	There is slightly much number of Piles Not recommended	It has excellent economic efficiency and workab Recommended	Steel pipe of the protrusion is expensive Not recommended

Source : JICA Survey Team

6.7 Preliminary Design for Thaton Bypass

6.7.1 Horizontal Alignment Design

The concept of the selected horizontal alignment is given as follows:

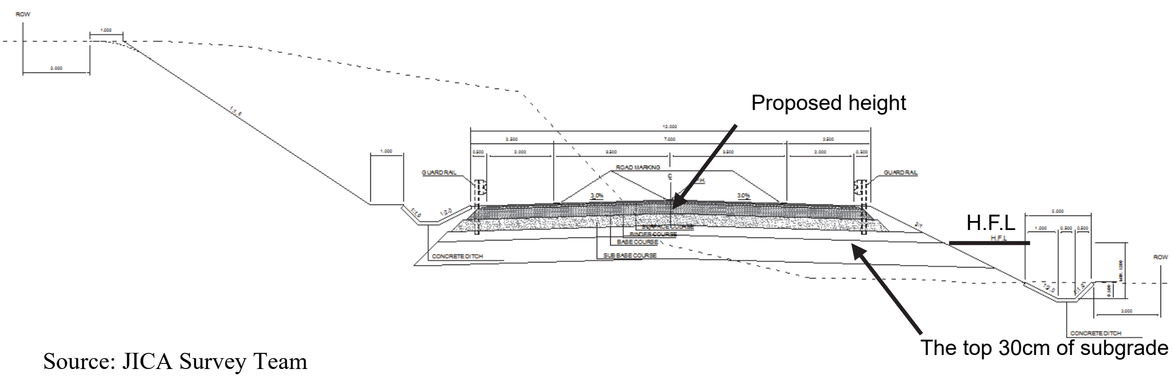
- The beginning point connects to the existing road near the east side of the existing Donthami Bridge. The end point connects to NR-8 at the northern part of Don Wun.
- The new alignment shall follow the alignment of the existing road as much as possible while satisfying the geometric design standards
- The new alignment shall avoid control points such as pagodas, schools, important public facilities, etc.
- The new alignment shall avoid villages and communities to minimize resettlement.

Horizontal alignment for Thaton Bypass is shown in Figure 6.7.2.

6.7.2 Vertical Alignment Design

The concept of vertical alignment setting is given as follows.

- To maintain a minimum clearance of 30cm above sub-grade from H.F.L to protect the pavement structure during flooding
- To maintain 0.3% of minimum vertical gradient for drainage of run-off water



Source: JICA Survey Team

Figure 6.7.1 Proposed Height of Thaton Bypass

Source: JICA Survey Team

Figure 6.7.2 Horizontal Alignment of Thaton BP

6.7.3 Pavement Design

(1) Basic Design Condition

At the meeting with MOC on March 12th, 2014, the decision was made to adopt asphalt pavement and to apply AASHTO Guide for Design of Pavement Structures (1993) for the pavement design of the approach roads of the four bridges.

In this standard, the required Structural Number (SN) is calculated as shown in the following sections, and the layer combination (the layer coefficient and the thickness of each layer) must satisfy the requirements of the SN. Performance period for pavement design is shown in Table 6.7.1.

Table 6.7.1 Performance Period for Pavement Design

Assumed completion year	Design Period
2021	20years (2022-2041)

Source: JICA Survey Team

Design condition for the pavement design is summarized in Table 6.7.2.

Table 6.7.2 Basic Design condition for pavement design

Design Input Requirements			Value
1	Design Variables	Performance Period, Analysis Period	20years
		Traffic - Cumulative 18kip Equivalent Single Axle Load (ESAL) ($\hat{w}_{18}$: 2 directions) -Directional Distribution Factor: D_D -Lane Distribution Factor: D_L	 - From the result of Traffic Demand Forecast - 0.5 (2 Lane) - 1.0 (2 lane)
		Reliability (Z_R)	90% (-1.282)
		Overall Standard Deviation (So)	0.45 (Flexible pavement)
2	Performance Criteria	Initial Service Index (Po)	4.2
		Terminal Serviceability (Pt)	2.5
		Design Serviceability Loss ($\triangle PSI = P_0 - P_t$)	1.7
3	Material Properties	Effective Roadbed Soil Resillent Modulus: M_R(psi)	1500 x CBR
		Layer Coefficient for Asphalt Concrete: a_1 Layer Coefficient for Base Course (Crushed Stone CBR＞80): a_2 Layer Coefficient for Sub Base Course (Gravel: CBR>30):, a_3	$a_1 = 0.42$ $a_2 = 0.14$ $a_3 = 0.11$
4	Pavement Characteristics	Drainage Coefficient for Base Course and Subbase Course: m_2, m_3	1.00

Source: JICA Survey Team

(2) Traffic Volume and Equivalent Single Axle Load (ESAL)

The forecast traffic volume (vehicle/day) for each vehicle type in 2030, 2035 is shown in Table 6.7.3.

Table 6.7.3 Traffic Demand Volume Forecastfor Thaton BP

Unit: vehicle/day

Year	PassengerCars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≥ 4 axles		
			Small	Big				
2035	7,210	680	300	960	640	2,090	1,140	13,020
2040	16,980	1,380	830	2,520	1,460	5.070	2,710	30,950

Source: JICA Survey Team

Traffic volume (vehicle/day) for each design period assumed from traffic demand forecast is shown in Table 6.7.4.

Table 6.7.4 Traffic Volume for Pavement Design Period of Thaton BP

Unit: vehicle/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≥ 4 axles		
			Small	Large				
2023	2,157	286	241	771	208	820	186	4,670
2024	2,296	307	245	785	229	887	217	4,966
2025	2,444	330	250	800	251	959	252	5,286
2026	2,602	355	255	815	276	1,036	293	5,631
2027	2,769	382	259	830	303	1,120	341	6,004
2028	2,948	410	264	845	332	1,211	396	6,407
2029	3,138	441	269	860	365	1,309	461	6,843
2030	3,340	474	274	876	401	1,415	536	7,316
2031	3,964	509	279	892	440	1,530	623	8,238
2032	4,705	548	284	909	483	1,654	725	9,308
2033	5,584	589	289	926	531	1,788	843	10,549
2034	6,627	633	295	943	583	1,933	980	11,994
2035	7,210	680	300	960	640	2,090	1,140	13,020
2036	8,557	783	368	1,164	755	2,495	1,356	15,478
2037	10,156	903	451	1,412	890	2,979	1,612	18,403
2038	12,054	1,040	552	1,713	1,050	3,557	1,917	21,883
2039	14,307	1,198	677	2,078	1,238	4,247	2,279	26,023
2040	16,980	1,380	830	2,520	1,460	5,070	2,710	30,950
2041	20,153	1,590	1,017	3,057	1,722	6,053	3,222	36,814
2042	23,919	1,832	1,247	3,707	2,031	7,227	3,832	43,794
Total (2022-2041)	**134,018**	**13,102**	**7,636**	**23,914**	**12,345**	**42,914**	**20,249**	**254,178**

Source: JICA Survey Team

Cumulative 18kip equivalent single axle load on each bridge is shown in Table 6.7.5.

Table 6.7.5 ESAL 18-kip for Thaton BP

	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≧4 axles		
			Small	Large				
Traffic Volume (v/d) 2023-2042	134,018	13,102	7,636	23,914	12,345	42,914	20,249	
Traffic Volume (v/y) 2023-2042	48,916,614	4,782,312	2,787,127	8,728,488	4,505,766	15,663,750	7,390,765	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	48,917	4,160,611	34,003	8,553,918	7,119,111	24,748,725	10,938,333	55,603,618
ESAL=DD×DL×ŵ 18=0.5×1.0×55,603,618= 27,801,809								

Source: JICA Survey Team

(3) CBR for Subgrade

The design CBR for Subgrade on the new embankment is set to 7.0.

(4) Design Structural Number (SN)

Based on below formula and above mentioned conditions, the design structural number (SN) is calculated as shown in Table 6.7.6

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

Table 6.7.6 Design Structural Number (SN)

Z_R	S_O	W_{18} ESAL	M_R	△PSI	SN (inch)
90%	0.45	23,461,86	10,500	1.7	5.14

Source: JICA Survey Team

(5) Determination of Structural Layer Thickness

Structural layer thickness is designed such that the following condition is satisfied.

Required Structural Number ≧ Design Structural Number

Required Structural Number SN = $a_1D_1+a_2D_2M_2+a_3D_3M_3$

where a_i: i Layer Coefficient

D_i: i Layer Thickness (inch)

M_i: i Layer Drainage Coefficient

Determined structural layer thickness is shown in Table 6.7.7.

Table 6.7.7 Structural Layer Thickness

<table>
<tr><td colspan="2" rowspan="2">Design SN</td><td>Surface Course</td><td>Binder Course</td><td>Base Course</td><td>Sub Base Course</td><td>Total Thickness (cm)</td></tr>
<tr><td colspan="4">Each Layer Thickness(cm)</td><td rowspan="2">Required Structural Number (cm)</td></tr>
<tr><td>inch</td><td>cm</td><td colspan="4">Layer Coefficient x Thickness</td></tr>
<tr><td rowspan="2">5.14</td><td rowspan="2">13.31</td><td>4</td><td>6</td><td>35</td><td>40</td><td>85</td></tr>
<tr><td>0.42 x 4 = 1.68</td><td>0.42x6 = 2.52</td><td>0.14 x 35 = 4.90</td><td>0.11 x 40 = 4.40</td><td>1.68 + 2.52 + 4.9 + 4.4 = 13.50</td></tr>
</table>

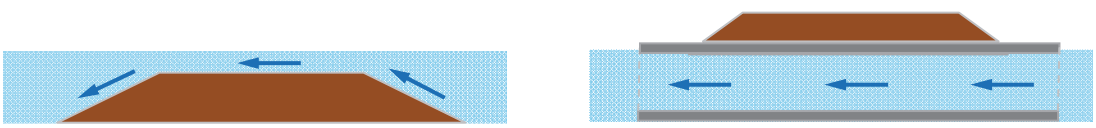
Source: JICA Survey Team

6.7.4 Drainage Design

(1) Surface Drainage

Runoff surface water is collected by ditches at the toes of cut-and-fill slopes. The collected water is guided to the proper location.

In the case of flooding, flood water is drained on the existing road surface. After the planned BP development, flood water will be unable to cross the road because the proposed height of the BP is greater than the HWL. Therefore, it is necessary to develop proper box culverts and bridges in order to allow flood water to pass.



<Current condition> <After BP development>

Source: JICA Survey Team

Figure 6.7.3 Drainage condition in case of flood

6.7.5 Traffic Safety Facilities

(1) Guardrails

In order to secure traffic safety, guardrails are to be installed alongside earth shoulders at all filled sections (except at intersections and sections that require access to the roadside).

(2) Road Markings

Lane edge lines (solid lines of width 0.15m) and road centre lines (broken lines at 5m-intervals of width 0.15m) are installed in the earth work section.

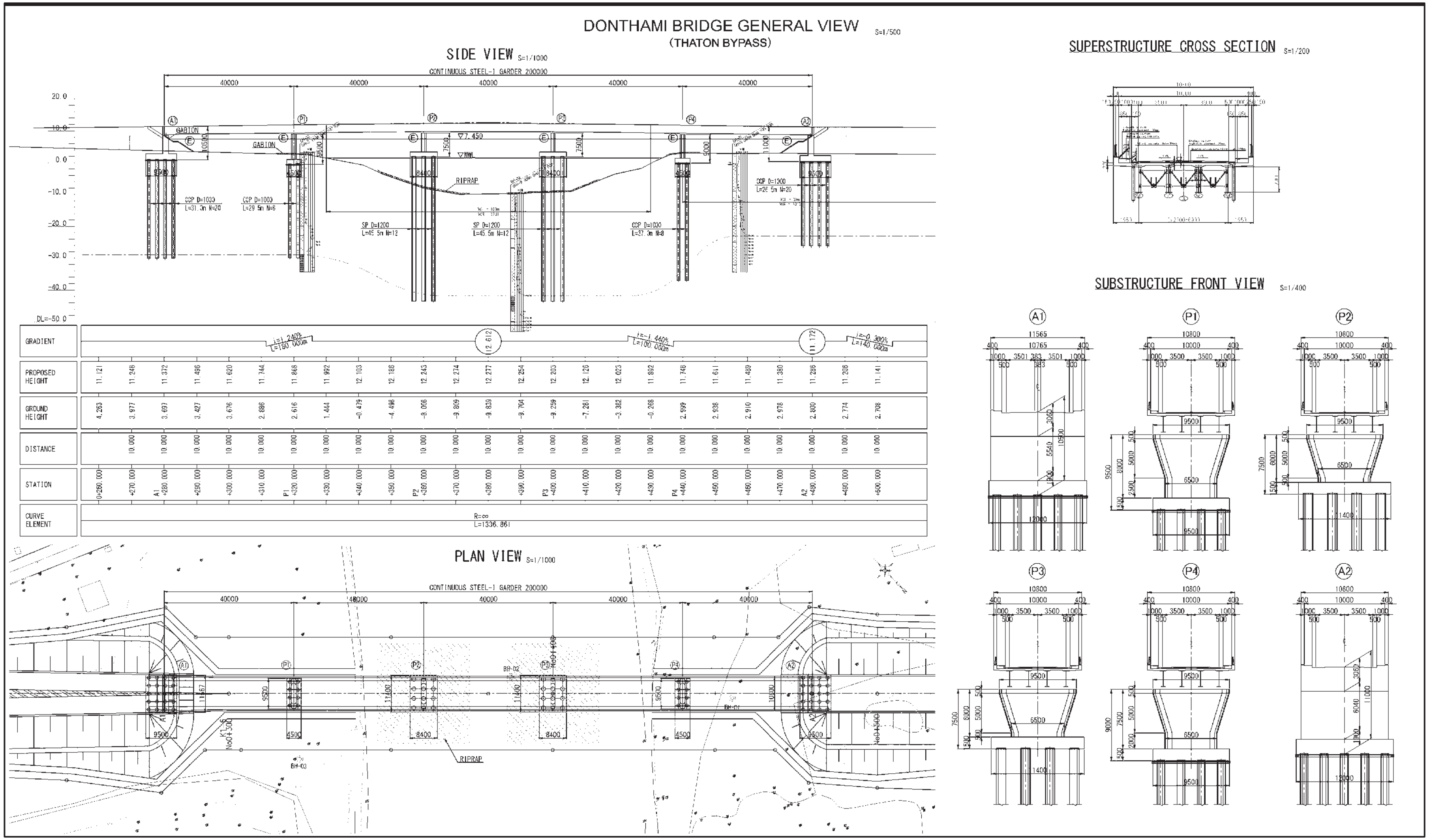
(3) Traffic Signs

Speed control signs (80 km/h) are installed in the vicinity of the beginning point, the end point and the main intersections of the BP.

6.7.6 Bridge Design

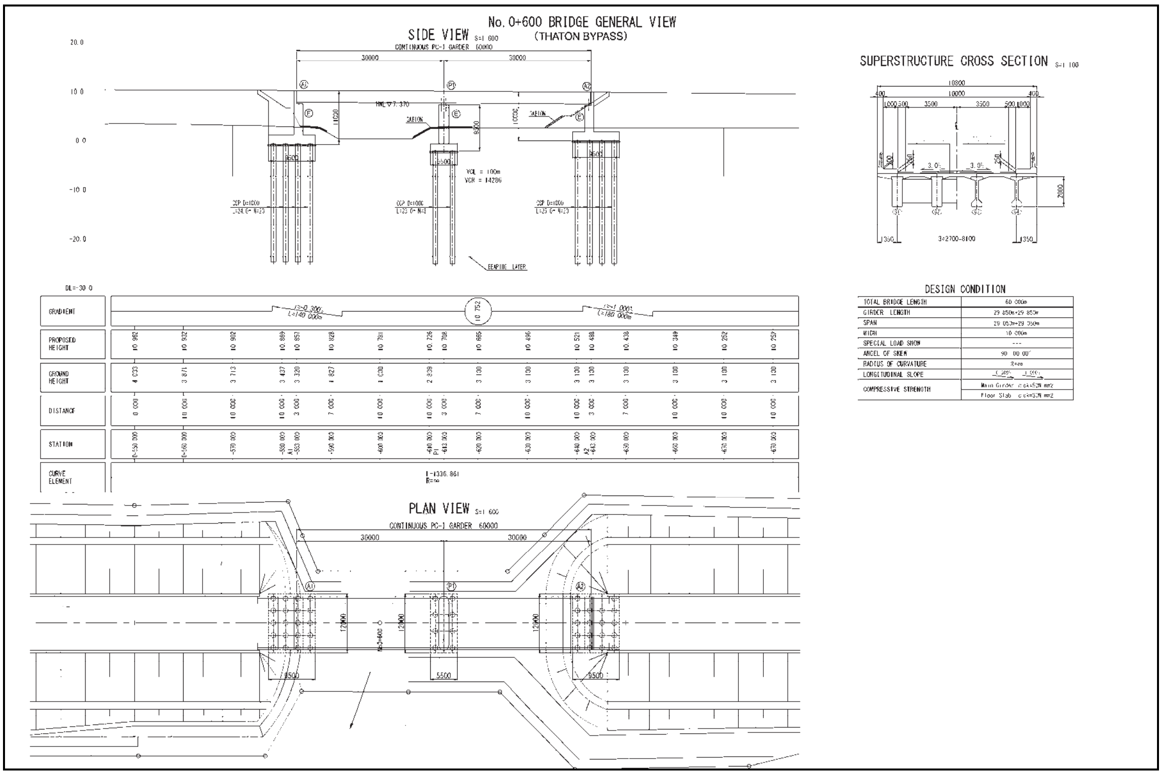
The design of bridges is preliminarily conducted for the proposed superstructure, substructure and foundation type, through comparison of several alternatives. The purpose of the preliminary design is to define the structural element sizes so that better estimates of cost and constructability could be obtained.

The general view of each bridge is shown in Figure 6.7.4 to Figure 6.7.9. The configuration of girders and the typical shapes of the substructures and foundations for Donthami Bridge are shown in Figure 6.7.10 to Figure 6.7.14



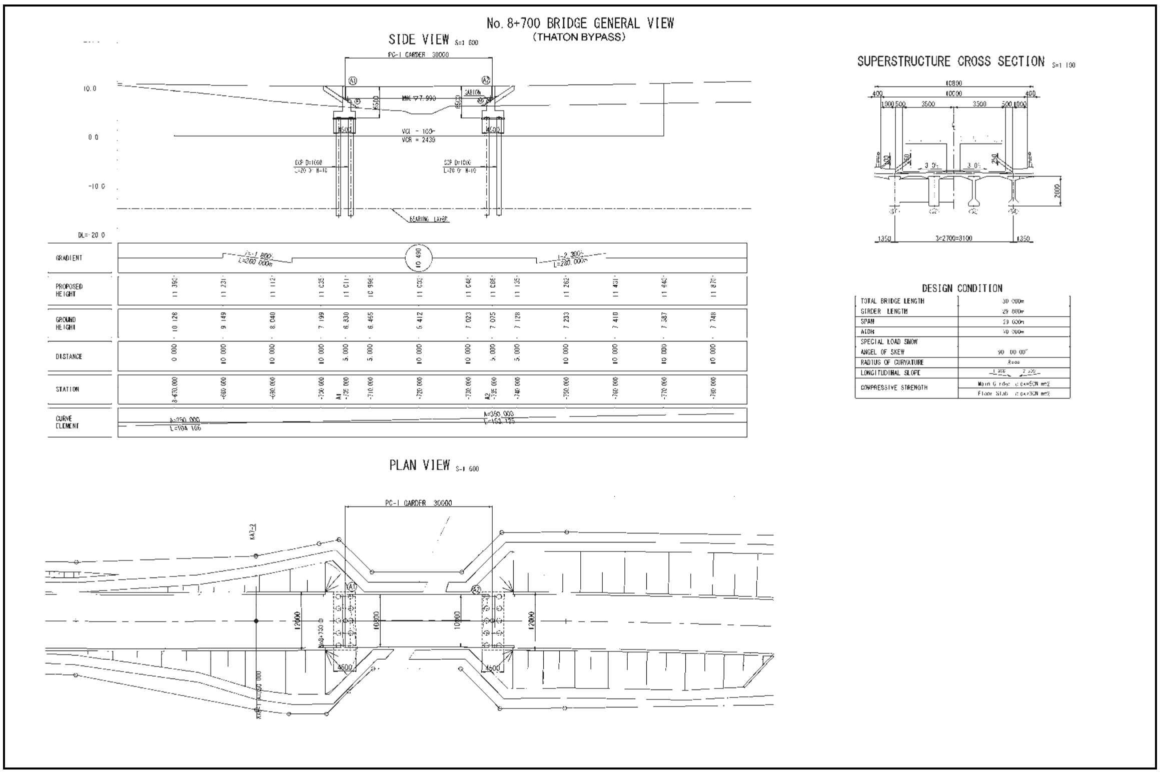
Source : JICA Survey Team

Figure 6.7.4 General View of Donthami Bridge



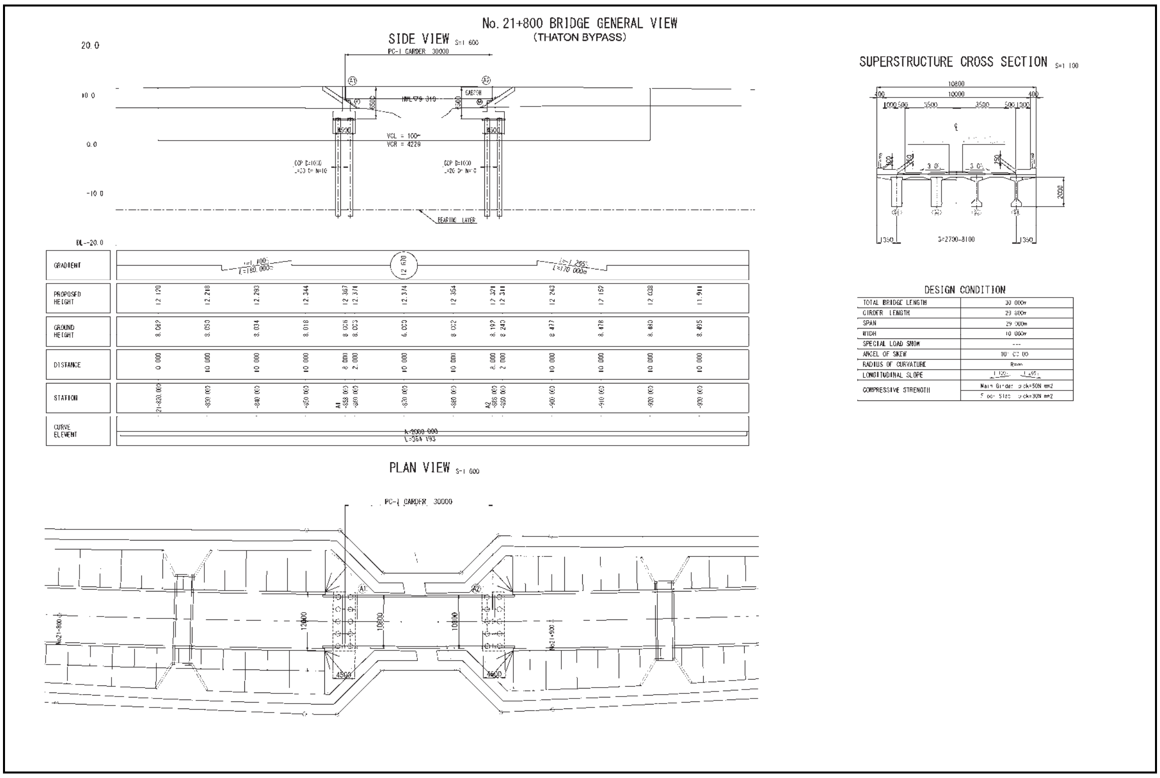
Source: JICA Survey Team

Figure 6.7.5 General View of No. 0+600 Bridge



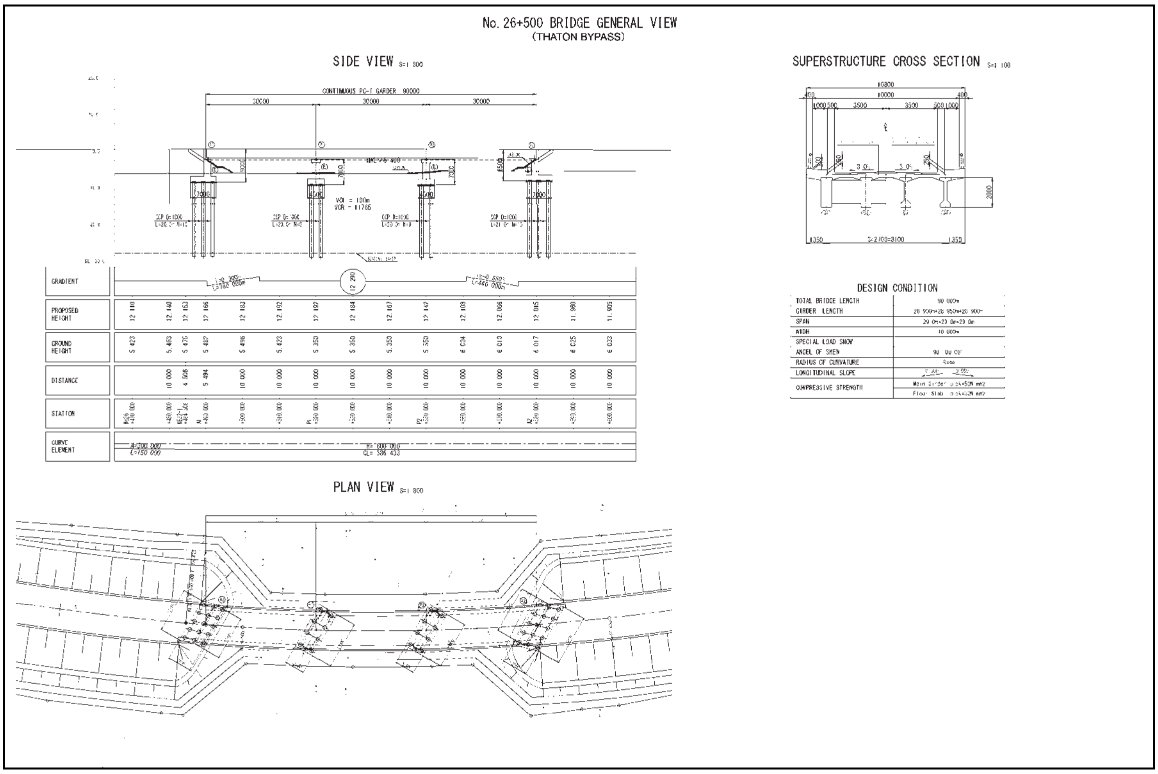
Source: JICA Survey Team

Figure 6.7.6 General View of No. 8+700 Bridge



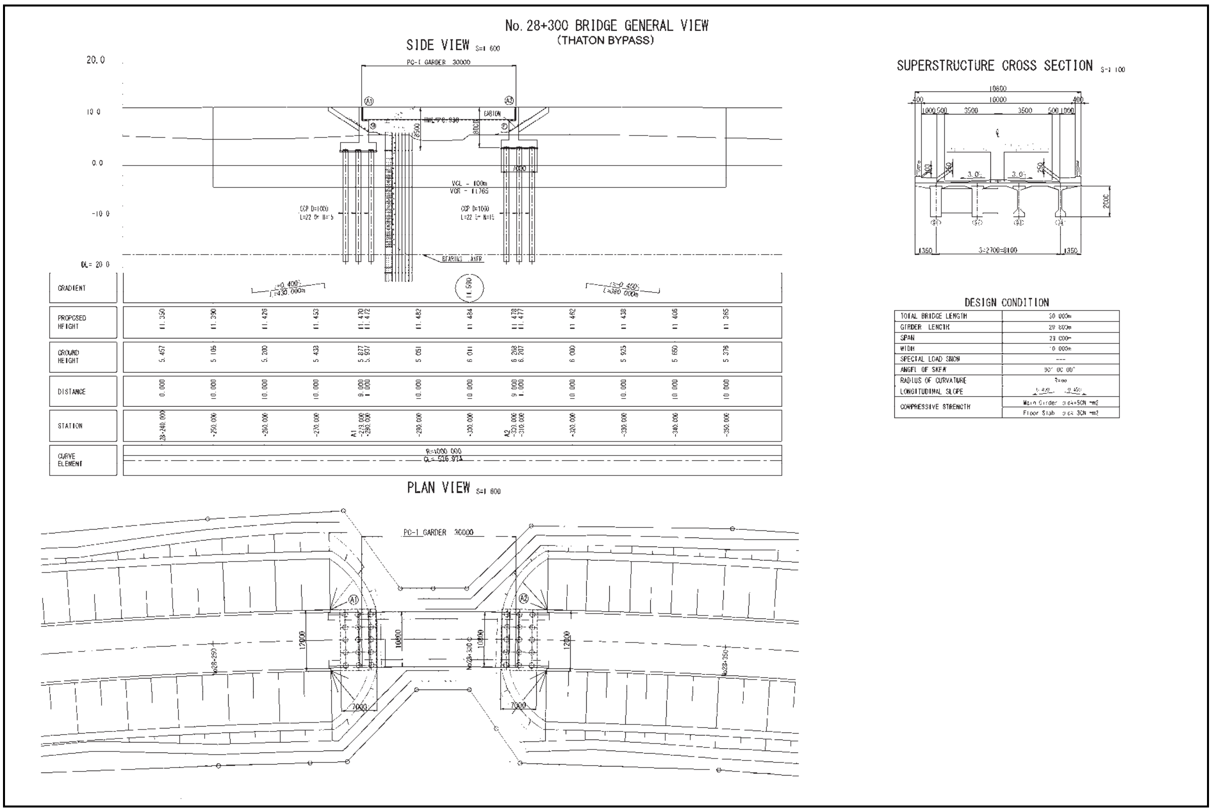
Source: JICA Survey Team

Figure 6.7.7 General View of No. 21+800 Bridge



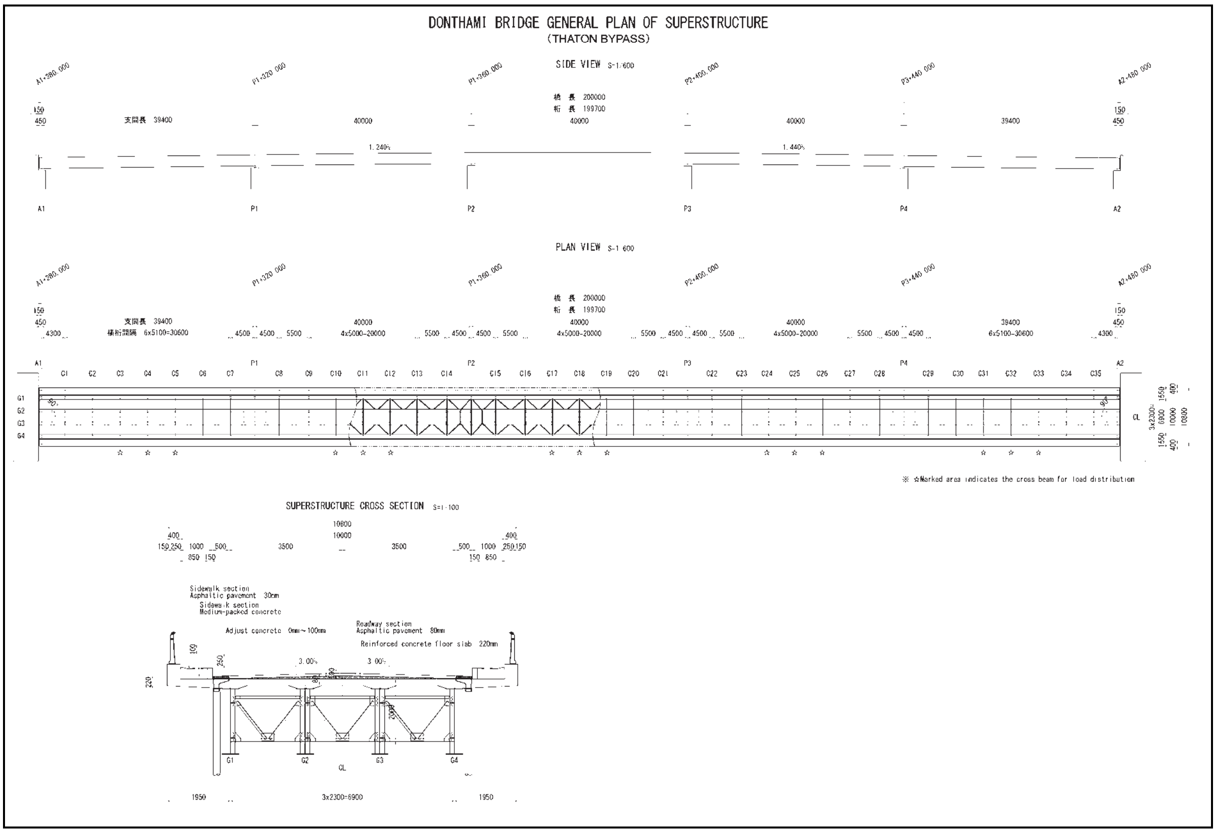
Source: JICA Survey Team

Figure 6.7.8 General View of No. 26+500 Bridge



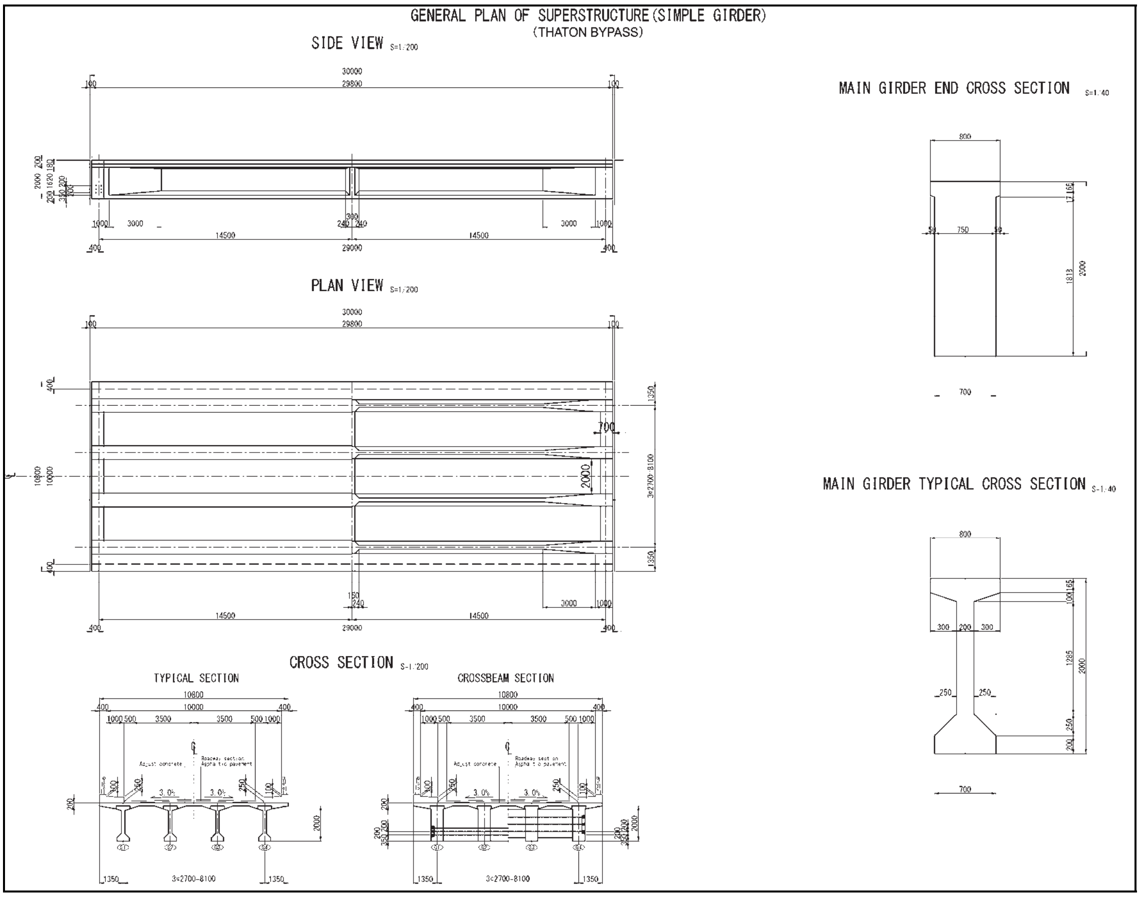
Source: JICA Survey Team

Figure 6.7.9 General View of No. 28+300 Bridge



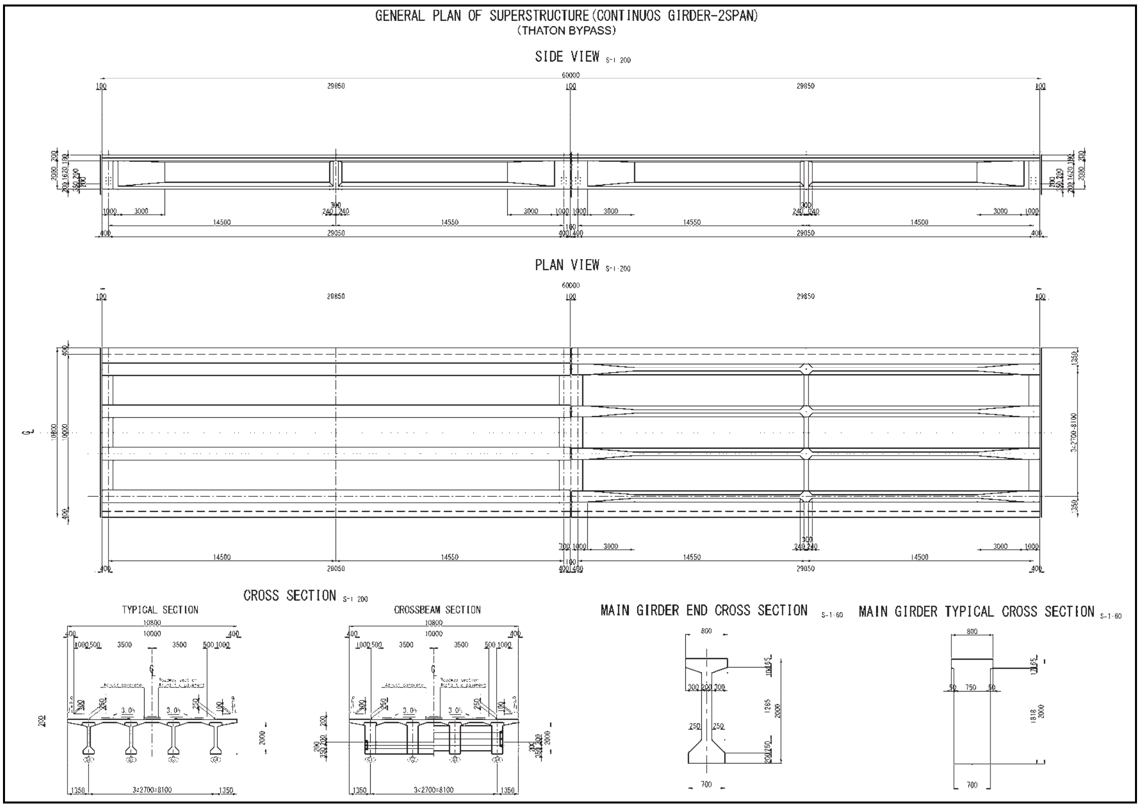
Source: JICA Survey Team

Figure 6.7.10 Configurations of Steel I-Girder (Donthami Bridge)



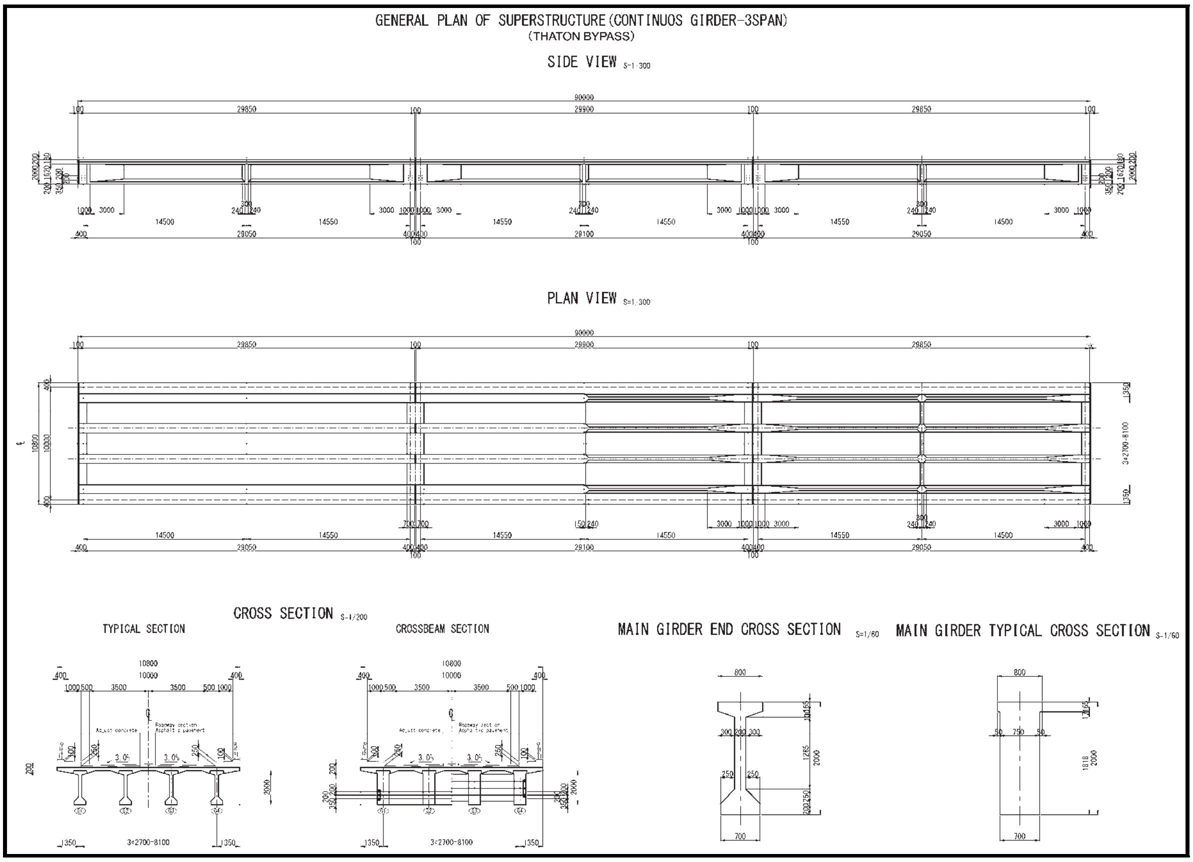
Source: JICA Survey Team

Figure 6.7.11 Configurations of PC I-Girder (Single Span Girder)



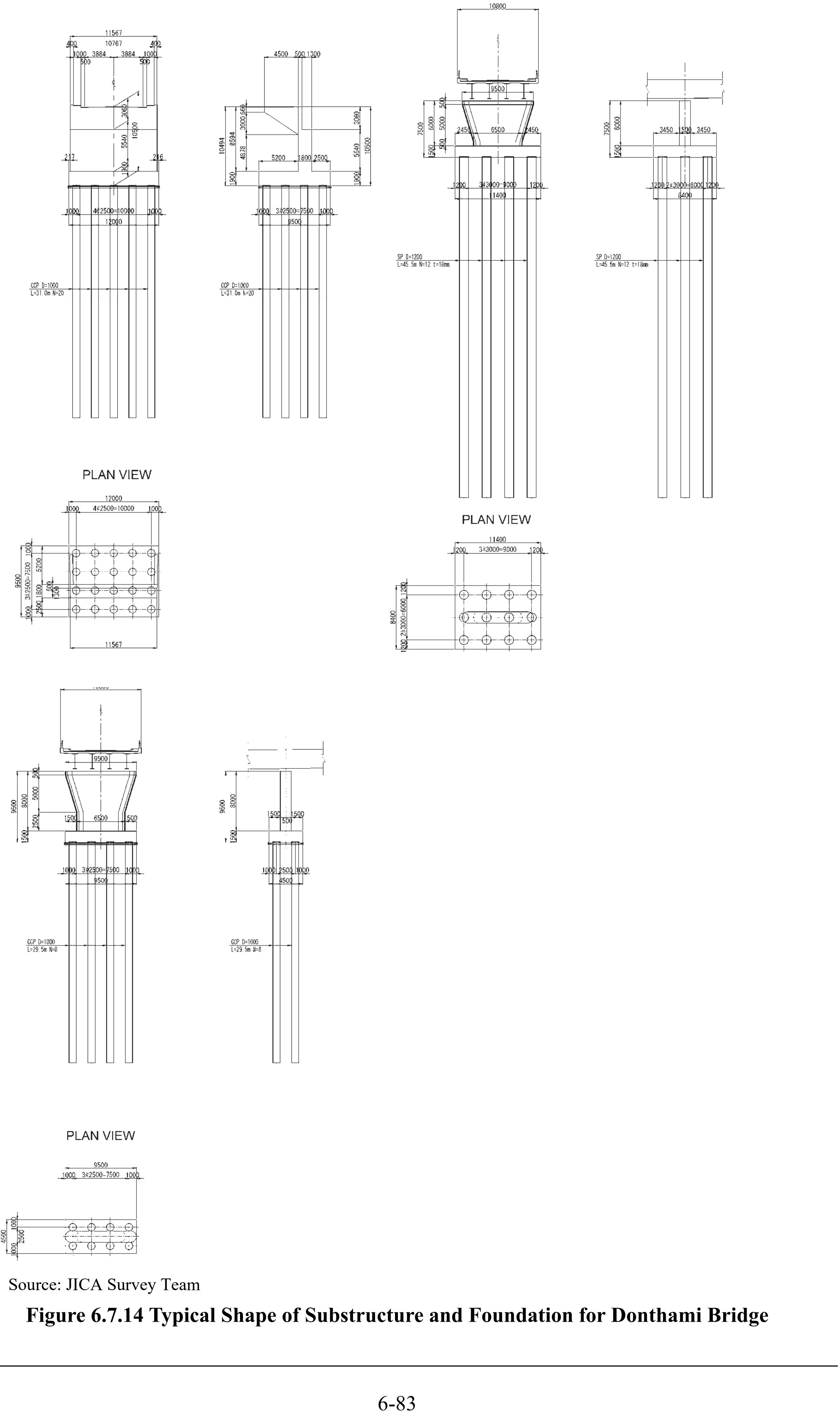
Source: JICA Survey Team

Figure 6.7.12 Configurations of PC I-Girder (Continuous Girder for Two Spans)



Source: JICA Survey Team

Figure 6.7.13 Configurations of PC I-Girder (Continuous Girder for Three Spans)



Source: JICA Survey Team

Figure 6.7.14 Typical Shape of Substructure and Foundation for Donthami Bridge

6.8 Preliminary Design for Kyargalay Bypass

6.8.1 Horizontal Alignment Design

The design concept for the horizontal alignment of Kyargalay BP is given as follows.

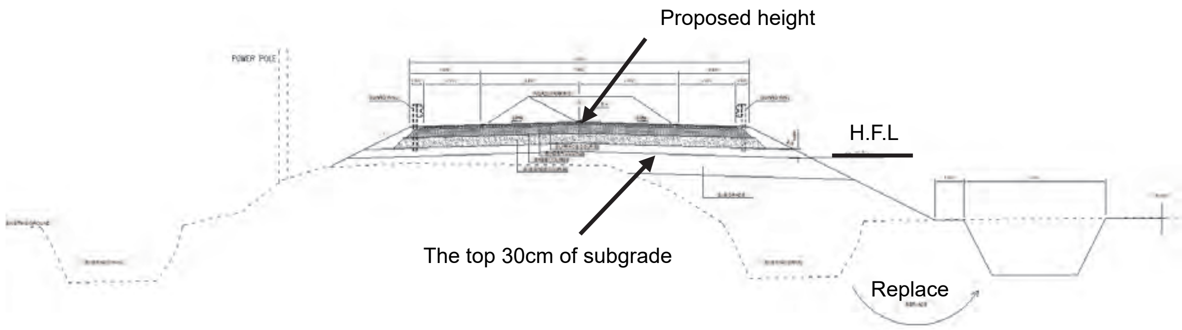
- The beginning point connects to the existing road following Gyaing Kawkareik Bridge. The end point connects to a road following Gyaing Zathapyin Bridge.
- The new alignment shall trace the alignment of the existing road as much as possible in satisfying the geometric design standard
- The new alignment shall avoid control points such as Pagodas, schools, important public facilities, etc.
- The new alignment shall avoid villages and communities to minimize resettlement.
- Basically widening is on one side and the existing canal is replaced.

The horizontal alignment is shown in Figure 6.8.2.

6.8.2 Vertical Alignment Design

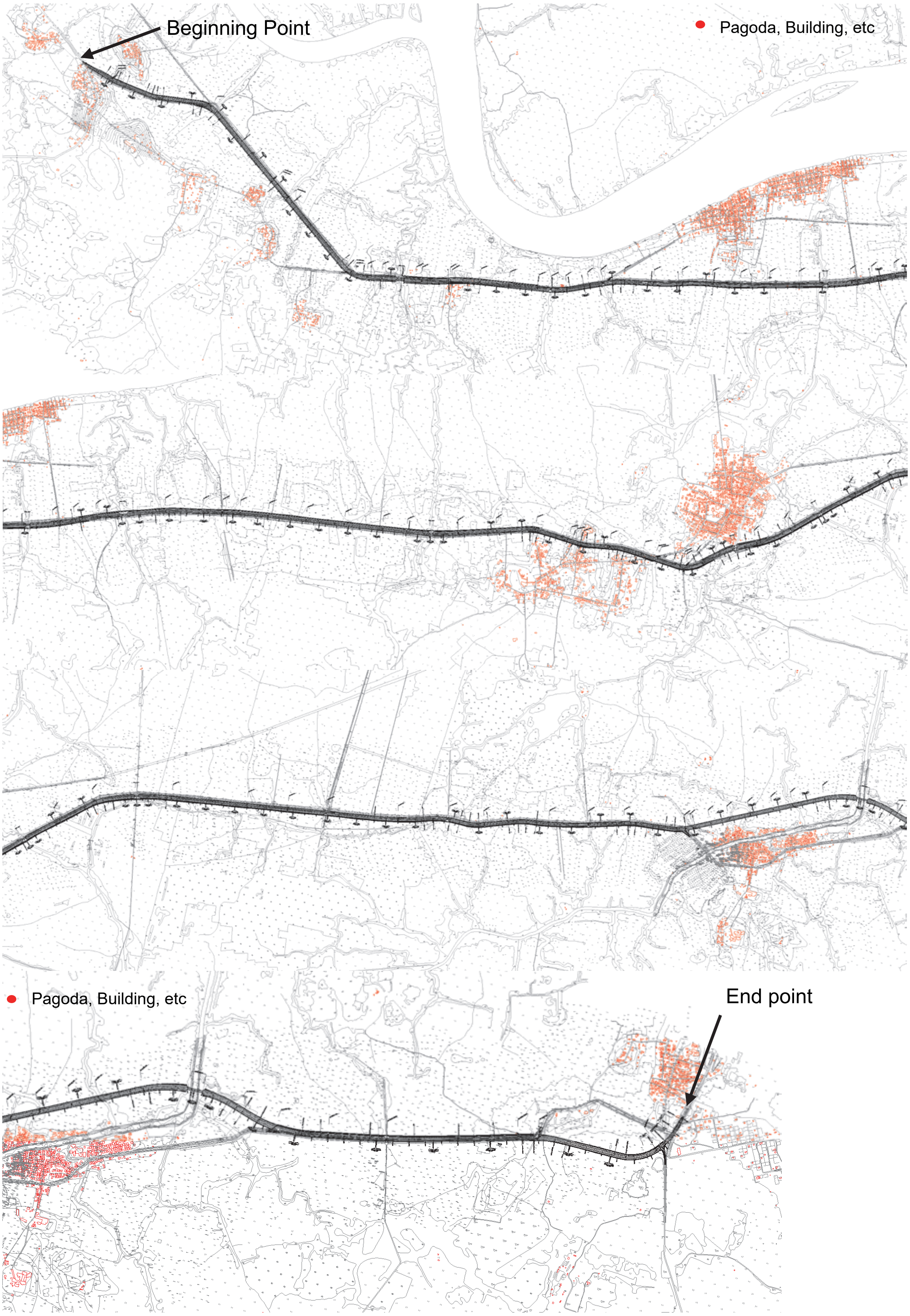
The design concept of vertical alignment is shown in below.

- The top 30cm of the subgrade maintain is higher than HFL to allow the road to function in case of flood.
- To maintain a minimum vertical gradient of 0.3% for road drainage



Source: JICA Survey Team

Figure 6.8.1 Proposed Height of Kyargalay BP



Source: JICA Survey Team

Figure 6.8.2 Horizontal Alignment of Kyargalay BP

6.8.3 Pavement Design

(1) Basic Design Condition

At the meeting with MOC on March 12th, 2014, participants decided that asphalt pavement shall be adopted for the pavement design of the approach road of the four bridges, and that AASHTO GUIDE FOR DESIGN OF PAVEMENT STRUCTURES (1993) shall be used as the standard for this design.

In this standard, the required Structural Number (SN) is calculated as outlined in the following sections, and the layer combination (the layer coefficient and the thickness of each layer) must satisfy the requirements of the SN.

The performance period for pavement design is shown in Table 6.8.1.

Table 6.8.1 Performance Period for Pavement Design

Assumed completion year	Design Period
2021	20years (2022-2041)

Source: JICA Survey Team

Design condition for pavement design is summarized in Table 6.8.2.

Table 6.8.2 Basic Design condition for pavement design

Design Input Requirements			Value
1	Design Variables	Performance Period, Analysis Period	20years
		Traffic - Cumulative 18kip Equivalent Single Axle Load (ESAL) (ŵ18: 2 directions) -Directional Distribution Factor: D_D -Lane Distribution Factor: D_L	 - From the result of Traffic Demand Forecast - 0.5(2 Lane) - 1.0(2 lane)
		Reliability(Z_R)	90% (-1.282)
		Overall Standard Deviation(S_o)	0.45 (Flexible pavement)
2	Performance Criteria	Initial Service Index (P_o)	4.2
		Terminal Serviceability (P_t)	2.5
		Design Serviceability Loss ($\Delta PSI=P_o-_{Pt}$)	1.7
3	Material Properties	Effective Roadbed Soil Resillent Modulus: M_R(psi)	1500 x CBR
		Layer Coefficient for Asphalt Concrete: a_1 Layer Coefficient for Base Course: (Crushed Stone CBR>80), a_2 Layer Coefficient for Sub Base Course: (Gravel: CBR>30), a_3	a_1 = 0.42 a_2 = 0.14 a_3 = 0.11
4	Pavement Characteristics	Drainage Coefficient for Base Course and Subbase Course: m_2, m_3	1.00

Source: JICA Survey Team

(2) Traffic Volume and Equivalent Single Axle Load (ESAL)

The forecast traffic volume (vehicles/day) classified by vehicle type in 2030, 2035 is shown in Table 6.8.3

Table 6.8.3 Traffic Demand Volume Forecast for Kyargalay BP

Unit: vehicle/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≥ 4 axles		
			Small	Big				
2035	7,260	460	1,000	1,560	520	1,200	670	12,670
2040	10,440	670	1,160	1,820	520	1,660	740	17,010

Source: JICA Survey Team

Traffic volume (vehicles/day) for each design period assumed from the traffic demand forecast is shown in Table 6.8.4.

Table 6.8.4 Traffic Volume for Pavement Design Period of Kyargalay BP

Unit: vehicles/day

Year	Passenger Cars	Buses	Trucks				Trailers	Total
			2 axles		3 axles	≥ 4 axles		
			Small	Large				
2022	1,860	202	215	336	37	82	12	2,744
2023	2,065	215	242	378	46	101	17	3,064
2024	2,293	229	273	425	56	124	23	3,423
2025	2,546	244	307	479	69	153	31	3,828
2026	2,828	260	345	539	84	188	42	4,285
2027	3,140	277	389	606	103	231	57	4,802
2028	3,487	295	437	682	126	284	77	5,389
2029	3,872	314	492	768	154	349	105	6,055
2030	4,300	335	554	864	189	428	143	6,813
2031	4,775	357	623	972	232	526	195	7,680
2032	5,302	380	702	1,094	283	647	266	8,674
2033	5,888	405	790	1,232	347	795	362	9,817
2034	6,538	432	889	1,386	425	977	492	11,138
2035	7,260	460	1,000	1,560	520	1,200	670	12,670
2036	7,807	496	1,030	1,609	520	1,280	683	13,426
2037	8,395	535	1,061	1,659	520	1,366	697	14,234
2038	9,028	576	1,093	1,711	520	1,458	711	15,098
2039	9,708	621	1,126	1,765	520	1,556	725	16,022
2040	10,440	670	1,160	1,820	520	1,660	740	17,010
2041	11,227	722	1,195	1,877	520	1,771	755	18,067
Total (2022-2041)	112,758	8,025	13,922	21,761	5,792	15,177	6,803	223,847

Source: JICA Survey Team

Cumulative 18kip equivalent single axle load on each bridge is shown in Table 6.8.5.

Table 6.8.5 ESAL 18-kip for Kyargalay BP

	Passenger Cars	Buses	Trucks				Trailer	Total
			2 axles		3 axles	≥ 4 axles		
			Small	Large				
Traffic Volume (v/d) 2023-2042	112,758	8,025	13,922	21,761	5,792	15,177	6,803	
Traffic Volume (v/y) 2023-2042	41,156,719	2,929,294	5,081,594	7,942,927	2,114,055	5,539,738	2,483,071	
Equivalency Factor	0.001	0.87	0.0122	0.98	1.58	1.58	1.48	
W_{18}	41,157	2,548,486	61,995	7,784,069	3,340,206	8,752,785	3,674,945	26,203,643
ESAL = DD×DL×$\hat{w}_{18}$ = 0.5×1.0×26,203,643 = 13,101,822								

Source: JICA Survey Team

(3) CBR for Sub-grade

Design CBR for Sub-grade on new embankment is assumed as 7.0.

(4) Design Structural Number (SN)

Based on below formula and above mentioned conditions, design structural number (SN) is calculated as given in Table 6.8.6.

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

Table 6.8.6 Design Structural Number (SN)

Z_R	S_O	W_{18} ESAL	M_R	△PSI	SN (inch)
90%	0.45	16,731,009	10,500	1.7	4.61

Source: JICA Survey Team

(5) Determination of Structural Layer Thickness

Structural layer thickness is determined to be satisfied with the below condition.

Required Structural Number ≧ Design Structural Number

Required Structural Number is calculated from below formula.

Required Structural Number SN = $a_1D_1\ M_1+a_2D_2M_2+a_3D_3M_3$

where a_i: i Layer Coefficient

D_i: i Layer Thickness (inch)

M_i: i Layer Drainage Coefficient

Determined structural layer thickness is shown in Table 6.8.7.

Table 6.8.7 Structural Layer Thickness

Design SN		Surface Course	Binder Course	Base Course	Sub Base Course	Total Thickness (cm)
inch	cm	Each Layer Thickness(cm)				Required Structural Number (cm)
		Layer Coefficient x Thickness				
4.61	11.71	4	6	30	35	75
		0.42x4 =1.68	0.42x6 =2.52	0.14x30 =4.20	0.11x35 =3.85	1.68+2.52 +4.2+3.85 =12.25

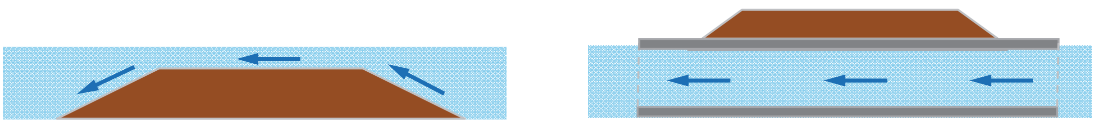
Source: JICA Survey Team

6.8.4 Drainage Design

(1) Surface Drainage

The existing canal is replaced and surface water is collected by ditches at the toes of fill embankments. The collected water is guided to the proper location.

In case of flooding, flood water is drained on the existing road surface. After the planned BP development, flood water will be unable to cross the road because the proposed height of the BP is greater than the HWL. Therefore, it is necessary to develop proper box culverts and bridges in order to allow flood water to pass.



<Current condition> <After BP development>

Source: JICA Survey Team

Figure 6.8.3 Drainage condition in case of flood

6.8.5 Traffic Safety Facilities

(1) Guardrails

In order to secure traffic safety, guardrails are to be installed alongside earth shoulders at all sections (except at intersections and sections that require access to the roadside).

(2) Road Markings

The edge line of lanes (solid lines with width 0.15m) and road centre lines (broken lines at 5m-intervals with width 0.15m) are to be installed at earth work sections.

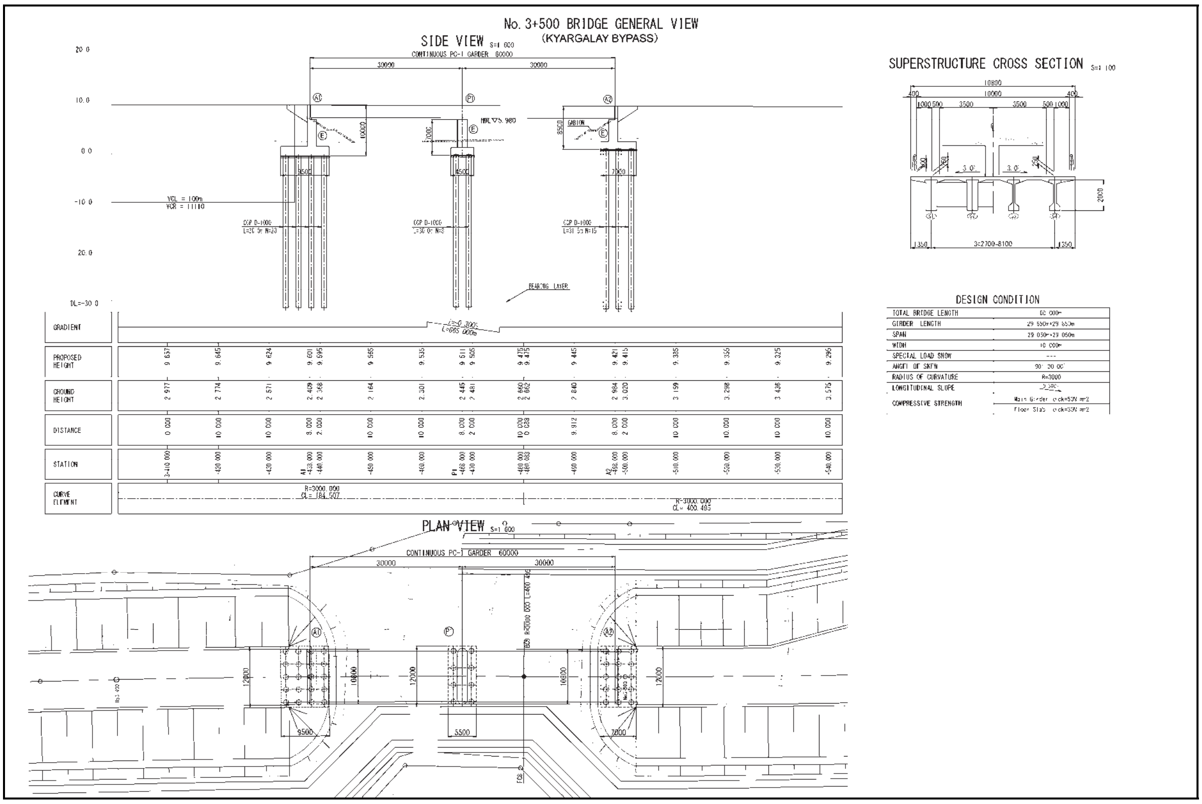
(3) Traffic Signs

Speed control signs (80 km/h) are installed in the vicinity of the beginning point and the end point, and the main intersection of the BP.

6.8.6 Bridge Design

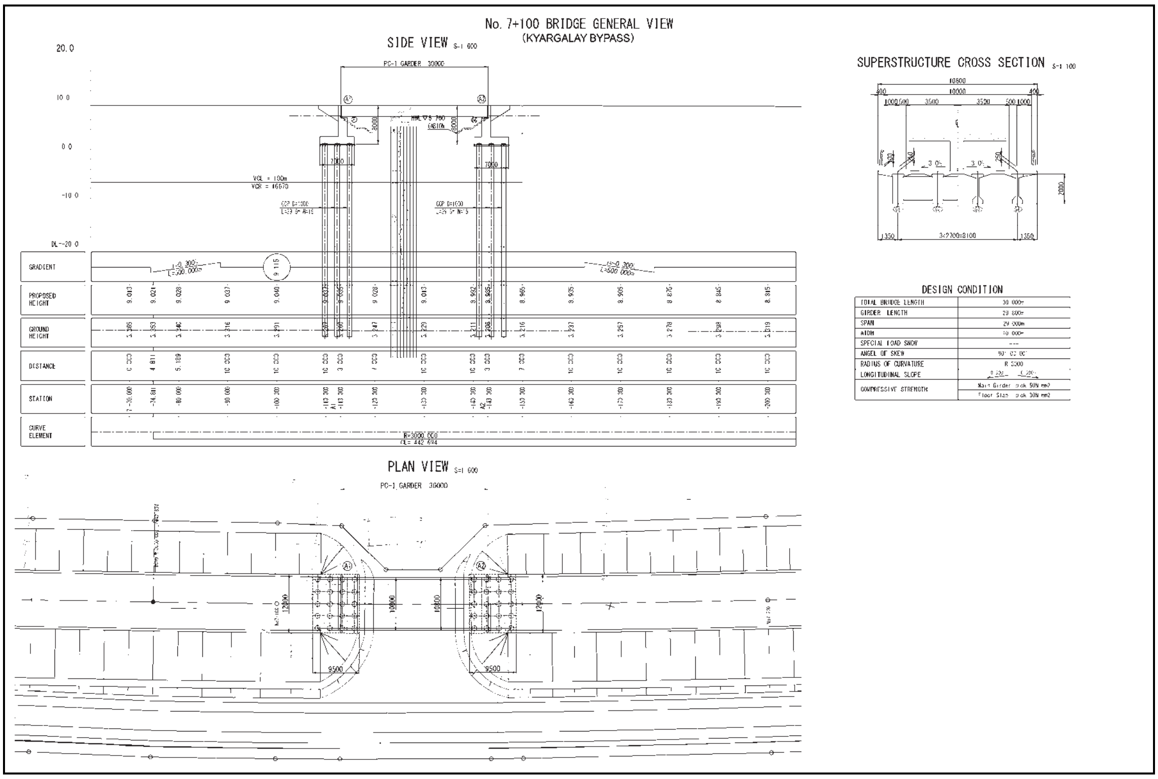
The design of bridges is preliminarily conducted for the proposed superstructure, substructure and foundation types selected from among the compared alternatives. The purpose of the preliminary design is to define the structural element sizes so that better estimates of cost and constructability could be obtained.

General views of each bridge are shown from Figure 6.8.4 to Figure 6.8.11.



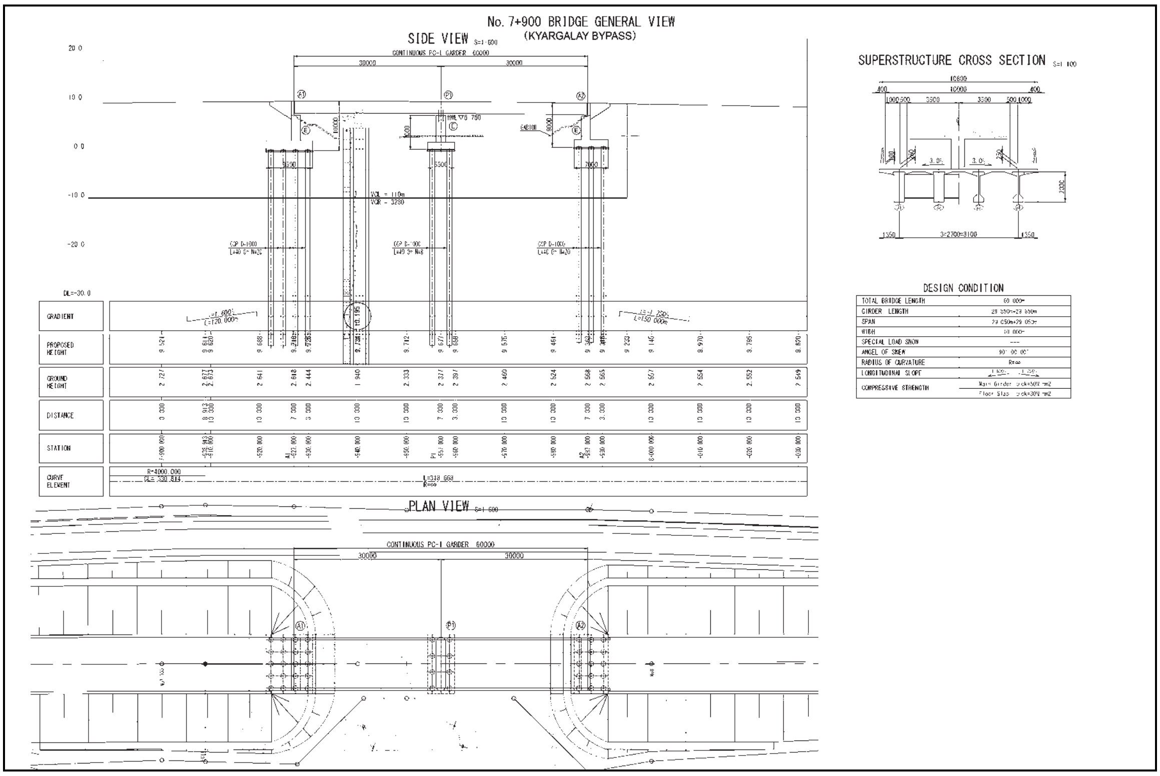
Source: JICA Survey Team

Figure 6.8.4 General View of No. 3+500 Bridge



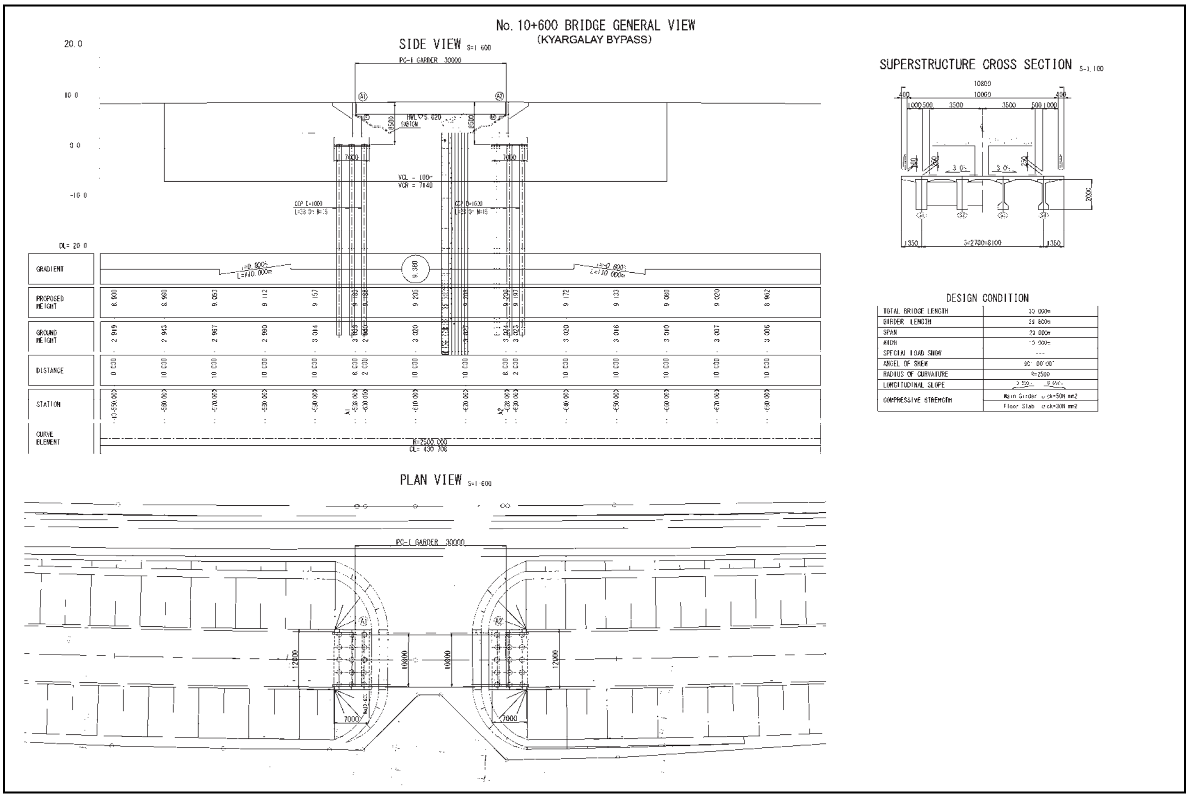
Source: JICA Survey Team

Figure 6.8.5 General View of No. 7+100 Bridge



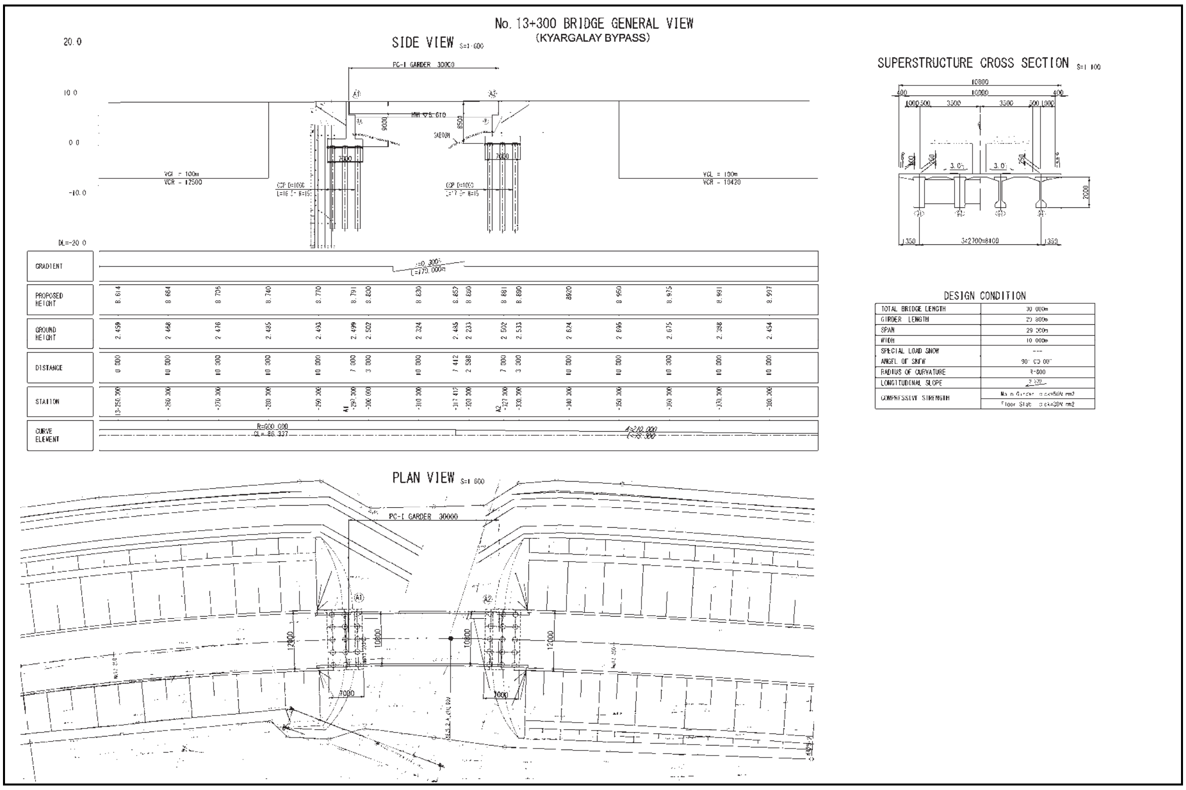
Source: JICA Survey Team

Figure 6.8.6 General View of No. 7+900 Bridge



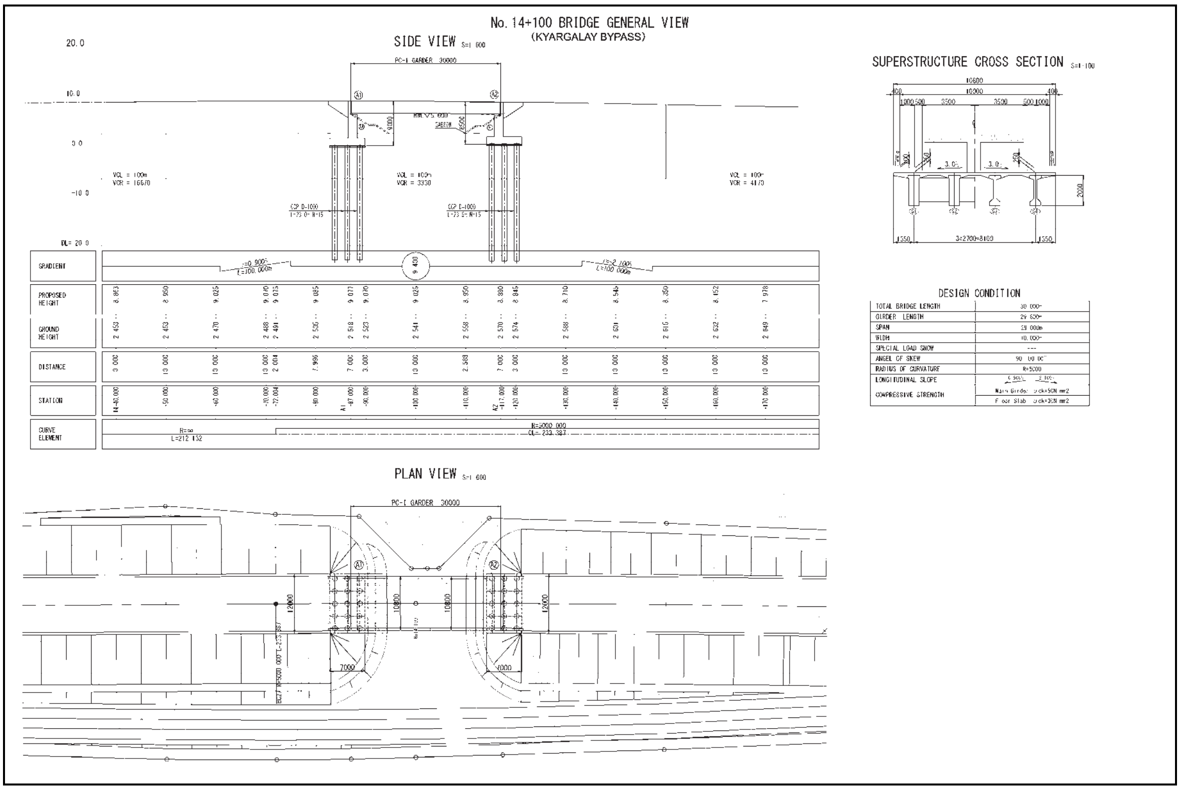
Source: JICA Survey Team

Figure 6.8.7 General View of No. 10+500 Bridge



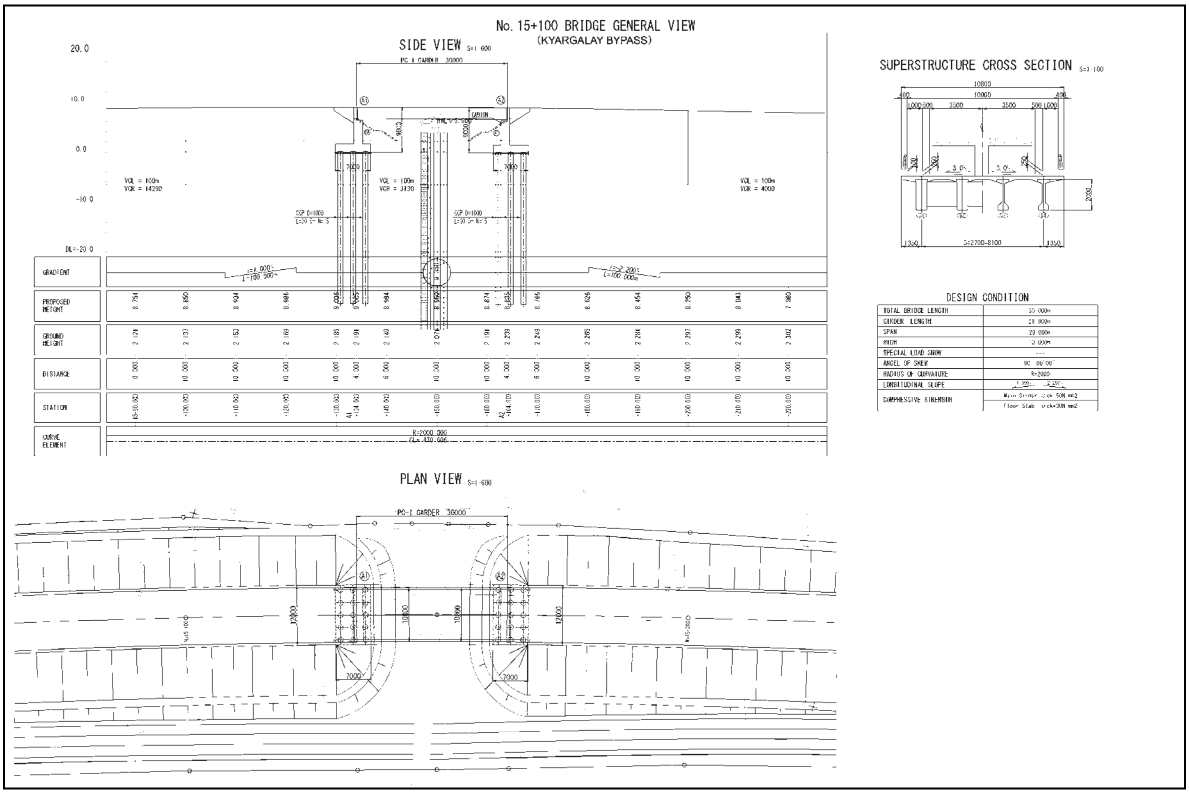
Source: JICA Survey Team

Figure 6.8.8 General View of No. 13+300 Bridge



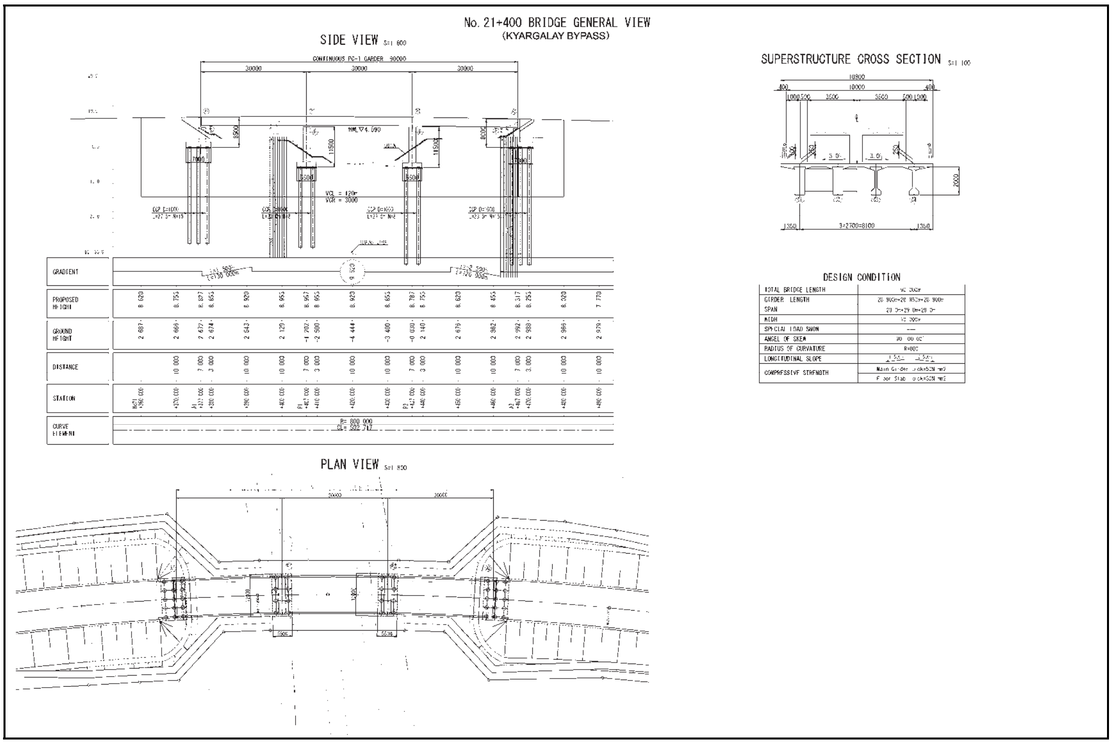
Source: JICA Survey Team

Figure 6.8.9 General View of No. 14+100 Bridge



Source: JICA Survey Team

Figure 6.8.10 General View of No. 15+100 Bridge



Source: JICA Survey Team

Figure 6.8.11 General View of No. 21+400 Bridge

CHAPTER 7 CONSTRUCTION PLANNING

7.1 Summary of Works

The work components of the project are summarized as shown in Table 7.1.1.

Table 7.1.1 Summary of Work Components

Sub projects	Description	
Naung Lon Bridge	Superstructure	4 span continuous steel plate girder bridge L = 160m /crane erection with bent
	Substructure	Abutment: Invert T shaped x 2 Pier: Wall type x 3
	Foundation	Abutment: Piled foundation (φ1000) Pier: Pile foundation (φ1000)
	Approach road	Embankment structure (L=316m、L=284m)
Gyaing Kawkareik Bridge	Superstructure	Main span: 3 span continuous PC extradosed bridge L = 360m /Balanced cantilever Approach span: 4 span continuous PC girder bridge L = 200m (Left)/All staging 5 span continuous PC girder bridge L = 250m (right)/ all staging
	Substructure	Main tower: Two column type piers (RC) Differential pier head: 2 Pier (Approach): Wall type x7 Abutment (Approach): Invert T shaped x 2
	Foundation	Main Tower: Steel Pipe Sheet Piled Foundation (φ1200) Differential pier head; Cast-in-place bored pile (φ1500) Abutment/ Pier (Approach): Cast-in-place bored pile (φ1500)
	Approach road	Embankment structure (L = 455m、L = 424m)
	Soft soil ground treatment	Vertical drain + Pre-loading method
Gyaing Zathapyin Bridge	Superstructure	3-span steel girder cable stated bridge L=880m/ traveller crane (centre span) Traveller crane with bent (Approach)
	Substructure	Main tower: Two column type pier (RC) Abutment (Approach): Invert T shaped x 2nos
	Foundation	Main tower: Steel pipe sheet piled foundation (φ1200) Abutment (Approach)：Cast-in-place bored bile (φ1500)
	Approach road	Embankment structure (L = 477m、L = 517m)
	Soft soil ground treatment	Vertical drain + Pre-loading method
Atran Bridge	Superstructure	Main span：3 span continuous PC extradosed Bridge L = 430m /Balanced cantilever Approach span: 3 span continuous PC girder bridge L = 150m (right)/All staging, 4 span continuous PC girder bridge L=200m (left) / All staging
	Substructure	Main tower: Two column type pier (RC) Differential pier head type：2 Pier (Approach): wall type x 5 Abutment (Approach): Invert T shaped x 2
	Foundation	Main Tower: Steel Pipe Sheet Piled Foundation (φ1200) Differential pier head; Cast-in-place bored pile (φ1500) Abutment/ Pier (Approach): Cast-in-place bored pile (φ1500)
	Approach road	Embankment structure (L = 560.5m、L = 344.5m)

	Soft soil ground treatment	Vertical drain + Pre-loading method
Thaton Bypass (including Donthami Bridge)	Superstructure	5 span continuous steel plate girder bridge L=200m / launching method (span)＋crane erection with bent
	Substructure	Abutment: Invert T shaped x 2 Pier: Wall type x 4
	Foundation	Abutment: Cast-in-place bored pile (φ1000) Pier: Cast-in-place bored pile (φ1000)
	Road length	L= Approximately 29km
	Structure	Box culvert × 65 Small bridge × 5 Donthami bridge L = 200m
	Soft soil ground treatment	Vertical drain + Pre-loading method
Kyargalay Bypass	Road length	L=Approximately 25km
	Structure	Box culvert × 82 Small bridge × 8
	Soft soil ground treatment	Vertical drain + Pre-loading method
Demolition of Existing Bridge	Existing Gyaing Kawkareik Bridge (Above ground level)	Demolition of Superstructure (Suspension Bridge/RC Girder) Demolition of Pylon x 2 Demolition of Anchorage x 2 Demolition of RC Substructure x 14
	Existing Gyaing Zathapyin Bridge (Above ground level)	Demolition of Superstructure (Suspension Bridge/RC Girder) Demolition of Pylon x 2 Demolition of Anchorage x 2 Demolition of RC Substructure x 14
	Existing Atran Bridge (Above ground level)	Demolition of Superstructure (Steel Cable Stayed Bridge/RC Girder) Demolition of Pylon x 2 Demolition of RC Substructure x 10

Source: JICA Survey Team

7.2 Construction Methodology

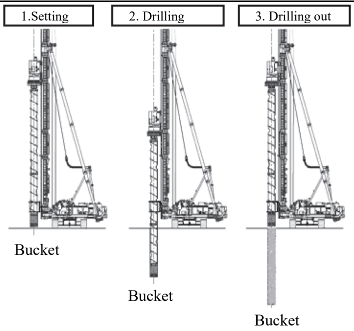
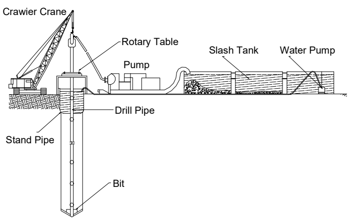
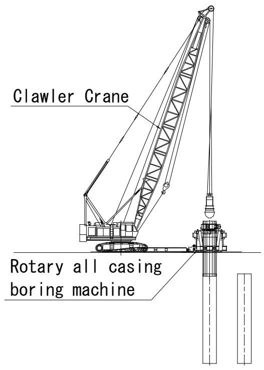
In this chapter, the key points of the construction methodologies for specific works in this project are introduced, excluding general civil works such as earth works, pavement works, etc.

7.2.1 Foundation

(1) Cast In-place Bored Pile

Cast in-place bored pile construction methods are introduced in the Table 7.2.1. It is estimated that the bearing stratum is very stiff with an N value of more than 100. Also, the borehole works should be conducted adjacent to the river where the ground water level is high. Based on these conditions, the All-Casing Method is recommended.

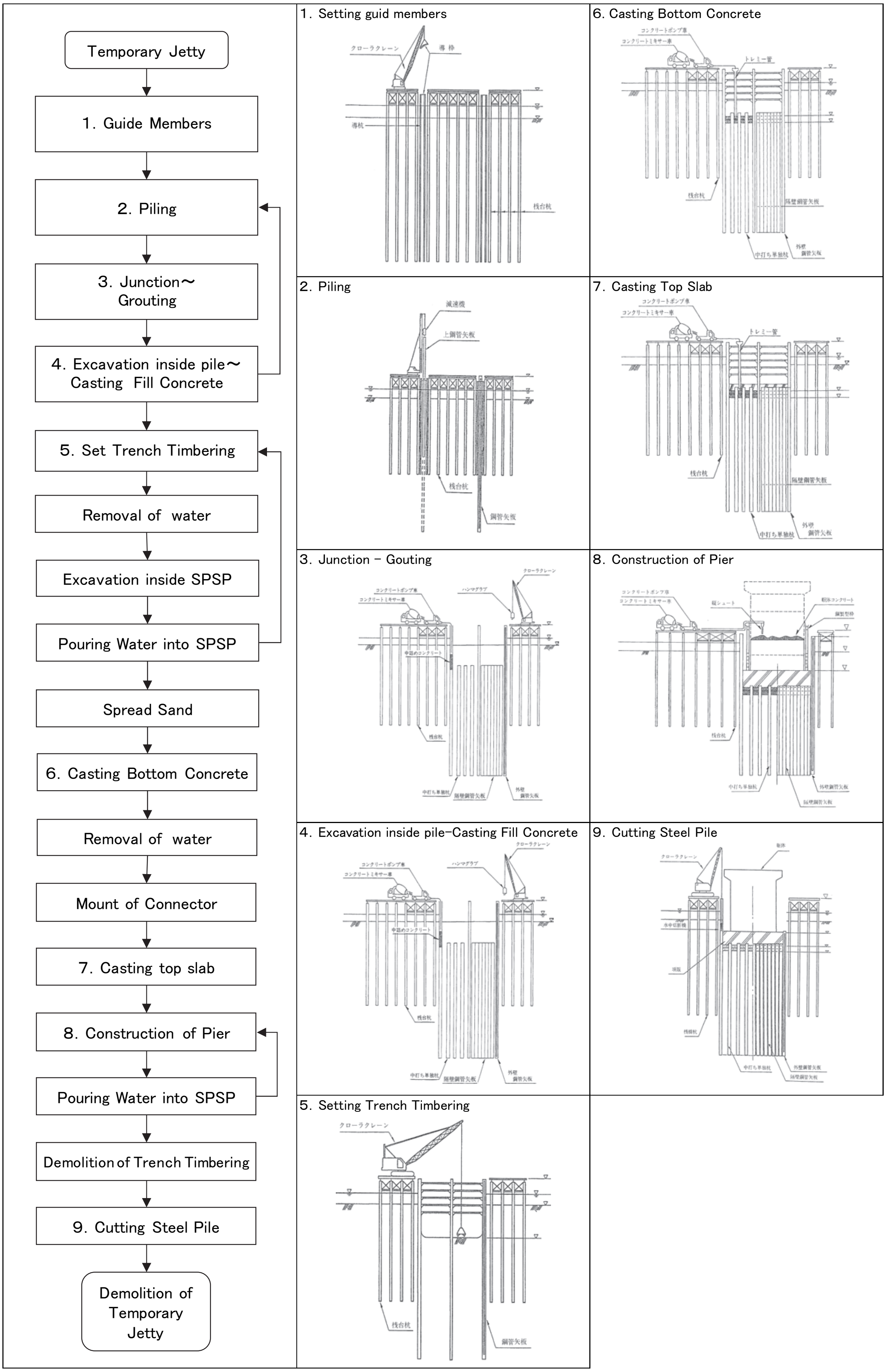
Table 7.2.1 Comparison of Cast In-place Bored Pile Methods

Work method	Earth Drill Method	Reverse Method	All Casing Method (Rotary all casing boring system)
Schematic View			
Applicable Diameter	0.8m–3.0m	0.8m–3.0m	0.8m–3.0m
Standard applicable depth	30m–60m	30m–60m	20m–40m
Underground water	Difficult to adopt	Applicable	Applicable
Hard substratum	Difficult to adopt with soft/hard rock	Not applicable	Applicable all soil conditions
Direct cost	Reasonable	Tolerable	Higher
Work speed	Fast	Normal	Faster
Evaluation	Not recommended	Not recommended	**Recommended**

Source: JICA Survey Team

(2) Steel Pipe Sheet Pile Foundation (SPSPF)

SPSPF is a well-shaped foundation formed with steel pipes installed by vibratory-hammer. This steel pipe sheet pile can work as a temporary cofferdam by waterproofing the joints of the steel pipes. It is assumed that the piling works probably need supplemental facilities for core drilling and a water jet system due to the expected hard substratum in the shallow depth. It is expected to conduct the trial pile prior to the actual works so that piling conditions can be identified if it needs supplemental facilities for drilling. The thickness of the steel pipe should be decided upon considering the stress status at the temporary cofferdam and the completion (permanent). The work procedure for the installation of SPSPF is shown in Figure 7.2.1.



Source : JICA Survey Team

Figure 7.2.1 Construction Steps for Steel Pipe Sheet Pile Foundation

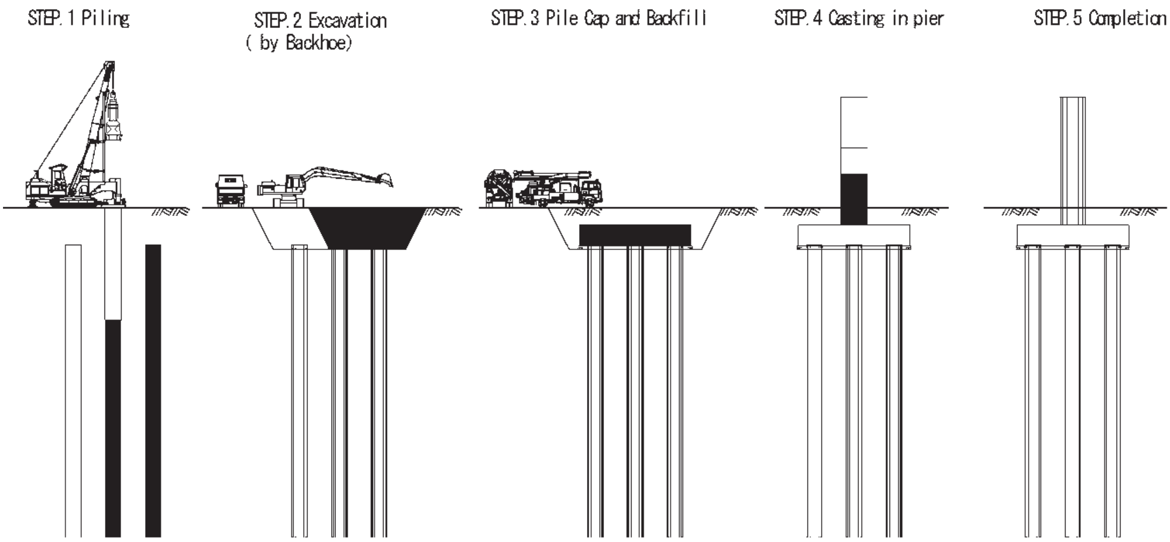
7.2.2 Substructure

(1) Abutment and Pier

After installation of cast in-place piles, pile top soils will be removed by excavator. Construction of the pile-cap will be followed by the installation of scaffolding, setting of form works, arrangement of the reinforcement bars, and casting of fresh concrete by rot. After securing specified curing time, the next step is to remove the form and backfill the structure.

If the construction site is located in the soft soil ground, the settlement should be closely monitored, and this settlement should be compared to the expected residual settlement (calculated at the design stage).

The Donthami Bridge requires the construction of temporary jetties prior to the construction of piers since it is located in the river. After the cast-in-place bored piles and their pile caps are constructed, the piers are to be constructed using temporary jetties as the process given in the construction step Figure 7.2.2 below.



Source: JICA Survey Team

Figure 7.2.2 Work Sequence of Pier Construction

(2) Tower

After SPSPF is constructed, the works for scaffolding, form, rebar arrangement and casting concrete are to be carried out. Self-lifting formwork could be utilized for the works above water level. It would require the use of a pumping system in order to cast concrete at high levels.

Figure 7.2.3 shows works using self-lifting formwork (climbing formwork) in Japan.

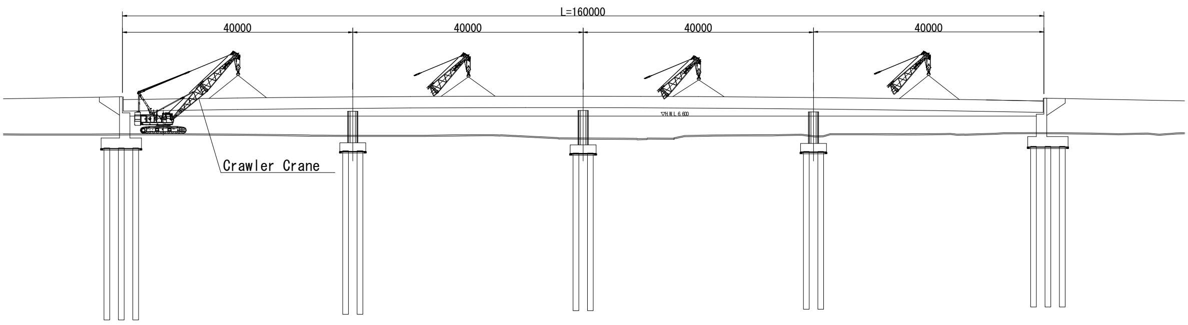
Source: JICA Survey Team

Figure 7.2.3 Self lifting formwork (Climbing Formwork)

7.2.3 Superstructure

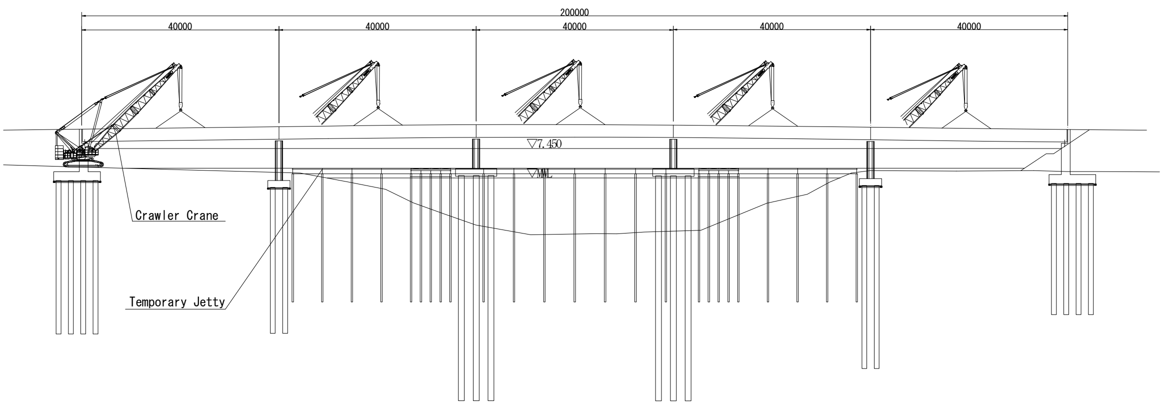
(1) Steel Plate Girder Bridge

Steel Plate Girder Bridges are to be used for both Naung Lon Bridge and Donthami Bridge as the result of the comparative study taking into account the practices and cost (Chapter 6). The erection works are mainly conducted by using crawler cranes as shown in Figure 7.2.4 and Figure 7.2.5.



Source: JICA Survey Team

Figure 7.2.4 Erection Works for Steel Plate Girder Bridge (Naung Lon Bridge)



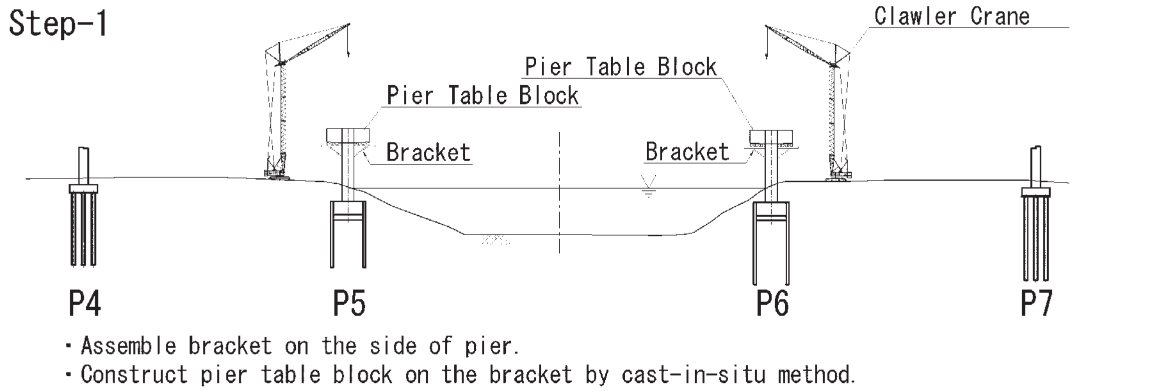
Source: JICA Survey Team

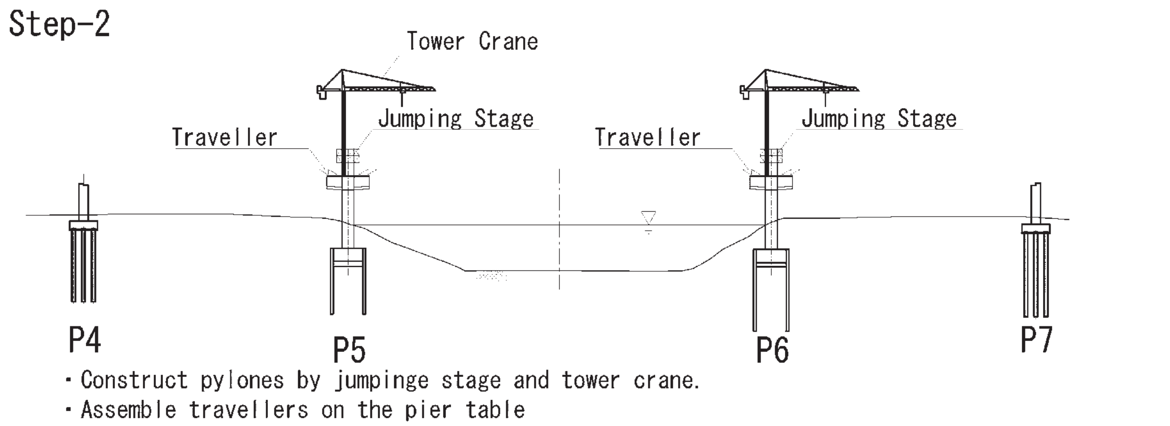
Figure 7.2.5 Erection Works for Steel Plate Girder Bridge (Donthami Bridge)

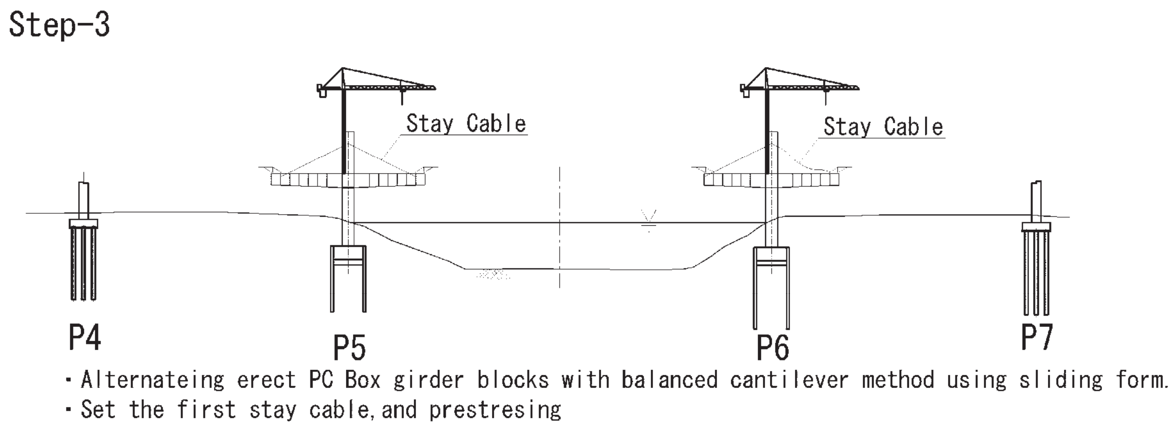
(2) Extradosed Bridge

Gyaing Kawkareik Bridge is to be constructed as an extradosed bridge, It shall be erected using the balanced cantilever method with sliding formwork.

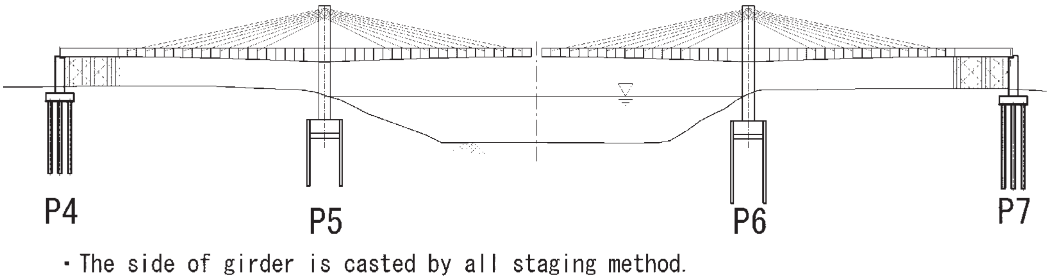
Figure 7.2.6 gives an example of the erection steps for Gyaing Kawkareik Bridge.



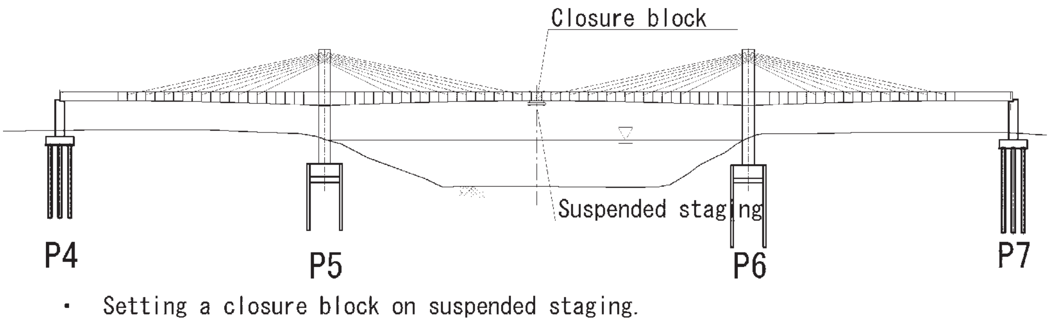




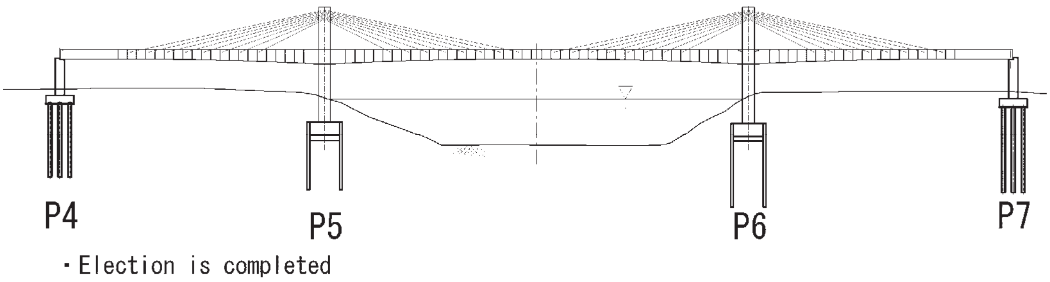
Step-4



Step-5



Step-6



Source: JICA Survey Team

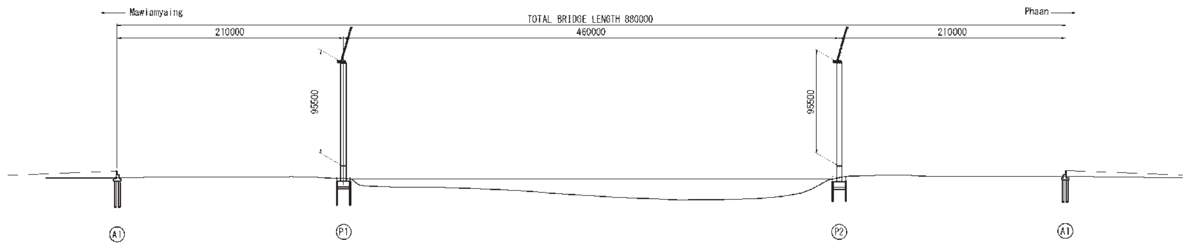
Figure 7.2.6 Erection Steps for Extradosed Bridge

(3) Cable-Stayed Steel Girder Bridge

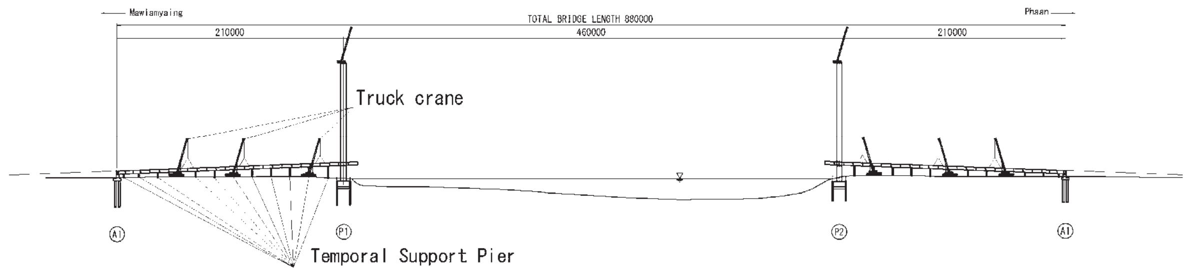
The steel girders used in the cable stayed bridge are to be launched by using hanger cables fixed with the tower taking into account loading balance during the erection. The towers are built up by movable elevated formwork lifted up by tower crane. After the completion of tower construction, the approach girders are to be erected using a truck cranes supported by temporary bents. For the main bridge span (over the river), girders and stay cables are to be set by a traveller crane (installed on steel girders). After the closure of the centre segments of girders, casting the counterweight at the end of each girder and adjusting the cable tensile force, then removing temporary bent will be preformed.

Erection steps for the cable-stayed steel girder bridge is given in Figure 7.2.7.

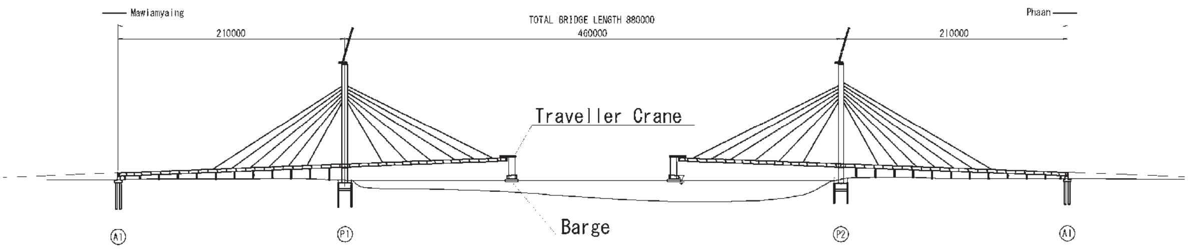
STEP-1
・Construction of Pylones by Tower Crane and Sliding Form



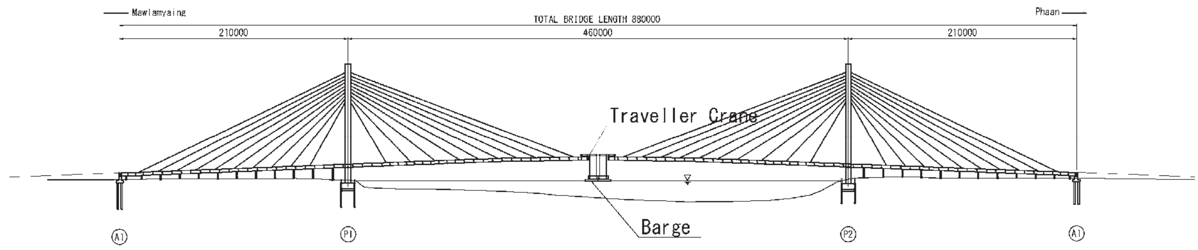
STEP-2
・Erection of side span girders by Truck crane and temporal support pier



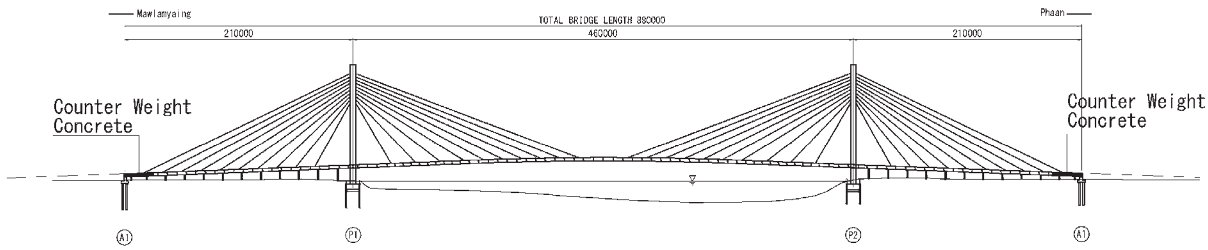
STEP-3
・Erection of center span steel girder blocks by cantilever method using traveller crane and barge.



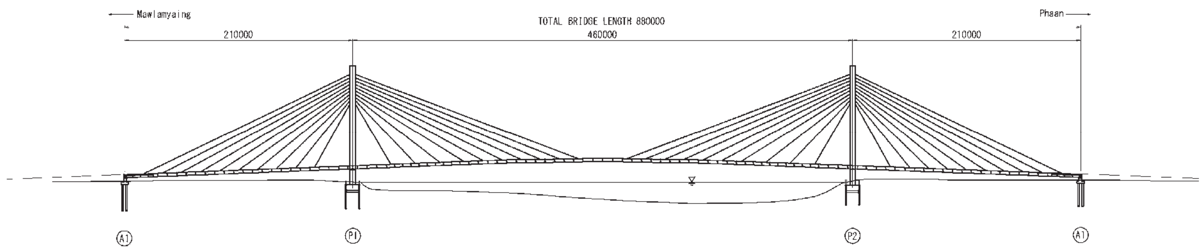
STEP-4
・Setting closure blocks by traveller crane and barge



STEP-5
・Casting counter weight concrete on side span



STEP-6
・Balancing tension of stay cables, Demobilization of temporal support piers

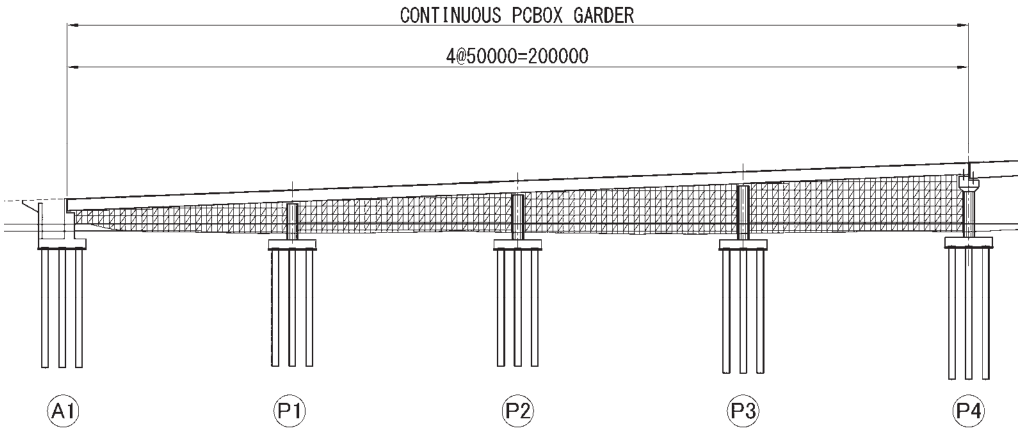


Source: JICA Survey Team

Figure 7.2.7 Erection Steps for Cable Stayed Steel Girder Bridge

(4) PC Box Girder Bridge

The approach bridges are to be constructed as PC box girder bridges. These will be erected on land without the need to consider any obstruction due to crossing facilities underneath the bridges. Accordingly, the girders can be erected at a reasonable cost using the full staging method (FSM). However, it is observed that the surrounding area is mostly covered by soft soil. It is therefore necessary to check the ground conditions to ensure that the ground has enough bearing capacity before the installation of supporting facilities. If the bearing capacity cannot accommodate the design load, either the replacement of top soil or the use of a different foundation system (e.g. pile foundations) should be considered.



Source: JICA Survey Team

Figure 7.2.8 Erection Method of PC Box Girder (All Staging Method)

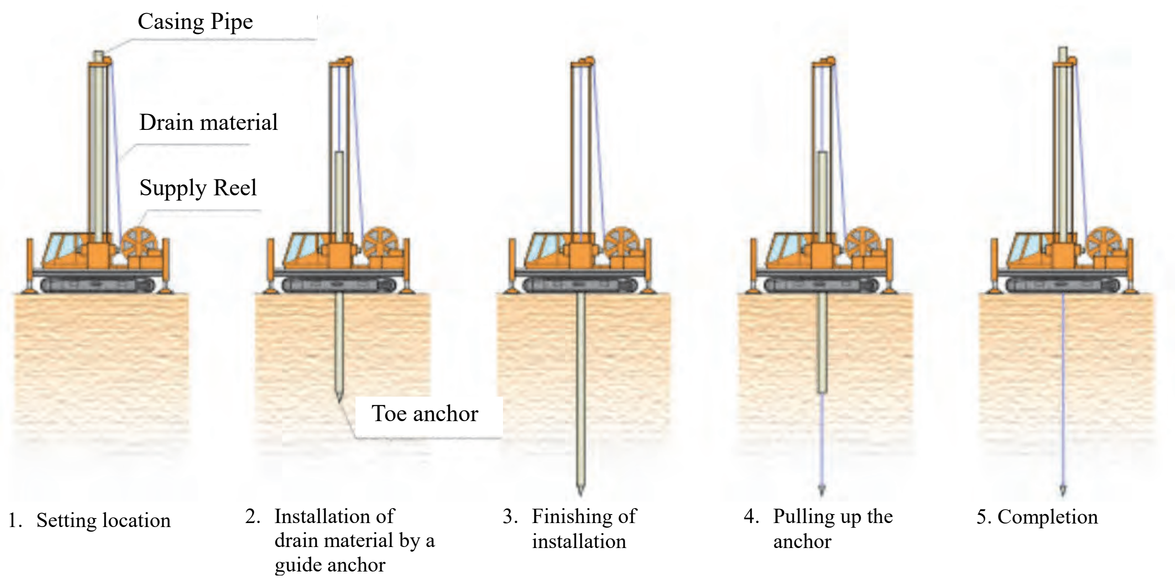
7.2.4 Soft Soil Ground Treatment

(1) General

It is observed that the Project Area is mostly covered by soft soil. The subsoil layer is composed of thick sediment soft clay which can often lead to the failure of embankment and lateral movement of the structure due to consolidation settlement, and also might induce negative friction phenomena of pile foundation. If no countermeasures are applied, it is predicted that the consolidation settlement would last for several decades. Accordingly, based on the stability analysis, it is necessary to apply soft ground stabilization measures to the sections where embankments shall be filled above the fill limit.

There are several types of countermeasures which separate the different approaches for treatment of soft soil ground. The application of pre-loading with vertical drain (paper & sand) method should be appropriate to deal with consolidation issues. The grouting method can be applied for the direct improvement of soft soil ground. Light weight banking structure is another approach to alleviate the settlement by reducing the self-weight of the embankment. In this project, taking into account various practices and reasonable cost, pre-loading in combination with vertical drain (paper) is recommended. This method increases soil strength, preventing both the lateral movement of the structure and the negative friction phenomena for pile foundations. Note that settlement should be monitored to trace the residual settlement and its progress, and this recorded data should be compared with the stability analyses performed at the design phase.

The construction steps for the vertical drain method are given in Figure 7.2.9.



Source: JICA Survey Team

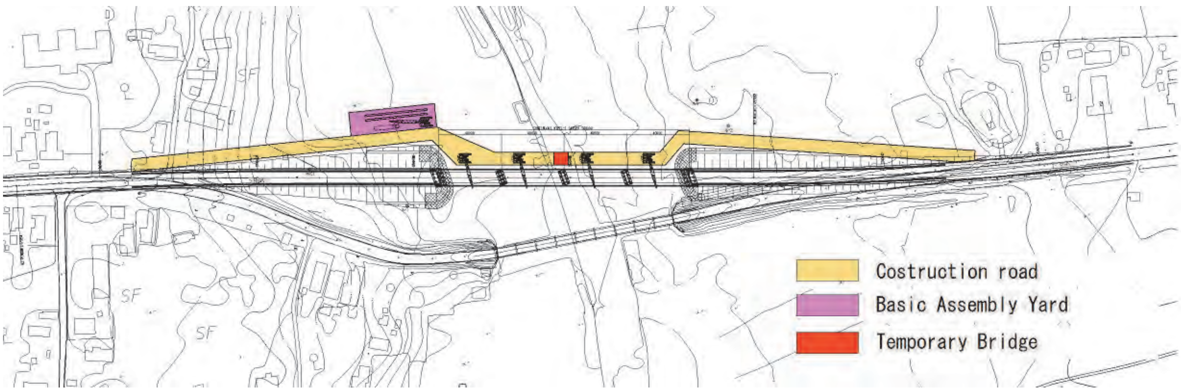
Figure 7.2.9 Construction Sequence of Vertical Drain Method

7.2.5 Layout of Temporary Access Roads and Construction Yard

(1) Naung Lon Bridge

Naung Lon Bridge is located on EWEC so that the materials and equipment can be hauled using land transport. The access road to the construction site should be proposed beside the new bridge site diverting from the connecting point with the existing road. The fabrication of steel girders can be done on-site, utilizing these access roads.

The temporary access road and layout of temporary yards are shown in Figure7.2.10.



Source: JICA Survey Team

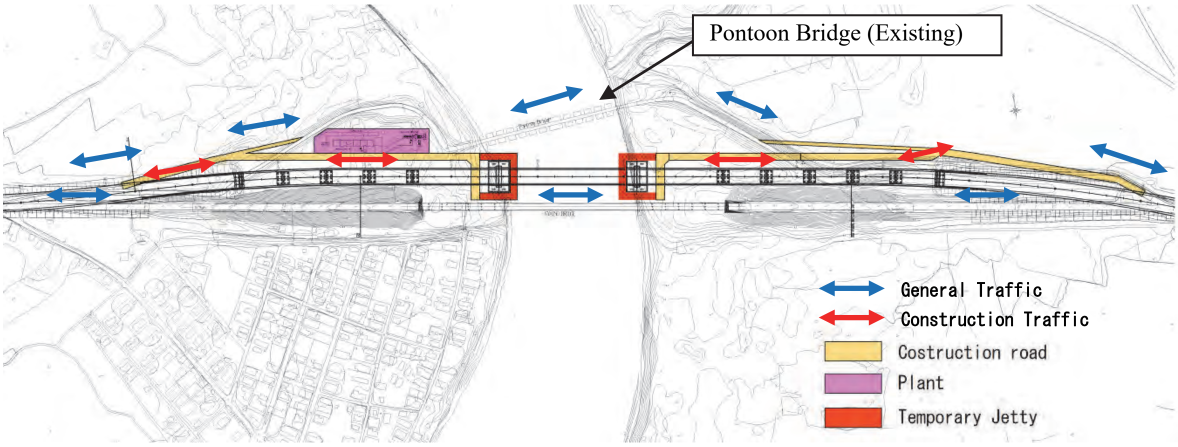
Figure7.2.10 Layout of Temporary Access Road and Construction Yard (Naung Lon Bridge)

(2) Gyaing Kawkareik Bridge

A vehicular weight limit of 20 tons has been imposed on the existing bridge. Vehicles exceeding this limit are diverted to a temporary pontoon bridge located beside the existing bridge. This pontoon bridge should be considered for use during construction of the new bridge, as opposed to the installation of a temporary crossing specifically for the bridge construction.

The temporary access roads can primarily follow the existing approach roads for the pontoon bridge. The road shall branch out to the temporary construction yard located between the existing bridge and the new bridge with adequate space accommodating various temporary facilities such as mixing plants.

Also, temporary stages should be located in the river for the construction of piers to install the SPSPF. The layout of the temporary road and construction yard is given in Figure 7.2.11.

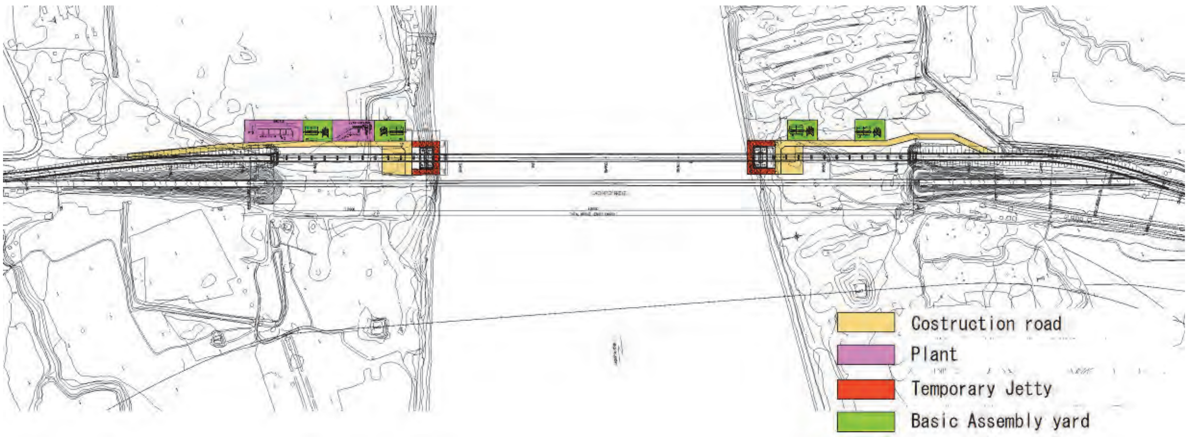


Source: JICA Survey Team

Figure 7.2.11 Layout of Temporary Access Road and Construction Yard (Gyaing Kawkareik Bridge)

(3) Gyaing Zathapyin Bridge

Temporary access roads shall branch off from the existing road into the construction yards underneath of bridge. These yards shall have enough space to accommodate necessary temporary facilities such as mixing plants. Additionally, temporary jetties should be located in the river for the construction of piers to install the SPSPF. The layout of the temporary road and construction yard is given in Figure7.2.12.

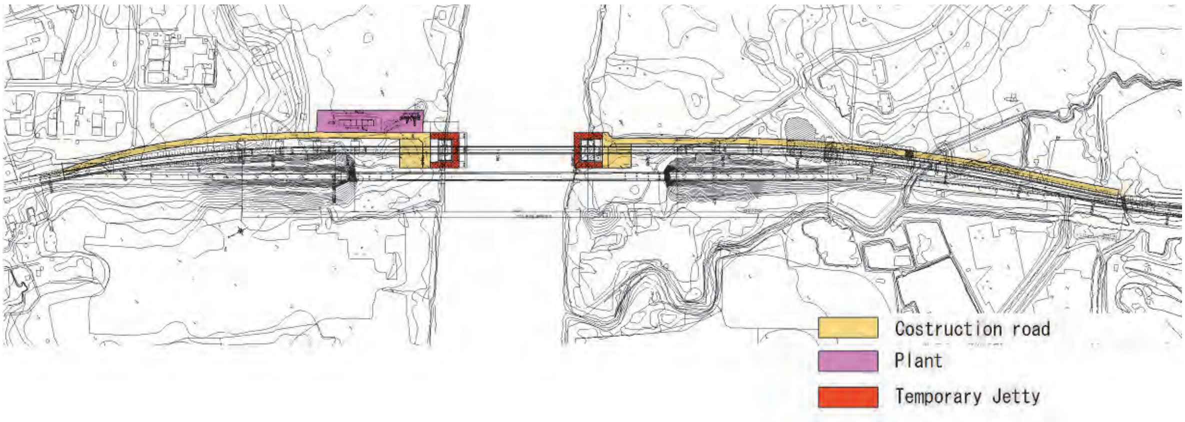


Source: JICA Survey Team

Figure7.2.12 Layout of Temporary Access Road and Construction Yard (Gyaing Zathapyin Bridge)

(4) Atran Bridge

Temporary access roads shall branch off from the existing road into the construction yards underneath the bridge. These yards shall have enough space to accommodate necessary temporary facilities such as mixing plants. Additionally, temporary jetties should be located in the river for the construction of piers to install the SPSPF. The layout of the temporary road and construction yard is given in Figure 7.2.13.



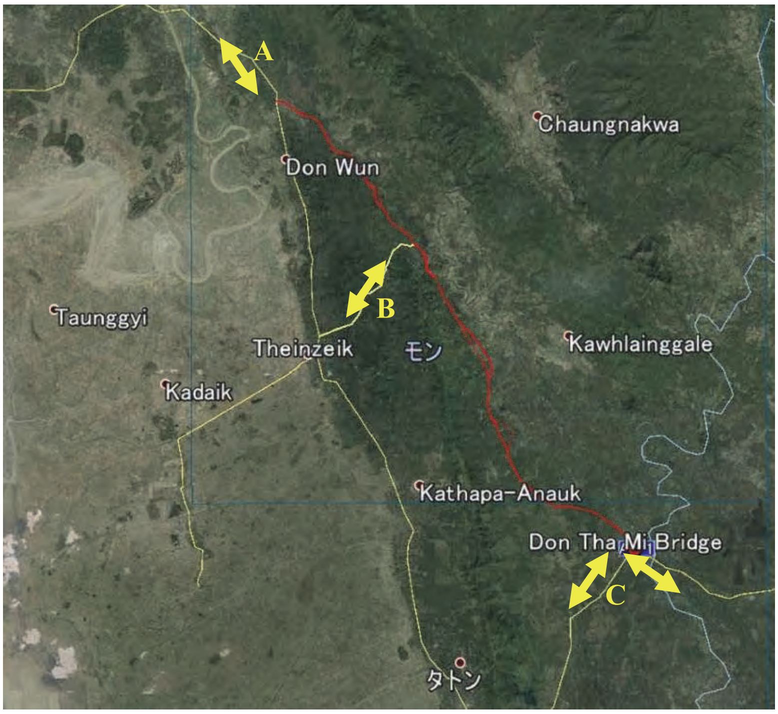
Source: JICA Survey Team

Figure 7.2.13 Layout of Temporary Access Road and Construction Yard (Atran Bridge)

(5) Thaton and Kyargalay Bypass

1) Access Roads for Construction Sites

Three access roads are assumed to connect to Thaton Bypass as shown in Figure 7.2.14. Each of these existing roads has at least one paved lane, and is judged to be usable as access roads.



Source: JICA Survey Team

Figure 7.2.14 Access Roads for Thaton Bypass

Two access roads are assumed to enter the construction site of Kyargalay Bypass from Zathapyin and Kawkareik respectively as given in Figure 7.2.15. The construction of Kyargalay Bypass is required for the mass volume of borrow and is critical to the overall schedule of construction. The appropriate hauling plan of borrow needs to be established prior to the construction.

Source: JICA Survey Team

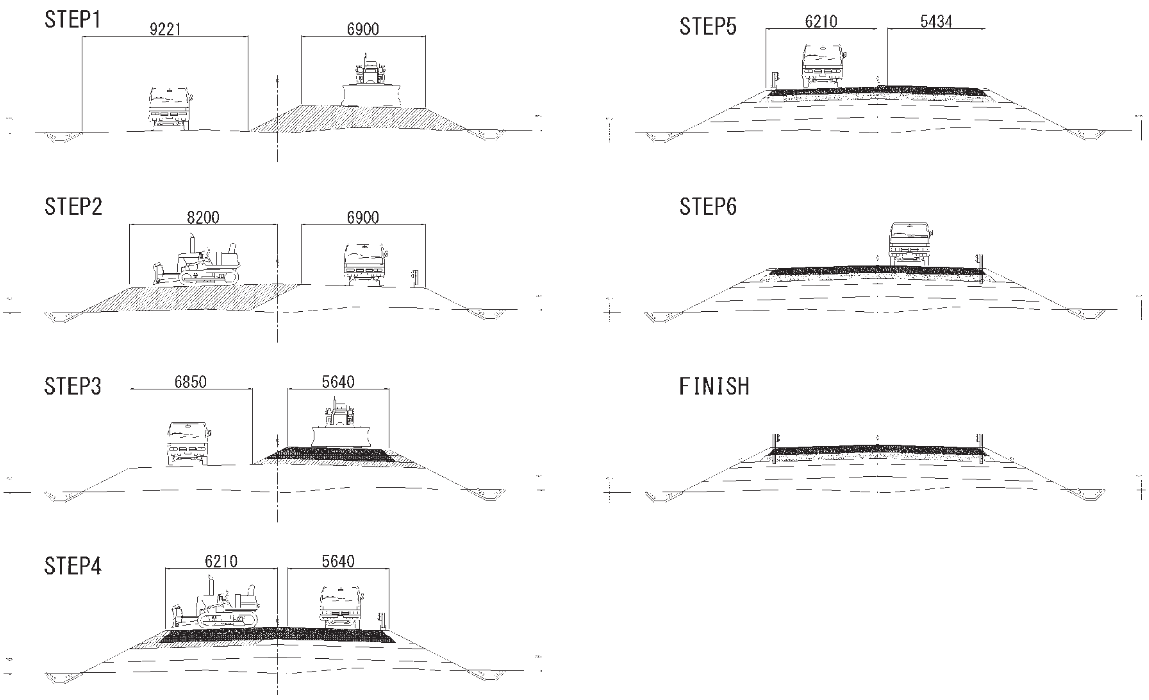
Figure 7.2.15 Access Roads for Kyargalay Bypass

2) Temporary Diversion of Existing Roads

The construction of the bypasses mostly involves the upgrading of sections of existing roads, so some existing roads shall require temporarily detour roads. The steps for temporary diversion of roads and bridges are given in Figure7.2.16 and Figure 7.2.17, respectively.

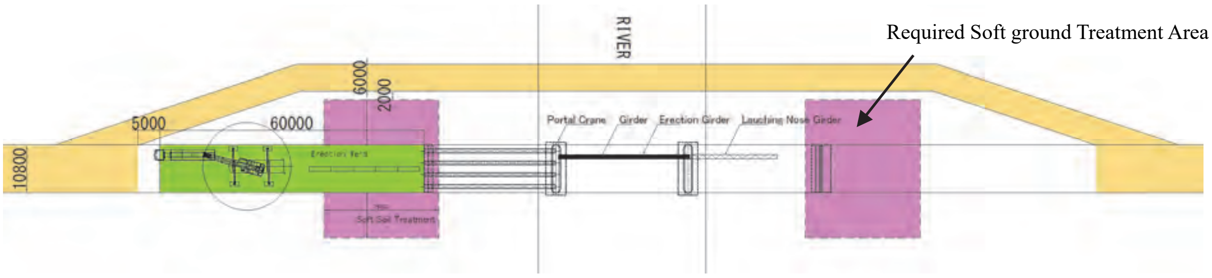
The diversion process for sections undergoing road earth works involves the diversion of traffic to a side lane during fill works, and repeating the steps.

Bridge sections require the diversion of traffic around abutment construction yards. At locations where water flows even during the dry season, temporary crossings are to be installed; and at locations where water does not flow during dry seasons, temporary pipes are to be installed.



Source: JICA Survey Team

Figure7.2.16 Diversion of Existing Roads (Earth Works Section)



Source: JICA Survey Team

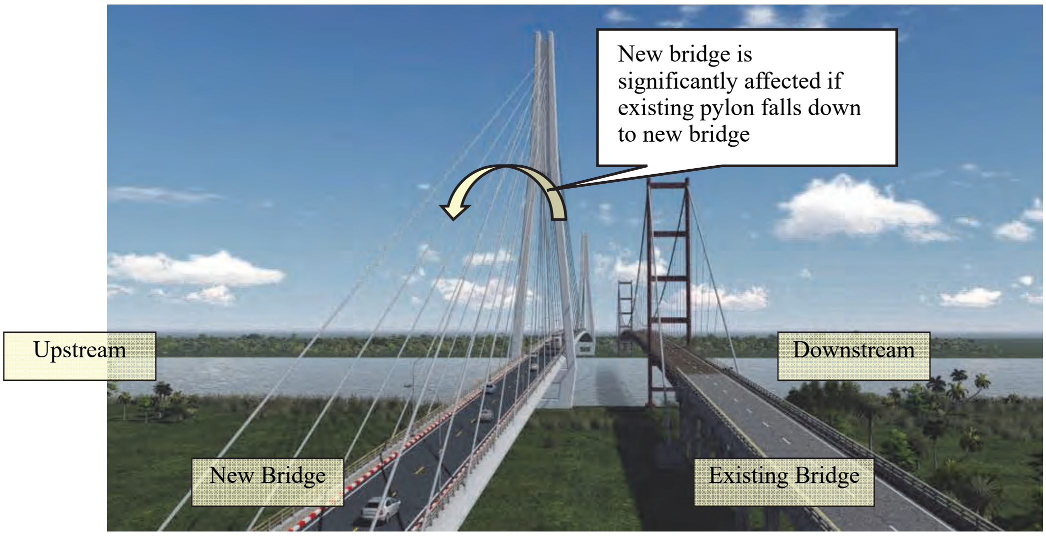
Figure 7.2.17 Diversion of Existing Roads (Bridge Works Section)

7.2.6 Demolition of Existing Bridge

(1) Necessity for Demolition

It is considered that the existing four bridges except Donthami Bridge should be demolished as soon as completion of the new bridges for the following reasons. It is desirable that demolition of the three long-spanned bridges (Gyaing Kawkareik, Gyaing Zathapyin and Atran) is eligible for yen loan in consideration of technical validity in Myanmar.

- Load bearing capacity of each existing bridge is unclear because the material specification and quality control in construction are unknown although the design drawing is available.
- It has been 40 years since Naung Lon bridge has been completed. Critical damage to the bridge is observed, such as large deflection of the girder and settlement of piers so that the possibility for bridge fall is high.
- Soundness for each structural component is unknown though amelioration/therapeutic repairing such as anticorrosion for the main cables of the three existing long-spanned bridges was conducted in 2014.
- New bridges are planned to be constructed upstream side of eac existing bridge, which is to mitigate affection on the new bridges in case of the collapse of the existing bridges. However, there might be inevitable impact on the new bridges if the existing pylons collapse.（Figure 7.2.19）。
- It is assumed that sufficient budget allocation is difficult for the maintenance of the existing bridges after the construction of new the bridges since there is budget limitation in the implementation organization (MOC).
- It is necessary that international contractors are involved in the demolition work for the existing three bridges except Naung Lon Bridge in order to secure safety during demolition in consideration of technical validity in Myanmar.



Source: JICA Survey Team

Figure 7.2.18 Graphical Image for Gyaing Zathapyin Bridge(Without Demolition

(2) Timing of Demolition

It is considered that the existing bridges except Donthami Bridge should be demolished as soon as possible since critical damage for road operation is observed even in the 15th year after opening. It is necessary that the construction yard, machineries and materials are separately procured if demolition work is carried out fifteen years after the completion of the new bridges. In this context, it is desirable that the demolition is conducted on the heels of new bridge construction which will enable the smooth use of the common yard and machineries.

(3) Structural Components to be Removed

Existing structures above the ground level shall be demolished in consideration of cost reduction, shortening period for demolition work and utilization of the existing site for another purpose.

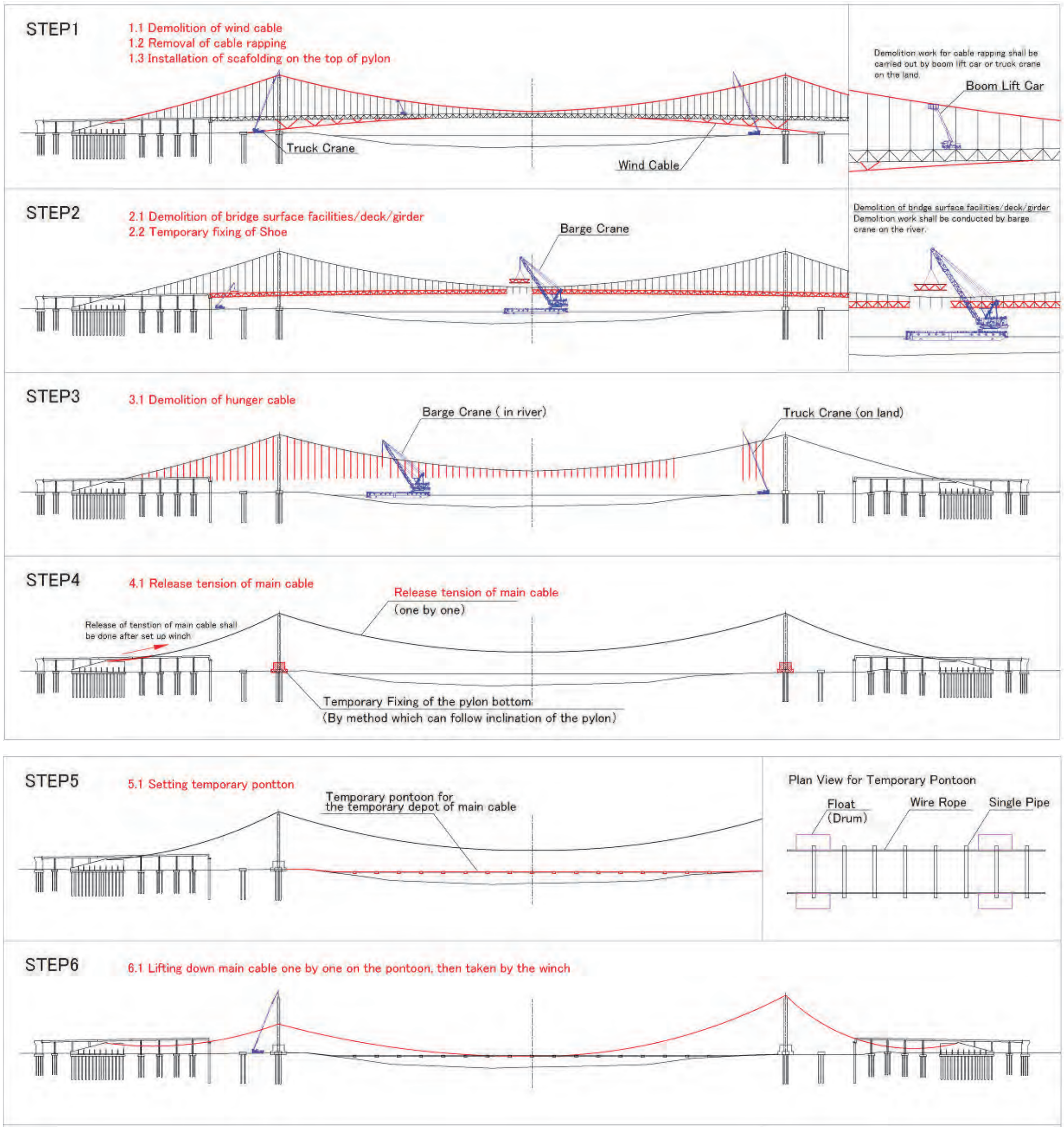
(4) Demolition Procedure

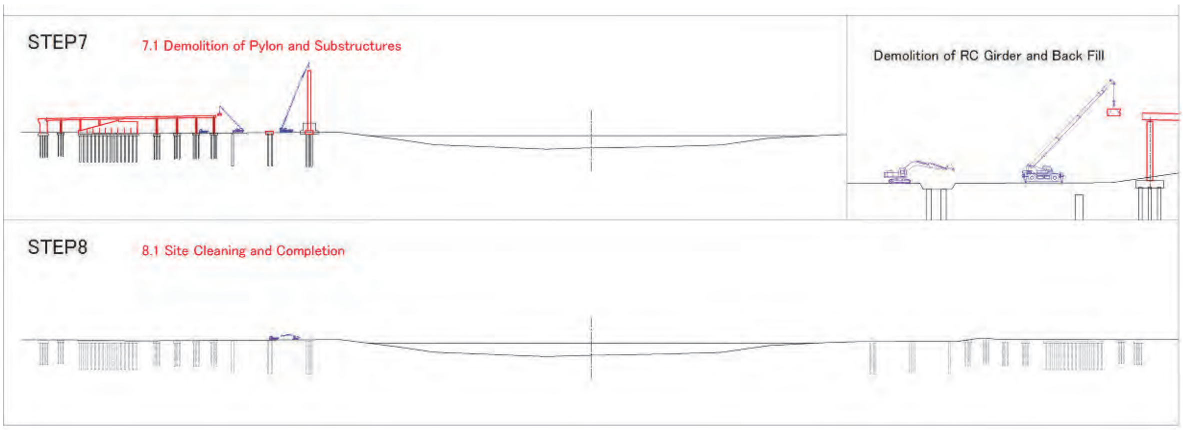
There are two kinds of superstructures among the existing bridges to be demolished as part of this project: the first is suspension, and the second is steel cable-stayed. Demolition procedures for each superstructure type are shown in Figure 7.2.19 and Figure 7.2.20.

Table 7.2.2 Summary of Existing Bridge to be Removed

Bridge Name	Superstructure Type	Bridge Length
Gyaing Kawkareik Bridge	Suspension Bridge (Main) + RC Bridge (Approach)	365m
Gyaing Zathapyin Bridge	Suspension Bridge (Main) + RC Bridge (Approach)	882m
Atran Bridge	Steel Cable Stayed Bridge (Main) + RC Bridge (Approach)	432m

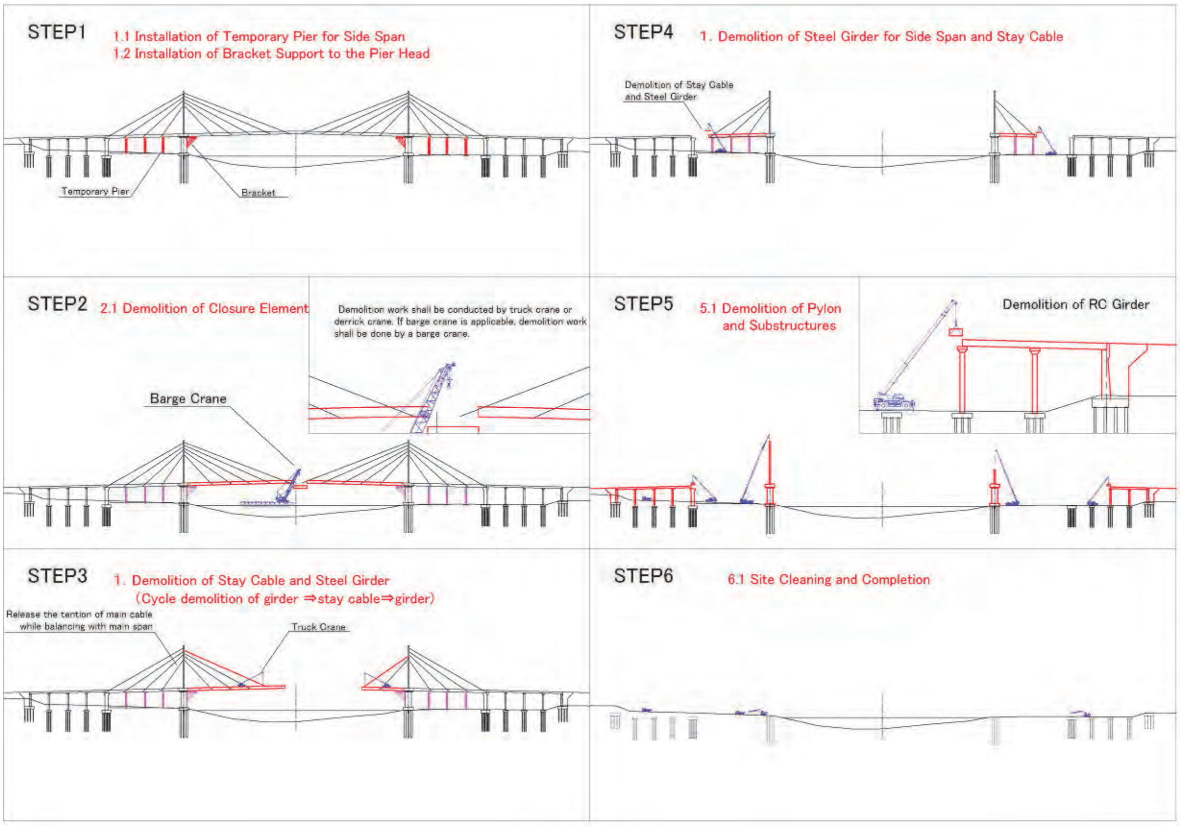
Source: JICA Survey Team





Source: JICA Survey Team

Figure 7.2.19 Construction Sequence for Demolition of Existing Bridge (Suspension Bridge)



Source: JICA Survey Team

Figure 7.2.20 Construction Sequence for Demolition of Existing Bridge (Steel Cable Stayed Bridge)

7.3 Construction Schedule

Myanmar is generally considered to have two clearly-definable seasons. The wet season lasts from June to October, and the dry season lasts from November to May. In the hydraulic survey, it is observed that the project areas are mostly submerged during the wet season due to floods of adjacent rivers. Accordingly, the construction schedule is to be established such that, in principle, major works should be conducted in the dry season. However, superstructure works (including the construction of towers and the erection of girders) are to be conducted during the wet season where possible in order to shorten the schedule.

The construction schedules for all major works are given from Figure 7.3.1 to Figure 7.3.10.

(1) Naung Lon Bridge

The construction schedule for Naung Lon Bridge is shown in Figure 7.3.1.

(2) Gyaing Kawkareik Bridge

The critical works for the construction of Gyaing Kawkareik Bridge are the construction of pylons (P5 and P6) and balanced cantilever works after the completion of pylons. Note that day/night shift is assumed for the construction schedule of Gyaing Kawkareik based on the request from MOC for shortening the construction period.

(3) Gyaing Zathapyin Bridge

The critical works for the construction of Gyaing Zathapyin Bridge are the construction of pylons (P1 and P2) and balanced cantilever works after the completion of pylons.

(4) Atran Bridge

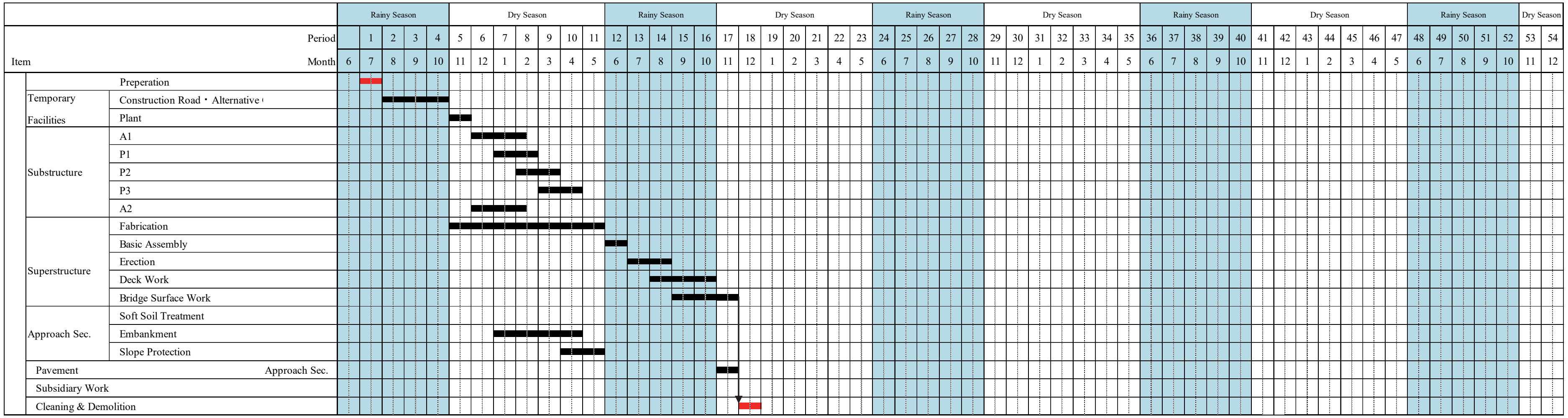
The critical works for the construction of Atran Bridge are the construction of pylons (P5 and P6) and balanced cantilever works after the completion of pylons.

(5) Kyargalay Bypass and Thaton Bypass including Donthami Bridge

The critical works for the construction of Kyargalay Bypass and Thaton Bypass are earth works, because these works depend on the hauling of borrow materials from outside of the construction site.

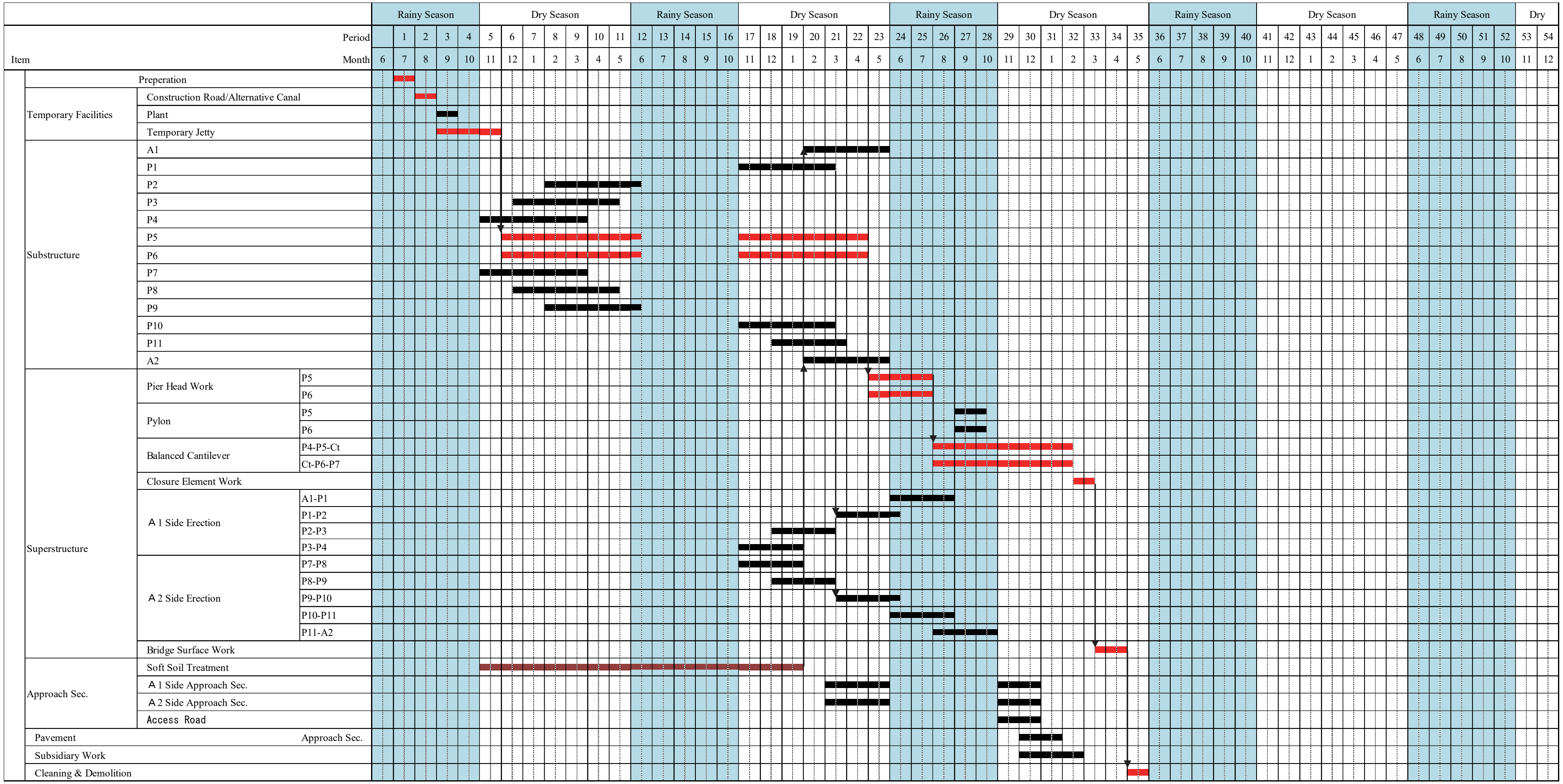
Note that the use of sand in the Gyaing River is assumed for Kyargalay Bypass in order to shorten the construction period as requested by MOC.

The critical works for construction of Donthami Bridge include soft soil treatment behind the abutments as well as the erection of the superstructure.



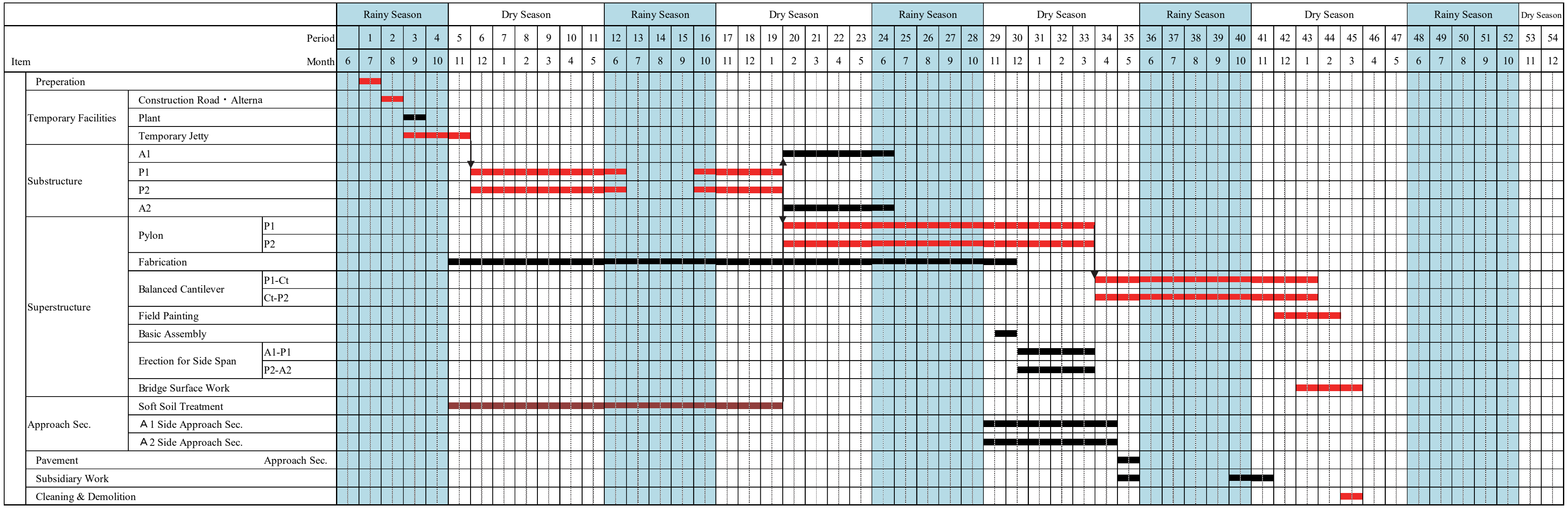
Source: JICA Survey Team

Figure 7.3.1 Construction Schedule (Naung Lon Bridge)



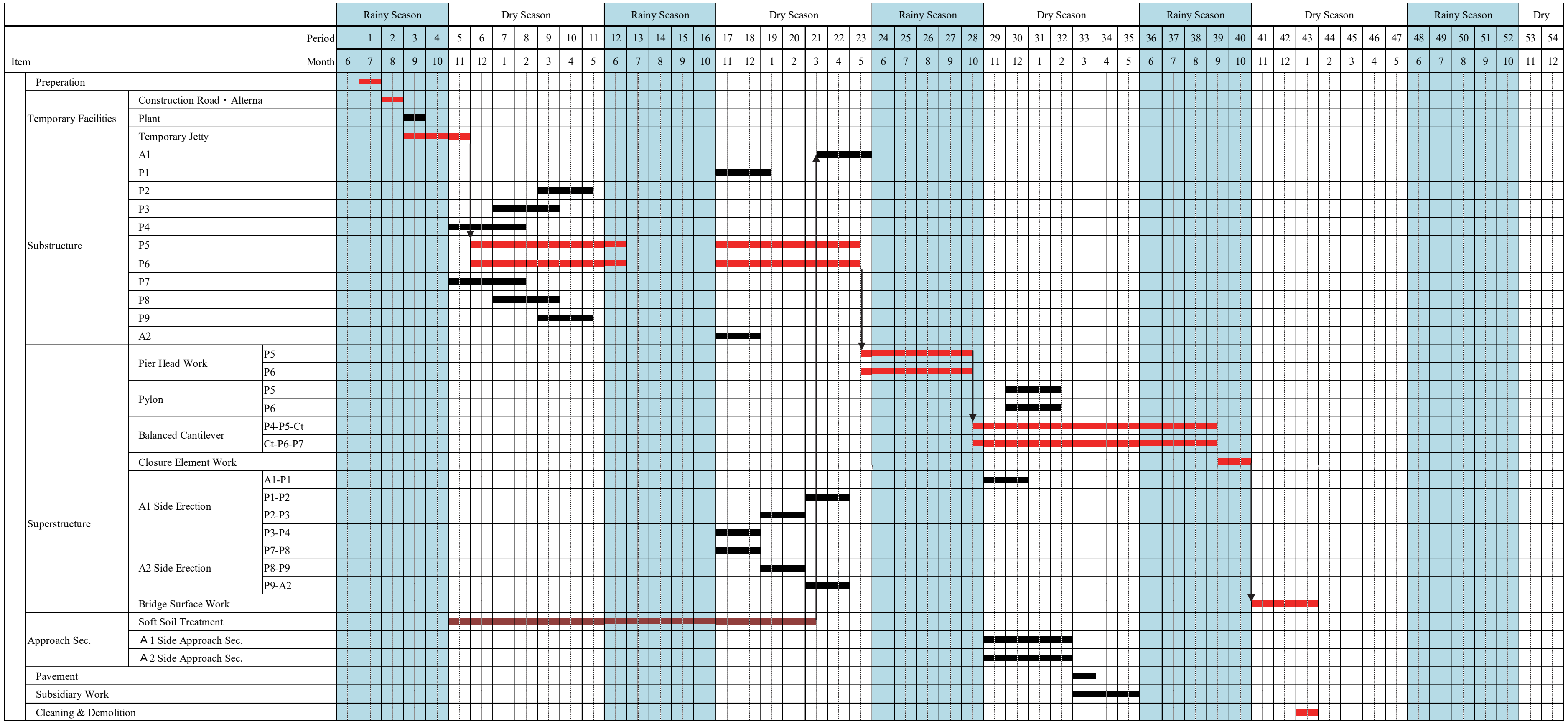
Source: JICA Survey Team

Figure 7.3.2 Construction Schedule (Gyaing Kawkareik Bridge)



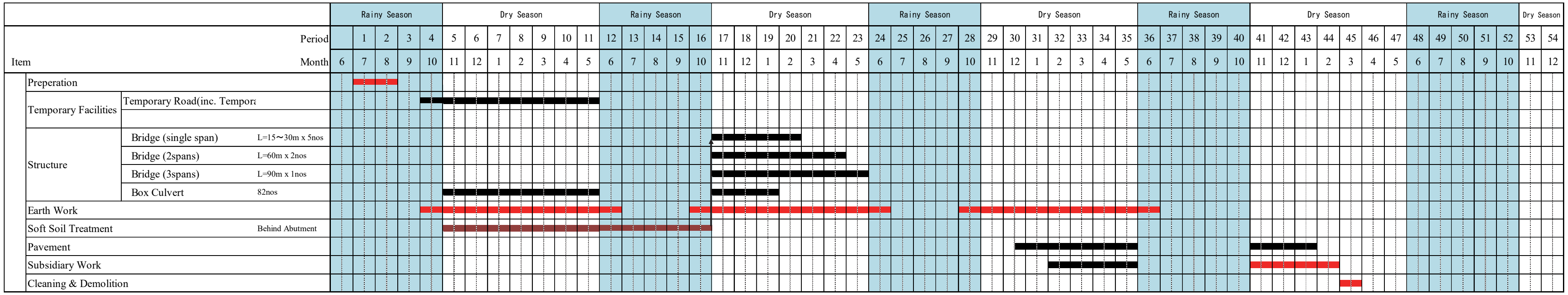
Source: JICA Survey Team

Figure 7.3.3 Construction Schedule (Gyaing Zathapyin Bridge)



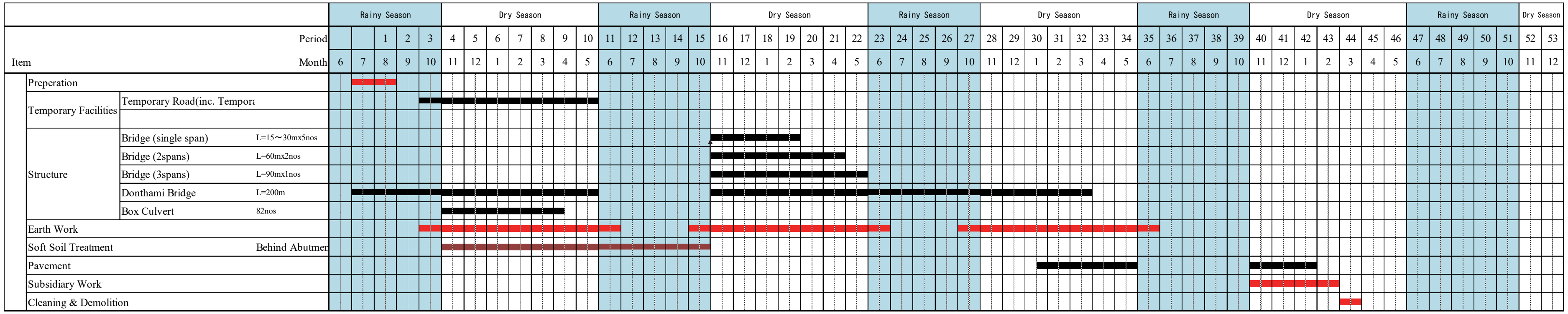
Source: JICA Survey Team

Figure 7.3.4 Construction Schedule (Atran Bridge)



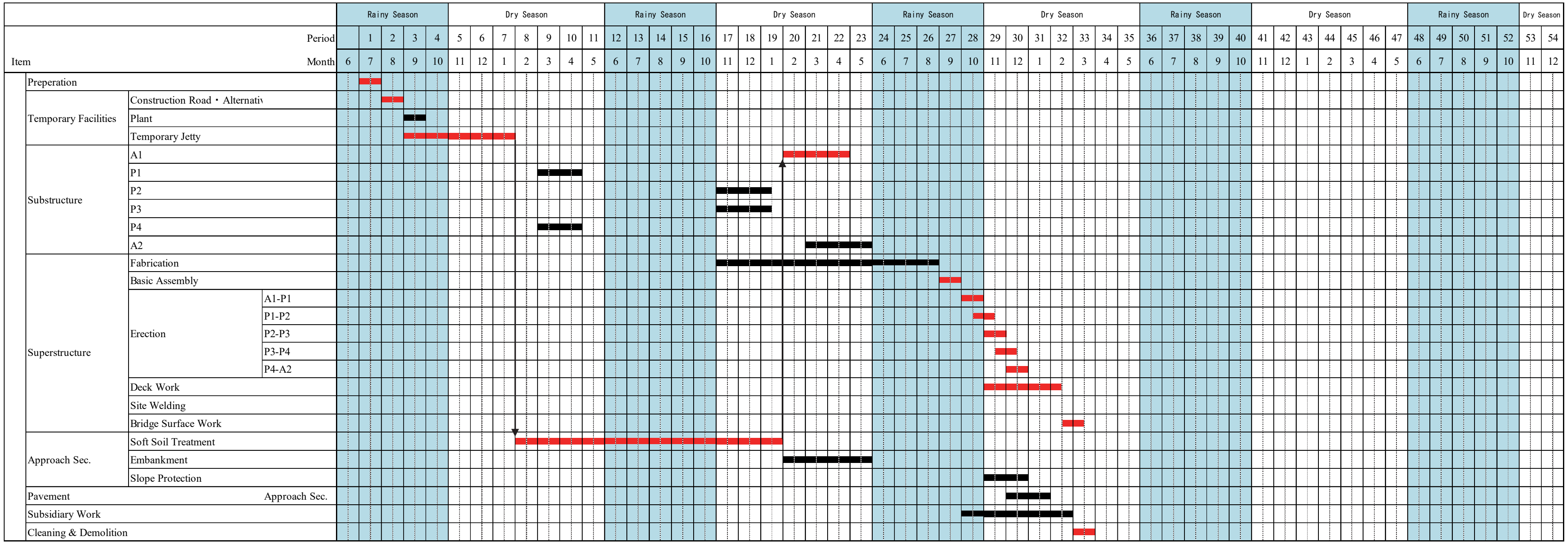
Source: JICA Survey Team

Figure 7.3.5 Construction Schedule (Kyargalay Bypass)



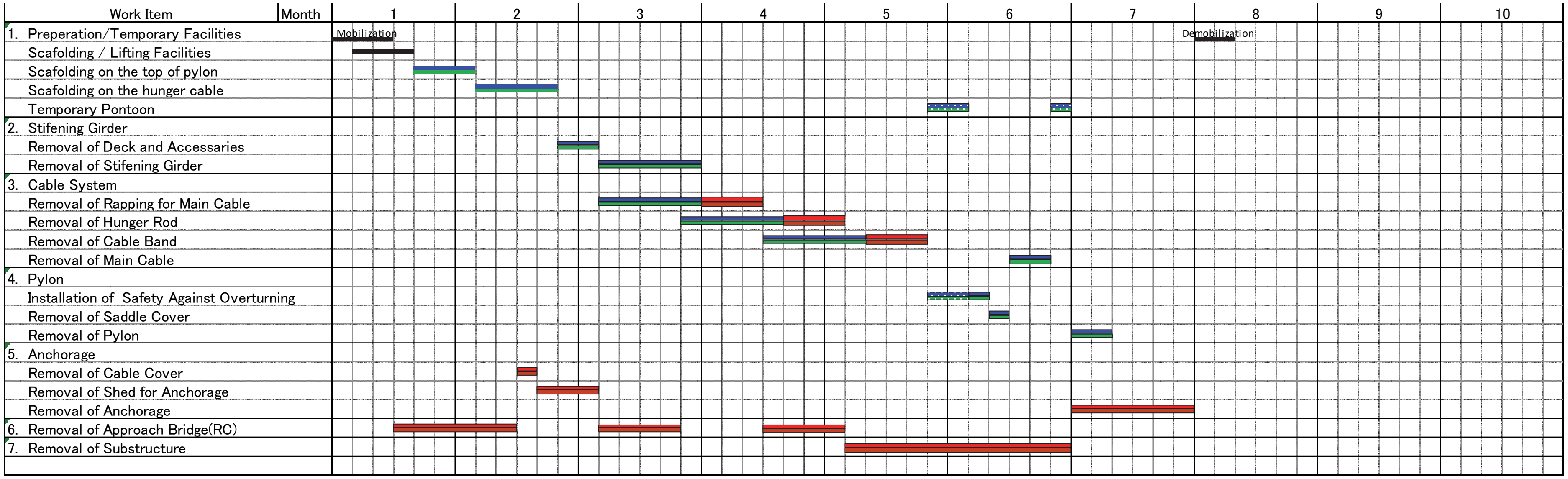
Source: JICA Survey Team

Figure 7.3.6 Construction Schedule (Thaton Bypass including Donthami Bridge)



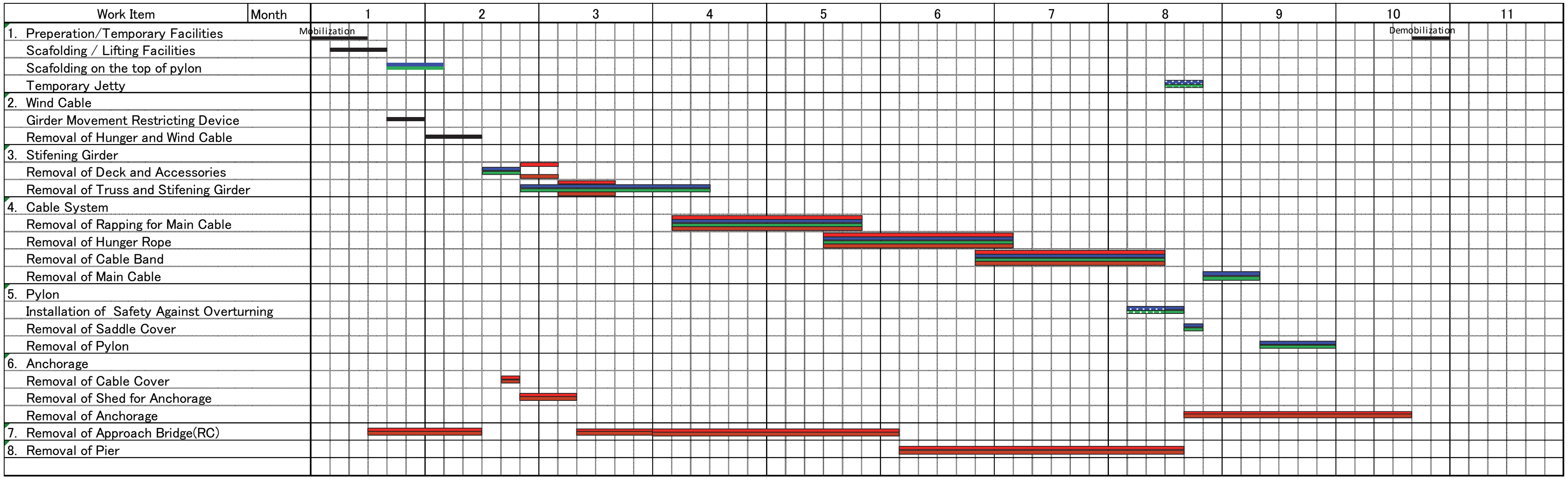
Source: JICA Survey Team

Figure 7.3.7 Construction Schedule (Donthami Bridge)



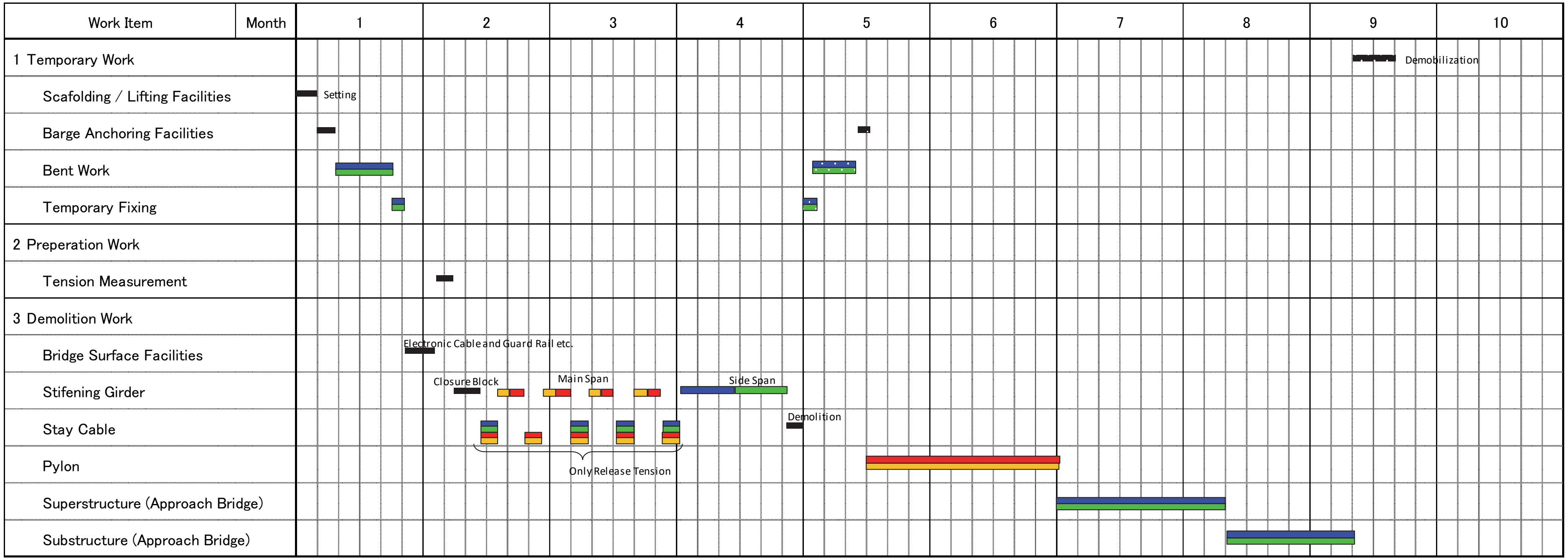
Source: JICA Survey Team

Figure 7.3.8 Demolition Work Schedule (Existing Gyaing Kawkareik Bridge)



Source: JICA Survey Team

Figure 7.3.9 Demolition Work Schedule (Existing Gyaing Zathapyin Bridge)



Source: JICA Survey Team

Figure 7.3.10 Demolition Work Schedule (Existing Atran Bridge)

7.4 Procurement Plan

7.4.1 Procurement Plan for Major Materials

The procurement sources of major materials for road and bridge works are given in Table 7.4.1. Raw materials, such as cement, aggregate, and sand, etc. can be procured in the domestic market, however PC cables, rebar and other steel materials shall be procured from overseas.

Table 7.4.1 Procurement Source for Major Materials

Materials	Procurement source		Remarks
	Domestic	Overseas	
Earth Works			
Borrow	○		
Aggregate	○		
Concrete			
Cement	○		
Course Aggregate	○		
Fine Aggregate	○		
Sand	○		
Fresh Concrete	○		
Rebar		○	The use of imported materials is assumed due to limited supply in domestic product
Steel Works			
Steel plate		○	Plate girders, Steel cable-stayed
Shaped steel		○	Temporary jetties, plate girders, steel cable stayed
Steel pipe		○	Steel pipe sheet piles, etc.
Bolt & Nut		○	
Welding materials		○	
Paint		○	
Temporary Works			
Steel Sheet Pile		○	
Deck panel		○	Temporary jetties
H shaped steel		○	Temporary work platforms
Steel bent		○	
Bridge Accessories			
Bearing		○	
Expansion joint		○	
Railing		○	
Waterproof sheet		○	
PC strand, etc.		○	PC cables
Road Accessories			
Light		○	
Guard rail		○	
Signal		○	
Drainage		○	
Soft soil ground treatment			
Drain materials		○	Plastic pieces
Oil and Emulsion			
Fuel	○		
Asphalt	○		

Source: JICA Survey Team

7.4.2 Procurement Plan for Major Equipment

General equipment for civil works can be procured in Myanmar's domestic market. However, special equipment used for piling works and bridge works (erection of girders) shall be imported from overseas. Additionally, over 100 dump trucks shall be required for earth works, so the overseas procurement should be assumed. The procurement sources for major equipment are shown in Table 7.4.2.

Table 7.4.2 Procurement Source for Major Equipment

Equipment	Procurement Source		Remarks
	Domestic	Overseas	
Backhoe	○		
Bulldozer	○		
Rafter rain crane	○	○	
Truck crane	○	○	
Crawler crane	○	○	
Tower crane		○	
Crane self-elevated platform		○	Erection of cabled stayed bridge
Concrete pumping machine	○		
Concrete pump vehicle		○	
Pier		○	
All casing powered jack rig		○	Cast-in-place bored pile
Vibration hummer		○	Piling
Vertical drain equipment		○	
Tire roller	○		
Vibration roller	○		
Road roller	○		
Asphalt paver	○		
Vibration compactor	○		
Form traveller		○	PC girder erection
Dump truck		○	10t
Semi-trailer		○	Hauling PC girder

Source: JICA Survey Team

7.4.3 Source of Borrow Materials

Approximately 3 million cubic meters of borrow materials will be required for the construction of both Thaton Bypass and Kyargalay Bypass. Kyargalay Bypass will require more than 70% of this (2.1 million cubic meters). It is also assumed that a similarly huge embankment volume shall be required for the road improvement of the ADB section between Eindu and Kawkareik. The limited sources of borrow materials in the adjacent area might cause conflict with regards to procurement.

One option is to use materials from the Gyaing River, as the geotechnical investigation identified that the sand sediment lying within 10m from the bottom of this river has relatively good grain size distribution and would probably be eligible to use as borrow. Thus, there is a possibility that borrow material would be procured from the river sand, although a follow-up survey to confirm the quality and reserves will need to be performed in the detail design stage.