REPUBLIC OF THE UNION OF MYANMAR
MINISTRY OF CONSTRUCTION
DEPARTMENT OF BRIDGE

DETAILED DESIGN STUDY ON THE BAGO RIVER BRIDGE CONSTRUCTION PROJECT

FINAL REPORT

DECEMBER 2017

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

NIPPON KOEI CO., LTD.
ORIENTAL CONSULTANTS GLOBAL CO., LTD.
METROPOLITAN EXPRESSWAY COMPANY LIMITED.
CHODAI CO., LTD.
NIPPON ENGINEERING CONSULTANTS CO., LTD.

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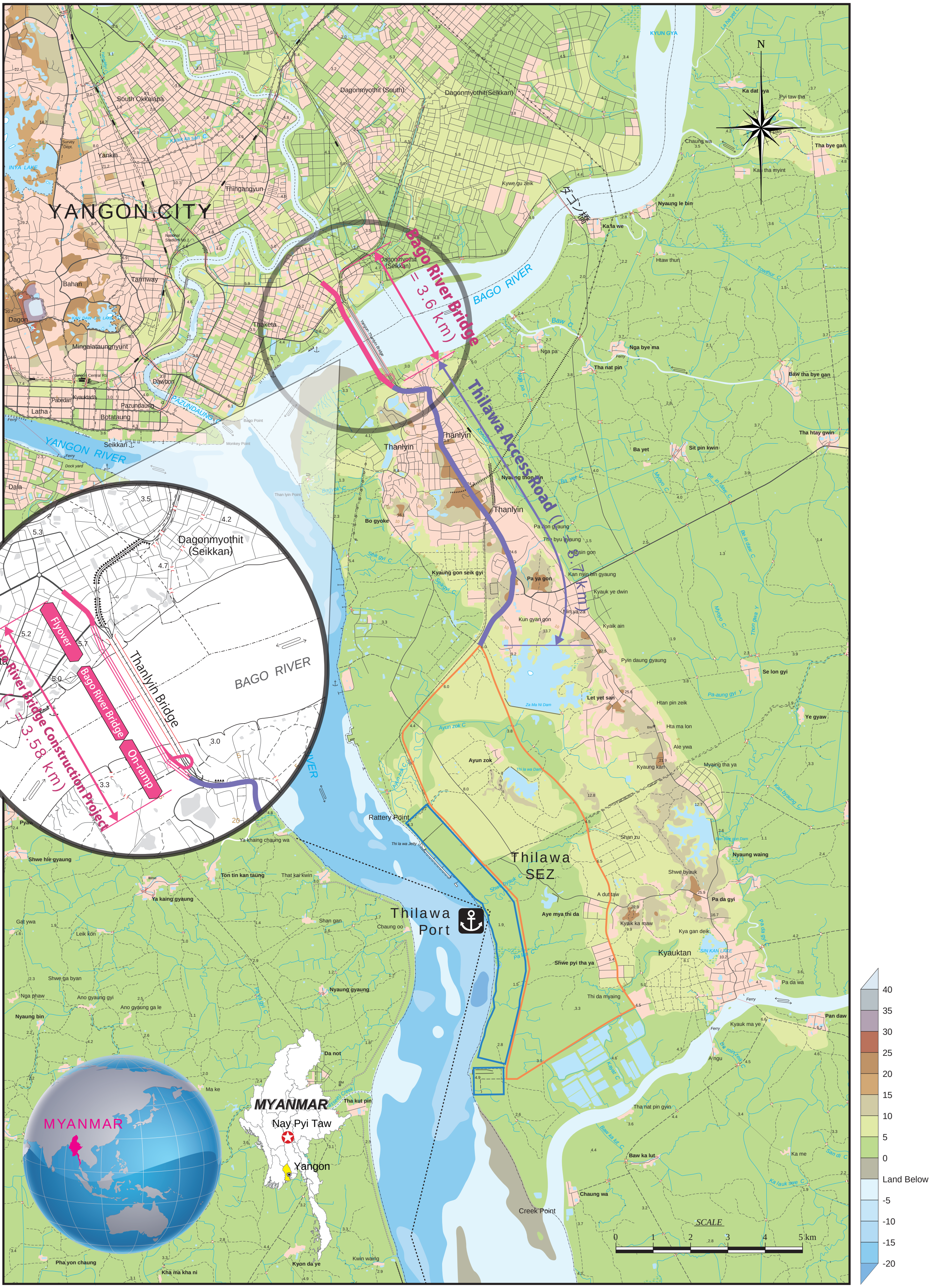

Location Map of the Project

Perspective of the Project (Bago River Bridge)

Perspective of the Project (Bago River Bridge)

Perspective of Cable-stayed Bridge

Perspective of Cable-stayed Bridge

Perspective of On-ramp (Thanlyin Side)

Perspective of Steel Box Girder Bridge

Perspective of the Project (Thaketa Side)

Perspective of Flyover Bridge (Thaketa Side)

The Final Report of the "Detailed Design Study on The Bago River Bridge Construction Project ", consists the following reports and documents.

FINAL REPORT

FINAL REPORT ATTACHMENTS

VOLUME I	**DRAWINGS**
Part I	Package 1
Part II	Package 2
Part III	Package 3
Part IV	MOC Portion
VOLUME II	**DESIGN REPORT**
Part I	Road Design
Part II	Steel Cable Stayed Bridge
Part III	Steel Box Girder Bridge
Part IV	PC Box Girder Bridge & On-ramp Bridge
Part V	Flyover Bridge
Part VI	Toll Collection Facility
VOLUME III	**QUANTITY CALCULATION REPORT**
Part I	Road Design
Part II	Steel Cable Stayed Bridge
Part III	Steel Box Girder Bridge
Part IV	PC Box Girder Bridge & On-ramp Bridge
Part V	Flyover Bridge
Part VI	Toll Collection Facility
VOLUME IV	**COST ESTIMATE REPORT**
VOLUME V	**DRAFT TENDER DOCUMENT**
	PACKAGE 1
	PACKAGE 2
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DETAILED DESIGN STUDY ON
THE BAGO RIVER BRIDGE[
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FINAL REPORT
(MAIN REPORT)

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LIST OF APPENDIX

Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
AfDB	African Development Bank
AIDS	Acquired Immune Deficiency Syndrome
ARP	Airport Reference Point
A-RAP	Abbreviated Resettlement Action Plan
ART	Antiretroviral Therapy
ASEAN	Association of Southeast Asian Nations
B/D	Basic Design
BD/R	Basic Design Report
BRT	Bus Rapid Transit
CBD	Central Business District
CNG	Compressed Natural Gus
COD	Cut-off Date
CPLAD	City Planning and Land Administration Department
CS	Construction Supervision
CT	Contractor
D/D	Detailed Design
DF/R	Draft Final Report
DFID	UP Department for International Development
DHSHD	Department of Human Settlement and Housing Development
DMH	Department of Meteorology and Hydrology
DMS	Detailed Measurement Survey
DO	Dissolved Oxygen
DOB	Department of Bridge
DOF	Degree of Freedom
DOH	Department of Highway
DOI	Department of Immigration
DOL	Department of Labor
DUHD	Department of Urban Housing Development
DWIR	Directorate of Water Resources and Improvement of River Systems
ECC	Environmental Compliance Certificate
ECD	Environmental Conservation Department
EHS	Environmental, Health, and Safety
EIA	Environmental Impact Assessment
EMoP	Environmental Monitoring Plan
EMP	Environmental Management Plan
E/N	Exchange of Notes
EQG	National Environmental Quality (Emission) Guidelines

ERL	Effect Range Law
ERM	Effect Range Median
FD	Forest Department
F/R	Final Report
F/S	Feasibility Study
FS	Fire Station (Relevant Office)
GAD	General Administration Department
GOM	Government of Myanmar
GOJ	Government of Japan
GPS	Global Positioning System
HIV	Human Immunodeficiency Virus
HSE	Health and Safety Engineer
IC/R	Inception Report
IEE	Initial Environmental Examination
IFC	International Finance Corporation
I/P	Implementation Program
IUCN	International Union for Conservation of Nature
IWT	Inland Water Transport
JICA	Japan International Cooperation Agency
JPY	Japanese Yen
JSHB	Japanese Specifications for Highway Bridge
L/A	Loan Agreement
MFSD	Myanmar Fire Services Department
MITT	Myanmar International Thilawa Terminal
MMK	Myanmar Kyat
MMPS	Myanmar Maritime Police Station
MOC	Ministry of Construction
MOEE	Ministry of Electricity Power and Energy
MONREC	Ministry of Natural Resources and Environmental Conservation
MOGE	Myanmar Oil and Gas Enterprise
MOHS	Ministry of Health and Sports
MOI	Ministry of Industry
MOL	Ministry of Labor, Immigration and Population
MOTC	Ministry of Transport and Communications
MPA	Myanma Port Authority
MPPE	Myanmar Petroleum Products Enterprise
MPT	Myanmar Port and Telecommunication
MR	Myanmar Railways
MSD	Myanmar Survey Department
MTP	Myanmar Traffic Police
NAP	National Aid Program

NEXCO	Nippon Expressway Company
NGO	Non-Governmental Organization
NO2	Nitrogen Dioxide
ODA	Official Development Assistance
OP	Operational Policy
O&M	Operation and Maintenance
PAHs	Project Affected Households
PAPs	Project Affected Persons
PC	Prestressed Concrete
PCD	Pollution and Cleansing Department
PC-T	Prestressed Concrete T-shaped
PCU	Passenger Car Unit
PM2.5	Fine particulate matter 2.5
PM10	Suspended particulate matter 10
PMU	Project Management Unit
PPGD	Playgrounds, Parks and Gardening Department
PS	Police Station (Relevant Office)
ROW	Right of Way
RTAD	Road Transport Administration Department
Rd	Road
R&BD	Roads and Bridge Departments in YCDC
SEZ	Special Economic Zone
SO2	Sulphur Dioxide
SPSP	Steel Pipe Sheet Pile
SPT	Standard Penetration Test
SS	Suspended Solids
STDs	Sexually Transmitted Diseases
SUDP	The Strategic Urban Development Plan of the Greater Yangon, JICA (2013)
Supplemental F/S	Supplemental Feasibility Study
SV	Supervision
TN	Total Nitrogen
TOC	Total Organic Carbon
TOR	Terms of References
TP	Total Phosphorus
TRESC	Traffic Rules Enforcement Supervisory Committee
TS	Total Station
USD	US Dollar
V/C	Volume to Capacity
WB	World Bank
WSSD	Water Supply and Sanitation Department
YCDC	Yangon City Development Committee

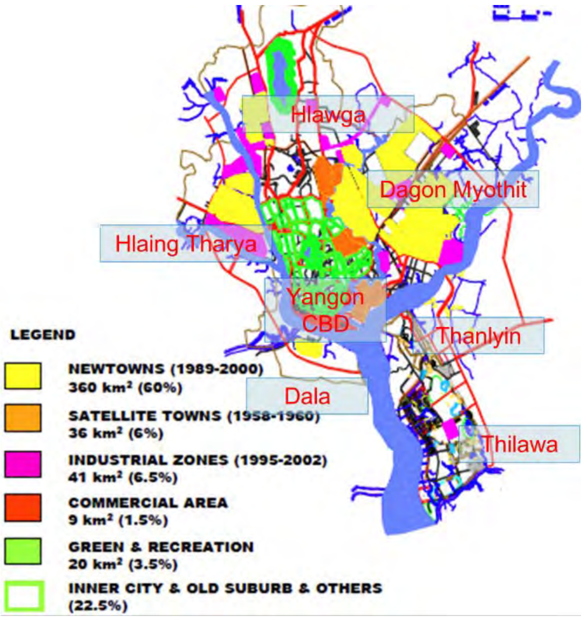
YESC	Yangon Electricity Supply Corporation
YRDC	Yangon Region Development Committee
YRG	Yangon Region Government
YUTRA	Project for Comprehensive Urban Transport Plan of the Greater Yangon

CHAPTER 1. GENERAL

1.1 INTRODUCTION

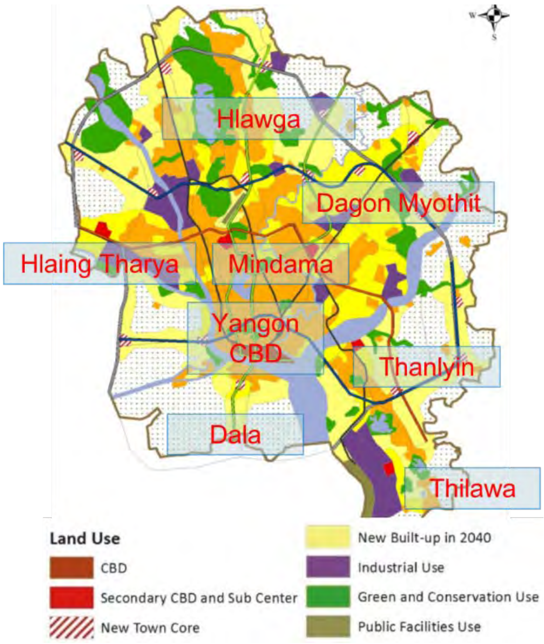
The Greater Yangon, which consists of Yangon City and its surrounding townships, has a population of 7.3 million (2014) and is the economic center of the growing Myanmar. Being the center of the economic activities in Myanmar, Yangon City faces excessive centralization accelerated by recent rapid economic growth, generating transport demand larger than ever. The present transport infrastructure is not enough to sustain the rapid development of the economy.

As shown in Figure 1.1.1, economic activities have been expanding outwards including development of new towns, satellite towns, industrial zones, and green and reclamation. The development in land use and its expansion are making sub centers surrounding the central business district (CBD) including, Hlaing Tharya, Mindama, Dagon Myothit, Dala,Thanlyin, and Thilawa. These development and expansion in future land use can be effectively supported by transportation enhancement including arterial roads, outer ring roads, railways, MRT, and BRT, as defined in the Strategic Urban Development Plan (SUDP) of the Greater Yangon, JICA (2013).



Source: DHSHD

Figure 1.1.1 New Towns, Satellite Towns and Industrial Zones in Yangon Region up to 2002



Source: SUDP

Figure 1.1.2 Future Land Use MAP (2040)

In the next twenty years, person trips will be increased drastically, in particular, between Thilawa and Yangon CBD mainly due to the development of Thilawa Special Economic Zone (SEZ). As a result, the area needs high-order transit services that will be expanded as highlighted in red.

Similarly, logistics traffic between Yangon CBD and Thilawa will also increase, exhibited by the number of truck traffic as shown in this slide. The truck traffic demand between Thilawa and CBD crossing Bago River will be increased by three times. The truck traffic between Thilawa and Bago Subcenter crossing Bago River is also similarly increased.

As a result, new bridges crossing Bago River are needed in the near future to accommodate the bigger traffic demand.


Source: JICA Study Team

Figure 1.1.3 Photos of Thanlyin Bridge

Currently, there are two existing bridges connecting Yangon CBD and Thilawa crossing Bago River, which are Thanlyin Bridge and Dagon Bridge. Comparing the two bridges on current traffic volume, the traffic volume on the Thanlyin Bridge route is much more because the Dagon Bridge route has a longer distance and narrower access roads. Similarly, majority of traffic between Bago Subcenter and Thilawa passes Thanlyin Bridge and the Thanlyin Bridge route is the access between Thilawa and CBD or Bago Subcenter.

Thanlyin Bridge has two major problems for accommodating such big traffic demand in the near future: the number of lanes and weight limitation. The bridge has only one lane on each direction which is vulnerable to terrible congestion by only a small incident like a tiny trouble of a vehicle. The bridge has weight limitation of 32 tons, which cannot accommodate heavier trucks like large trailers.

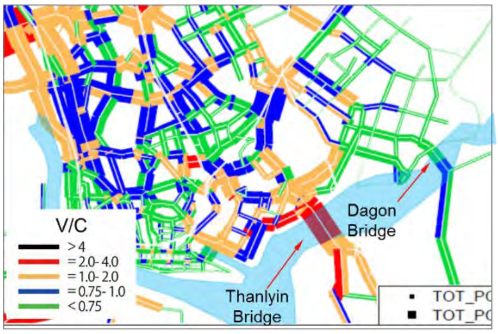
Table 1.1.1 shows the estimated traffic volume in 2025 represented by the ratio of traffic volume and capacity of the roads. In ten years, the traffic volume along Thanlyin Bridge will increase up to nearly twice its capacity and it is estimated that travel time on the bridge is 88 minutes and jam length is more than 6 km. With a new bridge with four lanes, the travel time is going to be reduced to six minutes and jam length to 150 m. Consequently, the construction of a new bridge is very effective for accommodating the bigger traffic demand on Thanlyin Bridge.

Table 1.1.1 Estimated Travel Time and Jam Length of based on V/C at Thanliyn Bridge (2025)

	Volume / Capacity	Travel Time (min.)	Jam Length* (km)
Without New Bridge	1.8	88	6.37
With New Bridge	1.0	6	0.15

Note(*): (peak volume - capacity)*(vehicle distance) / (number of lanes)

Source: extracted from YUTRA by JICA Study Team



Therefore, the necessity of constructing a new bridge over the Bago River is one of the high priorities in Myanmar's development agenda. The Strategic Urban Development Plan of the Greater Yangon (SUDP) (2013) and the Comprehensive Urban Transport Plan of the Greater Yangon (YUTRA) (2014) have been published under Japanese assistance. These master plans clearly pointed out the inadequate transport infrastructure between Yangon City and Thanlyin Township. The construction of Bago River Bridge will surely guarantee the expected economic growth in Thanlyin Township, with acceleration of Thilawa SEZ development, and thus contribute to the economic development of the whole of Myanmar. Furthermore, in the SUDP, traffic flows from/to sub-centers are induced by ring roads and thus, congestion in Yangon CBD will be mitigated.

Therefore, the construction of a new bridge, i.e., Bago River Bridge (hereinafter referred to as “the Project”), is urgently required.

As stated in the minutes of the meeting between the Ministry of Construction (hereinafter “MOC”) and the Japan International Cooperation Agency (hereinafter “JICA”), signed on May 15, 2013, a preparatory survey was conducted for the feasibility study on the new construction of Bago River Bridge and approach road to the bridge and the final report was submitted on August 31, 2014, which was accepted by MOC. The preparatory survey was followed by a supplemental survey conducted in February 2016 for studying improvement of the adjacent intersections and connecting roads, and updating the traffic demand forecast, cost estimate, environmental and social considerations, and project evaluation.

Based on the results of the preparatory surveys, the Government of Myanmar secured a loan from JICA for the Project.

1.2 OUTLINE OF THE DESIGN STUDY

1.2.1 Title of Design Study

Detailed Design Study on Bago River Bridge Construction Project

1.2.2 Objectives of Design Study

The objective of the Design Study is to prepare the detailed design and draft tender documents for the Project. The Department of Bridge (DOB) of MOC and JICA confirmed that the drawings and documents formulated by the Design Study (hereinafter referred to as “the Design Documents”) shall be fully utilized for the procurement procedure of the Project.

1.2.3 Project Profile

(1) Name of the Project: Bago River Construction Project

(2) Signing L/A: March 1, 2017 (MY-P16)

(3) Proposed Facilities of the Project

The proposed facilities of the Project are shown in Table 1.2.1

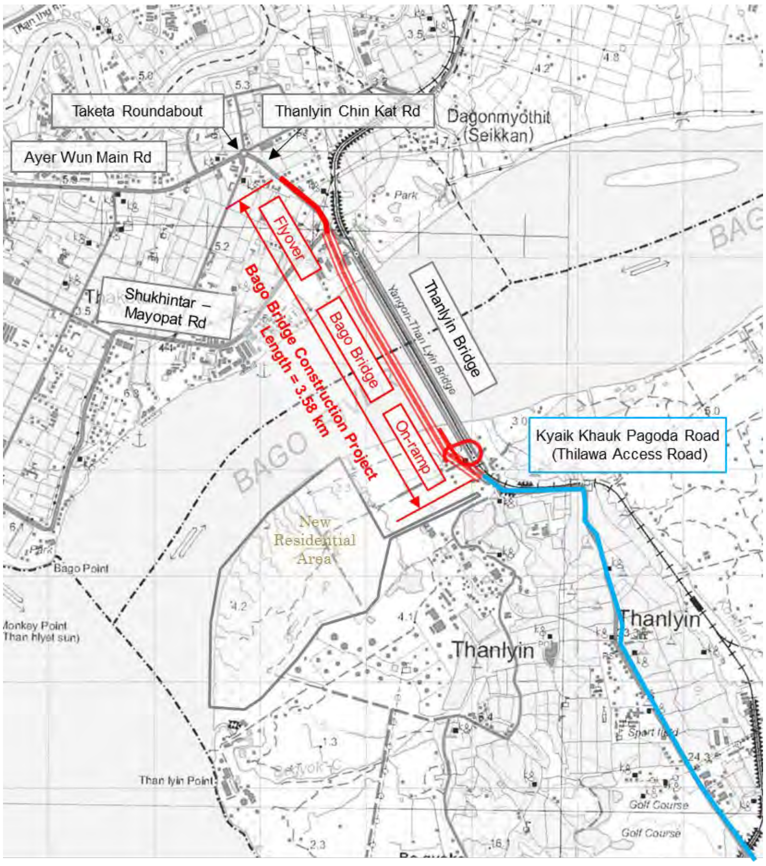
Table 1.2.1 Proposed Features of the Project

No.	Item	Package 1	Package 2	Package 3
1	BP	STA 0+000, Boundary of Thilawa Access Road	STA 1+312.0, Pier (P) 13 (P13: Package 1)	STA 2+676.0, (AF1: Package 3)
2	EP	STA 1+312.0, Pier (P) 13 (P13: Package 1)	STA 2+676.0, Abutment AF1 (South Abutment of Flyover: Package 3)	STA 3+644.3, Connect Thanlyin Chin Kat Road to Thaketa Roundabout
3	Length	1,312.0 m	1,364.0 m (1,424.0 m)	968.3 m
4	Road Design Standard/ Class	Equivalent to Road Class in Japanese Road Structure Ordinance, and ASEAN Highway Standard		
		Type 2 Class 1	Type 2 Class 1	Type 4 Class 1
5	Design Speed	60 km/hr: Main carriageway 30 km/hr: On-ramp	60 km/hr: Main carriageway 30 km/hr: On/off ramps (frontage roads)	60 km/hr: Flyover bridge 40 km/hr: Road at-grade
6	Nos. of Lane	Four lanes: Main Carriageway One lane: On-ramp	Four lanes: Main Carriageway Two lanes: On/off ramps (frontage)	Two lanes: Flyover bridge 2 x two lanes: At-grade roads
7	Overall Road Width	19.0 - 20.7 m: Approach road 20.7 m: PCa PC box girder bridge 22.9 m: Stay-cable bridge 6.25 m: On-ramp	20.7 m: Steel box girder 20.7 m: PC box girder bridge 53.2 m: Toll Gate	12.75 m: Flyover & approach road 11.5 m: At grade roads
8	Cross Section Elements	0.6+1.5+2@3.5+0.5+3.7+0.5+2@3.5+1.5+0.6: Cable-stayed bridge - Carriageway : 4@3.5 m = 14.0 m - Shoulder : 2@1.5 m = 3.0 m - Median : 4.7 m - Barrier : 2@0.6 m = 1.2 m	0.6+1.5+2@3.5+0.5+1.5+0.5+2@3.5+1.5+0.6: Steel box girder - 4@3.5 m = 14.0 m - 2@1.5 m = 3.0 m 2.5 m - 2@0.6 m = 1.2 m	0.5+1.5+3.5+1.75+3.5+1.5+0.5 : Flyover - 2@3.5 m = 7.0 m - 2@1.5 m = 3.0 m 1.75 m - 2@0.5m = 1.0 m
9	Intersections, Ramps and Toll Gate	One (1) interchange and one (1) ramp <u>Intersection: STA 0+030</u> - Signal with 4 directions <u>On-ramp: STA 0+607</u> - 3.25 m wide 1 lane with shoulders (0.75&1.25) - 115.2m (4@28.8 m) long bridge PC-T Girder (Composite Slab Deck)	Toll gate and on/off ramps (frontage roads) <u>Toll Gate: STA 2+500</u> - 10 lanes with 9 booths, - management office building <u>On/off ramps (frontage roads)</u> - 3.5 m wide two lane with 1.5 m width	Two interchanges <u>Shukhinthar Intersection</u> - Signal with five directions <u>Yadanar Intersection</u> - Signal with four directions
	Diversion or Widening		<u>Diversion to Thanlyin Bridge</u> - 3.5m wide two lanes for on and off	<u>Widening of Thanlyin Chin Kat Road</u> - 2.0+1.5+2@3.5+0.5+0.5
10	Bridges	Total Length: 955 m <u>Nos. of Spans</u> - 11 spans (Abutment (A) 1 to P13) <u>Superstructure</u> - PC Box Girder: 5@50=250m - Steel Box Girder: 2@76.5+104=257m - Cable-stayed bridge: 112 +224 +112 =448m <u>Substructure</u> - Reinforced Concrete (RC) Pier <u>Foundation</u> - Land: RC Bored Pile (D=2.0m,1.5 m) - River: Steel Pipe Sheet Pile (D=1.2 m)	Total Length: 1,076 m <u>Nos. of Spans</u> - 13 spans (P13 to A2) <u>Superstructure</u> - Steel Box Girder: 6@122+104=776m - PC Box Girder: 6@50 =300m <u>Substructure</u> - RC Pier <u>Foundation</u> - Land: RC Bored Pile (D=2.0m, 1.5 m) - River: Steel Pipe Sheet Pile (D=1.2 m)	Total Length: 602 m <u>Nos. of Spans</u> - 16 spans (AF1 to AF2) <u>Superstructure</u> - PC-T Girder (Composite Deck Slab): 2@30=60m, 6@30=180m, 2@30=60m - Steel Box Girder: 55+70+55 =180m - Steel Plate Girder: 35+52+35 =122m <u>Substructure</u> - RC Pier <u>Foundation</u> - RC Bored Pile (D=1.5 m)
11	Pavement Structure	<u>Bridge Deck</u> <u>PC Box Girder, PC-T Girder (Composite Slab Deck)</u> - Coarse 40 mm + Dense 50 mm <u>Steel Girder, Steel Cable-stayed Bridge</u> - Stone Mastic Asphalt 40 mm+40 mm	<u>Approach Road</u> - Subbase 250 mm + Base 200 mm - Binder 50 mm + Surface 50 mm <u>Toll Gate</u> - Subbase 250 mm + Base 100 mm - Concrete Pavement 250 mm	
12	Auxiliary Works	Drainage system, road lighting system, illumination system, obstruction lights, bridge bearings, expansion joints, navigation signs, road signs, road markings, inspection access, monitoring system, supports for water pipes and telecom fibers, signals, etc.		

** Japanese Government Order on Road Design Standards*
Source: JICA Study Team

1.3 STUDY AREA

The study area is located in-between and surrounding Thanlyin Chin Kat Road in Taketa Township and the north end of Kyaik Khuk Pagoda Road in Thanlyin Township, Yangon, the Republic of the Union of Myanmar.



Source: JICA Study Team

Figure 1.3.1 Study Area

1.4 SCOPE OF THE DESIGN STUDY

1.4.1 Stage 1: Preparatory Works

(1) Review of Existing Information and Data

The JICA Study Team reviewed relevant surveys and studies and collected necessary information to develop the basic design and detailed design for the Project.

(2) Preparation of Plan for the Study

The JICA Study Team prepared the plan for the Study with confirmation of the objectives, scope, basic concept, methodologies, and schedule. Especially, the detailed methodologies and implementation plan for the Study were established.

(3) Preparation of Inception Report (IC/R)

Based on the study mentioned above, the JICA Study Team prepared an inception report (IC/R) including basic policy, study plan, schedule, and undertakings by MOC. The detailed programs for technical transfer was discussed in the “Inception Report for Technical Transfer”, which was submitted in September 2017.

(4) Explanation of IC/R

The JICA Study Team explained and confirmed contents of the IC/R. Especially, scope and methodologies of study and survey, schedule and implementation structure of the Study, and the entire schedule of the Project were confirmed with MOC and JICA.

(5) Review of Previous Studies Based on Site Reconnaissance

Additionally, for the review of previous studies mentioned in (1), the JICA Study Team reviewed information and data that were newly obtained in Myanmar and updated the plan of the Study as required.

1.4.2 Stage 2: Basic Design Phase

(1) Field Surveys

The JICA Study Team conducted field surveys to obtain the data including natural conditions, utility facility conditions, environmental and social conditions using sub-contractors as shown below.

Table 1.4.1 Field Surveys

Surveys	Schedule	Sub-Contractor	Position in JICA Study Team
Boring Survey	End of September 2016~ Middle of January 2016	Fukken Co., Ltd.	Geotechnical Engineer
Topographic Survey	End of September ~ Middle of December 2016	Saramar Fuji Construction Co., Ltd.	Topographical Engineer
Material Survey	End of September ~ Middle of December 2016	- Fukken Co., Ltd.	Material Engineer
Hydrological Survey	End of September ~ Middle of December 2016	Asia Air Survey Myanmar Co., Ltd.	Hydrological Engineer
Utility Facility Survey	End of September ~ Middle of December 2016	Asia Air Survey Myanmar Co., Ltd.	Utility Engineer
Environmental Survey	Beginning of October 2016 ~ End of March 2017	- Environ Myanmar Co., Ltd.	Environmental Consideration
Social Survey	December 2016 ~ End of May 2017	- E Guard Environmental Services Co., Ltd.	Social Consideration

Source: JICA Study Team

(2) Basic Design

The JICA Study Team carried out basic design for confirmation of the design policy, design criteria, structure types, and the rough sizes so as not to cause any changes of design policy and criteria in the detailed design phase.

(3) Preparation and Explanation of Basic Design Report (BD/R)

The JICA Study Team prepared the basic design report (BD/R) based on the results of site reconnaissance, review on previous studies, field surveys, study on basic design, construction plan, implementation schedule, and updated preliminary project cost including issue in detailed design phase. The JICA Study Team also explained the BD/R to MOC and TAC, and confirm the scope and structures for the detailed design.

1.4.3 Stage 3: Detailed Design Phase

(1) Detailed Design

The JICA Study Team carried out detailed design for the scope and structures that were confirmed in the basic design phase.

(2) Verification of Design

The JICA Study Team has been carrying out verification of design so as not to cause any error on the process and technical details of the design study.

(3) Operation and Maintenance Planning

The JICA Study Team prepared operation and maintenance plan for the Project.

(4) Preparation of Tender Documents

The JICA Study Team prepared tender documents based on the technical specifications and the bill of quantities.

(5) Preparation of HIV/AIDS Prevention Program

The JICA Study Team prepared HIV/AIDS prevention program for construction workers with the Yangon Regional Government.

(6) Preparation and Explanation of Draft Final Report (DF/R)

The JICA Study Team prepared the draft final report (DF/R) including the results on the study of basic and detailed design. The JICA Study Team will also explain and confirm DF/R with MOC and TAC. MOC and TAC shall prepare comments on DF/R and submit to the JICA Study Team within four weeks after submission of DF/R.

(7) Support on Promotion

The JICA Study Team updated the image perspectives based on the results of design and prepares a project movie (approximately 7 min.).

(8) Preparation and Submission of Final Report (F/R)

The JICA Study Team prepared final report (F/R) based on the comments on DF/R that MOC and TAC submitted.

1.4.4 Stage 4: Environmental and Social Considerations

The initial environmental examination (IEE) report was updated and baseline survey was conducted. For social considerations, ARAP was also updated and detailed measurement survey was conducted.

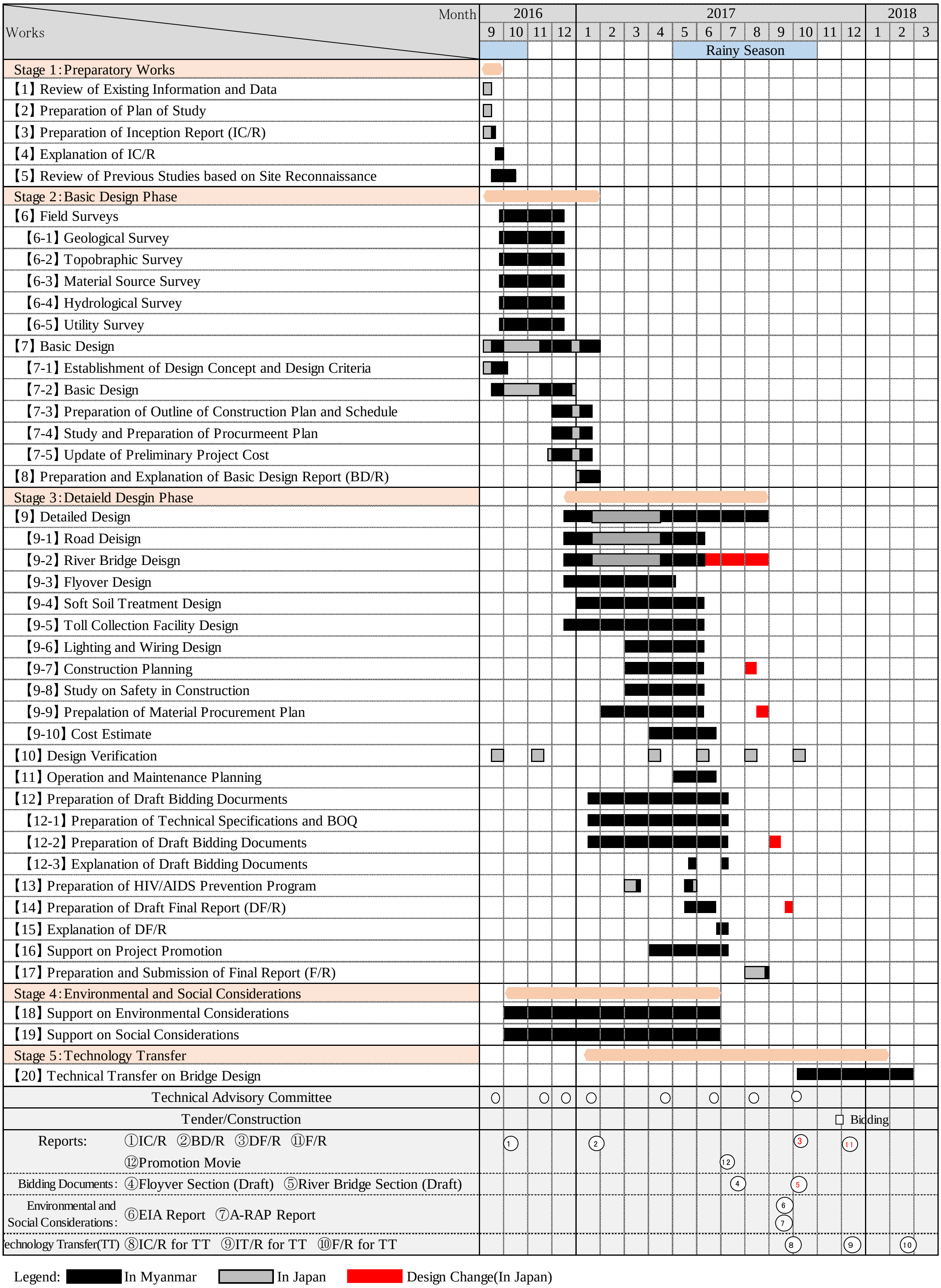
1.4.5 Stage 5: Technical Transfer

The details of the technical transfer program were submitted in September 2017 as the “Inception Report for Technical Transfer”.

1.5 WORK SCHEDULE

The entire work period of this detailed design study is approximately 17 months, including technical transportation program. The preparatory works were carried out from the middle of September 2016, the final report for the detailed design study will be submitted in early December 2017, and the main technical transportation program will be carried out from the middle of October 2017 up to the end of February 2018, as shown in Table 1- 3. The time schedule for design change due to the revision in span arrangement is shown in red in the table.

Table 1.5.1 Work Schedule



Source: JICA Study Team

CHAPTER 2. FIELD SURVEYS ON NATURAL AND EXISTING CONDITIONS

2.1 SOIL INVESTIGATION

2.1.1 Survey Scope and Purpose

(1) Survey Purpose

Soil investigation was conducted in obtaining the geological and geotechnical information required for the detailed design of roads and bridges construction.

The main purposes of this survey are as follows:

1) To clarify the geological conditions, geological strata and their characteristics, of the construction site for detailed design; and

2) To determine geotechnical properties of the strata at the project site.

(2) Survey Scope

Soil survey is divided into six subcomponents:

1) Mobilization and demobilization,

2) Borehole drilling on land and in the river,

3) Standard Penetration Test (SPT),

4) Pressure meter Test,

5) Laboratory test, and

6) Reporting.

The contents of the laboratory test are the following:

- Natural moisture content test,
- Specific gravity test,
- Particle size analysis,
- Atterberg limit test,
- Unconfined compression test, and
- Consolidation test.

All field investigation works and laboratory tests were carried out in accordance with the American Society of Testing and Materials (ASTM), and the International Systems of Units (SI Units) are applied.

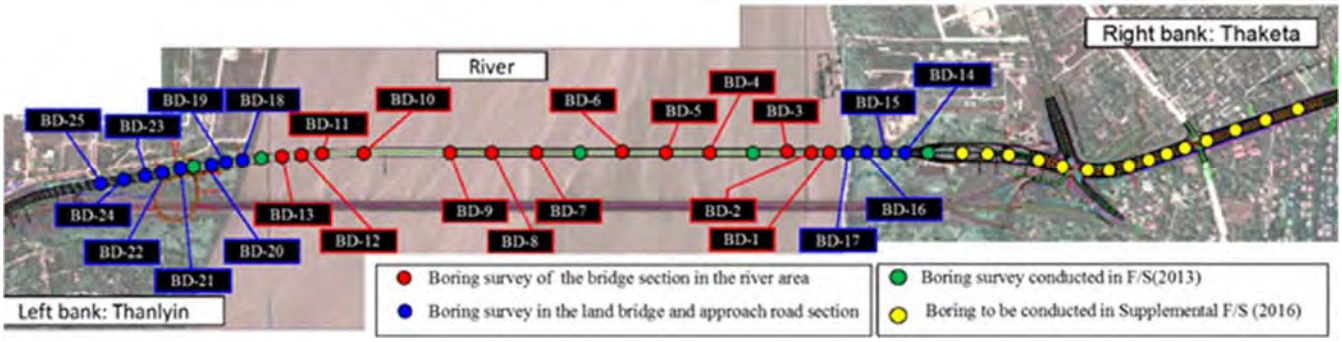
The termination criteria of the depth of each borehole was based on layer that can be confirmed as stable soil condition as a bearing layer (N- value is more than 50, and its thickness is not less than 5 m continuously).

For construction planning of the bridge, approach road section, and viaduct, information on the groundwater level obtained by the boring surveys should be determined.

(3) Project Location (Locations of the Boring Survey)

The soil investigation survey was conducted from the Thanlyin side of the left bank to the Thaketa side of the right bank of the Project. In this survey, the JICA Survey Team used the soil investigation results of not only the feasibility study (F/S) survey in 2013 but also the supplemental F/S survey for the flyover section at Thaketa side which was conducted in September 2016.

The locations of where the survey was conducted are shown in Figure 2.1.1.



Source: JICA Study Team

Figure 2.1.1 Locations of Boring Survey

Table 2.1.1 shows the details of the soil investigation.

Table 2.1.1 Details of Soil Investigation

Survey Contents		Unit	Volume	
			Plan	Actual
(1) Boring Survey		set	1	1
1-1 Bridge section in the river area (1.58 km)	1 location/pier	hole	13	13
		m	780	737
1-2 Approach road section, left bank (0.40 km)	1 location/at intervals of 50-100 m	hole	3	3
		m	180	174
1-2 Land bridge section, left bank (0.25 km)	1 location/pier or abutment	hole	5	5
		m	300	309
1-3 Land bridge section, right bank (0.14 km)	1 location/pier or abutment	hole	4	4
		m	200	203
Total		hole	25	25
		m	1460	1423
(2) Standard Penetration Test	At intervals of 1 m of boring depth	nos.	1460	1365
(3) Pressure Meter Test		nos.	18	18
(4) Undisturbed Sampling		nos.	50	61
(5) Laboratory Test		set	1	1
Physical Property Test	Specific gravity, particle size, natural moisture content	nos.	125	643
	Atterberg limit	nos.	125	315
Strength Test (Unconfined Compression Test)		nos.	50	59
Consolidation Test		nos.	50	47

Source: JICA Study Team

(4) Policy of the Investigation

The soil survey was conducted based on the following policies by design engineers' requirements and considering the total survey quantities.

- Standard Penetration Test shall be carried out every 1 m interval except in undisturbed sampling places.
- In order to grasp the physical properties of the soil, one or more physical property test(s) is/are conducted for each layer. In addition, in order to examine for liquefaction analysis for possible liquefied layer, physical property tests are conducted every 1 m at depth shallower than 20 m.
- Undisturbed sampling shall be carried out for soft soil layer of less than N-value 4 and different clay layers; approximately, it should be about every 5 m interval of different soft soil layers.
- According to the F/S survey results, clayey soils of low N-value layers are distributed at the deeper part of Thanlyin side. Therefore, undisturbed sampling should be carried out for testing as per above procedure.
- Pressure meter tests for soft soil layers should be within 10 m from the top surface layer and test points are located on the left bank, right bank, and in the Bago River. Test points shall be different in soft soil layers of designated boring points. Total test points are six boreholes; two boreholes are on the left bank; one borehole is on right bank and 3 boreholes are in the river for cable-stayed bridge.
- Possible estimated Young's Modulus (E) = 700 N will be used for the project based on the F/S report; however, it should be confirmed with Myanmar standard and/or locally used standards. Moreover, E vs. N-value graph should show not only the estimated E value = 700 N but also pressure meter test E value in the report.
- Bearing layer shall be more than 5 m of N-value≧50 continuously.
- For consideration of major bearing stratum for the cable-stayed bridge location at the Thanlyin side (BD-10), it shall be investigated around 10 m of N-value≧50 continuously.

2.1.2 Stratum Classification

(1) Topography

As for the project area, the proposed Bago River Bridge is located at the flood plain deposit area of Bago River, thus the area is dominated by flat lying topography in general. Hence, the Thaketa site has erosional banks and the Thanlyin site is a depositional site.

In the project area, the Bago River shows the old age stage of meandering. The river process of deposition is dominant than erosional. The cross-sectional profile of the river is U-shaped. Both banks are gently sloping and the mid-river section is fairly steep.

(2) Summary of Geological Condition

Referring to the geological map from the Geology of Burma published by Friedrich Bender in 1983, the project site and surrounding area lay on the southwest end of Inner-Burma Tertiary Basin, especially located in back arc basin. In this basin, the sediments are of Miocene, Oligocene, Eocene, and small amount of Paleocene. The overburden soil layer of the project site is Quaternary Alluvial deposit (Q2). The geological map is shown in Figure 2.1.2 and geological stratigraphy is shown in Table 2.1.2.

By boring results of soil investigation, the project area is made up of alluvial deposit of clay, silty sand and clayey sand. According to the geological map, the regional geological setting of the stratigraphic succession of the project area is as follows:

Description Symbols Age

Alluvium Q2 Quaternary

Irrawaddy Formation Tm-Tp Miocene – Pliocene

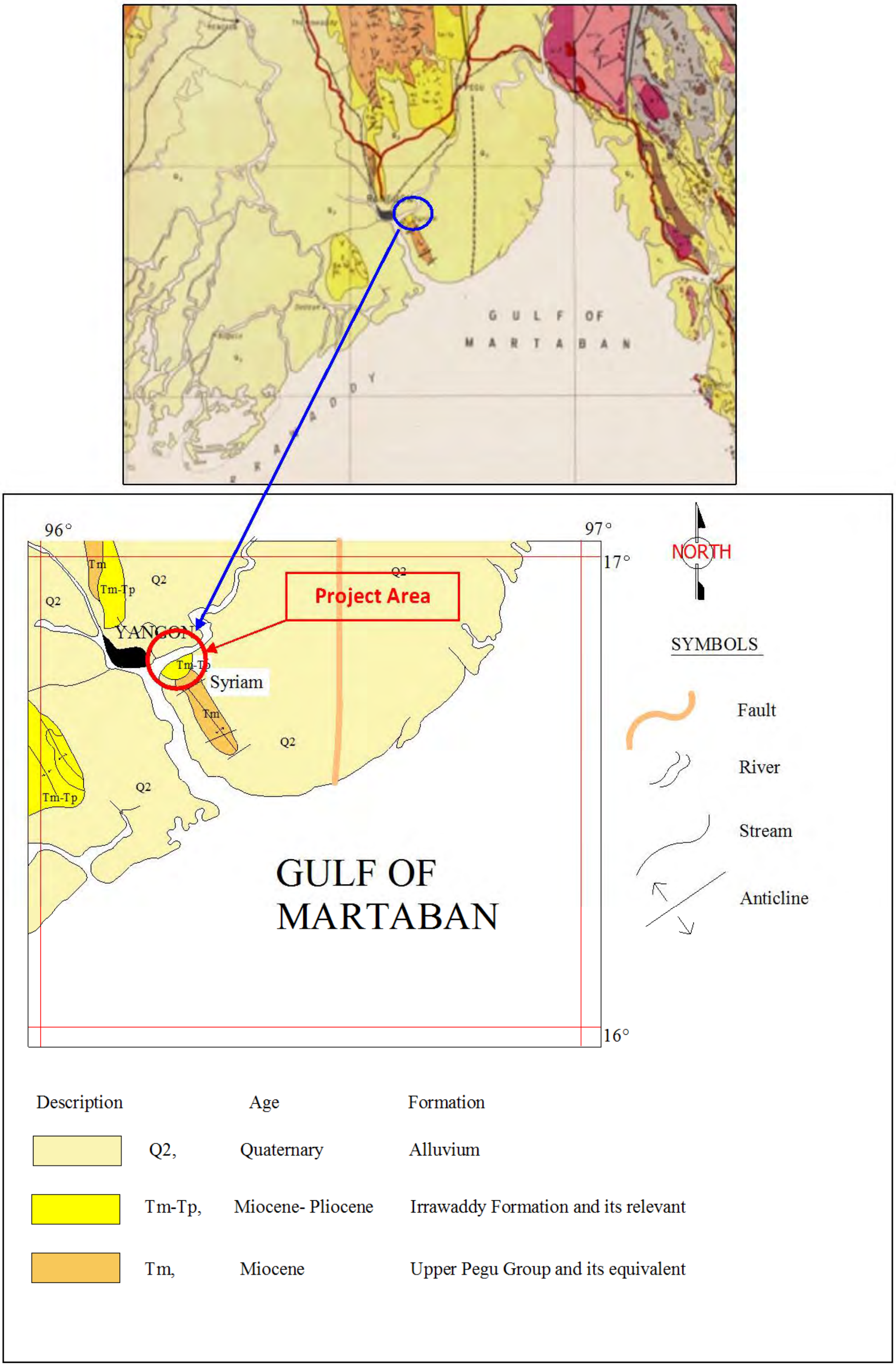
Upper Pegu Group Tm Miocene

Generally, the Yangon area is covered by alluvium. The Irrawaddy Formation comprises the bedrock along the Bago Yoma, the Arzanigone Sandstone in the north of the Shwedagon Pagoda, and Danyingone Clay in the east of the Arzanigone Sandstone. The Pegu Group comprises the Besapet Alternation, Thadugan Sandstone, and Hlawga Shale distributed in the north of the Yangon area.

Table 2.1.2 Geological Stratigraphy of the Survey Area

Age	Symbols	Formation	Description
Quarter-nary	Q2	Alluvium	- This top soil was deposited in recent time as river deposits and it is blanketing over the project area. - This formation has brown to gray in color and the main constituent is clay and silty sand with clay patches. These deposits are built by the effect of flood action. - This formation yields medium to high in water content.
Miocene-Pliocene	Tm-Tp	Irrawaddy Formation and its relevant	- This formation is composed of yellowish fines and of the Irrawaddian Group. - The outcropping areas can be seen in Danyingone, Arzarnigone, Southern Twin Te, and the left bank ofYangon-Thanlyin across the Pegu (Bago) River.
Miocene	Tm	Upper Pegu Group and its equivalent	- This formation is mainly composed of sand and shale interbeds. - The outcropping areas are found along the anticlinal ridges of the Danyingone and Thanlyin areas. Most of them are composed of reddish brown oxidized lateritic soil.

Source: JICA Study Team



Source: Geology of Burma, 1983, Dr. Friendrich Bender, JICA Study Team

Figure 2.1.2 Geological Map of Project Area

(3) Stratum Classification

The soil survey commenced on October 8, 2016 and was completed on January 20, 2017.

1) Design section and survey distinction

The design section of this project is about 3.7 km, starting from the Thanlyin side passing through the Bago River and ending with the Flyover section at the Thaketa side. Topographically, it is divided into the left bank corresponding to Thanlyin side and the right bank of Thaketa side with Bago River as the border.

For the Thaketa side, the soil survey for the Flyover section has been completed. For this reason, the right bank of Bago River was divided into Approach Bridge section (right bank section: Thaketa side) and Flyover section.

The relation between the design section and the geological survey section will be summarized as follows with reference to the boring survey position.

① Left bank, Thanlyin side (from BD-25 to BH-2 of 2013 report)

② River section, (from BH-2 of 2013 report to BD-17)

③ Right bank, Thaketa side (from BD-17 to BH-5 of 2013 report)

④ Flyover section, Thaketa side (from BH-5 of 2013 report to BH-1 of 9.2016 report of supplemental F/S report)

There are twenty-five boreholes in total that were carried out in this investigation work and five boreholes in the F/S stage survey and fourteen boreholes in the supplemental F/S stage survey.

Boring points and coordinates are shown in Table 2.1.3.

Table 2.1.3 Boring Points and Coordinates

Borehole No.	Coordinates E	Coordinates N	Drilling Depth (m)	Ground Height (m)	Remarks
BD-1	204,573.197	1,859,026.672	49	-4.40	in water
BD-2	204,600.791	1,858,985.918	49	-5.45	
BD-3	204,623.803	1,858,937.665	46	-6.22	
BD-4	204,732.060	1,852,751.630	51	-6.87	
BD-5	204,790.571	1,858,656.661	53	-6.90	
BD-6	204,845.093	1,858,556.617	59	-4.41	
BD-7	204,958.214	1,858,360.117	51	-6.35	
BD-8	205,013.754	1,858,268.627	61	-6.56	
BD-9	205,073.242	1,858,170.312	62	-6.97	
BD-10	205,181.555	1,857,979.926	72	-5.47	
BD-11	205,237.522	1,857,879.348	65	-3.35	
BD-12	205,261.919	1,857,832.226	63	-4.41	
BD-13	205,289.363	1,857,790.671	56	-4.42	
BD-14	204,473.747	1,859,195.701	48	4.13	on land
BD-15	204,501.604	1,859,154.812	51	4.24	
BD-16	204,526.627	1,859,111.524	57	4.35	
BD-17	204,551.650	1,859,068.236	47	0.35	
BD-18	205,350.820	1,857,705.598	59	0.60	
BD-19	205,381.139	1,857,664.590	60	3.52	
BD-20	205,411.868	1,857,625.150	62	3.41	
BD-21	205,475.433	1,857,547.954	66	3.34	
BD-22	205,507.335	1,857,509.453	62	3.38	
BD-23	205,541.753	1,857,475.540	59	3.98	
BD-24	205,570.999	1,857,432.621	57	3.85	
BD-25	205,605.365	1,857,393.002	58	4.15	

Pre-existing Borehole No.		Coordinates E	Coordinates N	Drilling Depth (m)	Ground Height (m) F/S・Sup. F/S	Ground Height (m) D/D[1)]	Remarks
F/S	13BH-01	205,414.384	1,857,587.742	62	4.51	4.23	on land
	13BH-02	205,312.000	1,857,753.000	54	-4.35	-4.63	in water
	13BH-03	204,870.318	1,858,476.432	58	-4.48	-4.76	
	13BH-04	204,651.368	1,858,845.879	45	-5.90	-6.18	
	13BH-05	204,429.640	1,859,229.371	50	4.96	4.68	on land
Sup. F/S	16BH-01	203,871.632	1,860,013.429	50	5.02	4.74	Flyover (on land)
	16BH-02	203,939.419	1,859,955.273	50	5.05	4.77	
	16BH-03	203,988.555	1,859,910.930	50	5.21	4.93	
	16BH-04	204,044.248	1,859,862.131	50	5.26	4.98	
	16BH-05	204,091.678	1,859,823.064	51	5.00	4.72	
	16BH-06	204,138.122	1,859,780.059	50	5.18	4.90	
	16BH-07	204,182.001	1,859,742.035	50	5.27	4.99	
	16BH-08	204,231.206	1,859,695.127	50	5.76	5.48	
	16BH-09	204,264.719	1,859,651.489	50	5.66	5.38	
	16BH-10	204,261.084	1,859,612.551	50	4.97	4.69	
	16BH-11	204,288.053	1,859,558.128	50	5.20	4.92	
	16BH-12	204,312.961	1,859,485.491	50	4.37	4.09	
	16BH-13	204,341.023	1,859,405.546	42	4.01	3.73	
	16BH-14	204,384.785	1,859,326.929	43	4.52	4.24	

1) Reduced elevation by 28 cm from F/S and Supplemental(Sup.) F/S

Source: JICA Study Team

The ground height of boreholes is based on the Bench Mark(BM) - 89004 (6.49955 m above MSL) in the Thaketa side of Yangon City, which is the standard for the elevation of soil survey at F/S. The reference point at the time of the Supplemental F/S also has used the reference point at F/S.

Because the reference point at this survey (D/D) is that the BM in the Thaketa side of Yangon City is not issued a certificate by the Myanmar Survey Department (MSD), the BM - 76097 (23.89504 m above MSL) in the Thanlyin district was used. It is pointed out that BM of the Thaketa area could be 28.0 cm lower in comparison to the BM in both areas.

In Table 2.1.3, the ground height at the time of detailed design (D/D) is also shown. In the preparation of the geological profile of this time, the ground height of the existing boreholes was used to match existing data. Therefore, at the time of detailed design, it is necessary to consider values obtained by subtracting 28.0 cm for all boreholes results performed in the F/S and supplemental F/S.

2) Soil Composition of Each Survey Section

Based on the survey results, in the design section of this area, 20 different soil layers including the flyover section were recognized. For each section, as shown in Table 2.1.4, 11 soil layers in the Thanlyin section, 14 soil layers in the river section, 7 soil layers in the Thaketa section, and 10 soil layers in the fyover section have been confirmed.

Table 2.1.4 Distribution of Soil Layers in Survey Area

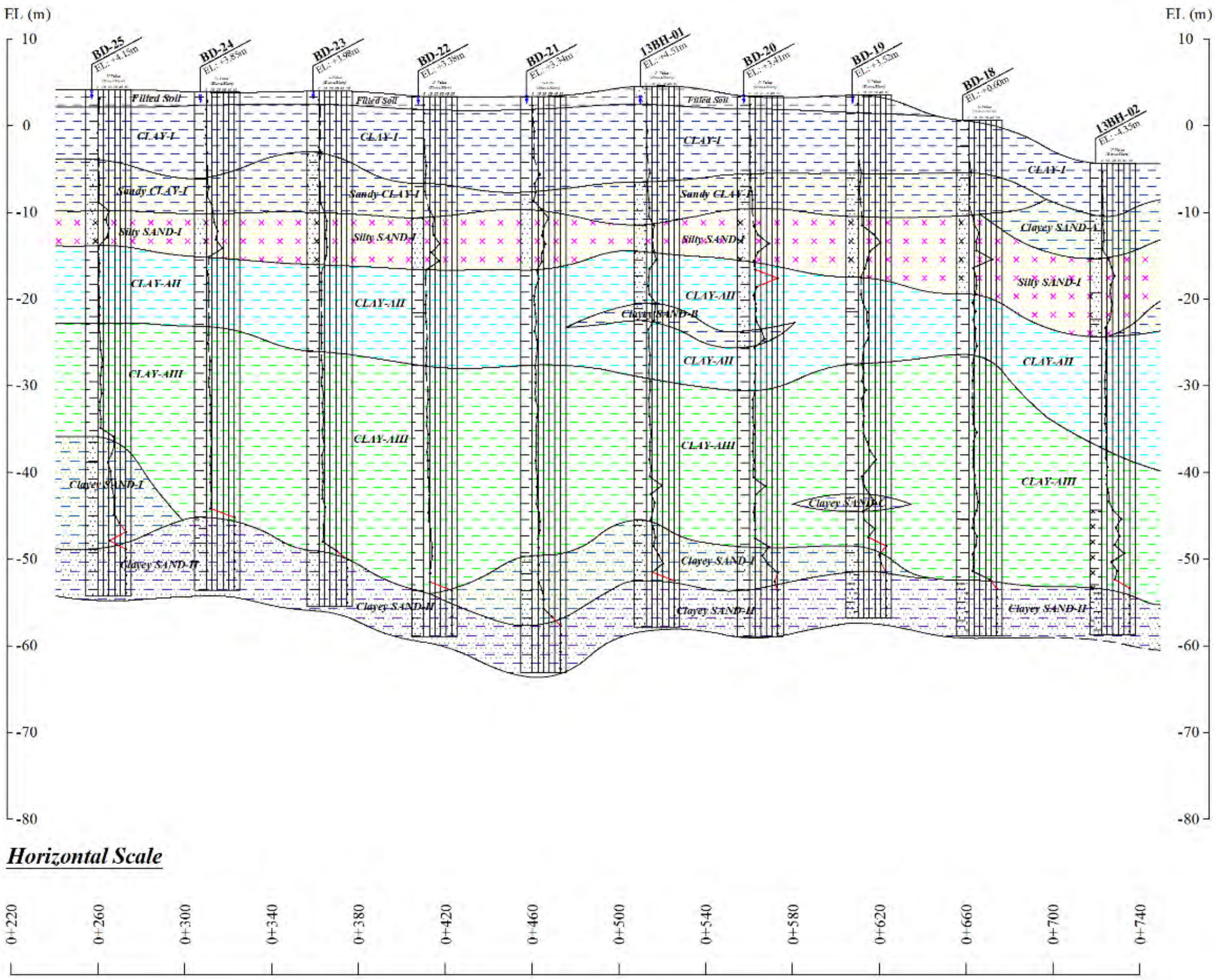
Formation	Section (Soil name for each section)				
	Thanlyin	River	Thaketa	Flyover(Thaketa)	All sections
	BD-25～(13)BH-2	(13)BH-2～BD-17	BD-17～(13)BH-5	(13)BH-5～(16) BH-1	BD-25～(16) BH-1
Alluvium		Silty SAND-River Sediments			1.Silty SAND-River Sediments
	Filled Soil		Filled Soil	Filled Soil	2. Filled Soil
	CLAY-I	CLAY-I	CLAY-I	CLAY-I	3. CLAY-I
	Sandy CLAY-I				4.Sandy CLAY-I
	Clayey SAND-A	Clayey SAND-A			5.Clayey SAND-A
	Silty SAND-I	Silty SAND-I	Silty SAND-I	Silty SAND-I	6. Silty SAND-I
			Sandy SILT	Sandy SILT	7. Sandy SILT
		Sandy CLAY-II			8.Sandy CLAY-II
	CLAY-AII	CLAY-AII			9.CLAY-AII
	Clayey SAND-B	Clayey SAND-B			10.Clayey SAND-B
		Silty SAND-A			11.Silty SAND-A
	CLAY-AIII	CLAY-AIII			12.CLAY-AIII
	Clayey SAND-C	Clayey SAND-C			13.Clayey SAND-C
		Silty SAND-II	Silty SAND-II	Silty SAND-II	14. Silty SAND-II
				CLAY-II	15. CLAY-II
Irrawaddy Formation	Clayey SAND-I	Clayey SAND-I	Clayey SAND-I	Clayey SAND-I	16. Clayey SAND-I
		CLAY-AIV			17. CLAY-AIV
				CLAY-III	18. CLAY-III
	Clayey SAND-II	Clayey SAND-II	Clayey SAND-II	Clayey SAND-II	19. Clayey SAND-II
				CLAY-IV	20. CLAY-IV
Number of soil layers	11	14	7	10	20

Source: JICA Study Team

In the survey area, river sediments are distributed along the Bago River. The soil constitution is greatly changed in the alluvium distributed under this river sediment.

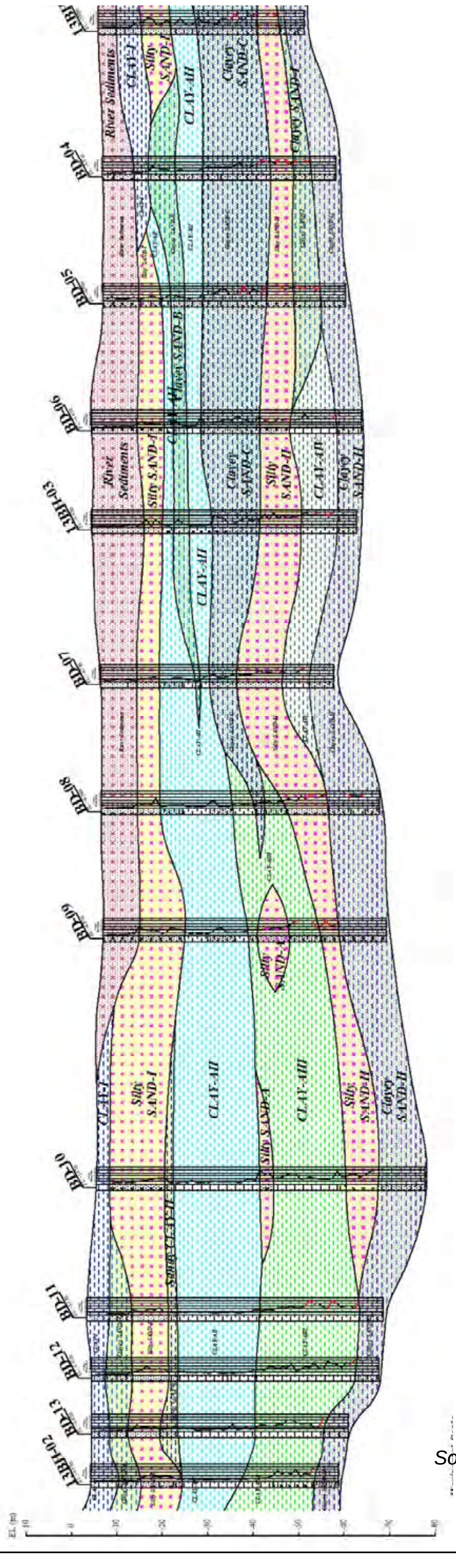
Cohesive soil dominates from the left bank of the Thanlyin side to the right bank side of the Bago River, and is characterized by sandy soil prominent from the right bank side of the river section to the right bank of the Thaketa side. The sedimentary relationship of cohesive soil and sandy soil of alluvium is considered to be largely interfinger relationship at this stage.

The soil profiles of each section of the project area are shown in Figure 2.1.3 to Figure 2.1.6.



Source: JICA Study Team

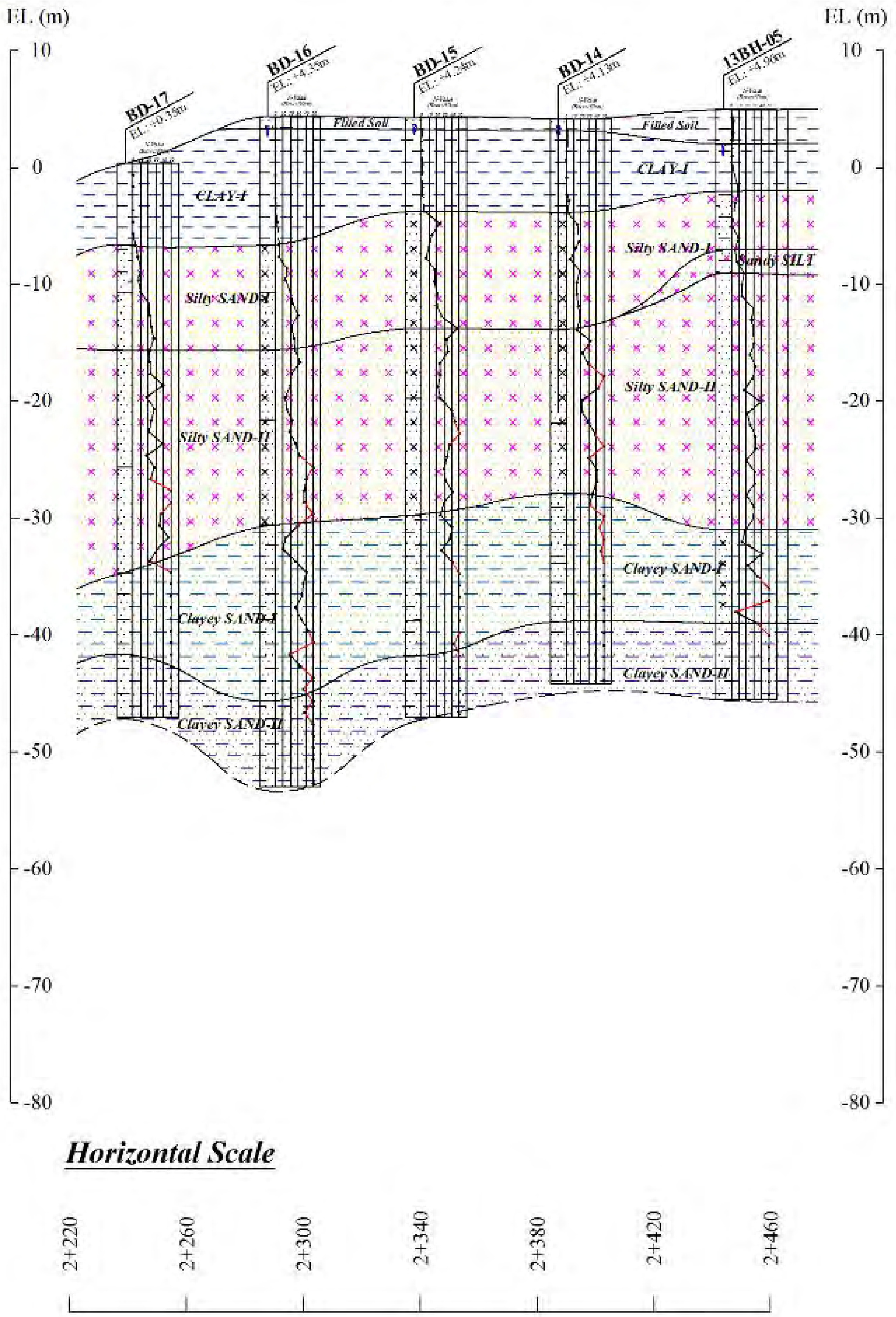
Figure 2.1.3 Soil Profile for the Left Bank (Thanlyin Side)



Source: JICA Study Team

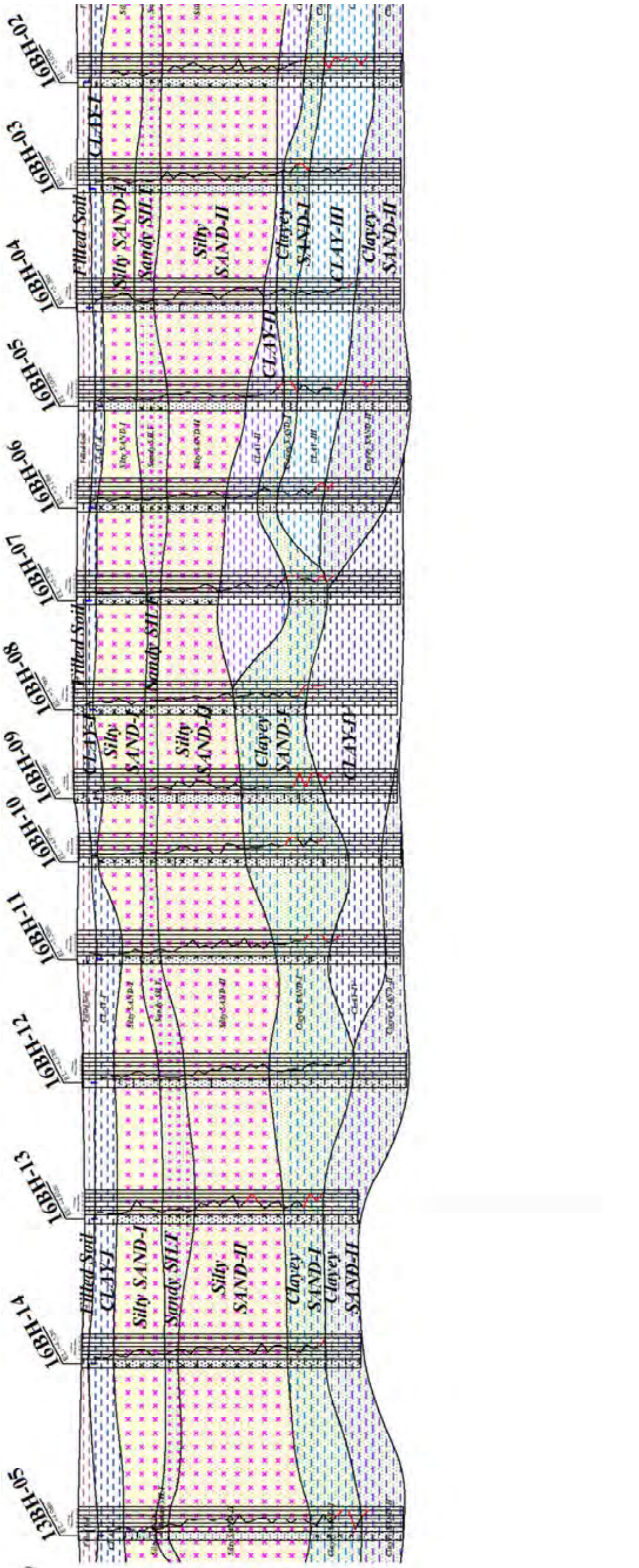
Figure 2.1.4 Soil Profile for the River

Section



Source: JICA Study Team

Figure 2.1.5 Soil Profile for the Right Bank (Thaketa Side)


16BH-02
16BH-03
16BH-04
16BH-05
16BH-06
16BH-07
16BH-08
16BH-09
16BH-10
16BH-11
16BH-12
16BH-13
16BH-14
13BH-05
Filled Soil
CLAY-I
Silty SAND-I
Sandy SILT
Silty SAND-II
Clayey SAND-I
CLAY-II
CLAY-III
Clayey SAND-II
EL (m)
10
0
-10
-20
-30
-40
-50
-60
-70
-80

Source: JICA Study Team

Figure 2.1.6 Soil Profile for the Flyover Section

The stratum structure of each section will be explained below.

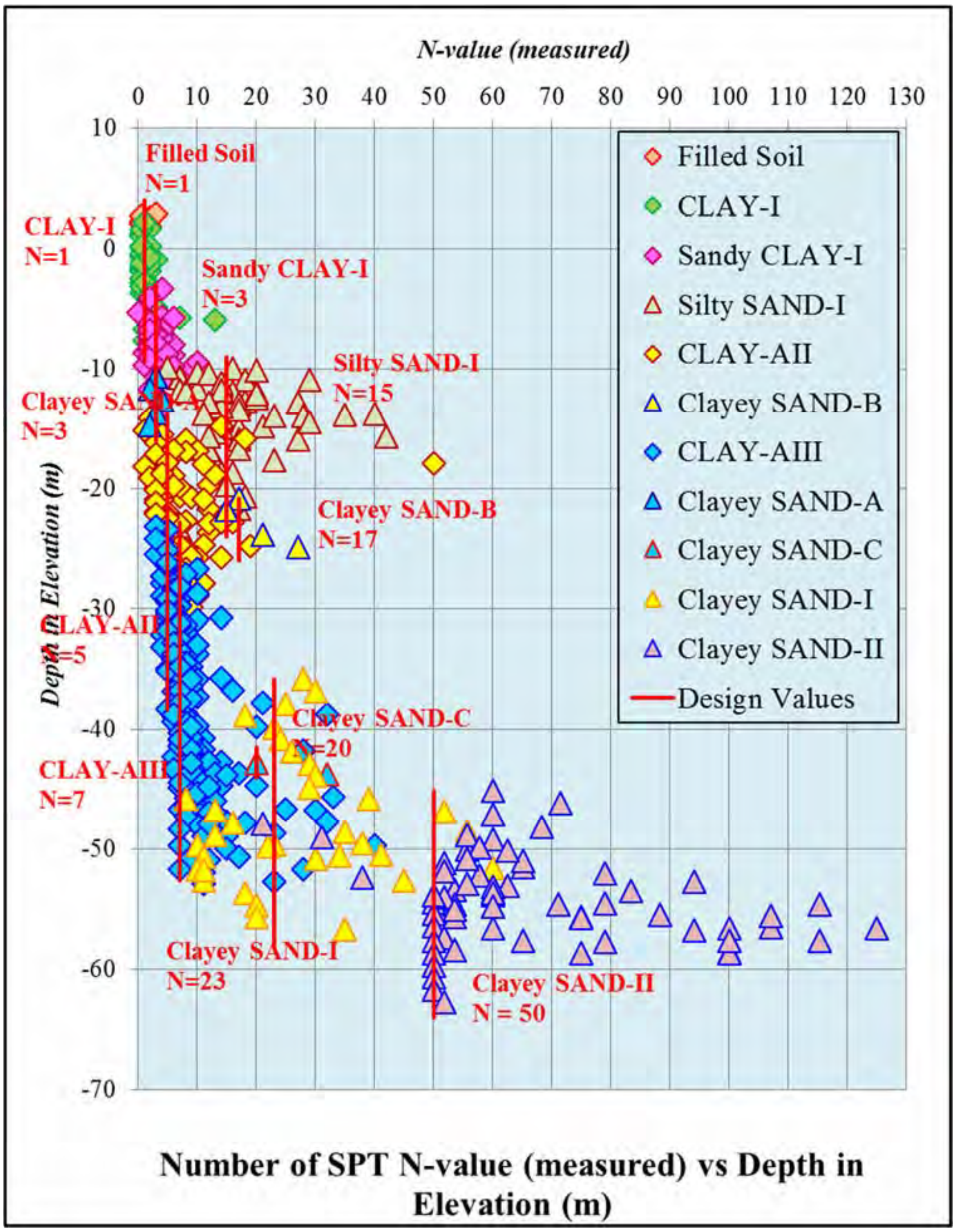
① Left bank, Thanlyin side (from BD-25 to BH-2 of 2013 report)-5)

Eleven different soil layers are confirmed in this area. Table 2.1.5 shows the soil stratigraphy.

Table 2.1.5 Soil Stratigraphy of the Survey Area (Thanlyin Side)

Formation	Soil Type	N-Value (Representative -Value)	Description
Alluvium	1. Filled Soil	0~3 (1)	The thickness is about 1.0 m to 2.0 m. The color is brown. The plasticity is low to medium and the water content is moist. The consistency is very soft to soft.
	2. CLAY-I	0~4 (1)	The thickness is about 3.0 m to 11.0 m. The color is gray. The water content is moist to wet and the plasticity is low to high. The consistency is very soft to soft.
	3. Sandy CLAY-I	2~10 (3)	The thickness is about 2.0 m and 7.0 m. The color is gray and the water content is moist. The plasticity is low to medium. The consistency is soft to stiff.
	4. Clayey SAND-A	2~15 (3)	The thickness is about 4.0 m to 6.0 m. The color is brownish gray and the water content is moist to wet. The plasticity of clay is low. The grain size of sand is fine to medium.
	5. Silty SAND-I	5~29 (15)	The thickness is about 3.0 m to 9.0 m. The color is gray and the water content is moist. The grained size is fine to medium. The relative density is loose to medium dense.
	6. CLAY-AII	2~19 (5)	The thickness is about 7.0 m to 13.0 m. The color is gray and the water content is moist. The plasticity is low to medium. The consistency is soft to very stiff.
	7. Clayey SAND-B	15~27 (17)	The thickness is about 2.0 m. The color is gray and the water content is moist. The plasticity of clay is low and the grain size of sand is fine. The relative density is medium dense.
	8. CLAY-AIII	3~33 (7)	The thickness is about 14.0 m to 26.0 m. The color is gray and the water content is moist to wet. The plasticity is low to medium. The consistency is soft to hard.
	9. Clayey SAND-C	20~32 (20)	The thickness is about 2.0 m. The color is gray and the water content is moist. The plasticity of clay is low to medium. The grain size of sand is fine to medium.
Irrawaddy Formation	10. Clayey SAND-I	10~≧50 (23)	The thickness is about 3.0 m to 12.0 m. The color is greenish gray to yellowish brown and the water content is moist. The grain size of sand is fine to medium.
	11. Clayey SAND-II	≧50 (50)	The thickness of this layer is more than 9.0 m. The color is yellowish brown and the water content is moist. The grain size of sand is fine to medium.

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.7 Distribution of SPT N-values for Thanlyin Side

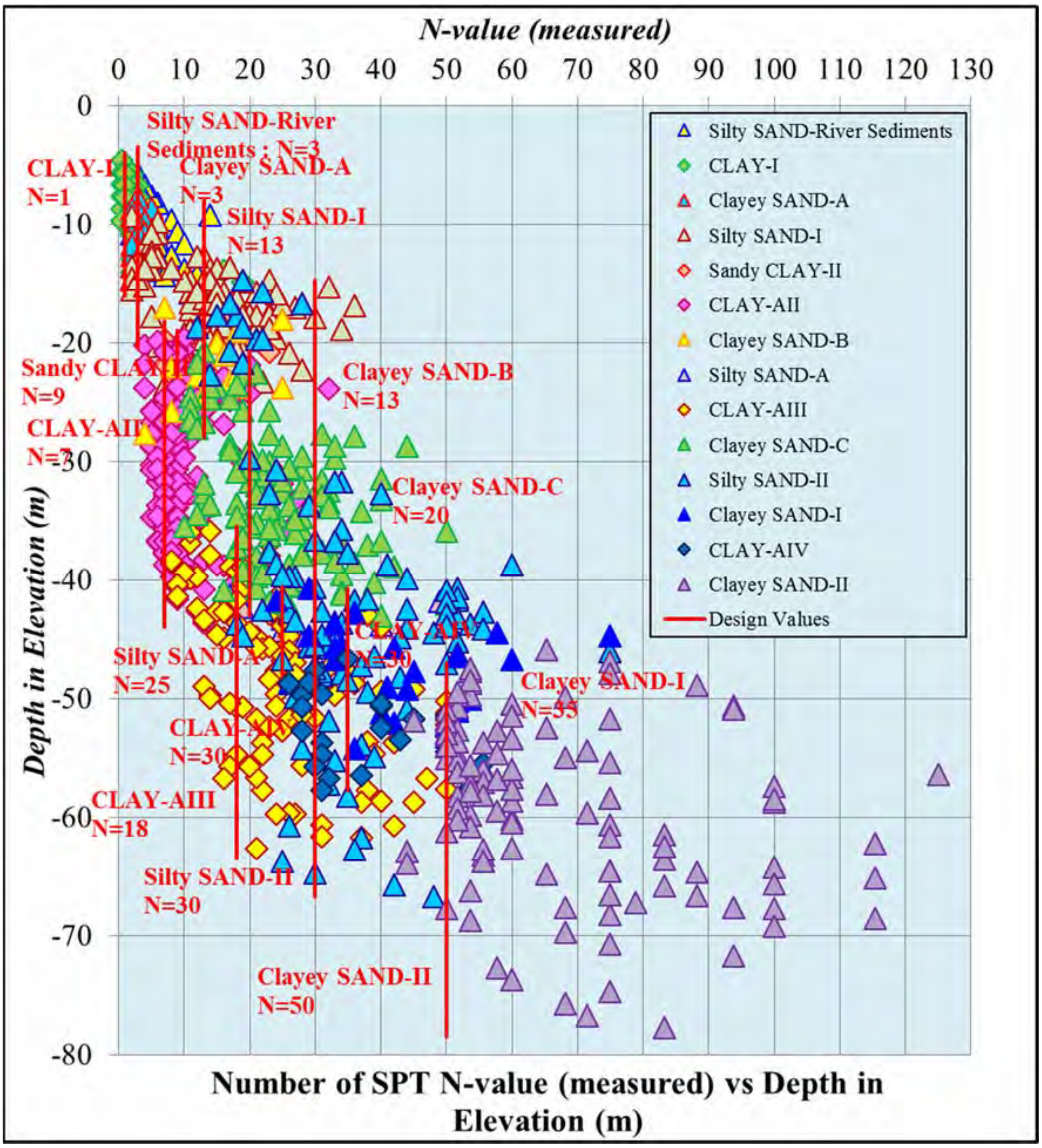
② River section, (from BH-2 of 2013 report to BD-17)

Fourteen different soil layers are confirmed in this area. Table 2.1.6 shows the soil stratigraphy.

Table 2.1.6 Soil Stratigraphy of the Survey Area (River Section)

Formation	Soil Type	N-Value (Representative -Value)	Description
Alluvium	1. Silty SAND-River Sediments	2~10 (3)	The thickness is about 2.0 m to 11.0 m. The color is brownish gray and the water content is moist to wet. The grain size of sand is fine to medium grained.
	2. CLAY-I	0~4 (1)	The thickness is about 1.0 m to 5.5 m. The color is gray and the water content is wet to moist. The plasticity is low to medium. The consistency is very soft to soft.
	3. Clayey SAND-A	2~5 (3)	The thickness is about 4.0 m to 6.0 m. The color is brownish gray and the water content is moist to wet. The grained size is fine to medium. The relative density is very loose to loose.
	4. Silty SAND-I	3~38 (3)	The thickness is about 4.0 m to 12.0 m. The color is gray and the water content is moist. The grain size of sand is fine to medium. The relative density is very loose to medium.
	5. Sandy CLAY-II	7~14 (9)	The thickness is about 2.0 m to 4.0 m. The color is gray and the water content is moist. The plasticity of clay is low to medium. The consistency is firm to stiff.
	6. CLAY-AII	4~19 (7)	The thickness is about 2.0 m to 19.0 m. The color is gray and the water content is moist. The plasticity of clay is low to medium. The consistency is soft to very stiff.
	7. Clayey SAND-B	7~19 (13)	The thickness is about 1.0 m to 6.0 m. The color is gray and the water content is moist. The grain size is fine to medium. The relative density is loose to medium dense.
	8. Silty SAND-A	17~36 (25)	The thickness is about 3.0 m to 7.0 m. The color is gray and the water content is moist. The grain size is fine to medium grained. The relative density is medium dense to dense.
	9. CLAY-AIII	11~35 (18)	The thickness is about 5.0 m to 23.0 m. The color is gray and the water content is moist. The plasticity is medium to high. The consistency is stiff to hard.
	10. Clayey SAND-C	10~40 (20)	The thickness is 2.0 m to 19.0 m. The color is gray and the water content is moist. The grain size is fine to medium. The relative density is medium dense to dense.
	11. Silty SAND-II	17~43 (30)	The thickness is about 3.0 m to 16.0 m. The color is gray and the water content is moist. The grain size is fine to medium. The relative density is medium dense to dense.
Irrawaddy Formation	12. Clayey SAND-I	24~50 (35)	The thickness is about 1.0 m to 8.0 m. The color is gray and reddish brown to yellowish brown in some depth. The water content is moist. The grain size is fine to medium.
	13. CLAY-AIV	26~≧50 (30)	The thickness is about 6.0 m to 10.5 m. The color is gray and the water content is moist. The plasticity is low to medium. The consistency is very stiff to hard. Fine grain sand is included.
	14. Clayey SAND-II	44~≧50 (50)	The thickness is more than 12.0 m. The color is yellowish brown. The grained size is fine to medium. The relative density is dense to very dense.

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.8 Distribution of SPT N-values for River Section

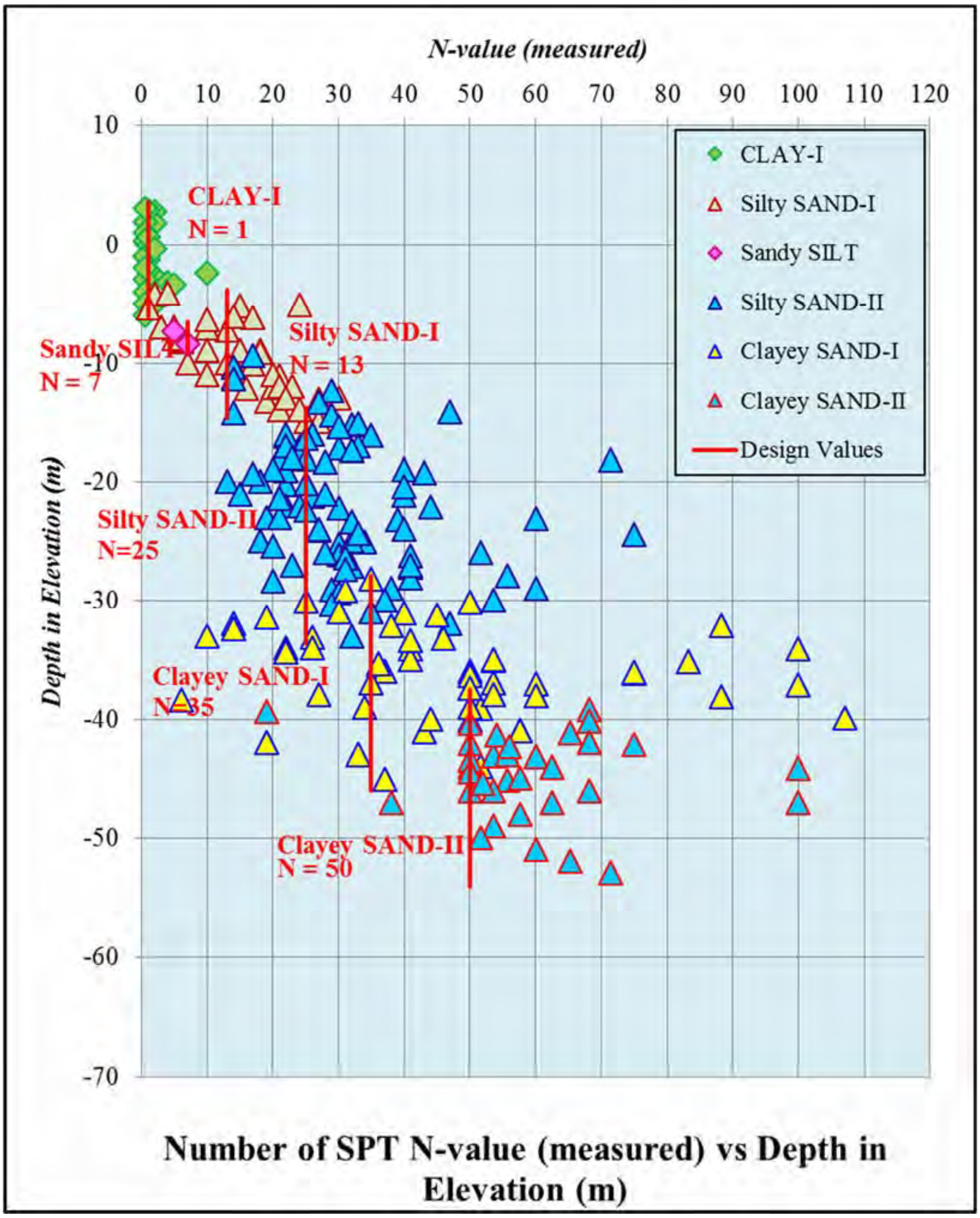
③ Right bank, Thaketa side (from BD-17 to BH-5 of 2013 report)

Seven different soil layers are confirmed in this area. Table 2.1.7 shows the soil stratigraphy.

Table 2.1.7 Soil Stratigraphy of the Survey Area (Thaketa Side)

Formation	Soil Type	N-Value (Representative -Value)	Description
Alluvium	1. Filled Soil	3 (3)	The thickness is about 3.0 m. The color is brown, and the water content is low to moist. The plasticity is low to medium. The consistency is soft.
	2. CLAY-I	0~5 (1)	The thickness is about 6.0 m to 10.0 m. The color is gray. The water content is moist to wet and the plasticity of low to high. The consistency is very soft to firm.
	3. Silty SAND-I	4~30 (13)	The thickness is about 3.0 m to 9.0 m. The color is gray and the water content is moist to wet. The grain size is fine. The relative density is loose to medium dense.
	4. Sandy SILT	5~7 (7)	The thickness is about 3.0 m. The water content is moist to wet, the plasticity is low to medium plasticity. The consistency is firm.
	5. Silty SAND-II	13~47 (25)	The thickness is about 14.0 m to 19.0 m. The color is gray and the water content is moist. The grain size is fine to medium grained. The relative density is medium dense to dense.
Irrawaddy Formation	6. Clayey SAND-I	14~50 (35)	The thickness is about 7.0 m to 15.0 m. The color is gray and the water content is moist. The grain size is fine to medium grained. The relative density is medium dense to dense.
	7. Clayey SAND-II	≧50 (50)	The thickness is more than 8.0 m. The color is yellowish brown to reddish brown and the water content is moist. The relative density is dense to very dense.

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.9 Distribution of SPT N-values for Thaketa Side

④ Flyover section, Thaketa side (from BH-5 of 2013 report to BH-1 of 9.2016 report of supplemental F/S report)

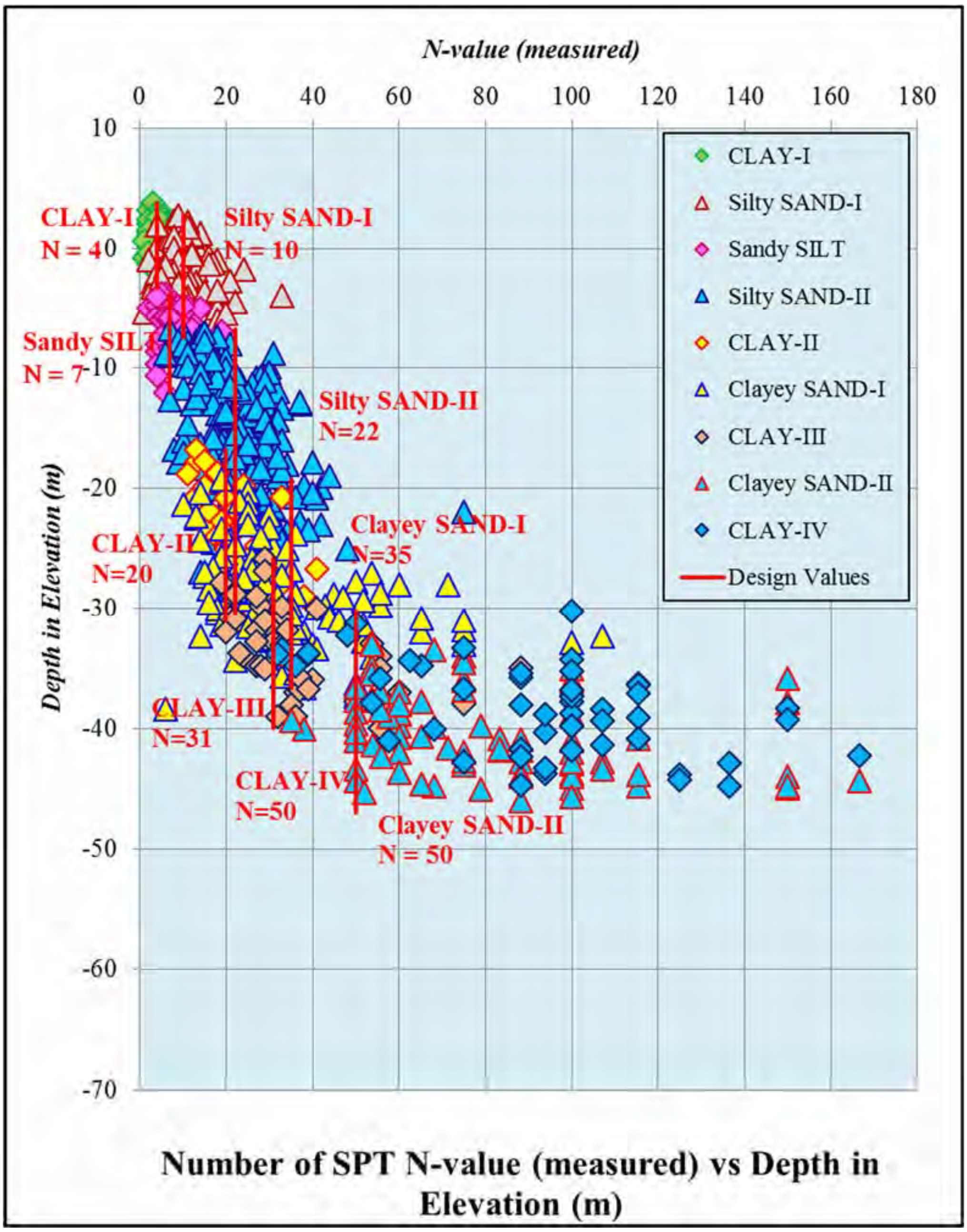
Soil survey was being conducted in this section at supplemental F/S in September 2016. The 14 boreholes were being carried out.

In this area, a total of ten different layers have been recognized. The soil layers are classified in accordance with their physical properties and/or their relative density. The soil stratigraphy is shown in Table 2.1.8.

Table 2.1.8 Soil Stratigraphy of the Survey Area (Flyover)

Formation	Soil Type	N-Value (Representative Value)	Description
Alluvium	1. Filled Soil	3~7 (4)	This filled soil layer is almost observed as CLAY, and Sandy CLAY and Silty SAND in some borehole. The thickness is about 1.0 m to 2.0 m.
	2. CLAY-I	2~8 (4)	The thickness is about 1.0 m to 6.0 m. The color is gray. The plasticity is low to medium and the water content is moist. The consistency is soft to firm.
	3. Silty SAND-I	2~33 (10)	The thickness is about 3.0 m to 8.0 m. The color is gray. The grained size is fine grained, and the water content is moist and wet in some depth. The relative density is very loose to dense.
	4. Sandy SILT	2~19 (7)	The thickness is about 2.0 m to 5.0 m. The color is gray and the water content is moist. The plasticity of silt is low plasticity. The consistency is soft to very stiff.
	5. Silty SAND-II	6~48 (22)	The thickness is about 9.0 m to 21.0 m. The color is gray and the water content is moist. The grain size of sand is fine to medium grained. The relative density is loose to dense.
	6. CLAY-II	11~41 (20)	The thickness is about 1.0 m to 11.0 m. The color is gray and the water content is moist. Moreover, fine grained sand is included in this layer. The consistency is stiff to hard.
Irrawaddy Formation	7. Clayey SAND-I	10~≧50 (35)	The thickness is about 2.0 m to 16.0 m. The color is yellowish brown and gray color in some depth, and the water content is moist. The relative density is loose to very dense.
	8. CLAY-III	19~≧50 (31)	The thickness is about 7.0 m to 9.0 m. The color is gray and the water content is moist. The plasticity of this layer is low to medium plasticity. The consistency is very stiff to hard.
	9. Clayey SAND -II	34～≧50 (50)	The thickness is more than 10.0 m. The color is gray and the water content is moist. The grain size of sand is fine to medium grained. The relative density is dense to very dense.
	10. CLAY-IV	32～≧50 (50)	The thickness of this layer is more than 14.0 m. The plasticity of this layer is low to medium plasticity. Moreover, fine grained sand is included. The consistency is hard.

Source: JICA Study Team



Source: JICA Study Team

Figure 2.1.10 Distribution of SPT N-values for Flyover Section

2.1.3 Soil Characteristics

(1) Policy of Geotechnical Design Parameter

Geotechnical parameters can be directly evaluated in many ways such as in situ and laboratory tests. Some of the design parameters could not be evaluated directly from field tests or laboratory tests due to the unfavorable nature of deposits or investigation methods. However, some parameters would be derived from other instrumental testing of past events and some mechanical and physical properties obtained from field and laboratory tests. In evaluating ground stability, shear strength parameters are significant.

The following is a basic policy for finding the ground design constants in the project.

However, ultimately, each design engineer of bridges and earthworks judges appropriate soil parameters in each field and applies it to the design.

- In principle, the geotechnical design parameters shall utilize the results of in situ testing and laboratory soil tests.
- As an empirical method, regarding the unit weight etc. refer to the geotechnical parameter of earthwork guidelines by Nippon Expressway Company (NEXCO) (08.2016). (Table 2.1.9).
- When obtaining the internal friction angle from the N value, use the effective overburden pressure shown in Japanese Specifications for Highway Bridge (JSHB) (2012 in Japanese version) and The Earthwork Guidelines (2012 in Japanese version). In the investigation stage, the internal friction angle is indicated in units of 1° and it is a policy to round down the decimal point.
- In the case of obtaining cohesion strength (Cu) from N value, qu = 12.3 N to 13.1 N ≈ 12.5 N (kN / m^2) obtained from Terzaghi and Peck's method. (Geotechnical Society of Japan: Geological Survey Method and Commentary p 308, 3.2013). In addition, there is a relation of C = 6 to 10 N (kN / m^2) of the Earthwork Guidelines (2012 edition, p 64, in Japanese version). For this time, we adopt the safety side from these relationships and set C = 6 N (kN / m^2). In the investigation stage, cohesion strength is indicated in units of 1 kN, and it is a policy to devalue decimal places.
- Deformation modulus is set to Ep = 700 N (kN / m^2) in Yoshinaka as a value corresponding to the loading test in the hole. (Geotechnical Society of Japan: Geological Survey Method and Commentary p 309, 3.2013). Deformation modulus shall be displayed in units of 100 kN and the policy is to devalue numbers less than 100.
- The value of pressure meter test should be corrected if it should be corrected with reference to the in-hole loading test result at the original position.

  In the evaluation of the N value, when the N value is 50 or more, the converted N value is adopted. For the setting of the geotechnical parameter for each stratum, with regard to the average N value of 50 or more, consider the in homogeneity of the soil ground and set the N value = 50 as a guide for the upper limit.

Table 2.1.9 Recommended Soil Parameters by NEXCO

Soil Type		Condition of Soil		Unit weight γt (kN/m^3)	Internal Friction Angle φ (°)	Cohesion Cu (kN/m^2)	Remarks *2) Symbol of JGS{ } and ASTM( )
Fill Material	Gravel Gravelly Sand	Compacted one		20	40	0	{G} (GW),(GP)
	Sand	Compacted one	Well graded one	20	35	0	{S} (SW)(SP)
			Poor Graded one	19	30	0	
	Silty Sand Clayed Sand	Compacted one		19	25	Less than 30	{SF} (SM)(SC)
	Silt Clay	Compacted one		18	15	Less than 50	{M},{C} (ML),(CL),(MH),(CH)
	Kanto Loam	Compacted one		14	20	Less than 10	{V}
Natural Ground	Gravel	Dense or Well graded one		20	40	0	{G} (GW),(GP)
		Not dens and Poor graded one		18	35	0	
	Gravelly Sand	Dense one		21	40	0	{G} (GW),(GP)
		Not dense one		19	35	0	
	Sand	Dense or Well graded one		20	35	0	{S} (SM),(SC)
		Not dens and Poor graded one		18	30	0	
	Silty Sand Clayed Sand	Dense one		19	30	Less than 30	{SF} (ML),(CL)
		Not dense one		17	25	0	
	Sandy Silt Sandy Clay	Stiff one *1)		18	25	Less than 50	{M},{C} (SM),(SC)
		Firm one *1)		17	20	Less than 30	
		Soft one *1)		16	15	Less than 15	
	Silty Clay	Stiff one *1)		17	20	Less than 50	{M},{C} (CH),(MH),(ML)
		Firm one *1)		16	15	Less than 30	
		Soft one *1)		14	10	Less than 15	
	Kanto Loam	---		14	5（φu）	Less than 30	{V}

Note *1) : The standard of the N value (Stiff one（N=8～15）、Firm one（N＝4～8）、Soft one（N＝2～4））

Note *2) : The symbols of JGS and ASTM are approximate guidelines.

ASTM: American Society for Testing and Materials JGS: Japanese Geotechnical Society

Earthwork P1-52, First volume, Design Procedure by NEXCO (8.2016), NEXCO: (East, Central, West) Nippon Expressway Company Limited

Source: JICA Study Team

(2) Geotechnical Design Parameters

Geological investigation section shall be separated into three parts such as left bank (Thanlyin side), in the river and right bank (Thaketa side) for consideration of geological design parameters. Existing soil profile from BH-5 of the 2013 report to BH-1 of the 2016 report of the supplemental F/S report will be used for reference at the flyover construction location at Thaketa side.

The geotechnical design parameters are compiled for each section.

In this project, pressure meter tests (PMT) were carried out at the project area. The correlation of PMT results and standard penetration test (SPT) N values are shown in Table 2.1.10.

Table 2.1.10 Correlation of SPT N-values and Pressure Meter Test Results

<table>
<tr><th rowspan="2">Side</th><th rowspan="2">BH No.</th><th rowspan="2">Layer Name</th><th rowspan="2">Depth(m)</th><th rowspan="2">NValue</th><th>Earth Pressure at Rest</th><th>Yield Pressure</th><th>Failure Pressure</th><th>Modulus of Elasticity</th><th colspan="3">Em/N Value</th></tr>
<tr><th>Po (kN/m2)</th><th>Py (kN/m2)</th><th>Pf (kN/m2)</th><th>Em(kN/m2)</th><th>Borehole</th><th>Persection</th><th>All</th></tr>
<tr><td rowspan="9">River</td><td>BD-03</td><td>Silty SAND</td><td>3</td><td>5</td><td>123.16</td><td>259.63</td><td>356.8</td><td>1955.44</td><td>391.09</td><td rowspan="9">397</td><td rowspan="12">672</td></tr>
<tr><td>BD-03</td><td>Silty SAND</td><td>6</td><td>3</td><td>103.28</td><td>140.27</td><td>261.34</td><td>882.76</td><td>294.25</td></tr>
<tr><td>BD-03</td><td>Silty SAND</td><td>10</td><td>2</td><td>154.8</td><td>290.04</td><td>363.08</td><td>901.66</td><td>450.83</td></tr>
<tr><td>BD-09</td><td>Silty SAND</td><td>3</td><td>4</td><td>73.84</td><td>197.82</td><td>344.59</td><td>1566.52</td><td>391.63</td></tr>
<tr><td>BD-09</td><td>Silty SAND</td><td>6</td><td>3</td><td>127.75</td><td>238.6</td><td>336.37</td><td>1017.73</td><td>339.24</td></tr>
<tr><td>BD-09</td><td>Silty SAND</td><td>10</td><td>18</td><td>179.19</td><td>752.74</td><td>378.82</td><td>6190.78</td><td>343.93</td></tr>
<tr><td>BD-10</td><td>Silty SAND</td><td>3</td><td>1</td><td>85.28</td><td>146.35</td><td>206.69</td><td>695.43</td><td>695.43</td></tr>
<tr><td>BD-10</td><td>Silty SAND</td><td>6</td><td>5</td><td>152.35</td><td>350.85</td><td>473.78</td><td>2103.07</td><td>420.61</td></tr>
<tr><td>BD-10</td><td>Silty SAND</td><td>10</td><td>10</td><td>166.66</td><td>290.91</td><td>437.95</td><td>2449.94</td><td>244.99</td></tr>
<tr><td rowspan="3">Right Bank</td><td>BD-14</td><td>CLAY</td><td>3</td><td>2</td><td>123.48</td><td>222.01</td><td>369.33</td><td>967.94</td><td>483.97</td><td rowspan="2">714</td></tr>
<tr><td>BD-14</td><td>CLAY</td><td>6</td><td>1</td><td>127.78</td><td>226.23</td><td>298.91</td><td>944.87</td><td>944.87</td></tr>
<tr><td>BD-14</td><td>Silty SAND</td><td>10</td><td>15</td><td>265.87</td><td>689.91</td><td>1013.04</td><td>7518.11</td><td>501.21</td><td>501</td></tr>
<tr><td rowspan="6">Left Bank</td><td>BD-20</td><td>CLAY</td><td>3</td><td>0(0.5)</td><td>85.26</td><td>146.42</td><td>219.26</td><td>734.67</td><td>1,469.34</td><td rowspan="6">1,099</td></tr>
<tr><td>BD-20</td><td>CLAY</td><td>6</td><td>1</td><td>114.53</td><td>212.85</td><td>273.62</td><td>993.08</td><td>993.08</td></tr>
<tr><td>BD-20</td><td>CLAY</td><td>10</td><td>2</td><td>154.81</td><td>416.27</td><td>588.08</td><td>3372.86</td><td>1,686.43</td></tr>
<tr><td>BD-23</td><td>CLAY</td><td>3</td><td>2</td><td>85.39</td><td>196.44</td><td>319.26</td><td>1225.4</td><td>612.70</td></tr>
<tr><td>BD-23</td><td>CLAY</td><td>6</td><td>0(0.5)</td><td>101.82</td><td>162.53</td><td>198.65</td><td>604.85</td><td>1,209.70</td></tr>
<tr><td>BD-23</td><td>CLAY</td><td>10</td><td>2</td><td>130.17</td><td>216.82</td><td>325.36</td><td>1244.05</td><td>622.03</td></tr>
</table>

Source: JICA Study Team

Remarks;

- In this calculation, SPT N-values were changed from 0 to 0.5 at 3.0 m at BD-14 and 6.0 m at BD-23.
- According to the testing results, the relationship between N value and pressure meter test satisfied Em = 672N ≒ 700N in Yoshinaka as a whole.
- Clay has confirmed Em = 700N or more on both banks.
- Right Bank; Em = 714N ≈ (approximately equal to) 710N
- Left Bank; Em = 1099N ≈ (approximately equal to) 1100N
  Sandy soil has confirmed Em = 397 ~ 501 ≈ (approximately equal to) 400 ~ 500N
- River Section

For geotechnical design parameters selection, Em = 397N ≈ (approximately equal to) 400N is used for the silty sand-river sediments layer. Similarly, clayey SAND-A and Silty SAND-I layer are used same as Em = 400N for this project. Another Soils are used Em = 700N

Right Bank

For geotechnical design parameters selection, Em = 501N ≈ (approximately equal to) 500N is used for Silty SAND-I layer for this project. Another Soils are used Em= 700N for safety side.

Left Bank

For geotechnical design parameters selection, Em = 1099N ≈ (approximately equal to) 1100N for CLAY-I layer. However, the range is largely varying from 612N ~1686N. Therefore, Em = 700N is used for safety side.

Em values were selected from unconfined compression test results for some clay layers.

The following shows the geotechnical design parameters proposed by the soil survey.

① Left bank, Thanlyin side (from BD-25 to BH-2 of 2013 report)

Table 2.1.11 shows the proposed geotechnical design parameters for Thanlyin side.

Table 2.1.11 Proposed Geotechnical Design Parameters for Thanlyin Side

No.	Soil Name	Representative N Value	Unit Weight			Internal Friction Angle	Cohesive Strength	Deformation Modulus
			γt (kN/m^3)	γsat (kN/m^3)	γ' (kN/m^3)	φ (°)	c (kN/m^2)	E_{50} (kN/m^2)
1	Filled Soil	1 1)	18.0 2)	18.0	8.0	-	6 3)	700 3)
2	CLAY-I	1 1)	17.5 1)	17.5	7.5	-	15 1)	900 1)
3	Sandy CLAY-I	3 1)	17.5 1)	17.5	7.5	-	15 1)	2000 1)
4	Silty SAND-I	15 1)	16.5 1)	17.5	7.5	33 3)	-	6000 3)
5	Clayey SAND-A	3 1)	17.0 2)	18.0	8.0	28 3)	-	1200 3)
6	CLAY-AII	5 1)	17.5 1)	17.5	7.5	-	30 1)	3200 1)
7	Clayey SAND-B	17 1)	17.0 2)	18.0	8.0	33 3)	-	11900 3)
8	CLAY-AIII	7 1)	17.6 1)	17.6	7.6	-	42 3)	4900 1)
9	Clayey SAND-C	20 1)	17.0 2)	18.0	8.0	32 3)	-	14000 3)
10	Clayey SAND-I	23 1)	17.0 2)	18.0	8.0	31 3)	-	16100 3)
11	Clayey SAND-II	50 1)	19.0 2)	20.0	10.0	35 3)	-	35000 3)

1) These values were set up by field test or soil laboratory test result.
2) These values were set up by the reference value shown in NEXCO.
3) These values were set up by formula of SPTN-value.
4) These values were set up by formula.

Source: JICA Study Team

② River section, (from BH-2 of 2013 report to BD-17)

Table 2.1.12 shows the proposed geotechnical design parameters for River section.

Table 2.1.12 Proposed Geotechnical Design Parameters for River Section

No.	Soil Name	Representative N Value	Unit Weight			Internal Friction Angle	Cohesive Strength	Deformation Modulus
			γt (kN/m^3)	γsat (kN/m^3)	γ' (kN/m^3)	φ (°)	c (kN/m^2)	E_{50} (kN/m^2)
1	Silty SAND-River Sediments	3[1)]	17.0[2)]	18.0	8.0	29[3)]	-	1200[1)]
2	CLAY-I	1[1)]	17.5[1)]	17.5	7.5	-	10[1)]	900[1)]
3	Clayey SAND-A	3[1)]	17.5[1)]	18.5	8.5	28[3)]	-	1200[3)]
4	Silty SAND-I	13[1)]	17.0[2)]	18.0	8.0	33[3)]	-	5200[3)]
5	Sandy CLAY-II	9[1)]	17.5 Same values as CLAY-AII	17.5	7.5	-	54[3)]	6300[3)]
6	CLAY-AII	7[1)]	17.5[1)]	17.5	7.5	-	42[3)]	4900[3)]
7	Clayey SAND-B	13[1)]	17.0[2)]	18.0	8.0	32[3)]	-	9100[3)]
8	Silty SAND-A	25[1)]	17.0[2)]	18.0	8.0	33[3)]	-	17500[3)]
9	CLAY-AIII	18[1)]	18.0[2)]	18.0	8.0	-	108[3)]	12600[3)]
10	Clayey SAND-C	20[1)]	17.0[2)]	18.0	8.0	33[3)]	-	14000[3)]
11	SiltySAND-II	30[1)]	17.0[2)]	18.0	8.0	34[3)]	-	21000[3)]
12	Clayey SAND-I	35[1)]	19.0[2)]	20.0	10.0	34[3)]	-	24500[3)]
13	CLAY-AIV	30[1)]	18.0[2)]	18.0	8.0	-	180[3)]	21000[3)]
14	ClayeySAND-II	50[1)]	19.0[2)]	20.0	10.0	35[3)]	-	35000[3)]

1) These values were set up by field test or soil laboratory test result.
2) These values were set up by the reference value shown in NEXCO.
3) These values were set up by formula of SPTN-value.
4) These values were set up by formula.

Source: JICA Study Team

③ Right bank, Thaketa side (from BD-17 to BH-5 of 2013 report)

Table 2.1.13 shows the proposed geotechnical design parameters for Thaketa aide.

Table 2.1.13 Proposed Geotechnical Design Parameters for Thaketa Side

No.	Soil Name	Representative N Value	Unit Weight			Internal Friction Angle	Cohesive Strength	Deformation Modulus
			γt (kN/m^3)	γsat (kN/m^3)	γ' (kN/m^3)	φ (°)	c (kN/m^2)	E50 (kN/m^2)
1	Filled Soil	3 1)	19.0 2)	20.0	10.0	-	18 3)	2100 3)
2	CLAY-I	1 1)	17.5 1)	17.5	7.5	-	15 1)	900 1)
3	Silty SAND-I	13 1)	17.0 2)	18.0	8.0	32 3)	-	6500 3)
4	Sandy SILT	7 1)	17.0 2)	17.0	7.0	-	42 3)	4900 3)
5	Silty SAND-II	25 1)	17.0 2)	18.0	8.0	34 3)	-	17500 3)
6	Clayey SAND-I	35 1)	19.0 2)	20.0	10.0	34 3)	-	24500 3)
7	Clayey SAND-II	50 1)	19.0 2)	20.0	10.0	35 3)	-	35000 3)

1) These values were set up by field test or soil laboratory test result.
2) These values were set up by the reference value shown in NEXCO.
3) These values were set up by formula of SPTN-value.
4) These values were set up by formula.

Source: JICA Study Team

④ Flyover section, Thaketa side (from BH-5 of 2013 report to BH-1 of 2016 report of the supplemental F/S report)

Table 2.1.14 shows the proposed geotechnical design parameters for the flyover section. Some of these parameters were modified in the detailed design of flyover by reference to the new soil investigation result in other sections.

Table 2.1.14 Proposed Geotechnical Design Parameters for Flyover Section

No.	Soil Name	Representative N Value	Unit Weight			Internal Friction Angle	Cohesive Strength	Deformation Modulus
			γt (kN/m^3)	γsat (kN/m^3)	γ' (kN/m^3)	φ (°)	c (kN/m^2)	E_{50} (kN/m^2)
1	Filled Soil	4 5)	18.0 2)	18.0	8.0	-	25 5)	1000 5)
2	CLAY-I	4 1)	18.0 1)	18.0	8.0	-	25 1)	1000 1)
3	Silty SAND-I	10 1)	18.0 1)	19.0	9.0	32 3)	-	5000 3)
4	Sandy SILT	7 1)	17.0 2)	17.0	7.0	-	42 3)	4900 3)
5	Silty SAND-II	22 1)	17.0 2)	18.0	8.0	33 3)	-	15400 3)
6	CLAY-II	20 1)	18.0 2)	18.0	8.0	-	120 3)	14000 3)
7	Clayey SAND-I	35 1)	19.0 2)	20.0	10.0	33 3)	-	24500 3)
8	CLAY-III	31 1)	18.0 2)	18.0	8.0	-	186 3)	21700 3)
9	Clayey SAND-II	50 1)	19.0 2)	20.0	10.0	37 3)	-	35000 3)
10	CLAY-IV	50 1)	18.0 2)	18.0	8.0	-	300 3)	35000 3)

1) These values were set up by field test or soil laboratory test result.
2) These values were set up by the reference value shown in NEXCO.
3) These values were set up by formula of SPTN-value.
4) These values were set up by formula.
5) Refer to CLAY-I.

Source: JICA Study Team

(3) Summary of Soil Survey Results

1) Ground Conditions and Bearing Layer

Based on the survey results, 20 different soil layers including the flyover section were recognized in the design section of this area. For each section, 11 soil layers in the Thanlyin section, 14 soil layers in the river section, 7 soil layers in the Taketa section, and 10 soil layers in the flyover section have been confirmed, as shown in Table 2.1.15.

In the survey area, river sediments are distributed along the Bago River. The soil constitution is greatly changed in the alluvium distributed under this river sediment.

Cohesive soil dominates from the left bank of Thanlyin side to the right bank side of the Bago River, and is characterized by sandy soil prominent from the right bank side of the river section to the right bank of Thaketa side. The sedimentary relationship of cohesive soil and sandy soil of alluvium is considered to be largely interfinger relationship at this stage.

As the proposed bridge is designed with heavy and dynamic load and large spans, the pier foundation is designed generally as pile foundation according to soil conditions at site.

According to the survey results, the soil layers with N values of 50 or more correspond roughly to the distribution range of the Clayey SAND - II layer of the surveyed area and the CLAY - IV layer of the flyover area.

As bearing layer for the design of this project, we propose the following values according to JSHB (Substructure Edition, Japan Road Association, 2012, pp.278-279). Figures 2.1.11 to 2.1.13 show the soil profiles including the bearing layer line.

<Bearing Layer>

Sand Layer: N value of 30 or more (Clayey SAND-II)
Cohesive Soil Layer: N value of 20 or more (CLAY-AIV, CLAY-III, CLAY-IV)

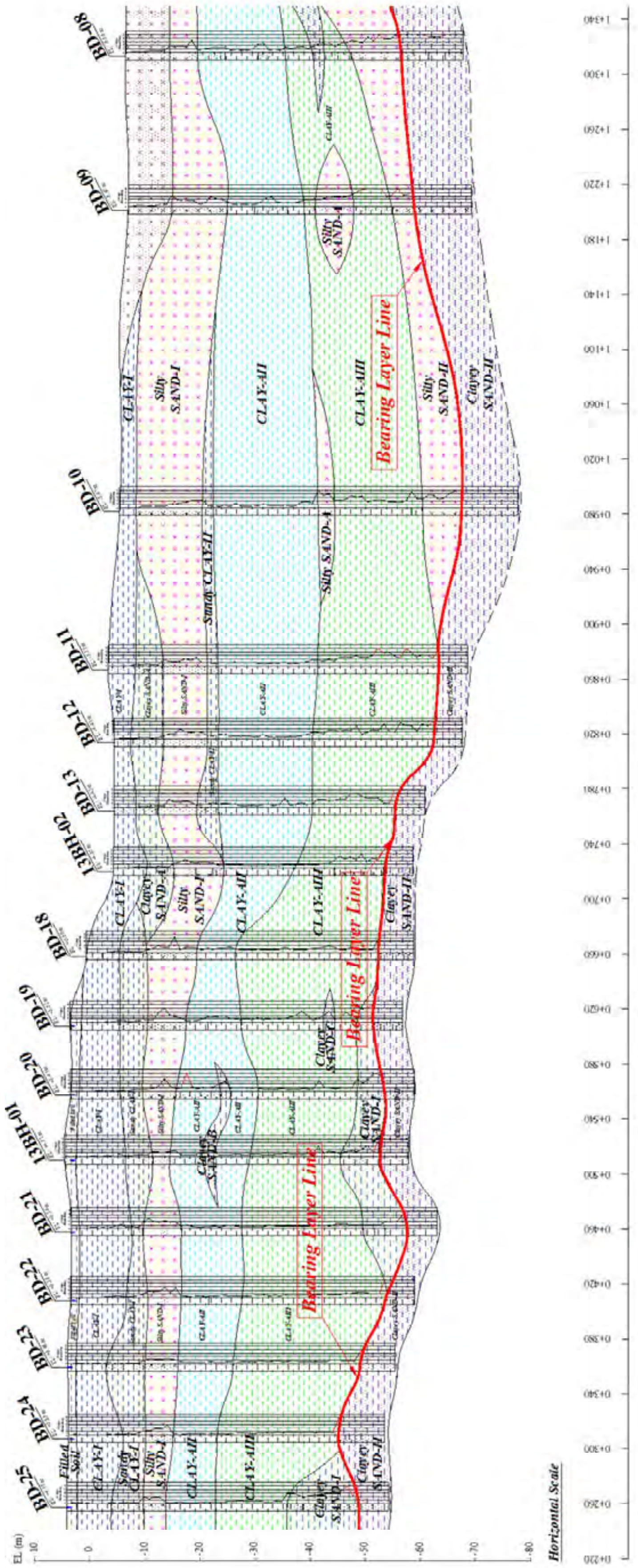
In addition, Clayey SAND – I distributed from the right bank of the river bed to the Taketa area was evaluated as a provisional bearing layer, since N values of 30 or more were continuously confirmed.

As the foundation surface for earthquake-resistant design, N value of 25 or more in the cohesive soil layer is required and N value of 50 or more in the sandy soil layer, so the bearing line shown in Figure 2.1.11 ~ Figure 2.1.13 roughly coincides with the foundation surface line. (“JSHB” - Earthquake Resistant Edition, Japan Road Association, 2012, p.33)

Table 2.1.15 Different Soil Layers of Each Section

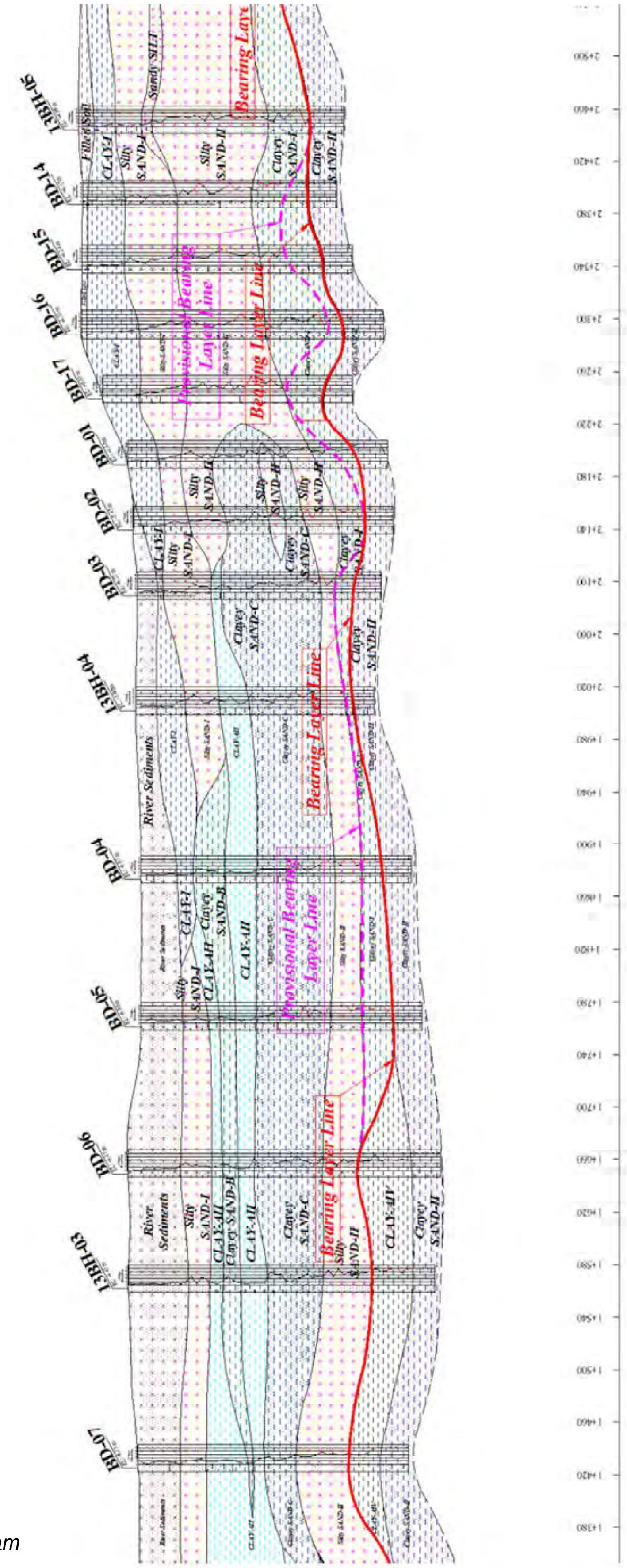
Formation	Section (Soil name for each section)			
	Thanlyin	River	Thaketa	Flyover(Thaketa)
	BD-25～(13)BH-2	(13)BH-2～BD-17	BD-17～(13)BH-5	(13)BH-5～(16) BH-1
Alluvium		Silty SAND- River Sediments		
	Filled Soil		Filled Soil	Filled Soil
	CLAY-I	CLAY-I	CLAY-I	CLAY-I
	Sandy CLAY-I			
	Clayey SAND-A	Clayey SAND-A		
	Silty SAND-I	Silty SAND-I	Silty SAND-I	Silty SAND-I
			Sandy SILT	Sandy SILT
		Sandy CLAY-II		
	CLAY-AII	CLAY-AII		
	Clayey SAND-B	Clayey SAND-B		
		Silty SAND-A		
	CLAY-AIII	CLAY-AIII		
	Clayey SAND-C	Clayey SAND-C		
		Silty SAND-II	Silty SAND-II	Silty SAND-II
				CLAY-II
Irrawaddy Formation	Clayey SAND-I	Clayey SAND-I	Clayey SAND-I	Clayey SAND-I
		CLAY-AIV		
				CLAY-III
	Clayey SAND-II	Clayey SAND-II	Clayey SAND-II	Clayey SAND-II
				CLAY-IV

Source: JICA Study Team



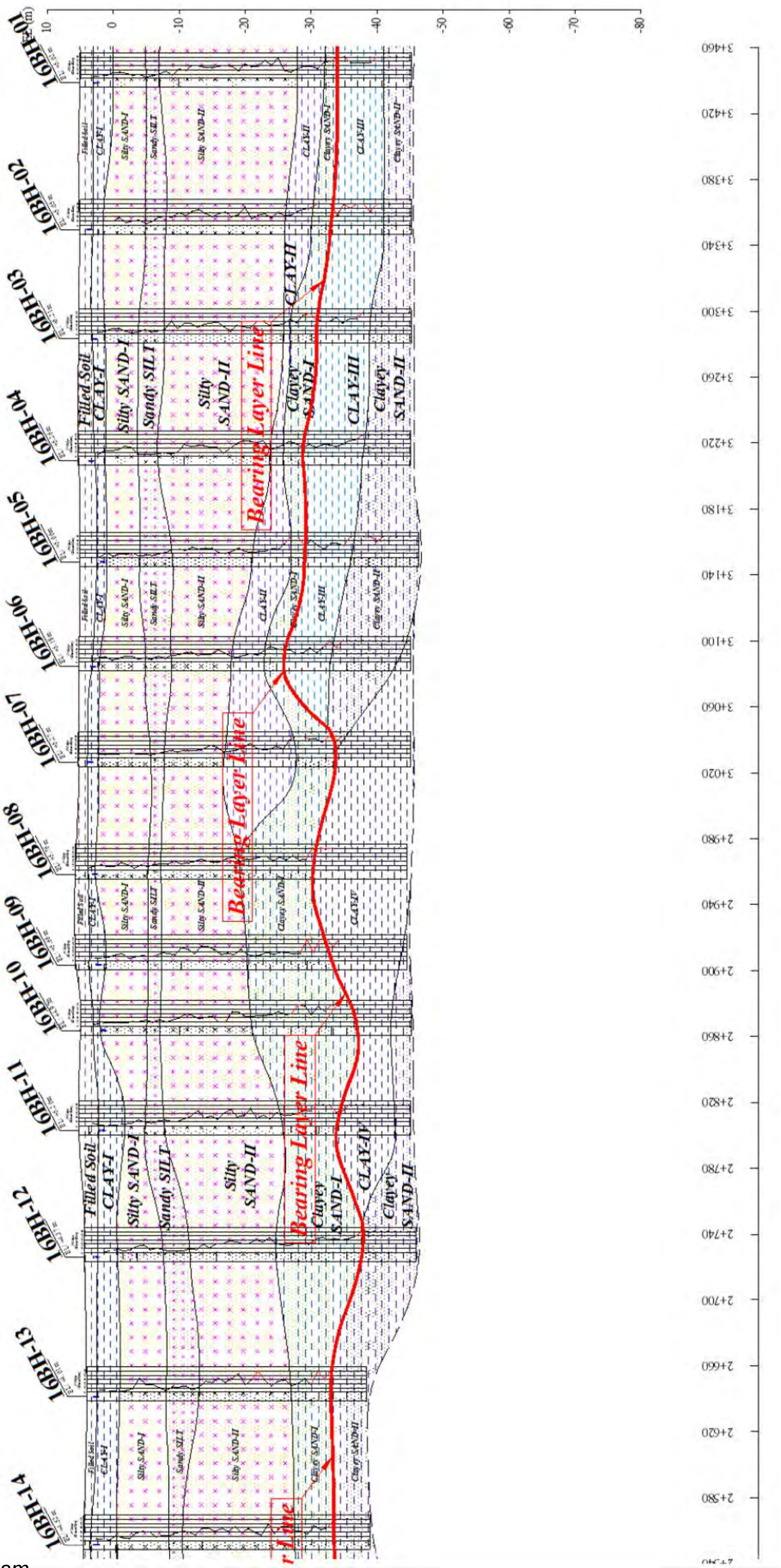
Source: JICA Study Team

Figure 2.1.11 Soil Profile with Bearing Layer (1/3)



Source: JICA Study Team

Figure 2.1.12 Soil Profile with Bearing Layer (2/3)



Source: JICA Study Team

Figure 2.1.13 Soil Profile with Bearing Layer (3/3)

2) Notes on Design and Construction

As considerations for design and construction, there are problems of settlement and liquefaction accompanying soft ground and earth retaining due to basic excavation. Generally, soft ground is N value 4 or less for cohesive soil, and N value 10 to 15 or less for sandy soil. (Road Earthworks - Guidelines for Measuring Soft Ground, Japan Road Association, 2012, P.6)

In the project area, cohesive soils such as filled soil, Clay-I and Sandy Clay distributed in the surface layer are subject to soft ground. In addition, it is necessary to secure trafficability accompanying the earthwork of the surface layer and to consider consolidation settlement and stability accompanying the embankment. Also, as sandy soil, Silty SAND - River Sediments, Clayey SAND – A, and Silty SAND - I are targeted and consideration of stability including damage of liquefaction at the time of earthquake is necessary.

Groundwater is confirmed on land in the project area at around GL -1 m from the surface ground as shown in Table 2.1.16. For this reason, it is necessary to consider groundwater taking into account measures such as soil fixation accompanying basic excavation.

Table 2.1.16 Groundwater Level of Investigation Points through Project Area

BH-No.	BH EL -(m)	Groundwater Level		Measured Date	Remark
		GL -(m)	EL -(m)		
BD-14	+4.13	-1.10	+3.03	19.11.2016	Right Bank (Thaketa)
BD-15	+4.24	-1.00	+3.24	12.11.2016	
BD-16	+4.35	-1.30	+3.05	12.11.2016	
BD-19	+3.52	-0.50	+3.02	05.12.2016	Left Bank (Thanlyin)
BD-20	+3.41	-0.35	+3.06	28.11.2016	
BD-21	+3.34	-0.30	+3.04	17.11.2016	
BD-22	+3.38	-0.42	+2.96	28.11.2016	
BD-23	+3.98	-0.42	+3.56	05.12.2016	
BD24	+3.85	-0.70	+3.15	25.11.2016	
BD-25	+4.15	-0.60	+3.55	12.11.2016	

- *It is considered that groundwater level in the boreholes may not be precise due to remnants of drilling slurry at the time of measurement.*

Source: JICA Study Team

By the global scope of geology, Myanmar lies in one of the great earthquake provinces called the Alpine Earthquake Belt. Therefore, minor catastrophic earthquakes have occurred many times in the territory of Myanmar since long ago. Due to these unstable events, it has expected that earthquakes will occur in Myanmar at any time.

According to the analysis of liquefaction possibility by the "JSHB - Earthquake Resistant Edition, Japan Road Association, 2012" conducted at this time, it was found that the possibility of liquefaction is high at this area.

Moreover, based on the result of liquefaction analysis (FL), the potential of liquefaction (PL) is calculated. Table 2.1.17 shows the PL values for each borehole and Table 2.1.18 shows the relationship between PL values and liquefaction risk. PL was originally developed in Japan and evaluates the possibility of liquefaction causing destruction of foundation ground (Iwasaki et al.: " Estimation of Degree of Soil Liquefaction During Earthquakes", Soil Mechanics and Foundation Engineering, Vol. 28, No. 4, 1980).

According to Table 2.1.17, the possibility of liquefaction in this area is high in the land section and extremely high in the river section. For this reason, appropriate liquefaction countermeasures are required for designing.

Table 2.1.17 P_L values of Each Borehole

Thanlyin Side		River Portion		Thaketa Side	
BH-No.	P_L Values	BH-No.	P_L Values	BH-No.	PL Values
BD-18	17.314	BD-01	29.320	BD-14	5.346
BD-19	10.614	BD-02	22.378	BD-15	8.214
BD-20	13.354	BD-03	31.136	BD-16	3.172
BD-21	4.304	BD-04	33.406	BD-17	32.522
BD-22	5.659	BD-05	26.388		
BD-23	13.175	BD-06	43.329		
BD-24	9.234	BD-07	30.413		
BD-25	10.544	BD-08	35.258		
		BD-09	35.298		
		BD-10	34.783		
		BD-11	50.819		
		BD-12	36.995		
		BD-13	32.748		

Source: JICA Study Team

Table 2.1.18 Relationship between P_L Values and Liquefaction Risk

P_L Values	Liquefaction Risk
$15 < P_L$	Very High Possibility of Liquefaction
$5 < P_L \leqq 15$	High Possibility of Liquefaction
$0 < P_L \leqq 5$	Low Possibility of Liquefaction
$P_L = 0$	Very Low Possibility of Liquefaction

By Iwasaki et al., 1980
Source: JICA Study Team

2.2 TOPOGRAPHIC SURVEY

2.2.1 Review of Topographic Survey in F/S

In Myanmar, high-rise buildings have been constructed in the progress of urbanization. It is supposed that the subsidence caused by pumping the groundwater up for building construction has occurred. Although Yangon City has urbanized rapidly, the subsidence has not been regarded as a significant problem in Myanmar.

Most of leveling networks in Myanmar was built in the 1970s before the recent rapid urbanization. It is assumed that there are many bench marks affected by the subsidence because it has not been considered in the modified surveys conducted by MSD.

The bench marks result cannot be certified especially in Yangon neighboring villages. In the F/S, BM89002 was chosen for the bench mark of the Project; however, the certification for it was not given by MSD.

BM76097 which is certified by MSD was chosen for the survey works in this D/D. BM76097 is located at approximately 10 km from the Thanlyin side.

In addition, existing global positioning system (GPS) stations in related studies are used because these do not show any abnormalities.

2.2.2 Survey Scope and Purpose

The results of topographic survey are utilized for the detailed engineering designs as well as other surveys including geological survey, materials investigation, underground survey, and hydrological survey.

The work period for the survey works is from the middle of October to the middle of December 2016.

Work items and quantities for topographic survey are as follows:

Table 2.2.1 DD Work Items and Quantities

Work Items	Quantity	
	Plan	Result
1. Control Point Survey		
1-1 Primary Control Points (by using GPS)	5 points	10
1-2 Secondary Control Points (by using TS)	20	20
1-3 Primary Leveling Network (fourth order leveling)	28.71	43.60
1-4 Secondary Leveling Network（Technical leveling)	3.71 km	3.71 km
2. Route Survey for Road and Flyover Portion (L=2.17 km including 391 m long on-ramp in Thanlyin)		
Land Portion		
2-1 Center Line Survey (20 m intervals with principal points)	1.20 km	1.20 km
2-2 Longitudinal Survey	1.20 km	1.20 km
2-3 Cross-section Survey (50 m both sides from center line)	90	117
On-ramp		
2-4 Center Line Survey (20 m intervals with principal points)	0.64 km	0.64 km
2-5 Longitudinal Survey	0.64 km	0.64 km
2-6 Cross-section Survey (50 m both sides from center line)	41	41
Additional Work (Star City)		
2-7 Center Line Survey (20 m intervals with principal points)	0.60 km	0.60 km
2-8 Longitudinal Survey	0.60 km	0.60 km
2-9 Cross-section Survey (50 m both sides from center line)	32	32
2-10 Planimetric survey (50 m both sides from center line)	17.8ha	42.4 ha

3. Route Survey for Bridge Portion (L = 1.928 km)		
3-1 Longitudinal Survey	1.93 km	1.93 km
3-2 Cross-section Survey (50 m both sides from center line)	96	38
3-3 Planimetric Survey (50 m both sides from center line)	19.3 ha	12.1 ha

Source: JICA Study Team

On the other hand, work items and quantities, as specified in the F/S, are as follows:

Table 2.2.2　F/S Work Items and Quantities

Survey Item	Unit	Quantity
1. Control Point Survey		
1-1 Control Points (by using GPS)	Point	5
1-2 Secondary Control Points (by using TS)	Point	20
2. Route Survey for Road and Flyover Portion		
2-1 Center Line Survey (20 m intervals with principal points)	km	2.17
2-2 Longitudinal Survey	km	2.17
2-3 Cross Section Survey (50 m both sides from center line)	Section	90
2-4 Plan Metric Survey (50 m both sides from center line)	ha	17.8
3. Route Survey for Bridge Portion		
3-1 Center Line Survey (20 m intervals with principal points)	km	1.93
3-2 Longitudinal Survey	km	1.93
3-3 Cross Section Survey (50 m both sides from center line)	Section	96
3-4 Plan Metric Survey (50 m both sides from center line)	ha	19.3

Source: F/S

2.2.3 Survey Methodology and Work Progress

Existing GPS points and benchmarks for these survey works were chosen at the beginning.

Source: JICA Study Team

Figure 2.2.1　Location of Control Point and Bench Marks

Coordinate systems generally adopted in Myanmar at present are as follows:

Table 2.2.3 Coordinate Reference Systems

Ellipsoid	WGS84 (World Geodetic System 1984)
Projection	Universal Transverse Mercator (UTM) Projection
UTM Zone	Zone number 47N
Central of Meridian Origin	99 degrees east of Meridian International
Latitude of Origin	Equator
Scale Factor at Origin	0.9996
False Easting	(0,500,000) at the Equator
Vertical Datum	BM height adopted by Myanmar Survey Department
Unit of Measurement	meter
EPSG	3247(WGS84 UTM coordinates. 47)

Source: JICA Study Team

The tolerance of primary control point survey, secondary control point survey, primary leveling, and the secondary leveling in the survey are as follows:

- Primary control point survey Third order control points or higher

  Residual of Base line 20 mm

  Circuit closure error of horizontal position 100 mm + 40 mm$\sqrt{N}$

  N: Number of minimum sides to Existing point

  Standard deviation of horizontal position 100 mm
- Secondary control points Fourth order control points

  Circuit closure error of horizontal position 150 mm + 100 mm$\sqrt{N\Sigma S}$

  N: Number of sides

  ΣS: Total distance of route (km)
- Primary leveling 20$\sqrt{S}$ mm

  S: Total distance of route(km)
- Secondary leveling 30$\sqrt{S}$ mm

  S: Total distance of route(km)

Existing control points and bench marks used for the survey are as follows: (see Appendix-1)

- Control Point : GPS08 and SD2
- Bench mark : BM7609

A control point survey was carried out by the following technique:

- Ten primary control points in the horizontal position were observed by GPS and the elevation by direct leveling.
- Twenty secondary control points in the horizontal position were observed by using the Total Station (TS) and elevation by direct leveling.

2.2.4 Control Point Survey

Five primary control points as well as a supplementary control point in each were installed to average out in the survey area. The total number of primary control points is ten.

The secondary control point was measured based on the primary control point and placed at 20 points in the whole area.

The locations and results of the primary and secondary control points are as follows:

Source: JICA Study Team

Figure 2.2.2 Location of Primary Control Points

Table 2.2.4 Primary Control Point Results

STATION	GEODETIC WGS84										UTM ZONE47N		ELEVATION Above MSL
	Latitude				Longitude				Northing (DD.dddd)	Easting (DD.dddd)	EAST	NORTH	
GPS01	16	46	45.42484	N	96	14	26.13589	E	16.77928468	96.2405933	205842.773	1857184.685	5.698
GPS011	16	46	47.66305	N	96	14	23.31533	E	16.7799064	96.2398098	205760.156	1857254.692	5.543
GPS02	16	47	1.7331	N	96	14	8.31563	E	16.78381475	96.2356432	205321.737	1857693.657	4.426
GPS021	16	46	58.2131	N	96	14	11.36158	E	16.78283697	96.2364893	205410.48	1857584.129	4.262
GPS03	16	47	46.71045	N	96	13	41.13763	E	16.79630846	96.2280938	204535.795	1859088.346	4.115
GPS031	16	47	49.67794	N	96	13	38.33112	E	16.79713276	96.2273142	204453.92	1859180.786	3.874
GPS04	16	48	2.98474	N	96	13	32.09699	E	16.80082909	96.2255825	204274.946	1859592.673	5.344
GPS041	16	47	59.15196	N	96	13	29.82522	E	16.79976443	96.2249515	204205.987	1859475.724	5.066
GPS05	16	48	24.60363	N	96	13	6.34695	E	16.80683434	96.2184297	203521.369	1860268.348	4.914
GPS051	16	48	24.67682	N	96	13	4.21657	E	16.80685467	96.2178379	203458.284	1860271.486	5.105

See Appendix-2
Source: JICA Study Team

- The observation result of the GPS survey was checked in 39 ways of loop closure. (see Appendix-3)
- The standard deviation of the GPS net adjustment was 0.051 m. (see Appendix-4)

Source: JICA Study Team

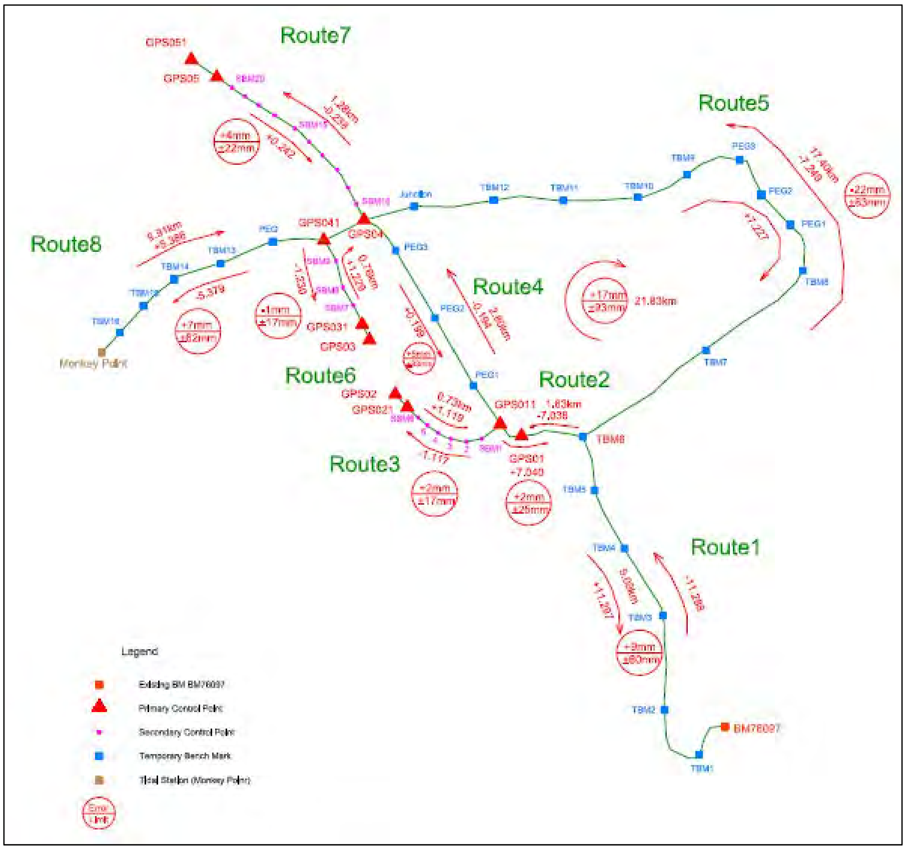
Figure 2.2.3 Location of Secondary Control Point

Table 2.2.5 Secondary Control Point Results

STATION	GEODETIC WGS84										UTM ZONE47N		ELEVATION Above MSL
	Latitude(DMS)				Longitude(DMS)				Latitude (DD.dddd)	Longitudeg (DD.dddd)	EAST	NORTH	
SBM-1	16	46	47.35511	N	96	14	21.61608	E	16.77982086	96.2393378	205,709.67	1,857,245.92	4.664
SBM-2	16	46	48.95431	N	96	14	19.527	E	16.78026509	96.2387575	205,648.46	1,857,295.97	3.968
SBM-3	16	46	51.59371	N	96	14	17.43543	E	16.78099825	96.2381765	205,587.61	1,857,378.02	4.452
SBM-4	16	46	52.98042	N	96	14	16.21884	E	16.78138345	96.2378386	205,552.16	1,857,421.17	4.242
SBM-5	16	46	54.4802	N	96	14	14.65647	E	16.78180006	96.2374046	205,506.51	1,857,467.95	4.582
SBM-6	16	46	56.49353	N	96	14	13.03845	E	16.78235931	96.2369551	205,459.43	1,857,530.55	4.476
SBM-7	16	47	51.54021	N	96	13	37.30862	E	16.79765006	96.2270302	204,424.43	1,859,238.49	4.324
SBM-8	16	47	56.30692	N	96	13	34.02803	E	16.79897414	96.2261189	204,329.28	1,859,386.47	4.361
SBM-9	16	48	0.86229	N	96	13	31.42905	E	16.80023953	96.225397	204,254.24	1,859,527.67	4.472
SBM-10	16	48	5.23242	N	96	13	31.54232	E	16.80145345	96.2254284	204,259.48	1,859,662.04	5.476
SBM-11	16	48	6.54561	N	96	13	29.36277	E	16.80181823	96.224823	204,195.47	1,859,703.34	4.441
SBM-12	16	48	8.63688	N	96	13	27.9489	E	16.80239913	96.2244303	204,154.48	1,859,768.25	4.809
SBM-13	16	48	10.4815	N	96	13	25.67421	E	16.80291153	96.2237984	204,087.89	1,859,825.93	4.82
SBM-14	16	48	11.75617	N	96	13	23.00795	E	16.8032656	96.2230578	204,009.41	1,859,866.25	4.668
SBM-15	16	48	15.26321	N	96	13	19.84692	E	16.80423978	96.2221797	203,917.30	1,859,975.43	4.711
SBM-16	16	48	17.01076	N	96	13	17.705	E	16.80472521	96.2215847	203,854.60	1,860,030.08	4.662
SBM-17	16	48	18.44514	N	96	13	15.36211	E	16.80512365	96.2209339	203,785.80	1,860,075.17	5.15
SBM-18	16	48	20.5082	N	96	13	12.17703	E	16.80569672	96.2200492	203,692.33	1,860,139.95	4.536
SBM-19	16	48	21.98804	N	96	13	11.68714	E	16.80610779	96.2199131	203,678.45	1,860,185.67	4.496
SBM-20	16	48	22.87761	N	96	13	8.85857	E	16.80635489	96.2191274	203,595.04	1,860,214.21	4.526

See Appendix-5
Source: JICA Study Team

The existing benchmark, BM76097, was used for the survey.



See Appendix-6
Source: JICA Study Team

Figure 2.2.4 Leveling Route Map

Table 2.2.6 Leveling Quality Control

NO	From	TO	Dist (km)	Forward (m)	Backward (m)	Diff ㎜ (mm)	Limit ㎜ (mm)	Mean	Remarks
1	BM76097	TBM6	9.09	-11.288	11.297	9	± 60	-11.293	BM76097-TBM1-TBM2-TBM3-TBM4-TBM5-TBM6
2	TBM6	GPS011	1.63	-7.038	7.040	2	± 25	-7.039	TBM6-GPS01-GPS011
3	GPS011	GPS02	0.73	-1.117	1.119	2	± 17	-1.118	GPS011-SBM1-SBM2-SBM3-SBM4-SBM5-SBM6-GPS021-GPS02
4	GPS011	GPS04	2.80	-0.194	0.199	5	± 33	-0.197	GPS011-PEG1-PEG2-PEG3-GPS04
5	TBM6	GPS04	17.40	-7.249	7.227	-22	± 83	-7.238	TBM6-TBM7-TBM8-PEG1-PEG2-PEG3-TBM9-TBM10-TBM11-TBM12-Junction-GPS04
6	GPS04	GPS03	0.76	-1.230	1.229	-1	± 17	-1.230	GPS04-GPS041-TBM9-TBM8-TBM7-GPS031-GPS03
7	GPS04	GPS051	1.28	-0.238	0.242	4	± 22	-0.240	GPS04-SBM10-SBM11-SBM12-SBM13-SBM14-SBM15-SBM16-SBM17-SBM18-SBM19-SBM20-GPS05-GPS051
8	Monkey	GPS041	9.91	5.386	-5.379	7	± 62	5.383	Monkey Point-TBM16-TBM15-TBM14-TBM13-GP

See Appendix-7
Source: JICA Study Team

Leveling observation data is shown in Appendix-8.

2.2.5 Route Survey

The route survey (4.37 km) is comprised of the following:

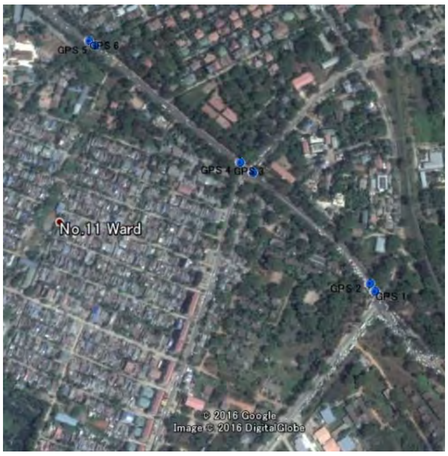
- Main route：On-ramp 1.20 km, the bridge section at Bago River 1.93 km
- Access road to the main route：0.64 km
- Access road to Star City：0.60 km

All center line points were staked out by TS. In addition, cross-section survey and longitudinal profile survey were conducted.

The elevation of the center line points were surveyed by direct leveling. Some points located in a bush at the Thanlyin side, on the other hand, were surveyed by TS.

2.2.6 Advanced GPS Survey for Basic Design

For the D/D of the flyover section, six points of the road center on the existing road were surveyed by GPS at first so that the B/D can be commenced without waiting for the completion of the survey by TS.



Source: JICA Study Team

Figure 2.2.5 Location of Advanced GPS Survey

GCP1009 and BM89004 were chosen as existing control points for this survey. Elevation of this benchmark was checked by using BM76097, whether the elevation of BM89004, which was installed 40 years ago, is the same as that of BM76097.

As shown in the following list, approximately 28 cm of gap was observed in this survey compared to the F/S results. Therefore, as described above, the occurrence of subsidence was confirmed.

BM76097 certificated by MSD was used as the standard of elevation for this project and the elevation in the case of the F/S was reviewed.

Table 2.2.7 Check of Elevation

STA	Nov. 2016	FS 2013	Geo-Sara	Remarks
GPS 1	5.026	5.312	-0.286	
GPS 2	5.023	5.306	-0.283	
GPS 3	5.137	5.421	-0.284	
GPS 4	5.115	5.402	-0.287	
GPS 5	4.838	5.116	-0.278	Thaketa side -0.281
GPS 6	4.855	5.134	-0.279	
CP1	4.039	4.311	-0.272	
CP2	4.499	4.774	-0.275	
CP4	4.244	4.528	-0.284	
		Average	-0.281	

Source: JICA Study Team

2.2.7 Level of Girder Soffit of Existing Thanlyin Bridge

In order to clarify the clearance of the Thanlyin Bridge, leveling survey was conducted at six points. Survey works were conducted twice and the levels of the girder soffit were confirmed as shown in Table 2.2.8.

Source: JICA Study Team

Figure 2.2.6 Location of Six Survey Points for Thanlyin Bridge Girder Soffit

Table 2.2.8 Elevation of Thanlyin Bridge Girder Soffit

NO	FIRST			SECOND			
	EAST	NORTH	ELEVATION	EAST	NORTH	ELEVATION	Difference
1	205372.930	1857890.014	13.232	205368.877	1857897.094	13.225	0.007
2	205316.840	1857987.121	13.150	205316.873	1857987.106	13.198	-0.048
3	205260.784	1858084.086	13.174	205260.871	1858084.133	13.254	-0.080
4	205203.776	1858182.774	13.174	205203.862	1858182.793	13.259	-0.085
5	205147.730	1858279.760	13.152	205147.840	1858279.818	13.254	-0.102
6	205091.693	1858376.789	13.164	205091.760	1858376.830	13.209	-0.045
7	204708.346	1859040.738	11.338				
8	204749.172	1858970.059	11.659				

Source: JICA Study Team

Figure 2.2.7 shows the basic longitudinal section of Thanlyin Bridge. Heavy freight ships mainly pass near the left bank because the clearance gradually gets lower from the center span to the right bank.

Source: JICA Study Team

Figure 2.2.7 Basic Longitudinal Section of Thanlyin Bridge

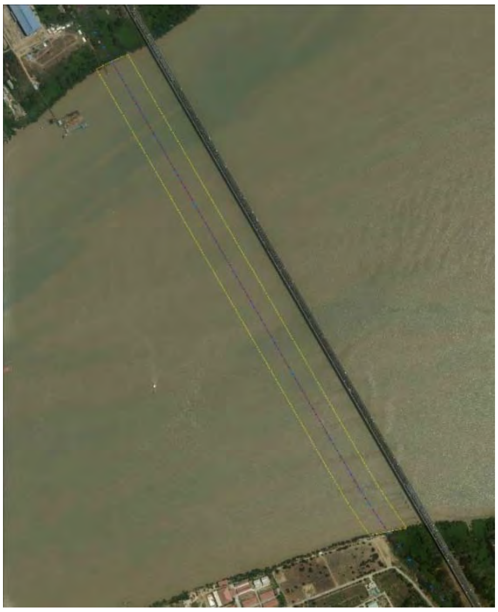
2.2.8 Topographic Survey

In the computer-aided design (CAD) data of topographic map made in the F/S, many initials are used for a layer name, and there were many things which were difficult to read and understand.

Layer name should be easy to know as much as possible. Layer name was newly provided in this topographic survey for the D/D. (see Appendix-9)

2.2.9 Bathymetric Survey

Bathymetric survey was carried out along the main line in the river part (1.93 km) from the middle of November to the middle of December, using the technique of echo sounding system. On the other hand, the technique of real time kinematic (RTK) was employed for the surveys on land.



Source: JICA Study Team

Figure 2.2.8 Location of Bathymetric Survey

Table 2.2.9 Work Quantity of Bathymetric Survey

Work Item	Quantity
1. Route Survey for Bridge Portion (L = 1.928 km)	
1-1 Longitudinal Survey	1.93 km
1-2 Cross-section Survey (50m both sides from	96 sections
1-3 Planimetric Survey (50 m both sides from center	19.3 ha

Source: JICA Study Team

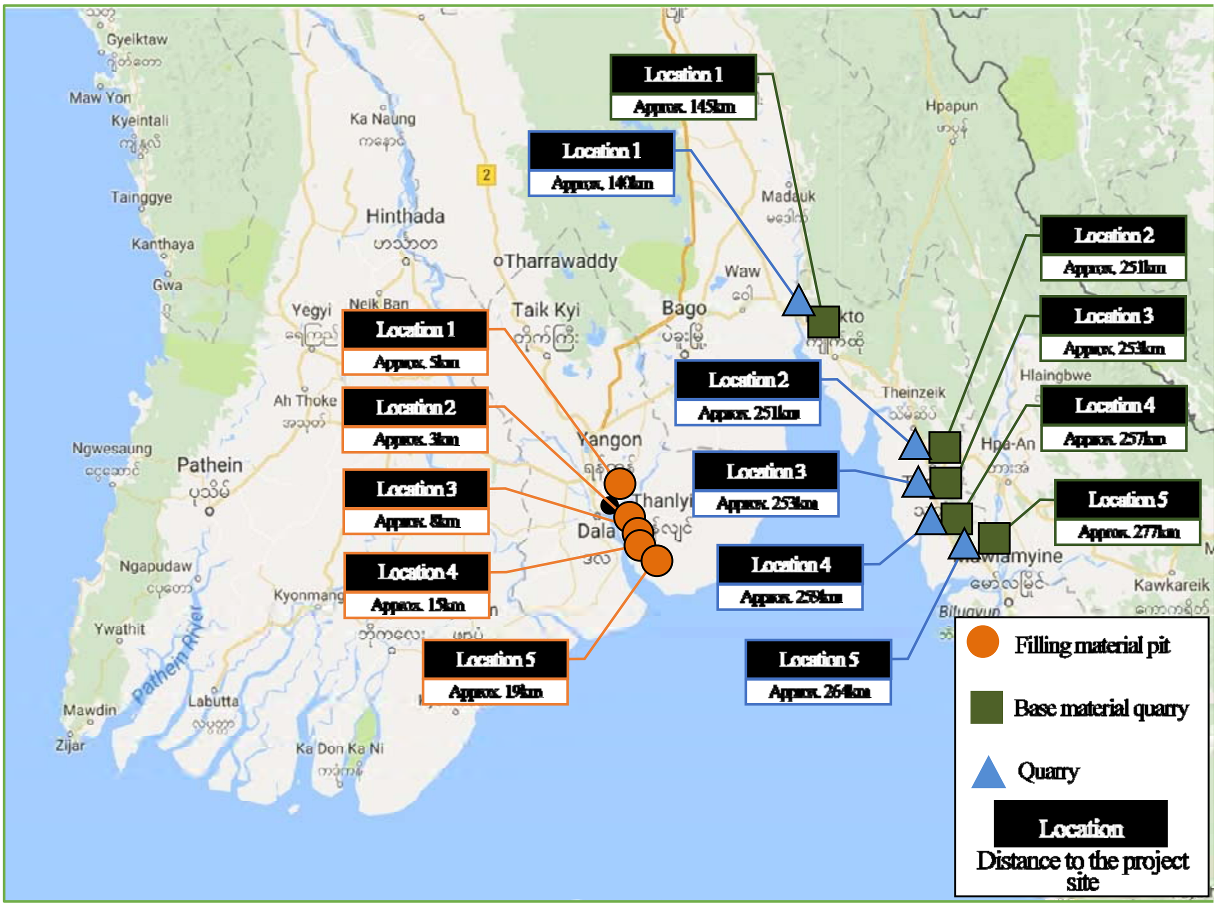
2.3 MATERIAL SURVEY

2.3.1 Survey Scope and Purpose

Material survey will be conducted with pits and quarries for gravel and crushed stone to get information required for construction concerning matters related to transporting capacity such as route, method of transportation from points of material supply to the site, as well as price, quality, and supply capacity. The survey will also be conducted with the suppliers of the materials (e.g. reinforcing bars, steel materials, cement, asphalt, and building equipment). Table 2.3.1 shows the details of the material survey.

(1) Location of Material Survey

The locations of the material survey are shown in Figure 2.3.1.



Source: JICA Study Team

Figure 2.3.1 Locations of Material Survey

(2) Testing Items and Applied Standards System

Testing items and applied standards for material source survey are shown in Table 2.3.1

Table 2.3.1 Standards for Laboratory Testing on Materials

Testing Items	Unit	Qty.	Applied Standards
Material Test for Roadbed			
1)Natural Moisture Content	nos.	12	ASTM D 2216
2)Specific gravity	nos.	12	ASTM D 854
3)Plastic limit	nos.	12	ASTM D 4318
4)Liquid limit	nos.	12	ASTM D 4318
5)Sieve analysis	nos.	12	ASTM D 422
6)Hydrometer test	nos.	12	ASTM D 422
7)Design CBR test	nos.	12	ASTM D 1883
Material Test for Filling			
1)Natural Moisture Content	nos.	15	ASTM D 2216
2)Specific Gravity	nos.	15	ASTM D 854
3)Plastic Limit	nos.	15	ASTM D 4318
4)Liquid Limit	nos.	15	ASTM D 4318
5)Sieve analysis	nos.	15	ASTM D 422
6)Hydrometer test	nos.	15	ASTM D 422
7)Compaction test	nos.	15	ASTM D 698
8)Design CBR test	nos.	15	ASTM D 1883
Material Test for Subgrade			
1)Natural Moisture Content	nos.	15	ASTM D 2216
2)Specific Gravity	nos.	15	ASTM D 854
3)Plastic Limit	nos.	15	ASTM D 4318
4)Liquid Limit	nos.	15	ASTM D 4318
5)Sieve analysis	nos.	15	ASTM D 422
6)Hydrometer test	nos.	15	ASTM D 422
7)Compaction test	nos.	15	ASTM D 1557
8)Modified CBR test	nos.	15	ASTM D 1883
Material Test for Aggregate			
1)Grain Size Analysis	nos.	15	ASTM C 136
2)Specific Gravity	nos.	15	ASTM C 127
3)Water Absorption	nos.	15	ASTM C 127
4)Abrasion	nos.	15	ASTM C 535

Source: JICA Study Team

2.3.2 Material Source's List

(1) List of Material Sources and Prices

The lists of material sources and prices are shown from Table 2.3.2 to Table 2.3.7.

2.3.3 Survey Results

2.3.3.1 Material Test for Roadbed

(1) Location of the Test Pitting Points

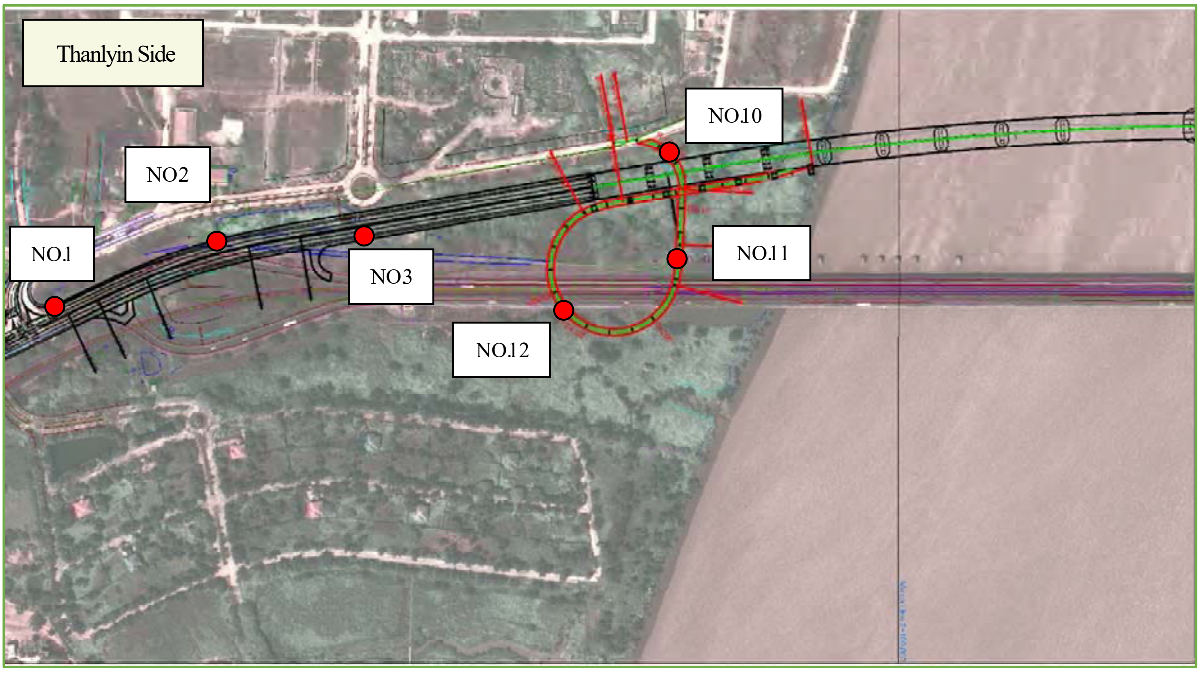
The location of the test pitting points are shown in Table 2.3.18 and from Figure 2.3.2 to Figure 2.3.3.

The location of the test pitting points were selected at intervals of about 100 to 200 m for the earthwork section.

Table 2.3.2 Location of the Test Pitting Points

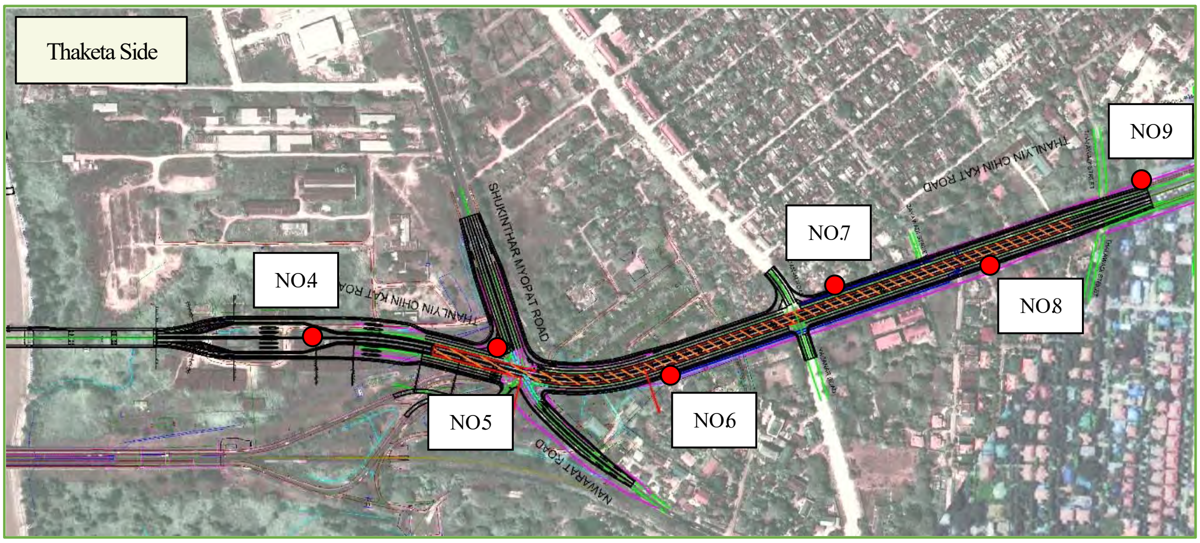
Test Pitting Point	Distance (KM)	Easting (m)	Northing (m)	Remarks
No.1	0+000	205795.000	1857204.000	Main Line
No.2	0+138	205675.000	1857298.000	Main Line
No.3	0+218	205639.000	1857373.000	Main Line
No.4	2+545	204406.000	1859339.000	Main Line
No.5	2+797	204278.000	1859557.000	Main Line
No.6	2+978	204207.000	1859723.000	Main Line
No.7	3+237	204000.000	1859880.000	Main Line
No.8	3+368	203915.000	1859982.000	Main Line
No.9	3+589	203734.000	1860111.000	Main Line
No.10	0+79	205455.000	1857634.000	On Ramp
No.11	1+79	205548.000	1857659.000	On Ramp
No.12	2+81	205574.000	1857574.000	On Ramp

Source: JICA Study Team



Source: JICA Study Team

Figure 2.3.2 Location of the Test Pitting Points (1/2)



Source: JICA Study Team

Figure 2.3.3 Location of the Test Pitting Points (2/2)

(2) Method of Sampling and Laboratory Test

In the road floor material survey in this section, field survey was conducted for 12 places within the designated section, California bearing ratio (CBR) survey spots required for the design were selected, excavation and specimen observation was carried out, and roadside clay CBR test and samples necessary for physical examination were collected.

Drilling survey depth at the survey site was set to 1.0 m lower than the local board surface, excavation by human power was performed, samples of the soil layer were confirmed, and samples of each soil layer were collected and backfilled.

Basically, sampling work is carried out by using shovel. However, No.1 point of roadbed is in road area. There is concrete pavement in this area. Thus, sampling work is performed after removing concrete pavement. Removal of concrete pavement is done by using coring cutter of diameter 160 mm.

The coring cutter used is shown in Photo 2.3.1 below.

Source: JICA Study Team

Photo 2.3.1 Coring Cutter

Specification of coring cutter

- Rated Input: 1,500 W
- Voltage: AC 110-120 V / AC 220-240 V 50/60 Hz
- Speed: 1
- Spindle Revolutions at No Load: 850 rpm
- Spindle Revolutions at Rated Load: 610 rpm
- Recommended Core Bit Diameter: 60-160 mm
- Spindle Thread: UNC 1 -1/4" / A-Rod
- Weight: R1511 motor: 5.9 kg / TS-132(L800): 7.1 kg / TS-132(AB52)(L1000): 9.4 kg
- Height: 803 mm / 1003 mm / 600 + 200 mm (Case)
- Base Size: 146 x 205 mm
- Available Stroke: 548 mm / 748 mm (L1003 mm) / 548 mm (Case)

After removing concrete pavement, sampling is performed by using auger and double scoop. Concrete pavement is repaired by installation of cement after completion of sampling work. Photo 2.3.2 and Photo 2.3.3 shows the auger and double scoop used in the sampling.

Photo 2.3.2 Auger

Photo 2.3.3 Double Scoop

Source: JICA Study Team

Photo of sampling work is shown in Table 2.3.3.

Table 2.3.3 Photo of Sampling Works

No.1

No.2

No.3

No.4

No.5

No.6

No.7

No.8

No.9	No.10
	
No.11	**No.12**
	

Source: JICA Study Team

Laboratory soil tests are shown in Table 2.3.4.

Table 2.3.4 Laboratory Soil Tests

Testing Items	Unit	Qty.	Applied Standards
1) Natural Moisture Content	nos.	12	ASTM D 2216
- Find the ratio of water and the soil included in the soil.			
2) Specific gravity	nos.	12	ASTM D 854
- Find the average mass per unit volume of the soil particle part constituting the soil.			
3) Plastic limit	nos.	12	ASTM D 4318
- Find the boundary between plastic and semi-solid.			
4) Liquid limit	nos.	12	ASTM D 4318
- Find the boundary between liquid and plastic.			
5) Sieve analysis	nos.	12	ASTM D 422
- Separate each particle size of soil and obtain the weight percentage.			
6) Hydrometer test	nos.	12	ASTM D 422
- Separate each particle size of soil and obtain the weight percentage.			
7) Design CBR test	nos.	12	ASTM D 1883
- Evaluate the strength of the subgrade and roadbed.			

Source: JICA Study Team

(3) Survey Results

The laboratory test results are shown in Table 2.3.5 to Table 2.3.8.

According to the laboratory test results, low plasticity to medium plasticity clay layer is well observed in the Thaketa side. Moreover, design CBR value is eight in average.

In the Thanlyin side, percentage of sand is more than the Thaketa side. Moreover, design CBR values are also less than in the Thaketa side, although for some places, value is more than eight.

Table 2.3.5 Summary of Soil Test Results (1/4)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Roadbed — Location : Near Existing Bago River Bridge (Thanlyin Bridge), Thanlyin Township, Yangon Region

Item		Symbol	Unit	No-1	No-2	No-3	No-10	No-11
Depth (m)				~	~	~	~	~
Moisture Content		w	%	23.54	24.25	23.26	62.57	33.69
Bulk Density		ρ t	g/cm³	- / -	- / -	- / -	- / -	- / -
Atterberg's Limit	Liquid Limit	WL	%	35.75	28.45	33.50	65.08	44.20
	Plastic Limit	WP	%	17.58	15.24	17.94	30.27	24.10
	Plasticity Index	IP		18.17	13.21	15.56	34.81	20.10
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	15.15	14.64	22.17	-	-
	Sand, (4.75 ~ 0.075) mm		%	38.15	45.49	41.53	0.72	20.80
	Silt, (0.075 ~ 0.005) mm		%	31.70	29.87	26.80	61.78	47.00
	Clay, (< 0.005 mm)		%	15.00	10.00	9.50	37.50	32.20
Specific Gravity of Soil		Gs (20°C)		2.624	2.645	2.647	2.657	2.659
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m²	- / -	- / -	- / -	- / -	- / -
	Failure Strain	ε_f	%	- / -	- / -	- / -	- / -	- / -
	E_{50}		kN/m²	- / -	- / -	- / -	- / -	- / -
	Sensitivity Ratio			-	-	-	-	-
Design CBR			%	9	4	13	3	4
Unconsolidated Undrained Triaxial	Cohesion	C_{UU}	kN/m²	-	-	-	-	-
	Phi Angle	ϕ_{UU}	Degree	-	-	-	-	-
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m²	-	-	-	-	-
	Phi Angle	ϕ'	Degree	-	-	-	-	-
	Cohesion	C	kN/m²	-	-	-	-	-
	Phi Angle	ϕ	Degree	-	-	-	-	-
Consolidation	Initial Void Ratio	e_0		-	-	-	-	-
	Conso. Yield Stress	P_y	kN/m²	-	-	-	-	-
	Compression Index	C_c		-	-	-	-	-
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SC	SC	SC	CH	CL
		Group Name		Clayey sand with gravel	Clayey sand	Clayey sand with gravel	Fat clay	Lean clay with sand
NOTE	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.6 Summary of Soil Test Results (2/4)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Roadbed — Location : Near Existing Bago River Bridge (Thanlyin Bridge), Thanlyin Township, Yangon Region

Sample No.				No-12				
Depth (m)				~	~	~	~	~
Moisture Content		w	%	24.63				
Bulk Density		ρ t	g/cm³	- / -				
Atterberg's Limit	Liquid Limit	WL	%	-				
	Plastic Limit	WP	%	-				
	Plasticity Index	IP		-				
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	28.41				
	Sand, (4.75 ~ 0.075) mm		%	37.61				
	Silt, (0.075 ~ 0.005) mm		%	24.48				
	Clay, (< 0.005 mm)		%	9.50				
Specific Gravity of Soil		Gs (20°C)		2.649				
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m²	- / -				
	Failure Strain	ε_f	%	- / -				
	E_{50}		kN/m²	- / -				
	Sensitivity Ratio			-				
Design CBR			%	20				
Unconsolidated Undrained Triaxial	Cohesion	C_{UU}	kN/m²	-				
	Phi Angle	ϕ_{UU}	Degree	-				
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m²	-				
	Phi Angle	ϕ'	Degree	-				
	Cohesion	C	kN/m²	-				
	Phi Angle	ϕ	Degree	-				
Consolidation	Initial Void Ratio	e_0		-				
	Conso. Yield Stress	P_y	kN/m²	-				
	Compression Index	C_c		-				
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SM (or) SC				
		Group Name		Silty sand with gravel (or) Clayey sand with gravel				
NOTE	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.7 Summary of Soil Test Results (3/4)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Roadbed — Location : Near Existing Bago River Bridge (Thanlyin Bridge), Thaketa Township, Yangon Region

Sample No.				No-4 (1st)	No-4 (2nd)	No-4 (3rd)	No-5	No-6
Depth (m)				0.50 ~ 0.60	0.60 ~ 0.80	0.80 ~ 1.00	~	~
Moisture Content		w	%	13.15	21.56	25.23	27.67	13.09
Bulk Density		ρ_t	g/cm³	-	-	-	-	-
				-	-	-	-	-
Atterberg's Limit	Liquid Limit	WL	%	-	22.18	33.90	43.75	30.20
	Plastic Limit	WP	%	-	13.39	17.80	22.68	16.75
	Plasticity Index	IP		-	8.79	16.10	21.07	13.45
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	1.44	1.10	-	0.81	7.72
	Sand, (4.75 ~ 0.075) mm		%	87.84	49.00	13.76	9.18	43.63
	Silt, (0.075 ~ 0.005) mm		%	6.52	39.90	71.24	71.81	42.16
	Clay, (< 0.005 mm)		%	4.20	10.00	15.00	18.20	6.50
Specific Gravity of Soil		Gs (20°C)		2.657	2.678	2.677	2.643	2.652
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m²	-	-	-	-	-
				-	-	-	-	-
	Failure Strain	ε_f	%	-	-	-	-	-
				-	-	-	-	-
	E_{50}		kN/m²	-	-	-	-	-
				-	-	-	-	-
	Sensitivity Ratio			-	-	-	-	-
Design CBR			%		8		8	7
Unconsolidated Undrained Triaxial	Cohesion	C_{UU}	kN/m²	-	-	-	-	-
	Phi Angle	ϕ_{UU}	Degree	-	-	-	-	-
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m²	-	-	-	-	-
	Phi Angle	ϕ'	Degree	-	-	-	-	-
	Cohesion	C	kN/m²	-	-	-	-	-
	Phi Angle	ϕ	Degree	-	-	-	-	-
Consolidation	Initial Void Ratio	e_0		-	-	-	-	-
	Conso. Yield Stress	P_y	kN/m²	-	-	-	-	-
	Compression Index	C_c		-	-	-	-	-
Soil Classification (ASTM D 2487 - 06)	Group Symbol			SP-SM (or) SP-SC	SC	CL	CL	SC
	Group Name			Poorly graded sand with silt (or) Poorly graded sand with clay (or silty clay)	Clayey sand	Lean clay	Lean clay	Clayey sand
NOTE								
	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.8 Summary of Soil Test Results (4/4)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Roadbed — Location : Near Existing Bago River Bridge (Thanlyin Bridge), Thaketa Township, Yangon Region

				No-7	No-8	No-9		
Sample No.				No-7	No-8	No-9		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	20.06	12.59	16.99		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	29.27	30.79	34.55		
	Plastic Limit	WP	%	19.24	18.45	19.29		
	Plasticity Index	IP		10.03	12.34	15.26		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	2.00	3.47	-		
	Sand, (4.75 ~ 0.075) mm		%	18.18	18.38	7.55		
	Silt, (0.075 ~ 0.005) mm		%	69.62	68.96	80.65		
	Clay, (< 0.005 mm)		%	10.20	9.20	11.80		
Specific Gravity of Soil		Gs (20°C)		2.642	2.642	2.672		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Design CBR			%	3	13	9		
Unconsolidated Undrained Triaxial	Cohesion	C_{UU}	kN/m^2	-	-	-		
	Phi Angle	ϕ_{UU}	Degree	-	-	-		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		CL	CL	CL		
		Group Name		Lean clay with sand	Lean clay with sand	Lean clay		
NOTE	Data used for reference are shown by red color.							

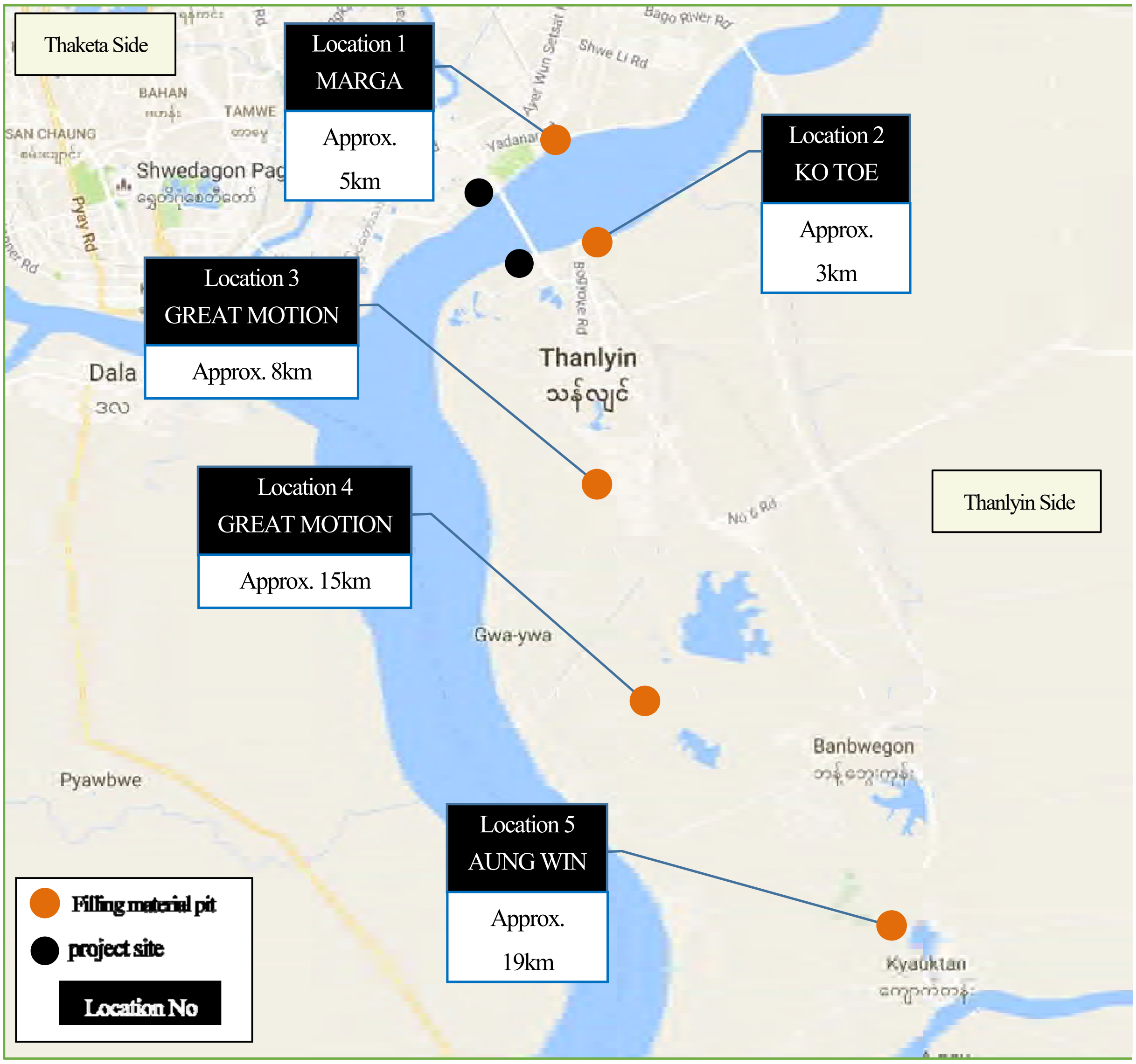
Source: JICA Study Team

2.3.3.2 Material Test for Filling

(1) Location of Surveys

The location of the surveys is shown in Figure 2.3.4.

The material sampling site was selected by price, quality, and supply area near the project site.



Source: JICA Study Team

Figure 2.3.4 Location of Surveys

The selected locations are shown in Table 2.3.9 to Table 2.3.13.

Table 2.3.9 Selected Location (1/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
1	Dagon Seikkan, Yangon	Marga, near the corner of Seikkan Thar Road and Mya Nandar Road, beside a shipyard, Tel: 0949207344 **Coordinate** **E206765.580; N1860458.260**	1.4 ha	

Soil Type

- Soil type: Sand with trace of silt, yellowish gray mottled.
- Exploitation condition: easily.

Transport Route to the Project Site

- Distance to the project site: Approximately 5 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2	Photo 3
		

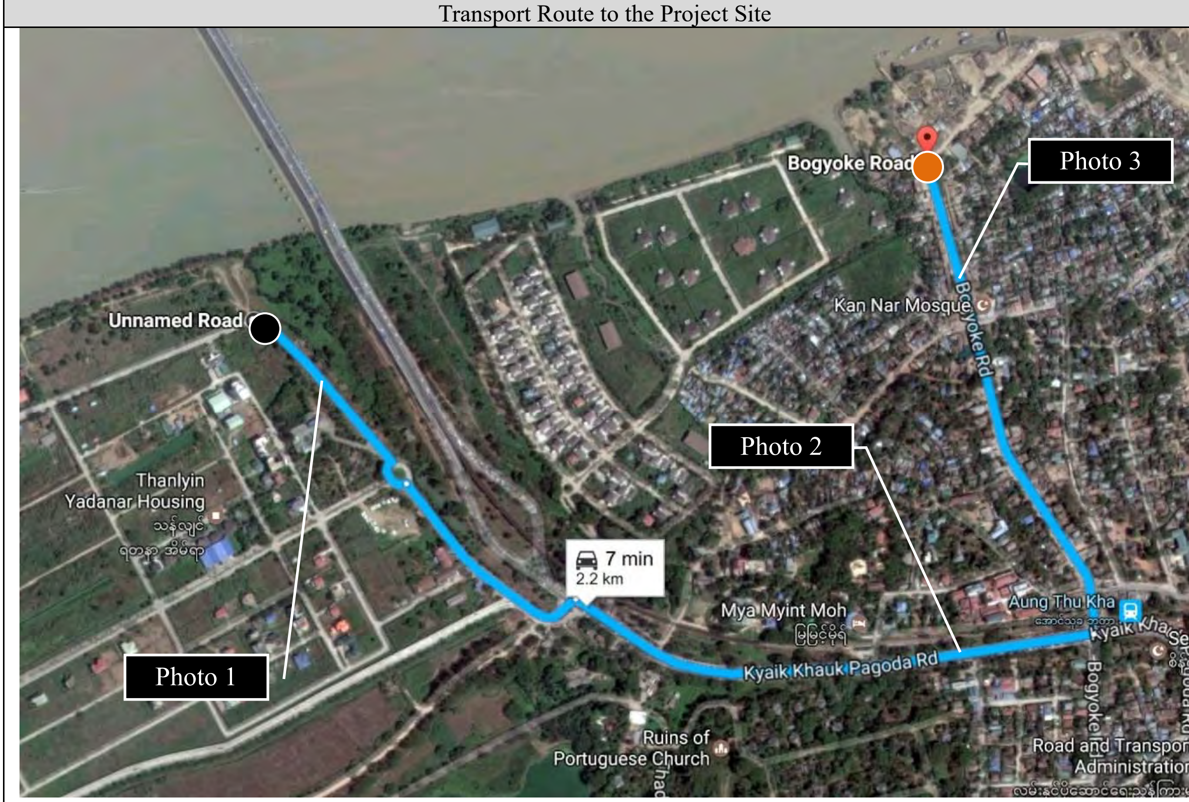
Table 2.3.10 Selected Location (2/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
2	Thida Jetty Compound, Thanlyin	Ko Toe, Thida Jetty Compound, Thanlyin Township, Yangon; 095091761, 09420018126, 09420301818 Coordinate E206246.650; N1857874.810	2.2 ha	

Soil Type

- Soil type: Sand with trace of silt, yellowish gray mottled.
- Exploitation condition: easily

Transport Route to the Project Site

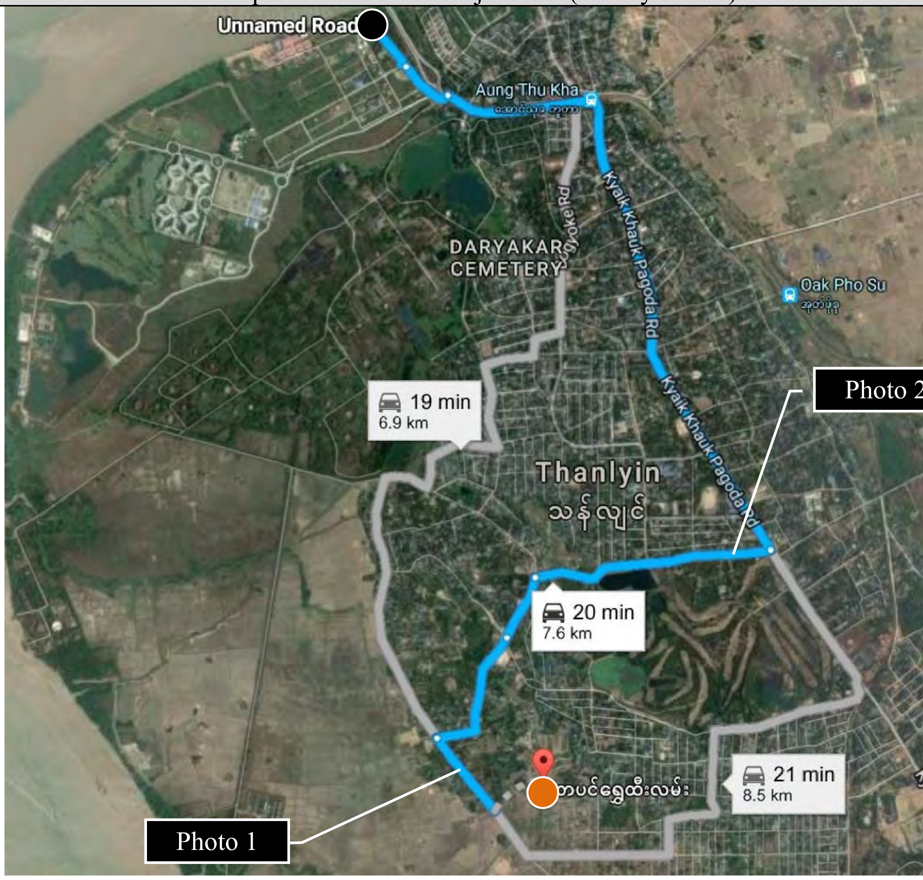


- Distance to the project site: Approximately 3 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2	Photo 3
		

Table 2.3.11 Selected Location (3/5)

<table>
<tr><th>Location</th><th>Address of Stockyard</th><th>Company/Supplier/Coordinate</th><th>Approximate Area</th><th>Location Photos</th></tr>
<tr><td>3</td><td>Thanlyin, Yangon</td><td>Great Motion Co., Ltd. No. 17, D, Masoeyeik Street, (5) Quarter, Mayangone, Yangon
Coordinate E206384.600 ; N1853185.660</td><td>0.4 ha</td><td></td></tr>
<tr><th colspan="5">Soil Type</th></tr>
<tr><td colspan="5">- Soil type: Latertic soil, red and yellow mottled
- Exploitation condition: easily</td></tr>
<tr><th colspan="5">Transport Route to the Project Site (Thanlyin Side)</th></tr>
<tr><td colspan="5">

- Distance to the project site: Approximately 8 km
- Transportation condition: easily by roadway</td></tr>
<tr><th colspan="5">Photograph of Transport Route (Thanlyin Side)</th></tr>
<tr><th colspan="3">Photo 1</th><th colspan="2">Photo 2</th></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
</table>

Transport Route to the Project Site (Thaketa Side)

- Distance to the project site: Approximately 30 km
- Transportation condition: easily by roadway

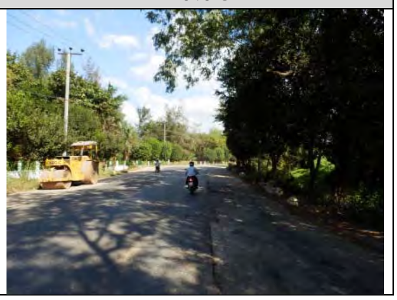
Photograph of Transport Route (Thaketa Side)		
Photo 1	Photo 2	Photo 3
		

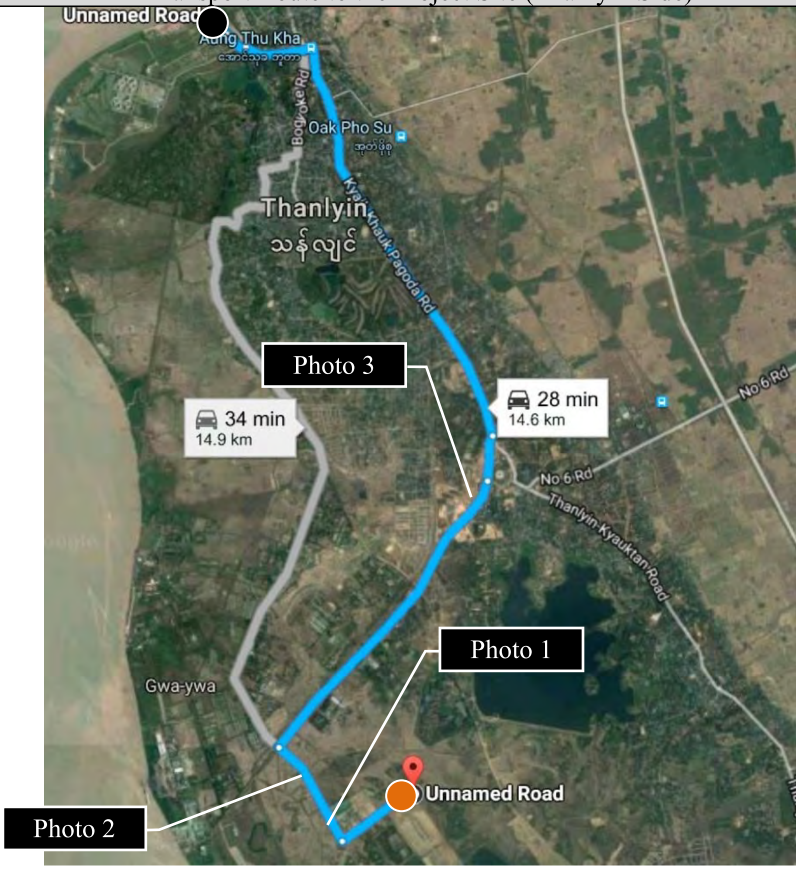
Table 2.3.12 Selected Location (4/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
4	Thanlyin, Yangon	Great Motion Co., Ltd. No. 17, D, Masoeyeik Street, (5) Quarter, Mayangone, Yangon **Coordinate E207825.110 ; N1847689.500**	1.1 ha	

Soil Type

- Soil type: Latertic soil, red and yellow mottled.
- Exploitation condition: easily

Transport Route to the Project Site (Thanlyin Side)

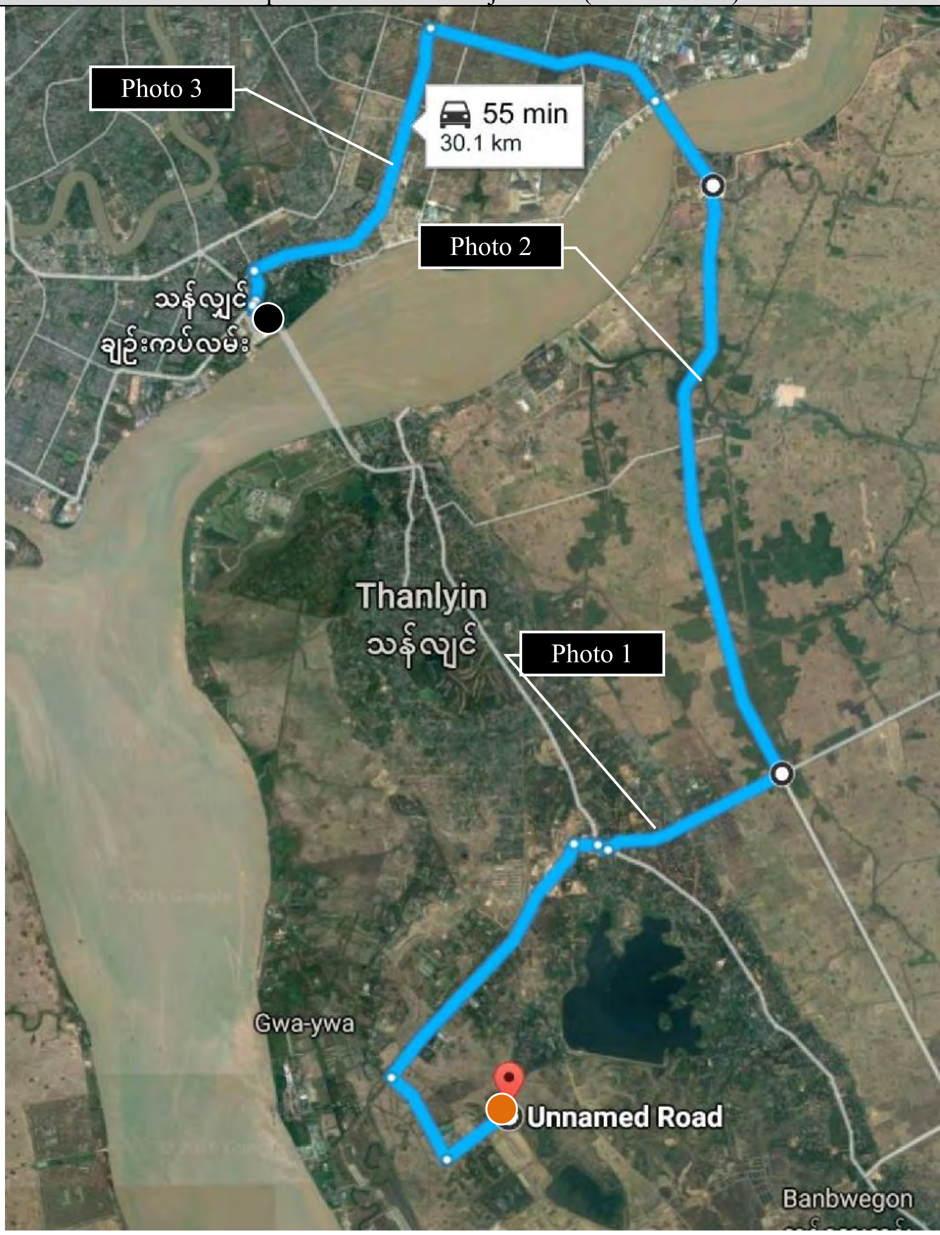


- Distance to the project site: Approximately 15 km
- Transportation condition: easily by roadway

Photograph of Transport Route (Thanlyin Side)

Photo 1	Photo 2	Photo 3
		

Transport Route to the Project Site (Thaketa Side)



- Distance to the project site: Approximately 31 km
- Transportation condition: easily by roadway

Photograph of Transport Route (Thaketa Side)

Photo 1	Photo 2	Photo 3
		

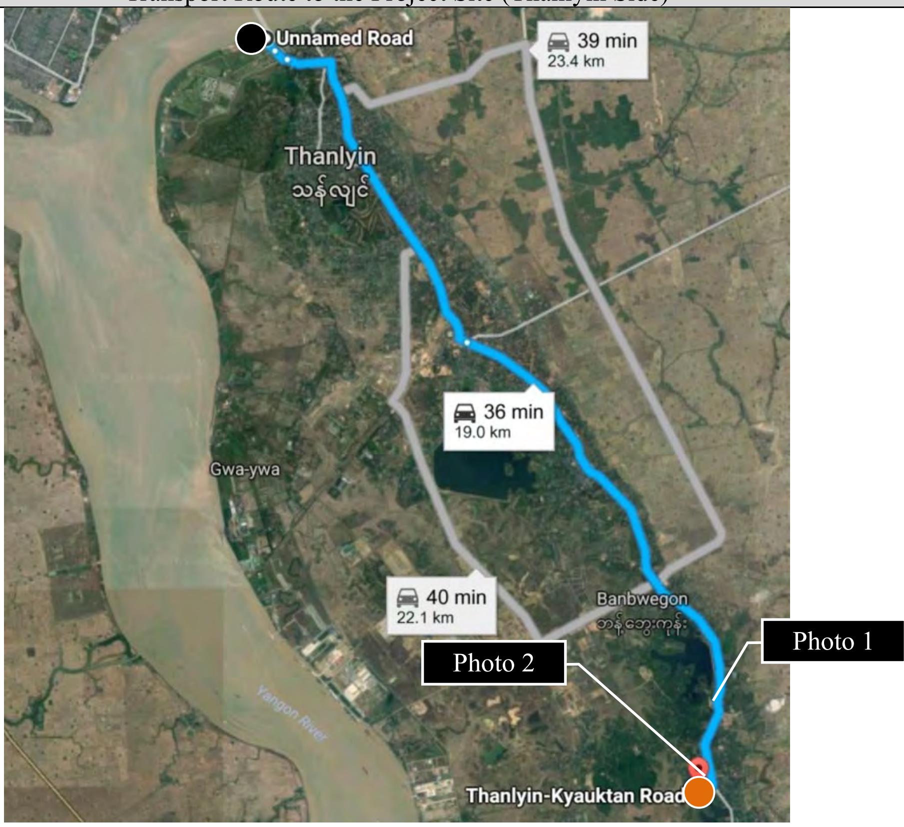
Table 2.3.13 Selected Location (5/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
5	Kyauktan, Yangon	Aung Win, Kyauktan, Township, Yangon Tel; 09799444909 **Coordinate E 213646.040 ; N 1842158.930**	7.4 ha	

Soil Type

- Soil type: Latertic soil, reddish brown.
- Exploitation condition: easily.

Transport Route to the Project Site (Thanlyin Side)

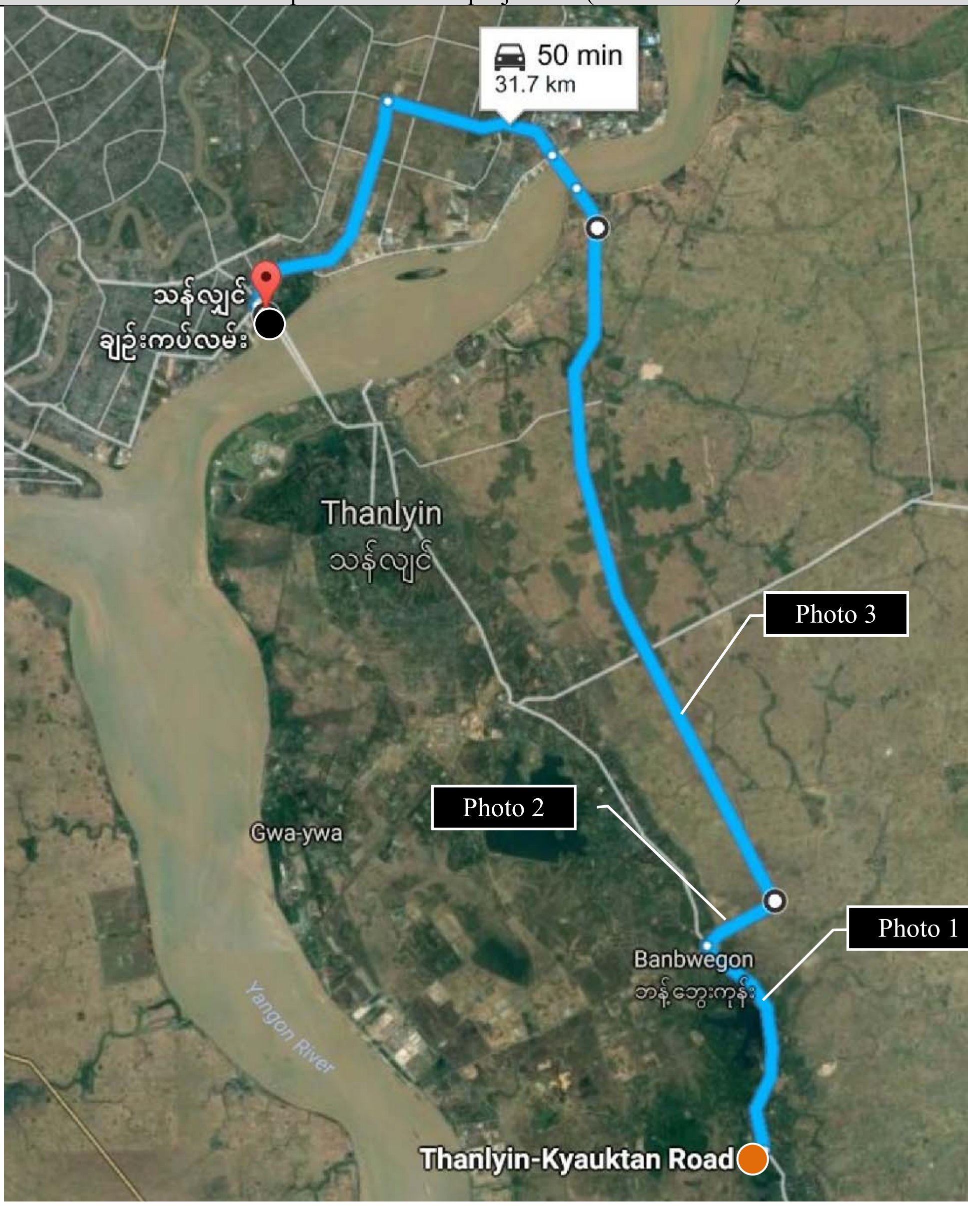


- Distance to the project site: Approximately 19 km
- Transportation condition: easily by roadway

Photograph of Transport Route (Thanlyin Side)

Photo 1	Photo 2
	

Transport route to the project site(Thaketa Side)



- Distance to the project site: Approximately 32 km
- Transportation condition: easily by roadway

Photograph of Transport Route (Thaketa Side)

Photo 1	Photo 2	Photo 3
		

(2) Method of Sampling and Laboratory Test

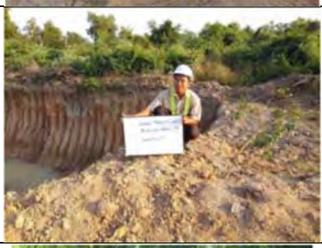
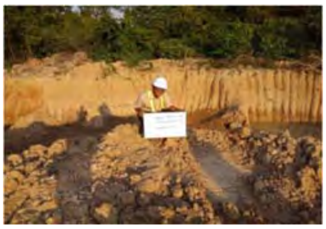
The amount of soil collected for the soil test and compounding test of the filling material is about 40 kg to 50 kg. After harvesting at the site, it was sealed and transported to the test room so the natural water content ratio did not change. Also, as much as possible, the JICA Study Team picked up the surface soil and collected it.

Soil sampling is performed by using auger and double scoop.

5 borrow pits x 3 testing samples = 15 testing samples.

Photo of sampling work is shown in Table 2.3.14.

Table 2.3.14 Photo of Sampling Works

Location	Soil Sampling		
	No. 1	No. 2	No. 3
1 MARGA, THILAWA AREA			
2 KO TOE, THANLYIN AREA			
3 GREAT MOTION, THANLYIN AREA			
4 GREAT MOTION, THILAWA AREA			
5 AUNG WIN, KYAUKTAN AREA			

Source: JICA Study Team

Laboratory soil tests are shown in Table 2.3.15.

Table 2.3.15 Laboratory Soil Tests

Testing Items	Unit	Qty.	Applied Standards
1) Natural Moisture Content	nos.	15	ASTM D 2216
-Find the ratio of water and the soil included in the soil.			
2) Specific Gravity	nos.	15	ASTM D 854
-Find the average mass per unit volume of the soil particle part constituting the soil.			
3) Plastic Limit	nos.	15	ASTM D 4318
-Find the boundary between plastic and semi-solid.			
4) Liquid Limit	nos.	15	ASTM D 4318
-Find the boundary between liquid and plastic.			
5) Sieve Analysis	nos.	15	ASTM D 422
-Separate each particle size of soil and obtain the weight percentage.			
6) Hydrometer Test	nos.	15	ASTM D 422
-Separate each particle size of soil and obtain the weight percentage.			
7) Compaction Test	nos.	15	ASTM D 698
-Find the reference density required for embankment management.			
8) Design CBR Test	nos.	15	ASTM D 1883
-Evaluate the strength of the subgrade and roadbed.			

Source: JICA Study Team

(3) Survey Results

The laboratory test results are shown in Table 2.3.16 to Table 2.3.20.

Based on the laboratory test results, the Aung Win, Kyauk Tan location sample has the maximum dry density more than the other places. The soil type is clayey sand. The second maximum dry density is jn Great Motion, Thanlyin location. The soil type of this location is fat clay.

The maximum dry density of Ko Toe, Thanlyin location is more than Marga, Thilawa sand location. Moreover, design CBR is also more than that location.

Table 2.3.16 Summary of Soil Test Results (Marga, Thilawa Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Filling				Location 1 MARGA, Seikkan Thar street, Dagon Seikkan Township, Yangon Region				
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	2.43	1.67	0.95		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-		-		
Atterberg's Limit	Liquid Limit	WL	%	NA	NA	NA		
	Plastic Limit	WP	%	NA	NA	NA		
	Plasticity Index	IP		NA	NA	NA		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	2.93	3.68	2.84		
	Sand, (4.75 ~ 0.075) mm		%	95.04	93.36	94.70		
	Silt, (0.075 ~ 0.005) mm		%	2.03	2.97	2.46		
	Clay, (< 0.005 mm)		%					
Specific Gravity of Soil		Gs (20°C)		2.661	2.681	2.654		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	1.627	1.647	1.639		
	Optimun Moisture Content	W_{opt}	%	14.80	14.80	16.00		
Design CBR			%	11	15	14		
Consolidated Undrained Triaxial Compression Test (Measurement of Pore	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SP	SP	SP		
		Group Name		Poorly graded sand	Poorly graded sand	Poorly graded sand		

NOTE

Data used for reference are shown by red color.

Source: JICA Study Team

Table 2.3.17 Summary of Soil Test Results (Ko Toe, Thanlyin Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Filling			Location 2 KO TOE, Thida Jetty Compound, Thanlyin Township, Yangon Region				
Sample No.			Location - 1	Location - 2	Location - 3		
Depth (m)			~	~	~	~	~
Moisture Content		w %	1.89	2.95	1.90		
Bulk Density		ρ_t g/cm^3	-	-	-		
			-	-	-		
Atterberg's Limit	Liquid Limit	WL %	NA	NA	NA		
	Plastic Limit	WP %	NA	NA	NA		
	Plasticity Index	IP	NA	NA	NA		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm	%	7.33	3.68	9.24		
	Sand, (4.75 ~ 0.075) mm	%	91.79	95.65	90.24		
	Silt, (0.075 ~ 0.005) mm	%	0.88	0.67	0.53		
	Clay, (< 0.005 mm)	%					
Specific Gravity of Soil		Gs (20°C)	2.637	2.648	2.647		
Unconfined Compression	Unconfined Compressive Strength	q_u kN/m^2	-	-	-		
			-	-	-		
	Failure Strain	ε_f %	-	-	-		
			-	-	-		
	E_{50}	kN/m^2	-	-	-		
			-	-	-		
	Sensitivity Ratio		-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max} t/m^3	1.786	1.736	1.732		
	Optimun Moisture Content	W_{opt} %	13.20	14.40	15.60		
Design CBR		%	20	17	12		
Consolidated Undrained Triaxial Compression Test (Measurement of Pore	Cohesion	C' kN/m^2	-	-	-		
	Phi Angle	ϕ' Degree	-	-	-		
	Cohesion	C kN/m^2	-	-	-		
	Phi Angle	ϕ Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0	-	-	-		
	Conso. Yield Stress	P_y kN/m^2	-	-	-		
	Compression Index	C_c	-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol	SP	SP	SP		
		Group Name	Poorly graded sand	Poorly graded sand	Poorly graded sand		

NOTE

Data used for reference are shown by red color.

Source: JICA Study Team

Table 2.3.18 Summary of Soil Test Results (Great Motion, Thanlyin Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Filling				Location 3 GREAT MOTION, Thanlyin Borrow Pit, Thanlyin Township, Yangon Region				
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	11.93	11.86	12.78		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	60.95	67.60	63.20		
	Plastic Limit	WP	%	23.14	22.78	23.08		
	Plasticity Index	IP		37.81	44.82	40.12		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	1.34	0.43	-		
	Sand, (4.75 ~ 0.075) mm		%	11.53	5.82	4.99		
	Silt, (0.075 ~ 0.005) mm		%	47.33	53.45	57.61		
	Clay, (< 0.005 mm)		%	39.80	40.30	37.40		
Specific Gravity of Soil		Gs (20°C)		2.712	2.716	2.710		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	1.743	1.737	1.730		
	Optimun Moisture Content	W_{opt}	%	17.20	18.20	18.20		
Design CBR			%	2	1	1		
Consolidated Undrained Triaxial Compression Test (Measurement of Pore	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		CH	CH	CH		
		Group Name		Fat clay	Fat clay	Fat clay		

NOTE

Data used for reference are shown by red color.

Source: JICA Study Team

Table 2.3.19 Summary of Soil Test Results (Great Motion, Thilawa Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Filling — Location 4 GREAT MOTION, Thilawa Borrow Pit, Thanlyin Township, Yangon Region

					Location - 1	Location - 2	Location - 3		
Sample No.					Location - 1	Location - 2	Location - 3		
Depth (m)					~	~	~	~	~
Moisture Content		w	%		10.91	11.90	11.33		
Bulk Density		ρ_t	g/cm^3		-	-	-		
					-	-	-		
Atterberg's Limit	Liquid Limit	WL	%		47.05	49.05	46.65		
	Plastic Limit	WP	%		25.73	26.23	25.24		
	Plasticity Index	IP			21.32	22.82	21.41		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%		12.67	10.61	8.04		
	Sand, (4.75 ~ 0.075) mm		%		25.50	26.05	22.65		
	Silt, (0.075 ~ 0.005) mm		%		37.83	41.23	41.91		
	Clay, (< 0.005 mm)		%		24.00	22.10	27.40		
Specific Gravity of Soil		Gs (20°C)			2.659	2.668	2.658		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2		-	-	-		
					-	-	-		
	Failure Strain	ε_f	%		-	-	-		
					-	-	-		
	E_{50}		kN/m^2		-	-	-		
					-	-	-		
	Sensitivity Ratio				-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3		1.674	1.674	1.672		
	Optimun Moisture Content	W_{opt}	%		20.40	20.40	20.60		
Design CBR			%		4	5	4		
Consolidated Undrained Triaxial Compression Test (Measurement of Pore	Cohesion	C'	kN/m^2		-	-	-		
	Phi Angle	ϕ'	Degree		-	-	-		
	Cohesion	C	kN/m^2		-	-	-		
	Phi Angle	ϕ	Degree		-	-	-		
Consolidation	Initial Void Ratio	e_0			-	-	-		
	Conso. Yield Stress	P_y	kN/m^2		-	-	-		
	Compression Index	C_c			-	-	-		
Soil Classification (ASTM D 2487 - 06)				Group Symbol	CL	CL	CL		
				Group Name	Sandy lean clay	Sandy Lean clay	Sandy lean clay		

NOTE

Data used for reference are shown by red color.

Source: JICA Study Team

Table 2.3.20 Summary of Soil Test Results (Aung Win, Kyauktan Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Filling				Location 5 AUNG WIN, Kyauktan Township, Yangon Region					
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	14.15	10.87	15.43		
Bulk Density		ρ t	g/cm³	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	30.78	20.91	39.35		
	Plastic Limit	WP	%	17.94	10.81	21.91		
	Plasticity Index	IP		12.84	10.10	17.44		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	11.78	18.98	15.01		
	Sand, (4.75 ~ 0.075) mm		%	42.80	43.73	41.42		
	Silt, (0.075 ~ 0.005) mm		%	20.62	19.59	18.97		
	Clay, (< 0.005 mm)		%	24.80	17.70	24.60		
Specific Gravity of Soil		Gs (20°C)		2.641	2.624	2.635		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m²	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m²	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m³	1.844	1.865	1.843		
	Optimun Moisture Content	W_{opt}	%	15.70	14.60	15.00		
Design CBR			%	34	5	4		
Consolidated Undrained Triaxial Compression Test (Measurement of Pore	Cohesion	C'	kN/m²	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m²	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m²	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SC	SC	SC		
		Group Name		Clayey sand	Clayey sand with gravel	Clayey sand with gravel		

NOTE

Data used for reference are shown by red color.

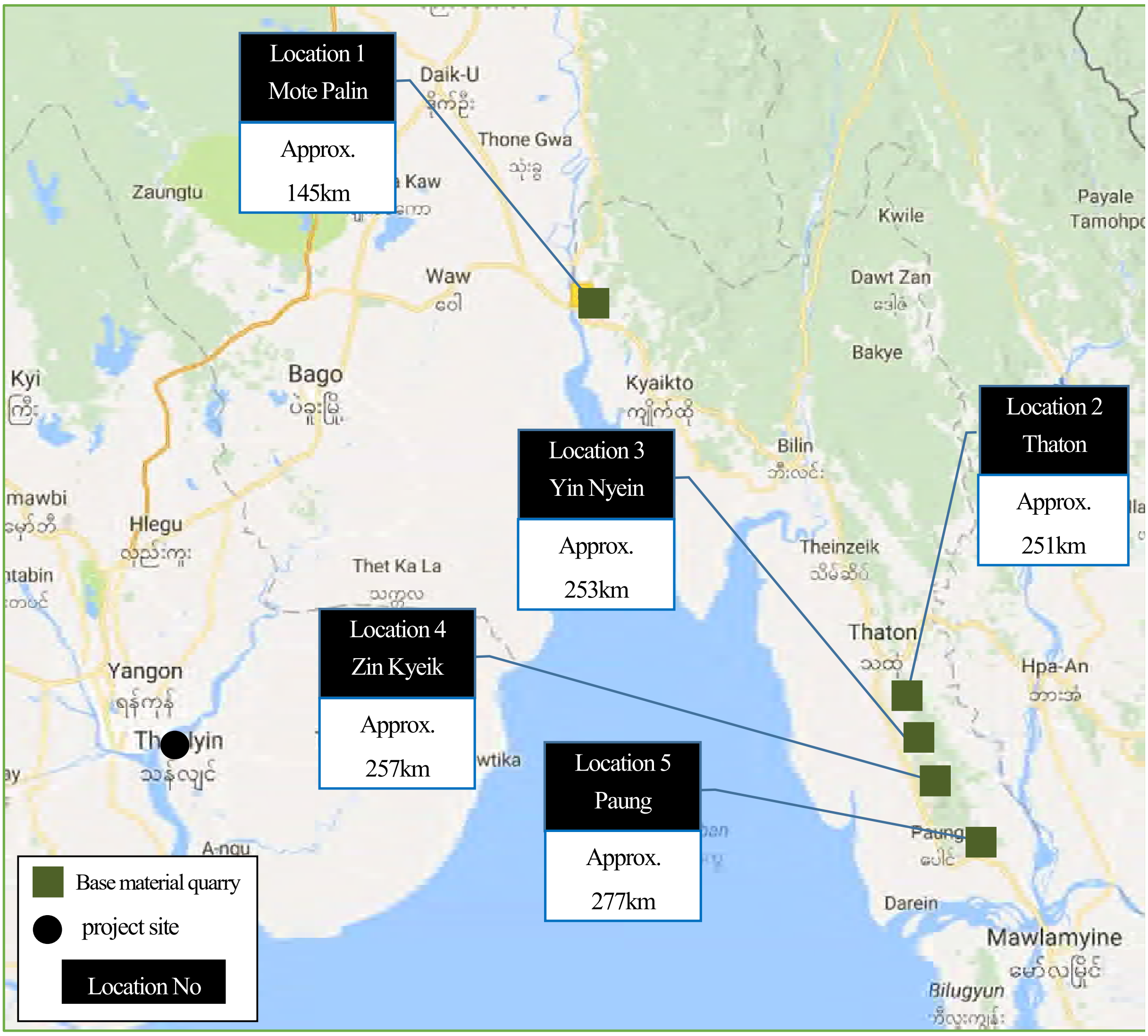
Source: JICA Study Team

2.3.3.3 Material Test for Subgrade

(1) Location of Surveys

The locations of surveys are shown in Figure 2.3.5.

The material sampling site was selected by price, quality, and supply area near the project site.



Source: JICA Study Team

Figure 2.3.5 Location of Surveys

The selected locations are shown in Table 2.3.21 to Table 2.3.25.

Table 2.3.21 Selected Location (1/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location photos
1	Mote Palin Township	Mote Palin Correctional Department **Coordinate E 279932.000 ; N 1928180.000**	11.0 ha	No photograph

Soil Type

- Soil type: CLAY with trace SAND, reddish brown.
- Exploitation condition: easily.

Transport Route to the Project Site

- Distance to the project site: Approximately 145 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

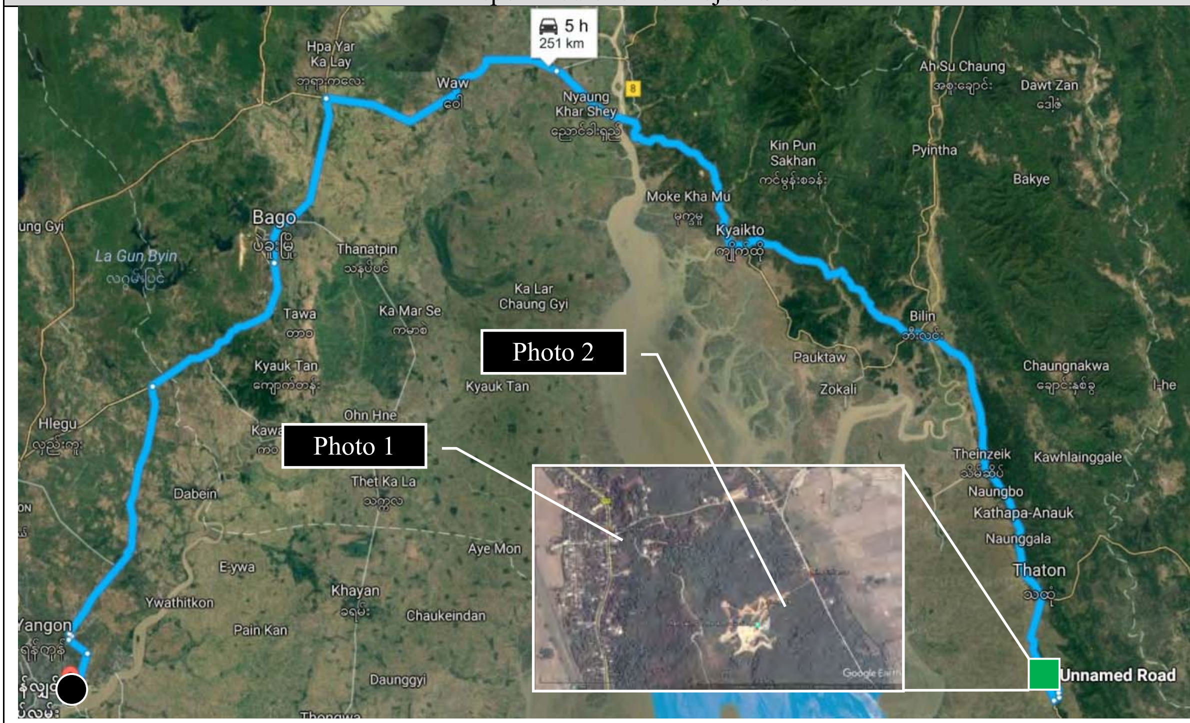
Table 2.3.22 Selected Location (2/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
2	Thaton Township	Than Lwin Oo (Rock Production) **Coordinate E327348.000 ; N1860711.000**	3.4 ha	

Soil Type

- Soil type: CLAY with trace SAND, yellowish brown and yellowish gray mottled.
- Exploitation condition: easily

Transport Route to the Project Site



- Distance to the project site: Approximately 251 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

Table 2.3.23 Selected Location (3/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
3	Yin Nyein Village	Inn Byaung Correctional Department **Coordinate E330380.000 ; N1853893.000**	3.2 ha	

Soil Type

- Soil type: CLAY with trace SAND, reddish brown.
- Exploitative condition: easily.

Transport Route to the Project Site

- Distance to the project site: Approximately 253 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

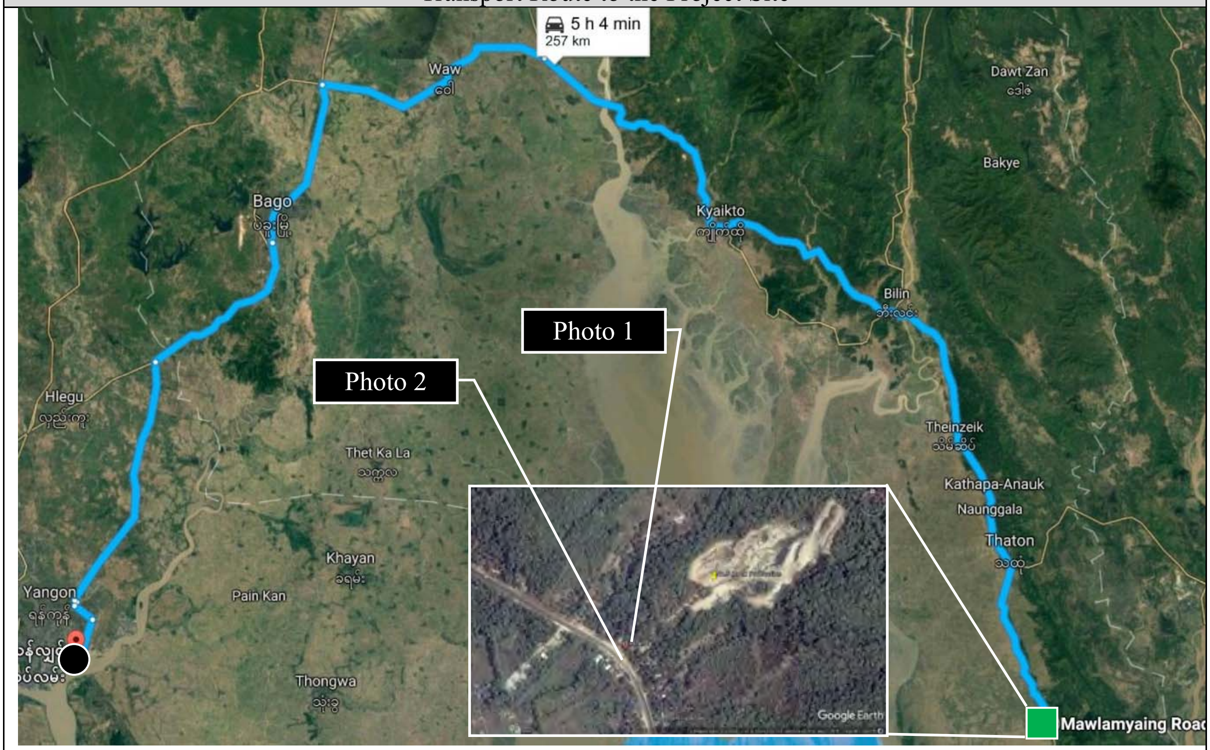
Table 2.3.24 Selected Location (4/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
4	Zin Kyeik Township	No. 5 Rock Production **Coordinate E331465.000 ; N 1850075.000**	2.2 ha	

Soil Type

- Soil type: CLAY with trace SAND, reddish brown.
- Exploitation condition: easily.

Transport Route to the Project Site



- Distance to the project site: Approx. 257 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

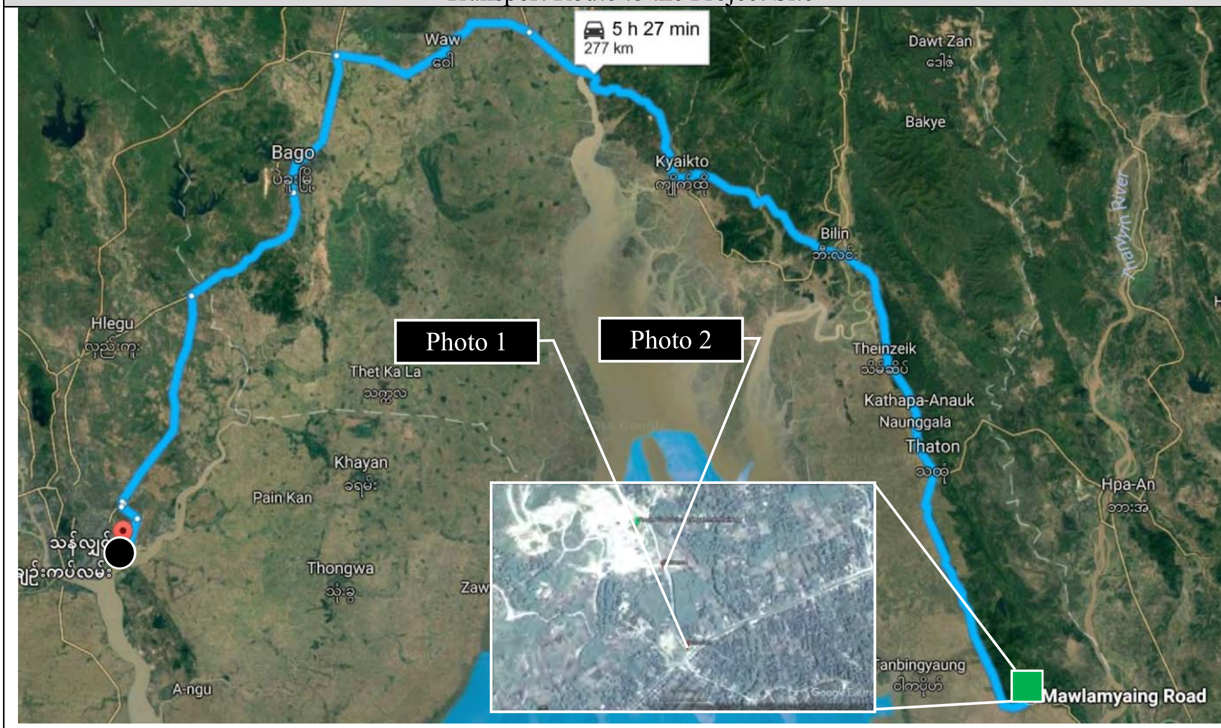
Table 2.3.25 Selected Location (5/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
5	Paung Township	Rock Production of Myanmar Railway **Coordinate E340482.000 ; N1836825.000**	12.4 ha	

Soil Type

- Soil type: CLAY with trace SAND, light gray and browish gray mottled.
- Exploitation condition: easily.

Transport Route to the Project Site



- Distance to the project site: Approximately 277 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

(2) Method of Sampling and Laboratory Test

- Three locations near the middle of mountain slopes of material were randomly selected.

- Considering the homogeneity of the sample, avoiding the material particle size and the portion with impurities are liable to be biased due to the influence of wind, rain, and gravity.

- Sampling was done 30 cm below from the surface of the sampling place.

- Samples were taken at about 6 to 7 kg (roughly two scoops) per sampling place and placed in a soil bag.

The photo of sampling work is shown in Table 2.3.26.

Table 2.3.26 Photo of Sampling Works

Location	Soil Sampling		
	No. 1	No. 2	No. 3
1 Mote Palin Area	No photograph	No photograph	No photograph
2 Thaton Area			
3 Yinnyein Area			
4 Zinkyeik Area			
5 Poung Area			

Source: JICA Study Team

The laboratory soil tests are shown in Table 2.3.27.

Table 2.3.27 Laboratory Soil Tests

Testing Items	Unit	Qty.	Applied Standards
1) Natural Moisture Content	nos.	15	ASTM D 2216
-Find the ratio of water and the soil included in the soil.			
2) Specific Gravity	nos.	15	ASTM D 854
-Find the average mass per unit volume of the soil particle part constituting the soil.			
3) Plastic Limit	nos.	15	ASTM D 4318
-Find the boundary between plastic and semi-solid.			
4) Liquid Limit	nos.	15	ASTM D 4318
-Find the boundary between liquid and plastic.			
5) Sieve analysis	nos.	15	ASTM D 422
-Separate each particle size of soil and obtain the weight percentage.			
6) Hydrometer test	nos.	15	ASTM D 422
-Separate each particle size of soil and obtain the weight percentage.			
7) Compaction test	nos.	15	ASTM D 1557
-Find the reference density required for embankment management.			
8) Modified CBR test	nos.	15	ASTM D 1883
-Evaluate the strength of the subgrade and roadbed.			

Source: JICA Study Team

(3) Survey Results

The laboratory test results are shown in Table 2.3.28 to Table 2.3.32.

Based on the laboratory test results, all soils are sandy soil location. The maximum dry density of Paung and Zin Kyeik location is more than 2 t/m^3. The modified CBR results are more than 50 in average.

The maximum dry density of Thaton and Yinnyein locations is also 1.9 t/m^3 in average. The average modified CBR values are also 40 in average.

Table 2.3.28 Summary of Soil Test Results (Mote Palin Area)

SUMMARY OF SOIL TEST RESULTS

				Location - 1	Location - 2	Location - 3		
Project Name : Material Test for Bago River Bridge Construction Project								
Material Test for Subgrade				Location 1 Moke Palin Correctional Department, Moke Palin Area, Mon State				
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	19.46	32.89	28.47		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	41.56	41.44	38.38		
	Plastic Limit	WP	%	32.40	34.12	31.65		
	Plasticity Index	IP		9.16	7.32	6.73		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	9.96	8.81	8.93		
	Sand, (4.75 ~ 0.075) mm		%	53.22	53.51	55.05		
	Silt, (0.075 ~ 0.005) mm		%	30.82	30.07	28.92		
	Clay, (< 0.005 mm)		%	6.00	7.60	7.10		
Specific Gravity of Soil		Gs (20°C)		2.636	2.670	2.672		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	1.744	1.730	1.767		
	Optimun Moisture Content	W_{opt}	%	17.70	18.50	16.60		
Modified CBR (ρd_{max} - 95 %)			(%)	26.50	31.40	36.80		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SM	SM	SM		
		Group Name		Silty sand	Silty sand	Silty sand		
NOTE	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.29 Summary of Soil Test Results (Thaton Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Subgrade — Location 2 Than Lwin Oo Rock Production, Thaton Area, Mon State

Item		Symbol	Unit	Location - 1	Location - 2	Location - 3		
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	12.06	14.27	7.84		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	35.30	33.72	34.64		
	Plastic Limit	WP	%	30.62	29.31	28.36		
	Plasticity Index	IP		4.68	4.41	6.28		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	5.78	7.57	7.17		
	Sand, (4.75 ~ 0.075) mm		%	64.42	62.77	66.11		
	Silt, (0.075 ~ 0.005) mm		%	22.30	22.66	19.93		
	Clay, (< 0.005 mm)		%	7.50	7.00	6.80		
Specific Gravity of Soil		Gs (20°C)		2.579	2.596	2.609		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	1.957	1.909	1.934		
	Optimun Moisture Content	Wopt	%	11.50	13.00	11.70		
Modified CBR (ρd_{max} - 95 %)			(%)	42.70	61.10	22.50		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SM	SM	SM		
		Group Name		Silty sand	Silty sand	Silty sand		

NOTE

Data used for reference are shown by red color.

Source: JICA Study Team

Table 2.3.30 Summary of Soil Test Results (Yinnyein Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Subgrade				Location 3 Inn Byaung Correctional Department, Yin Nyein Area, Mon State				
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	12.26	13.60	15.51		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	33.25	32.78	38.76		
	Plastic Limit	WP	%	21.26	21.15	24.71		
	Plasticity Index	IP		11.99	11.63	14.05		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	5.68	6.12	5.52		
	Sand, (4.75 ~ 0.075) mm		%	44.76	44.59	37.38		
	Silt, (0.075 ~ 0.005) mm		%	42.57	43.59	51.20		
	Clay, (< 0.005 mm)		%	7.00	5.70	5.90		
Specific Gravity of Soil		Gs (20°C)		2.612	2.604	2.608		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	1.959	1.788	1.858		
	Optimun Moisture Content	W_{opt}	%	12.80	12.00	12.70		
Modified CBR (ρd_{max} - 95 %)			(%)	59.60	27.40	28.00		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SC	SC	CL		
		Group Name		Clayey sand	Clayey sand	Sandy lean clay		
NOTE	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.31 Summary of Soil Test Results (Zinkyeik Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Subgrade	Location 4 No.5 Rock Production, Zin Kyeik Area, Mon State							
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	13.38	13.10	12.40		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	29.40	29.60	29.10		
	Plastic Limit	WP	%	18.83	19.43	19.69		
	Plasticity Index	IP		10.57	10.17	9.41		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	4.17	4.74	6.11		
	Sand, (4.75 ~ 0.075) mm		%	57.25	58.64	56.24		
	Silt, (0.075 ~ 0.005) mm		%	29.08	26.01	27.95		
	Clay, (< 0.005 mm)		%	9.50	10.60	9.70		
Specific Gravity of Soil		Gs (20°C)		2.603	2.618	2.624		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	rd_{max}	t/m^3	2.034	2.045	2.062		
	Optimun Moisture Content	W_{opt}	%	9.75	9.60	10.65		
Modified CBR (ρd_{max} - 95 %)			(%)	68.10	61.40	32.80		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SC	SC	SC		
		Group Name		Clayey sand	Clayey sand	Clayey sand		
NOTE								
	Data used for reference are shown by red color.							

Source: JICA Study Team

Table 2.3.32 Summary of Soil Test Results (Poung Area)

SUMMARY OF SOIL TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Material Test for Subgrade | Location 5 Rock Production of Myanmar Railway, Paung Area, Mon State

				Location - 1	Location - 2	Location - 3		
Sample No.				Location - 1	Location - 2	Location - 3		
Depth (m)				~	~	~	~	~
Moisture Content		w	%	5.24	6.96	6.84		
Bulk Density		ρ_t	g/cm^3	-	-	-		
				-	-	-		
Atterberg's Limit	Liquid Limit	WL	%	21.92	23.34	26.27		
	Plastic Limit	WP	%	17.41	18.04	20.50		
	Plasticity Index	IP		4.51	5.30	5.77		
Grain Size Analysis	Gravel, (76.20 ~ 4.75) mm		%	24.45	23.51	13.49		
	Sand, (4.75 ~ 0.075) mm		%	66.82	65.32	75.05		
	Silt, (0.075 ~ 0.005) mm		%	5.23	7.17	7.16		
	Clay, (< 0.005 mm)		%	3.50	4.00	4.30		
Specific Gravity of Soil		Gs (20°C)		2.619	2.612	2.626		
Unconfined Compression	Unconfined Compressive Strength	q_u	kN/m^2	-	-	-		
				-	-	-		
	Failure Strain	ε_f	%	-	-	-		
				-	-	-		
	E_{50}		kN/m^2	-	-	-		
				-	-	-		
	Sensitivity Ratio			-	-	-		
Compaction Test	Maximun Dry Density	ρd_{max}	t/m^3	2.042	2.162	2.045		
	Optimun Moisture Content	W_{opt}	%	8.20	7.15	8.30		
Modified CBR (ρd_{max} - 95 %)			(%)	74.00	15.60	99.50		
Consolidated Undrained Triaxial Compression Test (Measurement	Cohesion	C'	kN/m^2	-	-	-		
	Phi Angle	ϕ'	Degree	-	-	-		
	Cohesion	C	kN/m^2	-	-	-		
	Phi Angle	ϕ	Degree	-	-	-		
Consolidation	Initial Void Ratio	e_0		-	-	-		
	Conso. Yield Stress	P_y	kN/m^2	-	-	-		
	Compression Index	C_c		-	-	-		
Soil Classification (ASTM D 2487 - 06)		Group Symbol		SP - SC	SP - SC	SP -SC		
		Group Name		Poorly graded sand with clay and gravel (or silty clay and gravel	Poorly graded sand with clay and gravel (or silty clay and gravel	Poorly graded sand with clay (or silty clay)		
NOTE	Data used for reference are shown by red color.							

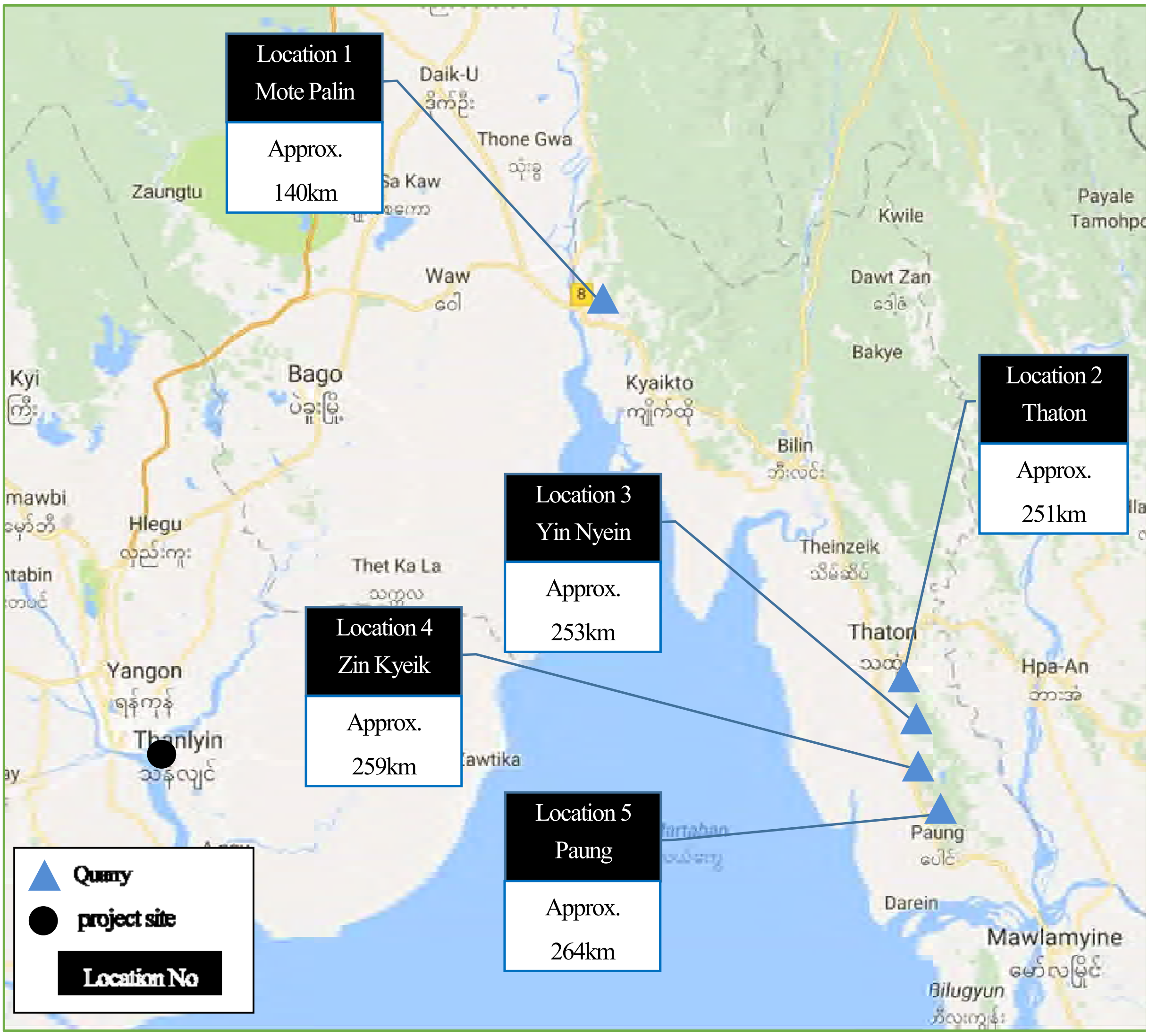
Source: JICA Study Team

2.3.3.4 Material Test for Aggregate

(1) Location of Surveys

The locations of surveys are shown in Figure 2.3.6.

The material sampling site was selected by price, quality, and supply area near the project site.



Source: JICA Study Team

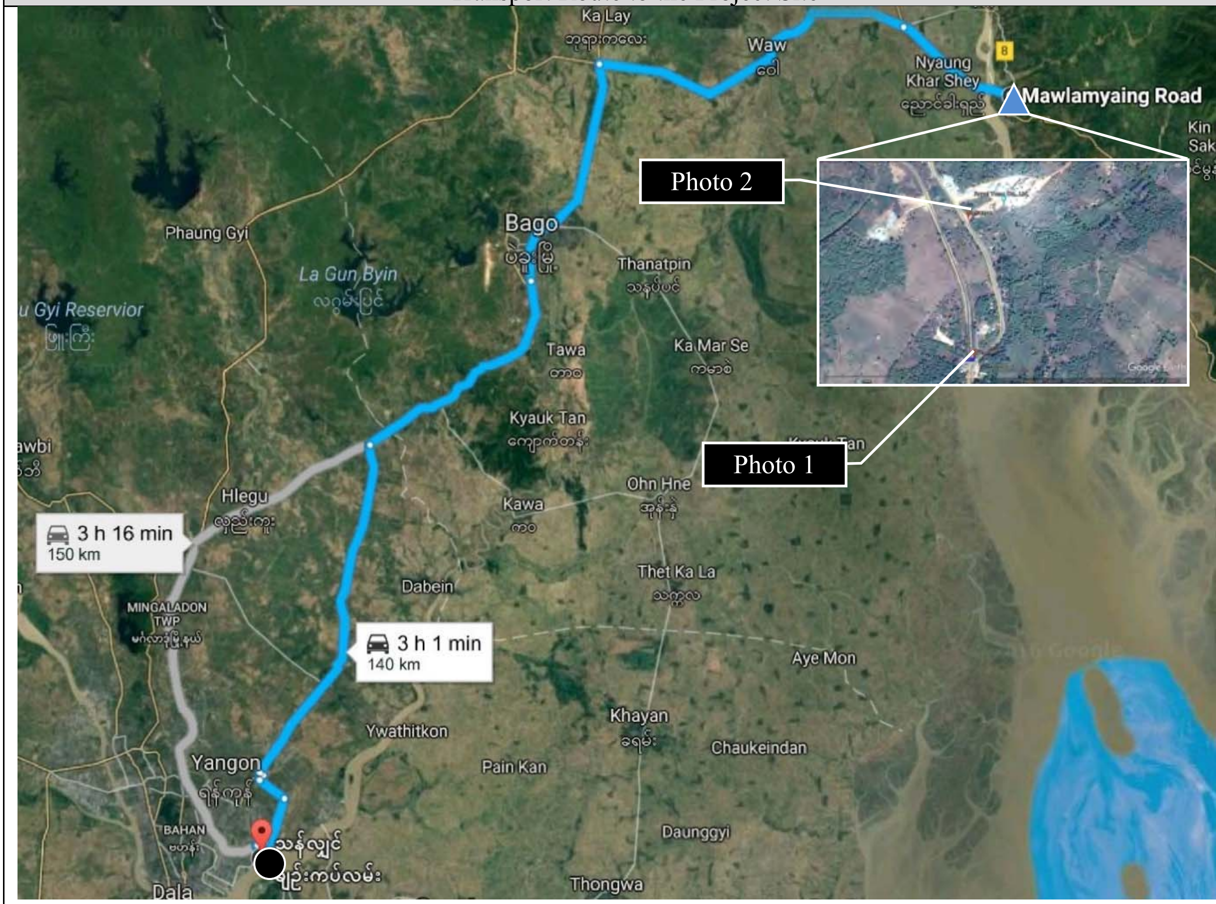
Figure 2.3.6 Locations of surveys

The selected locations are shown in Table 2.3.33 to Table 2.3.37.

Table 2.3.33 Selected location (1/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
1	Mote Palin Township	Royal Yoma Co., Ltd. **Coordinate E276440.000 ; N1930167.000**	2.0 ha	

Transport Route to the Project Site



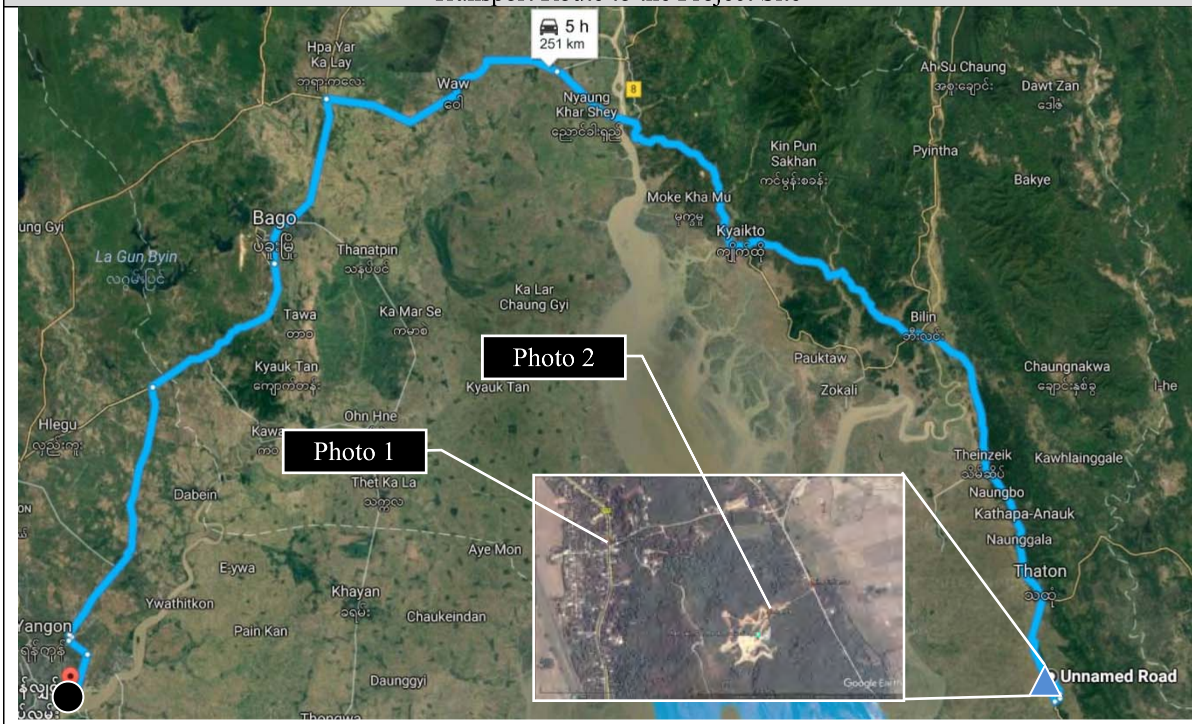
- Distance to the project site: Approximately 150 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

Table 2.3.34 Selected Location (2/5)

<table>
<tr><th>Location</th><th>Address of Stockyard</th><th>Company/Supplier/Coordinate</th><th>Approximate Area</th><th>Location Photos</th></tr>
<tr><td>2</td><td>Thaton Township</td><td>Than Lwin Oo (Rock Production)

Coordinate E 327348.000
N 1860711.000</td><td>3.4ha</td><td></td></tr>
<tr><td colspan="5">Transport Route to the Project Site</td></tr>
<tr><td colspan="5">

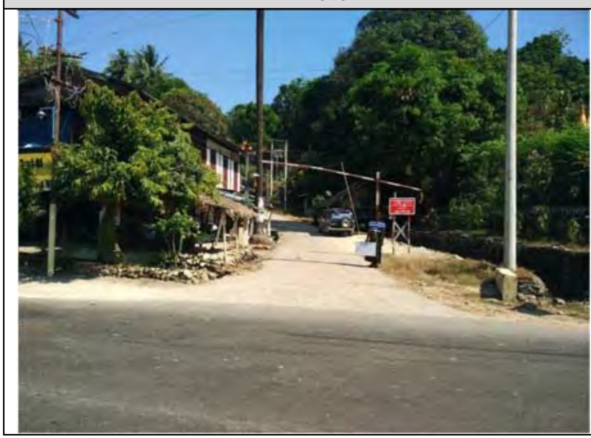
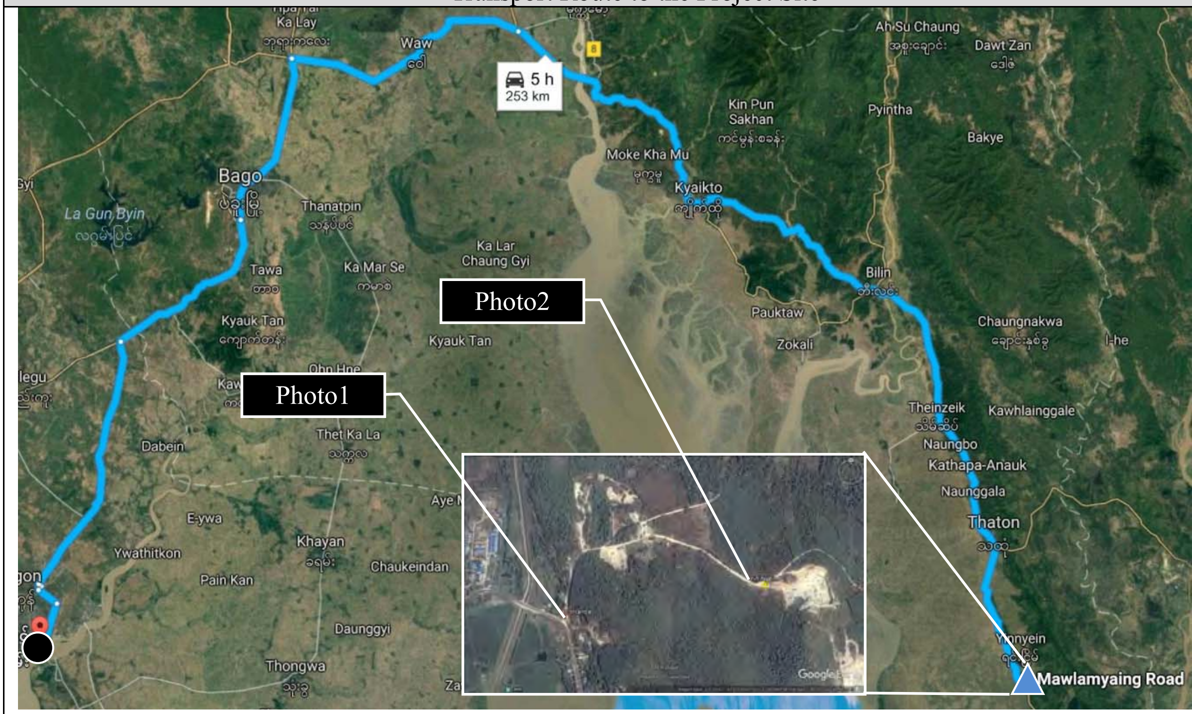
- Distance to the project site: Approximately 251 km
- Transportation condition: easily by roadway</td></tr>
<tr><td colspan="5">Photograph of Transport Route</td></tr>
<tr><td colspan="3">Photo 1</td><td colspan="2">Photo 2</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
</table>

Table 2.3.35 Selected Location (3/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
3	Yin Nyein Village	Inn Byaung Correctional Department **Coordinate** **E 330380.000 ; N 1853893.000**	3.2 ha	No photography

Transport Route to the Project Site



- Distance to the project site: Approximately 253 km
- Transportation condition: easily by roadway

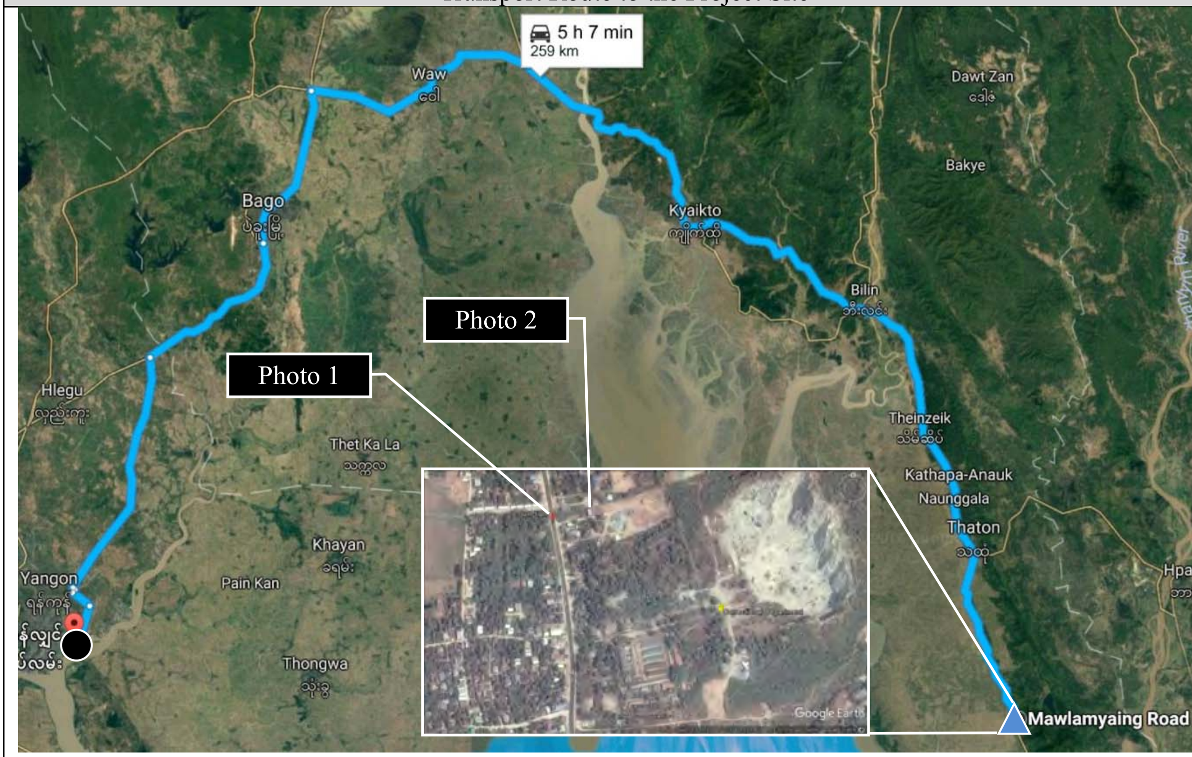
Photograph of Transport Route

Photo 1	Photo 2
	

Table 2.3.36 Selected Location (4/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
4	Zin Kyeik Township	Zin Kyeik Correctional Department **Coordinate E 331994.000 ; N 1848096.000**	4.0 ha	No photography

Transport Route to the Project Site



- Distance to the project site: Approximately 259 km
- Transportation condition: easily by roadway

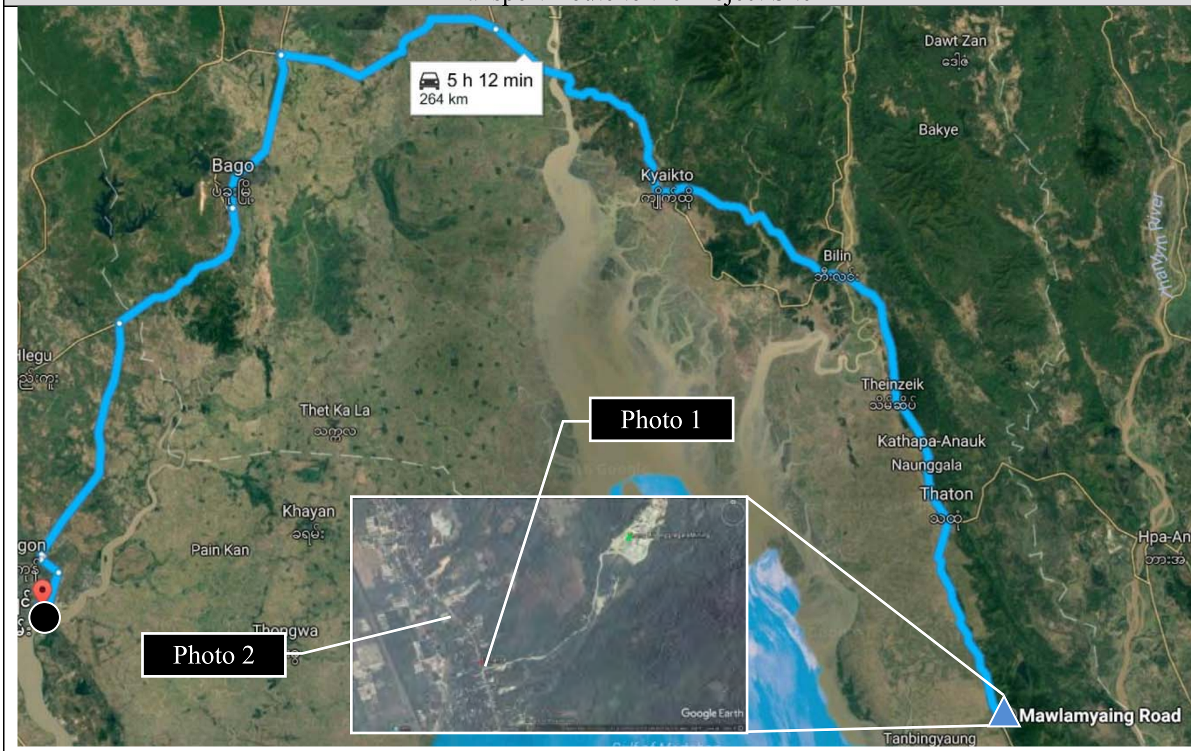
Photograph of Transport Route

Photo 1	Photo 2
	

Table 2.3.37 Selected Location (5/5)

Location	Address of Stockyard	Company/Supplier/Coordinate	Approximate Area	Location Photos
5	Paung Township	Long Life Aggregate Mining Co., Ltd. **Coordinate E 334430.000 ; N 1844368.000**	29.4 ha	

Transport Route to the Project Site



- Distance to the project site: Approximately 264 km
- Transportation condition: easily by roadway

Photograph of Transport Route

Photo 1	Photo 2
	

(2) Method of Sampling and Laboratory Test

- Three locations near the middle of mountain slopes of material were randomly selected.
- Considering the homogeneity of the sampled sample, avoiding the material particle size and the portion where impurities are liable to be biased due to the influence of wind, rain, and gravity.
- It was sampled 30 cm below from the surface of the sampling place.
- Samples were taken at about 6 to 7 kg (roughly two scoops of scoops) per sampling place and placed in a soil bag.

The photos of sampling work are shown in Table 2.3.38.

Table 2.3.38 Photo of Sampling Works

Location	Aggregate Sampling		
	No. 1	No. 2	No. 3
1 Mote Palin Area			
2 Thaton Area			
3 Yinnyein Area	No photograph	No photograph	No photograph
4 Zinkyeik Area	No photograph	No photograph	No photograph
5 Poung Area			

Source: JICA Study Team

The laboratory soil tests are shown in Table 2.3.39.

Table 2.3.39 Laboratory Soil Tests

Testing Items	Unit	Qty.	Applied Standards
1) Grain Size Analysis	nos.	15	ASTM C 136
-Find the particle size of aggregate used for concrete.			
2) Specific Gravity	nos.	15	ASTM C 127
-Judge the general property of the aggregate and find absolute capacity of the aggregate in the combination design of concrete.			
3) Water Absorption	nos.	15	ASTM C 127
-Find the cavity of the aggregate and the used quantity of water in the combination calculation of the concrete.			
4) Abrasion	nos.	15	ASTM C 535
-Find abrasion resistance of the aggregate.			

Source: JICA Study Team

(3) Survey Results

The laboratory test results are shown in Table 2.3.40 to Table 2.3.44.

Based on the laboratory test results, the main particular size of Moke Paline area, Paung area, and Zin Kyeik area is from 25 mm to 38 mm. On the other hand, the main size of Yinnyein area and Thaton area is from 12.5 mm to 25 mm. Hence, aggregate of Yinnyein area and Thaton area are relatively small.

Abrasion rate of Moke Paline area, Paung area, and Zin Kyeik area are less than 20%. Moreover, the one in Yinnyein area and Thaton area is less than 35%. According to JIS standard, the aggregates are suitable for the road since Grade 1 of road aggregate is not more than 35%.

Table 2.3.40 Summary of Aggregate Test Results (Mote Palin Area)

SUMMARY OF AGGREGATE TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Location 1 Moke Palin Area, Moke Palin Township, Mon State

Sample No.			Moke Palin No.1	Moke Palin No.2	Moke Palin No.3		
Sieve Analysis of Fine and Coarse Aggregates (ASTM C 136)	Retain Percent on 125 mm Sieve	(%)	-	-	-		
	Retain Percent on 100 mm Sieve	(%)	-	-	-		
	Retain Percent on 90 mm Sieve	(%)	-	-	-		
	Retain Percent on 75 mm Sieve	(%)	-	-	-		
	Retain Percent on 63 mm Sieve	(%)	-	-	-		
	Retain Percent on 50 mm Sieve	(%)	-	-	-		
	Retain Percent on 38 mm Sieve	(%)	2.76	0.46	2.23		
	Retain Percent on 25 mm Sieve	(%)	76.83	45.19	71.39		
	Retain Percent on 19 mm Sieve	(%)	17.87	41.14	23.48		
	Retain Percent on 12.5 mm Sieve	(%)	2.24	12.53	2.53		
	Retain Percent on 9.5 mm Sieve	(%)	0.07	0.33	0.20		
	Retain Percent on 6.3 mm Sieve	(%)	0.03	0.10	0.03		
	Retain Percent on 4.75 mm Sieve	(%)	0.01	0.01	0.02		
	Percent under 4.75 mm Sieve	(%)	0.19	0.23	0.12		
Sp Gr (ASTM C 127-88)	G, Bulk sp gr		2.654	2.661	2.662		
	G, Bulk sp gr (SSD)		2.664	2.671	2.673		
	G, Apparent sp gr		2.681	2.688	2.691		
	Absorption	(%)	0.37	0.38	0.401		
Los Angeles Abrasion Test (ASTM C 535)		(%)	18.75	19.12	18.76		

Source: JICA Study Team

Table 2.3.41 Summary of Aggregate Test Results (Thaton Area)

SUMMARY OF AGGREGATE TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Location 2 Thaton Area, Thaton Township, Mon State

Sample No.			Thaton No.1	Thaton No.2	Thaton No.3		
Sieve Analysis of Fine and Coarse Aggregates (ASTM C 136)	Retain Percent on 125 mm Sieve	(%)	-	-	-		
	Retain Percent on 100 mm Sieve	(%)	-	-	-		
	Retain Percent on 90 mm Sieve	(%)	-	-	-		
	Retain Percent on 75 mm Sieve	(%)	-	-	-		
	Retain Percent on 63 mm Sieve	(%)	-	-	-		
	Retain Percent on 50 mm Sieve	(%)	-	-	-		
	Retain Percent on 38 mm Sieve	(%)	-	-	0.68		
	Retain Percent on 25 mm Sieve	(%)	4.98	2.72	8.32		
	Retain Percent on 19 mm Sieve	(%)	26.88	27.47	32.70		
	Retain Percent on 12.5 mm Sieve	(%)	49.76	47.50	42.11		
	Retain Percent on 9.5 mm Sieve	(%)	10.20	10.17	9.20		
	Retain Percent on 6.3 mm Sieve	(%)	5.61	6.82	4.03		
	Retain Percent on 4.75 mm Sieve	(%)	0.83	1.56	0.83		
	Percent under 4.75 mm Sieve	(%)	1.74	3.76	2.14		
Sp Gr (ASTM C 127-88)	G, Bulk sp gr		2.589	2.580	2.582		
	G, Bulk sp gr (SSD)		2.610	2.605	2.606		
	G, Apparent sp gr		2.645	2.646	2.646		
	Absorption	(%)	0.82	0.96	0.94		
Los Angeles Abrasion Test (ASTM C 131)		(%)	30.60	32.06	32.52		

Source: JICA Study Team

Table 2.3.42 Summary of Aggregate Test Results (Yinnyein Area)

SUMMARY OF AGGREGATE TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Location 3 Yin Nyein Area, Paung Township, Mon State

Sample No.			Yin Nyein No.1	Yin Nyein No.2	Yin Nyein No.3		
Sieve Analysis of Fine and Coarse Aggregates (ASTM C 136)	Retain Percent on 125 mm Sieve	(%)	-	-	-		
	Retain Percent on 100 mm Sieve	(%)	-	-	-		
	Retain Percent on 90 mm Sieve	(%)	-	-	-		
	Retain Percent on 75 mm Sieve	(%)	-	-	-		
	Retain Percent on 63 mm Sieve	(%)	-	-	-		
	Retain Percent on 50 mm Sieve	(%)	-	-	-		
	Retain Percent on 38 mm Sieve	(%)	-	-	-		
	Retain Percent on 25 mm Sieve	(%)	1.08	0.67	0.97		
	Retain Percent on 19 mm Sieve	(%)	43.72	35.34	49.41		
	Retain Percent on 12.5 mm Sieve	(%)	49.88	58.88	48.03		
	Retain Percent on 9.5 mm Sieve	(%)	3.17	3.06	0.96		
	Retain Percent on 6.3 mm Sieve	(%)	0.94	0.90	0.21		
	Retain Percent on 4.75 mm Sieve	(%)	0.20	0.16	0.05		
	Percent under 4.75 mm Sieve	(%)	1.01	1.01	0.38		
Sp Gr (ASTM C 127-88)	G, Bulk sp gr		2.613	2.612	2.614		
	G, Bulk sp gr (SSD)		2.625	2.624	2.625		
	G, Apparent sp gr		2.644	2.644	2.644		
	Absorption	(%)	0.45	0.45	0.43		
Los Angeles Abrasion Test (ASTM C 131)		(%)	21.86	22.55	23.40		

Source: JICA Study Team

Table 2.3.43 Summary of Aggregate Test Results (Zinkyeik Area)

SUMMARY OF AGGREGATE TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project

Location 4 Zin Kyeik Area, Paung Township, Mon State

Sample No.			Zin Kyaik No.1	Zin Kyaik No.2	Zin Kyaik No.3		
Sieve Analysis of Fine and Coarse Aggregates (ASTM C 136)	Retain Percent on 125 mm Sieve	(%)	-	-	-		
	Retain Percent on 100 mm Sieve	(%)	-	-	-		
	Retain Percent on 90 mm Sieve	(%)	-	-	-		
	Retain Percent on 75 mm Sieve	(%)	-	-	-		
	Retain Percent on 63 mm Sieve	(%)	2.56	-	3.27		
	Retain Percent on 50 mm Sieve	(%)	15.28	9.37	17.74		
	Retain Percent on 38 mm Sieve	(%)	34.39	29.63	37.77		
	Retain Percent on 25 mm Sieve	(%)	38.01	51.03	31.59		
	Retain Percent on 19 mm Sieve	(%)	8.31	8.26	7.31		
	Retain Percent on 12.5 mm Sieve	(%)	1.12	1.30	1.82		
	Retain Percent on 9.5 mm Sieve	(%)	0.05	0.04	0.12		
	Retain Percent on 6.3 mm Sieve	(%)	0.07	0.04	0.12		
	Retain Percent on 4.75 mm Sieve	(%)	0.02	0.02	0.04		
	Percent under 4.75 mm Sieve	(%)	0.20	0.30	0.22		
Sp Gr (ASTM C 127-88)	G, Bulk sp gr		2.632	2.624	2.630		
	G, Bulk sp gr (SSD)		2.641	2.632	2.639		
	G, Apparent sp gr		2.656	2.646	2.654		
	Absorption	(%)	0.34	0.32	0.34		
Los Angeles Abrasion Test (ASTM C 535)		(%)	17.42	12.90	19.37		

Source: JICA Study Team

Table 2.3.44 Summary of Aggregate Test Results (Poung Area)

SUMMARY OF AGGREGATE TEST RESULTS

Project Name : Material Test for Bago River Bridge Construction Project							
Location 5 Paung Area, Paung Township, Mon State							
Sample No.			Paung No.1	Paung No.2	Paung No.3		
Sieve Analysis of Fine and Coarse Aggregates (ASTM C 136)	Retain Percent on 125 mm Sieve	(%)	-	-	-		
	Retain Percent on 100 mm Sieve	(%)	-	-	-		
	Retain Percent on 90 mm Sieve	(%)	-	-	-		
	Retain Percent on 75 mm Sieve	(%)	-	-	-		
	Retain Percent on 63 mm Sieve	(%)	2.63	-	-		
	Retain Percent on 50 mm Sieve	(%)	7.50	13.26	4.60		
	Retain Percent on 38 mm Sieve	(%)	37.56	38.04	37.46		
	Retain Percent on 25 mm Sieve	(%)	45.31	41.80	50.13		
	Retain Percent on 19 mm Sieve	(%)	5.73	5.37	6.58		
	Retain Percent on 12.5 mm Sieve	(%)	0.98	1.13	0.92		
	Retain Percent on 9.5 mm Sieve	(%)	0.05	0.10	0.10		
	Retain Percent on 6.3 mm Sieve	(%)	0.04	0.08	0.05		
	Retain Percent on 4.75 mm Sieve	(%)	0.01	0.03	0.01		
	Percent under 4.75 mm Sieve	(%)	0.18	0.18	0.15		
Sp Gr (ASTM C 127-88)	G, Bulk sp gr		2.620	2.620	2.621		
	G, Bulk sp gr (SSD)		2.630	2.629	2.630		
	G, Apparent sp gr		2.646	2.645	2.645		
	Absorption	(%)	0.38	0.36	0.35		
Los Angeles Abrasion Test (ASTM C 535)		(%)	13.78	15.44	15.14		

Source: JICA Study Team

2.3.4 Conclusion

2.3.4.1 Material Test for Filling

According to the laboratory test results, low plasticity to medium plasticity clay layer is well observed in Thaketa side. Moreover, design CBR value is eight in average.

In Thanlyin side, the percentage of sand is more than in the Thaketa side. Moreover, design CBR values are also less than for Thaketa side, although there are some parts that CBR value is more than eight.

2.3.4.2 Material Test for Filling

According to laboratory test results, Aung Win, Kyauk Tan location sample is more than other place in maximum dry density. The soil type is clayey sand. The seco nd maximum dry density is great motion Thanlyin location. The soil type of this location is fat clay.

The maximum dry density of Ko Toe, Thanlyin location is more than Marga, Thilawa sand location. Moreover, design CBR also is more than that location.

2.3.4.3 Material Test for Subgrade

According to the laboratory test results, all soils are sandy soil location. The maximum dry density of Paung and Zin Kyeik location is more than 2 t/m^3. The modified CBR results are more than 50 in average.

The maximum dry density of Thaton and Yinnyein location is also 1.9 t/m^3 in average. The average modified CBR values are also 40 in average.

2.3.4.4 Material Test for Aggregate

According to the laboratory test results, the main particle sizes for the Moke Paline area, Paung area, and Zin Kyeik area are from 25 mm to 38 mm. On the other hand, the main one for Yinnyein area and Thaton area is from 12.5 mm to 25 mm. Hence, aggregates from Yinnyein area and Thaton area are relatively small.

Abrasion rates for the Moke, Paung, and Zin Kyeik areas are less than 20%. Moreover, the one in Yinnyein area and Thaton area is less than 35%. According to JIS standard, every aggregate is suitable for road since Grade 1 of road aggregate is not more than 35%.

2.4 RIVER AND HYDROLOGICAL SURVEY

In order to design the new bridge, it is necessary to collect and correlate the basic meteorological and hydraulic data. In this section, hydrological and hydraulic analysis shall be carried out based on hydrological data collection and river section and bathymetric survey.

2.4.1 Review of Hydrological Survey from F/S

Hydrological assessment was carried out in the F/S and planned values for the bridge design were estimated. River and hydrological surveys were conducted at the D/D stage for improving the precision of the result of the hydrological assessment in the F/S. The hydrological data collection survey and river section survey were conducted. The location of the New Bago Bridge is in a tidal reach making historical tide levels and other hydrological data very important. Furthermore, river section survey has not been carried out upstream of the new bridge location but rather estimated by previous bathymetric survey map which was based on Myanma Port Authority (MPA) datum. As a result, hydraulic analysis was conducted with MPA datum. At the F/S stage, the ground elevation of the land survey is supposed to be indicated as zero from MWL +3.121 m at Bo Aung Kyaw Street Wharf Station; however, the relationship of these two data as written above could not be confirmed, and thus, it shall be verified in this survey.

Table 2.4.1 shows the result of the hydrological study in the F/S stage. There were three candidates for new bridge location in the F/S stage and Option 3 in the table below was judged as the most suitable. Design H.W.L. was estimated by comparison between H.W.L., which was the calculated water level in case of 100-year flood and the probable water level at Yangon Port was calculated through statistical analysis. Hydraulic calculation shall obtain these two values with new river and hydrological data at the D/D stage.

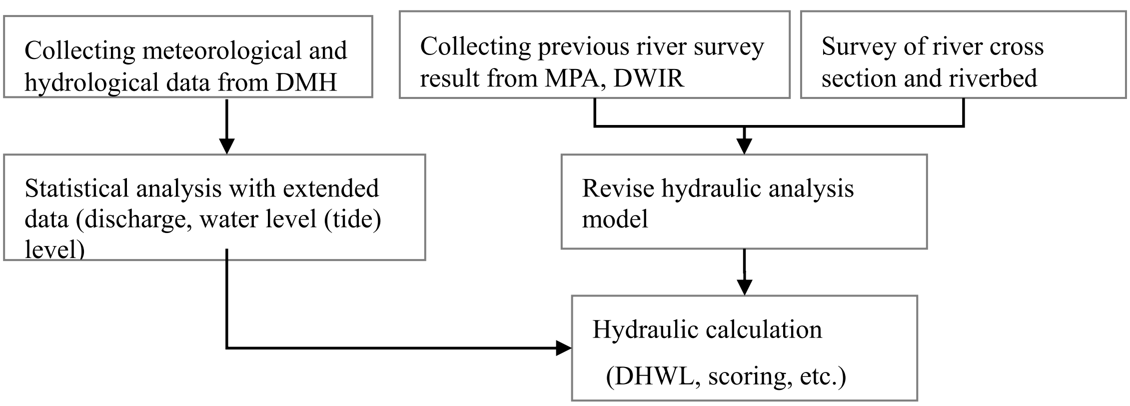
Table 2.4.1 Planned Value for New Bago Bridge at F/S

Item	Alternative 1 (Monkey Point Plan)	Alternative 2 (Bago Point Plan)	Alternative 3 (Second Thanlyin Bridge Plan)	Remarks
Design Discharge	18,292 (m^3/s)	15,503 (m^3/s)	14,398 (m^3/s)	100-year flood
Design H.W.L.	7.7 (m)	7.7 (m)	7.7 (m)	MPA-based
Design H.W.L.	4.579 (m)	4.579 (m)	4.579 (m)	Land survey

Source: The Preparatory Survey for The Project for Construction of Bago River Bridge

2.4.2 Outline of Hydrological Survey at D/D stage

Hydrological survey is composed of the hydrological data collection survey and river section survey. In the hydrological survey at D/D stage, the following items are conducted:



Source: JICA Study Team

Figure 2.4.1 Study Flow at D/D stage

2.4.3 Hydrological Data Collection Survey

Secondary hydrological data were collected from different government organizations such as the Department of Meteorology and Hydrology (DMH), Irrigation Department (ID), Myanmar Port Authority (MPA) and Navy. The list of each data collection item is shown in Table 2.4.2. This survey was carried out for improving preservation of statistical analysis and acquiring current/transition of river shape. The data book is attached in Appendix-11.

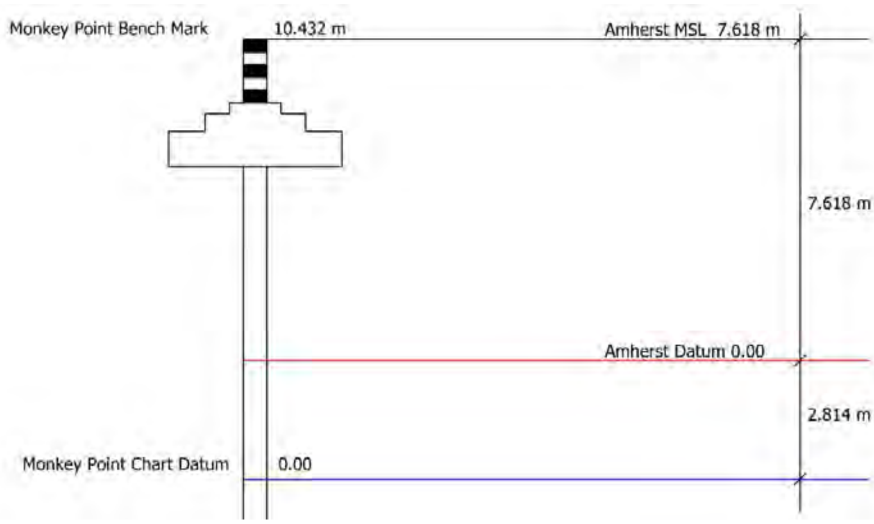
In this survey, if collected water/tide level data is not prepared by Amherst Mean Sea Level (MSL), it is modified to MSL. Since the relationship with MSL and other datum was unknown, the difference between the level in their datum was measured. It obtained that for MSL datum, ground elevation of land survey is +2.814 m at Monkey Point chart datum.

Table 2.4.2 Item List of Data Collection Survey

No.	Item	Unit	Quantity		Remarks
Meteorological Data Collection			Related Organ.:	DMH of MoT	
M-1	Daily Rainfall during 2013-2015	mm	Kaba-Aye station.	1095= 3 year * 365 days	DMH
Meteorological Data Collection			Related Organ.:	DMH and MPA of MoT, ID of MoAH	
H-1	Annual Maximum Discharge at 3 stations	m^3/sec	Bago station during 2015	1= 1 year * 1 day	DMH
		m^3/sec	Zaungtu station during 2012-2015	4= 4 years * 1 day	DMH
		m^3/sec	Khamonseik station during 2012-2015	4= 4 years * 1 day	DMH
H-2	Annual Maximum & Minimun Water\Tide Level at 2 stations	m MSL	More than 30 years at Monkey Point (Yangon) and Elephant Point (Estuary) stations	60= 30 years * 1 day *2 stations	MPA
H-3	Daily Water Level at 1 station	m MSL	More than 10-20 years at Bawt Creek Sluice station	3650-= 10-20 years * 365 days	ID
H-4	Past useful bathymetric survey results	-	DWIR - Bathymetry survey (Dec. 2015) MNHC - Nautical chart (Jan. 2016)		DWIR, MNHC

Note. MoT: Ministry of Transport
MoAH: Ministry of Agriculture and Irrigation
DMH: Department of Meteorology and Hydrology
DWIR: Department of Water Resources and Improvement of River System
MPA: Myanmar Port Authority
ID: Irrigation Department
MNHC: Myanmar Naval Hydrographical Center

Source: JICA Study Team

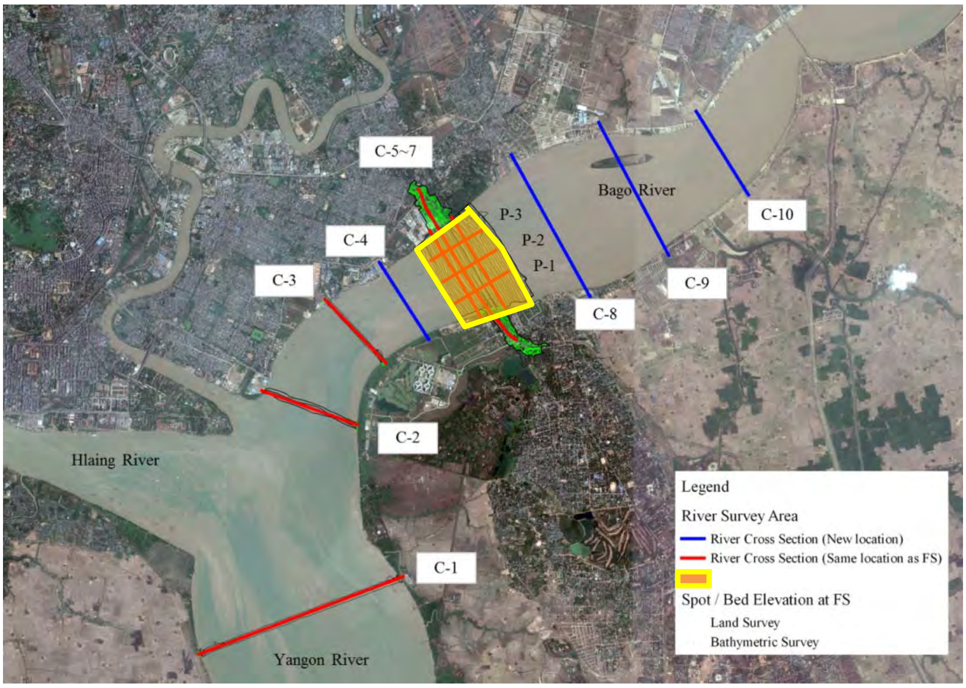


Source: JICA Study Team

Figure 2.4.2 Relationship between MSL and MPA Chart Datum

2.4.4 River Section and Bathymetric Survey

The profile/cross-section survey for river was conducted at the location of Figure 2.4.3 and Table 2.4.3. River section and bathymetric surveys were carried out by local consultants (Asia Air Survey Myanmar Co., Ltd). The survey was conducted to ground-survey portions on both banks from centerline of the river. In the river portions, it was performed by using an echo sounding machine and GPS for the bathymetric survey. The drawings of river sections are attached in Appendix-12.



Source: JICA Study Team

Figure 2.4.3 Survey Location

Table 2.4.3 Location of River Cross Section Survey

Item	ID of River Survey	Coordinates of River Survey Section by WGS84/UTM 47N				Ground / Bathymetric Survey Length	Remarks
		Left Bank		Right Bank			
		X (m)	Y (m)	X (m)	Y (m)	L (m)	
Cross Section	C- 1	203893.397	1853390.658	200529.369	1852174.488	3577.115	F/S location
	C- 2	203177.998	1855870.984	201624.546	1856447.178	1656.868	F/S location
	C- 3	203659.434	1856868.313	202683.342	1857913.420	1430.036	F/S location
	C- 4	204367.397	1857240.911	203576.584	1858502.916	1489.310	
	C- 5	205237.751	1857572.738	204406.285	1859011.418	1661.667	F/S location
	C- 6	(Same as Road/Bridge Center)				1686.716	F/S location
	C- 7	205628.401	1857736.159	204769.924	1859221.578	1715.649	F/S location
	C- 8	207012.397	1857903.495	205758.548	1860226.573	2639.854	
	C- 9	208311.581	1858554.664	207194.788	1860730.592	2445.790	
	C- 10	209629.357	1859518.909	208793.569	1860888.159	1604.178	
Profile section	P- 1	204815.777	1857830.529	205683.231	1858328.046	1000.000	F/S location
	P- 2	204616.770	1858177.511	205484.224	1858675.028	1000.000	F/S location
	P- 3	204417.763	1858524.493	205285.218	1859022.010	1000.000	F/S location
Total 13 sections						22907.183	

Source: JICA Study Team

2.4.5 Meteorological Condition

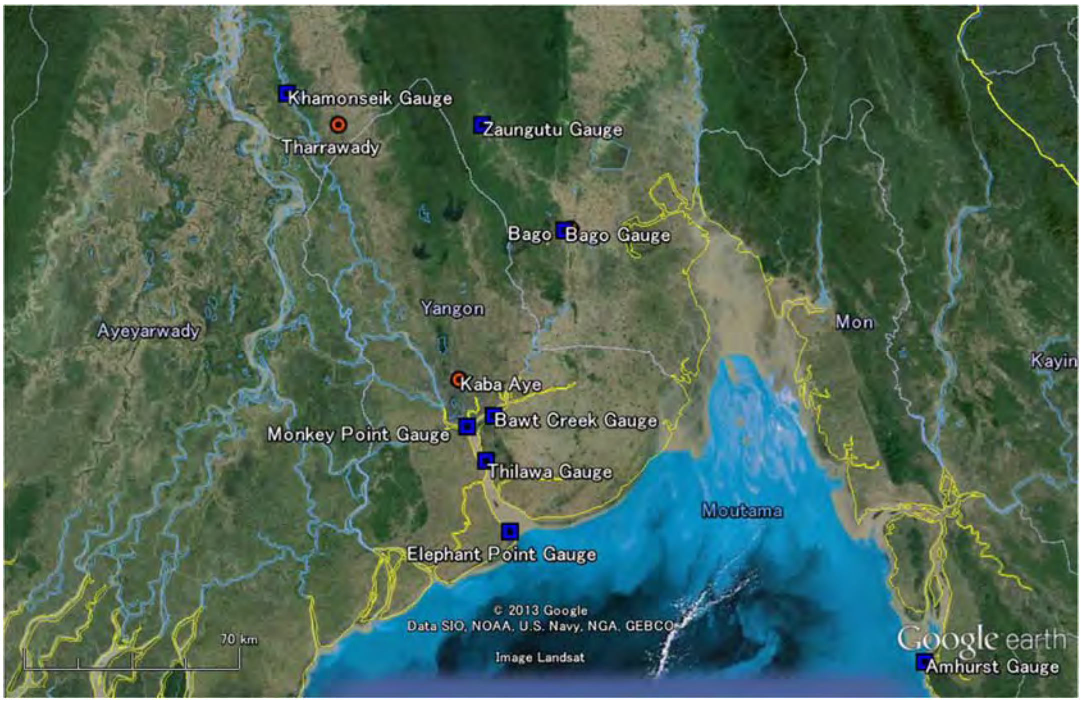
Yangon's climate is tropical monsoonal type. Rainfall is highly seasonal, being concentrated in the hot humid months of the southwest monsoon (May to October). In contrast, the northwest monsoon (December to March) is relatively cool and dry. Occasionally, severe cyclones cross the Myanmar coast in the April-May period.

There are three observation stations of climatic data in and around Greater Yangon, which were installed and are operated by DMH of the Ministry of Transport (MoT), as shown in Table 2.4.4. Also, the locations of meteorological and hydrological stations are shown in Figure 2.4.4.

Table 2.4.4 Inventory of Meteorological Station

Meteorological Station	Code (WMO)	Coordinates		Height (m)	Period of records						Remarks
		Latitude	Longitude		Tempera-ture	Relative Humidity	Rain fall	Sunshine	Evapo-ration	Wind	
1. Kaba Aye (Yangon)	48097	16-54	96-10	20	1968-	1968-	1968 -	1977-	1975-	1968-	
2. Bago	48093	17-20	96-30	9	1965-	1965-	1965 -	-	-	1965-	
3. Tharrawady	48088	17-38	95-48	15	1965-	1965-	1965 -	-	-	1965-	

Source: DMH

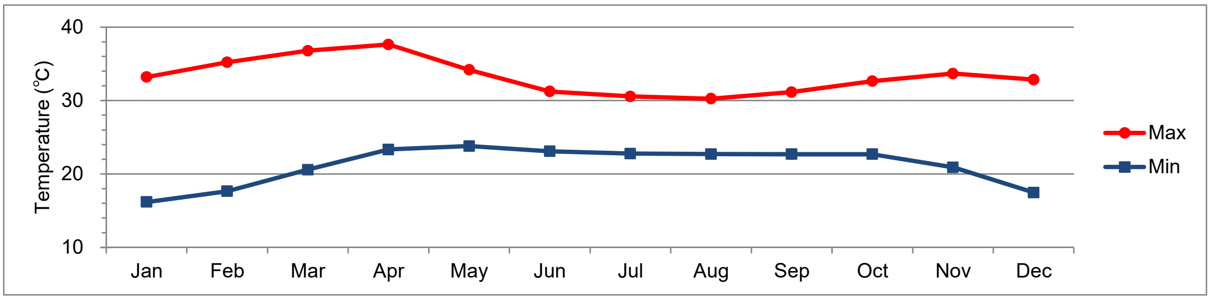


Source: DMH, MPA, ID (Google Earth Map)

Figure 2.4.4 Location Map of Meteorological and Hydrological Stations

(1) Temperature

The monthly mean temperature ranges from 24.8℃ to 30.3℃ in and around Yangon. According to collected data, a mean monthly maximum temperature of 37.6℃ (April) and a mean minimum temperature of 16.2℃ (January) in the Yangon region were recorded respectively during the most recent 25 years.

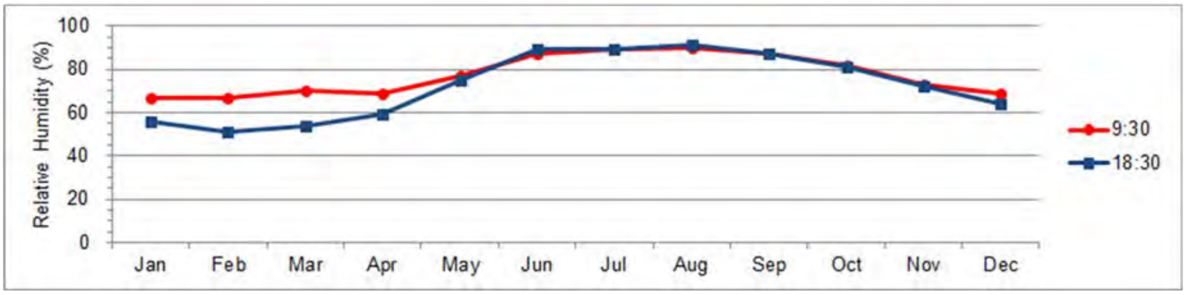


Source: JICA Study Team based on the data from DMH

Figure 2.4.5 Mean Monthly Maximum and Minimum Temperature at Kaba-Aye (1991-2015)

(2) Relative Humidity

The relative humidity is observed twice a day (at 9:30 and 18:30). As seen in Figure 2.4.6, the difference in humidity between morning and evening is quite small. Mean monthly relative humidity in Yangon ranges between 51% and 91%.

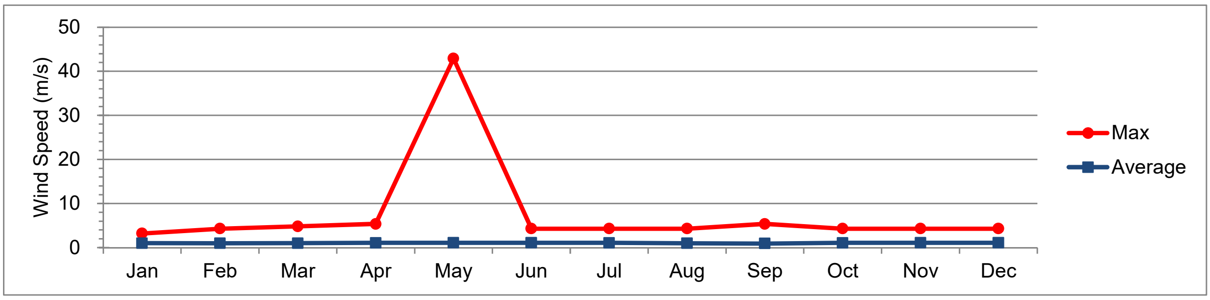


Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 2.4.6 Mean Monthly Maximum and Minimum Relative Humidity at Kaba-Aye (1991-2008)

(3) Wind Speed and Direction

The mean monthly wind speed is stable at a range between 1.0 and 1.2 m/s throughout the year. The wind condition in the Yangon area depends on the influence of the southwest monsoon in the rainy season. The maximum wind speed of 42.9 m/s was recorded during Cyclone Nargis in 2008.

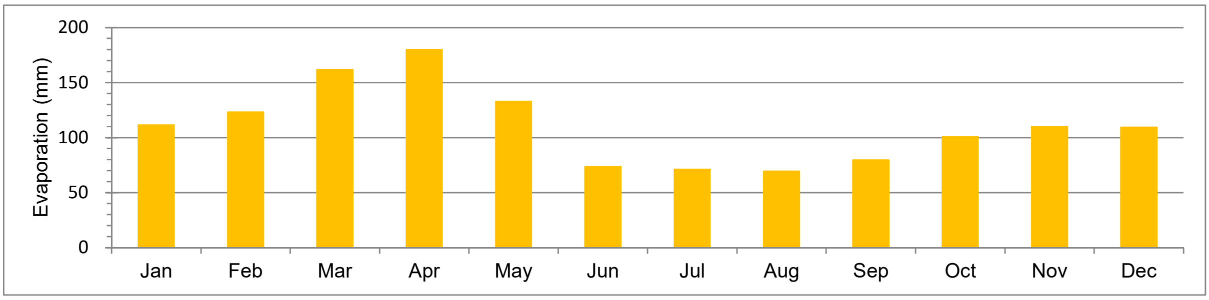


Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 2.4.7 Maximum Wind Speed and Mean Monthly Wind Speed at Kaba-Aye (1991-2015)

(4) Evaporation

The annual mean evapotranspiration is 1,349 mm in the Yangon area, which is at 50% of the annual rainfall.

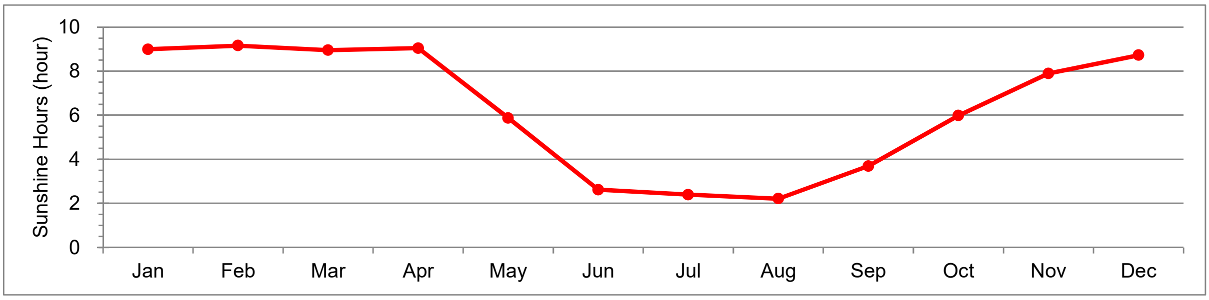


Source: JICA Study Team based on the data from DMH

Figure 2.4.8 Mean Monthly Evaporation at Kaba-Aye (1981-2015)

(5) Sunshine Hours

The annual mean sunshine hour is about 6.3 hours/day in the Yangon area. Sunshine hours during the rainy season are shorter than in other seasons and show a different pattern of fluctuation.



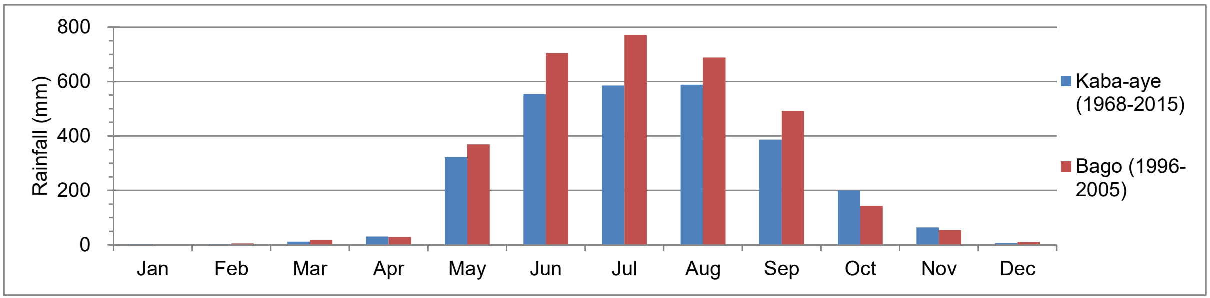
Source: JICA Study Team based on data from DMH

Figure 2.4.9 Mean Monthly Sunshine Hours at Kaba-Aye (1977-2015)

(6) Annual Rainfall and Seasonal Fluctuation

Seasonal variation of monthly total rainfall is similar in Yangon City (Kaba-aye) and Bago City. Regarding seasonal fluctuation of rainfall, about 96% of annual rainfall occurs in the rainy season from May to October, with the largest amount in July or August. The annual mean rainfall is 2,745 mm in Yangon and 3,288 mm in Bago. The annual rainfall fluctuates between 3,592 and 2,127 mm in Yangon. According to collected data/documents, the following rainfall characteristics in Yangon area can be observed:

- Bago, to the east of the Yangon area, has the largest annual rainfall volume.
- Tharrawady, to the northwest of the Yangon area, has the lowest annual rainfall. Annual rainfall progressively decreases toward the north (upstream) side of the Hlaing River.

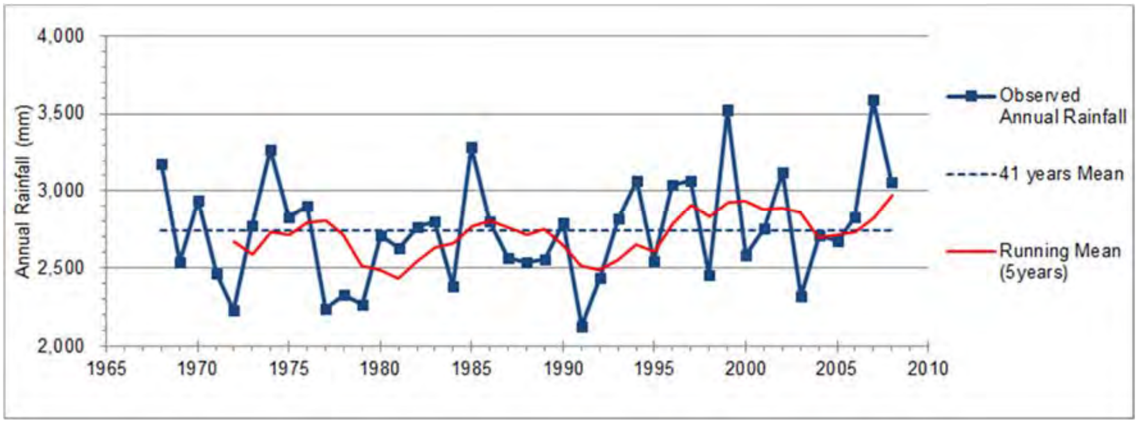


Source: JICA Study Team based on the data from DMH

Figure 2.4.10 Mean Monthly Rainfall in and around Greater Yangon

(7) Long-term Fluctuation of Annual Rainfall

Figure 2.4.11 shows the long-term fluctuation of annual rainfall by using five-year running mean at Kaba-aye. Although the cycle of wet and droughty periods is not clear, there are clear periods of the wet and drought according to this figure. It is indicated that limited rise trend of annual rainfall has occurred in recent years.



Source: JICA Study Team based on the data from DMH

Figure 2.4.11 Annual Rainfall and Five Year Running Mean Rainfall at Kaba-Aye (1986-2008)

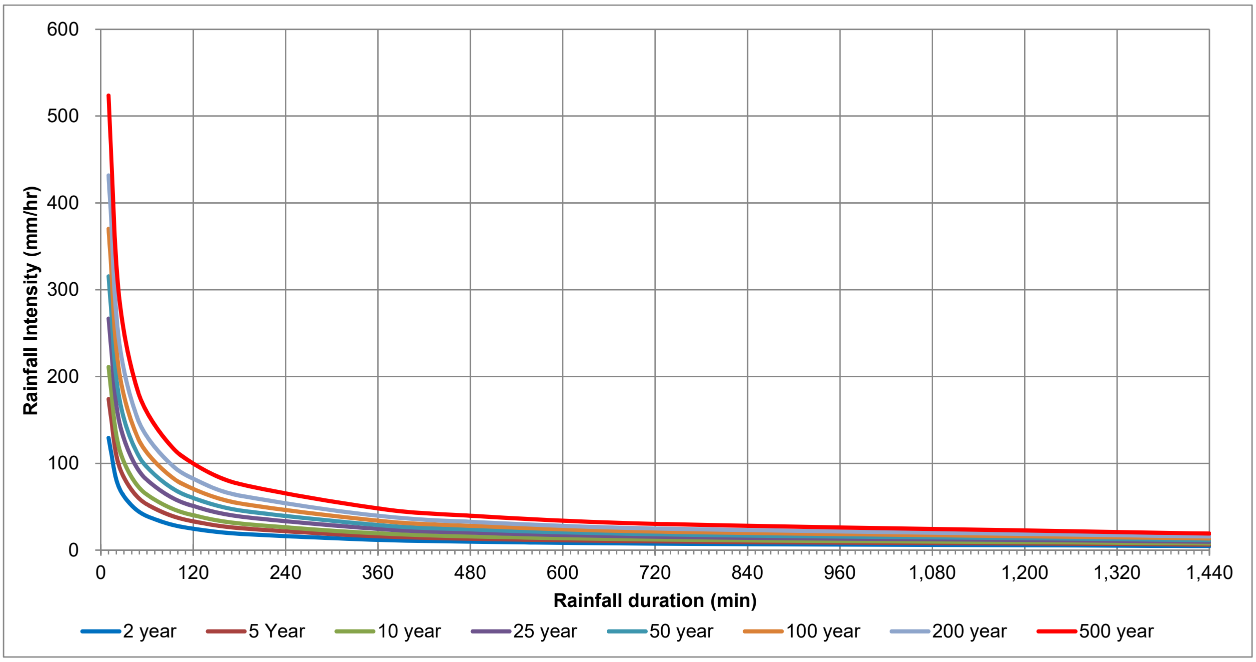
(8) Exceedance Probability and Intensity Curve of Rainfall

The annual maximum daily rainfall data (extremal value) over 40 years or more has been measured at Kaba-aye Station, which is near the location of the New Bago Bridge. The 24-hour rainfall of two 500- year probabilities are calculated by using these extreme values. Also, the correlation between the intensity of short rainfall duration and 24-hour rainfall is estimated in reference to Mononobe's equation. Probable rainfalls and intensity curves are shown in Table 2.4.5 and Figure 2.4.12.

Table 2.4.5 Correlation between Intensity of Short Time Rainfall Duration and Twenty-four Hour Rainfall at Kaba-aye Station (Mononobe's Equation, 1968-2015)

Return Period (Probability) (Year, %) Kaba Aye		Dairy Rainfall: R_{24} (mm/day)	Rainfall intensity each rainfall duration (mm/hr): It = $R_{24}/24*(24/t)^m$, m=2/3												Remarks
		24 hour	24	12	8	6	3	2	1.5	1	0.75	0.5	0.333	0.167	
		1,440 min.	1,440	720	480	360	180	120	90	60	45	30	20	10	
2	50.0%	112.9	4.7	7.5	9.8	11.9	18.8	24.7	29.9	39.1	47.4	62.1	81.4	129.2	
3	33.3%	130.1	5.4	8.6	11.3	13.7	21.7	28.4	34.4	45.1	54.6	71.6	93.8	148.9	
5	20.0%	152.1	6.3	10.1	13.2	16.0	25.4	33.2	40.2	52.7	63.9	83.7	109.7	174.1	
10	10.0%	184.3	7.7	12.2	16.0	19.4	30.7	40.3	48.8	63.9	77.4	101.4	132.9	211.0	
20	5.0%	220.4	9.2	14.6	19.1	23.1	36.7	48.1	58.3	76.4	92.6	121.3	158.9	252.3	
25	4.0%	233.0	9.7	15.4	20.2	24.5	38.8	50.9	61.6	80.8	97.9	128.2	168.0	266.7	
30	3.33%	243.7	10.2	16.1	21.1	25.6	40.6	53.2	64.5	84.5	102.3	134.1	175.7	279.0	
50	2.0%	275.5	11.5	18.2	23.9	28.9	45.9	60.2	72.9	95.5	115.7	151.6	198.7	315.4	
80	1.25%	307.3	12.8	20.3	26.6	32.3	51.2	67.1	81.3	106.5	129.1	169.1	221.6	351.8	
100	1.0%	323.4	13.5	21.4	28.0	34.0	53.9	70.6	85.6	112.1	135.8	178.0	233.2	370.2	
150	0.667%	354.1	14.8	23.4	30.7	37.2	59.0	77.3	93.7	122.8	148.7	194.9	255.4	405.3	
200	0.5%	377.1	15.7	24.9	32.7	39.6	62.9	82.4	99.8	130.7	158.4	207.5	271.9	431.7	
300	0.33%	411.4	17.1	27.2	35.7	43.2	68.6	89.8	108.8	142.6	172.8	226.4	296.7	470.9	
400	0.25%	436.9	18.2	28.9	37.9	45.9	72.8	95.4	115.6	151.5	183.5	240.4	315.1	500.1	
500	0.2%	457.5	19.1	30.3	39.7	48.0	76.3	99.9	121.0	158.6	192.1	251.8	329.9	523.7	
		Calculation formula of Probable rainfall = Generalized extreme value distribution													

Source: JICA Study Team based on data from DMH



Source: JICA Study Team based on data from DMH

Figure 2.4.12 Rainfall Intensity Curves at Kaba-aye Station

2.4.6 Hydrological Conditions for Road and Bridge Design

In order to predict the flow rate/water level during the flood season, it is necessary to collect and correlate the hydrological and hydraulic conditions of the Yangon (Hlaing), Bago River, and Pazundaung Creek, which surround Yangon. This study is examined in reference to previous reports (JICA report, etc.) in addition to the collection of information from relevant organizations in Myanmar.

Six existing gauging stations (water level / discharge) were managed by DMH and MPA in the Hlaing, Bago, and Yangon River basins. Of these stations, the three stations of MPA are not observed the discharge records. Also, the Bago Station of DMH is influenced by tidal level during October to May (dry season), therefore discharge records during this period are not available. However, discharge records at Bago Station during rainy season are utilizable for flood probability calculation. DMH has their own discharge rating tables and these rating tables have been changed several times to reflect discharge measurement records, taking into account the flow condition. Inventory of river/tidal gauge stations is shown in Table 2.4.6.

Table 2.4.6 Inventory of River / Tidal Gauging Station

River/Gauging Station	Code	Coordinates		Catchment Area (km 2)	Height (m)	Type of Gauge	Period of Record	Water (Tide)	Discharge	Observed by	Remarks
		Latitude	Longitude								
1. Hlain River/Khamonseik	6020	16-35	95-30	5,840	14.465	Pile Gauge	1987-	○	○	DMH	
2. Bago River/Zaungutu	6220	17-38	96-14	1,927	9.8	Pile Gauge	1987-	○	○	DMH	
3. Bago River/Bago (Pegu)	48093	17-20	96-30	2,580	9	Pile Gauge	1970-	○	○	DMH	
4. Hlaing River/Yangon Port	210	16-46	96-11	-	-	Steel Plate (Automatic)	-	○	-	MPA	other 2 stations at Yangon Port
5. Yangon River/Thilawa Point	-	16-40	96-15	-	-	Steel Plate (Automatic)	-	○	-	MPA	
6. Ynagon River/Elephant Point	-	16-28	96-19	-	-	Steel Plate (Manual)	-	○	-	MPA	

Source: DMH, MPA

2.4.6.1 Existing Conditions

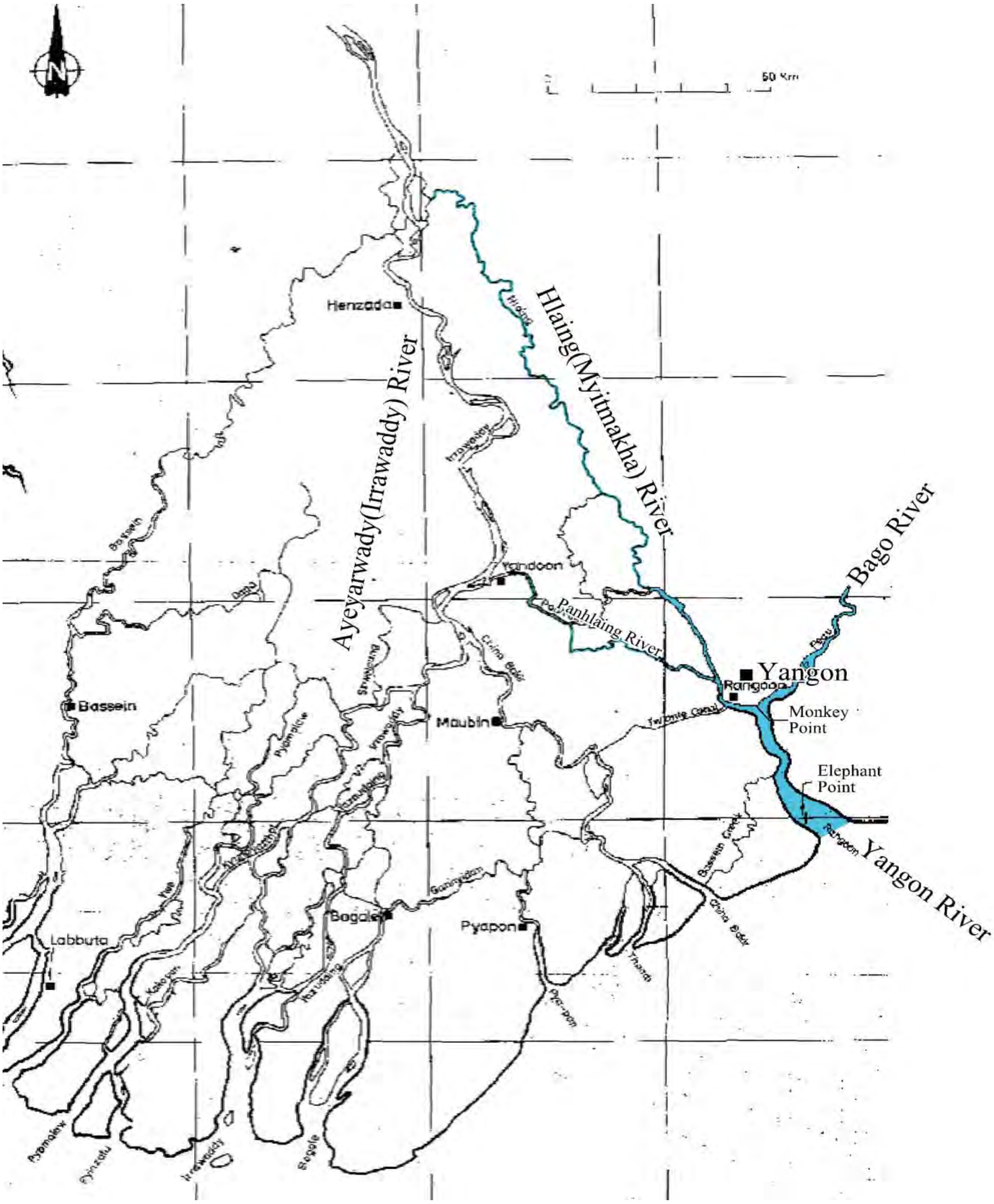
(1) Rivers and Characteristics of River Flow

The Yangon riverine system is located at the east end of Ayeyarwady (Irrawaddy) Delta as shown in Figure 2.4.13.

In Yangon City, the Yangon River is formed by the junction of the Panhaling and Hlaing rivers at a point about 13 km (8 miles) upstream of Monkey Point. The Panhlaing River is a distributary of the Ayeyarwady River, while the Hlaing River is a true river rising in the Bago Yomas and having a drainage area of about 12,950 km^2 (5,000 square miles). Pazundaung Creek, named Ngamoyeik Creek in the northern part of the city, joins the Yangon River at Monkey Point, the southeastern extremity of the city. Pazundaung Creek has a drainage area of about 1,487 km^2 (574 square miles). The Bago River with a drainage area of 5,180 km^2 (2,000 square miles), also joins the Yangon River just east of the city, from which point the Yangon River flows south some 45 km (28 miles) into the Gulf of Bengal. The catchment area at the Yangon river-mouth is 25,640 km^2 (9,900 square miles).

The Bago River has its source near Thikkyi in the Bago Yoma. It flows down the east-facing slope of the Bago Yoma from north to south approximately parallel to the Sittang River. When it reaches Bago, it turns to the southwest and flows into the sea as Yangon River.

Total length of Yangon River from its source to its mouth at the confluence is about 260 km (162 miles) long. Bago River at Bago gauging station is clearly influenced by the tidal level during the period of low flows.



Source: A one dimensional analysis of the tidal hydraulics of deltas (Nicholas Odd, Report OD 44, July 1982, Hydraulics Research Station, UK), from MoAI Library

Figure 2.4.13 Ayeyarwady (Irrawaddy) Delta and Yangon River

(2) Characteristics of River Flow

1) Characteristics of Upstream Part in Relative River

The discharge-duration curve, which is often used in Japan, is examined in order to understand the potential surface water characteristics of the river through the year. The flow regime shows the annual flow condition using the daily discharge at each hydrological station and is indicated by the daily discharge and the number of exceeded days. The annual flow regime is shown below as follows:

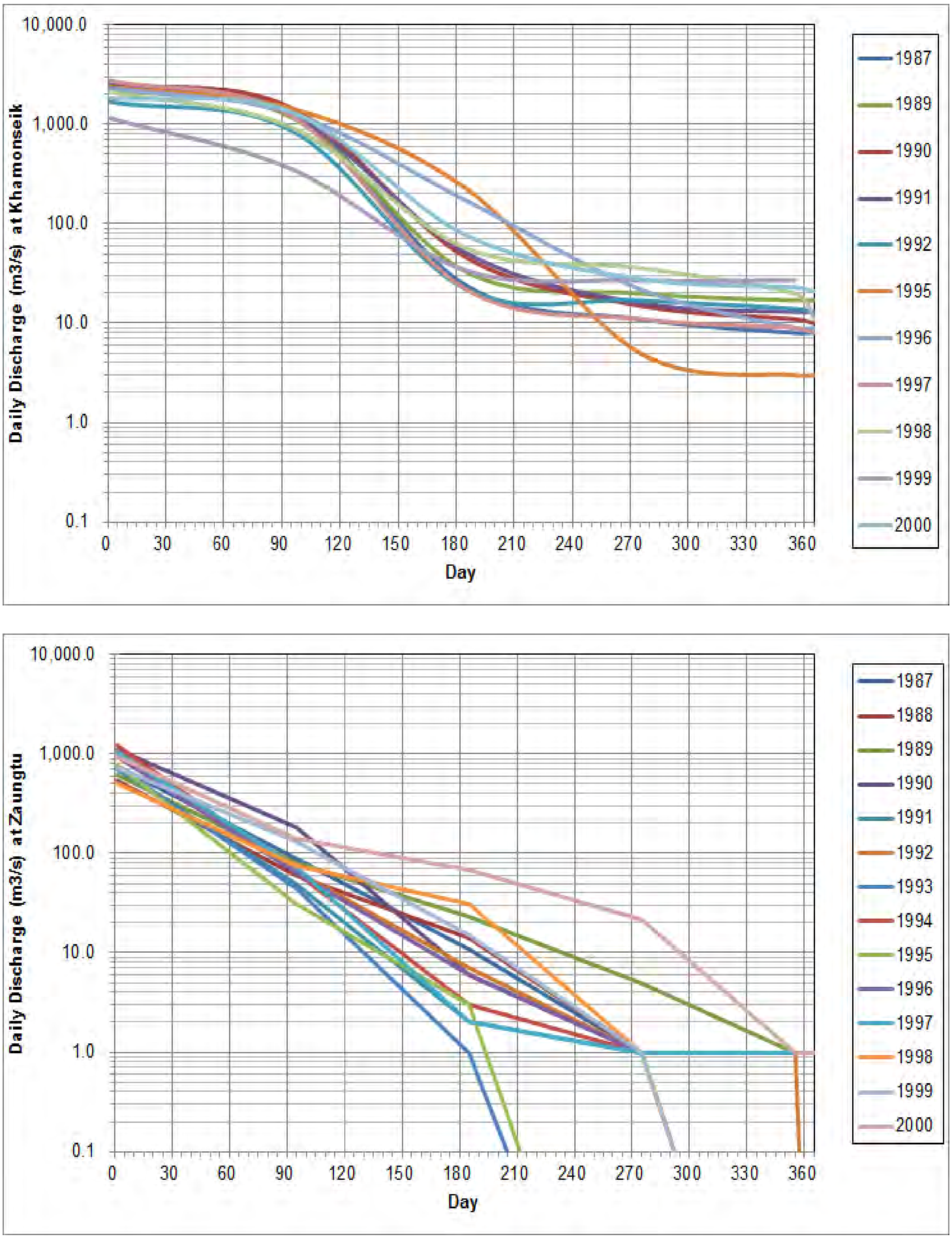
- High discharge (95th greatest daily discharge)
- Normal discharge (185th greatest daily discharge)
- Low discharge (275th greatest daily discharge)
- Drought discharge (355th greatest daily discharge)

The flow regime, which was computed at Zaungtu and Khamonseik stations for a 14-year period (1987-2000), is summarized in Table 2.4.7 and Figure 2.4.14. As seen in the following table and figure, the coefficient of river regime extremely differs by rivers. Although the low flow of Hlaing River at Khamonseik and Bago River flow at Zaungtu are not steady, their coefficients of river regime are large. Especially, it is found that the flow regime by Bago River at Zaungtu does not have a sustainable volume of base flow. Also, the magnitude of coefficient of river regime indicates that the flow fluctuation is large, and if it is large, it indicates that the full year water intake is difficult and flood damage occurs easily.

Table 2.4.7 Flow Regime (1987-2000) of Hlaing and Bago Rivers

River (station)	Mean Daily Discharge (m3/s)							Coefficient of River Regime	Remarks
	Max.	High Dischage	Normal Discharge	Low Discharge	Drought Discharge	Min.	Mean		
		95th day	185th day	275th day	355th day				
Hlaing (Khamonsek)	2,292	1226	99	20	14	13	602	176.3	
Bago (Zaungtu)	837	82	14	3	1	1	72	837.0	

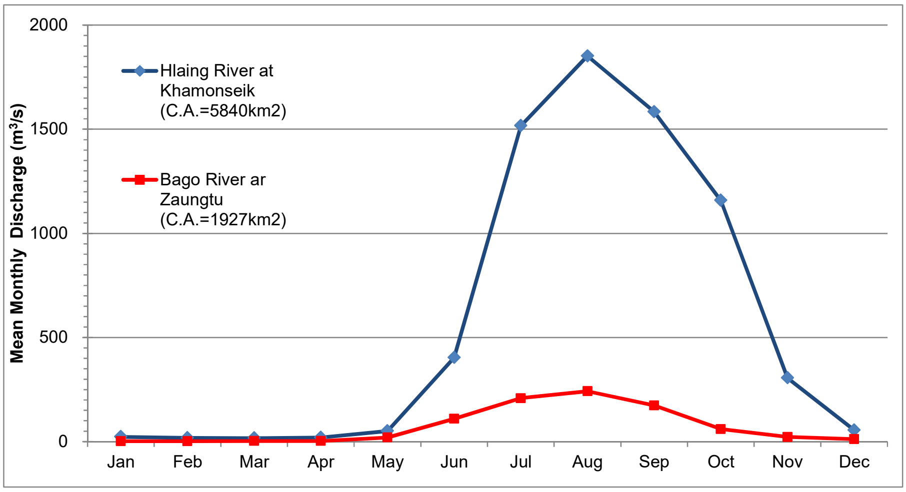
Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH



Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 2.4.14 Flow Regime (1987-2000) of Hlaing and Bago Rivers

In reference to a previous JICA report (records of 14-year period at 1987-2000), the mean monthly flow pattern at Khamonseik and Zaungtu stations are shown in Figure 2.4.15. As seen in the figure, the monthly discharge shows an increase during the rainy season and peak runoff occurs in August.



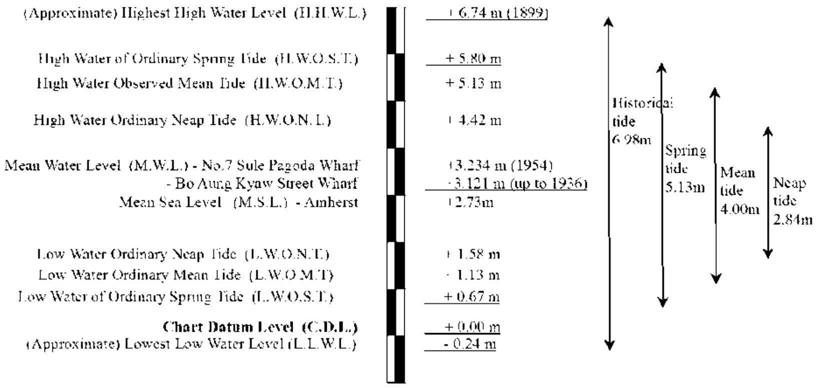
Source: JICA Library (The Study on Improvement of Water Supply System in Yangon City in the Union of Myanmar, 2002), DMH

Figure 2.4.15 Mean Monthly Flow Pattern at Khamonseik and Zaungth Stations (1987-2000)

2) Characteristics of Relative Tidal River

As mentioned above, the lower reaches of the Yangon riverine system are tidal river that are affected by the tidal variability for the length of more than 100 km from the estuary. The tide range around Yangon Port is about 5.1 m and 2.8 m at spring tide and neap tide, respectively. The spring tide to Yangon Port from estuaries is accompanied by flow of up to 3.0 m/s (velocities around Yangon Port on nautical chart are 1.6-1.8 m/s).

Regarding the tidal range around Yangon Port, the tide chart diagrams of Yangon Port are shown in Figure 2.4.16. From the tide chart diagram, fluctuations of spring, mean, and neap tides are observed as 5.13 m, 4.00 m, and 2.84 m. And, according to the hearing with MPA, the maximum storm surge at Yangon Port is reported 2.13 m (Cyclone Nargis, 2008 May 3, MPA measured as 2.13 m from flood mark after the storm).



Source: MPA

Figure 2.4.16 Tide Level of Yangon Port

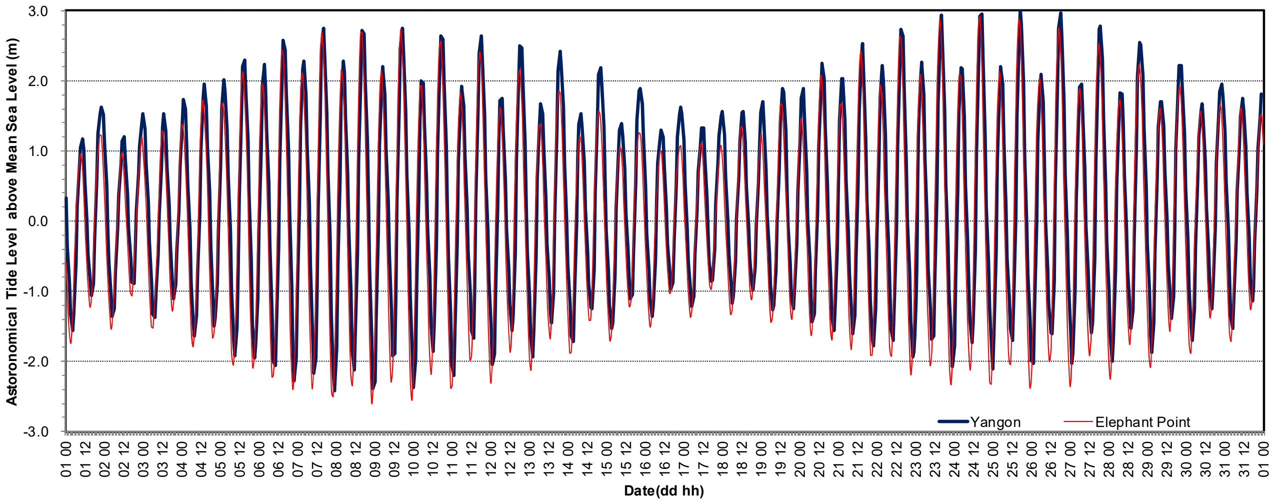
For comparison, the probable surge amplitudes (the sea level departure from normal) at Elephant Point per calculation result from the Hydrology Branch of the Irrigation Department are shown in Figure 2.4.8. From this, how high the storm surge of Cyclone Nargis at Yangon Port can be understood.

Table 2.4.8 Return Period and Surge Amplitude at Elephant Point

Return Period (year)	5	10	20	25	50	**100**	200
Surge (m)	0.889	1.046	1.196	1.244	1.391	**1.537**	1.682

Source: JICA Library (The Project for Preservation of Farming Area for Urgent Rehabilitation of Agricultural Production and Rural Life in Areas Affected by Cyclone Nargis, 2011), MoAI

Hourly calculated data of the astronomical tide at Yangon Port and Elephant Point are available from the website. Both station's astronomical tide levels in March 2005 are shown in Figure 2.4.17.



Source: Earthquake Research Institute, the University of Tokyo

Figure 2.4.17 Astronomical Tide at Elephant Point and Yangon Port (2005)

In addition to "the upland flow (river own flow) arising from the catchment area" and "the tidal flow based on the tidal motion", there are "the density current at a river-mouth due to the salinity difference between seawater and river water", "the density flow by concentration difference of suspended solids", "the heat convection", and "the wind-driven current", in the river tidal compartment. The scale of these flows varies greatly in both time and space, and since it shows a complex phenomenon, their prediction is difficult. However, since these flows are assumed as the well mixed type tide for the great tidal variability, it is considered that the effects of the stratified flow and density flow under the actual streaming motion are smaller at the time of rising tide and ebb tide. (Thus, in this study, the hydraulic analysis is performed by only simulating the river flow (upland flow) and tidal flow.)

In addition, as the tide is based on celestial motion, it is represented as the sum of many periodical components, and tidal flow (rising tide, falling tide) in the tidal river also shows a periodic fluctuation. Furthermore, the average velocity in one tidal cycle at one point in a tidal compartment does not become zero. The average flow associated with oscillatory tidal motion like this is defined as the tidal residual current resulting from the asymmetry of the tidal motion. Therefore, the simulation period that is desired is a relatively long period from the neap tide to the spring tide, not only a one tidal cycle. Also, the entire riverine system that affects the tidal motion is desirable as the simulation range.

Also of importance, a large amount of sediments has been flowing out of the vast basin of Yangon riverine system, which is deposited on the estuarine regions from the Yangon Port. Hence, the river channel/bed of the tidal reach at Yangon River has been changed a little. According to Myanmar Rivers Reference (1996, DWIR of MoT), the annual sediment transport has been estimated at 37 million tons for Yangon River based on the size and character of the drainage area. In the vicinity of Yangon Port, MPA has been dredging the sediment in order to secure the navigation channel.

3) Aggradation and Degradation of Rivers

Bathymetric survey data that is collected in this study is listed in Table 2.4.9. From this data, cross-sectional data of related rivers is prepared by the JICA Study Team. This cross-section data is useful to check and understand the change of cross-sectional/longitudinal profile, such as aggradations and degradations of rivers.

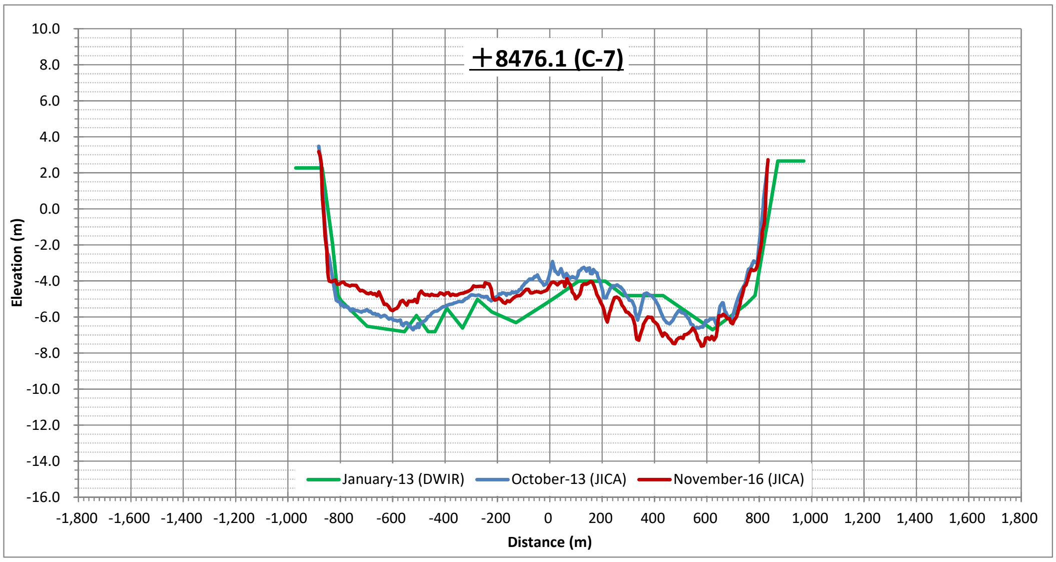
Table 2.4.9 Bathymetric Survey Data List

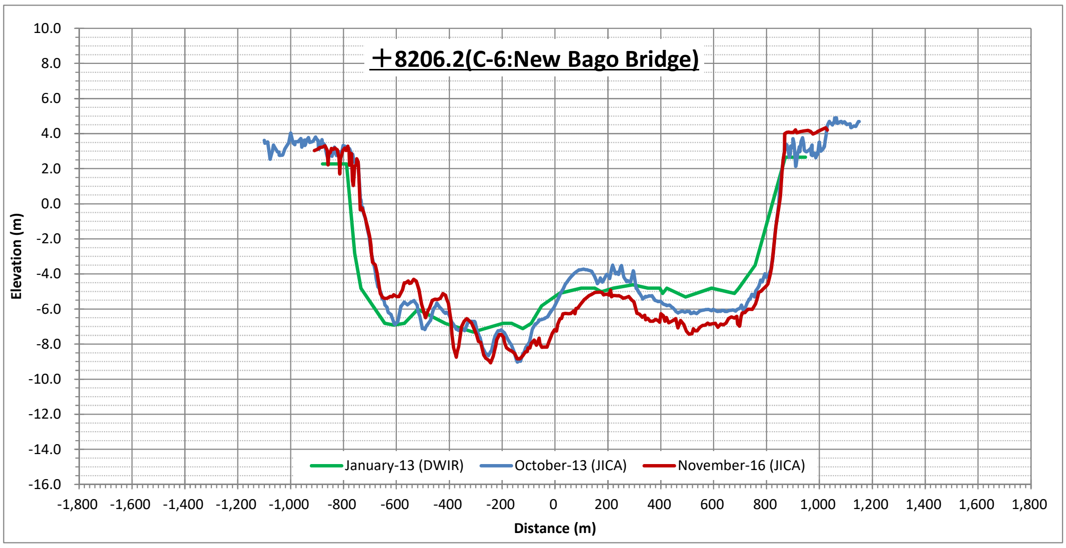
Organization	Reach	Survey Date	Remarks
Navy - Nautical Chart	Yangon River mouth – Bago River, Pazundaung Creek, Hlaing River to port limit	Jan. 2016	
MPA - Bathymetry Survey	Inner bar (Monkey Point)	Feb. 2010, Feb., Jun., Jul. 2013	Partial data
MPA - Bathymetry Survey	Liffy reach of Yangon River	Apr. 2011	Partial data
MPA - Bathymetry Survey	Monkey Point to Bo Aung Kyaw Wharves of Hlaing River	Feb. 2010	
DWIR - Bathymetry Survey	Upstream of Thanlyin to upstream of Dagon Bridge	Jan. 2013(Dagon) Dec. 2015(Thanlyin)	
DWIR - Bathymetry Survey	Confluence of Hlaing to Thanlyin Bridge	May 20007	
Thanlyin Estate Development Ltd. (Star City) – Bathymetric Survey	Monkey Point to Thanlyin Bridge of Bago River	Jul. 2012	
JICA Study Team	Confluence of Hlaing to upstream of Thanlyin Bridge, Pazundaung Creek	Aug. 2013	F/S
JICA Study Team	Confluence of Hlaing to upstream of Thanlyin Bridge	Nov. 2016	This study

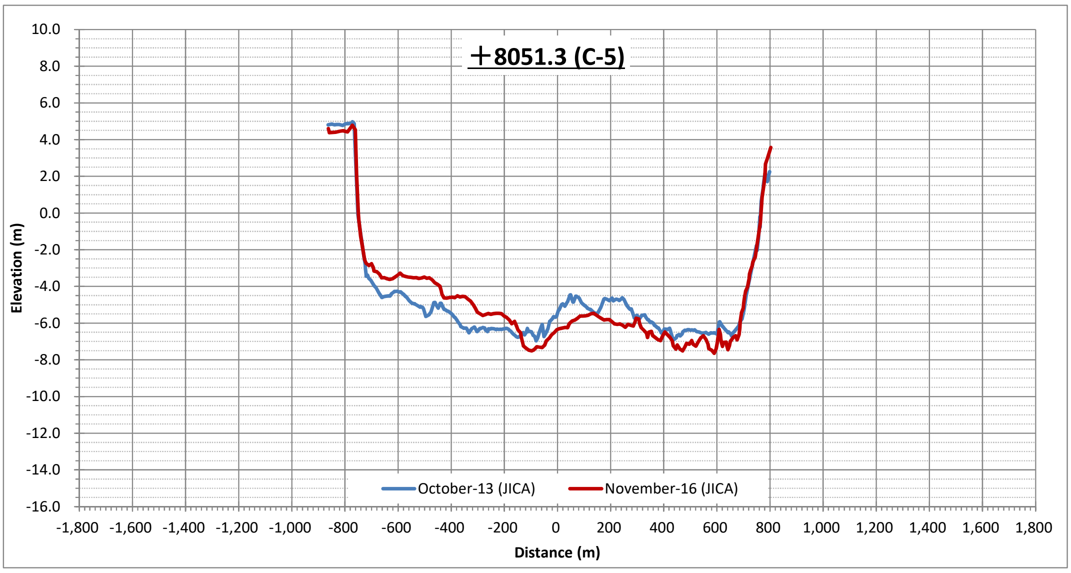
Source: JICA Study Team

The fluctuations of the cross-sectional shape of the river in recent years are shown in Figure 2.4.18.

- In station no. 8476 for hydraulic calculation, its shapes indicate the trend toward increasing erosion at the right bank, while increasing deposition at the left bank.
- In station no. 8206 at the location of the new bridge, its shapes also indicated the trend similar to it in No. 8467. In addition, there are no obvious differences of riverbank lines at both banks in 2013 and 2016.



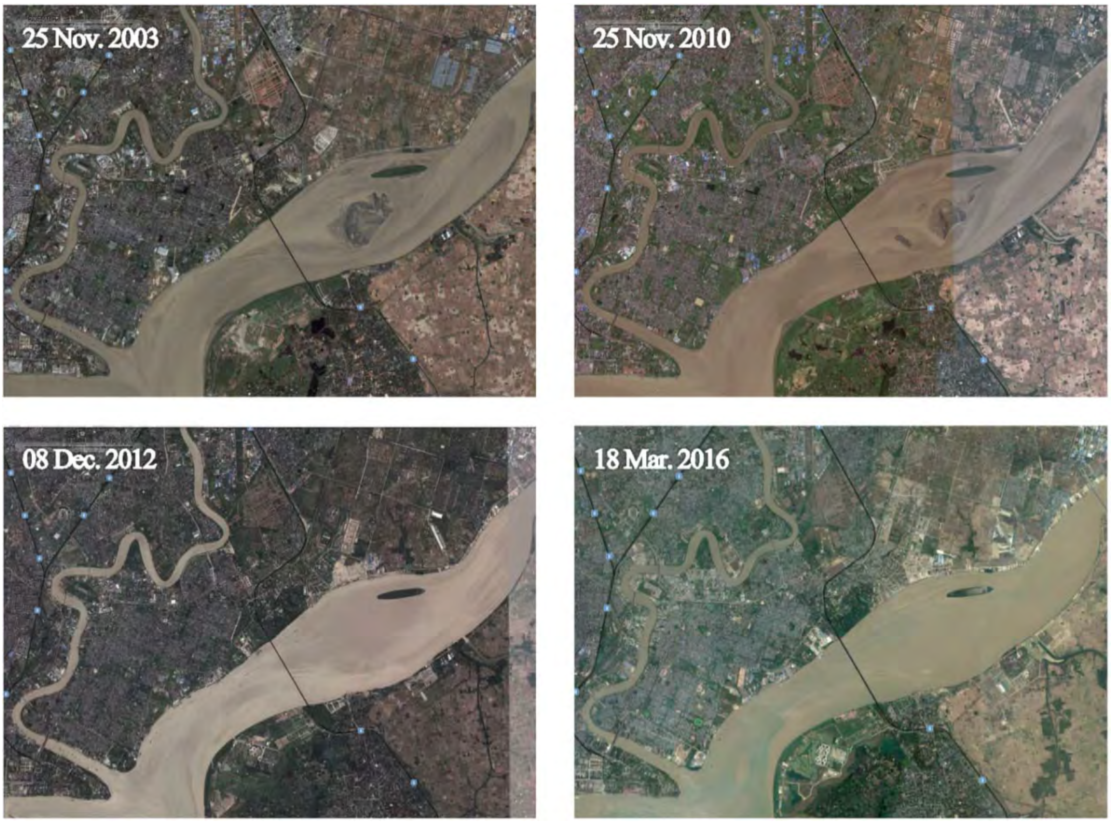




Source: JICA Study Team and DWIR

Figure 2.4.18 Change of Cross-section Data of River

The transition of the riverbank line is important for designing riverine structures. As shown in the figure above, the riverbank at the new bridge location (station no. 8144) has not fluctuated in recent years. Although the left side (Thanlyin side) is a practical navigation route for vessels, there are apprehensions since there is erosion by stream; however, the riverbank slope has been stable at approximately 1:0.8. According to the time series aerial photos of the vicinity of the new bridge site shown in Figure 2.4.19, the riverbank line has been stable at both banks for more than ten years. In addition, the obvious cut bank was not recognized in the field survey even though large water level fluctuation by tide occurs everyday as mentioned above. It says that river bank erosion is not proceeding at least around the new bridge location. As shown in Figure 2.4.20, the closer it is to the land, the steeper the slope of left river bank is. However, it is covered by dry grass.



Source: JICA Study Team (Google Earth Map)

Figure 2.4.19 Change of Cross-section Data of River

Source: JICA Study Team (Google Earth Map)

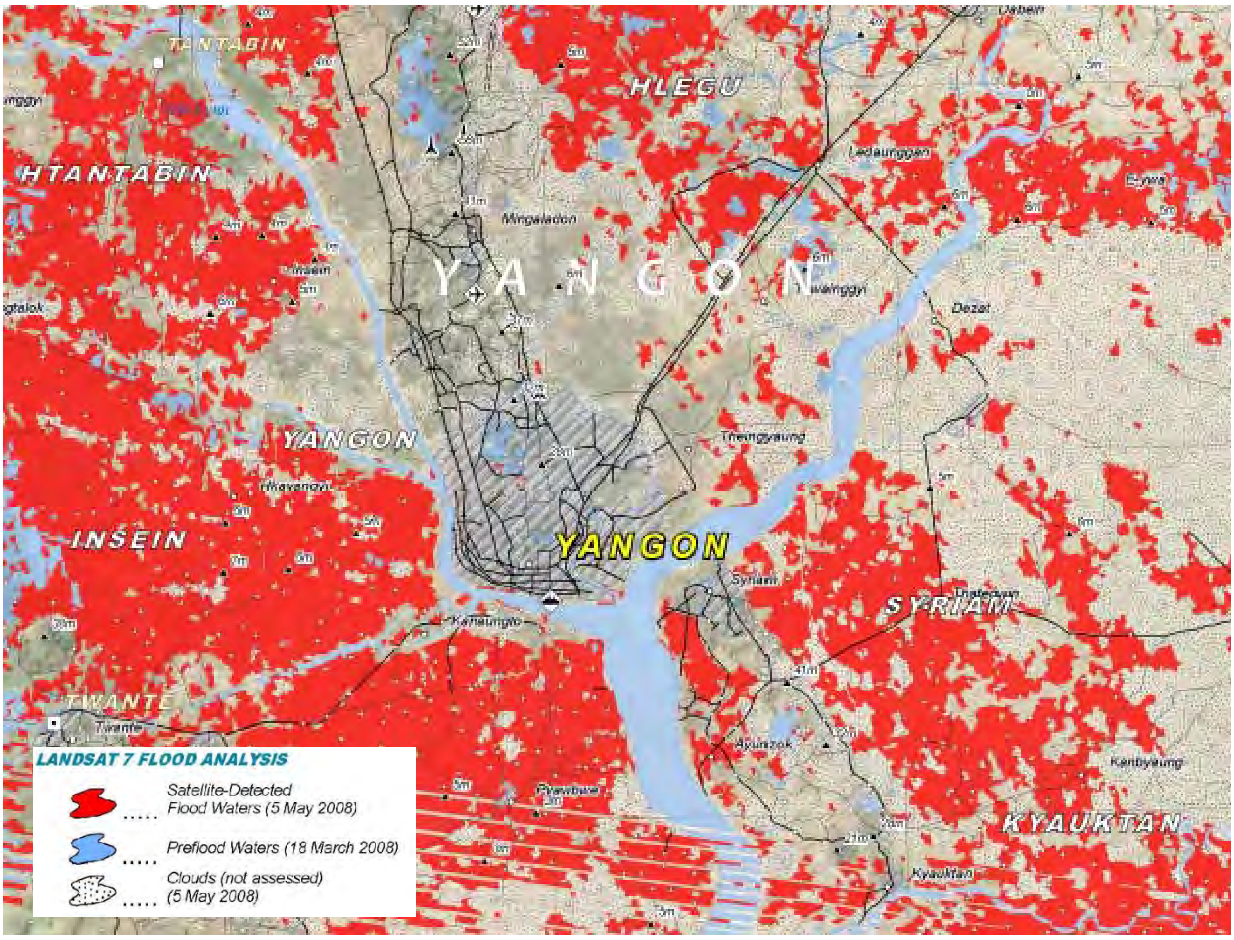
Figure 2.4.20 Current Condition of Bago River Bank at New Bridge Location (Left Side)

(3) Flood Condition including Storm Surge

According to the "Hazard Profile of Myanmar, 2009", flooding has always been one of the major hazards in Myanmar, accounting for 11% of all disasters, second only to fire. Floods around the Yangon area can be classified into three types:

- Riverine floods in the river delta;
- Localized floods in urban area due to a combination of factors, such as cloudburst, saturated soil, poor infiltration rates, and inadequate or poorly built infrastructure (such as blocked drains);
- Flooding due to cyclone and storm surge in the coastal areas.

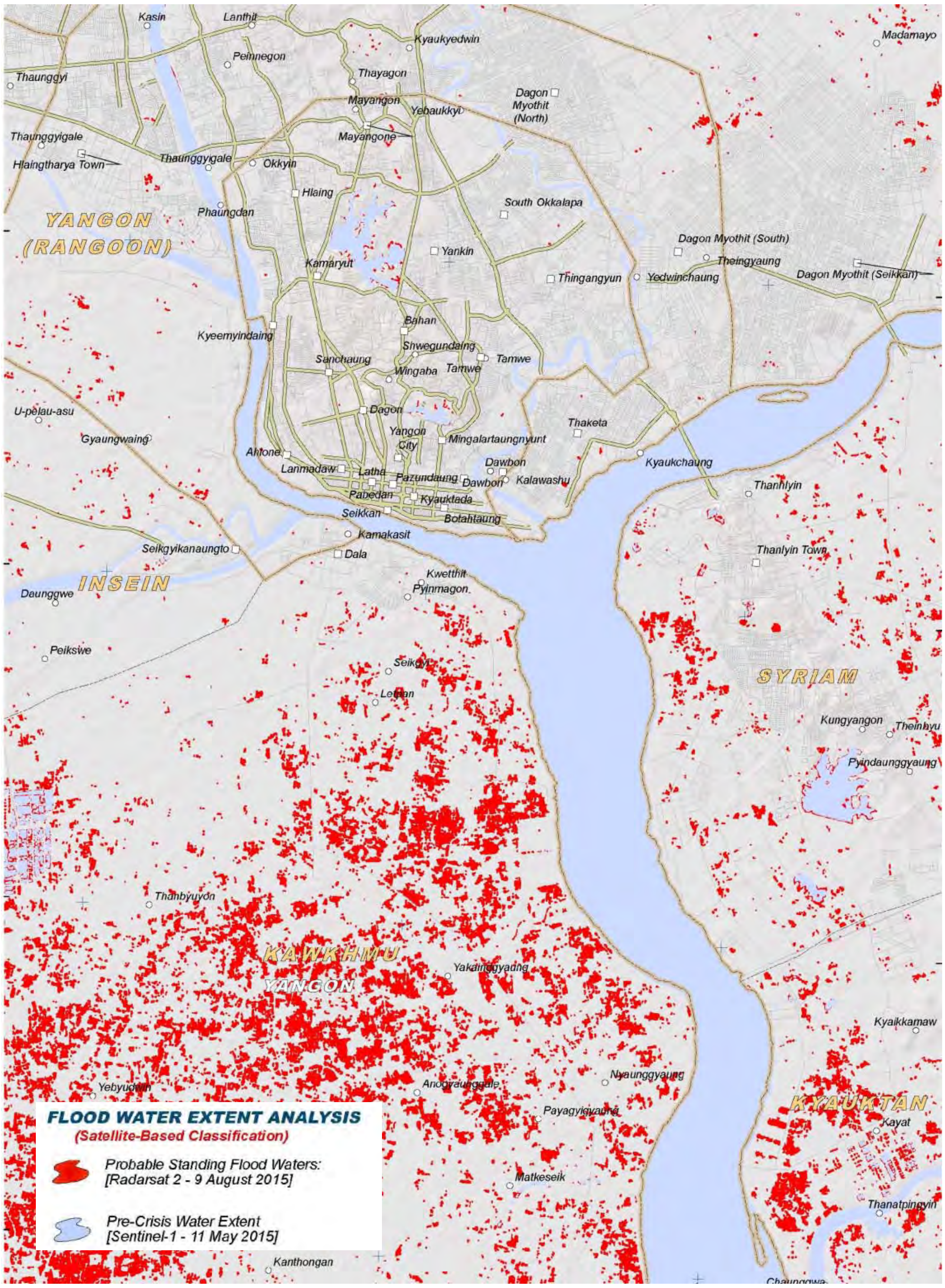
The types of flood from the aforementioned list that cause the most damages are due to cyclone and storm surges. Figure 2.4.21 shows the flood inundation areas resulting from Cyclone Nargis taken by satellite imagery on 5 May 2008. According to the "Hazard Profile of Myanmar," its damages are described as, "peoples of dead or missing were 138,373, killed cattle were 300,000, houses and schools over 4,000 in more than 6,000 villages were destroyed, damage cost was MMK 13 trillion", including damages that occurred in the Ayeyarwady and Yangon areas.



Source: UNOSAT (www.unosat.org)

Figure 2.4.21 Flood Waters Surrounding Yangon City (Cyclone Nargis, 5 May 2008)

Severe flooding in Myanmar began in July 2015 and continued up to September, affecting 12 of the country's 14 states, resulting in about 103 deaths and affecting up to 1,000,000 people. As for the vicinity of Yangon, most of the flood-affected lands were agricultural fields and there was no significant overflowing of water along the river bank.



Source: UNOSAT (www.unosat.org)

Figure 2.4.22 Flood Waters Surrounding Yangon City (9 Aug 2015)

(4) Inland Water Transportation Condition

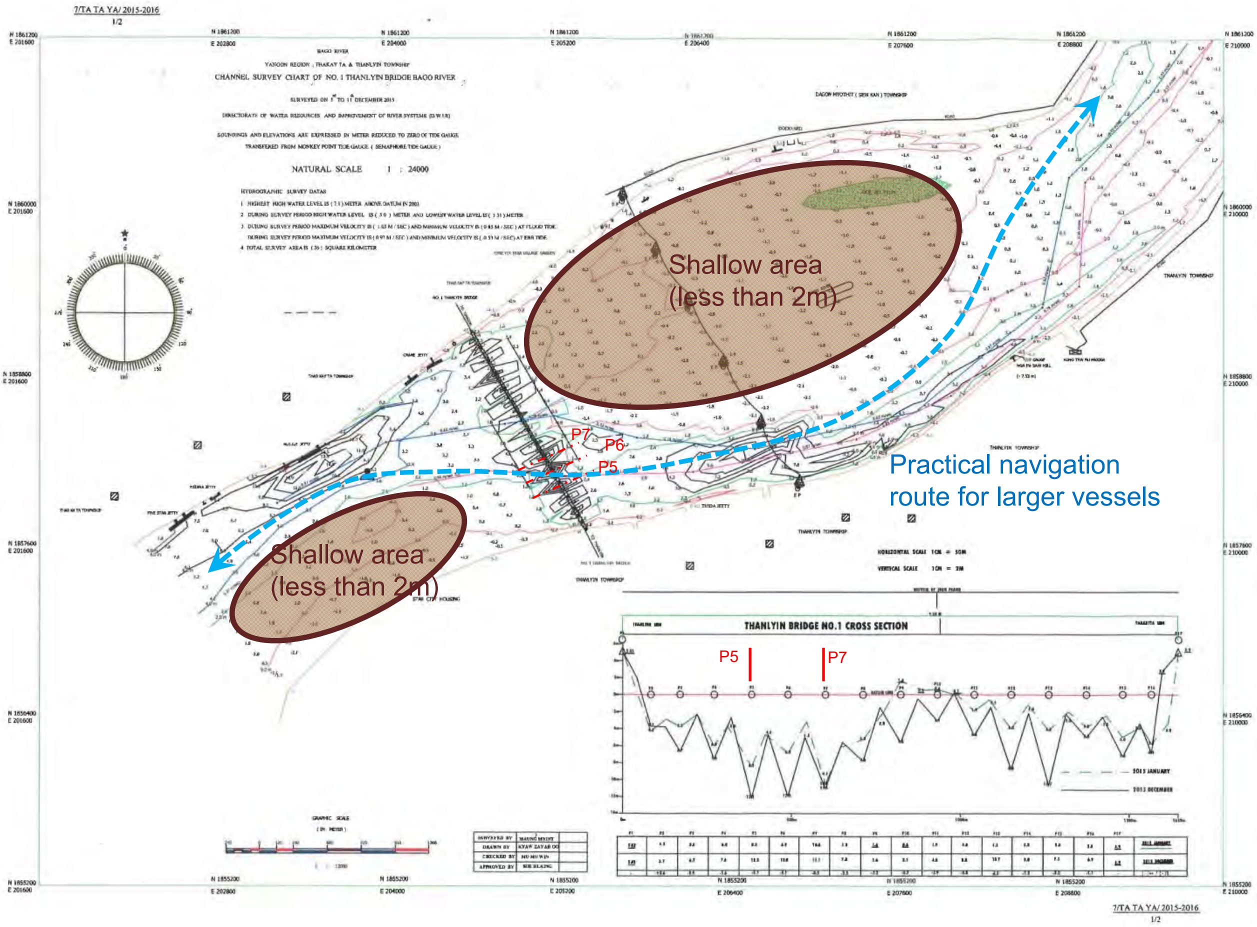
The Port of Yangon is a river port (having 18 wharves) and is the premier international port of Myanmar. It lies along the Yangon riverbank at the Yangon City side. At the new bridge site, the ships owned by a number of organizations are sailed only about once a day, except small ships or fishing boats. Also, there is a small shipyard upstream of the existing Thanlyin Bridge, and some small ships crossed over the Thanlyin Bridge. The navigation channel limitation of the existing bridge is shown in Table 2.4.10.

Table 2.4.10 Navigation Channel Limitation of Existing Bridge

Bridge Name	River Name	Clearance (m)	
		Width	Height
Thanlyin Bridge	Bago	106.1	10.2

Source: IWT

According to the result of the interview with MPA and IWT, the navigation fairway for the Thanlyin Bridge is commonly navigated as shown in Figure 2.4.23.



Source: JICA Study Team based on DWIR map

Figure 2.4.23 Current Status of Riverbed and Practical Navigation Route

2.4.6.2 Probable Flood and Water Level

(1) Probable Flood at Gauging Stations

Past annual maximum discharges (extremal values) of three stations (Zaungtu, Bago, Khamonseik) for the design discharges were collected as shown in Table 2.4.11.

Table 2.4.11 Collection Data List for Annual Maximum Discharge

Station Name	River Name	Catchment Area (km^2)	Period of Record	Collected Data No.	Remarks
Zaungtu	Bago	1,927	1987-	29 (1987-2015)	
Bago	Bago	2,580	1970-	46 (1970-2015)	
Khamonseik	Hlaing	5,840	1987-	26 (1987-2015)	Three year - missing observation

Source: DMH

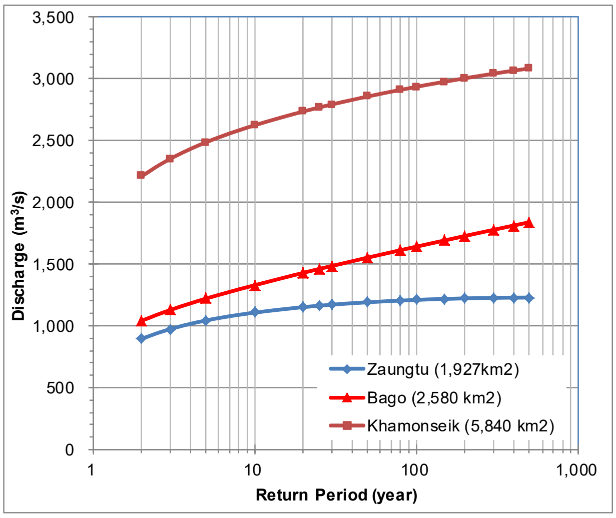
The probable discharges are calculated as follows:

- To select the appropriate model for probability distribution from the three methods: Gumbel distribution, Iwai distribution, and Lognormal distribution. In this study, Iwai distribution was adapted as it is the most common method.
- Calculation return periods are for years 2, 3, 5, 10, 20, 25, 30, 50, 80, 100, 150, 200, 300, 400, and 500.

The probable discharges at the three discharge-gauge stations (Zaungtu, Bago, Khamonseik) are shown in Table 2.4.12.

Table 2.4.12 Probable Flood Calculation at Zaungtu, Bago and Khamonseik Stations

Return Period (Probability) (Year, %)		Probable Discharge: Qmax (m^3/s)		
		Bago	Zaungtu	Khamonseik
		2580 km2	1927 km2	5840 km2
2	50.0%	1,042	896	2,212
3	33.3%	1,129	975	2,353
5	20.0%	1,221	1,044	2,486
10	10.0%	1,330	1,108	2,625
20	5.0%	1,430	1,152	2,736
25	4.0%	1,461	1,163	2,768
30	3.33%	1,485	1,172	2,793
50	2.0%	1,553	1,191	2,857
80	1.25%	1,613	1,205	2,911
100	1.0%	1,642	1,211	2,936
150	0.667%	1,693	1,219	2,977
200	0.5%	1,728	1,223	3,005
300	0.33%	1,778	1,227	3,042
400	0.25%	1,813	1,229	3,067
500	0.2%	1,840	1,230	3,085



Source: JICA Study Team based on data from DMH

(2) Probable Floods from River Flow for Design

The discharge at the proposed bridge sites are calculated by multiplying the proportion of the catchment area of each catchment area to the probable discharges of each gauge stations upstream. (Method by "specific discharge")

The probable discharges used for the hydraulic calculation are shown in Table 2.4.13. Incidentally, these discharges are the runoff volume from the river's own flow. Additional flow rates due to the influences of the falling tide are not included in these discharges.

Table 2.4.13 Probable Flood from River Flow for Design

Riverine System Name	Yangon river					Remarks
River Name	Bago river		Hlaing river		Pazundaung Creek	
Gauge Station Name	Bago		Khamonseik		(Bago)	
Catchment Area at Station (km2)	2,580	-	5,840	-	-	
Catchment Area at Construction Site (km2)	-	5,180	-	12,950	1,490	
Return period	Probability value	Discharge	Probability value	Discharge	Discharge	
1/10	1,330	2,670	2,625	5,821	768	
1/30	1,485	2,982	2,793	6,193	858	
1/50	1,553	3,118	2,857	6,335	897	
1/100	1,642	3,297	2,936	6,510	948	
1/500	1,840	3,694	3,085	6,841	1,063	
		Q1		Q3	Q2	
100 year discharge per unit drainage area (m^3/sec/km2)	0.63643		0.50274			=specific discharge

	Bago River Q1	Pazundaung Creek Q2	Hlaing River Q3	Yangon River (Monkey P.) Q4	Yangon River-mouth Q5	Remarks
Catchment Area (km^2)	5,180	1,490	12,950	19,620	(25,640)	
10 year flood (m^3/s)	2,670	768	5,821	9,259	(11,965)	
30 year flood (m^3/s)	2,982	858	6,193	10,033	(12,912)	
50 year flood (m^3/s)	3,118	897	6,335	10,350	(13,295)	
100 year flood (m^3/s)	3,297	948	6,510	10,755	(13,782)	Design Discharge
500 year flood (m^3/s)	3,694	1,063	6,841	11,598	(14,778)	

Source: JICA Study Team based on Data from DMH

(3) Probable High Water Level at Tidal Gauge Station

Past annual maximum high water levels (extremal values) of Monkey Point for the design high water levels were collected as shown in Table 2.4.15. From these values, probable high water levels were calculated as shown in Table 2.4.15.

Table 2.4.14 Observed High Water Level at Monkey Point

Year	Observed Maximum Annual Water Level: (m, MPA based) Monkey Point	Remarks	Year	Observed Maximum Annual Water Level: (m, MPA based) Monkey Point	Remarks
1981	6.80		1999	7.00	
1982	Not observed		2000	6.69	
1983	6.32		2001	7.13	
1984	Not observed		2002	6.71	
1985	6.94		2003	7.09	
1986	Not observed		2004	6.82	
1987	Not observed		2005	6.84	
1988	7.10		2006	7.07	
1989	Not observed		2007	7.46	
1990	Not observed		2008	6.75	
1991	6.82		2009	7.21	
1992	6.93		2010	6.78	
1993	7.12		2011	7.10	
1994	6.99		2012	7.03	
1995	6.78		2013	7.23	
1996	6.37		2014	7.07	
1997	7.16		2015	**7.53**	
1998	6.88		2016	7.06	

Source: MNHC

Table 2.4.15 Probable High Water Level at Monkey Point

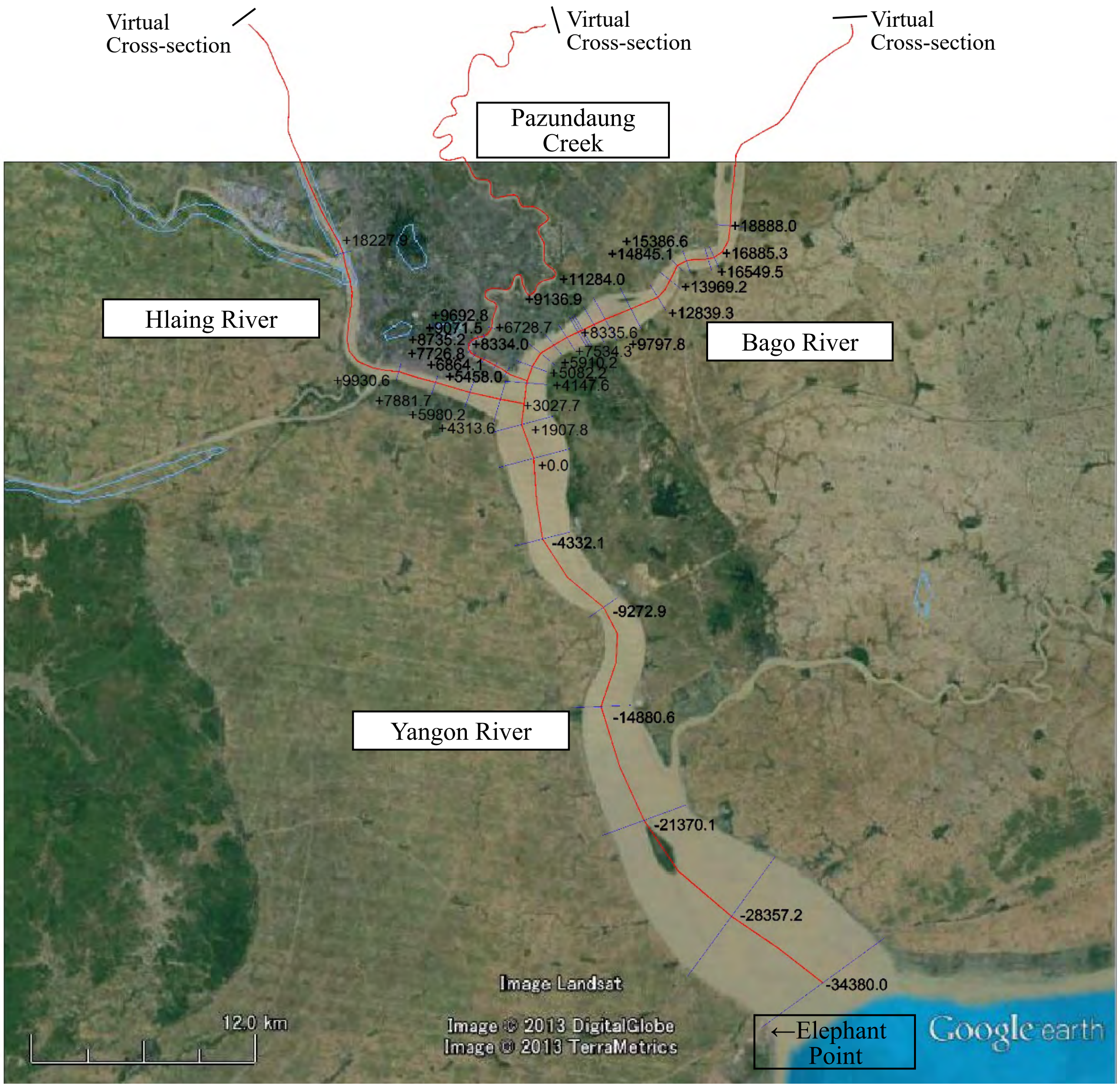
Return Period (Probability) (Year, %)		Porbable High Water Level: H.W.L. (m)		Remarks
		Yangon Port		
		30 (1981-2016) ('82,'84,'86-'87,'89-'90 are not observed)		Collected Data No.
		MPA	Land Survy	Benchmark
2	50.0%	6.92	4.11	
3	33.3%	7.03	4.22	
5	20.0%	7.15	4.34	
10	10.0%	7.31	4.50	
20	5.0%	7.46	4.65	
25	4.0%	7.51	4.70	
30	3.33%	7.55	4.74	
50	2.0%	7.65	4.84	
80	1.25%	7.75	4.94	
100	1.0%	7.80	4.99	
150	0.667%	7.88	5.07	
200	0.5%	7.95	5.14	
300	0.33%	8.03	5.22	
400	0.25%	8.09	5.28	
500	0.2%	8.14	5.33	

Source: JICA Study Team based on Data from MNHC

(4) Hydraulic Calculation

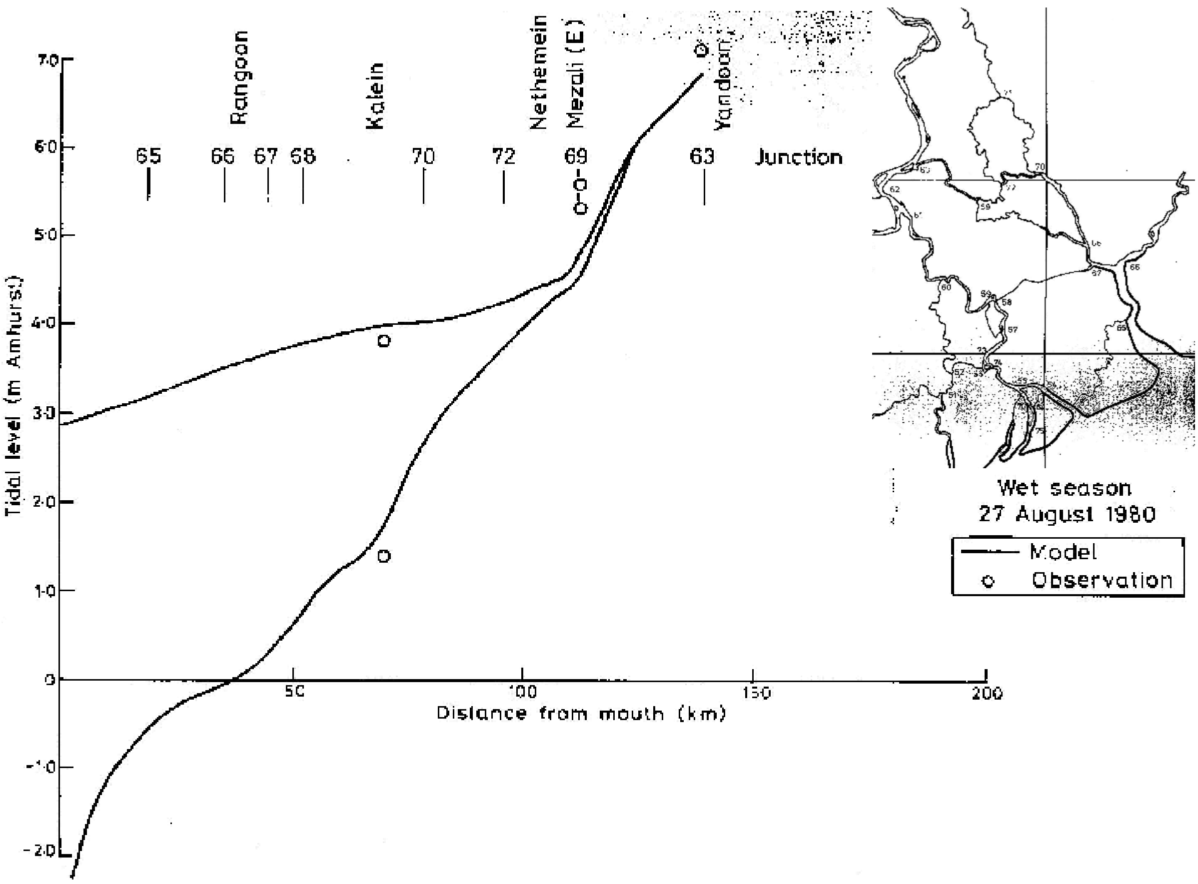
The hydraulic phenomena (rising tide and falling tide in addition to the river's own flood) at the tidal compartment of the river are needed to simulate all of the tidal reaches. Therefore, the range of numerical calculation shall target the whole tidal area of the Yangon riverine system together with their tributaries such as Bago River and Pazundaung Creek. Elephant Point (the river-mouth of Yangon River) is assumed as the downstream boundary. The upstream boundary of the tributaries is assumed in reference to past documents (Figure 2.4.25), the river length is measured from the river route on the topographic map, and river cross-sections at upstream end of the tributaries are assumed as the virtual cross-section, respectively. Lengths to the upstream boundary from the river-mouth are 100 km or more.

The hydraulic calculation model of the Yangon riverine system is shown in Figure 2.4.24.



Source: JICA Study Team

Figure 2.4.24 Hydraulic Calculation Model of Yangon River System



Source: A one dimensional analysis of the tidal hydraulics of deltas (Nicholas Odd, Report OD 44, July 1982,Hydraulics Research Station, UK), from MoAI Library

Figure 2.4.25 Past Simulation Example of High Water and Low Water Profiles at Yangon River (on Wet Season of August 1980)

1) Analysis Software

Hydraulic analysis was carried out to simulate the tidal and flood phenomena at the Yangon River using Hydrologic Engineering Center - River Analysis System (HEC-RAS), which was developed by the US Army Corps of Engineers, USA. HEC-RAS has the capability to compute one-dimensional water surface profiles for both steady and unsteady flows. Sub-critical, supercritical, and mix flow regime profiles can be calculated. Water surface profiles are computed from one cross section to the next by solving the energy equation using the standard-step method. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion coefficients. HEC-RAS requires inputs for boundary conditions of upstream discharge and either downstream water level or known energy gradient. Also, tidal waves are very dynamic. According to the user-manual of this software, in order for the solution to be able to accurately model a tidal surge, theta implicit weighting factor must be close to 0.6.

2) Hydraulic Analyses and Precondition

The hydraulic analyses are conducted through the following procedure:

- To estimate the roughness coefficient of the river channel by using the existing astronomical tide levels at two places in the dry season. (The water level of Yangon Port of upstream, which is calculated from the astronomical tide for Elephant Point of downstream, is approximated as the astronomical tide waveform of the Yangon Port, by changing the roughness coefficient of tidal reaches. The tide table for 2005 at Elephant Point and Yangon Port are given as the known water level data.)

- To conduct the calculation case at the time of flood (rainy season) by using the above roughness coefficient calculated from real tide level.
    - ✧ Also, the following are preconditions of the calculation case:
- The cross-sections for hydraulic calculation are given by using the bathymetry survey results, nautical chart, and others in reference to the above hydraulic model.
- The downstream boundary for the hydraulic calculation of the dry season is given as the tide level (from 4 Feb to 24 Feb 2005, neap tide - spring tide - neap tide) at the Elephant Point which varies from hour to hour. (Hence, the flow becomes an unsteady flow.) The upstream boundary of the dry season is given as the steady low-water runoff (275-day discharge).
- The downstream boundary for the hydraulic calculation of the rainy season is given as the tide level (from 17 Oct to 21 Oct 2005, spring tide) at the Elephant Point. The upstream boundary of rainy season is given the 100-year flood as the steady flow to each river.
- The flow rate to the upstream end is given as the proportional distribution between the catchment area at the upstream end and the total area, the flow rate of remaining catchment area is given as "the uniform lateral inflow" against the stream length.

3) Hydraulic Analyses and Result

Hydraulic analyses of the following two cases were performed.

Table 2.4.16 Case of Hydraulic Analyses

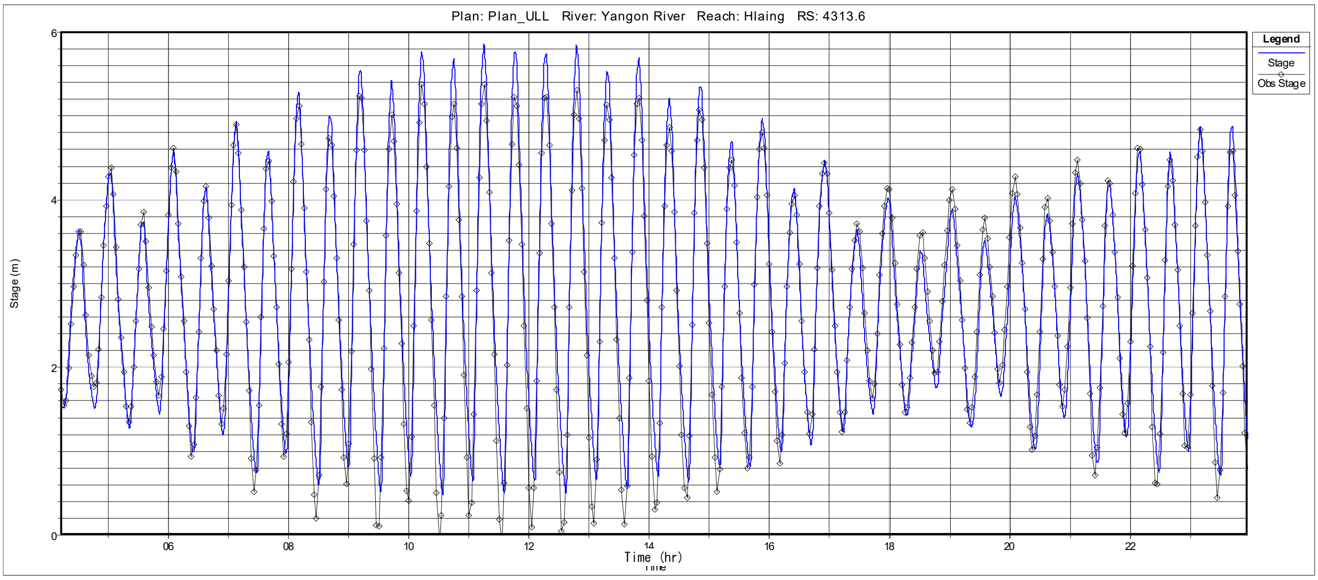
Case No.	Boundary Condition of Upstream (m^3/s)				Boundary Condition of Downstream (Elephant Point)	Remarks (Objectives)
	Discharge	Hlaing	Bago	Pazun-daung	Period of Tidal Waveform	
1	Low-water runoff	44	8	5	4 Feb – 24 Feb 2005 (Annual minimum tide, Neap - Spring – Neap tide)	(for calibration of roughness coefficient)
2	100-year flood	6,510	3,297	948	17 Oct to 21 Oct 2005 (Annual Maximum Tide, Spring tide)	(for calculation of HWL)

Note: Discharge is indicated the value at confluence of Hlaing, Bago, and Pazundaung.
Source: JICA Study Team

If the riverbed material is very small and the riverbed slope is very gentle such as in the delta area, the roughness coefficient of river channel is generally very small and its coefficient is estimated to be about 0.015 according to the past literatures 1. (From the results of geotechnical survey of the F/S, the mean grain size of riverbed material at the Bago Bridge site is very small and it was measured as 0.015-0.15 mm.)

1 Bed Form and Bed Variation During Floods of the TONE River Mouth, Journal of Japan Society of Civil Engineers, Ser. B1 (Hydraulic Engineering) Vol. 54(2010), Japan

The roughness coefficient for case 1 was set as 0.010, 0.015, 0.020, and 0.025. From the hydraulic calculation results, the calculation case of surge amplitude that was properly synchronized with the astronomical tide is the case wherein 0.015 was set as the roughness coefficient, while about 40 cm at most have a margin of error as shown in Figure 2.4.26.



Source: JICA Study Team

Figure 2.4.26 Synchronization between Astronomical Tide and Calculated Tide at Yangon Port by Hydraulic Calculation (Case of Roughness Coefficient: 0.015, Case 1)

From the results of low discharge during the dry season, the hydraulic calculation of high water level is calculated by using 0.015 for roughness coefficient. Hydraulic calculation results for cases 1 and 2 are shown in Table 2.4.17 and Figure 2.4.27.

Moreover, in the estimation of high water level, an allowance was made for the elevation of water surface due to a decrease in atmospheric pressure caused by a cyclone. (The increment caused by waves is not considered in this study.) The elevation of water surface due to a decrease in atmospheric pressure is estimated by using the following equation:

- Rising value of static water level by barometric depression

η PS=0.991･(1013 - p) = 0.991･(1013 - 962) = 50.54 cm = 0.505 m

where: ηPS: Rising value of static water level by barometric depression (hPa)

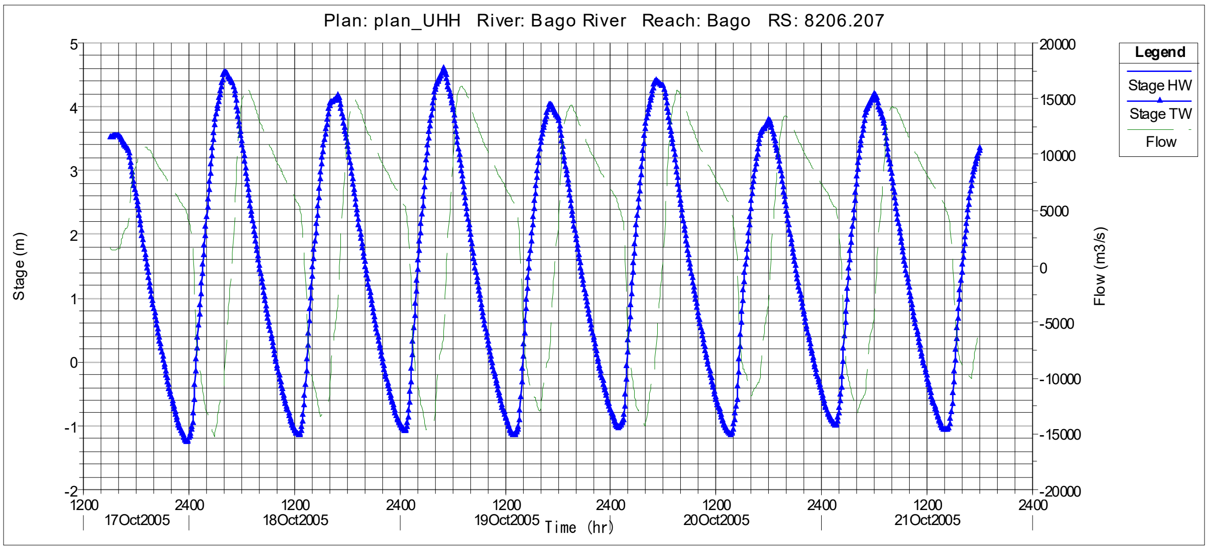
p: Atmospheric pressure value which is decreased due to cyclone (hPa)

(2008 Cyclone Nargis: 962 hPa)

Table 2.4.17 Result of Hydraulic Analyses

Item	Unit	New Bago Bridge +8206.2	Remarks
< Hydraulic Calculation Results >		Case 1: Annual Minimum Tide and Flood	
High Water Level	m	3.07	at Low Discharge
Maximum Discharge	m^3/s	9,298.12	
Low Discharge	m^3/s	8.06	
Tidal flow	m^3/s	9,290.06	falling tide
Minimum Discharge	m^3/s	-14,428.05	
100 year Flood	m^3/s	8.06	
Tidal flow	m^3/s	-14,436.11	rising tide
< Hydraulic Calculation Results >		Case 2: Annual Maximum Tide and Flood	
High Water Level:	m	4.59	at 100-year Flood
Maximum Discharge	m^3/s	16,168.13	
100 year Flood	m^3/s	3,296.73	
Tidal flow	m^3/s	12,871.40	falling tide
Minimum Discharge	m^3/s	-15,230.83	
100 year Flood	m^3/s	3,296.73	
Tidal flow	m^3/s	-18,527.56	rising tide
< Probability Calculation >			
Probable H.W.L. (MPA based)	m	7.80	
Probable H.W.L. (Land Survey)	m	4.99	△2.814m
< Planned Value >			
Design Discharge	m^3/s	16,169	100-year flood
Design H.W.L.	m	4.99	

Source: JICA Study Team



Source: JICA Study Team

Figure 2.4.27 Tidally-dominated Water Level and Discharge Fluctuation at New Bago Bridge – Case 2

(5) Design High Water Level and Discharge

From the above hydraulic analyses, the design high water level and discharge are determined as shown in Table 2.4.17. Regarding the discharge, most of the total discharge is decided by the component of tidal flow other than the river's own flow (upland flow) from the catchment area, for too large of a tidal variation.

2.4.6.3 Scouring Depth

(1) Basic Concept

Bridge scour is caused by the erosive action of flowing water, which excavates and carries away materials from the riverbed and its banks. Scour process is cyclic in nature, which makes it complicated to determine the magnitude of scour. Scour can be deepest near the peak of a flood; however, it is hardly visible since scour holes refill with sediment during the receding stage of floods. In general, several floods may be needed to attain maximum scour under typical flow conditions at bridge crossings.

(2) Methodology of Scour Computation

In designing the bridge substructure, it is very important to evaluate the scour potential at piers and abutments, carefully studying site-specific subsurface information. Total scour at a bridge crossing is comprised of three components:

- Long-term aggradation or degradation
- Contraction scour
- Local scour

1) Aggradation and Degradation

Aggradation and degradation are changes of streambed elevation in long-term due to natural or man-induced causes which can affect the streambed. Aggradation involves the deposition of material eroded from the stream or watershed upstream of the bridge and degradation involves the lowering of the streambed due to the lack of sediment supply from upstream. Generally, streams are considered to be stable and balance of sediment transport if the configuration is not changed in long-term.

2) Contraction Scour

Contraction scour at bridge crossings involves the removal of material from the streambed and banks across the channel width as a result from a contraction of the flow area and an increase in discharge at the bridge.

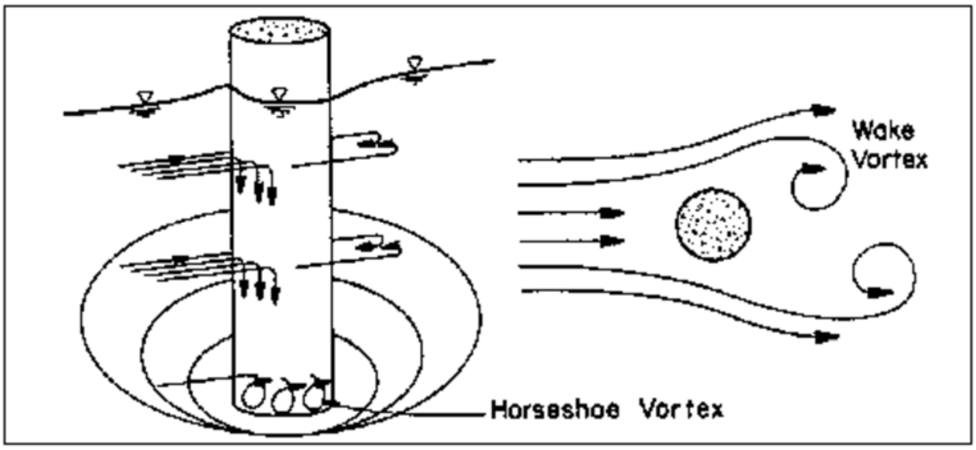
In the case of new bridge construction, common causes for contraction of flows are constriction (encroachment) of road embankment onto the floodplain and/or into the main channel or piers blocking a portion of flow. As a result, the flow area decreases thus causing an increase in velocity and bed shear stress. Hence, more bed material is removed from the contracted reach than transported into the reach. As bed elevation is lowered, the flow area increases, velocity decreases, and a situation of relative equilibrium is reached.

3) Local Scour

Local scour at piers or abutments is due to the removal of bed material as a result of formation of vortices known as the horseshoe vortex and wake vortex at their base. Horseshoe vortices result from a pileup of water on the upstream surface of the obstruction and subsequent acceleration of the flow around the nose of the pier or abutment. The action of the vortex removes bed material around the base of the obstruction. In addition to the horseshoe vortex around the base of a pier, there are vertical vortices downstream of the pier called the wake vortex. Both the horseshoe and wake vortices remove material from the pier base region. The intensity of wake vortices diminishes rapidly as the distance downstream of the pier increases. As a result, immediate downstream of a long pier, there is often deposition of material.

Factors which affect the magnitude of local scour depth at piers and abutments are:

1. Velocity of the approach flow,
2. Depth of flow,
3. Width of the pier,
4. Discharge intercepted by the abutment and returned to the main channel at the abutment,
5. Length of the pier if skewed to flow,
6. Size and gradation of bed material,
7. Angle of attack of the approach flow to a pier or abutment,
8. Shape of a pier or abutment,
9. Bed configuration, and
10. Ice formation or jams and debris.



Source: Evaluating Scour at Bridges (2012 Fifth Edition), Hydraulic Engineering Circular No. 18 (HEC 18), FHWA, USA

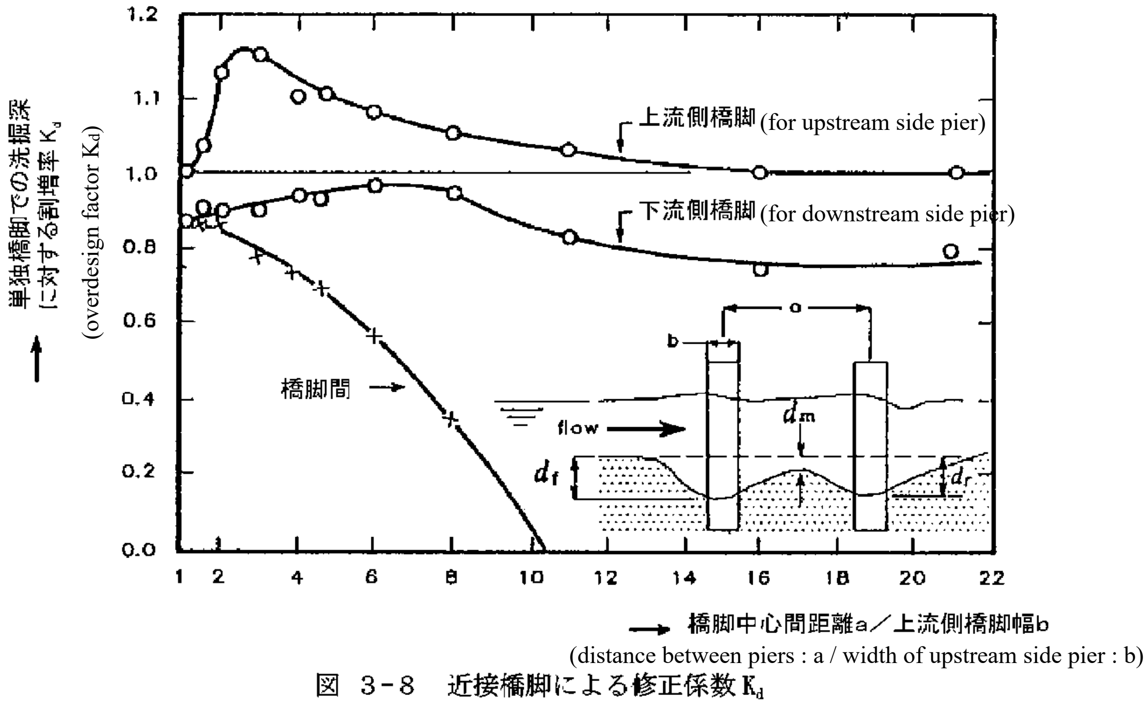
Figure 2.4.28 Simple Schematic Representation of Scour at a Cylindrical Pier

Bago Bridge is located near an existing bridge which is the Thanlyin Bridge. In addition to the factors mentioned above, in the case of local scouring by bridge piers of close bridges, it is said that both bridges affect each other hydraulically. The influence due to a close bridge is calculated with overdesign factor (Kd) in Figure 2- 29. Local scouring depth of close bridges is estimated by multiplying Kd by an estimated local depth without the close bridge. Kd is read by the figure with a/b, where:

a: distance between pier center of upstream bridge and downstream bridge

b: pier width of upstream bridge

In this case, the value of a/b is more than 20 (a≒125 m, b≒6 m) and Kd of the upstream bridge results to 1.0, which means that local scour depth by upstream bridge's pier is not affected by the close bridge of downstream. Meanwhile, Kd of downstream bridge is about 0.8. However, as the hydraulic character of the location of these bridges, the flow direction is changed by the tide effect. It means that the relative position of the two bridges, Thanlyin Bridge and Bago Bridge, interchanged due to tide level. Thus, the value of Kd should be larger than one for safety. Therefore, Kd becomes 1.0 respectively and it is the same as the result without close bridge. Incidentally, when Bago River flows from downstream side to upstream side, Kd becomes 16 (a≒125 m, b≒7.5 m) and it makes almost the same result as the case of forward flow direction.



Source: Guidance of the Plan about Bridge across a River (2009), JICE, Japan.

Figure 2.4.29 Overdesign Factor K_d for Close Bridges

4) Scour Estimation

All major streams intercepted by the proposed bridge alignment were modeled by HEC-RAS model developed by Hydraulic Engineering Center, USA. The model reach was covered by sufficient length from upstream to downstream of bridge location. These models were simulated for 100-year return period discharges under incorporating the bridge. In geometric data, all of the bridge data, including deck/roadway and piers, are given and the schematic diagram of the bridge are shown in Figure 2.4.32.

Scour estimation by steady flow analysis of HEC-RAS is conducted based on the Hydraulic Engineering Circular No. 18 (HEC 18) of the Federal Highway Administration (FHWA), USA by using the value of maximum discharge and high water level of unsteady flow analysis results. The equation of scouring is as follows:

- Contraction Scour equation (modified version of Laursen's 1960 equation)

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1}$$

$$y_s = y_2 - y_0$$

where:
y_1: Average depth in the upstream main channel (m)
y_2: Average depth in the contracted section (m)
y_0: Existing depth in the contracted section (m)
Q_1: Flow in the upstream channel transporting sediment (m^3/s)
Q_2: Flow in the contracted channel (m^3/s)
W_1: Bottom width of the upstream channel that is transporting bed material (m)
W_2: Bottom width of channel in contracted section less pier width (m)
k_1: Exponent determined by mode of bed material transport

- Local Scour (Pier scour) equation (based on CSU equation)

$$\frac{y_s}{y_1} = 2.0 \cdot K_1 \cdot K_2 \cdot K_3 \left(\frac{a}{y_1}\right)^{0.65} {Fr_1}^{0.43}$$

where:
y_S: Scour depth (m)
y_1: Flow depth directly upstream of the pier (m)
K_1 : Correction factor for pier nose shape
K_2 : Correction factor for angle of attack of flow
K_3 : Correction factor for bed condition
a : Pier width (m)
L : Length of pier (m)
Fr_1 : Froude Number directly upstream of the pier
V_1 : Mean velocity of flow directly upstream of the pier (m/s)

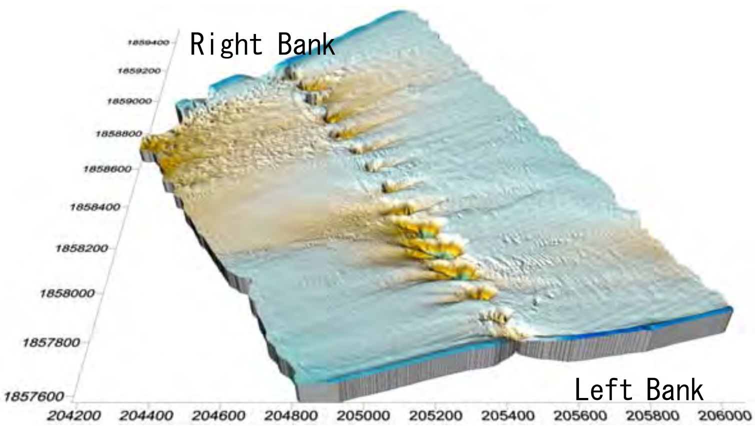
In addition to the CSU equation, an additional equation developed by Dr. David Froehlich has also been added as an alternative pier scour equation. The evaluated scour depth by the Froehlich equation includes the pier width regardless of flow conditions. Therefore, it can be too large if actual scour depth would be smaller than the pier width.

- Local Scour (Pier scour) equation (the Froehlich equation)

$$y_s = 0.32\varphi(a')^{0.62}{y_1}^{0.47}{Fr_1}^{0.22}{D_{50}}^{-0.09} + a$$

where:
φ : Correction factor for pier nose shape
a' : Projected pier width with respect to the direction of the flow (m)

In order to accurately figure out angle of attack of flow to each pier for local scour computation, horizontal two- dimensional structure of flow analysis (herein after referred to as "2D flow analysis") was conducted by HEC-RAS. The HEC-RAS 2D modeling requires a detailed and accurate terrain model for obtain applicable result. The bathymetric survey result, which was carried out in this study, is applied for the model. Two types of terrain models, with and without new bridge piers, were made to elucidate the influence of construction of new bridge in addition to the measure of oblique angles. The 2D flow analysis uses the computational mesh which one water level is calculated for each mesh at each time step. In general, smaller meshes may be required to define significant changes to geometry and rapid changes in flow dynamics. Thus, the size of mesh, which

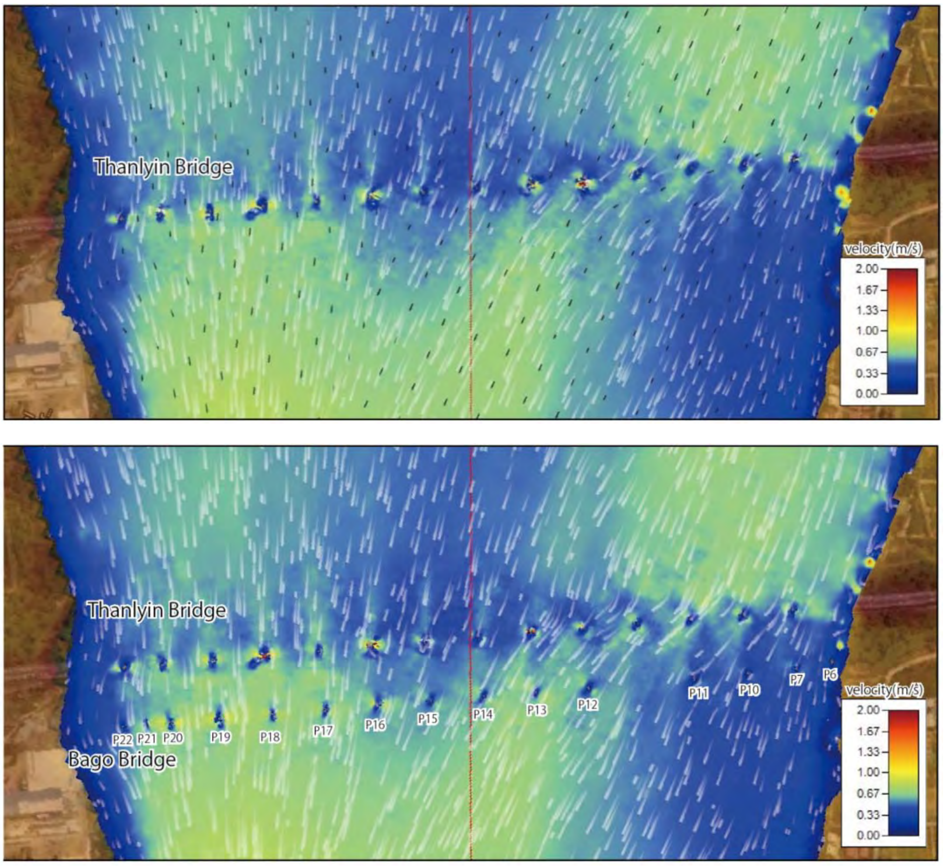


is around piers, was much smaller than the other area.

Source: JICA Study Team

Figure 2.4.30 3D Image of Bathymetric Survey Result

The boundary conditions for computation were the same as case no. 2 in Table 2.4.16 and the result of 2D flow analysis is indicated in Figure 2.4.31. According to the figure, flow direction around the new bridge location is not parallel to the center line of the Bago River but along the water course (the navigation fairway). Regarding the local sour of Thanlyin Bridge, 2D flow analysis result is consistent with the actual terrain of river bed since the scouring depth by the pier, which has large oblique angle against flow direction, is deeper than the others. Meanwhile, comparing with flow condition of the terrain model with and without new bridge in the figure, it can be said that the influence to the flow condition by new bridge is limited just around the new bridge's piers.



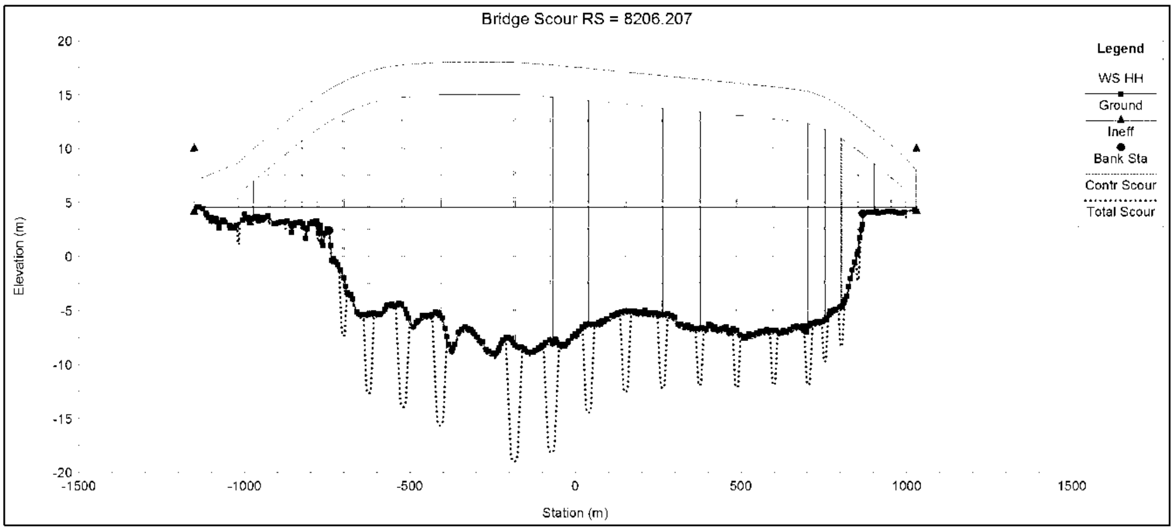
Source: JICA Study Team

Figure 2.4.31 2D Flow Analysis Result

Table 2.4.18 List of Oblique Angle for Piers of Bago Bridge

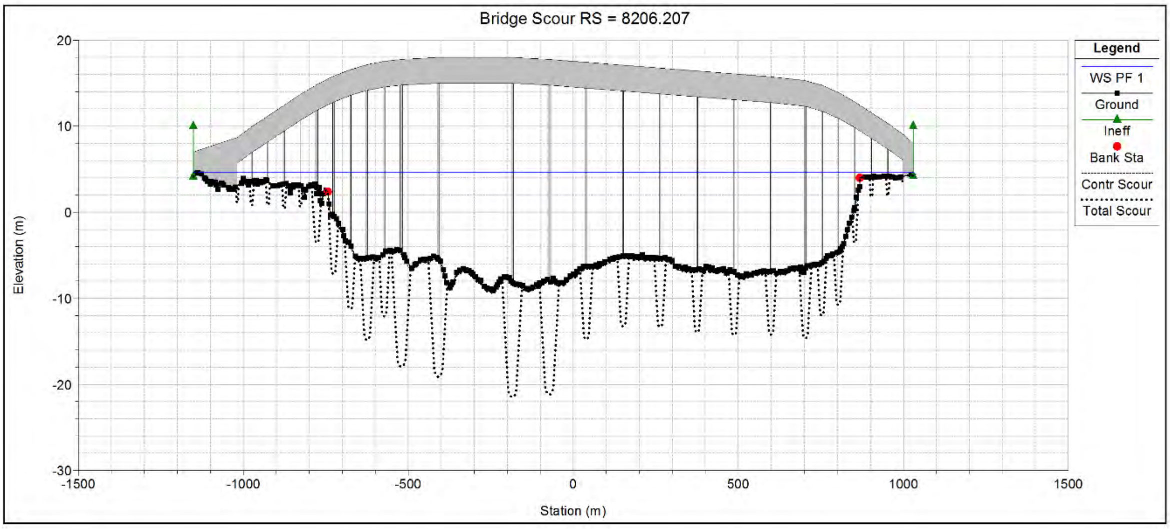
Pier No.	Oblique Angle	K_2 for CSU equation	a' for Froehlich equation	Pier No.	Oblique Angle	K_2 for CSU equation	a' for Froehlich equation
P6	16.6°	1.83	5.69	P16	19.1°	1.49	6.29
P7	30.3°	2.10	6.75	P17	4.1°	1.12	4.50
P10	32.9°	1.42	8.12	P18	2.8°	1.08	4.34
P11	38.6°	1.45	7.30	P19	1.6°	1.05	4.19
P12	39.1°	1.46	9.95	P20	1.4°	1.04	4.66
P13	32.0°	1.41	9.89	P21	1.3°	1.05	3.18
P14	32.8°	1.73	7.80	P22	0.3°	1.01	3.04
P15	29.5°	1.68	7.45				

Source: JICA Study Team



Source: JICA Study Team

Figure 2.4.32 Scouring Computation Result at New Bago Bridge by the CSU Equation



Source: JICA Study Team

Figure 2.4.33 Scouring Computation Result at New Bago Bridge by the Froehlich Equation

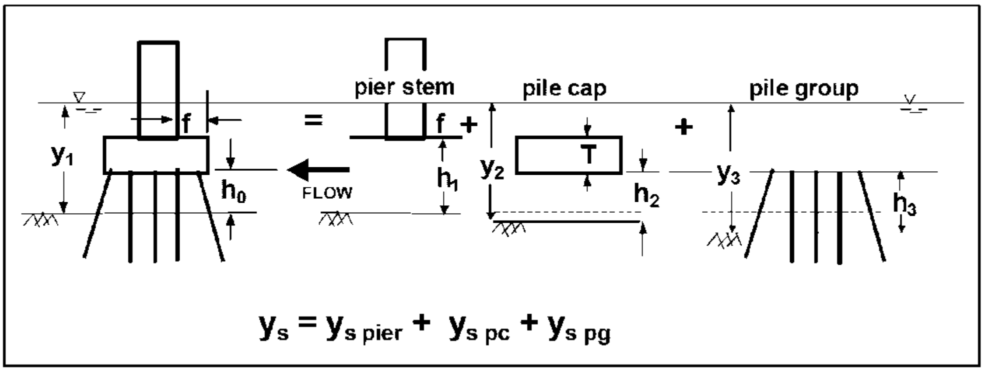
Table 2.4.19 Result of Scouring Computation

Pier No.	the CSU equation			the Froehlich equation		
	Total Scour (m)	Local Scour (m)	Contraction Scour (m)	Total Scour (m)	Local Scour (m)	Contraction Scour (m)
P1	0.62	0.62	0.00	2.72	2.72	0.00
P2	0.62	0.62	0.00	2.73	2.73	0.00
P3	0.70	0.70	0.00	2.83	2.83	0.00
P4	0.58	0.58	0.00	2.70	2.70	0.00
P5	1.02	1.02	0.00	5.77	5.77	0.00
P6	5.48	5.13	0.35	7.59	7.24	0.35
P7	7.40	7.05	0.35	8.08	7.73	0.35
P10	9.37	9.02	0.35	13.35	13.00	0.35
P11	10.20	9.85	0.35	13.62	13.27	0.35
P12	10.87	10.52	0.35	13.30	12.95	0.35
P13	10.25	9.90	0.35	13.21	12.86	0.35
P14	8.26	7.91	0.35	8.52	8.17	0.35
P15	7.53	7.18	0.35	8.19	7.84	0.35
P16	6.84	6.49	0.35	7.94	7.59	0.35
P17	5.30	4.95	0.35	7.30	6.95	0.35
P18	5.26	4.91	0.35	7.37	7.02	0.35
P19	5.11	4.76	0.35	7.37	7.02	0.35
P20	5.42	5.07	0.35	8.14	7.79	0.35
P21	3.91	3.56	0.35	6.12	5.77	0.35
P22	3.72	3.37	0.35	6.12	5.77	0.35
P23	2.77	2.42	0.35	4.07	3.72	0.35
P24	0.25	0.25	0.00	2.30	2.30	0.00
P25	0.24	0.24	0.00	2.27	2.27	0.00

Source: JICA Study Team

As shown in Table 2.4.19, the estimated scour depth reaches the foundation of some piers. The foundation of new bridge shall be designed to be stable for scouring without riverbed protection.

The components of a complex pier are illustrated in Figure 2.4.34 (Jones and Sheppard, 2000).



Source: Evaluating Scour at Bridges (2012 Fifth Edition), Hydraulic Engineering Circular No. 18 (HEC 18), FHWA, USA

Figure 2.4.34 Definition Sketch for Scour Components for Complex Pier

Total scour from superposition of components is given by:

$y_s = y_{s\,pier} + y_{s\,pc} + y_{s\,pg}$

where:

y_S: Total scour depth (m)

$y_{S\ pier}$: Scour component for the pier stem in the flow (m)
$y_{S\ pc}$: Scour component for the pile cap or footing in the flow (m)
$y_{S\ pg}$: Scour component for the piles exposed to the flow (m)

$$\frac{y_{s\ pier}}{y_1} = K_{h\ pier}\left[2.0K_1K_2K_3\left(\frac{a_{pier}}{y_1}\right)^{0.65}\left(\frac{v_1}{\sqrt{gy_1}}\right)^{0.43}\right]$$

$$\frac{y_{s\ pc}}{y_2} = 2.0K_1K_2K_3K_w\left(\frac{a_{pc}}{y_2}\right)^{0.65}\left(\frac{v_2}{\sqrt{gy_2}}\right)^{0.43}$$

$$\frac{y_{s\ pg}}{y_3} = K_{h\ pg}\left[2.0K_1K_3\left(\frac{a*_{pg}}{y_3}\right)^{0.65}\left(\frac{v_3}{\sqrt{gy_3}}\right)^{0.43}\right]$$

where;
a_{peir}, a_{pc}, $a*_{pg}$: Pier width, pile cap width, projected width of pile group (m)
$K_{h\ pier}$: Coefficient to account for height of pier stem above bed and shielding effect by pile cap
K_w : Wide pier factor
$K_{h\ pg}$: Pile group height factor

The results of scour estimation from superposition of components are shown in Table 2.4.20.

Table 2.4.20 Result of Scouring Computation

Pier No.	Scour of components				Rivebed Elevation (MSL+m)	Water Depth (m)	Mean Velocity (m/s)	Pile top Elevation (MSL+m)	Scoured Level (MSL+m)
	Total Scour (m)	Scoru for Pier (m)	Scoru for Pile cap (m)	Contraction Scour (m)					
P1	0.35	0.35	–	0.00	4.30	0.29	0.02	3.55	3.95
P2	0.36	0.36	–	0.00	4.30	0.29	0.02	3.49	3.94
P3	0.37	0.37	–	0.00	4.30	0.29	0.02	3.44	3.93
P4	0.20	0.20	–	0.00	4.30	0.29	0.02	3.49	4.10
P5	0.32	0.32	–	0.00	4.30	0.29	0.02	3.51	3.98
P6	3.86	3.15	0.36	0.35	-1.72	6.31	0.78	-3.45	-5.58
P7	2.34	1.01	0.99	0.35	-5.35	9.94	0.78	-3.45	-7.69
P10	6.72	5.80	0.58	0.35	-4.55	9.14	0.88	-9.20	-11.27
P11	6.72	5.53	0.84	0.35	-5.41	10.00	1.00	-9.20	-12.13
P12	5.71	4.25	1.11	0.35	-7.96	12.55	1.06	-9.20	-13.67
P13	5.46	4.14	0.97	0.35	-8.02	12.61	1.01	-9.20	-13.48
P14	5.14	4.03	0.76	0.35	-6.28	10.87	1.01	-8.06	-11.42
P15	5.74	4.73	0.66	0.35	-5.09	9.68	0.89	-8.06	-10.83
P16	5.08	4.11	0.63	0.35	-5.26	9.85	0.92	-8.06	-10.35
P17	2.99	2.28	0.36	0.35	-6.70	11.29	0.92	-8.06	-9.69
P18	3.00	2.12	0.53	0.35	-6.99	11.58	0.98	-8.06	-9.99
P19	2.89	2.09	0.45	0.35	-6.88	11.47	0.97	-8.06	-9.77
P20	2.97	2.00	0.62	0.35	-6.55	11.14	0.97	-7.28	-9.52
P21	2.40	1.71	0.34	0.35	-6.15	10.74	0.79	-7.55	-8.55
P22	2.86	2.51	–	0.35	-4.61	9.20	0.79	-7.59	-7.47
P23	2.01	1.66	–	0.35	-0.05	4.64	0.79	-2.39	-2.06
P24	0.13	0.13	–	0.00	4.11	0.48	0.01	3.73	3.98
P25	0.13	0.13	–	0.00	4.04	0.55	0.01	3.78	3.92

Source: JICA Study Team

2.5 PUBLIC UTILITIES SURVEY

2.5.1 Survey Scope and Purpose

Public utilities survey was conducted in order to get the information for all public utilities in the project area. The survey is comprised of underground utilities survey and aboveground utilities survey.

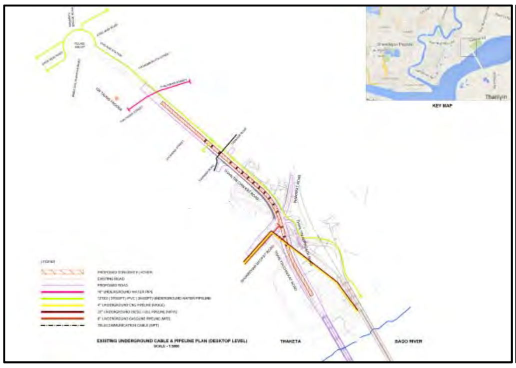
(1) Underground Utilities Survey

Test pit excavation was carried out in order to identify the location, type, and size of all underground utilities in the project area.

Scope and procedure of the test pit excavation are stated below.

1) Preparation Work

- Approximate locations of the underground utilities were confirmed in the supplemental F/S as shown in Figure 2.5.1.



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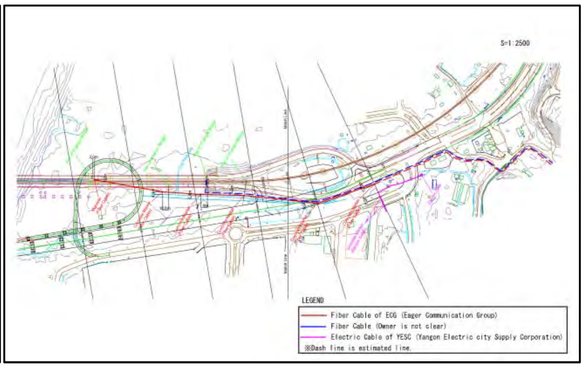


<Thanlyin Side>

Source: Supplemental F/S

Figure 2.5.1 Underground Utilities Survey Result in Supplemental F/S

- Locations for pit excavation are determined by reference to the information from the supplemental F/S.

2) Excavation

- Test pit excavations are conducted manually in order that the underground utilities are not damaged.
- Where any underground utilities are not found at the determined location, another excavation is conducted near the original location until the utility is found.

3) Measurement

- When the underground utility is found, the following information is recorded:
  - Test pit ID
  - Type of utility
  - Size of utility
  - Distance from identifiable location such as outer edge of sidewalk
  - Depth from surface
  - Sketch
  - Photos

4) Backfill

- The road excavated is brought back to original conditions after the measurement is completed.

5) Reporting

- Survey report is prepared for all test pit locations.

(2) Aboveground Utilities Survey

Aboveground utilities survey was carried out in order to identify the location, type, size, and material of all aboveground utilities in the project area.

In addition to public utilities such as electric pole, telecommunication pole, lighting, and private facilities such as advertisement, drinking water post were also surveyed.

2.5.2 Survey Result

(1) Underground Utilities Survey Result

As a result of underground utilities survey, i.e., test pit excavations, the following utilities were found in the project area:

- Water pipeline
- Diesel pipeline
- Gas pipeline
- Telecommunication line
- Fiber cable

A sample of underground utilities survey data sheet is shown in Figure 2.5.2.

All survey data sheets are attached in Appendix-13.

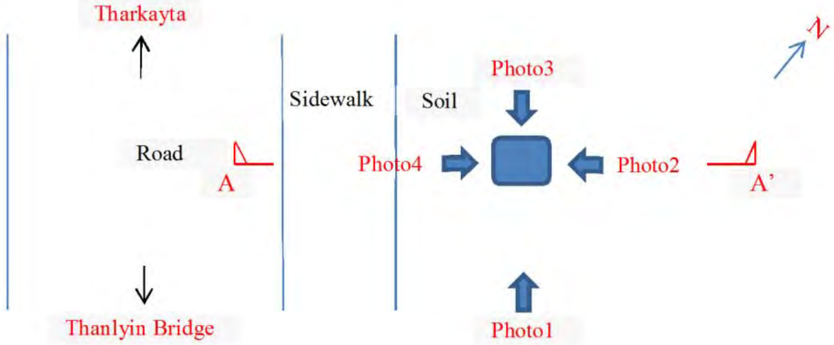
Survey Sheet of D-1

1. Summary of Location

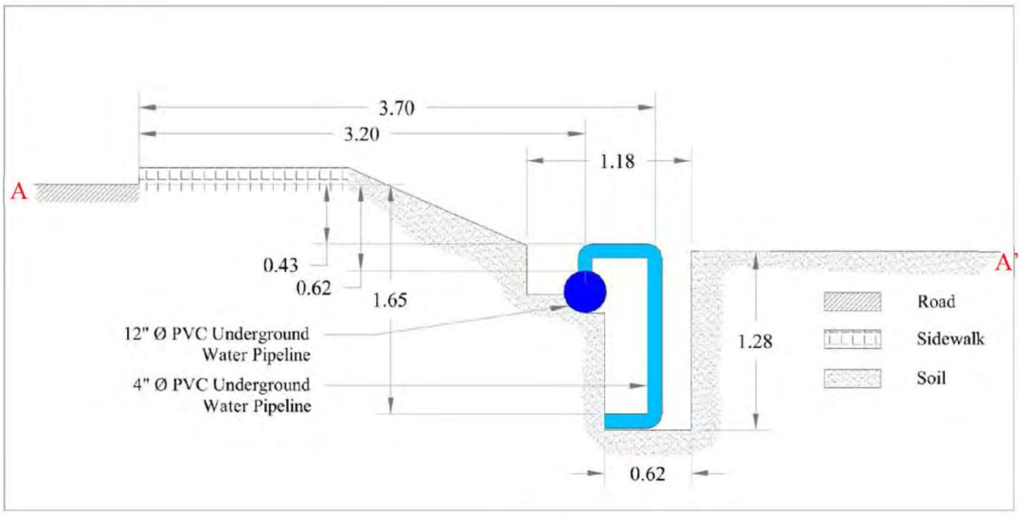
The location of D-1 pit is located at the following coordinate and the corner of Thanlyin approach road and Thalawadi road in the Tharkayta Township.

- Latitude 16° 48' 18.5436" N
- Longitude 96° 13' 15.9024" E

2. Sketch

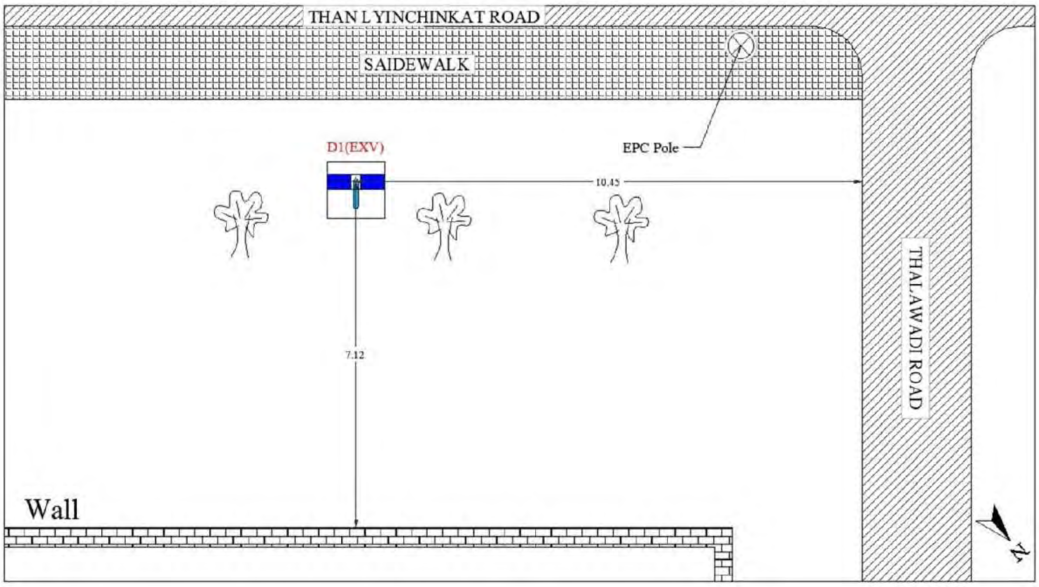


3. Cross Section



Cross Section

4. Plan View



5. Photos of D-1

Photo 1

Photo 2

Photo 3

Photo 4

Source: JICA Study Team

Figure 2.5.2 Underground Utilities Survey Data Sheet

(2) Aboveground Utilities Survey Result

As a result of the aboveground utilities survey, many kinds of utilities were found in the project area. A sample of aboveground utilities survey data sheet is shown in Figure 2.5.3.

No.	Type	Size	Material	Photo	Note
1	Phone Pole	0.2 Ø x 8 m	Concrete		
2	Electric Pole	0.3 Ø x 10 m	Concrete		
3	Electric Pole	0.3 Ø x 10 m	Concrete pole with support pole 0.2 Ø x 12 m		
4	Electric Pole with Lamp	0.2 Ø x 10 m	Concrete pole		
5	Phone Pole	0.2 Ø x 10 m	Concrete pole with support 0.2 Ø x 12 m		
6	Electric Pole	0.25 Ø x 12 m	Concrete pole		On the platform, 0.4 Ø x 0.2 footing

Source: JICA Study Team

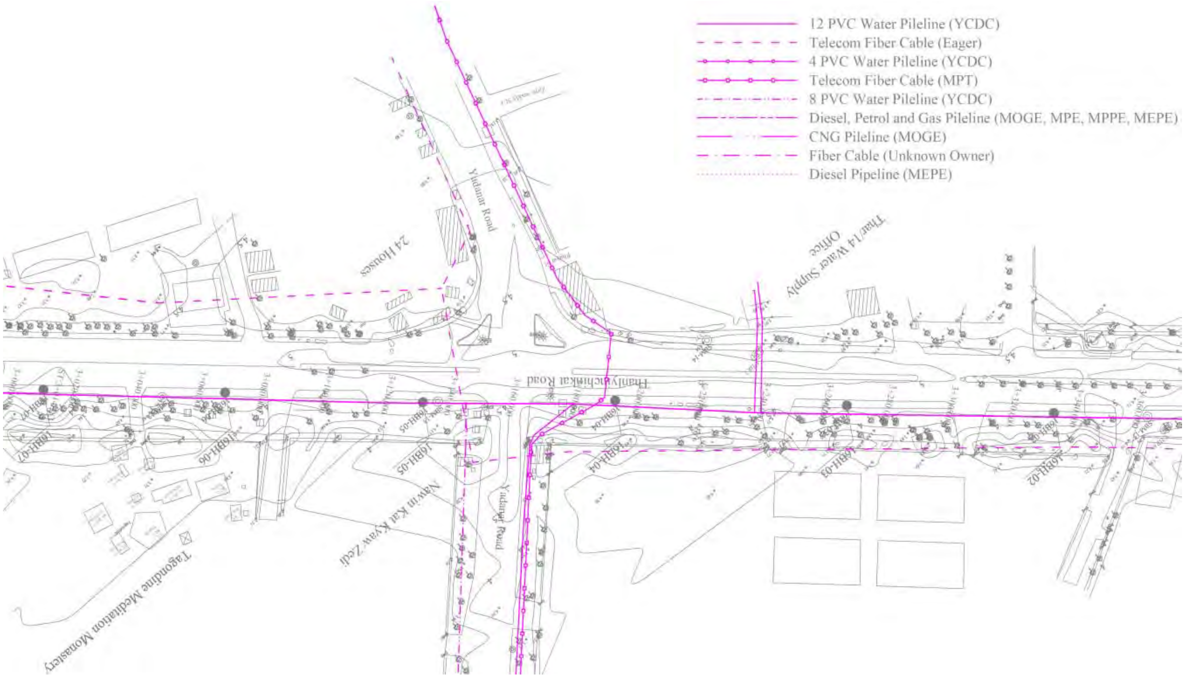
Figure 2.5.3 Aboveground Utilities Survey Data Sheet

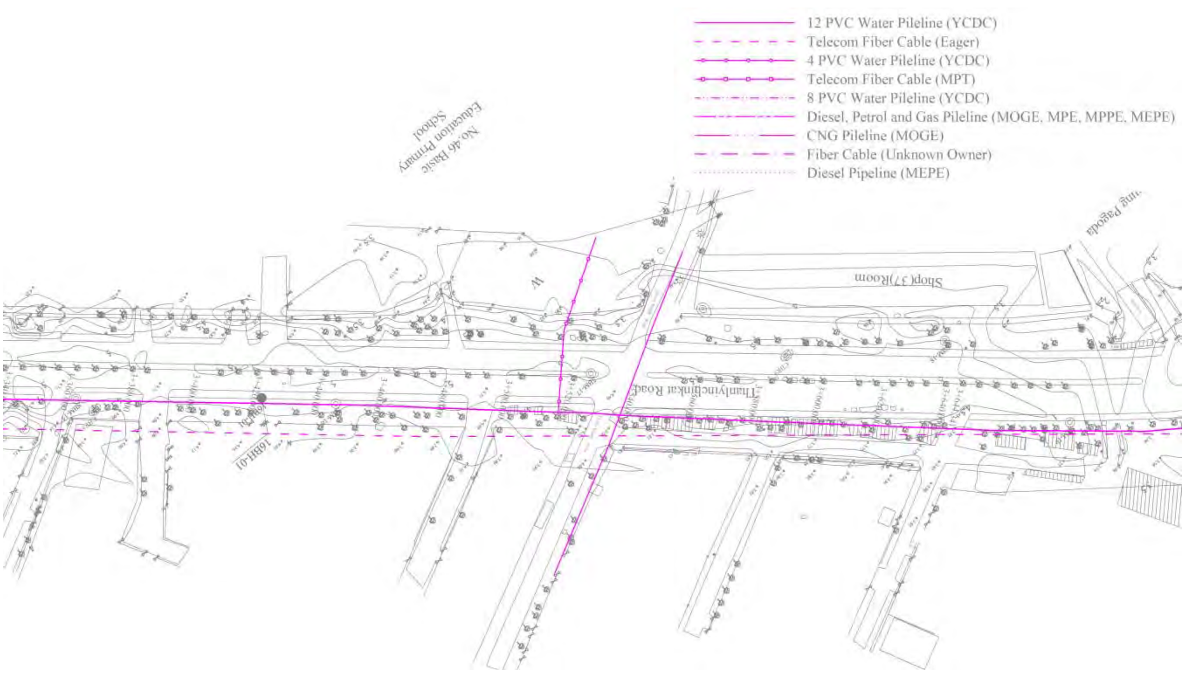
2.5.3 Existing Utilities Layout

(1) Existing Underground Utilities Layout

The existing underground utilities layout is shown in Source: JICA Study Team

Figure 2.5.4.



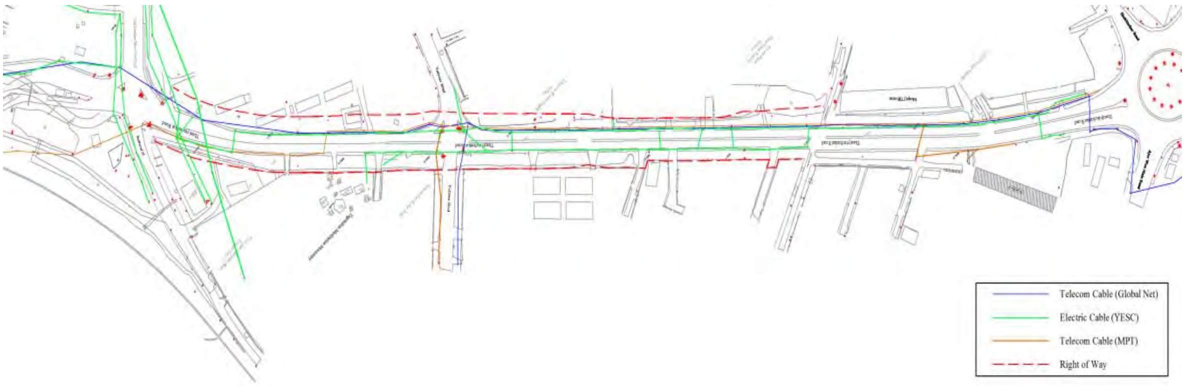


Source: JICA Study Team

Figure 2.5.4 Existing Underground Utilities Layout

(2) Existing Aboveground Utilities Layout

The existing aboveground utilities layout is shown in Figure 2.5.5.



Source: JICA Study Team

Figure 2.5.5 Existing Aboveground Utilities Layout

2.5.4 Procedure of Public Utilities Relocation

All public utilities within the road area must be relocated before construction is commenced. Relocation of public utilities will be conducted based on the following procedures:

Detailed Design (by JICA Study Team)

↓

Conceptual Plan for Relocation (by JICA Study Team)

↓

Request Letter from MOC to Related Authorities for Preparation of Relocation Plan and Cost Estimates (by MOC)

↓

Preparation of Relocation Plan and Cost Estimates (by Utility Authorities)

↓

Preparation of Budget for Relocation (by MOC)

↓

Relocation of Public Utilities (by Utility Authorities)

↓

Construction

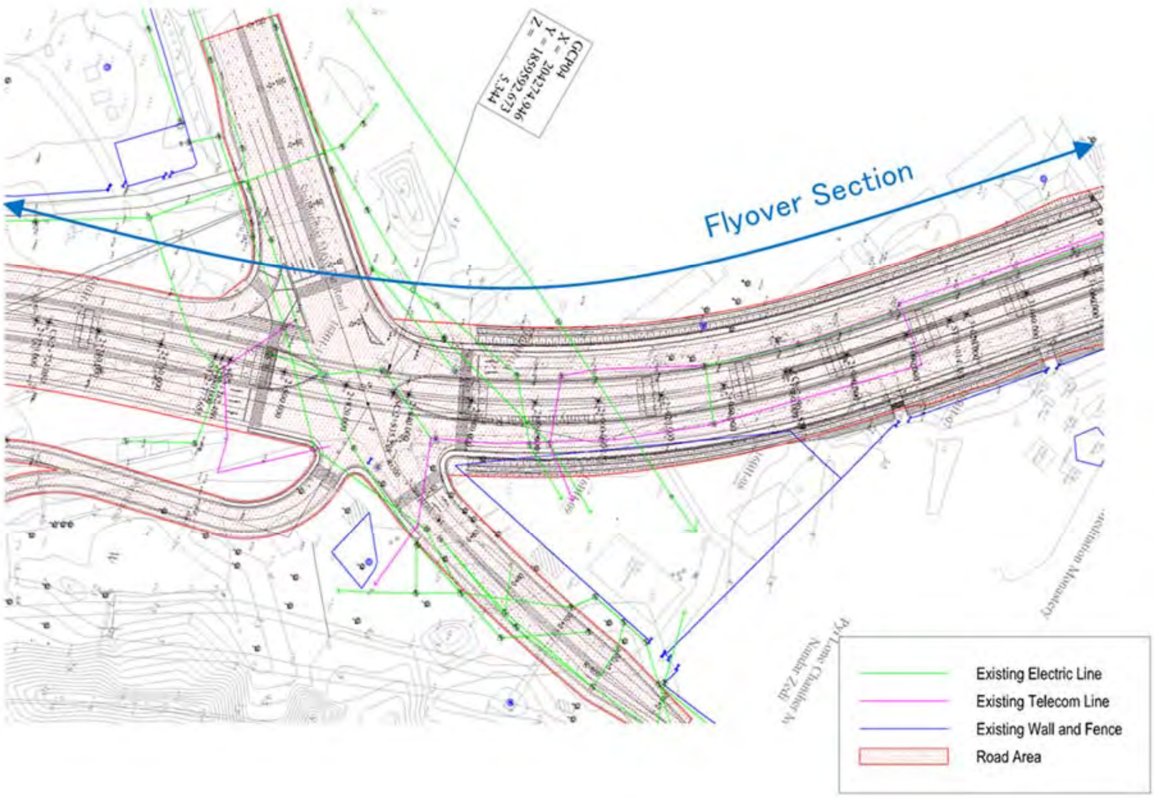
Source: JICA Study Team

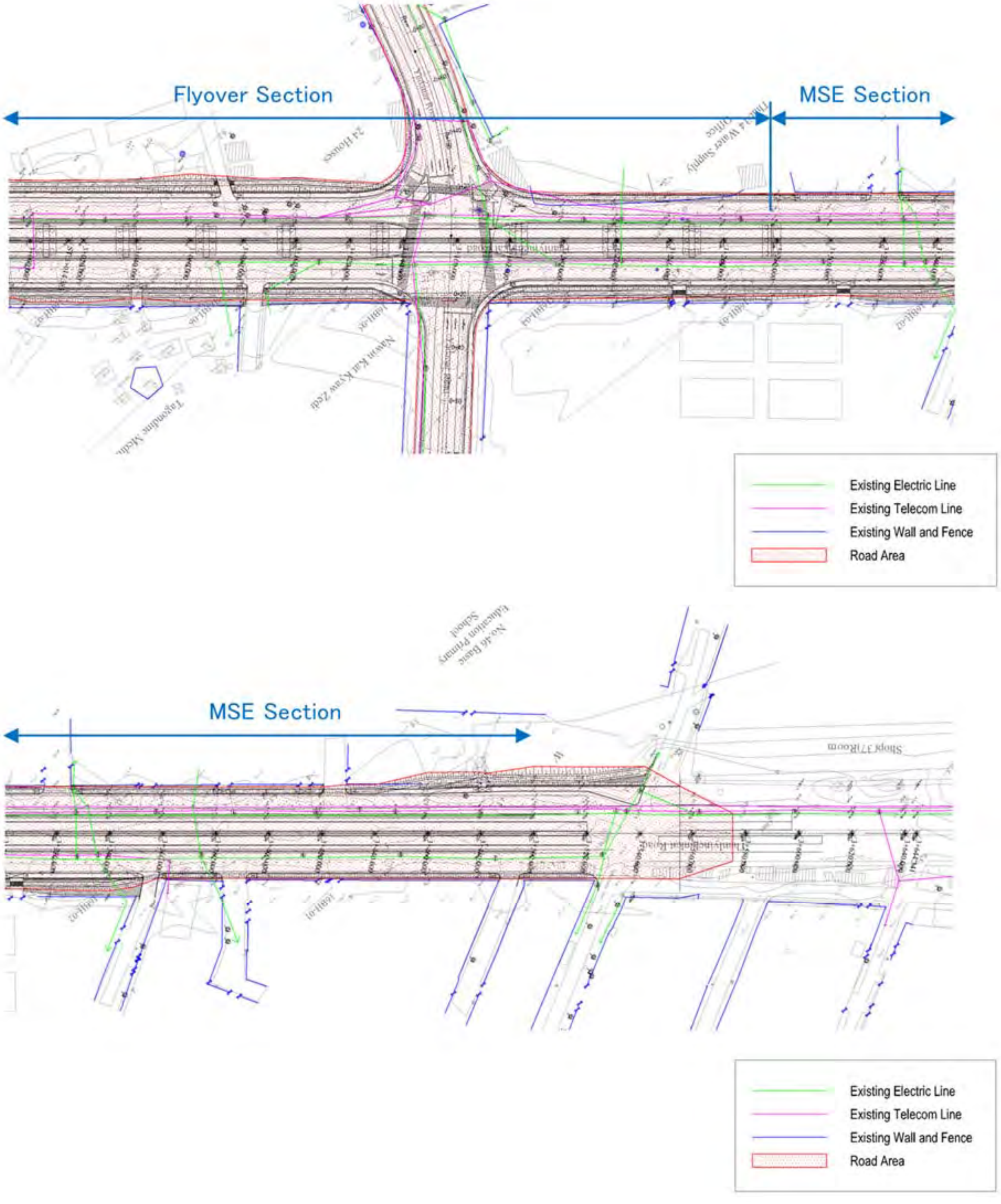
Figure 2.5.6 Procedure of Public Utilities Relocation

2.5.5 Conceptual Plan for Utility Relocation

(1) Plan for Existing Aboveground Utilities and Road Area

It is recommended that utility authorities will prepare the relocation plan based on the plan for existing aboveground utilities and road area shown in Figure 2.5.7. Relocation plan must be prepared so that all public utilities within the road area are removed.



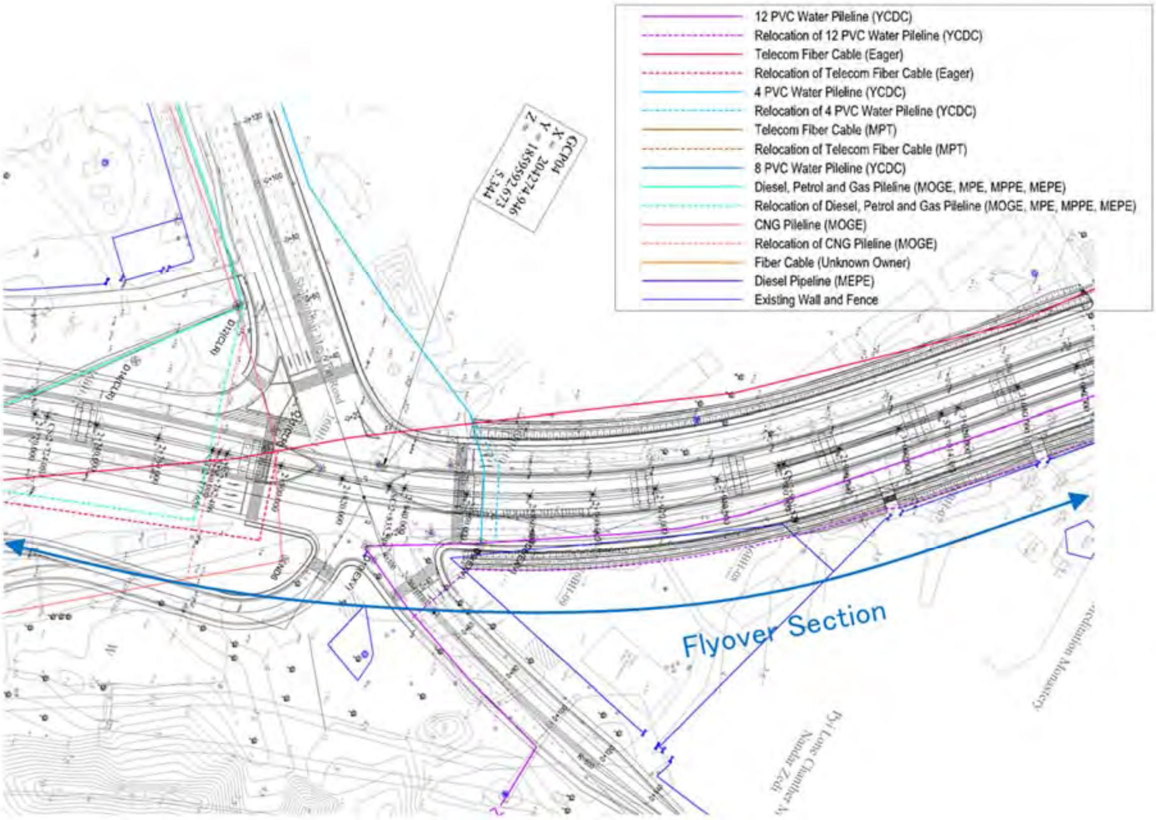


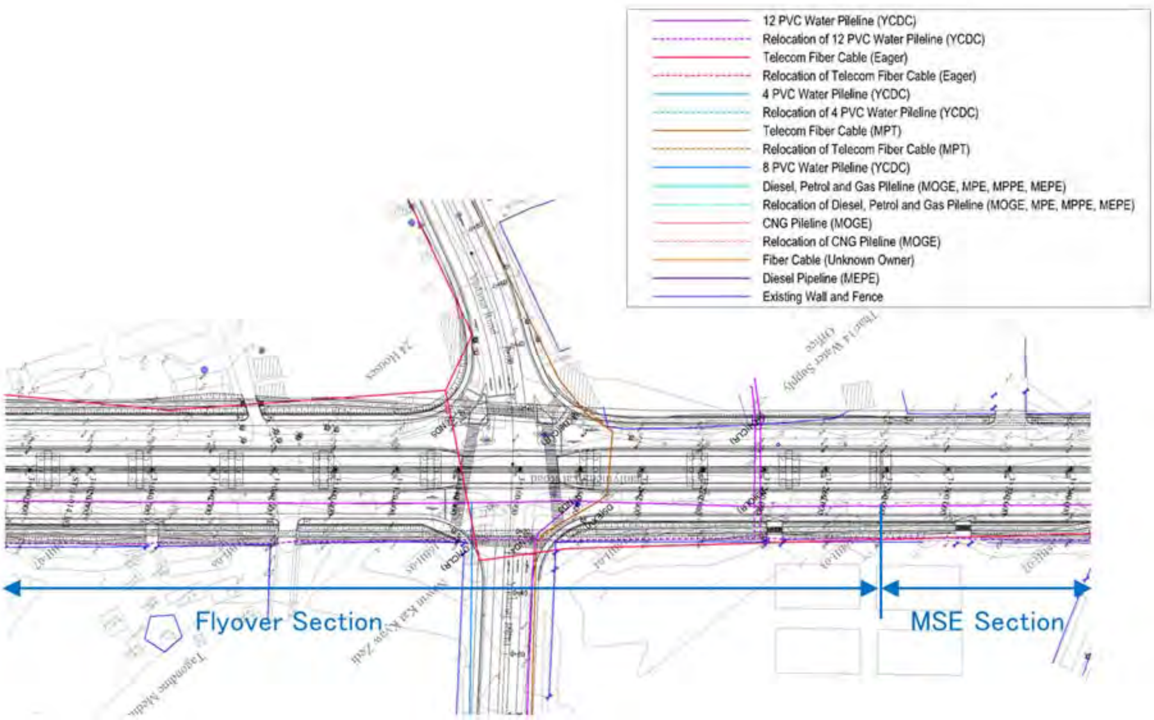
Source: JICA Study Team

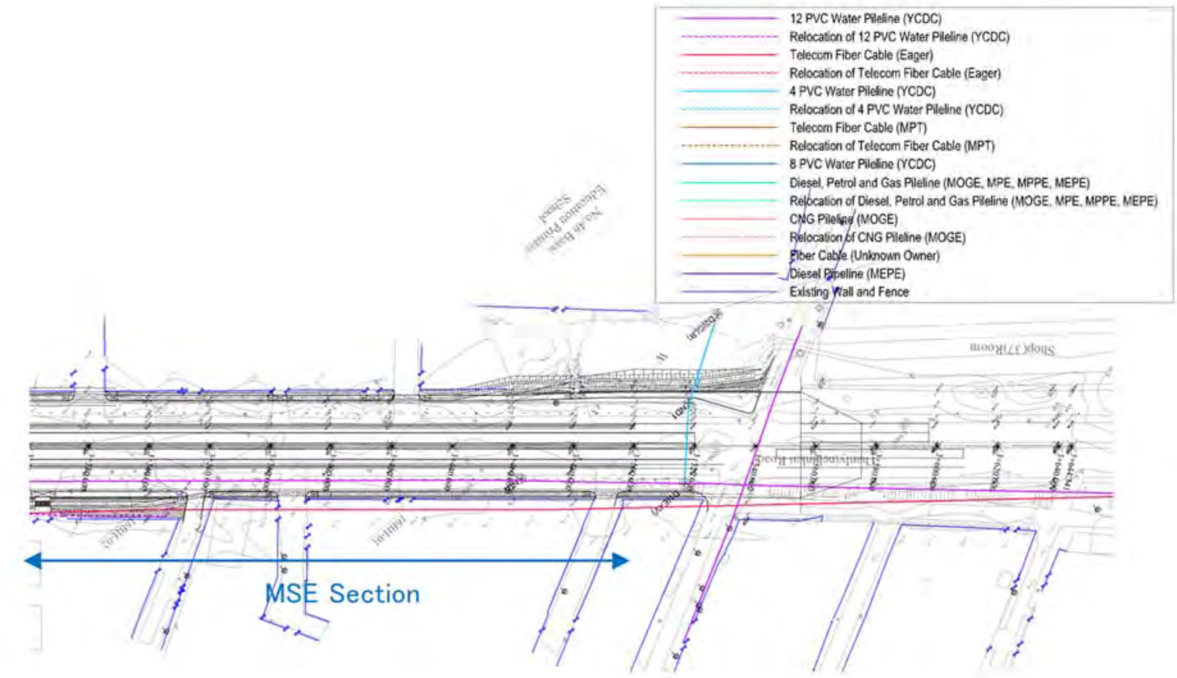
Figure 2.5.7 Plan for Existing Aboveground Utilities and Road Area

(2) Conceptual Plan for Underground Utilities Relocation

It is recommended that utility authorities will prepare the relocation plan based on the conceptual plan shown in Figure 2.5.8.


12 PVC Water Pileline (YCDC)
Relocation of 12 PVC Water Pileline (YCDC)
Telecom Fiber Cable (Eager)
Relocation of Telecom Fiber Cable (Eager)
4 PVC Water Pileline (YCDC)
Relocation of 4 PVC Water Pileline (YCDC)
Telecom Fiber Cable (MPT)
Relocation of Telecom Fiber Cable (MPT)
8 PVC Water Pileline (YCDC)
Diesel, Petrol and Gas Pileline (MOGE, MPE, MPPE, MEPE)
Relocation of Diesel, Petrol and Gas Pileline (MOGE, MPE, MPPE, MEPE)
CNG Pileline (MOGE)
Relocation of CNG Pileline (MOGE)
Fiber Cable (Unknown Owner)
Diesel Pipeline (MEPE)
Existing Wall and Fence
Flyover Section


12 PVC Water Pileline (YCDC)
Relocation of 12 PVC Water Pileline (YCDC)
Telecom Fiber Cable (Eager)
Relocation of Telecom Fiber Cable (Eager)
4 PVC Water Pileline (YCDC)
Relocation of 4 PVC Water Pileline (YCDC)
Telecom Fiber Cable (MPT)
Relocation of Telecom Fiber Cable (MPT)
8 PVC Water Pileline (YCDC)
Diesel, Petrol and Gas Pileline (MOGE, MPE, MPPE, MEPE)
Relocation of Diesel, Petrol and Gas Pileline (MOGE, MPE, MPPE, MEPE)
CNG Pileline (MOGE)
Relocation of CNG Pileline (MOGE)
Fiber Cable (Unknown Owner)
Diesel Pipeline (MEPE)
Existing Wall and Fence
Flyover Section
MSE Section

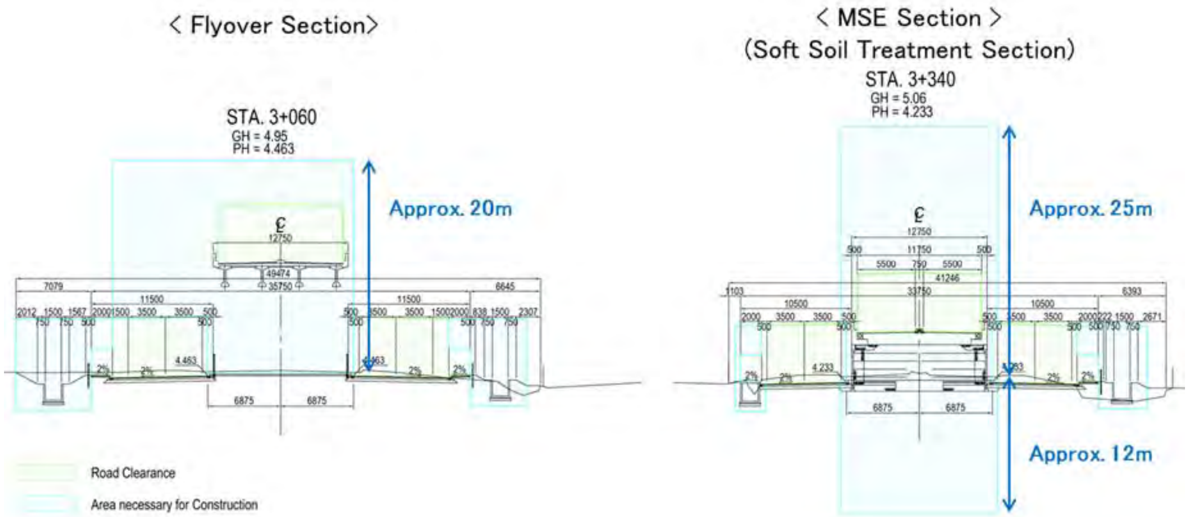


Source: JICA Study Team

Figure 2.5.8 Conceptual Plan for Underground Utilities Relocation

2.5.6 Preparation of Utility Relocation Plan

As shown in Figure 2.5.9, the areas above the flyover section as well as above/under the MSE section are required for the construction work.



Source: JICA Study Team

Figure 2.5.9 Cross Section for Road Area and Construction Area

Utility authorities should prepare the utility relocation plan in consideration of the following:

- Utilities can cross the road only by utilizing the underground in the flyover section except pier locations.
- Road crossing should be minimized.