THE REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS (DPWH)

THE PROJECT FOR STUDY ON IMPROVEMENT OF BRIDGES THROUGH DISASTER MITIGATING MEASURES FOR LARGE SCALE EARTHQUAKES IN THE REPUBLIC OF THE PHILIPPINES

FINAL REPORT

EXECTIVE SUMMARY

DECEMBER 2013

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

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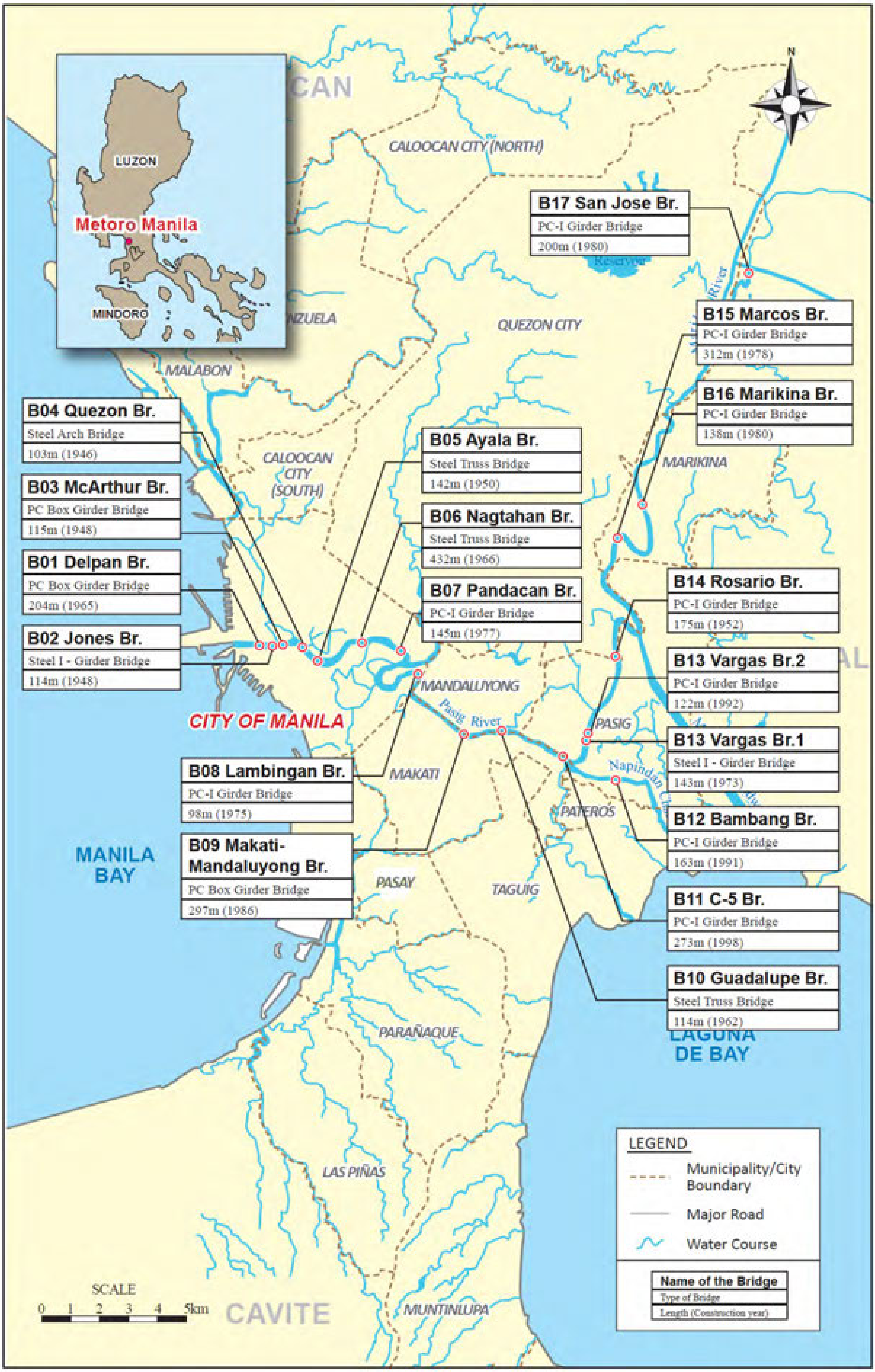
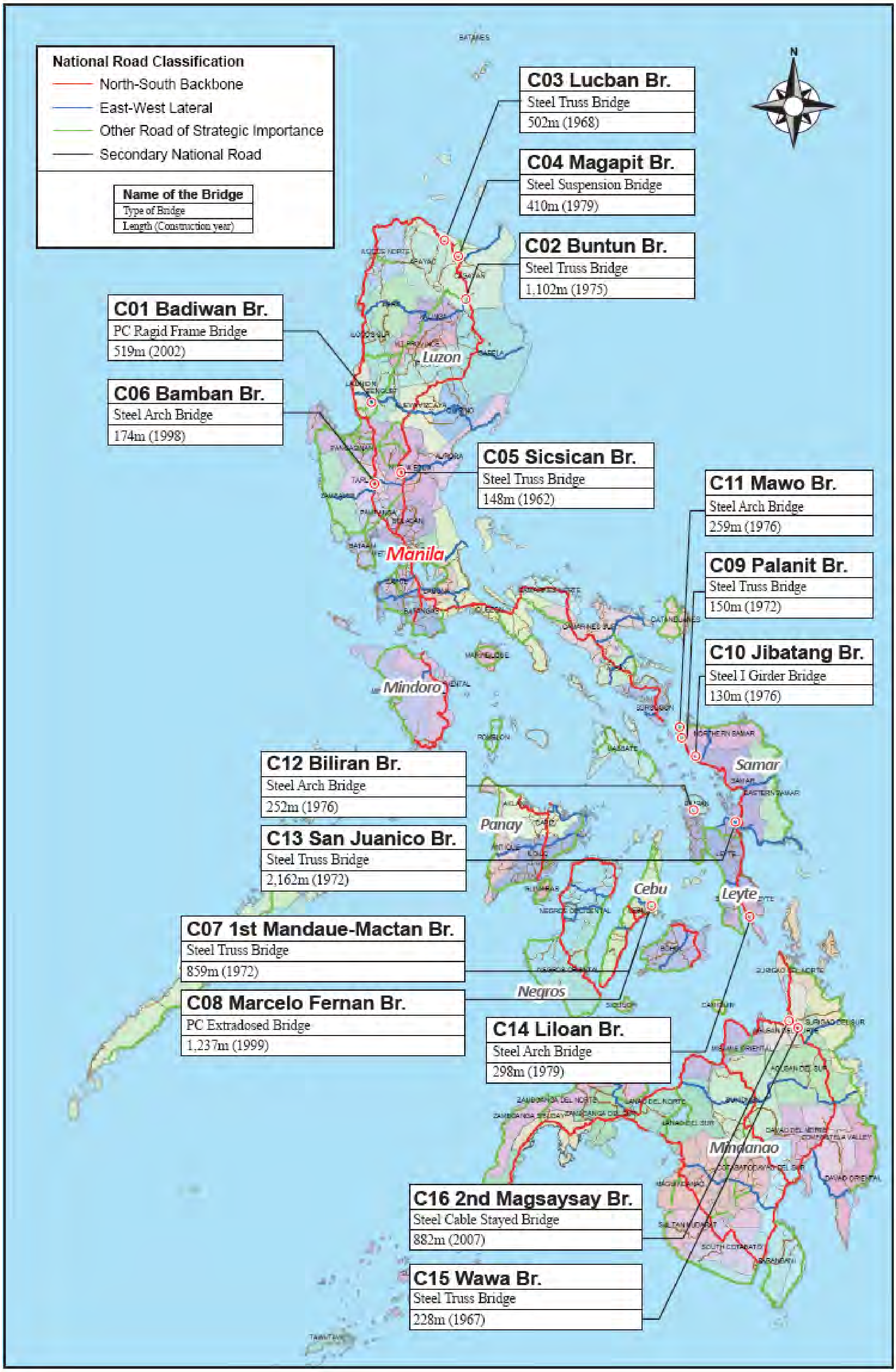


LOCATION MAP OF STUDY BRIDGES (PACKAGE B : WITHIN METRO MANILA)



LOCATION MAP OF STUDY BRIDGES (PACKAGE C : OUTSIDE METRO MANILA)


B01 Delpan Bridge


B02 Jones Bridge


B03 Mc Arthur Bridge


B04 Quezon Bridge


B05 Ayala Bridge


B06 Nagtahan Bridge


B07 Pandacan Bridge


B08 Lambingan Bridge


B09 Makati-Mandaluyong Bridge


B10 Guadalupe Bridge

Photos of Package B Bridges (1/2)

B11 C-5 Bridge

B12 Bambang Bridge

B13-1 Vargas Bridge (1 & 2)

B14 Rosario Bridge

B15 Marcos Bridge

B16 Marikina Bridge

B17 San Jose Bridge

Photos of Package B Bridges (2/2)


C01 Badiwan Bridge


C02 Buntun Bridge


C03 Lucban Bridge


C04 Magapit Bridge


C05 Sicsican Bridge


C06 Bamban Bridge


C07 1st Mandaue-Mactan Bridge


C08 Marcelo Fernan Bridge


C09 Palanit Bridge


C10 Jibatang Bridge

Photos of Package C Bridges (1/2)


C11 Mawo Bridge


C12 Biliran Bridge


C13 San Juanico Bridge


C14 Lilo-an Bridge


C15 Wawa Bridge


C16 2nd Magsaysay Bridge

Photos of Package C Bridges (2/2)

Perspective View of Lambingan Bridge (1/2)

Perspective View of Lambingan Bridge (2/2)

Perspective View of Guadalupe Bridge

Perspective View of Palanit Bridge

Perspective View of Mawo Bridge (1/2)

Perspective View of Mawo Bridge (2/2)

Perspective View of Wawa Bridge

TABLE OF CONTENTS

Location Map
Photos
Perspective View
Table of Contents
Abbreviations

PART 1: GENERAL

CHAPTER 1 INTRODUCTION 1
(1) Project Background 1
(2) Project Objectives 1
(3) Project Area 1
(4) Scope of the Study 1
(5) Schedule of the Study 2
(6) Organization of the Study 2
(7) Major Activities of the Study 3
(8) Reports 3

CHAPTER 2 ORGANIZATIONS CONCERNED FOR SEISMIC DESIGN OF BRIDGES .. 3

CHAPTER 3 SEISMIC VULNERABILITIES OF BRIDGES IN THE PHILIPPINES 4
(1) Natural Environment Related to Earthquakes 4
(2) Seismic Vulnerabilities of Bridges Based on Typical Damages due to the Past Relatively Large Earthquakes 6

CHAPTER 4 CURRENT INFORMATION ON EARTHQUAKE RELATED ISSUES 6
(1) Existing Plans for Earthquakes Issues of Concerned Organizations 7

PART 2: BRIDGE SEISMIC DESIGN SPECIFICATIONS (PACKAGE A)

CHAPTER 5 CHRONOLOGY OF BRIDGE SEISMIC DESIGN SPECIFICATIONS 9

CHAPTER 6 COMPARISON ON BRIDGE SEISMIC DESIGN SPECIFICATIONS BETWEEN DPWH / NSCP, AASHTO AND JRA 9

CHAPTER 7 IDENTIFICATION OF ISSUES ON CURRENT PRACTICE AND DPWH SEISMIC DESIGN SPECIFICATIONS FOR BRIDGES 10

CHAPTER 8 APPROACH TO THE DEVELOPMENT OF LOCALIZED SEISMIC ACCELERATION RESPONSE SPECTRA FOR BRIDGE DESIGN 11

(1) Method 1 – Based on AASHTO Acceleration Response Spectra (Currently Utilized by DPWH) 11
(2) Method 2 – Based on Probabilistic Seismic Hazard Analysis 13

CHAPTER 9 SEISMIC HAZARD MAPS FOR DESIGN OF BRIDGES 13

CHAPTER 10 OUTLINE OF BRIDGE SEISMIC DESIGN SPECIFICATIONS (BSDS) MANUAL AND DESIGN EXAMPLES 16
(1) Development of the Bridge Seismic Design Specifications (BSDS) 16
(2) Outline of the Bridge Seismic Design Specifications (BSDS) 16
(3) Outline of the Seismic Design Calculation Example using the Bridge Seismic Design Specifications (BSDS) 17
(4) Comparison between the DPWH Existing Design with the Bridge Seismic Design Specifications (BSDS) Using the Proposed Design Acceleration Response Spectra 17
(5) Example of Practical Application of Seismic Retrofit 17

PART 3: SELECTION OF BRIDGES FOR SEISMIC CAPACITY IMPROVEMENT (PACKAGE B AND PACKAGE C)

CHAPTER 11 PROCEDURES FOR SELECTION OF BRIDGES FOR OUTLINE DESIGN18
(1) Flowchart for Selection 18
(2) Evaluation Criteria for the First and Second Screening 18

CHAPTER 12 THE FIRST SCREENING 21

CHAPTER 13 THE SECOND SCREENING 22

CHAPTER 14 RECOMMENDATION ON TARGET BRIDGES FOR THE OUTLINE DESIGN 22

PART 4: OUTLINE DESIGN OF SELECTED BRIDGES FOR SEISMIC CAPACITY IMPROVEMENT (PACKAGE B AND PACKAGE C)

CHAPTER 15 DESIGN CONDITIONS FOR SELECTED BRIDGES 24
(1) Topographic Features and Design Conditions 24
(2) Geotechnical and Soil Profile Conditions 24
(3) River and Hydrological Conditions 24
(4) Existing Road Network and Traffic Condition 24
(5) Results of Natural and Social Environment Survey 25
(6) Highway Conditions and Design 26

CHAPTER 16 BRIDGE REPLACEMENT OUTLINE DESIGN OF SELECTED BRIDGES27
(1) Design Criteria and Conditions for Bridge Replacement....27
(2) Design Spectra....27
(3) SUMMARY OF OUTLINE DESIGN OF REPLACEMENT BRIDGE 27

CHAPTER 17 BRIDGE SEISMIC RETROFIT OUTLINE DESIGNS OF SELECTED BRIDGES....35
(1) Design Criteria and Conditions for Bridge Retrofit Design....35
(2) Design Spectra....35
(3) Summary of Outline Design of Replacement Bridge....35

CHAPTER 18 CONSTRUCTION PLAN AND COST ESTIMATE FOR SELECTED BRIDGES....38
(1) Construction Planning 38

CHAPTER 19 TRAFFIC ANALYSIS AND ECONOMIC EVALUATION FOR SELECTED BRIDGES....42
(1) Traffic Analysis....42
(2) Economic Evaluation....42

CHAPTER 20 NATURAL AND SOCIAL ENVIRONMENT ASSESSMENT 43

PART 5: PROJECT IMPLEMENTATION AND RECOMMENDATIONS

CHAPTER 21 PROJECT IMPLEMENTATION 46
(1) Project Outline....46
(2) Project Cost 46
(3) Implementation Schedule....46
(4) Project Organization 47
(5) Financial Analysis and Funding....47

CHAPTER 22 RECOMMENDATIONS....47
(1) Proposed Bridge Seismic Design Specifications (BSDS) 47
(2) Implementation of the Project for Seismic Strengthening of Bridge Recommended in the Study 51
(3) Importance of Construction Quality and Proper Maintenance Activities....52
(4) Recommendation of Improvement Project for Traffic Conditions in Traffic Intermodal Area trough Guadalupe Bridge Seismic Strengthening Project....52

ABBREVIATIONS

AADT	:	Annual Average Daily Traffic
AASHTO	:	American Association of State Highway and Transportation Officials
ABC	:	Approved Budget for the Contract
AH	:	Asian Highway
AHTN	:	Asean Harmonized Tariff Nomenclature
ASD	:	Allowable Stress Design
ASEP	:	Association of Structural Engineers of the Philippines
B/C	:	Benefit Cost
BCGS		Bureau of Coast and Geodetic Survey
BCR	:	Benefit Cost Ratio
BIR	:	Bureau of Internal Revenue
BOC	:	Bureau of Construction
BOD	:	Bureau of Design
BOM	:	Bureau of Maintenance
BRS	:	Bureau of Research and Standards
BSDS	:	Bridge Seismic Design Specification
CBD	:	Central Business District
CCA	:	Climate Change Adaptation
CCP	:	Cast-in-place concrete pile
CDA	:	Cooperative Development Authority
CLOA	:	Certificates of Land Ownership Award
CP	:	Counter Part
CPI	:	Consumer Price Index
DAO	:	Department Administrative Order
DEO	:	District Engineering Office
DIA	:	direct impact area
DL	:	Dead Load
DOF	:	Degree of Freedom
DPWH	:	Department of Public Works and Highways
DRR	:	Disaster Risk Reduction
DSWD	:	Department of Social Welfare and Development
ECA	:	Environmentally Critical Area

ECC	:	Environmental Compliance Commitment
EDC	:	Estimated Direct Cost
EDSA	:	Epifanio de los Santos Avenue
EGM	:	Earthquake Ground Motion
EIA	:	Environmental Impact Assessment
EIRR	:	Economic Internal Rate of Return
EIS	:	Environmental Impact Statement
EMB	:	Environmental Mnagement Bureau
EMoP	:	Environmental Monitoring Plan
EQ	:	Earthquake Load
ESCAP	:	Economic and Social Commission for Asia and the Pacific
ESSO	:	Environmental and Social Services Office
GRS	:	Grievance Redress System
ICC	:	Investment Coordinating Committee
IEE	:	Initial Environmental Examination
IMF	:	International Monetary Fund
IR	:	Involuntary Resettlement
IRR	:	Internal Rate of Return
ITC	:	Intersection Traffic Count
JBA	:	Japan Bridge Association
JCC	:	Joint Coordinating Committee
JICA	:	Japan International Cooperation Agency
JPCCA	:	Japan Prestressed Concrete Contractors Association
JRA	:	Japan Road Association
LAP	:	Land Acquisition Plan
LARRIPP	:	Land Acquisition, Resettlement, Rehabilitation and Indigenous Peoples'
LD	:	Longitudinal Direction
LFD	:	Load Factors Design
LGUs	:	Local Government Units
LL	:	Live Load
LOS	:	Level-of-Service
LPG	:	Liquefied Petroleum Gas
LRB	:	Laminated Rubber Bearing
LRFD	:	Load and Resistance Factor Design
MAD	:	Mean Absolute Difference

MC	:	Memorandum Circular
MGB	:	Mines and Geosciences Bureau
MHWL	:	Mean High Water Level
MRT	:	Mass Rapid Transit
MSL	:	Mean Sea Level
NAMRIA	:	National Mapping and Resource Information Authority
NCR	:	National Capital Region
NGO	:	Non-Governmental Organization
NIED	:	National Research Institute for Earth Science and Disaster Prevention
NLEX	:	North Luzon Expressway
NPV	:	Net Present Value
NSCP	:	National Structural Code of the Philippines
OC	:	Operational Classification
OD	:	Origin and Destination
OJT	:	On-the-Job Training
PAF	:	Project Affected Family
PAP	:	Project Affected Person
PC	:	Prestressed Concrete
PCG	:	Philippine Coast Guard
PD	:	Presidential Decree
PEIS	:	Philippine Earthquake Intensity Scale
PFI	:	Private Finance Initiative
PGA	:	Peak Ground Acceleration
PHIVOLCS	:	Philippine Institute of Volcanology and Seismology
PICE	:	Philippine Institute of Civil Engineers
PMO	:	Project Management Office
PPP	:	Public Private Partnership
R/D	:	Record and Discussion
RA	:	Republic Act
RAP	:	Resettlement Action Plan
RC	:	Reinforced Concrete
RIC	:	Resettlement Implementation Committee
RO	:	Regional Office
ROW	:	Right of Way
RTC	:	Roadside Traffic Count

SER	:	Shadow Exchange Rate
SLEX	:	South Luzon Expressway
SMR	:	Self-Monitoring Report
SPL	:	Seismic Performance Level
SPP	:	Steel Pipe Pile
SPSP	:	Steel Pipe Sheet Pile
SPT		Standard Penentration Test
SPZ	:	Seismic Performance Zone
SR	:	Superstructure Replacement
SWMP	:	Solid Waste Management Plan
SWR	:	Shadow Wage Rate
TCT	:	Transfer Certificate of Title
TD	:	Transversal Direction
TESDA	:	Technical Education and Skills Development Authority
TTC	:	Travel Time Cost
VAT	:	Value Added Tax
VOC	:	Vehicle Operating Cost
WB	:	World Bank

THE PROJECT FOR STUDY ON IMPROVEMENT OF BRIDGES
THROUGH DISASTER MITIGATING MEASURES FOR LARGE SCALE EARTHQUAKES
IN THE REPUBLIC OF THE PHILIPPINES

EXECUTIVE SUMMARY

PART 1: GENERAL

CHAPTER 1 INTRODUCTION

(1) Project Background

Disaster mitigation measures in recent years have been focused on large-scale earthquakes, especially after the March 2011 "Tohoku Pacific Coast Earthquake" in Japan. As pointed out in the "Earthquake Impact Reduction Study for Metropolitan Manila, Republic of the Philippines (March 2004)," since the Philippines is within the Pacific Rim of Volcanic Zone, it is geographically prone to large earthquake disasters similar to the "North Luzon Earthquake of 1990," situations of which imply the necessity of earthquake-related disaster mitigation measures.

Although the DPWH has carried out emergency seismic inspection and retrofit of public infrastructures, it still lacks the experience sufficient for inspection and retrofit of large and special type bridges along the major national highways serving as emergency lifeline road. Moreover, the seismic design standards and specifications for bridges have not been updated up to the present.

With this background, the Government of the Republic of the Philippines (GOP) had requested the Government of Japan (GOJ) to undertake a technical assistance study to improve the durability and safety of bridges against large-scale earthquakes. In accordance with the request and the decision of the GOJ, the Japan International Cooperation Agency (JICA) dispatched a study team to carry out the Study in collaboration with the officials of the GOP.

(2) Project Objectives

Purpose of the Project Study

The purpose of the Project Study is to propose a plan for bridge improvement that will have high durability and safety against large-scale earthquakes.

Overall Objective of the Project Study

The proposed plan will be implemented and thus, the bridges in the Philippines will have high durability and safety against large scale earthquakes.

(3) Project Area

The project study area shall cover bridges along the Pasig-Marikina River in Metro Manila (Package B) and special bridges along the arterial roads outside of Metro Manila (Package C).

(4) Scope of the Study

In order to achieve the above objectives, the Study shall cover the following activities.

Package A (Seismic Design Guidelines for Bridges)

1) Collection of earthquake records, soil and geological condition classifications, records of seismic damages on existing bridges.

2) Identification of issues and concerns on the current DPWH Seismic Design Specifications.

3) Analysis of issues and problems on the present Seismic Design Specifications.

4) Revision of the present seismic design specifications and reference materials to include methods of retrofitting.

5) Conduct of seminars on seismic design and related seismic design and construction technology for technology transfer.

Package B (Inside Metro Manila Area) And Package C (Outside Metro Manila Area)

1) Identification of bridges which require retrofitting/replacement to mitigate seismic disasters.

2) Inspection of bridge conditions, including environmental and social conditions around the bridges.

3) Carrying-out of traffic volume survey on the roads related to the bridges.

4) Prioritization and selection of bridges to be retrofitted or replaced.

5) Preparation of outline design of retrofit or replacement and estimation of cost for the selected bridges to be retrofitted or replaced.

(5) Schedule of the Study

The schedule of the Study is shown in Table ES-1-1.

(6) Organization of the Study

The organization for the Study is shown in Table ES-1-2.

Table ES-1-1 Schedule of the Study

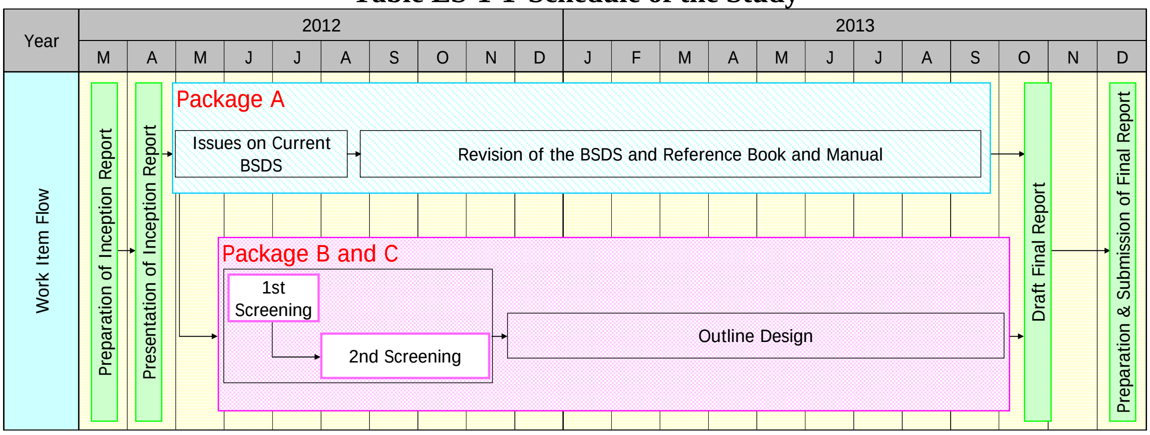


Table ES-1-2 Organization for the Study

Organization	Chairperson		No. of Members
Joint Coordinating Committee (JCC)	Mr. Raul C. Asis (Chairperson)	Undersecretary, DPWH	12
Counterpart Personnel (CP), Technical Working Group (TWG)	Mr. Adriano M. Doroy (Head)	Assistant Director, Bureau of Design, DPWH	8
JICA Advisory Committee (JAC)	Mr. Yukihiro TSUKADA (Chairperson)	Director, Road Department, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan	5
JICA Study Team (JST)	Dr. Shingo GOSE (Team Leader)	CTI Engineering International Co., Ltd.	16

(7) Major Activities of the Study

The Seminars/Workshops and Counterpart Personnel/Technical Working Group (CP/TWG) meetings have been implemented as activities for the technology transfer to the CP and other related organizations, as follows:

Seminar/Workshop

1st : August 6, 2012 in Manila

2nd : September 4, 2012 in Tacloban

3rd : October 11, 2012 in Manila

4th : January 17 and 18, 2013 in Manila

5th : June 20 and 21, 2013 in Manila

6th : November 13 and 14, 2013 in Manila

CP/TWG

1st : April 18, 2012 in Manila

2nd : June 1, 2012 in Manila

3rd : July 2, 2012 in Manila

4th : November 27, 2012 in Manila

5th : May 17, 2013 in Manila

6th : September 27, 2013 in Manila

7th : November 11, 201 in Manila

Japan Training

1st : April 14~27, 2013 in Japan

2nd : July 14~27, in Japan

(8) Reports

The following reports have been submitted to the Government of the Republic Philippines as part of the project scope and requirements:

Reports	Number of Copies Submitted
Inception Report (IC/R)	20
Interim Report (IT/R)	20
Draft Final Report (DF/R)	20
Final Report (F/R)	40 (CD-R: 1)

CHAPTER 2 ORGANIZATIONS CONCERNED FOR SEISMIC DESIGN OF BRIDGES

The DPWH and the Association of Structural Engineers of the Philippines (ASEP) are the organizations formulating the design guidelines and specifications for bridges in the Philippines. The DPWH, being mandated to control the design and construction of roads and bridges, prepares the design guidelines and specifications to have a standard and uniform approach in bridge design and construction. On the other hand, the ASEP, being a professional engineering association, has the mission to uphold the structural engineering profession through standardizing the national structural code for bridge design. Both DPWH Guidelines and ASEP's NSCP[1] incorporate some provisions on seismic design. However, the NSCP codes prepared by ASEP will need DPWH's endorsement for use in public infrastructures.

The functions and relationships between DPWH and ASEP, including the following organizations regarding seismic design issues, have been studied:

[1] NSCP: National Structural Code of the Philippines

- Department of Public Works and Highways (DPWH)
- Philippine Institute of Volcanology and Seismology (PHIVOLCS)
- Association of Structural Engineers of the Philippines (ASEP)
- Philippine Institute of Civil Engineers (PICE)
- Geological Society of the Philippines

CHAPTER 3 SEISMIC VULNERABILITIES OF BRIDGES IN THE PHILIPPINES

(1) Natural Environment Related to Earthquakes

1) Geographical Characteristics

Philippine tectonics is indeed one of the most active in the world. Tectonic activities such as the devastating Luzon Earthquake in 1990 and the catastrophic eruption of Mt. Pinatubo in 1991 are the results of interaction of the three major tectonic plates of the Western Pacific Domain, namely; the Pacific, the Eurasian and the Indo-Australian Plates.

The boundary between the Philippine Sea Plate and the eastern margin of the Eurasian Plate is a complex system of subduction zones, collision zones and marginal sea basin openings. In between these two plates, an actively deforming zone is created. This zone represents the Philippine Mobile Belt (Figure ES-3-1).

2) Geological Characteristics

The Philippine Archipelago can be divided into two geologic zones: the Philippine Mobile Belt and the Palawan-Mindoro micro-continent. These two geologic zones are composed of different types of lithologic units that can be classified into four groups as follows:

1) Metamorphic rocks;
2) Ophiolites and ophiolitic rock;
3) Magmatic rocks and active volcanic arcs; and
4) Sedimentary basins.

3) Hydrological Characteristics

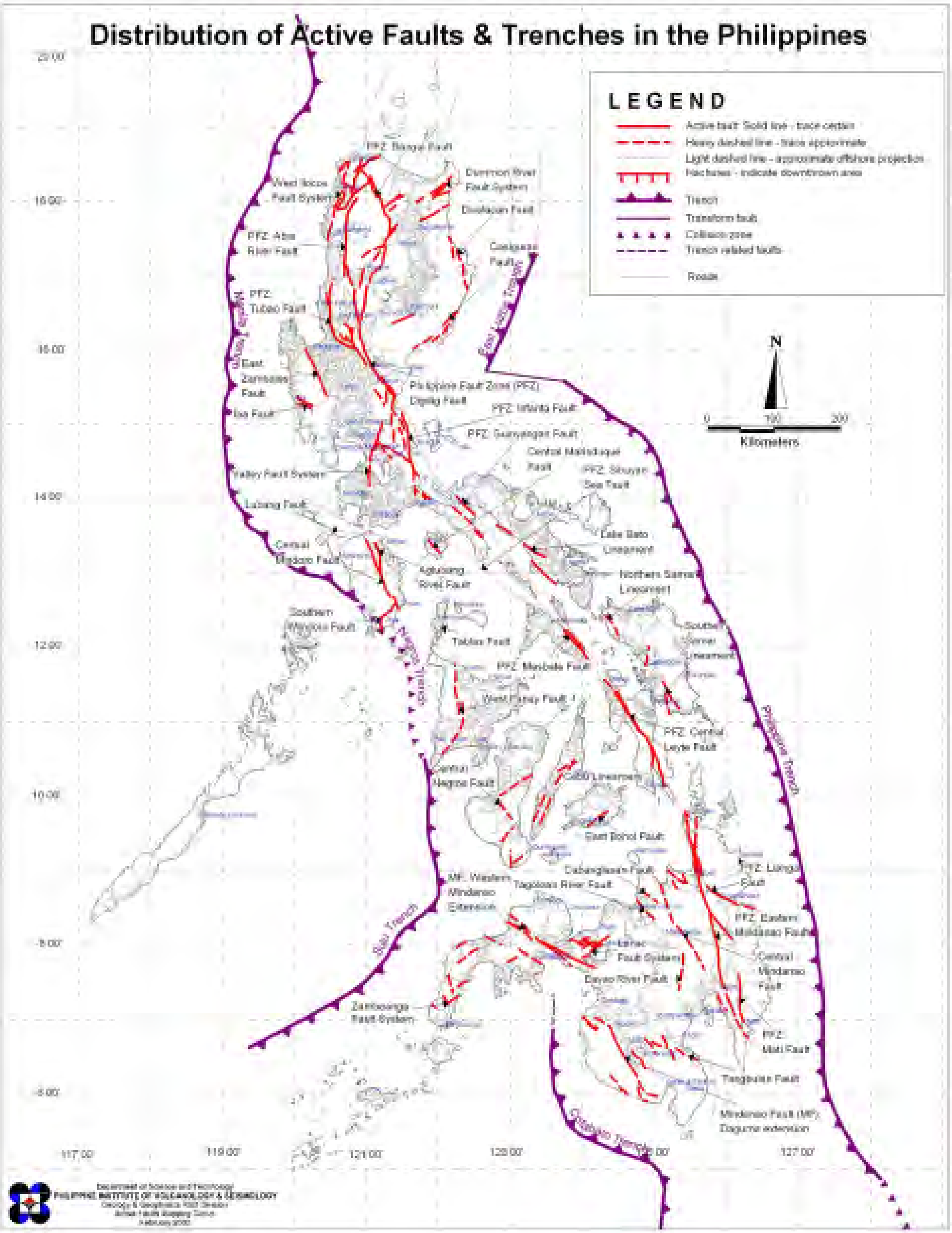
The Philippines is located southeast of the big Asian continent, with an almost north to south orientation. Due to its geographic location, the Philippines is influenced by weather-producing systems which occur at various spaces and time scales. Since the variability of rainfall is more pronounced compared with the variability in temperature, the climate is classified according to the rainfall distribution. As shown in Figure ES-3-2, the various areas in the Philippines are thus characterized by four types of climate, which are based on dry and wet seasons induced by minimum or maximum rain periods, according to the modified Corona’s Climate Classification:

Type I : Two pronounced seasons, dry from November to April, wet during the rest of the year

Type II : No dry season, with a very pronounced maximum rainfall period from November to January

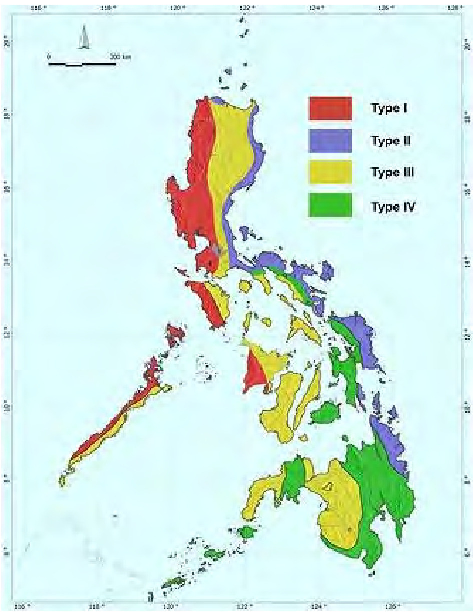
Type III: Seasons are not very pronounced, with relatively dry season from November to April and wet season during the rest of the year

Type IV: Rainfall more or less evenly distributed throughout the year



Source: PHIVOLCS

Figure ES-3-1 Distribution of Active Faults and Trenches in the Philippines



Source: PAGASA

Figure ES-3-2 Climate Map of the Philippines based on the Modified Coronas Classification

(2) Seismic Vulnerabilities of Bridges Based on Typical Damages due to the Past Relatively Large Earthquakes

Recent major earthquakes that caused damage to bridges along national roads and significantly affected road transportation are summarized in Table ES-3-1.

Through the previous major earthquake in the Philippines, the following seismic weak points have been recognized:

1) Falling down of superstructure due to insufficient seating length, or no unseating prevention structure;
2) Collapse of bridge pier due to lack of stiffness of foundation; and
3) Settlement, leaning and falling of foundation and piers due to soil liquefaction.

CHAPTER 4 CURRENT INFORMATION ON EARTHQUAKE RELATED ISSUES

This Chapter presents the current plans on earthquake issues of organization concerned including DPWH and PHIVOLCS.

Table ES-3-1 Major Earthquakes that occurred in the Philippines in Recent Years

No.	Name of Earthquake	Time	Magnitude	Remarks
1	Casiguran Earthquake	Aug 2,1968	M7.3	
2	Ragay Gulf Earthquake	March 17, 1973	M7.0	Collapse (Sumulong Br.)
3	Moro Gulf Earthquake	Aug 17, 1976	M7.9	Collapse (Quirino Br.), Fatalities: 8,000
4	Laoag Earthquake	Aug 17, 1983	M6.5	
5	Bohol Earthquake	Feb 8, 1990	M6.8	Collapse (Jagna-Duero Br.)
6	Panay Earthquake	June 14, 1990	M7.1	Collapse (4 bridges)
7	North Luzon Earthquake	July 16, 1990	M7.9	Collapse (many bridges), Fatalities: 1,621
8	Mindoro Earthquake	Nov 15, 1994	M7.1	Damaged (24 bridges)
9	Bohol Earthquake	May 27, 1996	M5.6	
10	Bayugan Earthquake	June 7, 1999	M5.1	
11	Palimbang Earthquake	March 6, 2002	M6.8	Fatalities: 11
12	Masbate Earthquake	Feb 15, 2003	M6.2	Fatalities: 1
13	Negros Oriental Earthquake	Feb 6, 2012	M6.9	Collapse (several bridges), Fatalities: 41
14	Eastern Samar (Guiuan) Earthquake	Aug 31, 2012	M7.6	Fatalities: 1
15	Bohol Earthquake	Oct 15, 2013	M7.2	Collapse and Severe Damage (11 bridges)

(1) Existing Plans for Earthquakes Issues of Concerned Organizations

1) DPWH (Department of Public Works and Highways)

- Design Guideline, Criteria and Standards for Public Works and Highways (DPWH Guidelines) published in 1982
- After the "1990 North Luzon Earthquake", DPWH issued Department Order 75 (D.O.75) requiring that seismic design of bridges shall conform to the latest AASHTO Standard Specifications.
- In 2004, the DPWH attempted to incorporate the AASHTO seismic design procedures and guidelines for bridge retrofitting in the DPWH Guidelines and issued a Draft Revision of Part 4, Bridge Design of the DPWH Guidelines. However, the revision was not mandated officially and therefore remains as a draft.
- NRIMP-2 Institutional Capacity Development – "Enhancement of Management and Technical Processes for Engineering Design in the DPWH."

2) ASEP (Association of Structural Engineers of the Philippines)

- ASEP had completed the drafting of the "National Structural Code of the Philippines 2011, Vol. 2 Bridge Code and Specifications, Third Edition", which is currently undergoing review internally by the ASEP Review Committee.

3) PHIVOLCS (Philippine Institute of Volcanology and Seismology)

- PHIVOLCS and JICA have been jointly implementing the project named "Enhancement of Earthquake and Volcano Monitoring and Effective Utilization of Disaster Mitigation Information in the Philippines" since February 2010.
- Metro Manila Strong Motion Network (1998): Tokyo Institute of Technology and PHIVOLCS established a strong motion network consisting of 10 stations in Metro Manila.
- As shown in Figure ES4-1, the maximum acceleration in the accelerograms recorded on the ground surface at the stations during this period were about 100 gal or smaller. Even the largest value was only 108 gal. Therefore, the collected data so far has been insufficient for fully understanding the characteristics of acceleration response at the ground surface in the Philippines.
- Nation Strong Motion Network (2000): JICA and PHIVOLCS started the Nation Strong Motion Network project in 1998 and installed instruments at 34 stations in 2000. The project involved establishment of 29 un-manned seismic stations and 5 volcano observatories so as to cover the entire nation.
- Strong Motion Network Development installation in 2011-2012: PHIVOLCS will install 27 new motion sensors in provinces near the National Capital Region and in Mindanao to record high-magnitude earthquakes and other earth movements.
- Strong Motion Network Development installation in 2010-2014: Broadband seismographs and strong-motion seismographs are to be installed at 10 satellite telemetered earthquake observation stations out of existing 30 stations.

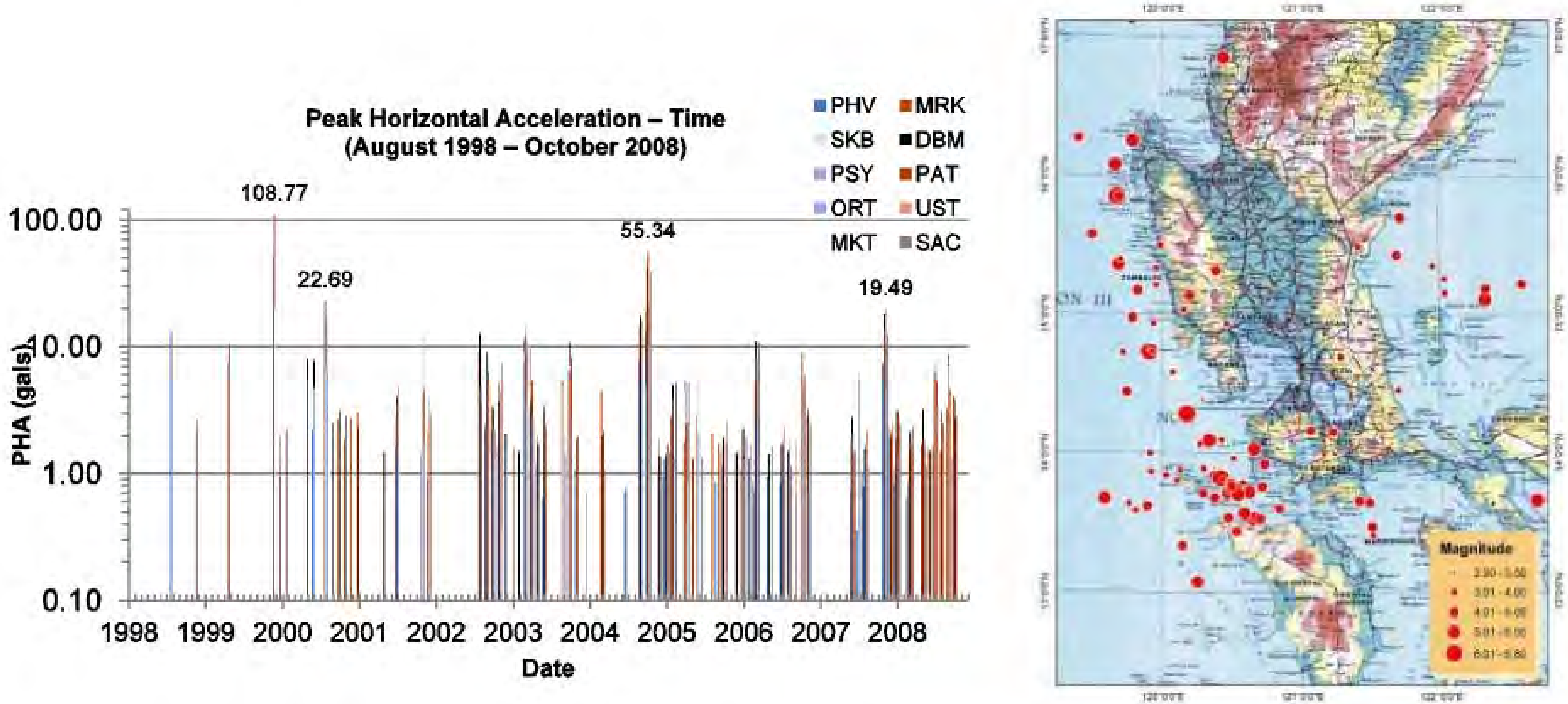


Figure ES-4-1 Observed Peak Horizontal Accelerations (Aug. 1998 to Oct. 2008)

PART 2: BRIDGE SEISMIC DESIGN SPECIFICATIONS (PACKAGE A)

CHAPTER 5 CHRONOLOGY OF BRIDGE SEISMIC DESIGN SPECIFICATIONS

This Chapter presents the chronology of development of the seismic design specifications for the Philippines, Japan and the USA based on large earthquake events that led to the current state of the seismic design codes.

CHAPTER 6 COMPARISON ON BRIDGE SEISMIC DESIGN SPECIFICATIONS BETWEEN DPWH / NSCP, AASHTO AND JRA

Since the seismic loading provisions of the DPWH Design Guidelines (1982) have been outdated by recent earthquake events, the current seismic design of bridges practiced by DPWH under D.O.75 requires, as a minimum, that bridge design shall conform to the AASHTO Guide Specifications for Seismic Design (1989 or latest edition). This seismic design provision (with reference to AASHTO 15th Edition, 1992) is applied by ASEP in the NSCP Vol. 2 – Bridges, using the allowable stress design with the load factor design. The latest edition of NSCP is the 2005 reprint of the 2nd Edition (1997).

However, since the issuance of D.O.75, the AASHTO seismic design have evolved from the working stress and load factor design to load and resistance factor design using the force-based procedures (AASHTO 6th Edition, 2012) and the displacement-based procedures (AASHTO 2nd Edition, 2011 Seismic Bridge Design) to calculate the elastic demand forces and the member ductility demand. Several large earthquakes occurring in the U.S.A. and elsewhere prompted the AASHTO to modify the seismic design provisions.

Likewise, the Japan Road Association (JRA) Seismic Design Specifications for Highway Bridges evolved as a result of the data accumulated and lessons learned from recent major earthquakes, with the latest revision being the acceleration response spectra for Type I design earthquake due to the 2011 Tohoku District Pacific Coast Earthquake.

In order to realize the differences in seismic design requirements and procedures between the DPWH/NSCP, the AASHTO and the JRA specifications, this Chapter compares the following recent specifications for seismic design of bridges:

- NSCP Volume 2 – Bridges, 2005 Reprint of 2nd Edition, ASEP, (Reference to AASHTO 1992, 15th Ed.). This code has been used in the comparison since the DPWH Guidelines was superseded by the DPWH D.O.75 which also refers to the AASHTO design procedures.
- AASHTO LRFD Bridge Design Specifications (2012, 6th Ed.) – Force-Based R-Factor Method
- AASHTO Guide Specifications for LRFD Seismic Bridge Design (2nd Edition, 2011) – Displacement-Based Method
- JRA Part V – Seismic Design (2012 Edition)

CHAPTER 7 IDENTIFICATION OF ISSUES ON CURRENT PRACTICE AND DPWH SEISMIC DESIGN SPECIFICATIONS FOR BRIDGES

In the Philippines the bridge seismic guidelines has been traditionally prepared based on the AASHTO design guidelines. However, geographical and geological characteristics including distribution of volcanoes, active faults and soft ground are largely different from those in the U.S.A. If intending to secure the safety of structures resulting in protecting nation's assets and people's life against natural disasters, the country needs to adapt the guidelines to its local conditions, carefully identifying local particularities with general or universal ones.

The following two items may be the key issues in the localization of guidelines in terms of bridge seismic design, taking account of big differences in conditions between the Philippines and the U.S.A.:

1) Seismic hazard (hazard sources related to seismic loads)
   - Active faults widely distributed in the Philippine islands.
   - Existence of several trenches sandwiching the Philippine Archipelago such as the Philippine Trench, East Luzon Trench, Manila Trench, Negros Trench and so on.
   - Distribution of active volcanoes.
2) Ground Conditions (hazard sources related to both seismic loads and resistance to such)
   - Widely distributed relatively or very soft layers.
   - Widely distributed sand or sandy soil layers having liquefaction potential.

In addition to the above, the current trend of seismic design analysis to assess bridge seismic performance should be considered in the design which is being shifted from the force-based R-factor design approach to the displacement-based design approach after the 1989 Loma Prieta Earthquake, the 1994 Northridge Earthquake, the 1995 Kobe Earthquake, etc., because neither the AASHTO force-based design specifications nor the LRFD design specifications provide detailed design criteria for estimating the ductile capacity of column subjected to the design earthquake. The estimation of a column's ductile capacity is essential for the verification of seismic performance requirements defined in the specifications.

In this Chapter, the following five items are taken up as major issues on the seismic design specifications identified in the Study considering the above context:

1) Necessity of formulation of policy on seismic performance requirements;
2) Establishment of acceleration response spectra according to the Philippines' geographical and geological characteristics;
3) Issues on soil type classification; and
4) Issues on bridge falling down prevention system.

CHAPTER 8 APPROACH TO THE DEVELOPMENT OF LOCALIZED SEISMIC ACCELERATION RESPONSE SPECTRA FOR BRIDGE DESIGN

The objectives of the development of the acceleration response spectra are to:

- Confirm whether the acceleration spectra of each soil type specified in AASHTO can be adopted into the ground properties of the Philippines;
- Study design earthquake motions reflecting Philippine conditions (local conditions); and
- Propose standard acceleration spectra fit for the Philippines.

(1) Method 1 – Based on AASHTO Acceleration Response Spectra (Currently Utilized by DPWH)

The development procedure is shown in Figure ES-8-1. The major results of the studies are shown in Figure ES-8-2 and Figure ES-8-3, and below.

- Ground response analyses were conducted, and ground surface acceleration response spectra were calculated, taking the ground characteristics of the Philippines into consideration.
- Comparison of the ground surface acceleration response spectra obtained from the ground response analysis and the AASHTO (2007) design acceleration response spectra has confirmed that there are some differences in maximum values and period characteristics.
- On the basis of the comparison results mentioned above, shapes of design acceleration response spectra based on the AASHTO (2007) design acceleration response spectra appropriate for the ground characteristics of the Philippines have been proposed.

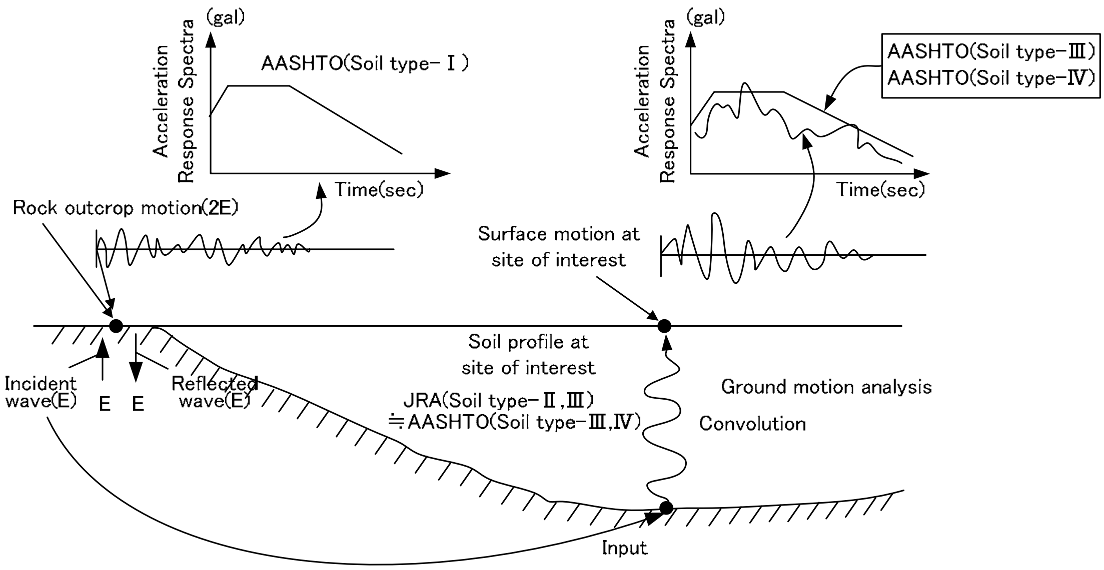


Figure ES-8-1 Development Procedure (Method 1)

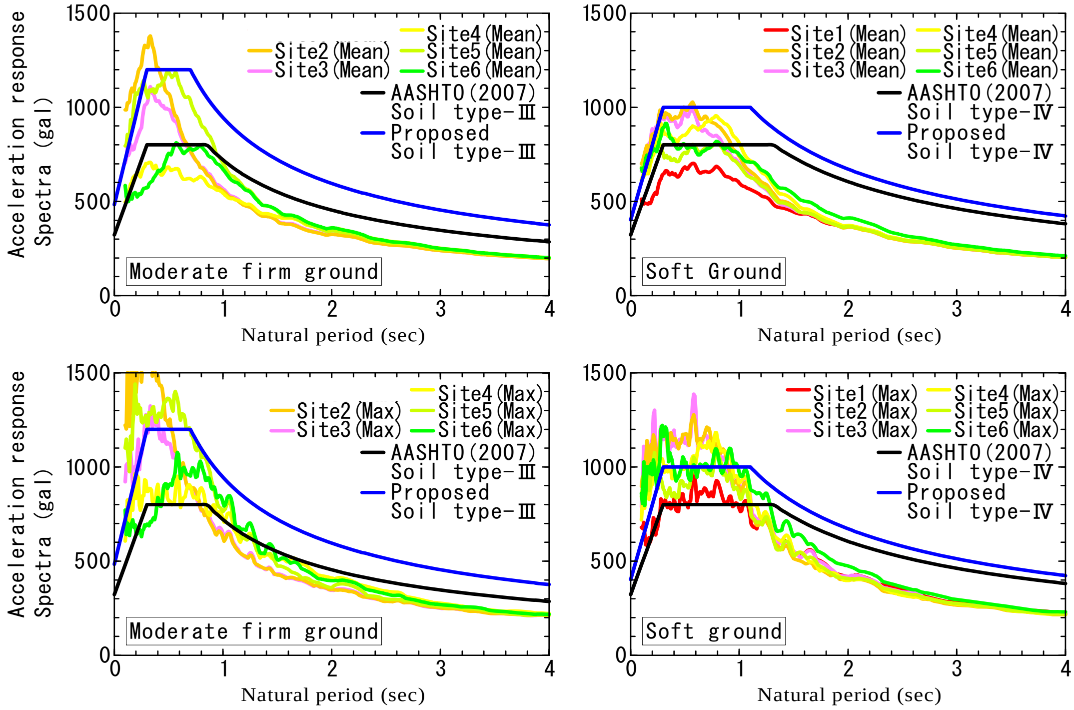
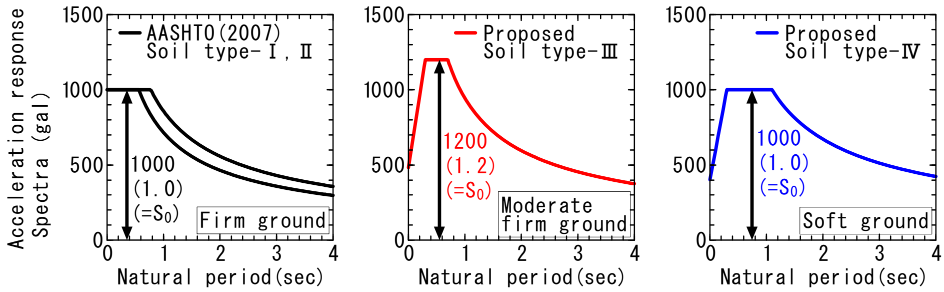


Figure ES-8-2 Proposed Design Acceleration Response Spectra based on Study Results



AASHTO 2012	Proposed S_0
1.0	1.0
1.1	1.2
0.9	1.0

Site Class	Spectral Acceleration Coefficient at Period 0.2 sec (SS)					Soil Type
	S_S<0.25	S_S=0.50	S_S=0.75	S_S=1.00	S_S>1.25	
A	0.8	0.8	0.8	0.8	0.8	
B	1.0	1.0	1.0	1.0	1.0	
C	1.2	1.2	1.1	1.0	1.0	Firm
D	1.6	1.4	1.2	1.1	1.0	Moderate Firm ground
E	2.5	1.7	1.2	0.9	0.9	Soft ground
F	-	-	-	-	-	

Figure ES-8-3 Comparison of Proposed Spectra and Design Spectra of AASHTO (2012)

(2) Method 2 – Based on Probabilistic Seismic Hazard Analysis

The Probabilistic Seismic Hazard Analysis (PSHA), in combination with the scenario earthquake evaluation method, was applied to establish the design acceleration response spectra in consideration of applicable data provided by PHIVOLCS, sufficient volume and quality of active fault and earthquake occurrence data in the Philippines.

The JICA Study Team decided to adopt the PSHA method which can incorporate future progressive accumulation of earthquake data, location of active faults, and strong ground motion record for sustainable development of the seismic design specifications in the Philippines.

Figure 8-4 illustrates the conceptual diagram of PSHA.

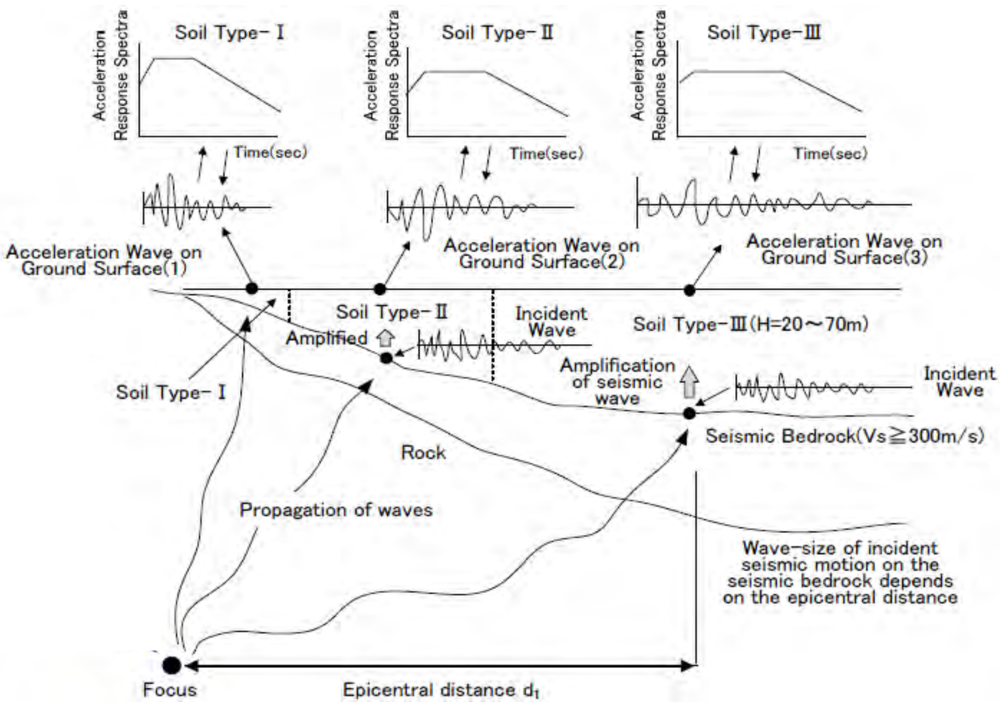


Figure ES-8-4 Development Procedure (Method 2)

CHAPTER 9 SEISMIC HAZARD MAPS FOR DESIGN OF BRIDGES

The design acceleration response spectra are established through the following two steps.

Step-1: Establishment of Site-specific Design Spectra

Site-specific design spectra were developed through the following 2 steps for 7 bridges selected for package B & C (2 bridges inside Metro Manila & 5 bridges outside Metro Manila);

1) Determination of Peak Ground Acceleration (PGA) at the 7 objective bridge sites (at seismic bedrock)

   PGA at seismic bedrock was determined under the condition of AASHTO soil type-B (soft rock, Vs=760m/s). The bedrock PGA is then propagated at the ground surface of interest using the soil profile at the sites.

2) Conduct of ground motion analysis at the 7 sites and establishment of site-specific response spectra with the analysis results using the generated ground motion at the surface, the design response spectra was developed from a single-degree-of-freedom dynamic analysis model.

Step-2: Establishment of Site-generalized Design Spectra: Probabilistic Seismic Hazard Approach (PSHA)

Site-generalized Design Spectra were established for the entire nation and specified in Bridge Seismic Design Specifications (BSDS). Specifically, localized contour map of seismic acceleration coefficients (PGA (soft rock, Vs=760m/s), Ss (at T=0.2sec), S1 (T=1.0sec) (see Figure 9-1) were provided. The localized contour maps were developed for 4 earthquake return periods (50-year, 100-year, 500-year, and 1000-year). 50-year and 100-year were assumed to be for small to moderate scale earthquakes (Level-1 earthquake ground motion (EGM)) while 500-year and 1000-year correspond to large scale earthquake (Level-2 EGM). Generally, the return period for seismic design is determined in consideration of tolerable limit for both area characteristics and economic loss.

The entire process of site-generalized design spectra establishment is shown in Figure-9-1. Also, “PGA zone map specified in the current design code” and “PGA contour map for 500-year & 1000-year return period prepared in this project are shown in Figure 9-2. The application of 100-year return period for Level-1 earthquake and 1000-year for Level-2 earthquake was decided during the BSDS working group meeting between the JICA Study Team and DPWH-BOD.

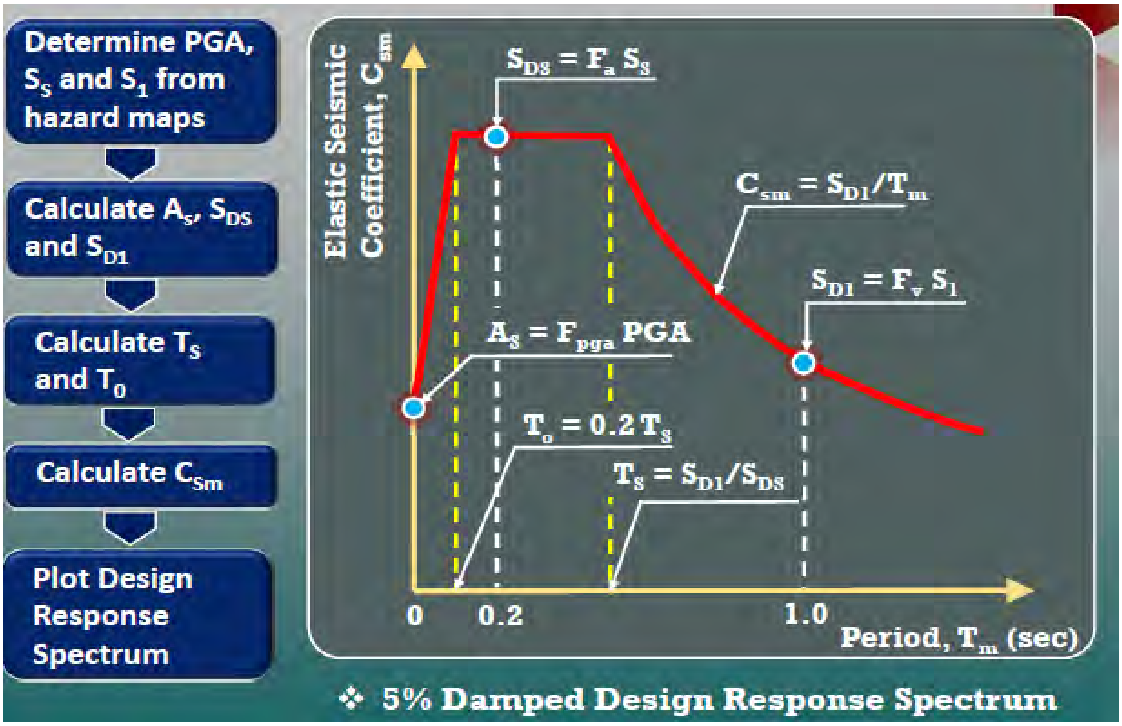
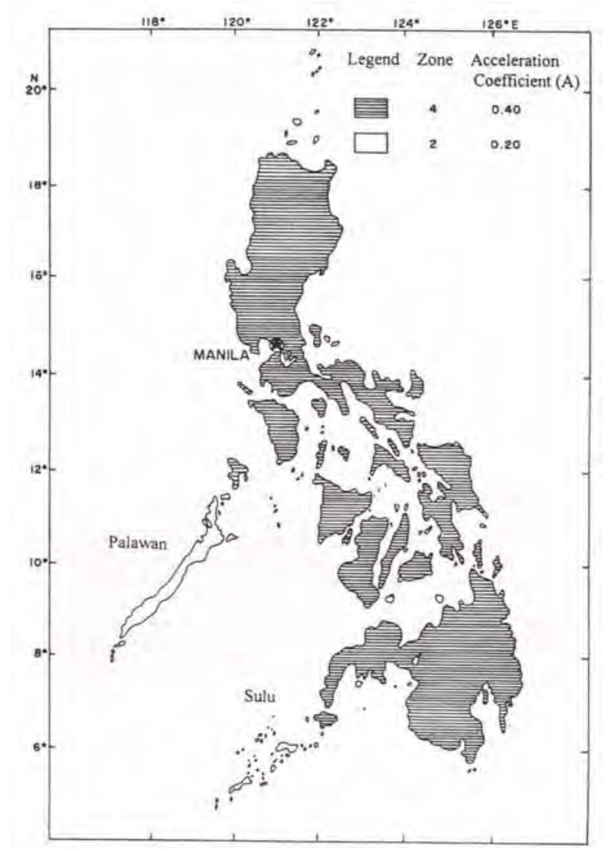
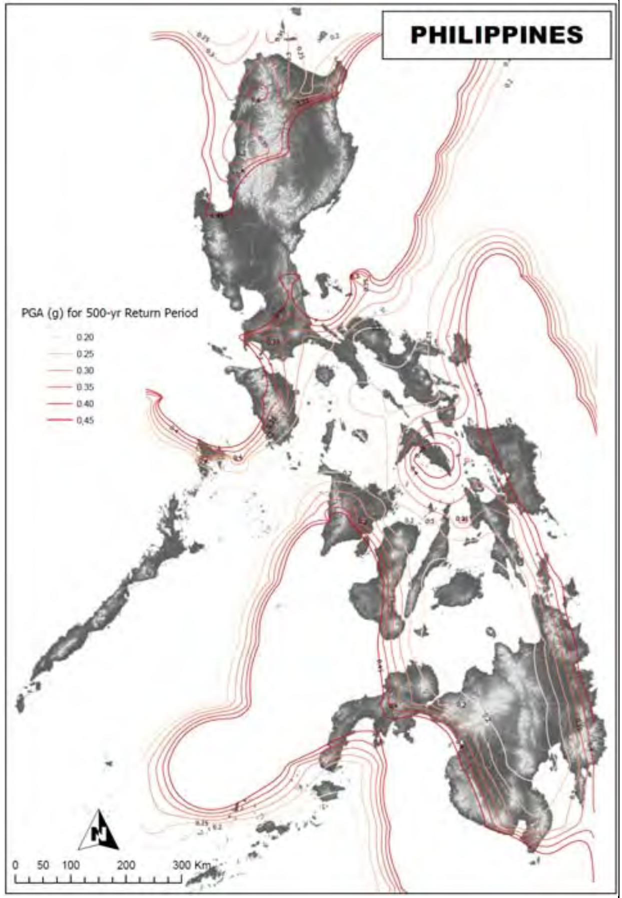


Figure ES-9-1 Development Procedure of Design Response Spectrum



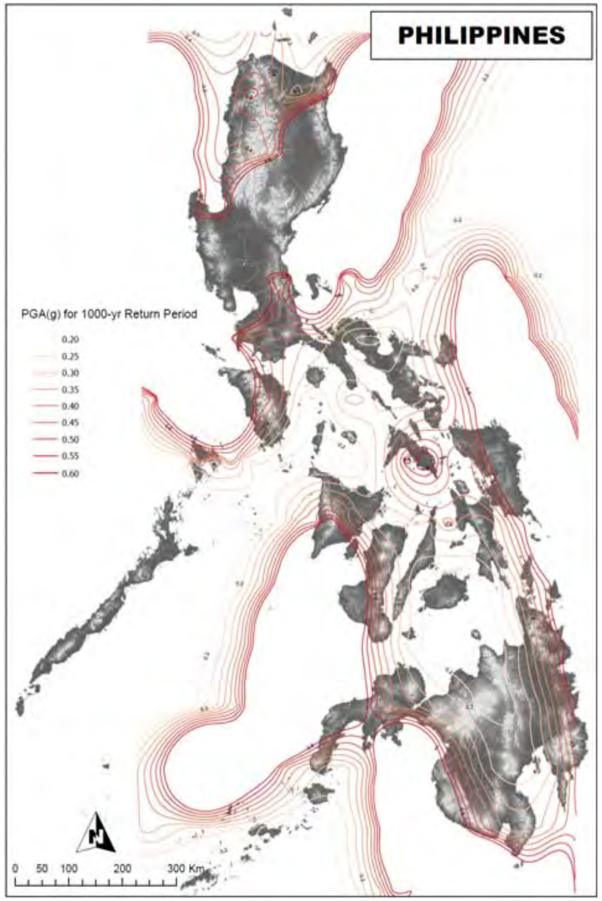
(Source: 1997, 2nd Edition of NSCP Vol. 2 – Bridges, 1997, ASEP)

(1) Philippine Seismic Zone Map
(Currently applied for Bridge seismic design)



(Source: JICA Study Team)

(2) Proposed Peak Ground Acceleration (g) for
500-year Return Period



(Source: JICA Study Team)

(3) Proposed Peak Ground Acceleration (g) for
1,000-year Return Period

Figure ES-9-2Contour map of PGA corresponding to return periods of 1,000 years and seismic zone map currently used by DPWH

CHAPTER 10 OUTLINE OF BRIDGE SEISMIC DESIGN SPECIFICATIONS (BSDS) MANUAL AND DESIGN EXAMPLES

(1) Development of the Bridge Seismic Design Specifications (BSDS)

The need to revise the current bridge seismic design guidelines and specifications is indicated to:

- keep the DPWH abreast with the latest practice and technology in seismic design of bridges;
- define the seismic performance required for bridges during an earthquake occurrence;
- localize certain seismic code provisions reflecting the actual site conditions including soil profile types, peak ground acceleration and design acceleration response spectra; and
- guide the DPWH and the private sectors with a uniform approach in the design of bridges against earthquake loading.

The following basic policies govern the revision of the current bridge seismic design specifications:

1) Provision of 3-Seismic Performance Levels (SPL) similar to JRA to define bridge response during earthquake, as opposed to 1-level, no collapse requirement of AASHTO.
2) Establishment of Bridge Operational Class (OC) based on road function and importance.
3) Adoption of JRA's 3-Ground Profile Types which is more appropriate than AASHTO's soil profile types.
4) Development of seismic hazard maps (PGA and response spectral acceleration coefficients) by PSHA to define earthquake loading
5) Adoption of AASHTO's 3-point (PGA, S_S and S_1) design response acceleration spectra
6) Adoption of JRA's design provisions for ground liquefaction and lateral spreading which is not specifically provided in AASTO.
7) Application of AASHTO's LRFD design philosophy.
8) Adoption of JRA's concept of unseating/fall-down prevention system which is more explicit than AASHTO.
9) Inclusion of JRA's provisions for seismically isolated bridges.
10) Adoption of JRA's provision on foundation analysis and design due to similarities between Philippine and Japan's ground types.

(2) Outline of the Bridge Seismic Design Specifications (BSDS)

The BSDS covers eight (8) sections as follows:

Section 1: Introduction
- (1) Background,
- (2) Purpose
- (3) Scope
- (4) Seismic Design Philosophy

Section 2: Definitions and Notations

Section 3: General Requirements
- (1) Applicability of Specifications
- (2) Bridge Operational Classification
- (3) Seismic Performance
- (4) Seismic Hazard
- (5) Ground Type
- (6) Design Response Spectrum and Site Factors
- (7) Response Modification Factors (R-Factors)

Section 4: Analysis Requirements
- (1) Minimum Analysis Requirements
- (2) Mathematical Model
- (3) Dynamic Analysis Requirements
- (4) Minimum Seat Length Requirements
- (5) P-Δ Requirements

Section 5: Design Requirements

(1) Combination of Seismic Force Effects

(2) Calculation of Design Forces

(3) Foundation Requirements

(4) Longitudinal Restrainers and Hold-Down Devices,

(5) Bearing Support System

Section 6: Effects of Seismically Unstable Grounds

(1) Geotechnical Parameters

(2) Liquefaction Assessment

(3) Liquefaction-Induced-Lateral Spreading

Section 7: Requirements for Unseating Prevention System

Section 8: Requirements for Seismically Isolated Bridges

(3) Outline of the Seismic Design Calculation Example using the Bridge Seismic Design Specifications (BSDS)

In order to guide the design engineers in utilizing the Bridge Seismic Design Specifications (BSDS), a seismic design calculation example has been developed as an accompanying volume of the BSDS. The design example covers the basic principles and processes of seismic design in accordance with the BSDS.

(4) Comparison between the DPWH Existing Design with the Bridge Seismic Design Specifications (BSDS) Using the Proposed Design Acceleration Response Spectra

New specifications are proposed in view of the deficiencies in the current seismic design practice of bridges in the Philippines. The proposed Bridge Seismic Design Specifications (BSDS) which is based on the latest AASHTO LRFD design specifications, however, have several design requirements which differ from the previous design practice of DPWH, namely:

- The use of response acceleration spectra based on the PGA, short-period and long-period acceleration response from the developed seismic hazard maps, as opposed to the current practice of using the AASTO spectra based on four soil type classification;
- The use of the proposed seismic hazard map for the entire Philippines based on the probabilistic seismic hazard analysis of past records of earthquake as opposed to the current use of 0.4g and 0.2g PGA to be applied in the design response spectra;
- The increase in return period of the design earthquake from 500-year (current) to 1,000-year (BSDS);
- The reduction of R-factors to almost half for Critical and Essential bridges as opposed to the current R-factors; and
- The application of LRFD (load and resistance factors) as opposed to the current LFD (load factors).

(5) Example of Practical Application of Seismic Retrofit

In order to assist the design engineers with appropriate application of seismic retrofitting schemes to existing structures, a seismic retrofitting work example has been developed as an accompanying volume of the BSDS. The retrofitting work example covers:

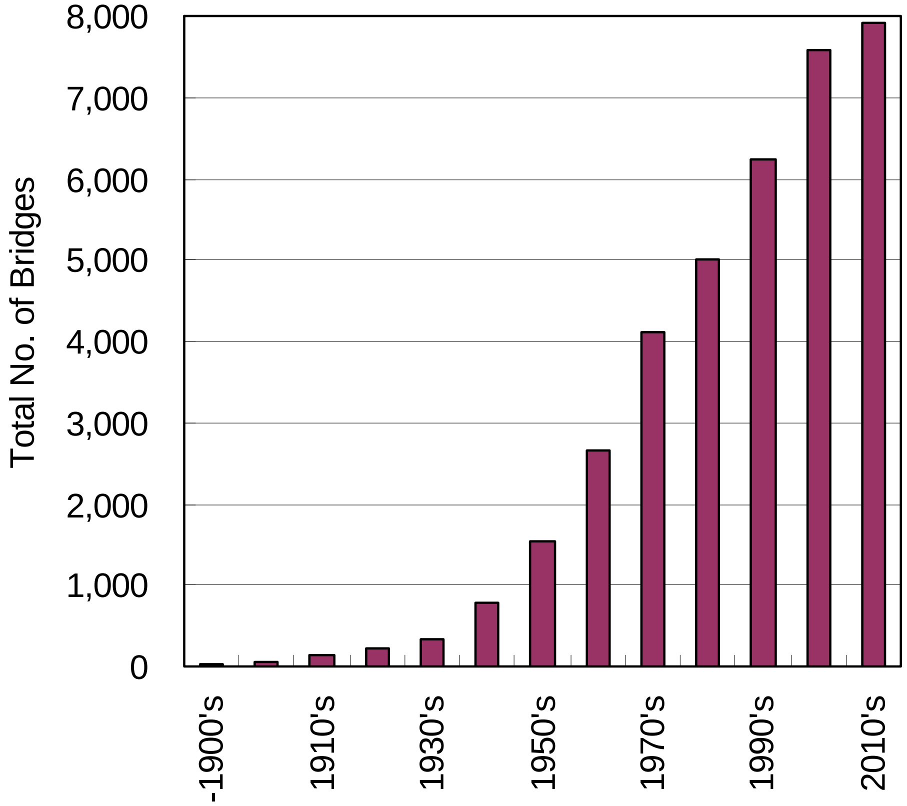
- Seismic lessons learned from past earthquakes;
- Outline of seismic retrofit schemes; and
- Detail of each seismic retrofit scheme.

Part 3: Selection of Bridges for Seismic Capacity Improvement (Package B and Package C)

Chapter 11 Procedures for Selection of Bridges for Outline Design

(1) Flowchart for Selection

The DPWH performs maintenance of about 8,000 bridges as shown in Figure ES-11-1.



Source: DPWH, 2013

Figure ES-11-1 Number of bridges maintained by DPWH

The selection of priority bridges for seismic strengthening has been undertaken as a two-screening process as shown in Figure ES-11-2.

(2) Evaluation Criteria for the First and Second Screening

In order to determine the bridges which require retrofitting or replacement to mitigate seismic disasters inside and outside of Metro Manila, two steps of screening were employed, which includes the inspection of bridge conditions, environmental and social conditions around the bridge, and undertaking of traffic volume survey on roads related to the bridges. The prioritization and selection of bridges to be retrofitted or replaced was carried-out based on these steps of screening.

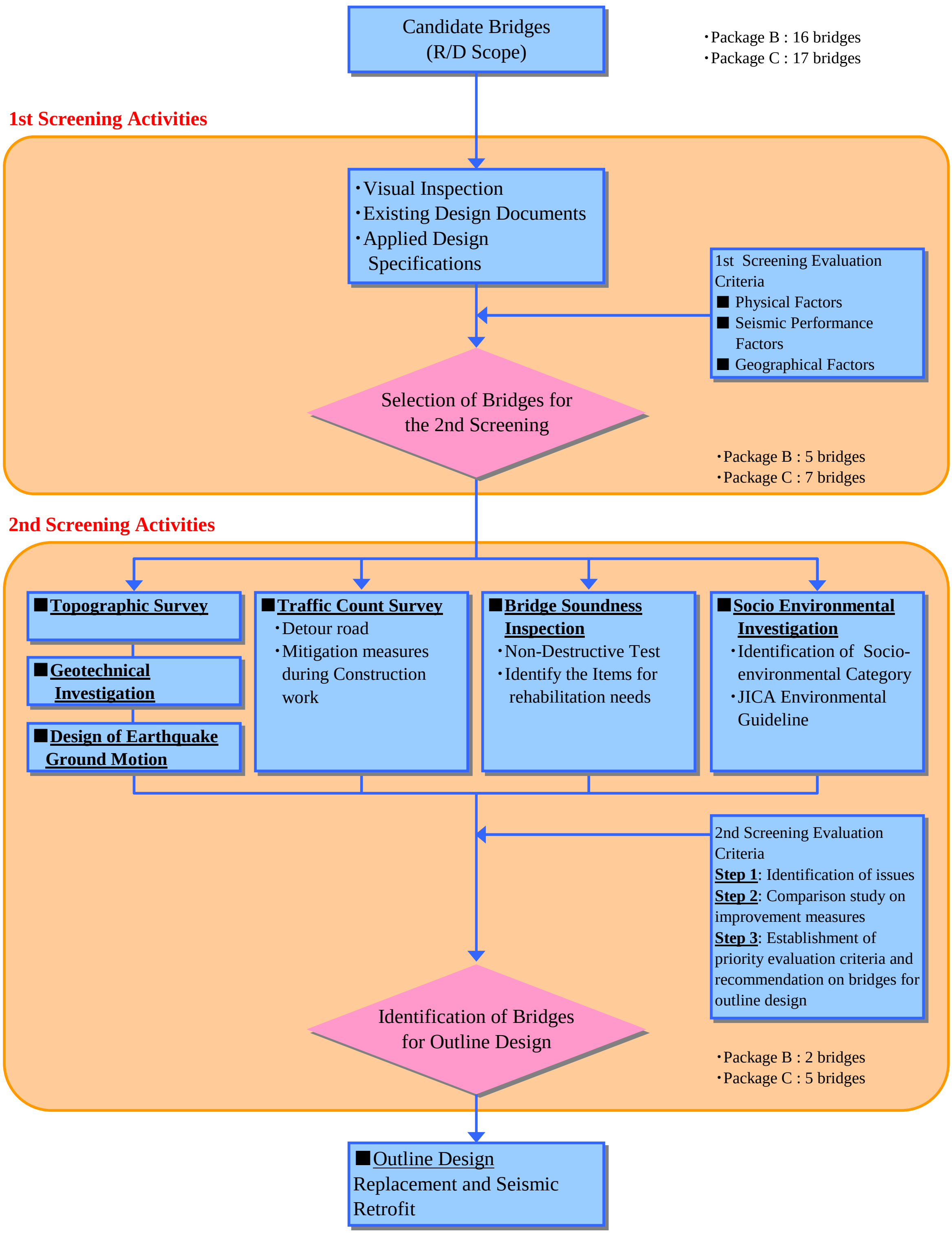


Figure ES-11-2 Procedure of Identification of Prioritized Bridges

The first screening aimed to prioritize bridges which should be widely categorized by not only physical factors due to the condition of bridge but also seismic performance factors to reduce seismic hazards and geotechnical factors. The purpose of the second screening was to select the target bridges for the outline design stage.

The evaluation criteria of first and second screenings are shown in Table ES-11-1 and Table ES-11-2.

Table ES-11-1 Evaluation Criteria of First Screening

No.	Category	Evaluation Criteria	Maximum Score
1.	Physical Factors (50 pt)	Construction Year & Applied Specification	10
2.		Vulnerability of Bridge	30
3.		Road Importance	5
4.		Load Carrying Capacity	5
5.	Seismic Performance Factors (30 pt)	Seating Length	10
6.		Fall-down Prevention Apparatus	10
7.		Type of Bridge	10
8.	Geotechnical Factors (20 pt)	Liquefaction Potential	10
9.		Soil Classification	5
10.		Impact to Environment	5
Total Points			100

Table ES-11-2 Evaluation Criteria of Second Screening

Component			Evaluation Items	Weight for Rating
Bridge Condition (80 pt)	Seismic Vulnerability (60 pt)	Earthquake Resisting System (20 pt)	1. Difference in soil types between adjacent piers	2
			2. Continuous or simply supported bridge	3
			3. Eccentric loads (longitudinal and transverse directions)	5
			4. Pier Type (single column / wall or multiple columns)	3
			5. Height of Abutment (Embankment)	2
			6. Built Year	5
		Falling Down Prevention System (15 pt)	7. Unseating/Fall-down prevention devices (both longitudinal and transverse directions)	5
			8. Bearing	5
			9. Seat length	5
		Foundation (15 pt)	10. Foundation type (known or unknown)	3
			11. Scouring	3
			12. Soil type	3
			13. Liquefaction potential	6
		Seismic Hazard (10 pt)	14. Distance from active faults	10
	Structural Soundness (20 pt)	Superstructures (15 pt)	1. Primary members	10
			2. Secondary members	2
			3. Deck slab	3
		Substructures (5 pt)	4. Deterioration of columns/walls	5
Importance (20 pt)		Traffic volume (5 pt)	1. Traffic volume (pcu) (AADT)	5
		Alternative bridge(s) (15 pt)	2. Existence of alternative bridge(s)	15

CHAPTER 12 THE FIRST SCREENING

The evaluation result of the first screening of Package B and Package C are shown in Table ES-12-1 and Table ES-12-2.

Table ES-12-1 Results of First Screening of Package B

No.	Name of Bridge	Score (Priority)	Result
B-1	Delpan Bridge	61 (5)	Selected
B-2	Jones Bridge	48 (10)	
B-3	MacArthur Bridge	48 (10)	
B-4	Quezon Bridge	51 (7)	
B-5	Ayala Bridge	93 (1)	(Reconstruction by Local Fund)
B-6	Nagtahan Bridge	57 (6)	Selected
B-7	Pandacan Bridge	39 (14)	
B-8	Lambingan Bridge	73 (3)	Selected
B-9	Makati-Mandaluyong Bridge	49 (9)	
B-10	Guadalupe Bridge	85 (2)	Selected
B-11	C-5 Bridge	23 (17)	
B-12	Bambang Bridge	39 (14)	
B-13	Vargas Bridge-1	42 (13)	
B-14	Vargas Bridge-2	32 (16)	
B-15	Marcos Bridge	43 (12)	
B-16	Marikina Bridge	65 (4)	Selected
B-17	San Jose Bridge	51 (7)	

Table ES-12-2 Results of First Screening of Package C

No.	Name of Bridge	Score (Priority)	Result
C-1	Badiwan Bridge	14 (16)	
C-2	Buntun Bridge	59 (5)	Selected
C-3	Lucban Bridge	74 (1)	(Under Reconstruction Planning)
C-4	Magapit Bridge	43 (10)	(Under Repair)
C-5	Sicsican Bridge	52 (8)	(Under Repair Planning)
C-6	Bamban Bridge	25 (15)	
C-7	1st Mandaue-Mactan Bridge	50 (9)	Selected
C-8	Marcelo Feman Bridge	34 (14)	
C-9	Palanit Bridge	64 (3)	Selected
C-10	Jibatang Bridge	60 (4)	(Under Repair)
C-11	Mawo Bridge	54 (7)	Selected
C-12	Biliran Bridge	36 (12)	Selected (Selected by DPWH)
C-13	San Juanico Bridge	40 (11)	
C-14	Liloan Bridge	55 (6)	Selected
C-15	Wawa Bridge	67 (2)	Selected
C-16	Macapagal Bridge (2nd Magsaysay)	35 (13)	

CHAPTER 13 THE SECOND SCREENING

The evaluation results of the second screening of Package B and Package C are shown in Table ES-13-1.

Table ES-13-1 Results of Second Screening of Package B and Package C

Bridge Name	Bridge Condition (80 points)							Importance (20 pt)		Total Score (100 pt)	Priority Ranking
	Seismic Vulnerability (60 pt)				Structural Soundness (20 pt)		Sub-Total Score (80 pt)				
	Earthquake Resisting System (20 pt)	Unseating / Fall-down Prevention System (15 pt)	Foundation (15 pt)	Seismic Hazard (10 pt)	Super-structures (15 pt)	Sub-Structures (5 pt)		Traffic Volume (5 pt)	Alternative Bridge (15 pt)		
Package B											
1. Delpan Br.	15	9	15	0	7	3	49	3	5	57	**4**
2. Nagtahan Br.	11	8	12	3	7	3	44	3	5	52	**5**
3. Lambingan Br.	17	13	12	3	12	3	60	0	10	70	**2**
4. Guadalupe Br.	17	13	12	6	12	3	63	5	10	78	**1**
5. Marikina Br.	11	13	12	10	4	3	53	3	10	66	**3**
Package C											
1. Buntun Br.	14	13	15	0	1	0	43	5	15	63	**6**
2. Mandaue-Mactan Br.	18	13	14	0	8	5	58	5	5	68	**4**
3. Palanit Br.	17	15	3	3	15	3	56	0	15	71	**3**
4. Mawo Br.	14	11	14	10	9	0	58	3	15	76	**1**
5. Biliran Br.	14	11	3	6	6	3	43	3	15	61	**7**
6. Liloan Br.	14	15	3	6	7	3	48	3	15	66	**5**
7. Wawa Br.	17	13	5	10	14	0	59	3	10	72	**2**

CHAPTER 14 RECOMMENDATION ON TARGET BRIDGES FOR THE OUTLINE DESIGN

The recommendation of bridges selected for the outline design and their countermeasures are summarized as follows:

Bridges selected for the outline design of Package B

1) Lambingan Br. Replacement

2) Guadalupe Br. Outer: Replacement
Inner: Seismic Retrofit

Bridges selected for the outline design of Package C

1) 1st Mandaue-Mactan Br. Seismic Retrofit

2) Palanit Br. Replacement

3) Mawo Br. Replacement

4) Liloan Br. Seismic Retrofit

5) Wawa Br. Replacement

With the evaluation criteria for the second screening established in Chapter 13, the evaluation for each bridge was carried out. Table ES-14-1 shows the summary of evaluation results with priority ranking for each bridge.

Figure ES-14-1 Recommendation of Target Bridges for Outline Design

Package B			
Bridge Name	Priority Rank based on Seismic Vulnerability, Structural Soundness and Importance	Recommended Improvement Measures	Recommendation for Outline Design
1. Delpan Br.	4	Seismic Retrofit	
2. Nagtahan Br.	5	Seismic Retrofit	
3. Lambingan Br.	2	Replacement	Recommended
4. Guadalupe Br.	1	Replacement/ Partial Seismic Retrofit	Recommended
5. Marikina Br.	3	Replacement	
Package C			
Bridge Name	Priority Rank based on Seismic Vulnerability, Structural Soundness and Importance	Recommended Improvement Measures	Recommendation for Outline Design
1. Buntun Br.	6	Seismic Retrofit	
2. 1st Mandaue-Mactan Br.	4	Seismic Retrofit	Recommended
3. Palanit Br.	3	Replacement	Recommended
4. Mawo Br.	1	Replacement	Recommended
5. Biliran Br.	7	Seismic Retrofit	
6. Liloan Br.	5	Seismic Retrofit	Recommended
7. Wawa Br.	2	Replacement	Recommended

PART 4: OUTLINE DESIGN OF SELECTED BRIDGES FOR SEISMIC CAPACITY IMPROVEMENT (PACKAGE B AND PACKAGE C)

CHAPTER 15 DESIGN CONDITIONS FOR SELECTED BRIDGES

This Chapter presents the design conditions based on the results of the existing condition survey conducted in the first and second screening for the outline design of Package B and Package C.

(1) Topographic Features and Design Conditions

The following survey works and studies have been conducted. Topographic survey results were used for the outline design, hydrological survey and social environment survey.

1) Review of Data
2) GPS Survey
3) Traverse Control Points
4) Establishment of Temporary Bench Marks
5) Centerline Profile Survey of Target Bridges and their Approach Roads
6) Cross Section Survey of Target Bridges and their Approach Roads
7) Topographic (Plan) Survey
8) Cross Section Survey of the Rivers
9) Centerline Profile Survey of the Rivers
10) Shape and Dimension Measurement of Target Bridges

(2) Geotechnical and Soil Profile Conditions

Geological investigation was implemented to confirm geological, geotechnical and soil properties, and design condition of the selected bridge sites for the Second Screening of the bridges inside and outside of Metro Manila. There are five (5) bridge sites inside Metro Manila and seven (7) bridge sites outside of Metro Manila. The geological investigation was undertaken by a local consultant.

The geological investigation for each bridge site is basically comprised of boring with standard penetration test, laboratory tests to know soil mechanical properties, and down-hole shear wave test, as follows:

1) Boring
2) Standard Penetration Test (SPT)
3) Laboratory Test
4) Downhole Shear Wave Test (DSWT)

The soil profile type classification, design condition, liquefaction potential assessment has been reviewed and analyzed based on the results of the geological investigation.

(3) River and Hydrological Conditions

The following major design conditions have been studied for the bridge design:

1) Design Flood Discharge and Design Flood Level
2) Flow Velocity
3) Navigation Clearance
4) Freeboard and Vertical Clearance
5) Considerations

(4) Existing Road Network and Traffic Condition

The following major design conditions has been reviewed and studied for the bridge design:

1) National Road Network
2) Road Network in Metro Manila
3) Road Classification of Selected Bridges
4) Traffic Condition

Traffic count survey was carried out inside and outside of Metro Manila to better understand the current traffic condition. The purposes of traffic count survey were as given below.

1) For consideration and plan of detour, the number of vehicles affected during the construction period for seismic strengthening (maintenance, repair and reinforcement) and forecasting future traffic volume;
2) To consider the traffic volume for detour road/bridge during seismic retrofit/replacement; and
3) To forecast future traffic volume to determine necessary number of lanes.

The summary of traffic count survey result inside Metro Manila (Annual Average Daily Traffic: AADT) is given in Table ES-15-1.

Table ES-15-1 Summary of Traffic Count Survey Result inside Metro Manila (AADT)

No.	Bridge Name	AADT (Veh/Day)									Rate of Truck and Trailer
		1. Motorcycle / Tricycle	2. Car / Taxi / Pick-up / Van	3. Jeepney	4. Large Bus	5. 2-Axle Truck	6. 3-Axle Truck	7. Truck trailer	Sub-Total	Total	
B1	Delpan Bridge	24,906	28,249	1,949	36	2,246	1,609	7,657	41,745	66,651	27.6%
B2	Jones Bridge	15,153	30,117	7,696	152	972	123	30	39,089	54,241	3.3%
B3	Ayala Bridge	13,160	27,632	1,153	612	914	223	688	31,222	44,382	5.8%
B4	Nagtahan Bridge	21,132	64,460	1,655	344	4,993	2,032	1,823	75,306	96,438	11.7%
B5	Pandacan Bridge	7,813	22,173	0	25	1,279	206	148	23,831	31,643	6.9%
B6	Lambingan Bridge	9,379	13,626	6,093	31	943	137	48	20,877	30,255	5.4%
B7	Makati-Mandaluyong Bridge	11,666	30,556	0	14	384	126	11	31,089	42,755	1.7%
B8	Estrella Pantaleon Bridge	3,573	21,013	0	13	16	1	0	21,043	24,616	0.08%
B9	Guadalupe Bridge	19,557	181,078	0	13,229	4,100	1,628	876	200,909	220,466	3.3%
B10	C-5 Bridge	34,157	116,353	0	408	9,067	4,668	1,516	132,212	166,368	11.5%
B11	Marcos Bridge	15,720	62,110	11,357	140	3,496	1,282	742	79,125	94,845	7.0%
B12	Marikina Bridge	17,421	29,718	8,649	95	1,433	65	15	39,973	57,394	3.8%
C1	Buntun Bridge	9,908	4,357	1,573	59	676	115	83	6,862	16,770	
C2	1st Mandaue-Mactan Bridge	28,497	34,573	8,285	12	49	6	1	42,924	71,421	
C3	Palanit Bridge	730	199	65	93	93	76	10	536	1,265	
C4	Mawo Bridge	2,889	322	73	93	130	102	14	735	3,625	
C5	Biliran Bridge	1,718	276	49	57	124	23	2	530	2,248	
C6	Liloan Bridge	1,979	226	45	84	180	25	15	575	2,554	
C7	Wawa Bridge	1,476	1,598	48	266	282	238	42	2,473	3,950	

(Note) AADT: Annual Average Daily Traffic, Sub-Total is without Motorcycle/Tricycle

(5) Results of Natural and Social Environment Survey

The following natural and social environmental conditions of each bridge selected for the outline design have been studied:

1) Households and Structures (Area facing the Bridge and the approach road)
2) Land use (Area facing the Bridge and the approach road)3) Existing Environmental Condition (Noise, Vibration, Air Pollution and Water Contamination)

4) Environmental Protection Area (National Park, Reserves and Designated Wetland)

5) Existence on Location Map of Valuable Habitats, as well as Ecological, Historical and Cultural Assets

The following household survey has also been conducted:

1) Age, Gender, Household Size, Tenure, Work-Gender, Educational and Occupational Profile

2) Economic Status Profile

3) Sanitation and Health Conditions

4) Awareness and Social Acceptability of the Proposed Project

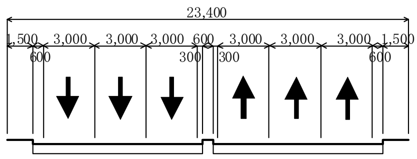
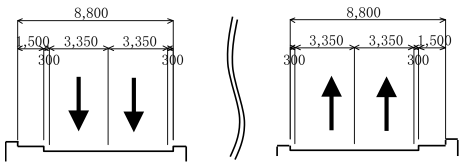
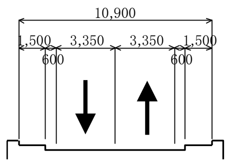
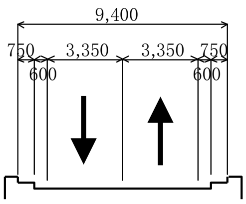
(6) Highway Conditions and Design

The highway condition of replacement bridges has been studied. The major design conditions of highway are shown in Table ES-15-2. The typical cross section of replacement bridges is shown in Table ES-15-3.

Table ES-15-2 Proposed Design Conditions of Highways

Bridge Name	B08 Lambingan	B10 Guadalupe	C09 Palanit	C11 Mawo	C15 Wawa
Road Classification	Urban Collector Road	Urban Arterial Road	Rural Arterial Road	Rural Arterial Road	Rural Arterial Road
Design Speed	50 km/h	60 km/h	60 km/h	60 km/h	60 km/h
Min. Horizontal Curvature	1,500m (Secure current condition)	∞ (Secure current condition)	∞ (Secure current condition)	∞ (Secure current condition)	200m (Secure current condition)
Length of the Minimum Horizontal Curve	36m (Secure current condition)	-	-	-	135m
Length of Spiral Curve	-	-	-	-	33m
Min. rate of Vert. Curvature K, Crest	9	-	46	100	16
Min. Rate of Vert. Curvature K, Sag	14	-	16	24	21
Min. Stopping Sight Distance	65m	-	85m	85m	85m
Max. Grade	5.0%	5.5% (Secure current condition)	5.7% (Secure current condition)	2.7% (Secure current condition)	4.0%
Min. Grade	0.7%	0.0% (Secure current condition)	0.3%	0.5%	0.3%
Length of the Minimum Vertical Curve	60m-	-	60m-	60m-	60m-
Min. Cross Slope	-	-	-	-	-
Max. Cross Slope	2.0%	2.0%	2.0%	2.0%	2.0%
Max. Superelevation	-	-	-	-	6.9%
Lane Width	3.00m (Secure current condition)	3.35m	3.35m	3.35m	3.35m (Secure current condition)
Shoulder Width	0.60m	0.30m (Secure current condition)	0.60m	0.60m-	0.60m-

Table ES-15-3 Proposed Typical Cross Section of Replacement Bridges

Bridge Name	No. of Lanes	Typical Cross Section of Bridge Section
B08 Lambingan	6	
B10 Guadalupe	10 (including 6-inner carriage way)	 South Bound lane North Bound lane
C09 Palanit C11 Mawo	2	
C15 Wawa	2	

CHAPTER 16 BRIDGE REPLACEMENT OUTLINE DESIGN OF SELECTED BRIDGES

(1) Design Criteria and Conditions for Bridge Replacement

The design standards utilized for the outline design of replacement bridges are as given in Table ES-16-1.

(2) Design Spectra

The site specific design spectra with 5% dumping as evaluated in the Study and utilized for the outline design are as shown in Figure ES-16-1.

(3) SUMMARY OF OUTLINE DESIGN OF REPLACEMENT BRIDGE

The project outline for replacement bridges is shown in Table ES-16-2. The general drawings of replacement bridges are as shown in Figure ES-16-2, ES-16-4, ES-16-6, ES-16-8 and ES-16-10. The perspective view of replacement bridges are as shown in Figure ES-16-3, ES-16-5, ES-16-7, ES-16-9 and ES-16-11.

Table ES-16-1 Design Standards utilized for Outline Design of Replacement Bridges

	Item	Design Condition	Specification
1) General	Design Load Combination	Level 2 Seismic Design: Extreme Event I	LRFD (2012)
	Seismic Design	Design Spectrum (1,000 year)	JICA Study Team
		Response Spectrum Analysis	JICA Study Team
2) Superstructure	Design Lane Width	3,350 mm (Package C and Guadalupe) 3,000 mm (Lambingan)	DPWH, AASHTO
	Dead Load	LRFD (2012)	
	Live Load	HL-93 and Lane Loads	LRFD (2012)
3) Substructure	Seismic Earth Pressure	LRFD(2012)	
	Column Section Design	R-factor method	LRFD (2012)
4) Foundation	Pile Foundation Analysis	JICA Study Team (JRA)	
	Soil Type	JICA Study Team (JRA)	
	Liquefaction design	JICA Study Team (JRA)	
	Pile Bearing	L1: FS=2, L2: FS=1	JICA Study Team (JRA)
	Pile Section Design	M-N chart (ϕ=1.0)	LRFD (2012)

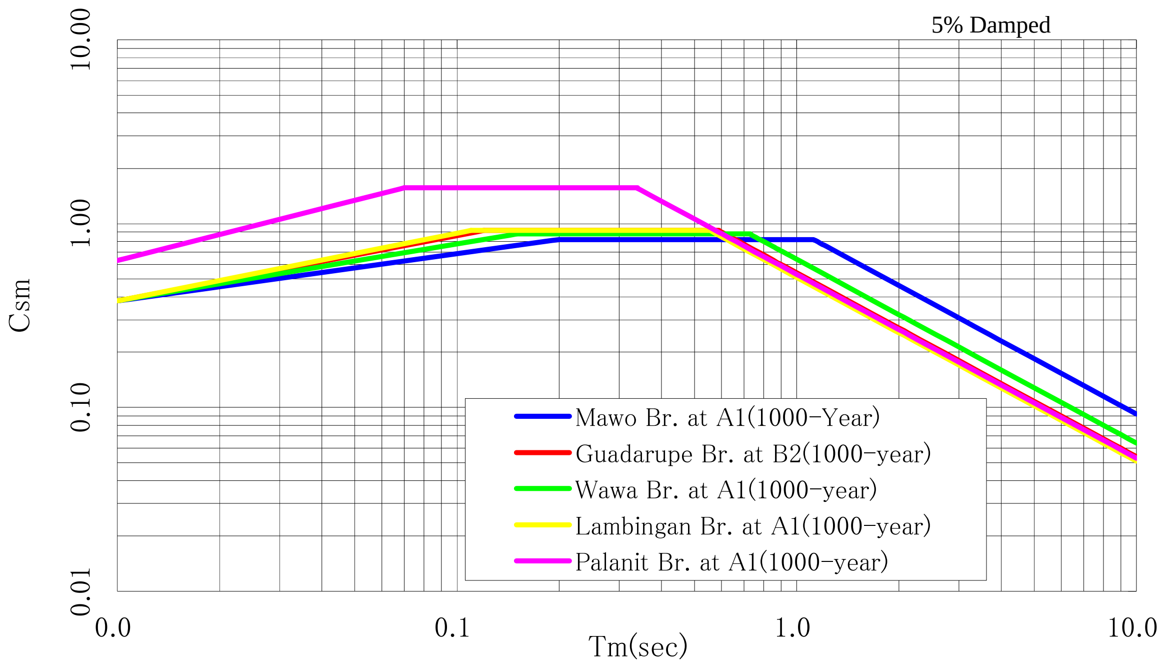


Figure ES-16-1 Site Specific Design Spectra for Replacement Bridge Design

.

Table ES-16-2 Project Outline for Replacement Bridge

Bridge Name	Proposed Improvement Measures	Description
Package B		
Lambingan Br.	Replacement	**Length** Bridge: 90 m Approach Rd.: 240 m (119 m+121 m) **Type** Superstructure: Simple Steel Deck Lohse Arch Stiffening Box Girder Substructure: RC Reversed-T Type Abutment Foundation: Cast-in-place Concrete Pile
Guadalupe Br.	Replacement/ Partial Seismic Retrofit	**Length** Bridge: 125 m (41.1 m + 42.8 m + 41.1 m) Approach Rd.: N/A **Type** Superstructure: 3-span Continuous Steel Deck Box Girder Substructure: RC Wall Type Pier / RC Reversed-T Type Abutment Foundation: Steel Pipe Sheet Pile Foundation **Seismic Retrofit** Soil Improvement
Package C		
Palanit Br.	Replacement	**Length** Bridge: 82 m (27 m + 28 m + 27 m) Approach Rd.: 135 m (98 m + 37 m) **Type** Superstructure: 3-span PC-I Girder Substructure: RC Single Column Pier (Circular Type)/ RC Reversed-T Type Abutment Foundation: Spread Footing Foundation
Mawo Br.	Replacement	**Length** Bridge: 205 m (62.5 m + 80.0 m + 62.5 m) Approach Rd.: 267 m (151 m + 112 m) **Type** Superstructure: 3-Span Continuous PC Fin-back Box Girder Substructure: RC Wall Type Pier / RC Reversed-T Type Abutment Foundation: Cast-in-place Concrete Pile
Wawa Br.	Replacement	**Length** Bridge: 230 m (75.0 m + 80.0 m + 75.0 m) Approach Rd.: 296 m (197 m + 99m) **Type** Superstructure: 3-Span Continuous Composite Steel Truss Substructure: RC Wall Type Pier / RC Reversed-T Type Abutment Foundation: Cast-in-Place Concrete Pile

Note: All replacement bridges including installation of unseating prevention system.

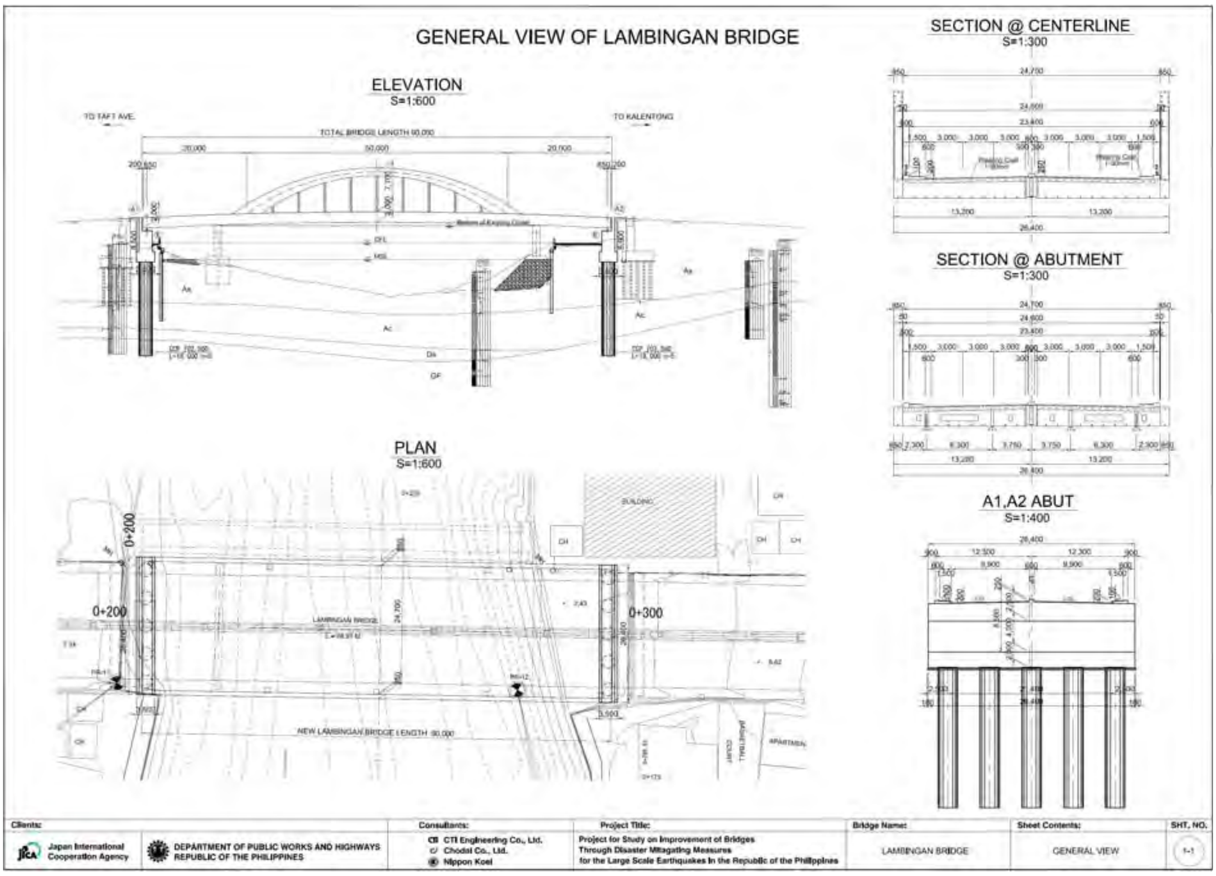


Figure ES-16-2 General Drawing of Lambingan Bridge

Figure ES-16-3 Perspective View of Lambingan Bridge

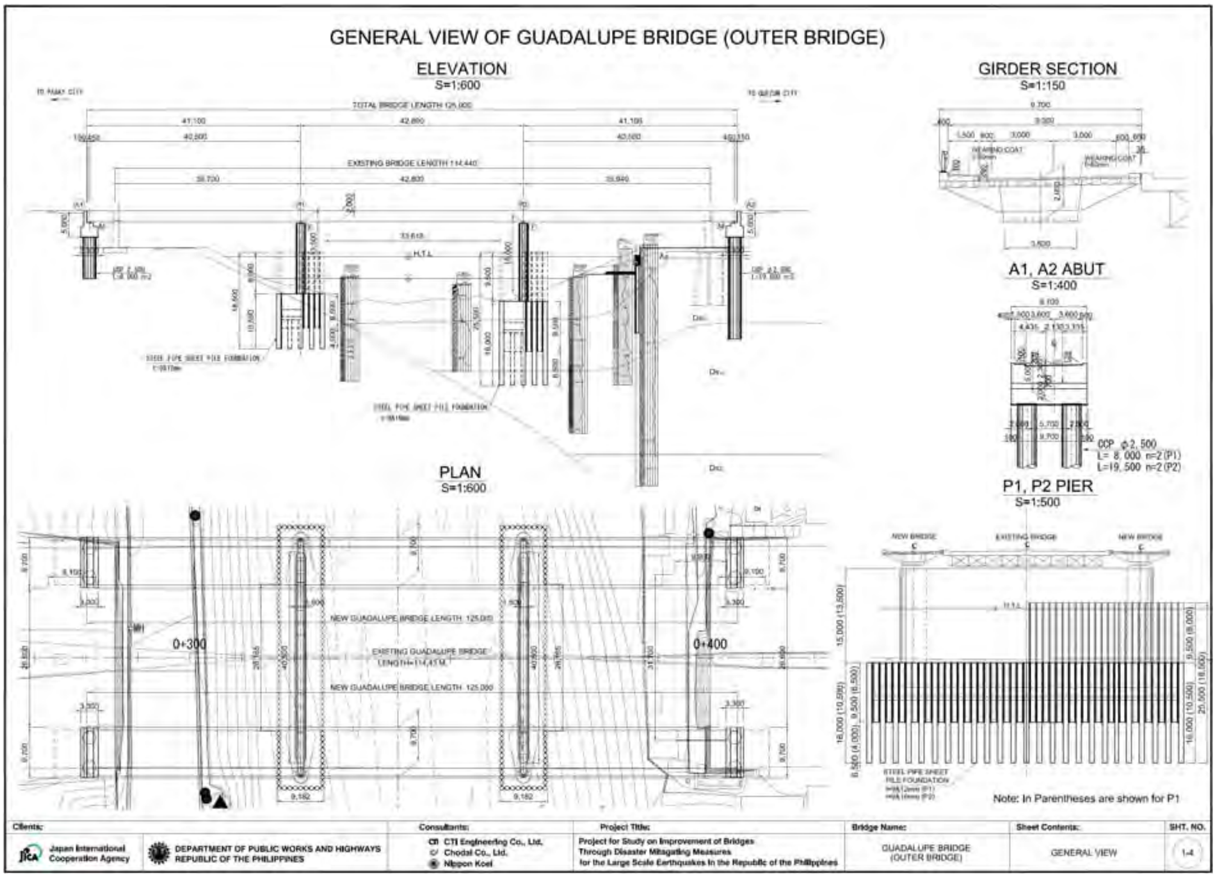


Figure ES-16-4 General Drawing of Guadalupe Bridge

Figure ES-16-5 Perspective View of Guadalupe Bridge

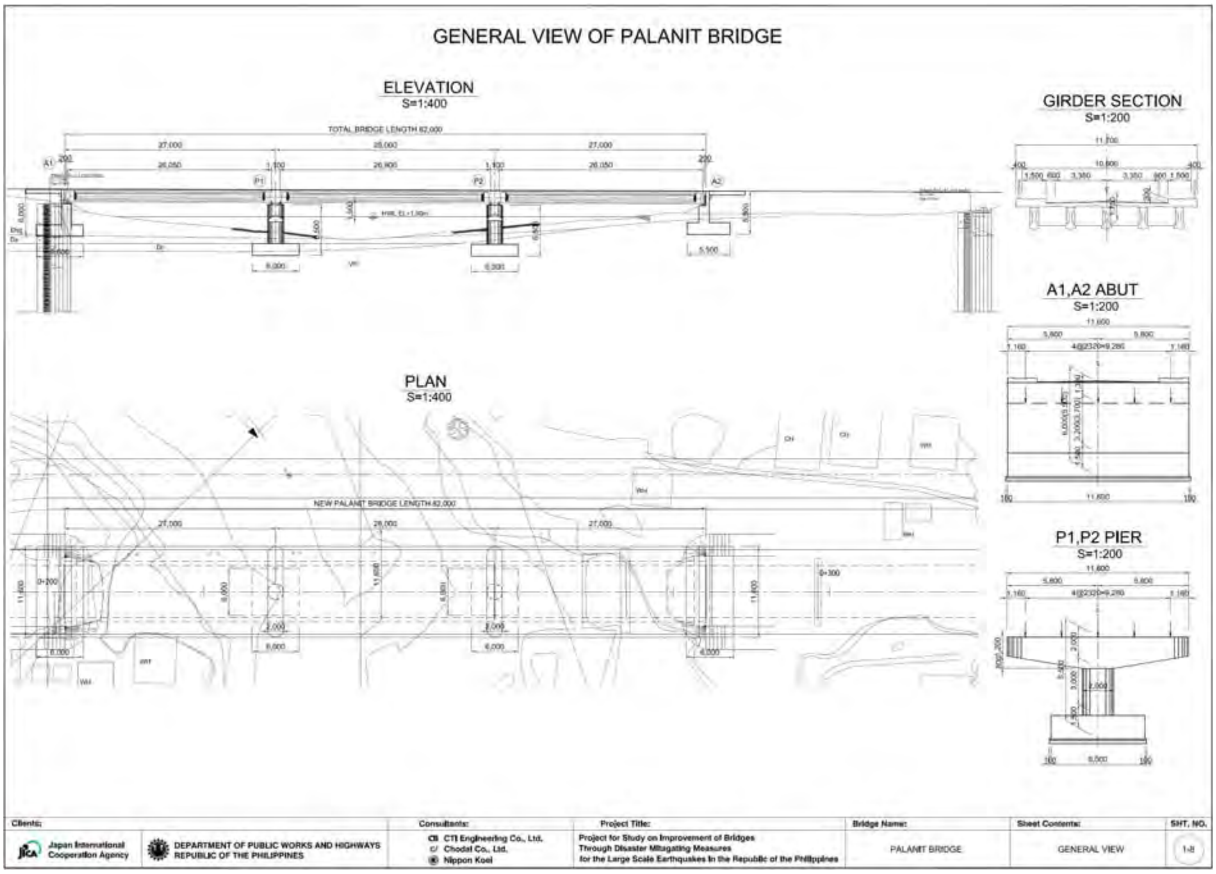


Figure ES-16-6 General Drawing of Palanit Bridge

Figure ES-16-7 Perspective View of Palanit Bridge

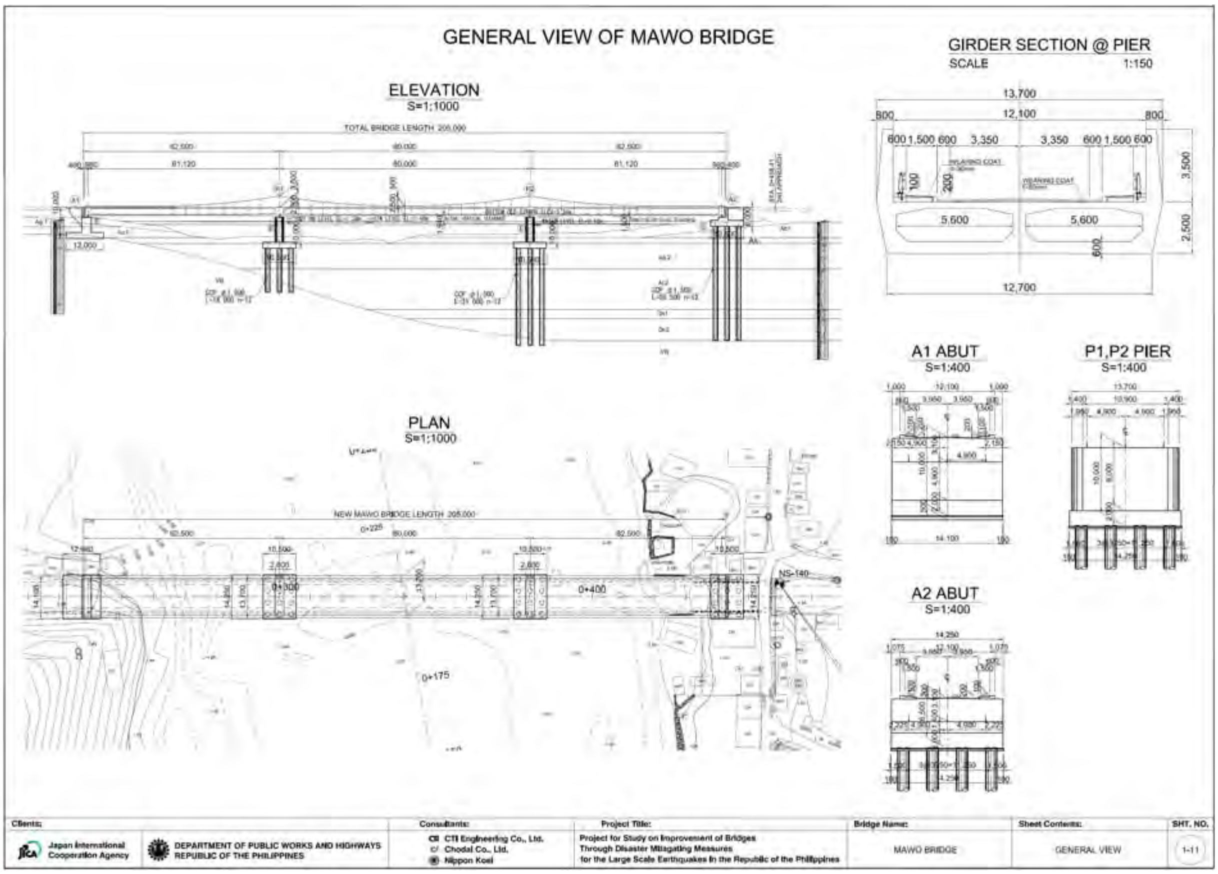


Figure ES-16-8 General Drawing of Mawo Bridge

Figure ES-16-9 Perspective View of Mawo Bridge

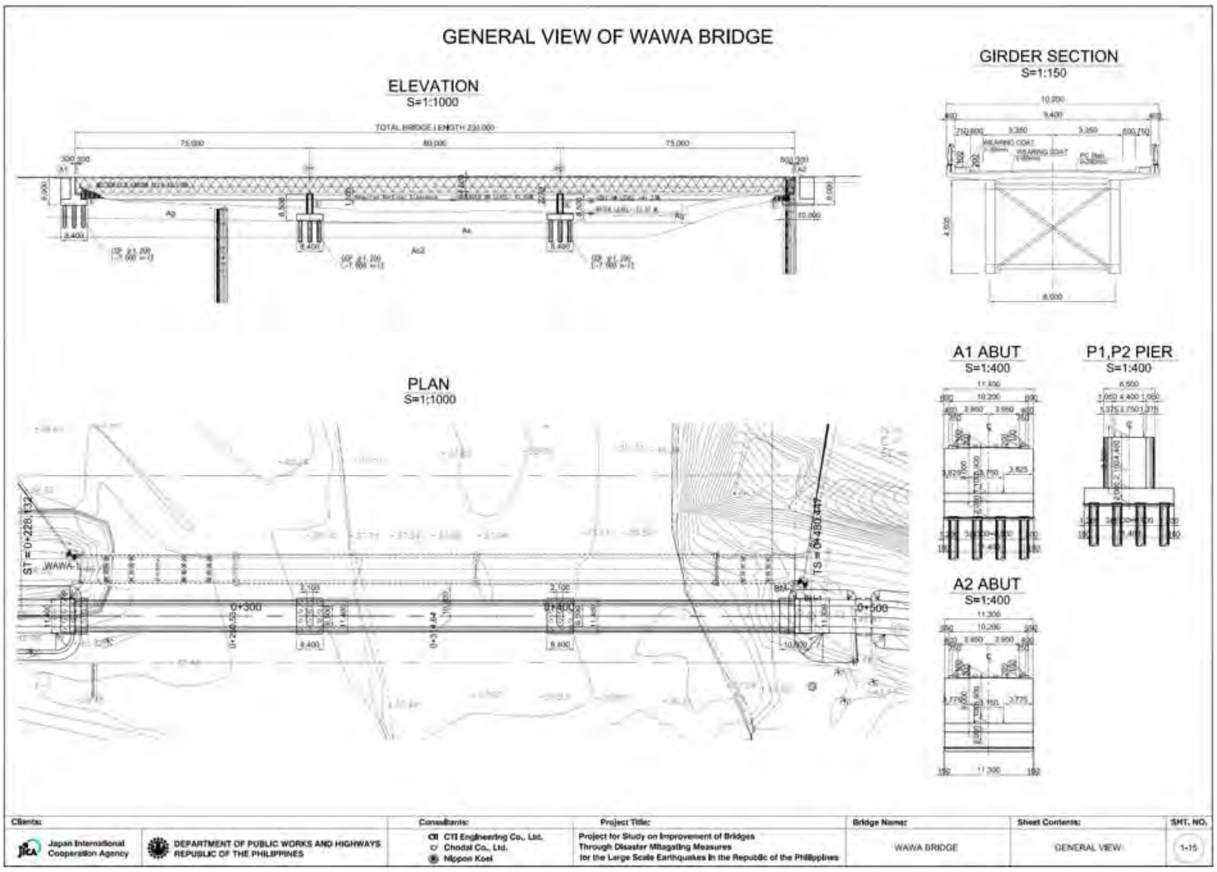


Figure ES-16-10 General Drawing of Wawa Bridge

Figure ES-16-11 Perspective View of Wawa Bridge

CHAPTER 17 BRIDGE SEISMIC RETROFIT OUTLINE DESIGNS OF SELECTED BRIDGES

(1) Design Criteria and Conditions for Bridge Retrofit Design

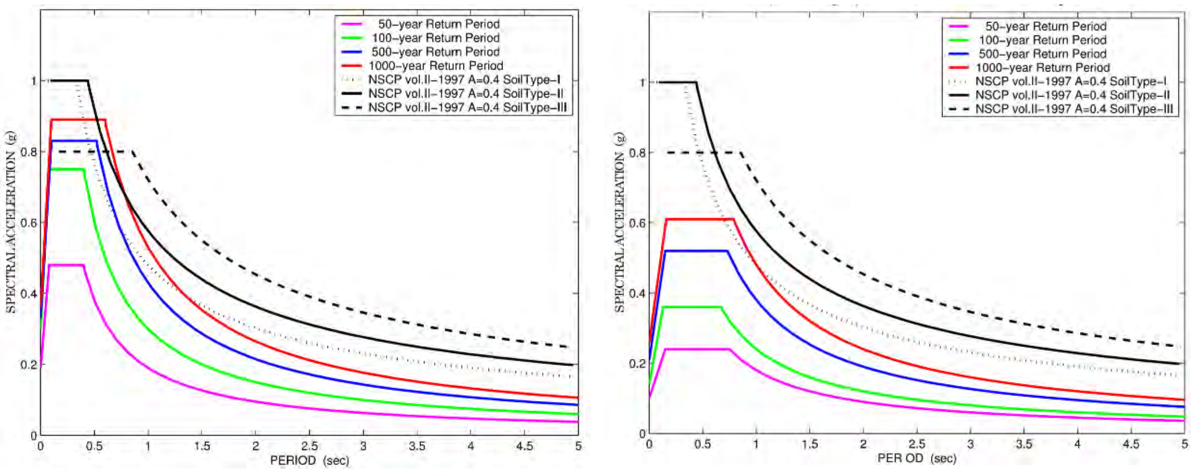
The seismic retrofit planning and design have been conducted in accordance with the provisions of the Bridge Seismic Design Specifications (BSDS) prepared in the Study.

(2) Design Spectra

The site specific design spectra with 5% dumping as evaluated in the Study and utilized for the outline design is shown in Figure ES-17-1.

(3) Summary of Outline Design of Replacement Bridge

The project outline for seismic retrofit bridge is shown in Table ES-17-1 and the general drawings of replacement bridges are shown in Figure ES-17-2 to ES-17-6.



Liloan Bridge 1st Mandaue-Mactan Bridge

Note) Level-1 earthquake: 50-year return period, Level-2 earthquake: 1000-year return period

Figure ES-17-1 Site Specific Design Spectra for Seismic Retrofit Bridge

Table ES-17-1 Project Outline for Seismic Retrofit Bridge

Bridge Name	Proposed Improvement Measures	Description
Package C		
1st Mandaue-Mactan Br.	Seismic Retrofit	**Length** Bridge: 860 m (Existing) **Seismic Retrofit** Seismic Damper, Concreting Jacket, Cast-in-Place Concrete Pile, Steel Pipe Sheet Pile Foundation and Unseating Prevention System
Liloan Br.	Seismic Retrofit	**Length** Bridge: 298 m (Existing) **Seismic Retrofit** Seismic Damper, Concreting Jacket, Cast-in-Place Concrete Pile and Unseating Prevention System

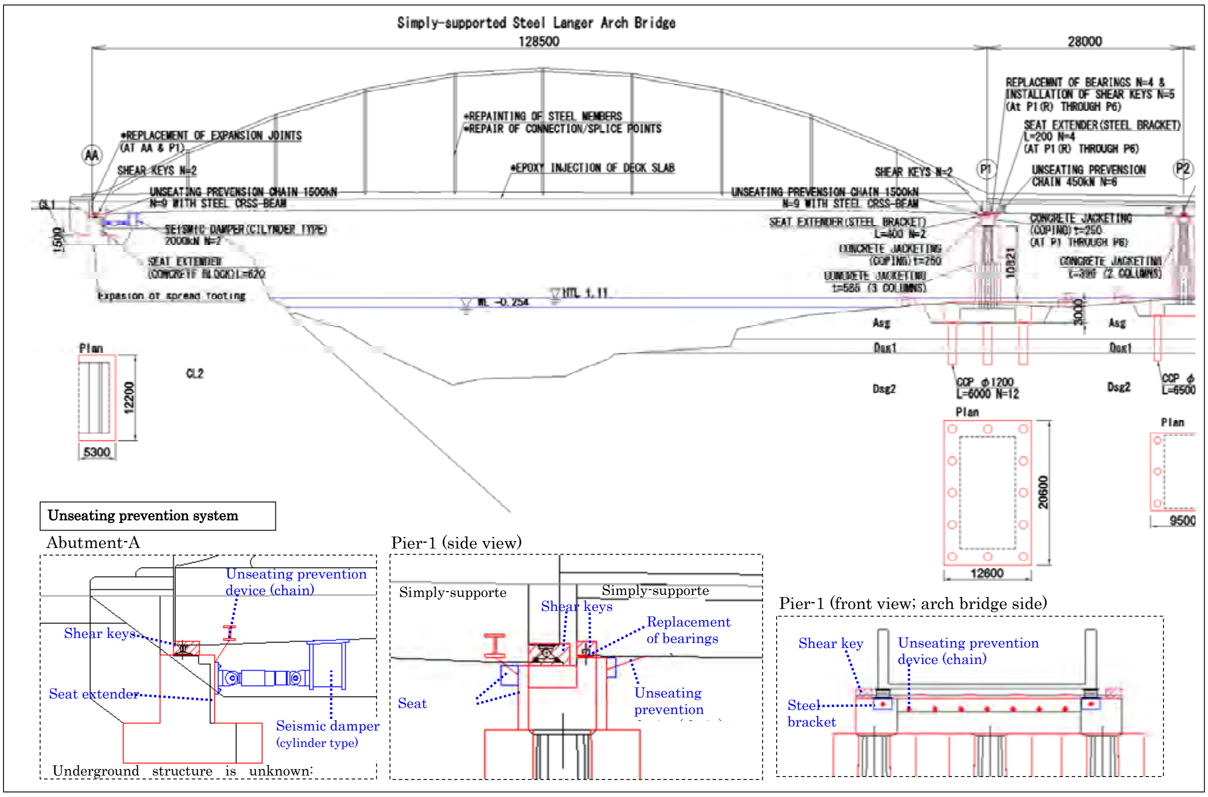


Figure ES-17-2 General Drawing of Liloan Bridge (1)

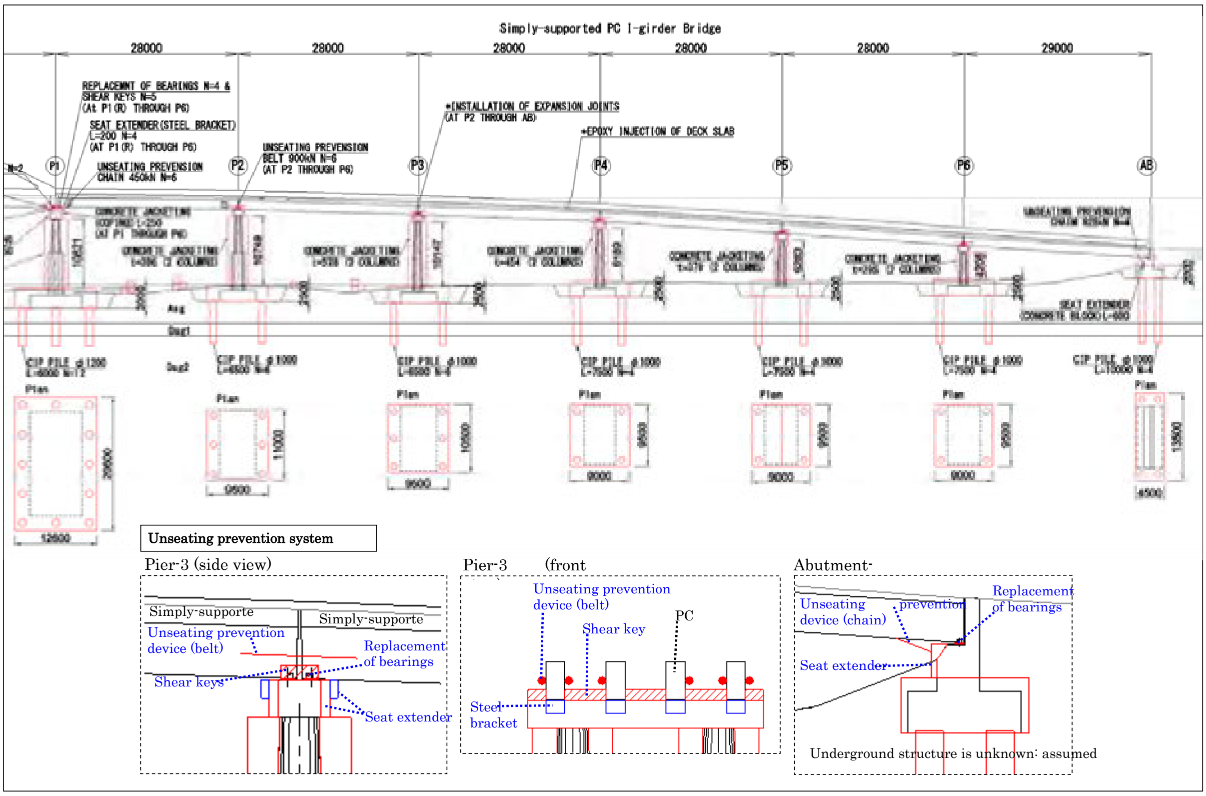


Figure ES-17-3 General Drawing of Liloan Bridge (2)

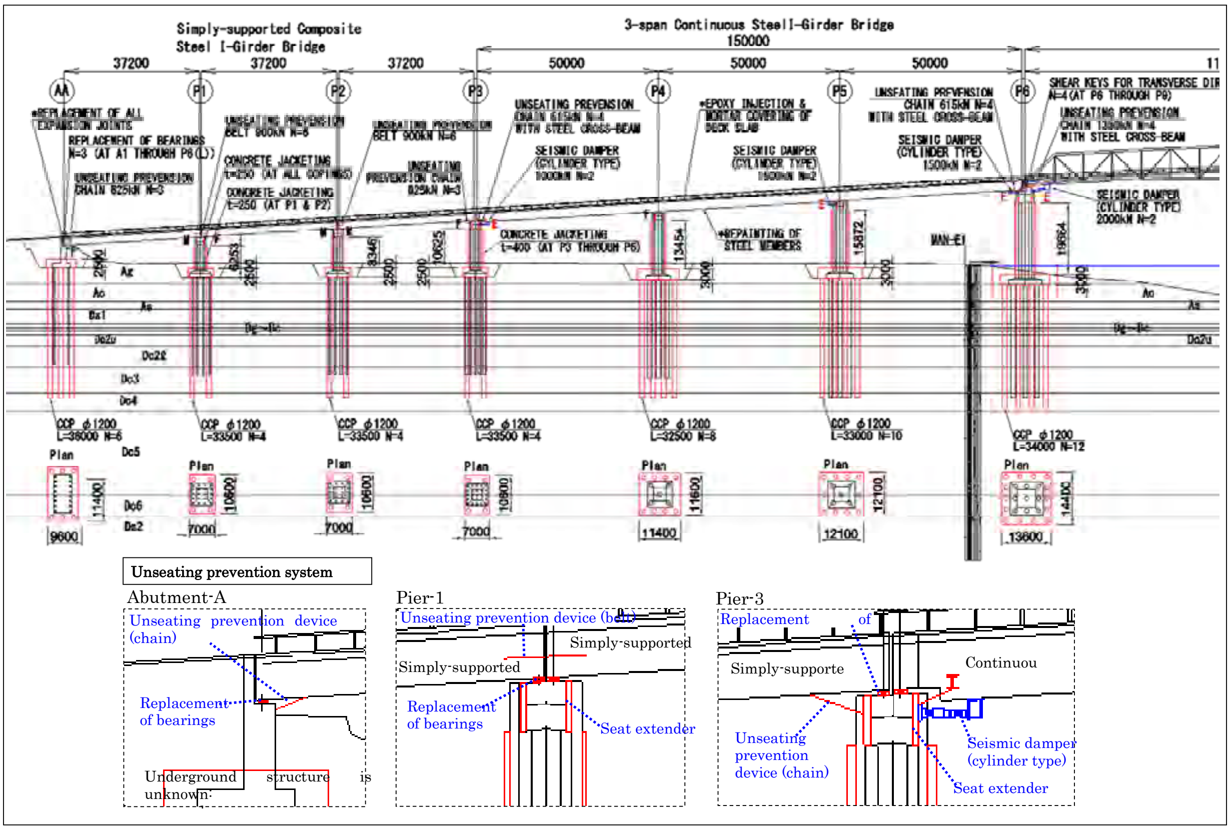


Figure ES-17-4 General Drawing of 1st Mandaue-Mactan Bridge (1)

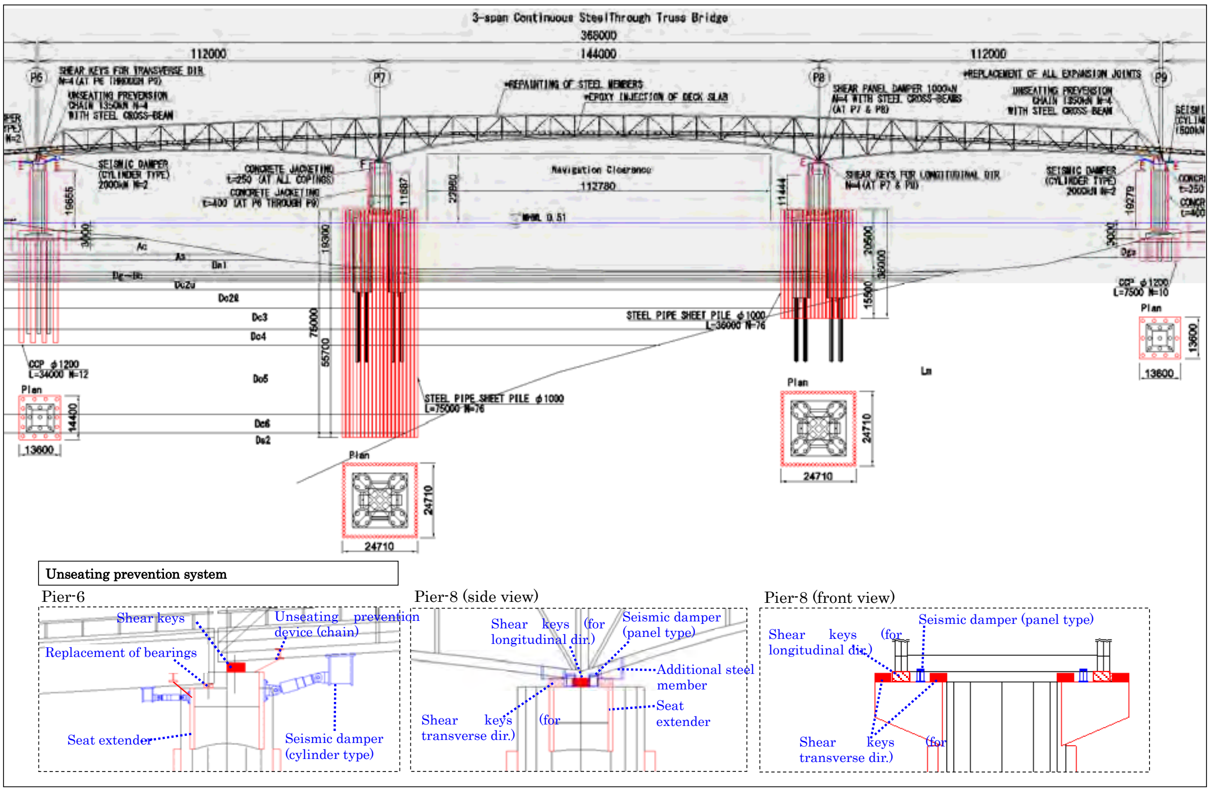


Figure ES-17-5 General Drawing of 1st Mandaue-Mactan (2)

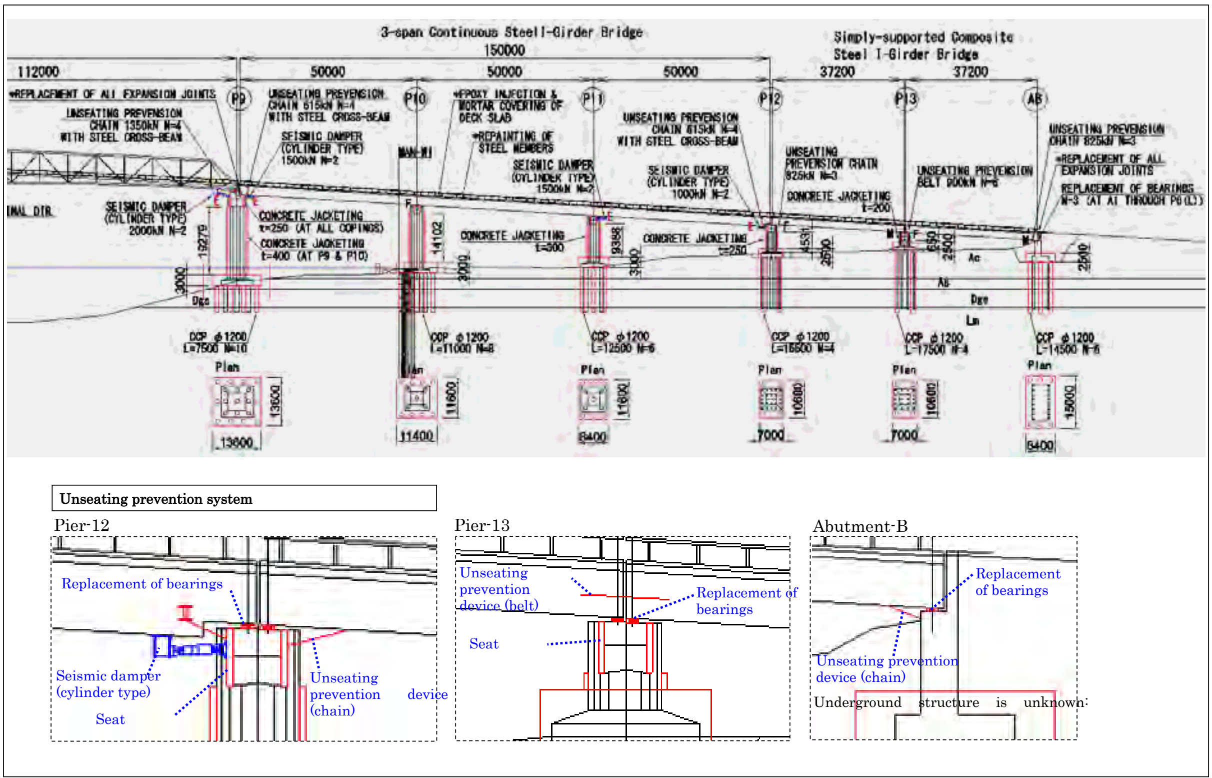


Figure ES-17-6 General Drawing of 1st Mandaue-Mactan (3)

CHAPTER 18 CONSTRUCTION PLAN AND COST ESTIMATE FOR SELECTED BRIDGES

(1) Construction Planning

1) Purpose of Construction Planning

The purpose of construction planning are as follows:

- To study the construction method of the selected bridge for replacement/retrofit planning;
- To study the traffic detour plan under minimum influence to existing traffic and environment; and
- To plan the necessary temporary structures for cost estimate.

2) Right-of-Way

The construction is to be conducted within the Right-of-Way after the resettlement of informal dwellers and removal of facilities are completed. From the result of site investigation and survey interview with the DPWH engineers, the Right-of-Way width for the target bridges is summarized as shown in Table ES-18-1.

Table ES-18-1 Width of Right-of-Way from Road Center

Bridge Name	Width of Right of Way
Lambingan	Width of Bridge
Guadalupe	Width of Bridge
1st Mandaue Mactan	30m
Palanit	30m
Mawo	30m
Liloan	30m
Wawa	60m

3) Procurement Planning

Generally, most of the construction materials and equipment will be procured in the Philippines. However, the steel materials and special equipment as shown in Table ES-18-2 are to be imported from a foreign country.

Table ES-18-2 List of Imported Items

Components		Imported Items
Steel Girder	Steel and Fabrication	- Fabricated girder
	Erection	- Skilled Labor for erection - Equipment for Slide and Block erection
PC Structure	PC steel	- Material
	Casting	- Skilled Labor
CIP Pile (Under limited space)		- Equipment and Skilled Labor
Steel Pipe Sheet Pile		- Material, Equipment and Skilled Labor
Bearing, Expansion, Unseating Prevention System		- Material (Installation cost is included in the girder erection cost)

4) Temporary Road

The temporary access road for construction and detour traffic is planned within the Right-of-Way. The drawings for temporary road is presented in the Outline Design Drawings.

5) Construction Schedule

The construction schedules are presented in Table ES-18-3 to ES-18-9.

Table ES-18-3 Construction Schedule of Lambingan Bridge

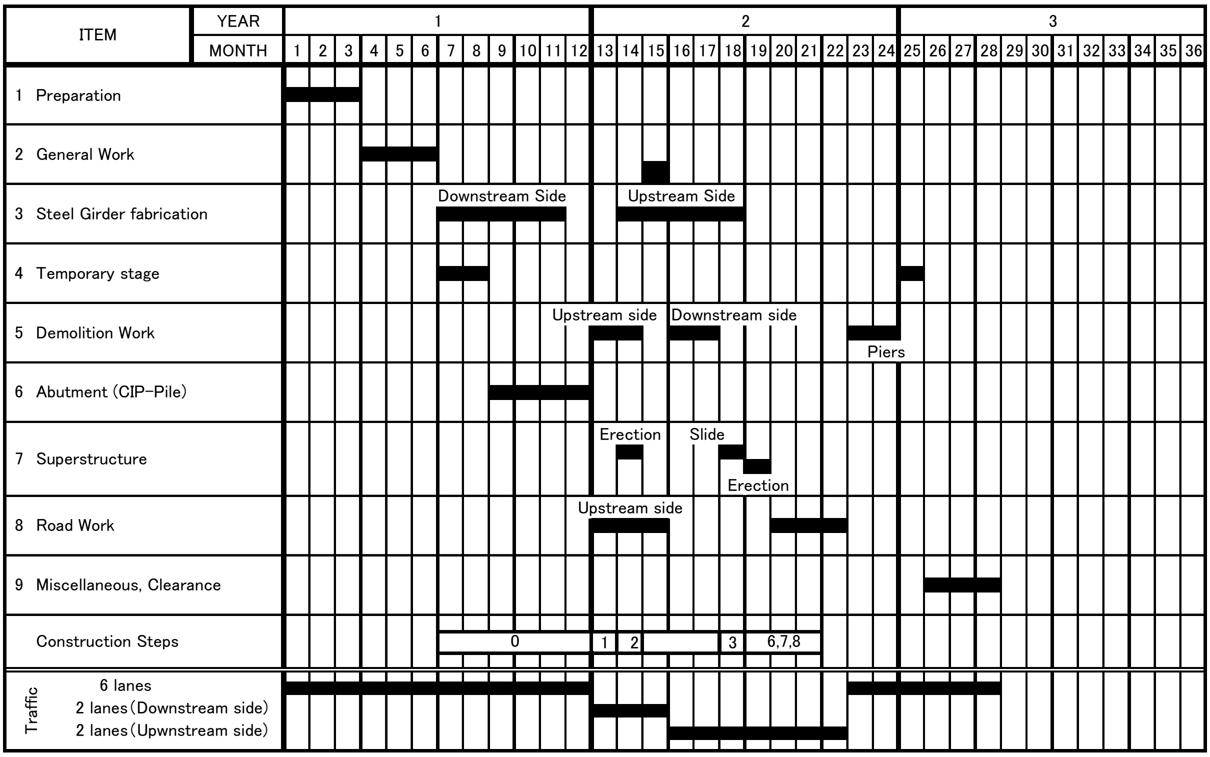


Table ES-18-4 Construction Schedule of Guadalupe Bridge

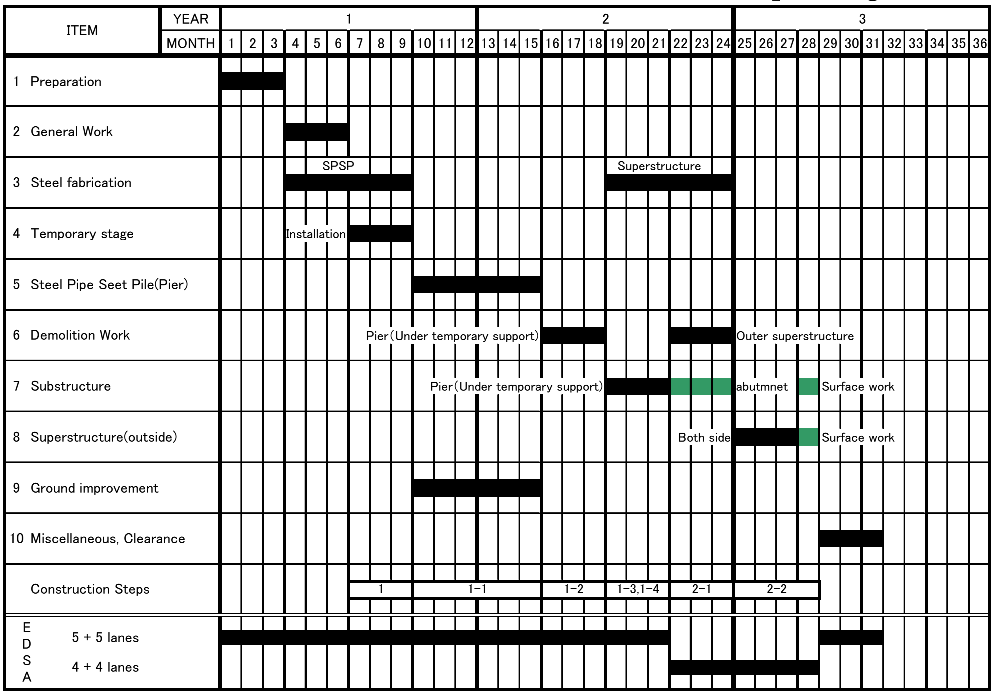


Table ES-18-5 Construction Schedule of 1st Mandaue-Mactan Bridge

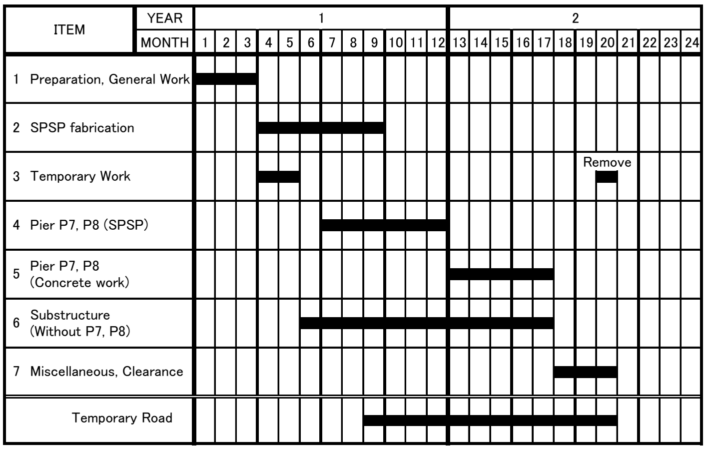


Table ES-18-6 Construction Schedule of Palanit Bridge

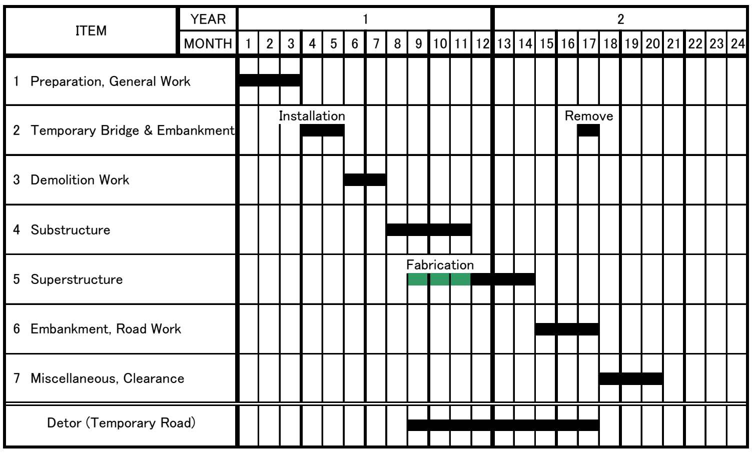


Table ES-18-7 Construction Schedule of Mawo Bridge

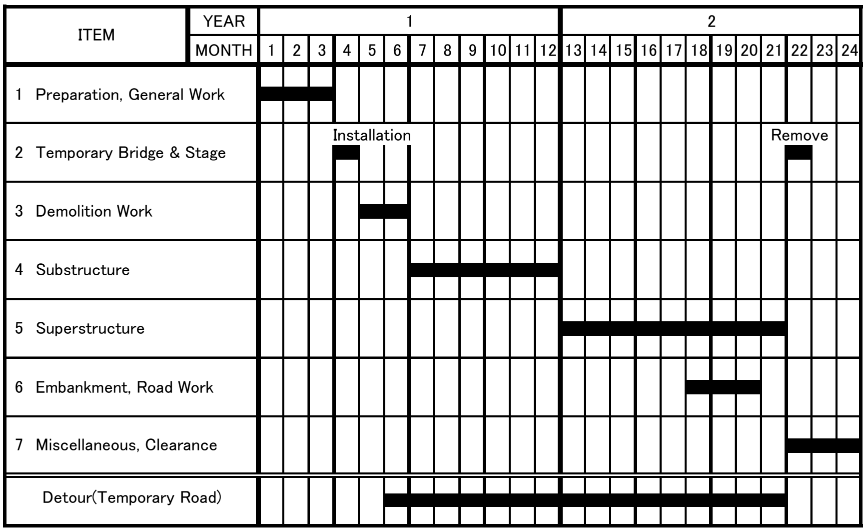


Table ES-18-8 Construction Schedule of Liloan Bridge

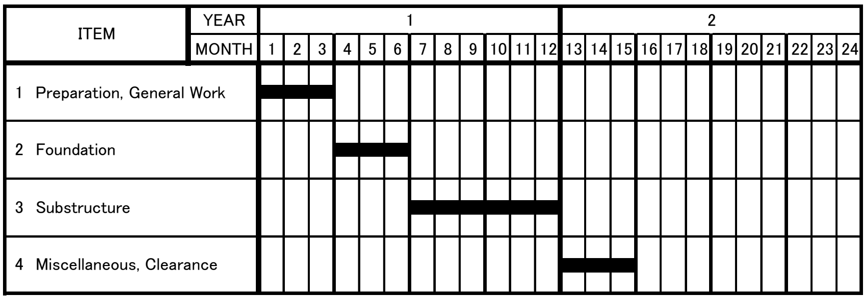
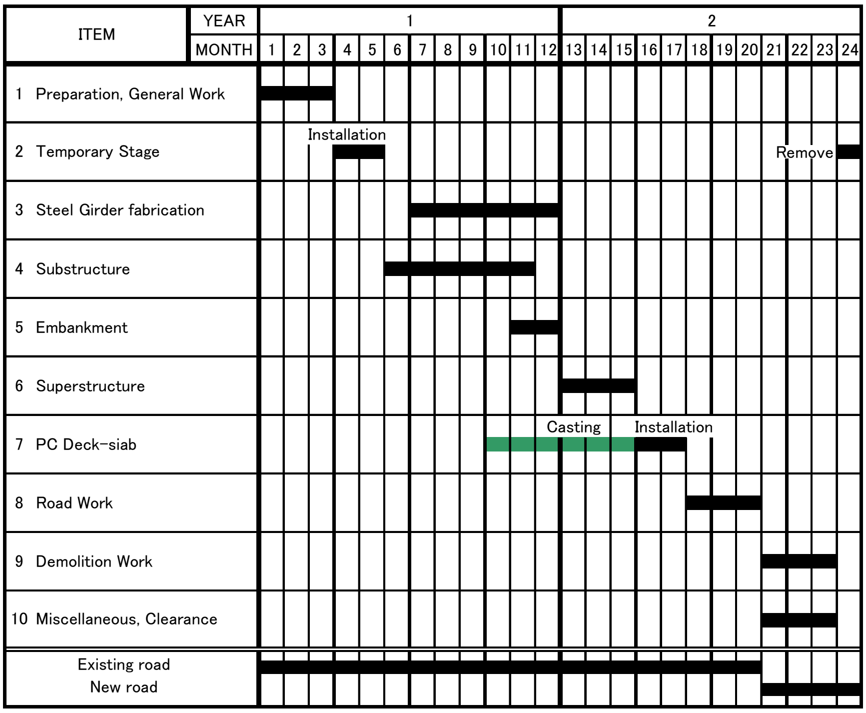


Table ES-18-9 Construction Schedule of Wawa Bridge



CHAPTER 19 TRAFFIC ANALYSIS AND ECONOMIC EVALUATION FOR SELECTED BRIDGES

This Chapter describes the traffic analyses and economic evaluation for the seven (7) bridge projects. The purpose of the traffic analysis was to estimate the traffic congestion during the bridge improvement work, and to prepare the traffic database for the evaluation of economic benefit.

(1) Traffic Analysis

The procedures of traffic analyses and economic evaluation are given in Figure ES-19-1.

Although Lambingan Bridge and Guadalupe Bridge will have reduced number of lanes during construction, traffic on the other five (5) bridges will not be affected during construction due to the installation of temporary bridges or retrofitting substructure as shown in Table ES-19-1.

(2) Economic Evaluation

The economic evaluation of bridge improvement projects has been carried out by comparing the economic cost of the project with the economic benefit that will be brought about by the bridge replacement or seismic retrofitting.

The following three indexes were used to assess project viability:

- Economic Internal Rate of Return (EIRR)
- Benefit-Cost Ratio (B/C Ratio)
- Net Present Value (NPV)

Project Sensitivity to the identified risks is shown in Table ES-19-3.

Results show that the project is able to hurdle the minimum acceptable criteria of EIRR, that is, 15%. Even if cost goes up and/or benefit goes down as shown in the following condition, the minimum criteria of 15% EIRR would still be met.

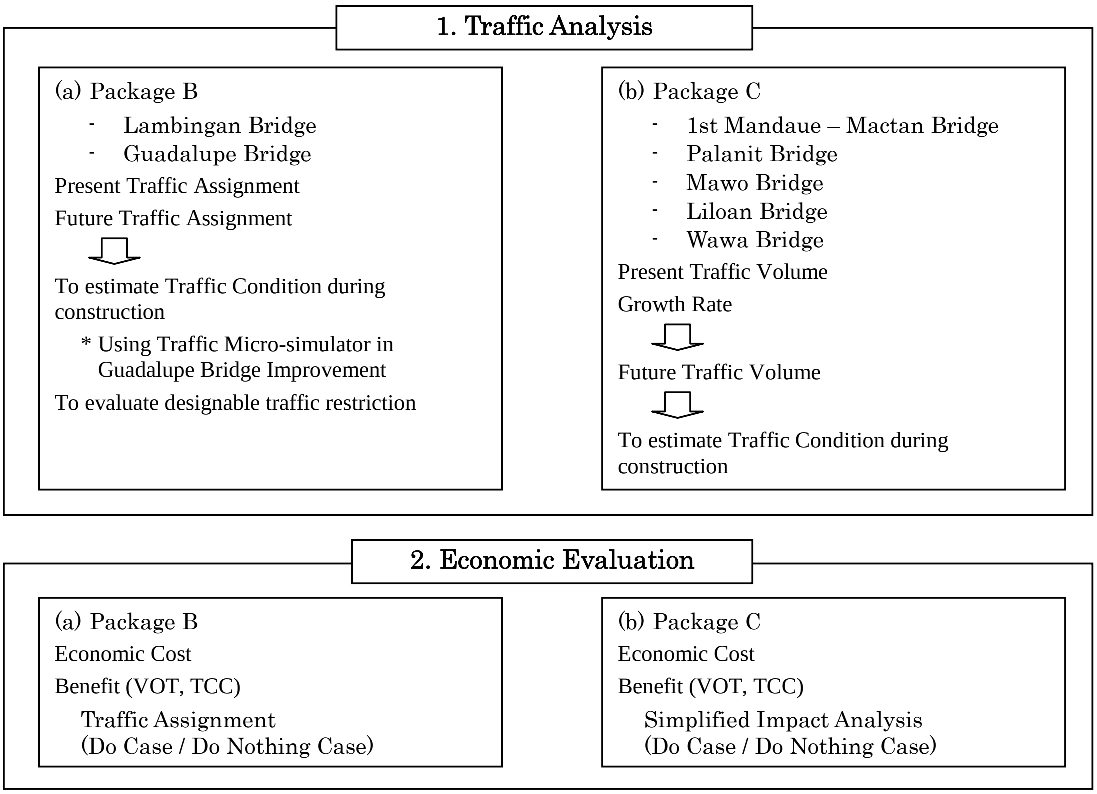


Figure ES-19-1 Procedure of Traffic Analysis and Economic Evaluation

Table ES-19-1 Basic Traffic Restriction during Construction

Item No.	Bridge	Improvement	Present No. of Lanes	No. of Lanes during Construction	Remarks
1	Lambingan	Replacement	6 (3+3)	2 (1+1)	
2	Guadalupe	Replacement of outer bridge only	10 (5+5)	9 (5+4)	
3	1st Mandaue-Mactan	Retrofit of substructure only	2 (1+1)	2 (1+1)	Traffic will not be affected during construction because of installation of temporary bridge
4	Palanit	Replacement	2 (1+1)	2 (1+1)	
5	Mawo	Replacement	2 (1+1)	2 (1+1)	
6	Liloan	Retrofit	2 (1+1)	2 (1+1)	
7	Wawa	Replacement	2 (1+1)	2 (1+1)	

Table ES-19-3 Project Sensitivity

	Base	Cost plus 10%	Cost plus 20%
Base	22.9%	21.1%	19.6%
Benefit less 10%	20.9%	19.3%	17.8%
Benefit less 20%	18.9%	17.3%	16.0%

Source: JICA Study Team

- Cost plus 60%
- Benefit less 47%
- Cost plus 23% and Benefit less 23%

CHAPTER 20 NATURAL AND SOCIAL ENVIRONMENT ASSESSMENT

Infrastructure projects including the construction of major roads and bridges (80 m<length<10 km) are not considered as Environmentally Critical Project under the Philippine Environmental Impact Statement System (PEIS). Entire project sites not located in historical, cultural and national reserves but with water bodies are technically considered to be located in Environmentally Critical Area.

Thus all replacement/retrofit bridge projects require an IEE (Initial Environmental Examination). The maximum time to grant or deny an ECC (Environmental Compliance Commitment) application for replacement/retrofit bridge projects is 60 working days. In case that PAPs (Project Affected Persons) are over 200, full RAP (Resettlement Action Plan) and procedures are required and it is also necessary to consult the JICA Advisory Committee on environmental and social considerations.

A proposed project may inevitably create various impacts on the surrounding land, air, water, biological environment and local population throughout its construction, operations and abandonment phases. Table ES-20-1 summarizes the identified environmental impacts that may be created based on the various activities for the proposed project. The sectors most affected and the significance of each impact was also evaluated to identify the issues, as follows:

- Will the identified/perceived impact generate positive/negative impacts?
- Will the identified/perceived impact cause direct/indirect effects?
- Will the identified/perceived impact cause long/short term effects?

- Will the identified/perceived impact on the surrounding environment be reversible or irreversible?

Table ES-20-1 Matrix of Proposed Project's Environmental Impacts

Activities	Aspects	Environmental Impacts	Parameter Most Affected	Significance of Impact			
				+/-	D/In	L/S	R/I
A. Construction							
Implementation of major civil and construction activities along the proposed Project and Road Right-of-Way (ROW)	Earth movement and other civil works	Generation of solid wastes	Land	-	D	S	R
		Dust propagation and migration	Air	-	D	S	
		Restriction or alteration of stream flows	Water	-	D	S	R
		Storm water run-off	Water	-	In	S	R
		Siltation and increased water turbidity	Water	-	D	S	R
		Disturbance/ displacement of flora and fauna	Flora / Fauna	-	D	S	R
		Traffic congestion	People	-	D	S	R
		Displacement of human settlements	People	-	D	L	I
	Use of heavy equipment	Ground vibration	Land	-	D	S	R
		Generation of hazardous wastes (i.e. used oil)	Land	-	D	S	R
		Increase in air emission levels	Air / People	-	D	S	R
		Increase in noise levels	Air / People	-	D	S	R
		Increased risks to occupational safety	People	-	D	S	R
	Influx of heavy equipment and construction personnel	Generation of solid wastes	Land	-	D	S	R
		Generation of wastewater	Water	-	D	S	R
		Traffic congestion	People	-	D	S	R
		Generation of employment	People	+	D	S	R
B. Operations							
Bridge operation	Bridge maintenance	Storm water run-off	Water	-	In	L	R
		Faster traffic flow	People	+	D	L	R
C. Abandonment							
Closure	Bridge demolition	Generation of solid wastes	Land	-	D	S	R
		Generation of wastewater	Water	-	D	S	R
		Traffic congestion	People	-	D	L	R

Note) (+) positive, (-) negative
(D) direct, (In) indirect
(L) long-term, (S) short-term
(R) reversible, (I) irreversible

Based on the environmental survey, the status of settlers around the project areas is as summarized in Table ES-20-2.

Table ES-20-2 Status of Settlers around Candidate Bridges (Packages B and C)

Name of Bridge	Along Approach and Crossing Road	Under Bridge
Package B		
Lambingan	Many legal and illegal houses, factory and vendors exist. Also, many informal houses were confirmed to exist immediately beneath the bridge. There is a water pipe adjacent to the bridge.	(Right side) There is one house with 5 PAPs outside of the new dike wall.
Guadalupe	(North side) Many houses and business establishments exist along the sidewalks and immediately beneath the bridge. (South side) Both sides of the road are used as parking lot.	(North side) There are 12 units of informal houses and some stores with 27 PAPs.
Package C		
1 st Mandaue-Mactan	(North side) Many houses and stores exist around the bridge.	There are 189 houses and 733 PAPs.
Mawo	There are many houses immediately beside the bridge (within the ROW, that is, 10 meters on each side from the center of the road).	(North side) The space beneath the bridge is used as shed for boats. Within the ROW (=20m), there are two informal settler families. Number of people is 12. (South side) The space beneath the bridge is used for breeding of domestic animals such as fighting cocks and pigs and for drying of washed clothes, etc.. There is no house within the ROW.
Palanit	There are many houses immediately beside the Bridge (within the ROW, that is, 10 meters on each side from the center of the road). Water pipe is held by the bridge.	(North side) The space beneath the bridge is used as shed for fishing tools. There are 7 PAPs within the ROW (=20m).
Liloan	There is no house along the road near the bridge.	(South side) The space beneath the bridge nearby the street is used for basket court. There are two vendors under the Bridge. Some parts under the Bridge are used for orchard, block storage site, chicken house, waste collection point and dock for boat.
Wawa	(North side) Some thatch houses exist along the road. Some PAPs will be affected in case of replacement of the approach road between the existing bridge and the dam structure.	(South side) There is no structure under the Bridge.

PART 5: PROJECT IMPLEMENTATION AND RECOMMENDATIONS

CHAPTER 21 PROJECT IMPLEMENTATION

(1) Project Outline

The priority ranking and improvement measures of the target bridges have been studied as the results of the evaluation of conditions of existing bridges through the first and second screening. Based on the studies, the outline design of two (2) bridges from Package B and five (5) bridges from Package C were conducted including the recommendable improvement measures, as shown in Chapter 16 and Chapter 17. The project in Metro Manila is to be implemented under severe urban environment such as construction work at traffic congested area and narrow working space, so that works to minimize traffic disturbance, as well as safety of construction, are absolutely necessary.

Most Japanese contractors have enough experience and technology to cope with such severe conditions in densely urbanized areas. Moreover, the project needs special technology for bridge seismic improvements. Thus, the project can be one of the model projects in which Japanese contractors can exercise their technology in the following fields:

1) Seismic Retrofitting of Bridge Pier
2) Installation of Unseating/Fall-down Prevention System
3) Seismic Retrofitting of Foundation
4) Ground Improvement against Liquefaction
5) Base Isolation / Menshin Technology
6) Neighboring / Proximity Construction Technology
7) Rapid Construction Technology

(2) Project Cost

The estimated Project Cost with the base year of 2013 is shown in Chapter 18.

(3) Implementation Schedule

The proposed implementation schedule is shown in Table ES-21-1.

Table ES-21-1 Proposed Implementation Schedule

	2014	2015	2016	2017	2018	2019	2020	2021
ECC (Environmental Compliance Certificate)	X							
NEDA-ICC (NEDA Board, Investment Coordination Committees)	X							
Appraisal Mission	X							
Detailed Design and Tender Assistance		Selection 12 month						
Tendering				15 month				
Construction					32 month			
Operation & Maintenance								Jan. 2021

(4) Project Organization

The project implementing agency is the DPWH and the project implementing office is the Project Management Office (PMO) of DPWH. The proposed project organization is shown in Figure ES-21-1.

(5) Financial Analysis and Funding

The economic evaluation of bridge improvement projects was carried out by comparing the economic cost of the project with the economic benefit that will be brought about by the bridge replacement/retrofitting. The following three indexes were used to assess project viability:

Economic Internal Rate of Return (EIRR)

Benefit Cost Ratio (B/C Ratio)

Net Present Value (NPV)

The results of economic evaluation of bridges are shown in Chapter 19. All bridges were evaluated as economically feasible.

CHAPTER 22 RECOMMENDATIONS

(1) Proposed Bridge Seismic Design Specifications (BSDS)

The major points of the proposed BSDS that is different from the current bridge seismic design specifications are as follows.

(A) Establishment of Seismic Performance Requirements

- Seismic performance requirements and bridge operational classification were established, which is to be for the first time in the Philippines.

(B) Localized Seismic Hazard Maps

- Distribution of active faults and ocean trenches in the Philippines were reflected in the seismic hazard maps which are shown as design seismic ground acceleration and response spectral acceleration coefficient contour maps by region at the surface of soil type B specified in AASHTO, which is likewise for the first time in the Philippines.
- The design seismic ground accelerations specified in the BSDS will be the basis for sustainable development of the bridge seismic design in the Philippines because the future data gained from new earthquake events in the Philippines can be reflected into the specifications following the process done in this study.

(C) Adoption of Latest Design Method

- The Load and Resistance Factor Design (LRFD) method was employed following AASHTO 2012 version as the base specifications, including change in design earthquake return period from 500 years to 1,000 years.

(D) Introduction of JRA Falling Down Prevention System

- The JRA falling down prevention system was introduced, considering similarity of ground conditions between the Philippines and Japan.
- Components of the system are: (a) design method on effects of seismically unstable ground, (b) unseating prevention system, and (c) requirements for seismically isolated bridges.

(E) Other Major Points

- Ground types for seismic design were classified into three types based on the JRA methods, which can be identified with the Characteristic Value of Ground (TG(s)) which are to be calculated with N-values.
- Effects and extent of liquefaction were reflected in the foundation design.

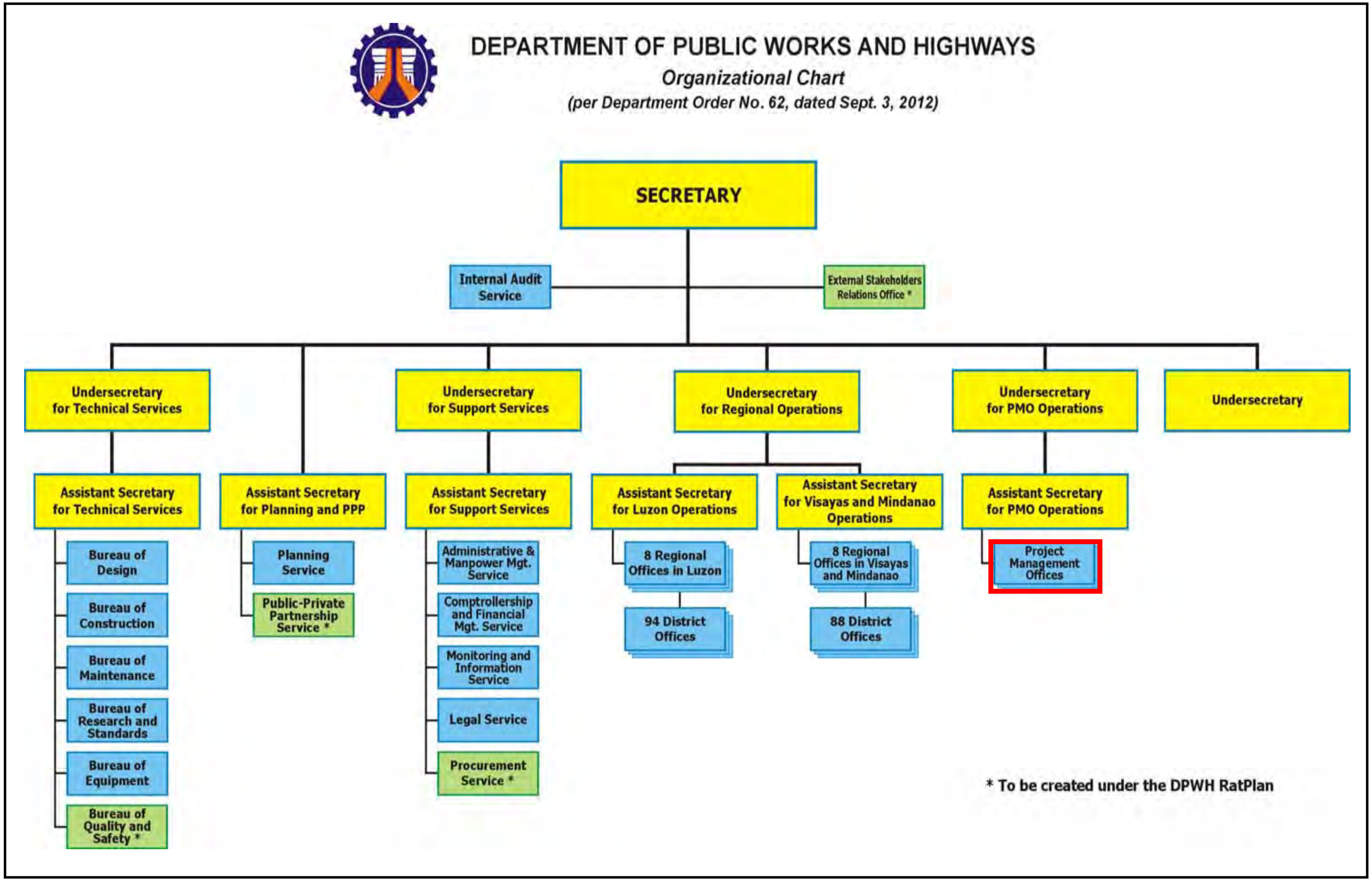


Figure ES-21-1 Organizational Structure of Proposed Projects

In this study, a seismic design manual and two seismic design examples were prepared to deepen the understanding and prevent misunderstanding of the proposed BSDS. The following six (6) actions are recommended for DPWH in order to make the proposed BSDS effective and useful, leading to mitigation of disasters caused by large scale earthquakes.

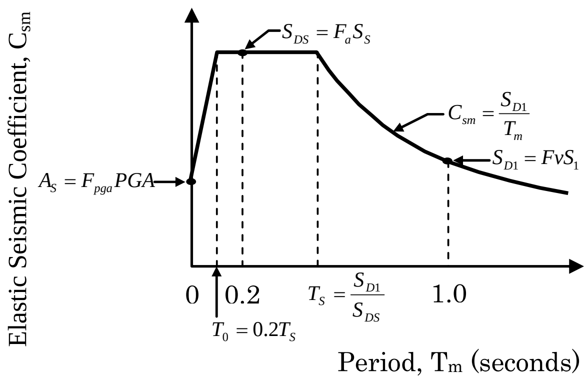
(i) Since the major points of Items (A), (B) and (C) above largely affect the scale of bridge substructures including foundations, the DPWH should make careful trial design and accumulate design experiences from the various angles so as to avoid sudden large change in the scale of bridge substructures including foundations compared to the one designed by the current seismic design procedures. When determining the acceleration response spectra acting on the structure as seismic forces, administrative judgment sometimes is required considering uncertainties of the analysis results without referring to actual recorded ground motion data and the country's budgetary capacity.

Figure ES-22-1 shows recommendation on the acceleration response spectra at present for Level-2 earthquake, which recommends setting the upper and lower limits for PGA considering the present situations of experience and the progress of technology and research in this field.

Future Issue ← | Recommended Range of PGA for Level-2 Earthquake (PGA = 0.20 to 0.60) | → Future Issue

As and S_{DS} corresponding to PGA

PGA (Soil Type B)		PGA= 0.10	S_{DS}/As	PGA= 0.20	S_{DS}/As	PGA= 0.30	S_{DS}/As	PGA= 0.40	S_{DS}/As	PGA= 0.50	S_{DS}/As	PGA= 0.60	S_{DS}/As	PGA= 0.80	S_{DS}/As
Reference (Soil Type B)	**Fpga(=Fa)**	1.00		1.00		1.00		1.00		1.00		1.00		1.00	
	As(Fpga*PGA)	0.10	2.50	0.20	2.50	0.30	2.50	0.40	2.50	0.50	2.50	0.60	2.50	0.80	2.50
	S_{DS}(Fa*Ss)	0.25		0.50		0.75		1.00		1.25		1.50		2.00	
Soil Type I (C)	**Fpga(=Fa)**	1.20		1.20		1.10		1.00		1.00		1.00		1.00	
	As(Fpga*PGA)	0.12	2.50	0.24	2.50	0.33	2.50	0.40	2.50	0.50	2.50	0.60	2.50	0.80	2.50
	S_{DS}(Fa*Ss)	0.30		0.60		0.83		1.00		1.25		1.50		2.00	
Soil Type II (D)	**Fpga(=Fa)**	1.60		1.40		1.20		1.00		0.90		0.89		0.88	
	As(Fpga*PGA)	0.16	2.50	0.28	2.50	0.36	2.50	0.40	2.50	0.45	2.51	0.54	2.50	0.70	2.50
	S_{DS}(Fa*Ss)	0.40		0.70		0.90		1.00		1.13		1.35		1.75	
Type III (E, F)	**Fpga(=Fa)**	2.50		1.70		1.20		0.90		0.80		0.77		0.75	
	As(Fpga*PGA)	0.25	2.50	0.34	2.50	0.36	2.50	0.36	2.50	0.40	2.50	0.47	2.51	0.60	2.50
	S_{DS}(Fa*Ss)	0.63		0.85		0.90		0.90		1.00		1.18		1.50	



Future Issues*):
Upper and lower limits will be expanded based on the future experience, development of technology and research in this field including recommended As and S_{DS} corresponding to each PGA.
Regarding Fv corresponding to the above, please refer to this report.

Minimum PGA=0.2 is recommended only for Palawan and Sulu islands, for the other areas 0.3 is recommended as a minimum PGA taking account of the 2013 Bohol Earthquake.

Figure ES-22-1 Recommendation on Acceleration Response Spectra

(ii) Major points of Items (B), (D) and (E) above should be authorized immediately after submission of this final report because they are directly linked with the safety of bridges during earthquakes. DPWH does not need to fix, at present, the return periods in the major point

Item (B) for the seismic design. It is better to improve the proposed BSDS through the above trial design, which means that transition period is to be required.

(iii) Through the above process, the proposed BSDS should be totally authorized as soon as possible, and the DPWH should take actions to disseminate the authorized BSDS nationwide in order to firmly make it rooted in bridge seismic design practice.

(iv) The Standard design procedure and the standard design drawings should be revised based on the new BSDS.

In addition to the above, action (V) and (Vi) below is recommended to be taken.

(v) With data on the new fault of the 2013 Bohol Earthquake, seismic hazard maps are recommended to be verified and updated.

(vi) The BSDS categorizes bridges according to its operational class, which is a function of the bridge importance. In this regards, it is recommended that DPWH-BOD coordinates with the Planning Service division in order to designate the bridge operational classification according to the road function especially roads belonging to the regional disaster prevention routes.

(vii) Since the current design practice in AASHTO has been shifting from the force-based R factor design approach to the displacement-based design approach, it is recommended for DPWH to consider the displacement-based design approach in the future so that design engineers could easily imagine and judge the behavior of the structures' displacement according to the scales of the seismic design lateral forces. It should be noted that the BSDS is based on the current design procedure being employed by the DPWH.

With respect to the activities or items shown in Table ES-22-1, further supports seem to be needed as a transition period so as to make the outcome of this study meaningful and sustainable.

Table ES-22-1 Transition Period Recommended for Sustainable Development

	1st Year	2nd Year
(1) Trial Design/Accumulation of Design Experience	Design Trial and Accumulation Stage ↔	Finalizing Stage ↔
(2) Capacity Development	Repeated Training and Holding Seminar ↔	↔
(3) Implementation of a Pilot Project	Target Bridge Selection and Detailed Design ↔	Implementation →
(4) Preparation of New Standard Design Procedure and Drawings		Preparation ↔
(5) Preparation of Bridge Retrofit Manual	Preparation ↔	
(6) Inter Agency Committee Meeting*	★ ★ ★	★ ★
Remarks	* Inter Agency Committee Meeting (IACM) consists of DPWH, PHILVOCS, ASEP, UP, Geological Society, under which working group will be needed to maintain close coordination.	

(2) Implementation of the Project for Seismic Strengthening of Bridge Recommended in the Study

(a) Urgency of Project Implementation

Seismic resistance capacities of seven (7) bridges out of 33 subject bridges are recommended to be strengthened urgently after conducting the various careful investigation and study in this project. Among them, Lambingan Bridge and the outer section of Guadalupe Bridges are strongly recommended to be replaced immediately in terms of not only seismic safety but also the superstructures' safety against traffic loads considering their importance. Though both bridges are located on the soft ground having high potential of liquefaction, nobody knows the foundation types and conditions of both bridges including whether the foundations are being placed in the stable bearing layers. If Guadalupe Bridge collapses similar to the bridges which collapsed mainly due to liquefaction by the 2013 Bohol Earthquake, the 2012 Negros Earthquake and the 1990 North Luzon Earthquake, its impact on the Philippine economy and the human lives cannot be imagined which may lead to devastation.

Properly designed and constructed new Lambingan Bridge and Guadalupe Bridges will have reliable resistance capacity against expected large earthquakes, which will perform as if they were the "Savior Bridges" because the real seismic resistance capacities of the other old bridges crossing over the Pasig and Marikina Rivers against expected large earthquakes are unknown.

The other five (5) bridges of Package C, of which three (3) bridges are to be replaced and two (2) bridges are to be retrofitted, are all vulnerable to large scale earthquakes and recommended to be implemented according to the implementation schedule of this report at appropriate timing, considering their importance.

(b) Utilization of Japanese Technology for Project Implementation

Seismic resistance improvements of bridges require experience and special technology for design and construction. Therefore, it is recommended that this project be a model project for Philippine seismic performance improvement of bridges utilizing Japan's rich technology in the area of:

- Seismic Retrofitting of Bridge Piers.

- Installation of Unseating/Fall-down Prevention System.

- Seismic Retrofitting of Foundation

- Improvement of soil layers with liquefaction potential.
- Base Isolation/ Menshin Technology.
- Construction Technology under limited space or constrained working conditions / very near by existing Structures).

- Rapid Construction Technology.

(3) Importance of Construction Quality and Proper Maintenance Activities

Seismic resistance capacity of structures will not be governed only by appropriate seismic design but also by the construction quality. Proper maintenance activities, on the other hand, are also essential to maintain the quality of the constructed structures having appropriate seismic resistance capacity. It is recommended that the DPWH take proper care to construct structures with high quality and maintain their quality through proper maintenance activities.

(4) Recommendation of Improvement Project for Traffic Conditions in Traffic Intermodal Area through Guadalupe Bridge Seismic Strengthening Project

Makati side of Guadalupe Bridge is the intermodal area connecting such public transport as MRT, buses, taxies and Jeepneys, the situation of which has been giving rise to traffic confusion involving their passengers' and customers' movement using the public market located near by the area. By making the most of the opportunity of the Guadalupe Bridge seismic strengthening works, solving the traffic situation above is strongly recommended, because there is no room but the bridge section for widening and improving the area.

Improvement Level 3 is recommended for solving traffic confusion and improving environmental circumstances in and around traffic intermodal area by utilizing the opportunity of seismic strengthening project. Figure ES-22-2. shows the recommended scheme.

The Level 3 plan includes as follow plans.

- Bridge seismic strengthening
- Improvement of traffic conditions on ramps
- Providing New Bus Stops
- Development of Traffic Intermodal Facilities

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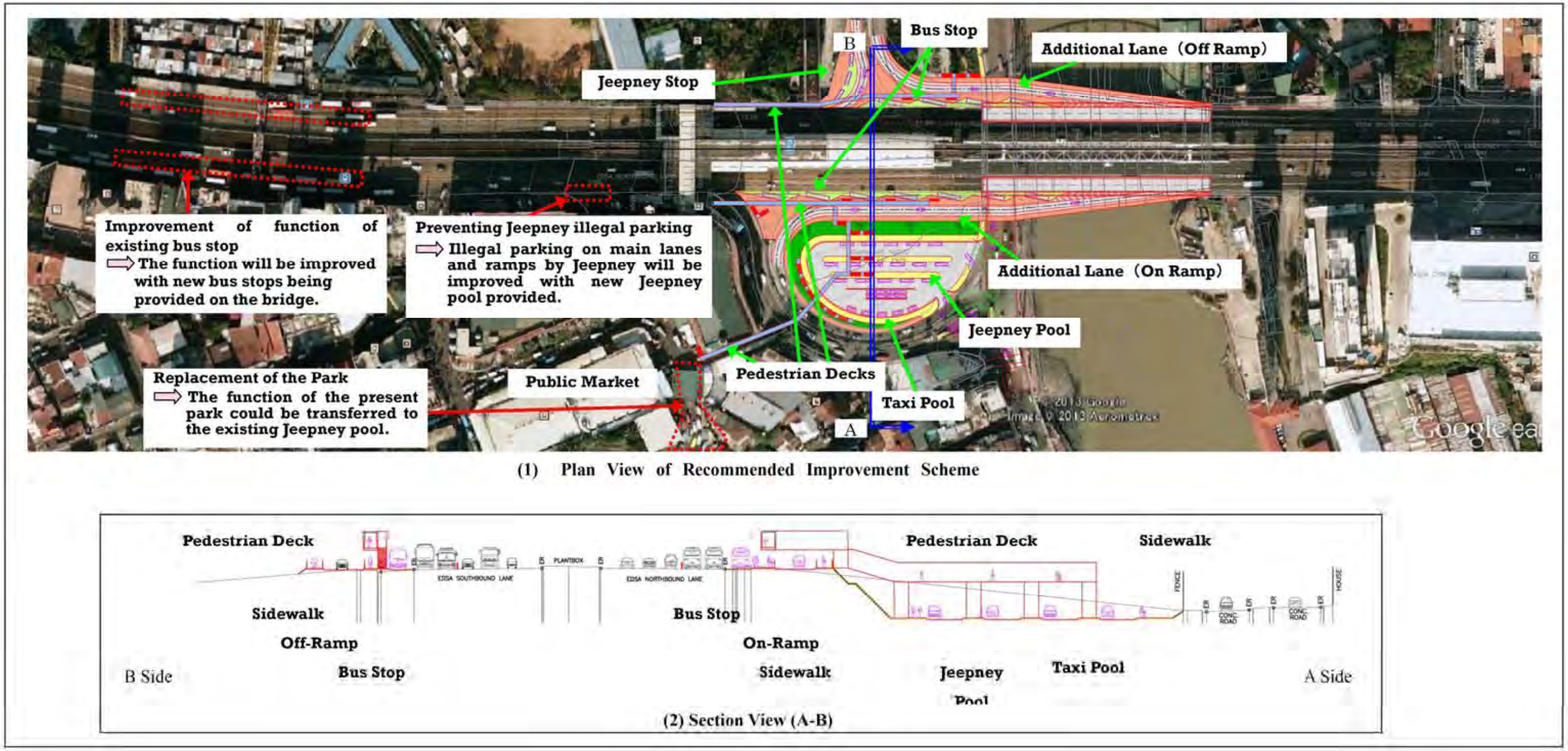

Figure ES-22-2 Recommended Improvement Scheme in and around Traffic Intermodal Area near Guadalupe Bridge

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