Ministry of Works and Human Settlement
Department of Roads
The Kingdom of Bhutan

No.

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR
RECONSTRUCTION OF BRIDGES (PHASE III)
IN
THE KINGDOM OF BHUTAN

NOVEMBER 2008

JAPAN INTERNATIONAL COOPERATION AGENCY

CONSTRUCTION PROJECT CONSULTANTS, INC.

CHODAI CO., LTD.

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PREFACE

In response to a request from the Government of the Kingdom of Bhutan, the Government of Japan decided to conduct a basic design study on the Project for Reconstruction of Bridges (Phase III) and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bhutan a study team from April 15 to May 27, 2008.

The team held discussions with the officials concerned of the Government of Bhutan, and conducted a field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Bhutan in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Bhutan for their close cooperation extended to the teams.

November 2008

Eiji Hashimoto
Vice-President
Japan International Cooperation Agency

November 2008

LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the Project for Reconstruction of Bridges (Phase III) in the Kingdom of Bhutan.

This study was conducted by the Consortium of Construction Project Consultants, Inc. and Chodai Co., Ltd., under a contract to JICA, during the period from March, 2008 to November, 2008. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation of Bhutan and formulated the most appropriate basic design for the project under Japan's Grant Aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Jiro Koyama
Project manager,
Basic design study team on the Project for Reconstruction of Bridges (Phase III) in the Kingdom of Bhutan
The Consortium of Construction Project Consultants, Inc. and Chodai Co., Ltd.

SUMMARY

SUMMARY

(1) Country Profile

The total population of the Kingdom of Bhutan (hereinafter referred to as "Bhutan") is 635,000 and most of its total land area 46,500km^2 is mountainous. Some of its rivers begin their journey from the Himalaya Mountains in the north at an altitude of over 7,000m and flow down southwards for approximately 150km, forming deep canyons until they merge with the Brahmaputra River in India's Assam District. Meteorological conditions include a monsoon season with a large amount of rainfall occurring between June and September, a dry season between November and March, and the remaining months as transition periods.

Regarding the Bhutanese economy, the gross national income (GNI) per capita is $1,410 US (2006, World Bank). The recent economic growth rate is 7.8% (2006, World Bank) and an unemployment rate is relatively low at 2.5% (2004, Government of Bhutan), accordingly the social conditions remain stable. The component ratio of gross domestic product (GDP) by industry is 22% in the primary industries, 38% in the secondary industries and 40% in the tertiary industries (2006, World Bank). Distinguishing industries include agriculture (rice and wheat), and the forestry and hydro-electric power. In addition, India accounts for nearly 80% of all imports and exports so the relationship with neighboring India runs deep.

(2) Background, Details and Outline of the Requested Project

Most of the Bhutanese land is mountainous, so roads are the sole means of transportation and are the most vital as the country's infrastructure. Under such circumstances, in 2006 the Ministry of Works and Human Settlement formulated the "Road Sector Master Plan" for road development and announced its goals for road development over a 20-year period starting in 2007. Based on this, the Department of Roads from the said ministry worked out the "10th Five Year Plan". The plan states that, ① present situation of currently poor areas will be improved through raising accessibility and convenience, and ② reliability, economic efficiency, safety and amenity of the road network will be enhanced by shortening traveling times and reducing transportation cost and traffic accidents.

Of the total 4,545km of roads in Bhutan, the length of national highways is 1,556km and 99% of the highways are paved with asphalt. The road network is composed of five major routes including one route running east-west (National Highway No. 1) and four routes running north-south (National Highways No. 2 to No. 5). Although National Highways No. 2 and No. 3 are national roads in Bhutan, they were constructed by India and are presently being maintained through the Dantak Project, a bordering organization belonging to the Indian Armed Forces.

Since there are many curves along National Highway No. 5 which passes through the project site, visibility is not always good. In addition, landslides occurring during the rainy season temporarily disrupt traffic flow along the highway. Although the cross-sectional configuration has to consist of 3.5m wide carriageway with 1.5m wide shoulders on both sides, or 6.5m for the total road width, actually at many locations not two lanes but only 1.5 lanes are secured, and thus making it necessary for vehicles to slow down when passing each other. However, most portions of the route are paved by simple surface treatment.

Since many bridges are temporary Bailey bridges constructed in the 1970s and 1980s, in due consideration of the importance of reconstruction, the Royal Government of Bhutan requested to Japan the implementation of a development study of 22 bridges under the jurisdiction of the Department of Roads of the Ministry of Works and Human Settlement. The “Study on National Highway Bridge Construction in the Kingdom of Bhutan” was conducted in 1997 and 1998. In the study, since 12 of the 22 bridges were regarded to require urgent replacement, in particular five bridges which were given high priority, the “Project for Reconstruction of Bridges” was implemented and completed in 2003 as Japanese Grant Aid. The “Project for Reconstruction of Bridges (Phase II)” for three other bridges was subsequently implemented and completed in November 2007. Although Wakleyter Bridge, one of the three, reconstructed on National Highway No. 5 was replaced by a permanent steel bridge, the other 11 bridges on the highway are capable of less than 20t and thus cannot withstand large vehicles in addition to their significant damage or deterioration.

Accordingly, as the subsequent Grant Aid for the above-mentioned project, Bhutan submitted a request to Japan for reconstruction of six bridges on National Highway No. 5 in August 2006. In response to the request, the preliminary study pertaining to the Project was conducted in October 2007 for the purpose of confirming the requested components, the project site, the existing bridges and roads and implementing IEE in accordance with the JICA Environmental and Social Considerations Guidelines.

The Project aims at securing stable transportation of people and goods by reconstructing eleven bridges on the highway from temporary bridge to permanent, the following six requested bridges and also the remaining five bridges by the Bhutanese side.

- Lawakha Bridge (bridge length: 45m)
- Basochu Bridge (bridge length: 30m)
- Nyarachu Bridge (bridge length: 45m)
- Burichu Bridge (bridge length: 48m)
- Chanchey Bridge (bridge length: 54m)
- Loring Bridge (bridge length: 120m)

(Bridge lengths above are requested lengths.)

(3) Outline of Study Findings and Project Contents

The Japan International Cooperation Agency (JICA) dispatched the Basic Design Study Team to Bhutan between April 15 and May 27 in 2008. The Study Team discussed with concerned parties in the Government of Bhutan and conducted a field survey during which it confirmed the necessity and urgency of reconstruction of the requested bridges by investigating the conditions of the requested bridges and other bridges on National Highway No. 5, progress of the Punatsangchu Hydropower Construction Project and impact, the progress of procedures for environmental and social considerations, development plans in the southern areas mainly in Gelephu. After returning to Japan, based on the components shown in the following table, the project for reconstruction of bridges was established and a draft of the basic design study report was explained and discussed in Bhutan between October 2 and 9, 2008, thereby basic consent was obtained from the Government of Bhutan.

1) Design Policy

National Highway No.5, on which the proposed bridges in the Study are located, is only national highway connecting with India that Bhutan is able to manage on its own and is an important route passing through the development district along the southern plains. Of the 12 bridges along National Highway No.5, “Wakleytar Bridge” was replaced from a temporary Bailey bridge to a permanent steel Langer bridge through the Japanese Grant Aid (Project for Reconstruction of Bridges, Phase II). However, according to the findings of the Study, the 11 remaining bridges have exceeded their design life, so vehicles cannot cross safely due to 8t to 18t load limits and 3.25m width. In addition, deterioration such as damage resulting from deflection or falling rocks, wearing and corrosion of components can be observed. Although the situation is not too dangerous to the extent of complete bridge failure, if the development plan in the south continues at its current rate of progress, an increase in traffic volume, and in particular, an increase in large-sized vehicles is anticipated. Since the existing bridges could create a bottleneck against safe and stable transportation of the people and their goods, which is the project goal, the existing bridges should be rebuilt. In order to secure smooth and safe traffic flow along National Highway No. 5, the principles for the Project design are described as follows.

① Based on the findings of the field survey, since the bridge length of the proposed six bridges exceeds 30m making implementation by Bhutan difficult from viewpoints of their achievements, topographic features and procurement conditions, etc., they will be reconstructed through the Japanese Grant Aid scheme. The five other bridges will be reconstructed by the Bhutanese side in due consideration of the Bhutanese achievements.

② According to the “Road Survey & Design Manual”, on which the road standards in Bhutan are based, the width of National Highway No. 5 is 6.0m, so 6.0m will be secured as the effective road width taking drivability, safety and continuity into account.

③ In the similar manner as the Wakleytar Bridge (Phase II Project), a “Class A live load” as prescribed in the “Indian Roads Congress (IRC Standard)” will be applied in the bridge designs.

④ In due consideration of “cost reduction”, designs and an implementation plan, etc. were examined in order to display the maximum effects with minimal required cost. As the result, temporary Bailey bridges will be replaced by simple PC box girder bridges (four bridges), a simple composite steel plate girder bridge (one bridge) and a simple steel Langer bridge (one bridge).

⑤ Weathering steel will be utilized for the simple composite steel plate girder and simple steel Langer bridges in consideration of Bhutanese competency in maintenance and achievements in order to keep the burden to a minimum.

2) Description and Scale

Bridges after rebuilding are outlined in the following chart.

Table Outline of Bridges to be Rebuilt

Bridge Name	Lawakha Bridge	Basochu Bridge	Nyarachu Bridge
Bridge Type	Simple composite steel Plate girder bridge	Simple PC box girder bridge	Simple PC box girder bridge
Bridge Length	45.0m	40.0m	40.0m
Span Length	44.0m	39.0m	39.0m
Girder Depth	2.2m×3 main girders	2.2m	2.2m
Width	6.0m (2-lane)	6.0m (2-lane)	6.0m (2-lane)
Foundation	Spread foundation (A1 abutment) Caisson type pile foundation (A2 abutment、φ2.0m)	Spread foundation (A1, A2 abutment)	Spread foundation (A1, A2 abutment)
Major Materials	Steel material (SMA490, SMA400 : Weathering steel) Concrete σ_{ck}=21N/mm^2(Abutment) σ_{ck}=24N/mm^2(Caisson type pile foundation) σ_{ck}=30N/mm^2(Superstructure deck slab)	Main girder concrete (σ_{ck}=30N/mm^2) Abutment concrete (σ_{ck}=21N/mm^2)	Main girder concrete (σ_{ck}=30N/mm^2) Abutment concrete (σ_{ck}=21N/mm^2)
Superstructure Construction	Launching method using temporary vent (2 units)	Stationary scaffolding using columns ＋ flow bypassing	Stationary scaffolding using columns ＋ flow bypassing
Earth Retaining Method	Earth retaining wall for earthwork of A2 abutment using soldier piles and lagging method	Earth retaining wall for earthwork of A1 and A2 abutment using soldier piles and lagging method	Earth retaining wall for earthwork of A2 abutment using soldier piles and lagging method
Remarks	➢ Necessary to relocate the existing bridge ➢ Retaining wall for the approach road at Punatsangchu Dam and junction with the national highway are scheduled in the vicinity of A1 abutment.	➢ Well point drainage of spring water at the excavation for abutments using a submerged pump	➢ Well point drainage is jointly applied using cut-off wall by chemical injection and a submerged pump for good permeability on ground to be load bearing layer for bridge abutments ➢ Due to high road elevation of the bridge, traffic should be restricted to smooth the existing national highway.

Bridge Name	Burichu Bridge	Chanchey Bridge	Loring Bridge
Bridge Type	Simple PC box girder bridge	Simple PC box girder bridge	Simple steel Langer bridge
Bridge Length	50.0m	45.0m	70.0m
Span Length	48.9m	43.9m	68.6m
Girder Depth	2.8m	2.5m	11.0m
Width	6.0m (2-lane)	6.0m (2-lane)	6.0m (2-lane)
Foundation	Spread foundation (A1, A2 abutment)	Caisson type pile foundation （A1・A2 abutment,φ3.0m）	Spread foundation (A1 abutment) Caisson type pile foundation (A2 abutment,φ3.0m)
Major Materials	Main girder concrete (σ_{ck}=30N/mm^2) Abutment concrete (σ_{ck}=21N/mm^2)	Main girder concrete (σ_{ck}=30N/mm^2) Concrete σ_{ck}=21N/mm^2(abutment) σ_{ck}=24N/mm^2 Caisson type pile foundation, superstructure deck slab)	Steel material (SMA490, SMA 400 : Weathering steel） Concrete σ_{ck}=21N/mm^2(abutment) σ_{ck}=24N/mm^2(Caisson type pile foundation, superstructure deck slab)
Superstructure Construction	Stationary scaffolding using columns ＋ flow bypassing	Stationary scaffolding using pickets ＋ flow bypassing	Cable erection ＋ vertical hanging method
Earth Retaining Method	Earth retaining wall for earthwork of A 1 and A2 abutments using soldier piles and lagging method	Earth retaining wall for earthwork of A1 abutment using soldier piles and lagging method	Earth retaining wall for earthwork of A2 abutment using soldier piles and lagging method
Remarks	-	-	-

(4) Project Period and Estimated Project Cost

In case the Project is implemented through Japan's Grant Aid, the detailed design will take 8.0 months and the construction will take 37.5 months. The Project will be implemented in accordance with the Japan's Grant Aid scheme and the cost will be determined before concluding the Exchange of Notes (E/N) for the Project.

(5) Verifying the Relevance of the Project

The following direct and indirect effects are expected through the implementation of the Project. Approximately 120,000 residents in four districts (Wangdue Phodrang, Dagana, Tsirang and Sarpang *dzongkhags*) along National Highway No. 5 are expected to benefit.

1) Direct Effects

① The load capacity of all six bridges will increase from 18t (minimum value for the proposed six bridges) to 40t. Consequently, the weight limit of passing vehicles can be substantially eased; in particular, traffic of large-sized vehicles will be revitalized.

② The travel distance for large-sized vehicles between Gelephu, the center of the development in the south which is regarded as a priority development district in the 10th Five Year Plan and Thimphu, the capital of Bhutan, will decrease sharply.

Specifically, since the load capacity of the existing bridges along National Highway No. 5 is 18t, larger vehicles are unable to utilize the route. Accordingly, large-sized vehicles over 18t in both cities must utilize National Highway No. 2 at a distance of approximately 380km (passing through India). After the completion of the Project, since the route from Thimphu to Gelephu will be converted into approximately 260km route passing through National Highways No. 1 and No.5, the travel distance will decrease approximately by 120km and double transit across the border can be prevented.

2) Indirect Effects

① Two-way traffic on the existing bridges is impossible, so vehicles must slow down when crossing. This leads to a bottleneck for traffic. In addition, it also invites the possibility of traffic accidents since the width of the bridge section is narrower. By reconstructing the bridges, not only will load capacity increase but also road width. The drivability and safety of bridges will therefore be improved.

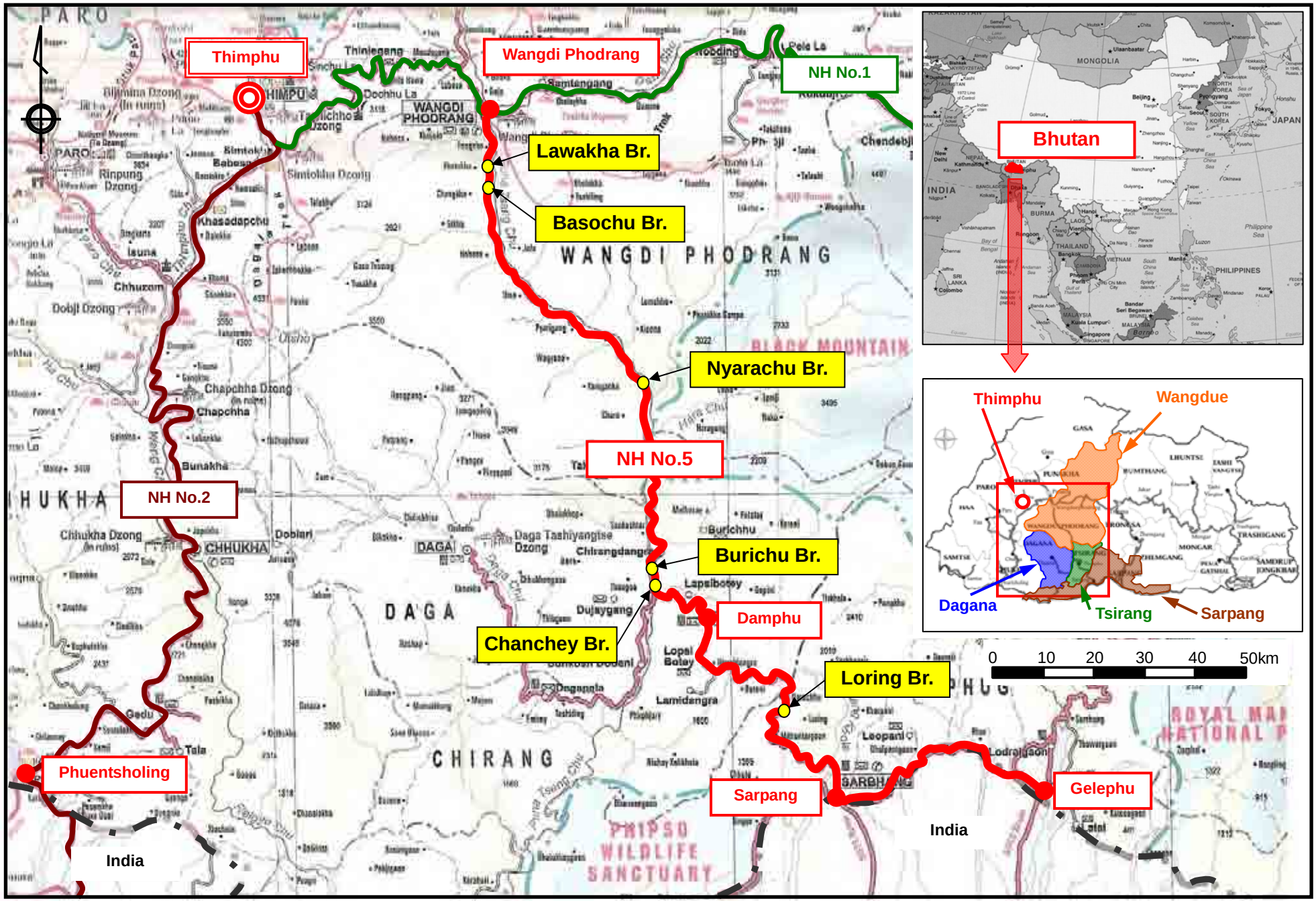
② As the project site relies on road traffic and National Highway No. 5 is the only trunk road, the improvement in drivability along National Highway No. 5 through the

rebuilding of bridges will promote the distribution of people and commodities and in turn regional economic development.

③ Since there are development programs along National Highway No. 5 and in the southern district (Punatsangchu Hydropower Station Construction Project, Industrial Estate Construction Project, New Airport Construction Project and 2nd East-West Highway Construction Project), the reconstruction of bridges will support the transportation of materials and equipment during the implementation of the Project. Therefore, this will help to support the implementation of these development projects.

From the description above, the Project is considered to be significant as a request through the Japanese Grant Aid Scheme since tremendous overall effects are expected for Bhutan and the Project will contribute considerably through improved public convenience. Moreover, in due consideration of past results, the implementing agency in Bhutan is considered to have sufficient expertise with respect to maintenance and future measures after the facilities are completed.

CONTENTS



Location Map

Perspective (1/6)　Lawakha Bridge

Perspective (2/6)　Basochu Bridge

Perspective (3/6)　Nyarachu Bridge

Perspective (4/6)　Burichu Bridge

Perspective (5/6)　Chanchey Bridge

Perspective (6/6)　Loring Bridge

LIST OF FIGURES AND TABLES

(Figures)

(Tables)

ABBREVIATIONS

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ADB	Asian Development Bank
B/D	Basic Design Study
BHU	Bhutan
Dantak	Indian Border Roads
DEC	District Environment Commission
DoE	Department of Energy, Ministry of Economic Affairs
DoR	Department of Roads, Ministry of Works and Human Settlement
EC	Environmental Clearance
ECOP	Environmental Code of Practice
EIA	Environmental Impact Assessment
F/S	Feasibility Study
GDP	Gross Domestic Product
GNHC	Gross National Happiness Commission
GNI	Gross National Income
GOI	Government of India
GPS	Global Positioning System
IEE	Initial Environmental Examination
IRC	Indian Road Congress
JICA	Japan International Cooperation Agency
JBIC	Japan Bank for International Cooperation
MoA	Ministry of Agriculture
MoEA	Ministry of Economic Affairs
MoF	Ministry of Finance
MoWHS	Ministry of Works and Human Settlement
NCD	Nature Conservation Division, Forest Department
NEC	National Environmental Commission
NGO	Non-Governmental Organization
NH	National Highway
NCL	National Land Commission
PC	Prestressed Concrete
PHPA	Punatshangchu Hydroelectric Power Authority
RC	Reinforced Concrete
ROW	Right of Way
RSPN	Royal Society of Protection Nature
TA	Technical Assistance
WB	World Bank
WWF	World Wide Fund for Nature

CHAPTER 1

BACKGROUND OF THE PROJECT

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1.1 Background of the Request for Japanese Grant Aid

Most of the land (46,500km^2) of the Kingdom of Bhutan (hereinafter referred to as "Bhutan") is mountainous, so roads are the sole means of transportation and are the most vital as the country's infrastructure. Under such circumstances, in 2006 the Ministry of Works and Human Settlement formulated the "Road Sector Master Plan" for road development and announced its goals for road development over a 20-year period starting in 2007. Based on this, the Department of Roads from the said ministry worked out the "10th Five Year Plan". The plan states that, ① present situation of currently poor areas will be improved through raising accessibility and convenience, and ② reliability, economic efficiency, safety and amenity of the road network will be enhanced by shortening traveling times and reducing transportation cost and traffic accidents.

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(Bridge lengths above are requested lengths.)

1.2 Natural Conditions

(1) Meteorological Conditions

The meteorological conditions in Bhutan include a monsoon season with a large amount of rainfall occurring between June and September, a dry season between November and March, and the remaining months as transition periods. Although this trend is similar at the proposed sites, Sarpang is close to India and has more rainfall during the rainy season than Wangdi Phodrang and Sunkosh. Since both the latitude and altitude at Wangdi Phodrang are higher than Sunkosh and Sarpang, its temperature is lower than the other two sites.

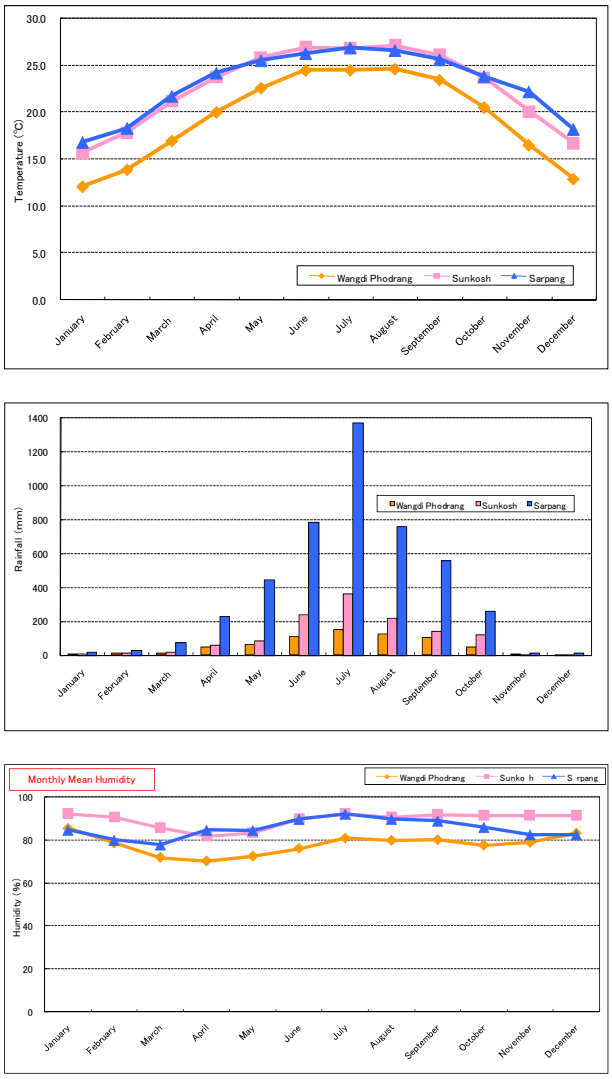
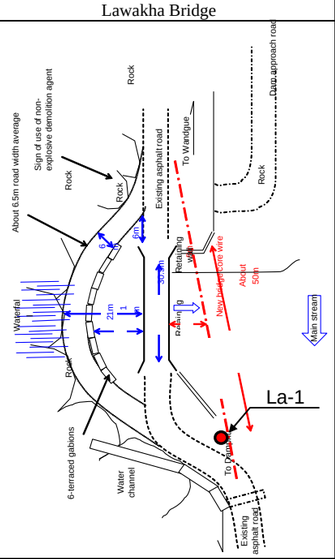
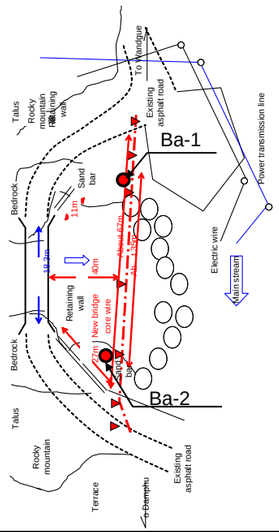
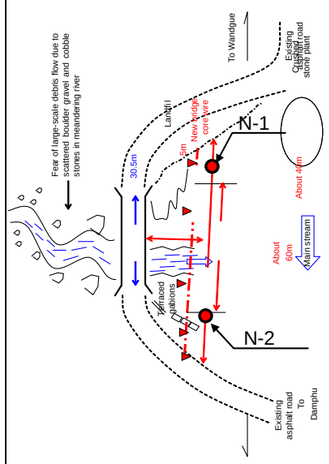
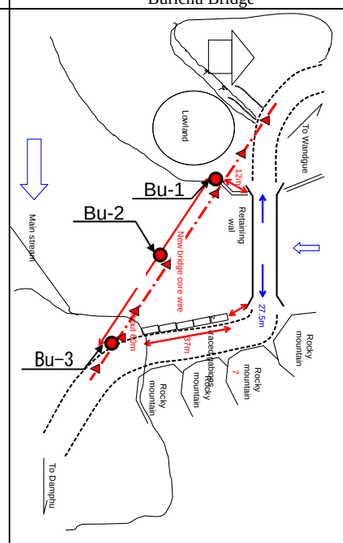
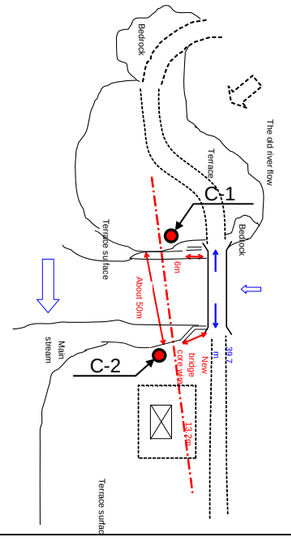
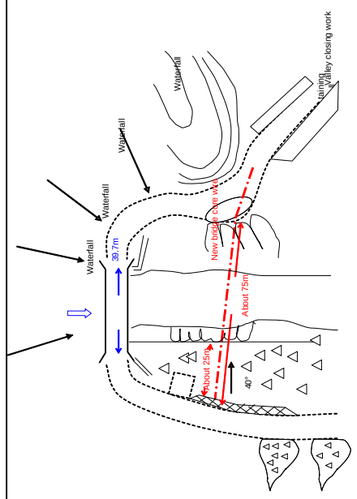


Fig. 1-1 Meteorology at Observation Sites
Source: Prepard based on the Data by Department of Energy, Ministry of Economic Affairs

(2) Topographic and Geological Features

The topographic and geological features and river grades at each bridge site are shown on the Table 1-1. In addition, the details on topographic and geological features are attached at the end of the report as reference.

Table 1-1　Topographical and Geological Features at Each Site

Site Name		Lawakha Bridge	Basochu Bridge	Nyarachu Bridge	Burichu Bridge	Chanchey Bridge	Loring Bridge
Site Sketch							
Geographic Features		Base rock is cropped out at the proposed site on the left bank side A waterfall splashes over the existing bridge during the rainy season. The left bank is covered by former talus layer.	The present abutments on both banks exist on the bedrock. A waterfall is located at the back of the bridge and 40m downstream. The proposed site is located where the flow is gentle due to sand sedimentation between the falls.	Cobbles resulting from a debris-avalanche exist on the riverbed, and also there are repetitively collapsing talus layers on both banks. In particular, collapsing on the right bank is remarkable.	The right bank is a lower terrace and is composed of bedrock and the talus layer. Bedrocks inclines sharply at 85% slope on the left bank near the existing bridge and becomes milder to 36% slope at the end point side.	There are approach roads lie on the medium terrace on both banks. The right bank abutment of the existing bridge rests on a bedrock; whereas, the left abutment is on the riverbed.	The site is located at a deep valley in a steep mountain. There is a waterfall on the upper stream, and more waterfalls come out during a rainy season within 30m range of the beginning point side. There is a small-scale swamp where alluvial cones (gravel) are distributed.
River Grade		The elevation of the existing bridge is10m above the riverbed. The difference from the main stream is over 50m and so many waterfalls stay before reaching to the main stream.	The existing bridge is about 7m above the reverbed. The difference from the main stream is over 25m and so many waterfalls stay before reaching to the main stream.	The riverbed grade is 3% upstream and over 4% downstream. The difference in elevation from the main stream is 60m.	The existing bridge is located approximately 180m from the main stream; the riverbed is about 2m higher than the main stream. The slope is about 1 to 2%.	The existing bridge is located approximately 280m from the main stream, and the riverbed is about 7m higher than the main stream. The slope is about 2 to 3%.	Although the river is steep and the water volume increases during the rainy season, the water level will not rise so much (about 2m)due to the high current velocity.
H.W.L.		1,173.0m	1,032.0m	526.0m	373.0m	336.0m	1,093.0m
Basement Rock	Stratigraphy	Thimphu layer	Thimphu layer	Checa layer	Thimphu layer	Thimphu layer	Thimphu layer
	Rock Name	Fine-grained gneiss	Augen gneiss	Hard sandstone	Augen gneiss	Augen gneiss	Gneiss
	Features	Axis of syncline exists in the center of the bridge site, both left and right banks are opposite dip. There are few cracks in the bedrock, which is massive and hard.	Bedrock is limited near the present abutments. Schistosity inclines at 55 degree to the south. It is fresh but there are many cracks.	Although there is no bedrock near the abutments, it exists at the top of the slope on both banks as collapsed land. The bedding stratification is slightly inclined to the north.	It is confirmed that basement rock is only distributed in a 30m scope from the abutments on the left bank. The bedding stratification drops 15 degrees to the east. Rock of cut is also weathered.	Although bedrock is located in the vicinity of the abutments on the right bank, there is terraced deposit at the back, so thickness appears to be about 2m considering the gap from the cliff.	Basement rock is distributed on the road on both banks and bedding stratification is inclined at about 50 degrees to the northwest. Although basement rock is hard, there are cracks every 5 to 10cm cracks.
Blanket Bed	Formation Name	Former talus layer	Riverbed sediment, old talus layer	Riverbed sediment, old talus layer, new talus layer	Lower terrace deposit, old talus layer	Medium terrace deposit	Former talus layer, new talus layer
	Features	The former talus layer exists on the right bank side, which is composed of rubble and silty sand, so the degree of compaction is favorable. However, pebbles have overflowed during construction under the road, so it is loose.	Over 1m boulder gravel and sand have sedimented. Cut on roadside is the talus layer mixing with pebbles and rubble.	Riverbed sedimentation deposits as debris flow during the rainy season. The old talus layer is distributed on both banks. The former talus layer which is distributed on the right bank collapses repeatedly and a new talus layer has deposited.	The lower terrace contains gravely silty sand, which is relatively loose. The former talus layer contains sandy silt mixing rubble, so the degree of compaction is tight.	The medium terraced deposit mainly contains pebbles and is a sandy layer. At the beginning point side, boulder gravel bedrock is included.	The talus layer exists under the road on the right bank. The new talus layer covers the former talus layer, so it is loose.
Borehole (145.52m)	Location	1 borehole on the left bank (on the end point side) : Road shoulder	1 borehole on left bank (on the beginning point side) : Riverbed 1 borehoe on right bank (at the end point side) : Riverbed	1 borehole on left bank (on the beginning point side): Riverbed 1 borehole on right bank (on the end point side) : Riverbed	1 borehole on left bank (on the beginning point side) :Riverbed during the rainy season 2 borehole s on right bank (on the end point side) : 1 spot : Slope under the road 2 spots : Road shoulder	1 borehole on left bank (on the beginning point side):Roadside 1 borehole on right bank (on the end point side) : Roadside	1 borehole on left bank (on the beginning point side):Road shoulder 2 boreholes on right bank (on the end point side) : 1 spot : Slope under the road 2 spots : Under road retaining wall
	Depth	La-1 : 13.1m	Ba-1 : 9.94m Ba-2 : 10m	N-1 : 10m N-2 : 10m	Bu-1: 10m Bu-2: 10m Bu-3: 15m	C-1 : 8.67m C-2 : 17.97m	L-1 : 5.05m L-3 : 13.1m L-4 : 12.69m
	Rock Surface	La-1 : GL-8.75m	Ba-1 : GL-7.95m Ba-2 : GL-10 m or deeper	N-1 : GL-10 m or deeper N-2 : GL-10 m or deeper	Bu-1: GL-10m or deeper Bu-2: GL-10 m or deeper Bu-3: GL-12.55m	C-1 : GL-8.0m C-2 : GL-16m	L-1 : GL-2m L-3 : GL-10.1m L-4 : GL-7.64m
	Blanket Bed N Value	Measured Value : Impossible to penetrate Setting N value : 50 (Old talus layer)	Measured Value : Impossible to penetrate Setting N value : 30 (Riverbed sediment) 50 (Old talus layer)	Measured Value : 25- impossible to penetrate Setting N value : 30 (Riverbed sediment)	Measured Value : 21 - impossible to penetrate Setting N value : 30 (Old talus layer) 50 (Terrace deposit)	Measured Value : 11 - impossible to penetrate Setting N value : 50 (Terrace deposit)	Measured Value : 16 - impossible to penetrate Setting N value : 50 (Old talus layer)

(3) Implementation of Survey on Natural Conditions

Topographic surveying, river surveying and geological survey were implemented based on the following points and the results were reflected in the basic design.

1) Surveying

Topographical surveying of the sections of the proposed road was conducted by commissioning a local contractor. Surveying operations include the setting up of bench marks, road center line surveying (vertical section), road crossing surveying, surveying of existing structures and river surveying. From the outcome, floor plans for the periphery including the present bridges were prepared.

2) Geological Features
(Boring and Laboratory Test)

By commissioning a local contractor, a boring survey was conducted for the purpose of confirming load bearing layers in the vicinity of structures by selecting the following 13 positions. At the sites, sandy soil partially composed of silt and sand and containing boulder gravels (boulder gravel) is distributes at a dept of 10 to 15m with an N value of 20 to 50. Due to high content of boulder gravels, hard rock excavation was mainly implemented. The bedrock could not be confirmed even through 10m was partially excavated. However, bedrock was confirmed in many locations. Table 1-2 shows spots where a boring survey was conducted are shown as right.

Table 1-2 Boring Spots

No.	Site Name	Boring	
		No. of Borings	Name
1	Lawakha	1	Bh1 (right)
2	Basochu	2	Bh1 (left)
			Bh2 (right)
3	Nyarachu	2	Bh1 (left)
			Bh2 (right)
4	Burichu	3	Bh1 (right)
			Bh2 (left-down)
			Bh3 (left-up)
5	Chanchey	2	Bh1 (right)
			Bh2 (left)
6	Loring	3	Bh1 (right)
			Bh3 (left-down)
			Bh4 (left-up)
Total Number of Spots		13	

Sampling and laboratory testing was conducted for the purpose of confirming natural ground materials and construction materials. During the laboratory tests, soil collected was tested for its physical properties; whereas, rocks collected were tested for strength. In addition, an aggregate test was carried out based on samples of crushed stone from two locations.

1.3 Environmental and Social Considerations

(1) Environment-related Procedures

Environment-related procedures are taken in accordance with the Environment Assessment Act enacted in 2000 and the guidelines established in 2002. Although the environment-related surveys and procedures have been taken by the National Environment Commission (NEC), the concerned governmental agencies other than NEC independently carry out an environmental assessment and the competent organization provides Environmental Clearance (EC) after the administration reform. As the competent governmental agency in the Project is the Ministry of Works and Human Settlement (MoWHS), the Standard and Quality Control Authority under MoWHS carries out an evaluation, and based on its results, issues an EC. The implementing agency and the environmental unit of the Department of Roads (DoR) are responsible for implementing surveys for the purpose of obtaining an EC and preparing materials and applications, etc.

(2) Natural Environment

In the proposed areas under the Project, as shown in Fig. 1-2, Nyarachu Bridge faces Jigme Singye Wangchuk National Park and an ecological route, and Loring Bridge is located within a conservation area.

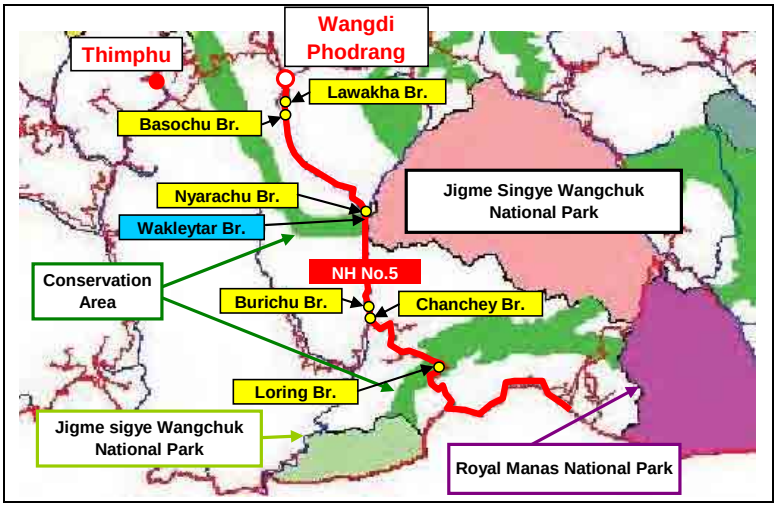


Fig. 1-2 Natural Reserves at Study Sites

CHAPTER 2

CONTENTS OF THE PROJECT

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 Basic Concept of the Project

Most of the land of Bhutan is mountainous, so roads are the sole means of transportation and are the most vital to the country's infrastructure. Since the commencement of the 1st Five Year Plan in 1961, during which time the development of major roads and bridges in Bhutan was given high priority, arterial roads connecting major cities or the seats of *dzongkhas* (administrative districts) across the country have been preponderantly developed. However, many temporary Bailey bridges (pre-fabricated truss bridges) which were constructed on national highways in the 1970s and 1980s have already exceeded their serviceable life, and have become severely damaged or deteriorated. Due to the increase in traffic volume and heavier loads associated with regional economic development primarily in agriculture, various conditions such as bridge girder deformity, wearing and corrosion of components, loose joints and deflection of bridge due to girder deformity can be observed, and therefore it has been pointed out that some bridges are at risk of collapsing.

Under these circumstances and considering the importance of bridge replacement, the Royal Government of Bhutan submitted a request to Japan for the implementation of a development study of 22 bridges under the jurisdiction of the Department of Roads of the Ministry of Works and Human Settlement. In response to the request, Japan conducted the "Study on National Highway Bridge Construction in the Kingdom of Bhutan" in 1997 - 1998. In the study, 12 of the 22 bridges were selected for urgent replacement. And the "Project for Reconstruction of Bridges" was implemented and completed in 2003 as Japanese Grant Aid for five of those bridges which required immediate attention. In addition, "Project for Reconstruction of Bridges, Phase II" for three other bridges was subsequently implemented and completed in November 2007.

In August 2006, as the subsequent Grant Aid for the above-mentioned project, Bhutan requested Japan to reconstruct six bridges (Lawakha Bridge, Basochu Bridge, Nyarachu Bridge, Burichu Bridge, Chanchey Bridge and Loring Bridge) among 11 bridges on National Highway No.5, which have not yet been reconstructed. In response to the request, the following requirements were established in the preliminary study dispatched in October 2007.

① National Highway No.5 which connects to India is the only road Bhutan can manage itself and is extremely important because it passes through a region of development in the southern plains. Consequently, safe and smooth traffic flow should be ensured.

② Related to ①, almost all bridges on National Highway No.5 are temporary Bailey bridges and are not designed and built to be permanent. Although there is no risk of collapse at the present

time, since the bridges were not designed or constructed to endure the traffic volume anticipated from future regional development, especially the increase in heavy vehicles, the traffic safety should be ensured for the future.

In response to the above-mentioned findings, with respect to the following components initially requested, the Basic Design Study Team was dispatched in April 2008 to Bhutan in order to verify technical and economic relevance from the viewpoint such as the positioning of the Grant Aid Scheme at the time of implementing the Project and effects.

In response to the findings of the Study, for the purpose of attaining the above-mentioned goal, 11 bridges on National Highway No.5 will be reconstructed. Accordingly, it is expected that stable transportation on the National Highway will be secured. Of those, the Grant Aid Project will reconstruct the requested six temporary bridges to permanent bridges. At the same time the five bridges which are not subject to the request will be rebuilt by the Bhutanese side.

<Components initially requested by Bhutan＞

Lawakha Bridge (bridge length: 45m), Basochu Bridge (bridge length: 30m), Nyarachu Bridge (bridge length: 45m), Burichu Bridge (bridge length: 48m), Chanchey Bridge (bridge length: 54m) and Loring Bridge (bridge length: 120m)
(Bridge length is corresponding to length requested)

2.2 Basic Design of the Requested Japanese Assistance

2.2.1 Design Policy

2.2.1.1 Basic Policy

Of the 12 bridges on National Highway No.5 on which the proposed bridges in the Study are located, “Wakleytar Bridge” was raplaced from a temporary Bailey bridge to a permanent steel Langer bridge through Japanese Grant Aid (Project for Reconstruction of Bridges, Phase II Project). However, according to the findings of the Study the 11 remaining bridges have exceeded their design life, so vehicles cannot cross safely due to an 8t to 18t load limit and 3.25m width limit. In addition, deterioration such as damage resulting from deflection or falling rocks, wearing and corrosion of components can be observed. Although the situation is not too dangerous to the extent of complete bridge failure, if the development plan in the south continues at its current rate of progress, an increase in traffic volume, and in particular, an increase in large-sized vehicles is anticipated. Since the existing bridges could create a bottleneck against safe and stable transportation of people and goods, which is

the project goal, the existing bridges should be rebuilt. In order to secure smooth and safe traffic flow on National Highway No.5, the design principles for the Project are described as follows.

① Based on the findings of the field survey, since the bridge length of the proposed six bridges exceeds 30m making implementation by Bhutan difficult from viewpoints of their achievements, topographic features and procurement conditions, etc., they will be reconstructed through the Japanese Grant Aid scheme. The other five bridges will be reconstructed by the Bhutanese side in due consideration of the Bhutanese achievements.

② According to the "Road Survey & Design Manual", on which the road standards in Bhutan are based, the width of National Highway No. 5 is 6.0m, so 6.0m will be secured as the effective road width taking drivability, safety and continuity into account.

③ In the similar manner as the Wakleytar Bridge (Phase II Project), a "Class A live load" as prescribed in the "Indian Roads Congress (IRC Standard)" will be applied in the bridge designs.

④ In due consideration of "cost reduction", designs and implementation plan, etc. were examined in order to display the maximum effects with minimal required cost. As the result, temporary Bailey bridges will be replaced by simple PC box girder bridges (four bridges), a simple composite steel plate girder bridge (one bridge) and a simple steel Langer bridge (one bridge).

⑤ Weathering steel will be utilized for the simple composite steel plate girder and simple steel Langer bridges in consideration of Bhutanese competency in maintenance and achievements in order to keep the burden to a minimum.

2.2.1.2 Policy on Natural Conditions

(1) Topographical features

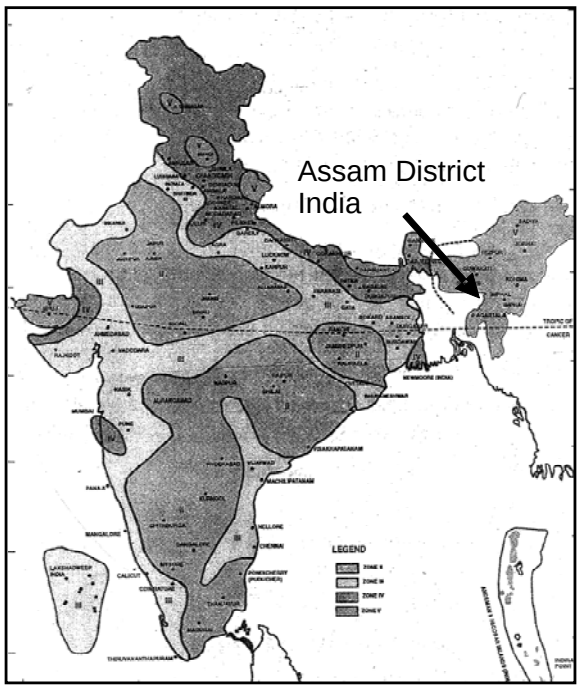
Since National Highway No.5 passes through a mountainous region, the road goes along a steep alignment along steep land formations, and in addition most of proposed sites are located on the Punatsangchu River. Consequently, transport restrictions and possibility of securing temporary yards necessary for construction were reflected in preparing construction plan and design of the road alignment of approach roads.

(2) Meteorological conditions

The meteorological conditions in Bhutan are described in "1-2 Natural Conditions". The characteristics were reflected in the design, implementation plan and schedule including drainage system design appropriate to rainfall and the possibility of construction during the rainy season.

(3) Earthquakes

Although Bhutan is a country with frequent earthquake, an accurate record of earthquake distribution cannot be identified because there are no available records of devastation from earthquakes, official historical events or scale. Therefore, if we refer to the Indian Roads Congress (IRC) standards with respect to earthquake scale in Bhutan, although the seismic zone map in the said standards does not indicate the zone to which Bhutan belongs, the seismic conditions ("Zone V" greatly affected by earthquakes) of the Assam district in India are assumed to conform and were reflected in design in principle.



(Source : IRC)

Fig. 2-1 Seismic Conditions Assam District, India

2.2.1.3 Policy on Socio-economic Conditions

Socio-economic conditions mainly on National Highway No.5 are described as follows.

① National Highway No.5 is only a trunk road at the project area and is a route utilized for accessing to Thimphu, the Capital of Bhutan, and major cities in the region such as Wangdue Phodrang, Damphu, Sarpang and Gelephu, thus it is an important route for public transportation such as buses.

② The industries in the region along National Highway No.5 are forestry in the north where there are many forest zones and agriculture along the plains in the south. National Highway No.5 is utilized as a route to transport the products to Thimphu and Wangdue Phodrang, etc.

③ Since the Punatsangchu River along National Highway No. 5 has an abundance of water and its topography is so steep making it suitable for hydroelectric power, the Basochu Hydropower Plant is already in operation. At the present time, the Punatsangchu Hydropower Plant near Wangdue Phodrang is scheduled for construction, and the steel towers for power transmission lines are already being built.

④ By utilizing the topography along the plains in the south, the Jigmiling Industrial Estate Construction Project and the Greenfield Airport Construction Project are scheduled. National Highway No.5 will therefore be used to transport materials and equipment during the implementation of the projects.

Based on the above-mentioned conditions, in due consideration of the utilization of public transportation, it is necessary to consider the design for bridges and approach roads to ensure smooth and safe traffic flow. In particular, due to an increase in the transportation of commodities associated with development of the regional economy and development projects scheduled along National Highway No. 5, since large vehicle traffic may increase in the future, the DoR has already begun to widen roads along some sections. This was therefore reflected in the designs for bridges and approach roads so as to ensure smooth large vehicle traffic flow.

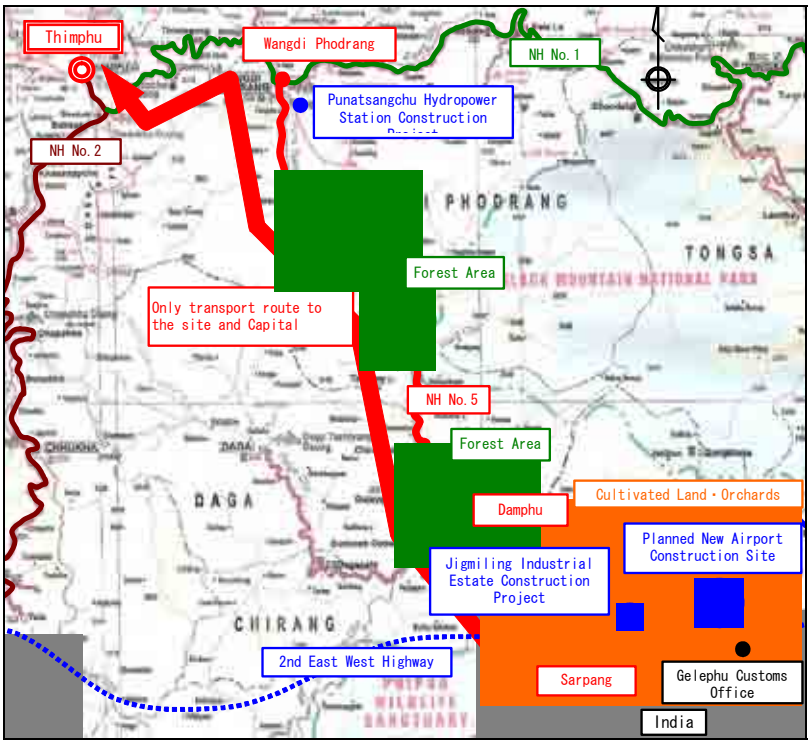


Fig. 2-2 National Highway No.5 Roadside Conditions

Fig. 2-3 Bus Service

Fig. 2-4 Sharp Curve Widening Conditions

2.2.1.4 Policy on Environmental and Social Considerations

(1) Environmental Considerations

① Environmental Permits

Regarding the environmental permit procedures under the Project, an Initial Environmental Examination (IEE) was conducted for an environmental permit and the Environmental Unit of the Department of Roads submitted an application during the preliminary study.
As the result, since there are no environmental concerns requiring an Environmental Impact Assessment (EIA), an environmental permit was approved in December 2007. As the results of confirming the necessity for additional procedures for an environmental permit during the basic study period, the National Environment Commission (NEC) responded that the permit presently obtained was sufficient and further procedures were not necessary. In particular, with respect to wild animals and plants, based on the opinions of local residents, NEC, the Department of Forestry Services at the Ministry of Agriculture and environmental NGOs during the Basic Design Study, although there is little impact on wild animals and plants, an implementation plan in due consideration of the environment at the time of construction work was requested.

② Environmental impact and mitigation

As considerations for the project implementation, items for assessment B (some impact is anticipated) and over are shown in the IEE level study conducted during the preliminary study. By reviewing these items, measures for reducing the environmental impact at the time of construction work have been examined. The items shown in Tables 2-1 and 2-2 should be taken into account during planning and implementation. At the same time, monitoring should be conducted during the project implementation.

Table 2-1 Environmental Impact and Mitigation under the Project (1)

Item	Points	Measures	Monitoring Time		
			Before Construction	During Construction	After In-service
Regional economy such as employment or making a living	Examination of the minimization of restricted traffic associated with construction of all proposed bridges	To avoid traffic interception as much as possible by utilizing the existing bridges and roads as detours	Confirmation of implementation plan	Confirmation of implementation conditions	-
Utilization of land or local resources	▪ Examination of a method to repair approach roads for bridge construction for securing water channels adjacent to Lawakha Bridge and its functions ▪ Applying for expropriation of partial lot for forest Administration Office adjacent to Chanchey Bridge and confirmation of need or no need for relocation	▪ To take measures in order not interrupt water supply in water channels even during road repair ▪ As relocation of the office will be taken by Bhutan, the possibility of relocation has already been confirmed	Confirmation of designs, implementation plan	Confirmation of implementation conditions	Confirmation at defect inspection time
Existing social infrastructure or social services	Examination of the minimization of restricted traffic associated with construction of all proposed bridges	By utilizing the existing bridges and roads as detours, to avoid traffic interruption as much as possible	Confirmation of implementation plan	Confirmation of implementation conditions	-
Water usage, right to access water common rights	Examination of a method to repair approach roads for bridge construction for securing water channels adjacent to Lawakha Bridge and its functions	To take measures to prevent interruption of water supply in water channels even during road repairs	Confirmation of designs, implementation plan	Confirmation of implementation conditions	Confirmation at defect inspection time
Public hygiene	Examination of a method to control and to appropriately dispose of waste resulting from construction work at all proposed bridges, and also discharged by people involved with the work	To implement dependable waste disposal at designated places	Confirmation of implementation plan	Confirmation of implementation conditions	-
Disasters	Examination of measures for avoiding and reducing disaster risk during construction of excavation for abutment foundations at all proposed bridges	To formulate and to conduct implementation plan so that substructure construction during the rainy season shall not be carried out	Confirmation of implementation plan	Confirmation of implementation conditions	−
Geological and topographic features	Examination of selection of abutment locations to minimize geomorphologic transformation associated with abutment construction at all proposed bridges	To adopt an implementation method for minimizing geomorphologic transformation based on the findings of the geological and geographical survey	Confirmation of designs implementation plan	Confirmation of implementation conditions	−
Soil erosion	Establishing an appropriate construction period and construction methods and examination of measures in order to avoid damaged by erosion due to rainfall during construction of excavation for abutment foundations at all proposed bridges	To formulate and conduct an implementation plan so that substructure construction during the rainy season shall not be carried out by considering the examination of a method to avoid erosion damage (such as chemical injection and earth retaining work)	Confirmation of construction methods	Confirmation of implementation conditions	−

Table 2-2 Environmental Impact and Mitigation under the Project (2)

Item	Points	Measures	Monitoring Time		
			Before Construction	During Construction	After In-service
Animals and plants ecosystem	In order to avoid and reduce the impact on ecosystems at Nyarachu and Loring Bridges within environmental conservation districts, examination of a construction period to avoid wild animal migration periods and blasting work and measures for avoiding the impact of noise or lighting. Examination of measures to control the catching of wild animals and plants and mitigation through afforestation	To implement construction work in conformity with various environmental standards such as environmental noise standards and to formulate an implementation plan in order to minimize the impact on wild animals and plants as much as possible through minimal blasting, education for workers to prevent the catching of animals and plants and application of sodding planting	Confirmation of implementation plan	Confirmation of implementation conditions	Confirmation at defect inspection time
Landscape	Examination of mitigation of tree felling, etc. associated with bridge reconstruction work at Loring Bridge	To minimize the impact on the landscape by adopting sodding planting	Confirmation of implementation plan	Confirmation of implementation conditions	−
Water pollution	Setting up of a construction period for preventing river water pollution during construction work at all proposed bridges and examination of construction methods and measures for water conservation	To prevent the outflow of polluted water by refraining construction during the rainy season, to adopt a construction method for controlling preventing outflow of polluted water at construction sites and to grasp water conditions by conducting a water quality test during a construction work period	Confirmation of construction methods implementation plan	Confirmation of implementation conditions	−
Waste	Examination of reuse and recycling of waste discharged due to dismantling of the existing bridges at all proposed bridges, and examination of the adequacy of final waste disposal, of controlling waste and of appropriate final waste discharged by people involved with the work	To request the Bhutanese side to remove scrap wood at the sites when removing the existing bridges, and to discharge waste at designated places resulted from people involved with the work	Confirmation of implementation plan	Confirmation of implementation conditions	Confirmation at defect inspection time
Noise, vibration	Examination of appropriate construction methods and measures for controlling excessive noise and vibration during a construction period at all proposed bridges	To implement construction work in conformity with environmental noise standards	Confirmation of implementation plan	Confirmation of implementation conditions	−

It is required to draw up a plan for an implementation of the environmental monitoring, and to follow Environmental Codes of Practice (ECoP) by the environmental permit.

According to ECoP, DoR or external agency shall conduct the environmental monitoring/evaluation, in the concrete daily monitoring will be carried out by the contractor's engineer, while periodic monitoring should be carried out by DoR. Thus, it was confirmed that DoR should carry out the environmental monitoring in an appropriate manner.

In addition, the further detailed land acquisition is described as follows.

(2) Land acquisition

From the viewpoint of ensuring construction lots, the following measures will be taken for Lawakha, Burichu and Chanchey Bridges.

① Lawakha Bridge

Since there is a private household and paddy fields on the right bank (on the side of Damphu) and a road for a dam construction is being constructed on the left bank (on the side of Wangdue Phodrang), it is difficult to set up a temporary yard. Consequently, it will be shared with the Basochu Bridge, which is the neighboring site. Although an approach road for substructure construction is planned for the right bank, this will not affect the private household or paddy fields at the time of construction.

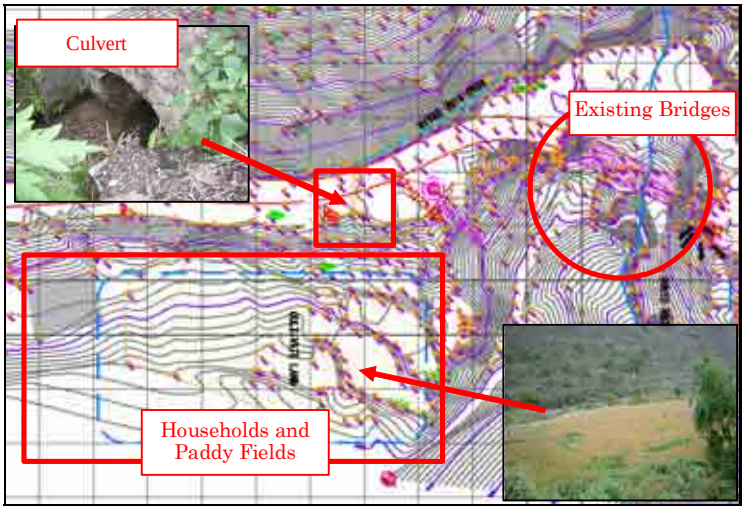


Fig. 2-5 Right Bank of Lawakha Bridge

Additionally box culverts on the right bank utilized for agricultural irrigation canals to paddy fields will not be affected by the road construction.

② Burichu Bridge

Due to the existence of private households on the right bank (on the side of Wangdue Phodrang), the bridge locations and approach road alignment will be considered so that they will not have any impact on the private households.

③ Chanchey Bridge

Since there is a forest administration office on the left bank (on the side of Damphu), an approach road for a new bridge may pass the office lot. However, since the office is a governmental facility and can be relocated at Bhutanese expense, in accordance with the alignment, the office will be relocated.

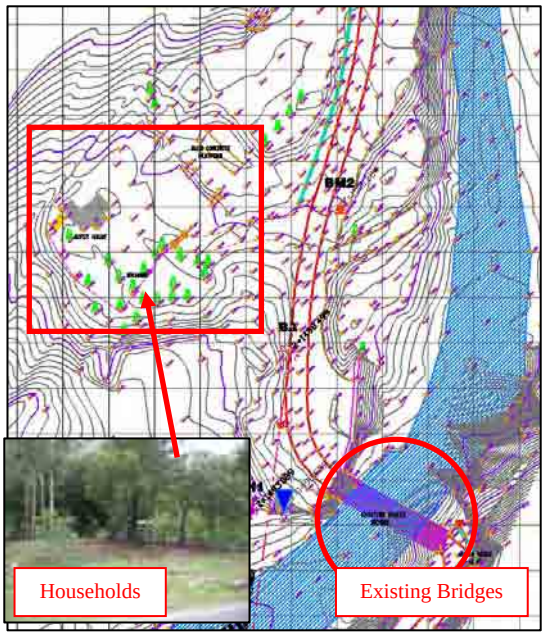


Fig. 2-6 Right Bank of Burichu Bridge

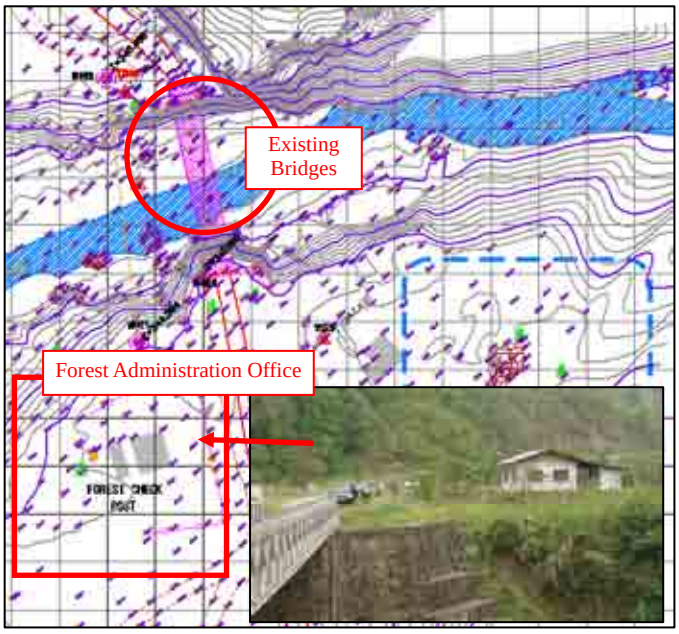


Fig. 2-7 Left Bank of Chanchey Bridge

2.2.1.5 Policy on Construction Conditions

(1) Local Construction Situation

The 2006 actual GDP growth in Bhutan was 8.5% (2007 Statistical Data) and the rate for the construction-related sector of GDP was 13.4%, which was 3rd ranking after agricultural and electric power sectors. In addition, the rate of employment in the construction-related sector was 12.4%, which was the 3rd ranking after agriculture and other sectors. The construction related sector in Bhutan has become an important sector not only because hydropower accounts for nearly half of foreign currency revenue, but also because it contributes to road development, which is a lifeline in this mountainous nation. Major works in road development includes new road construction, road improvements (including road surface regeneration) and bridge construction, but there is very little bridge reconstruction.

Although the local construction industry is very active, it faces the following problems.

- Shortage of construction workers (especially skilled workers) and civil engineers
- Dependence on importation of construction-related industrial products (except for cement)
- Shortage of construction machinery (delay of mechanization)
- Lack of experience in medium-scale or larger permanent bridge construction
- Restrictions in operation of heavy machinery and vehicles due to road / bridge traffic limitations

The current situation invites deteriorating quality and delays in construction periods.

(2) Policy on Design Related to Construction Situation

Design policy in due consideration of the above-mentioned local construction situation is described as follows.

- In the selection of superstructure type, PC bridges will be examined in order to utilize local material effectively and improve local technology of bridge.
- If a steel bridge is selected, weathering steel will be adopted in order to reduce bridge maintenance cost.
- If large heavy machinery and vehicles are utilized, an implementation plan in due consideration of traffic restriction will be taken.
- In order to facilitate effective utilization of local contractors, Bhutan-style masonry retaining walls or drainage system will be adopted for approach roads. In the asphalt surfacing work, Bhutan-style labor-intensive methods (manual mixing) will be applied.

2.2.1.6 Policy on Impact by Punatsangchu Hydropower Station Construction Project

(1) Rise in water level

According to the Department of Energy (hereinafter referred to as “DoE” in the Ministry of Economic Affairs), when the dam was full, the water level rose nearly 15m from the road surface in the vicinity of Hesothangkha Bridge on the northernmost section of National Highway No. 5. However, all the six planned bridges are located downstream and are lower than the scheduled dam location, so the bridges will not be affected by the water level of the dam. In addition, as shown in the following figures, after the water discharged from the dam passes through the power station by way of the total 8.5km headrace tunnel, the water returns to the Punatsangchu River from an outlet installed between Basochu Bridge and Nyarachu Bridge.

In such a manner, since the six planned bridge locations are not affected by the water level of the dam, the proposed elevation was decided through present hydrological data and approach road elevation.

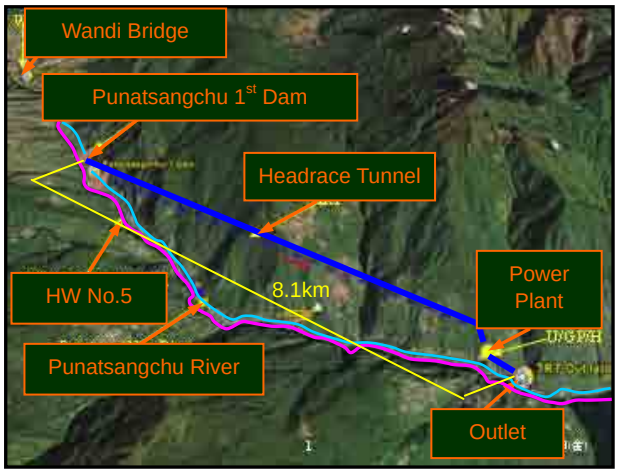


Fig. 2-8 Headrace Tunnel at Punatsangchu Dam

Fig. 2-9 Planned High and Low Water Level at Punatsangchu Dam

(2) Traffic of Transport Vehicles for Power Station Construction

According to DoE, National Highway No.5 will be utilized for the transport of materials for the power station construction and National Highway No.2 will be utilized for heavy equipments such as power generators. Consequently, in a similar manner as common national highway bridges, Class A of IRC was applied to the design of the six planned bridges as live load.

(3) Temporary Approach Road for Power Station Construction

At the time of the Study, it was unexpectedly confirmed that approach road construction had started for the dam construction in the vicinity of the bridge abutment on the left bank of Lawakha Bridge. Unavoidably a new bridge will be constructed at a site that does not intervene with the approach road. A detour during the construction work would be secured by relocating the existing bridge the mountain side.

Fig. 2-10 Construction at Punatsangchu Dam and Approach Road

2.2.2 Basic Plan

2.2.2.1 Applicable Standards

(1) Road Design

The “Road Survey & Design Manual (First Edition, June 2005), Royal Government of Bhutan, Ministry of Works & Human Settlement, Department of Roads, Thimphu” was applied to the road design.

(2) Bridge Design

Although the “Standard Specifications and Code of Practice for Road Bridge, The Indian Roads Congress (IRC Standard)” was applied to bridge design in principle, the Japanese Specifications for Highway Bridges was applied to matters that were not clarified in the above-mentioned standards such as a calculation method for load capacity of components.

(3) Design Standard of Temporary Structures, Etc.

Design on temporary structures and earth retaining structures such as stationary scaffolding for bridge construction was conformed to the design standards for Japanese temporary structures.

2.2.2.2 Road Design Basis

(1) Road Standards

The Department of Roads (DoR) is proceeding with double lane construction work at national trunk highways. Other than the six bridges subject to the Project, a double lane system is scheduled for all five remaining bridges to be reconstructed by Bhutan. Accordingly, the double lane design as illustrated in Fig. 2-11 figure was principally used for the proposed bridges.

- Road class : Class A
- Road standard : National Highway (Double Lane)
- Design speed : 60km/hr

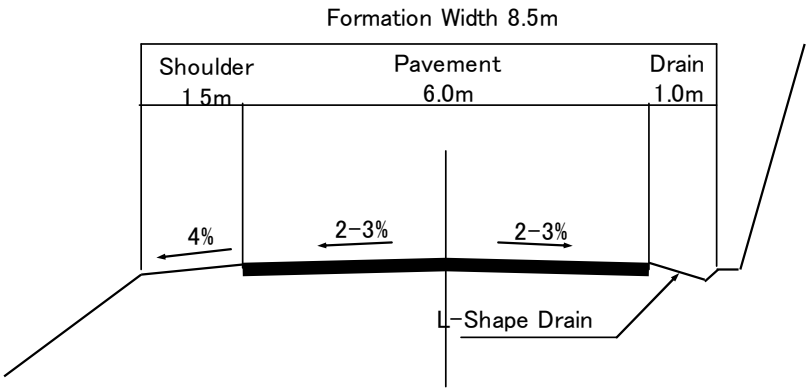


Fig. 2-11 Standard Cross-section (National Highway / Double Lane)

(2) Relaxation of Design Speed

As shown in the preceding paragraph, although the design speed of National Highway No.5 is 60km/hr, in some locations, for example, at steep cliffs where it is difficult to secure alignment for the prescribed design speed at the bridge, the design speed for the approach road was 20km/hr which should not promote severe deterioration of the present traffic function.

(3) Road Width

Since a 6m width was applied to the Wakleytar Bridge which was built during the Phase II Project, a 6m width is also scheduled for the five bridges to be reconstructed by Bhutan. Therefore, a 6m width is also applicable for the six planned bridges. The basic cross-sections for the Project are shown in Fig. 2-12, 2-13 and 2-14.

① Road Section

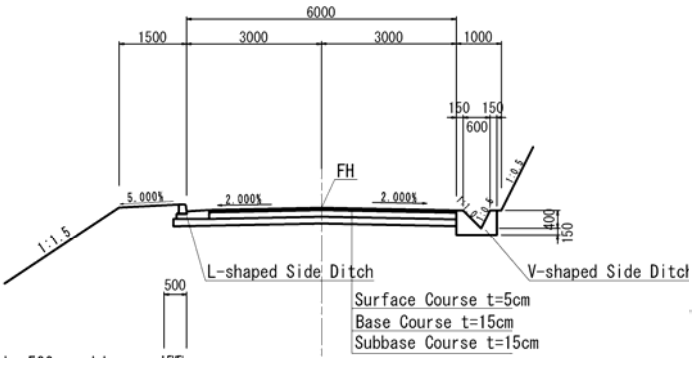


Fig. 2-12 Cross-section (Road • Earthwork)

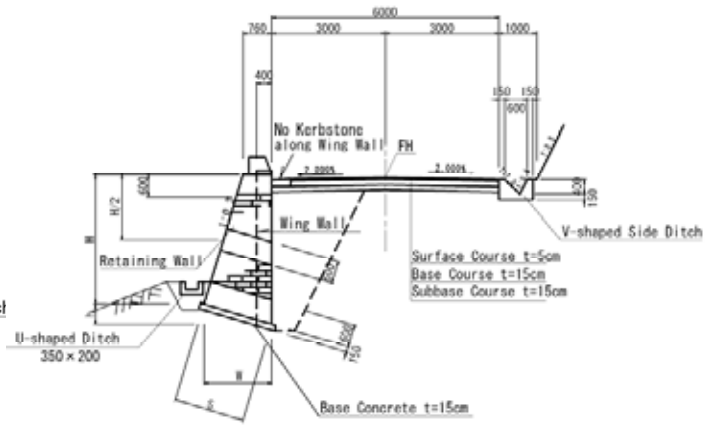


Fig. 2-13 Cross-section (Road • Masonry Retaining Wall)

② Bridge Section

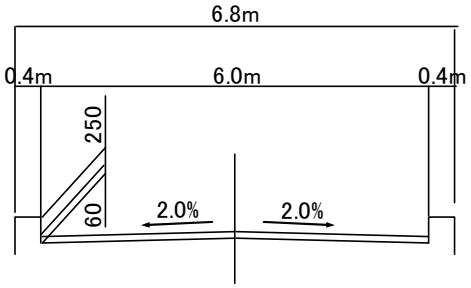


Fig. 2-14 Cross-section (Bridge)

(4) Minimum Horizontal Curve Radius

Three of the six bridges subject to reconstruction, Basochu Bridge, Nyarachu Bridge and Loring Bridge will be constructed almost perpendicular to the national highway. When the prescribed design speed was applied, since amount of land cutting on the mountain side of the approach road would be large, the design speed of the bridge approach road was relaxed. During the Phase II Bridges, although 12.5m was adopted as the minimum horizontal curve radius on the assumption that trailer size continues to increase and 13.5m semi-trailers owned by DoR will be traveling the total length, the prescribed minimum curve radius (15m) was adopted. For the other three bridges, 60km/hr design speed was applied since they are almost perpendicular.

(5) Horizontal and Vertical Alignment

In designing the horizontal alignment at sections where the road and bridge cross each other almost perpendicularly, although a widening of the road for sight distance has been considered; super elevation will not be applied. In addition, due to drainage on the bridge, the minimum longitudinal grade was 0.5%.

(6) Road Cutting Slope and Banking Grade

In association with alignment planning at each site, where cutting is unavoidable, the cutting slope shown in Table 2-3 was applied depending on the cutting height and geological features of the soil.

Table 2-3 Cutting Slope

Soil Property and Texture of Natural Mountain		Cutting Height	Grade (%)
Hard Rock to medium-hard rock		--	0.3 to 0.8
Soft rock (Weathered rock)		--	0.5 to 1.2
Gravel, rock block or cobblestone mixed sandy soil mixed	Good particle size distribution	10m or less	0.8 to 1.0
		10 to 15m	1.0 to 1.2
	Poor particle size distribution	10m or less	1.0 to 1.2
		10 to 15m	1.2 to 1.5

(7) Summary of Road Design Standards

The road design standards to be utilized in the project are summarized in Tables 2-4 and 2-5.

Table 2-4 Bhutan Road Design Standards

Road Type (Traffic Volume)			Design Speed
			60 (km/hr)
National Highway	CLASS A 2-lane	Carriageways	3.5m
		Road Shoulders	1.5m
		Roads	6.5m

Table 2-5 Road Geometry

Item	Unit	Numerical Value	
Design Speed	Km/hr	60	20
Cross Fall	%	2.0	2.0
Maximum Super elevation	%	7	--
Horizontal Alignment : Min. Curve Radius	m	120	15
Vertical Alignment : Max. Incline	%	7.0	8.0
: Mix. Incline (Bridge Face)	%	0.5	

2.2.2.3 Bridge Design

(1) Major Design Loads

① Live Load

The Bhutanese side will finish reconstructing the remaining five bridges other than those under the Project in line with the completion of the planned bridges. In a similar manner as bridges implemented under the Phase 2 Reconstruction Project, the bridges were designed by adopting the live load as a permanent bridge. Accordingly, the Class A live load of the IRC standard was utilized as the live load for permanent bridges in Bhutan.

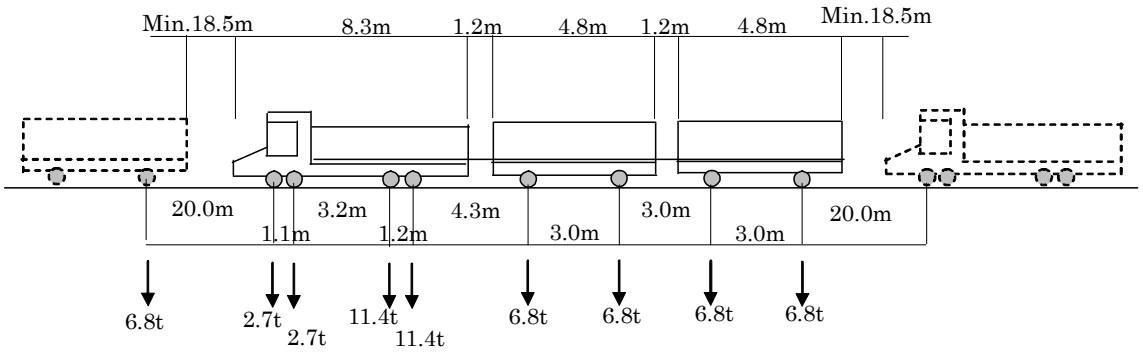


Fig. 2-15 Class A Live Load of IRC Code

② Horizontal Seismic Coefficient

Although Bhutan is not included in the seismic zone map of the IRC standard, according to the map, the Assam district of India, along the border to the south and east of Bhutan belongs to “Zone V”. It is therefore reasonable to assume that Bhutan also falls into “Zone V”. Consequently, Ah=0.22 was adopted for the horizontal seismic coefficient (Ah) based on the formula indicated in 222.5 of the IRC standard. In addition, the vertical seismic coefficient (Av) didn’t take into account.

$$Ah = (Z/2)\times(Sa/g) / (R/I)\times\alpha = 0.216$$

then, Z : Zone factor (V) = 0.36
Sa/g : 2.5 (T<0.5sec : h=0.05)
R : Response reduction factor (=2.5)
I : Importance factor (=1.5 Importance Bridge)
α : Correction factor (=0.8) due to dumping constant

③ Other Loads

Loads such as dead pressure or earth load were determined utilizing a general formula.

(2) Concrete

1) Concrete design standard strength

a) Substructure

Since concrete is mixed by a mobile-type mixer at the site, the accuracy of measurement is insufficient. Therefore, it is necessary to prepare for strength unevenness or lower strength due to transportation during construction work. Accordingly, proportioning strength should be higher and design standard strength should be lower. Based on this, the design standard strength for concrete to be utilized in sub-structures was the lowest design standard strength of the RC structure, σ_{ck}=21N/mm^2 (CYLINDER).

b) Superstructure

① Pre-stressed concrete girders

Although there are few examples of pre-stress concrete (PC) bridges in Bhutan, numbers of such bridges have been increasing in the recent years. As the design standard strength, for these girders 30N/mm^2 to 40N/mm^2 was applied. At the Pangzurmani Bridge (Gelephu-Trongsa Highway) presently under construction (near completion), 40N/mm^2 concrete has been utilized. On the other hand, according to the material procurement study, the maximum design standard

strength for concrete frequently utilized in Bhutan is 32N/mm^2, so 40N/mm^2 is considered to be rare. In accordance with the Japanese Specifications for Highway Bridges, the minimum design standard strength for the post tension method is 30N/mm^2. Accordingly, the concrete design standard strength was σ_{ck}=30N/mm^2 (CYLINDER) for post tensioned PC girders. A higher-class mixing strength is preferred for assured quality and concrete density.

② Deck slabs

Dense concrete is preferred for deck slabs. Since conditions for concreting are also more favorable than those of the substructure, σ_{ck}=30N/mm^2 (CYLINDER) of the concrete design standard strength was applied to composite girders and PC beams; whereas, σ_{ck}=24N/mm^2 was applied to others.

(3) Pavement for bridges

Since a water proof layer cannot be laid on the concrete pavement often utilized in Bhutan, there is a fear that water will penetrate into the deck slab through cracks on the pavement concrete, which could reduce the durability of the deck slab. Consequently, the Project adopted asphalt pavement (60mm thick).

(4) Design Standards for Incidental Road Structures

With respect to incidental structures around the bridges such as retaining walls and drain gutters, methods utilized in Bhutan from the aspects of local labor force and material procurement will be adopted as much as possible. Although the IRC standard will be generally applied to the design, provisions that are not prescribed in the code conformed to the “Handbook on Road Earthwork Design” compiled by the Japan Road Association.

2.2.2.4 Proposed Elevation

The results from a compilation of the requirements for proposed elevation and bridge piers based on river conditions are outlined in Table 2-6.

Table 2-6 List of Requirements Based on River Conditions

Bridge Name	H.W.L (m)	Impact of H.W.L	Possibility of Pier Installation
Lawakha Bridge	1173.0	No need to change the elevation because of the sufficient clearance below the soffit.	Impossible to install due to topographic conditions
Basochu Bridge	1032.0		Due to the possibility of scouring from rapid water flow or damage from falling rock, it is desirable to avoid.
Nyarachu Bridge	526.0	Need to raise the elevation by 1.0m.	
Burichu Bridge	373.0	No need to change the elevation because of the sufficient clearance below the soffit.	
Chanchey Bridge	336.0		
Loring Bridge	1093.0		Impossible to install due to topographic conditions

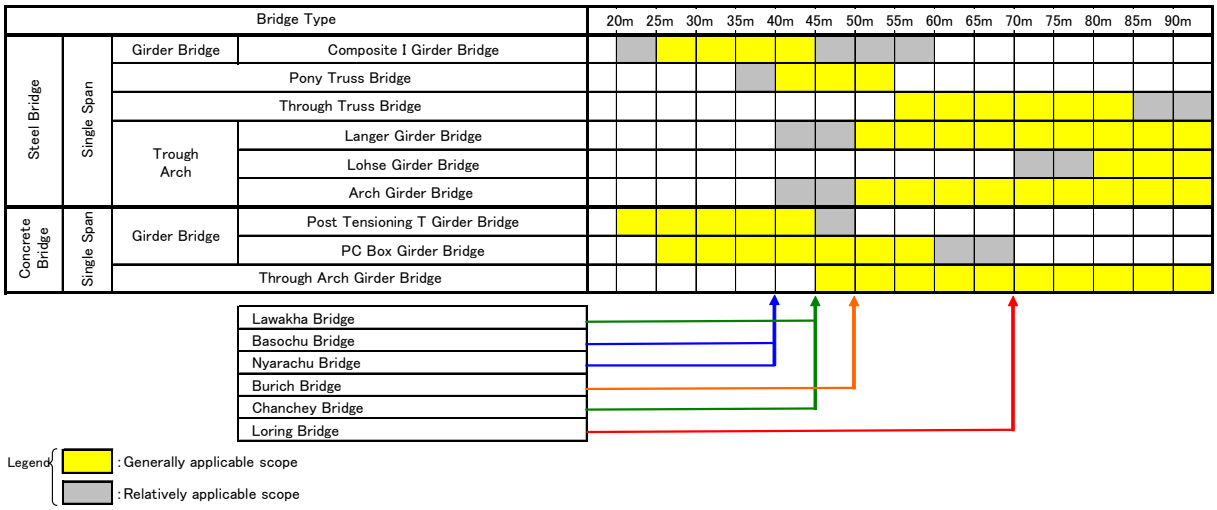
2.2.2.5 Comparison of Bridge Type

The following examination was conducted for the selection and comparison of bridge type for (1) Lawakha Bridge, (2) Basochu Bridge, (3) Nyarachu Bridge, (4) Burichu Bridge, (5) Chanchey Bridge and (6) Loring Bridge.

- Conditions of bridge locations
- Examination of bridge routes
- Location of abutments and hindrances
- Relationship between geographical and geological features, hydrological factors, and foundation
- Basic requirements for selection of superstructure construction method
- Feasible superstructure type (first selection results)
- Bridge type examination

The examined results are shown in the following page and thereafter. In the selection of superstructure type, the conformity table of span length and types shown in Table 2-7 of was utilized. This table was compiled from the past results by categorizing applicable bridge types to spans.

Table 2-7 Application Tables of Bridge Types to Range of Span Length



Where the supporting strata can be found in a relatively shallow position, a spread foundation was adopted. In-situ caisson type pile foundation method was taken, which enabled manual constructing of concrete piles without utilizing heavy machine on deep stratum or steep ground.

1. Lawakha Bridge

②Detour

Detour on the upstream side. Poss ble to pass during the dry season but impossible during the rainy season due to an increase in water flow.

To Damphu

⑤Waterfall on the upstream side

Extremely steep waterfall upstream. Water volume increases during the rainy season.

①Bird Eye's View

Extreme limit of new bridge location due to road on a steep slope.

③Periphery

Road for dam under construction on this side. Private houses and paddy fields observed around 40km on the opposite bank.

④Approach road for Punatsangchu Dam

Road for dam project construction is being built.

※ ▭ : Assumed abutment position

(1) Site Conditions

1) Located approximately 9km from Wangdi Phodrang
2) A waterfall on the mountain side of the existing bridge, the valley side is a steep cliff. Although vehicles can pass via the detour on the mountain side due to few waterfalls during the dry season, transit on the detour is impossible because heavy waterfall occurring during the rainy season splashes onto the present bridge.
3) As the result of the Study, an approach road for constructing of the Punatsangchu Hydropower Station was found under construction on the left bank. The road being constructed is very close to the project site, so this limits the alignment and the implementation plan under the Project.
4) Since there are private houses and paddy fields in the 40m neighborhood, it may need to rent part of the land at the time of construction work.
5) Water pipes are loaded to the bridge.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Evaluation
A	Impossible due to high level of water flow during the rainy season.	×
B	Impossible because transit cannot be secured at the time of construction work. Due to a lack of space on both the mountain and valley sides, the temporary bridge or the existing bridge cannot be relocated.)	×
C	Only feasible alignment The impact (fear of collapse) resulting from excavation on the existing retaining wall cannot be predicted, alignment avoiding the existing retaining wall is preferable. However, cautious planning and execution is necessary due to lack of space on the left bank other than the exiting retaining wall.	○

(3) Abutment Position and Hindrance

The only space for installation of the abutment (A1) on the Wangdi Phodrang side exists inside of the existing retaining wall due to the steep slope along the periphery. Since there is a slope on the valley side of the present road, the abutment (A2) on the Damphu side will be installed on this slope in order to "shorten the bridge length" and "to secure a space for super-structure construction". In this case, the bridge length will be approximately 45m. The A1 abutment position conflicts with the abutment of the existing bridge, so it is necessary to relocate the super-structure and to demolish the abutment of the existing bridge at the time of execution.

(4) Topographic, Geological and Hydrological Conditions and Foundation

Due to outcrop of gneiss on the steep slope in the vicinity of A1 abutment, spread foundation can be considered. On the other hand, soil is accumulated in the surface layer on the side of A2 abutment, then the former talus layer and gneiss layer exist underneath. In the case of spread foundation, since excavation of abutments hinders the national highway and traffic, a caisson pile method which does not require large excavating machinery is examined as a prerequisite condition for the smallest size of foundation shape. In addition, bridge piers will not be installed in due consideration of geological and topographic conditions or damage by debris flow. The clearance under the girders is sufficient because the high water level is EL+1173m based on the flood mark and hearing survey.

(5) Requirements for Superstructure Types

Although it is difficult for a hydraulic crane to enter the river bed due to the steep slope and severe unevenness, the vertical clearance is more than 20m so that installation of a temporary support for bridge construction is difficult. Accordingly, a construction method such as a cast-in-place concrete bridge utilizing an all staging method cannot be applied. In addition, a space on the back of A1 and A2 abutments is limited, so it is impossible to adopt PC-T girders by using erection beams.

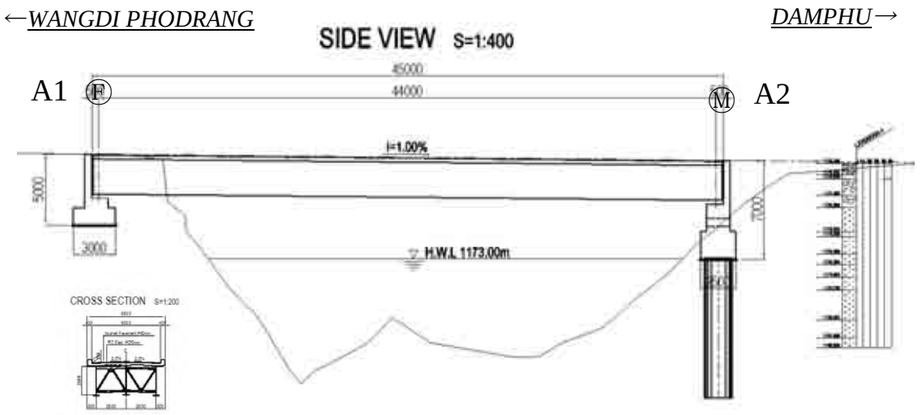
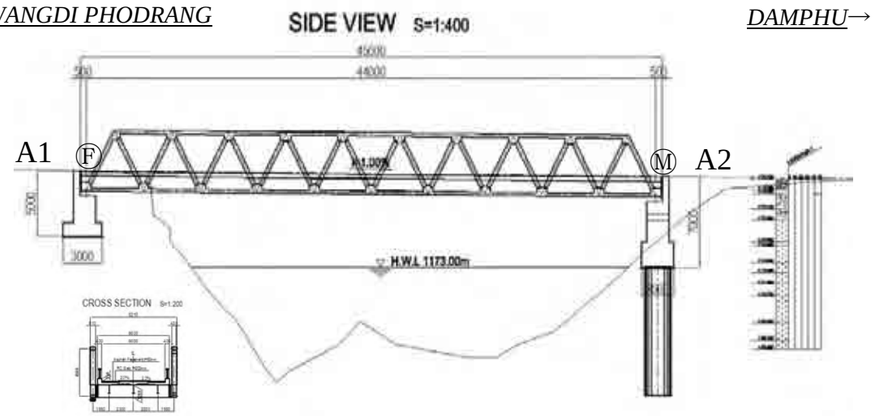
(6) Possible Superstructure Types (First Selection Results)

If the span length is approximately 40 to 50m, although the following four bridge types can be considered based on the past records, etc., from the results of the first selection in accordance with the above-mentioned requirements, two types of bridges will be compared and examined and are shown in the following table.

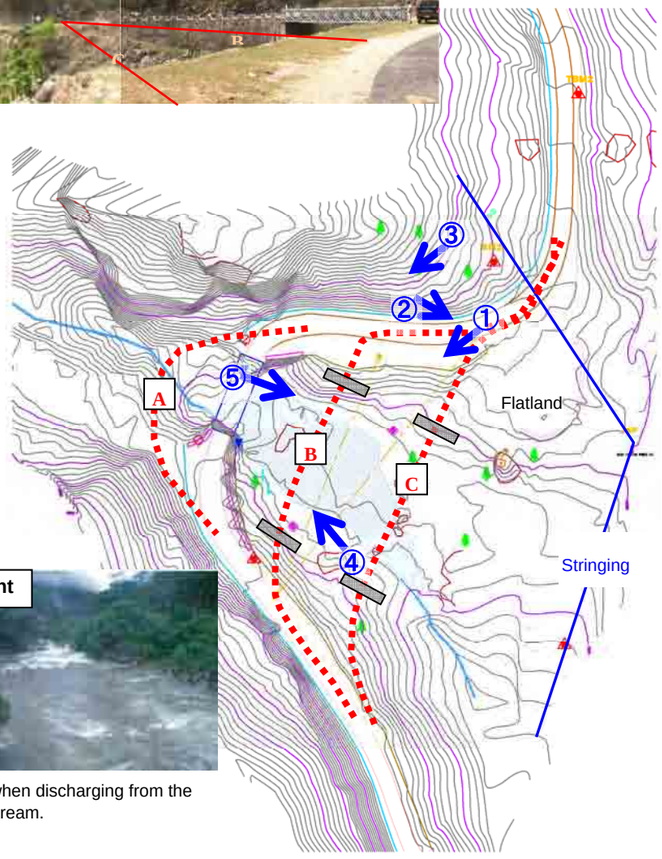
Bridge Type	Summary	Evaluation
1) **Composite simple steel I girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○
2) **Simple steel pony truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) Simple PC box girder bridge	Impossible to construct because scaffolding cannot be installed due to large unevenness resulting from steep river channel and uneven rock	×
4) Simple RC through-type arch bridge		×

(7) Bridge Type Study (LAWAKHA Bridge)

Comparison of two bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

Bridge Type		Case-1 Composite Simple Steel I Girder Bridge	Case-2 Simple Steel Pony Truss Bridge
General View		←*WANGDI PHODRANG* *DAMPHU*→ 	←*WANGDI PHODRANG* *DAMPHU*→ 
Bridge Outline		➢ Superstructure: Composite simple I girder bridge utilizing weathering steel ➢ Substructure: Spread foundation and caisson pile method are influential to A1 abutment and A2 abutment respectively. The abutment width will be 6.8m and is the smallest type compared to pony truss type. ➢ Structural problems: No structural problems arise due to the bridge type from the past records. ➢ Approach road: A surface height will be in conformity with the present road elevation. ➢ Vertical clearance: A vertical clearance will be approximately 4.4m (＞1.0m), which is sufficient.	➢ Superstructure: Simple pony truss bridge using weathering steel and no structural problems. ➢ Substructure: Spread foundation and caisson pile method are influential to A1 abutment and A2 abutment respectively. The abutment width will be 10.0m and is wider than the steel plate girder type. ➢ Structural problems: The past results from five bridges in Bhutan show no structural problems ➢ Approach road: Same as on the left ➢ Vertical clearance: Vertical clearance will be approximately 5.4m (＞1.0m), which is sufficient .
Evaluation Item	Workability	➢ Although a transportation difficult may arise due to taller steel components compared to the pony truss bridge, if web plate height is 2.2m or less, the problem can be avoided. ➢ The number of components (members) is less and a construction period is shorter. ➢ Since an abutment width is 3.2m narrower than that of a pony truss bridge, the construction of A1 will be advantageous.	➢ Steel elements are smaller in site and advantageous to transport. ➢ Since the number of the elements is greater due to truss type, the construction period is slightly longer. ➢ The construction on the A1 side will be disadvantageous since the abutment width will be 3.2m wider than that of the steel plate girder type.
	Construction Period	The total construction period will be 19 months.	The total construction period will be 19 months.
	Construction Cost	1.000 (standard)	1.069 times
	Maintenance	➢ As stable rust will settle by utilizing weathering steel, a repainting is unnecessary thus minimizing maintenance.	➢ Same as on the left
Overall Evaluation		➢ There is little difference in structural property, workability and construction period so that no problems will arise. ➢ As the abutments will be 3.2m narrower, they do not conflict with the abutments of the existing bridge. ➢ Construction cost will be lower. ➢ There is no difference in maintenance. 1	➢ Same as on the left ➢ Since abutment will be wide, the construction of abutments must be worked so close to the existing bridge . ➢ Construction cost will be slightly higher. ➢ There is no difference in maintenance. 2

2. Basochu Bridge



Torrent when discharging from the dam upstream.

Flatland in the vicinity of 60m from beginning point. However, electric lines are installed about 5m overhead.

About 9m below the girders of the existing bridge. Outcrop of bedrock in the vicinity of the abutment.

Slope with outcrop of rock on the mountain side of the existing bridge. Gentle topography on mountain side like the basin of a waterfall.

※ : Assumed abutment position

(1) Site Conditions

1) Located approximately13km from Wangdi Phodrang.
2) The slope where an outcrop of rock exists on the mountain side of the existing bridge, and gentle topographical features such as the basin of a waterfall from the vicinity of the bridge to the mountain side.
3) Normally, the water depth in the vicinity of the bridge is shallow because the river water volume is controlled by a hydropower station dam upstream; however, flow quantity increases during discharges from the dam and it becomes torrent. The large rocks scattered on the river bed are an indication of the intensity.
4) There is flatland in the vicinity of 60m from the starting point, which is suitable for a construction yard and stock yard. However, power lines installed overhead may hinder construction work.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Cost	Evaluation
A	Impossible with no space due to bedrock slope on both banks of the valley side	—	×
B	Feasible route. However, it is unreasonable for alignment and bridge structure (such as widening of road) due to sharp curve on the left bank. A construction cost becomes almost the same since the bridge length is almost same as route C (40m).	1.00	△
C	Feasible route. This is an ideal route since there is no unreasonable alignment on the left bank. A position to install the abutment is flat. A construction cost becomes almost the same as route B.	1.00	○

(3) Abutment Position and Hindrance

Both abutments (A1 on the Wangdi Phodrang side and A2 on the Dumphu side) can be installed at a relatively flat point approximately 40m downstream of the present bridge. Based on the findings of the topographical survey, if the bridge length is as short as possible within the dead water region so that it can be protected by the abutment of the present bridge at the time of flooding, the bridge length becomes approximately 40m. As a hindrance, power lines on the flatland to be installed in the construction yard can be considered.

(4) Topographic, Geological and Hydrological Conditions and Foundation

The geological composition at the bridge site is riverbed sediment, and former talus layer and gneiss layer from the top. The former talus layer (30<N≦50 gravel layer) is desirable as a supporting stratum. In this case, since the depth of the supporting stratum of A1 abutment is shallow, spread foundation is selected. However, the depth of the supporting stratum on the A2 side is deep, spread foundation or open caisson foundation can be applied. For this bridge, in due consideration of damage by debris flow, bridge piers will not be applied. Since the high water level is EL+1996m based on the flood mark and hearing survey, even if the surface height is decided based on the elevation of the present road, the clearance under the girders is sufficient.

(5) Requirements for Superstructure Types

Due to the relatively gentle riverbed, if an approach road for heavy machinery from the national highway can be provided, support can be installed during the dry season due to approximately 8m of a vertical clearance. In this manner, each one of (a) temporary support with openings at the part of the flow ＋launching method, (b) temporary support ＋ crane erection or (c) an all staging method can be adopted. However, it is impossible to adopt PC-T girders since there is no space to temporarily place an erection or main girder between the front of the abutment and the national highway in the direction of the bridge axis.

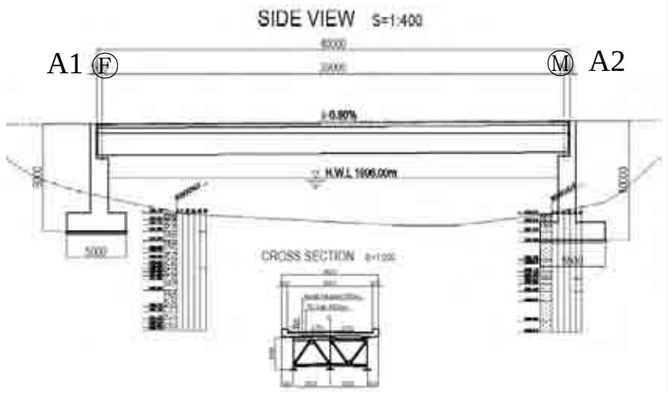
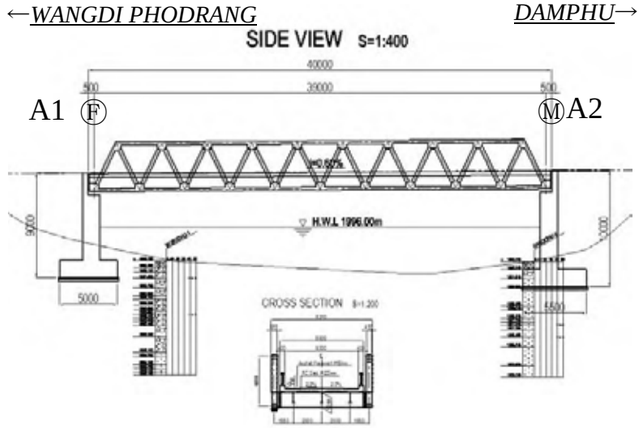
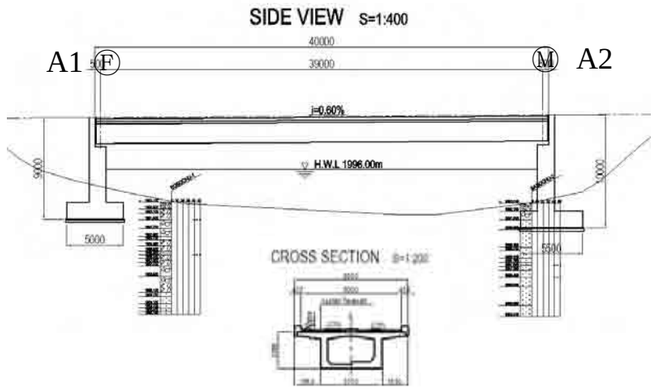
(6) Possible Superstructure Types (First Selection Results)

If the span length is approximately 40m, although the following four bridge types can be considered based on the past records, etc., from the results of the first selection in accordance with the above-mentioned requirements, three bridge types will be compared and examined as shown in the following table.

Bridge Type	Summary	Evaluation
1) **Composite simple steel I girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○
2) **Simple steel pony truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) PC post tensioning T girder bridge	Excluded from the examination due to lack of space for launching girders on both banks.	×
4) **Simple PC box girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○

(7) Bridge Type Study （BASOCHU Bridge）

Comparison of three bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

Bridge Type	Case-1 Composite Steel I Girder Bridge	Case-2 Simple Steel Pony Truss Bridge	Case-3 Simple PC Box Girder Bridge
General View	←*WANGDI PHODRANG* *DAMPHU*→ 	←*WANGDI PHODRANG* *DAMPHU*→ 	←*WANGDI PHODRANG* *DAMPHU*→ 
Outline	➢ Superstructure: Composite simple steel I girder bridge utilizing weathering steel ➢ Substructure: Inverted T-type spread foundation or open caisson foundation as the former talus layer is a bearing support layer on both A1 and A2 abutments is desirable. ➢ Structural problems: No structural problems arise due to bridge type and from the past results. ➢ Approach road: Since the elevation of the bridge surface will conform to the present road, grade will be 0.6%. ➢ Vertical clearance: Vertical clearance will be approximately 2.1m（＞1.0m), which is sufficient.	➢ Superstructure: Simple pony truss bridge utilizing weathering steel ➢ Substructure: Same as on the left. However, an abutment width will be approximately 10m. ➢ Structural problems: Bhutan has the five experiences of this bridge type, so no structural problem will arise. ➢ Approach road: Same as on the left ➢ Vertical clearance: Vertical clearance will be approximately 3.0m (＞1.0m), which is sufficient.	➢ Superstructure: Post tensioning type simple PC box girder bridge ➢ Substructure: Same as on the left. Abutment width will be 6.8m, which is the smallest. ➢ No structural problems will arise because member-related risk can be avoided since specified concrete design strength will be 30N/mm2. ➢ Approach road: Same as on the left ➢ Vertical clearance: Vertical clearance will be approximately (＞1.0m), which is sufficient.
Evaluation Item — Workability	➢ Although a transportation difficulty will arise due to taller steel elements compared to pony truss bridge, since web plate height will be 2.2m, no problems will arise. ➢ Although rigidity during the bridge construction is less than that of a pony truss bridge, the number of members is less and construction period is shorter.	➢ Each component section is small and advantageous from a transportation point of view. ➢ Since the number of members becomes more due to truss type, construction period is slightly longer.	➢ Construction through an all staging method is possible by working only in the dry season. ➢ Since most construction materials can be locally procured in Bhutan, it is unnecessary to transport large materials for constructing girders at site. ➢ Construction period is slightly longer than that of a steel bridge.
Evaluation Item — Construction Period	➢ The total construction period will be 22 months	➢ The total construction period will be 22 months.	➢ The total construction period will be 22 months.
Evaluation Item — Construction Cost	1.177 times	1.284 times	1.000 (basis)
Evaluation Item — Maintenance	➢ Since stable rust will settle by utilizing weathering steel, repainting is unnecessary so that maintenance can be minimized.	➢ Same as on the left	➢ The durability is basically superior. So maintenance will be the least.
Overall Evaluation	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost is the second highest among the three proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 2	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the highest among the three proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 3	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the lowest among the three proposed bridges. ➢ Maintainability will be the most superior. 1

3. Nyarachu Bridge

①General view

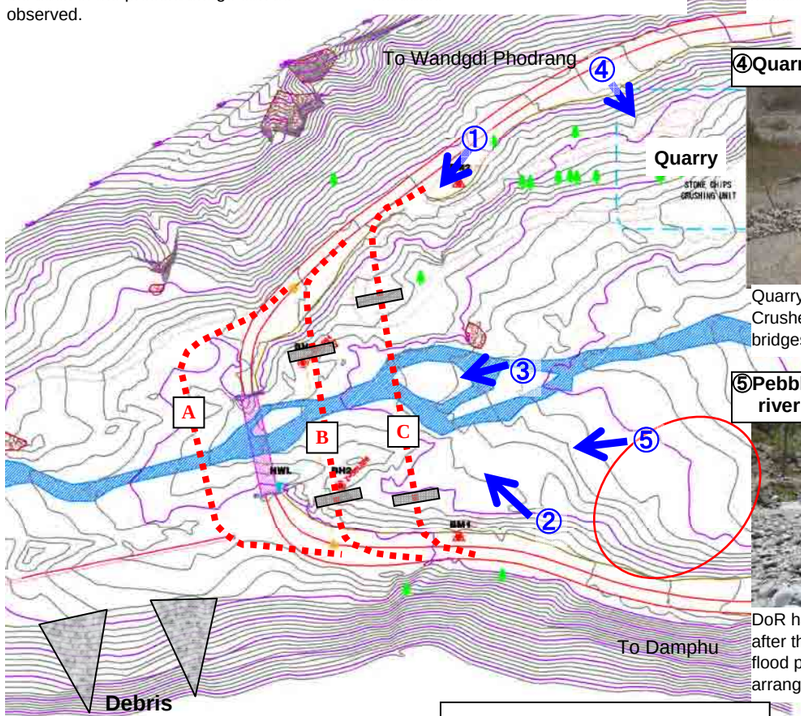
Talus layer that collapses repeatedly at the back of the present bridge can be observed.

②Outcrop of bedrock

Outcrop of bedrock on the slope on the left bank.

③Side View

Pebbles spread on riverbed and steep inclination of 3 to 4%.



④Quarry

Quarry at the side of Nyrachu Bridge. Crushed stone was utilized for the two bridges in Phase 2.

⑤Pebbles in riverbed

DoR has arranged pebbles accumulated after the flood. A pile of pebbles on the flood plain was created during the arrangement.

(1) Site Conditions

1) Located approximately 50km from Wangdi Phodrang.
2) The slope with 3 to 4% inclination of the river bed continues before and after the existing bridge. Pebbles resulted from an avalanche of debris flow spread all over the riverbed. The both sides of the river are surrounded by steep slope and there is the talus layer on the slope that repeats collapse (especially on the right bank).
3) Although pebbles spread resulted from an avalanche of debris flow spread in the vicinity of the abutment, rocks outcrop on the upper part of some slopes in the back of the both banks. Consequently, bedrock is considered to exist even in the underground in the vicinity of the abutment.
4) At the recent maximum flood time (September 2007), the water level rose up to the existing bridge surface and water poured into the bridge surface from the approach road. In addition, pebbles accumulated some 10m on the riverbed. Accordingly, DoR has arranged the riverbed after the flood.
5) A quarry is located in the vicinity of 140m on the valley side on the left bank. The crushed stones from the quarry were effectively utilized for the construction of Wakleyter and Sunkosh Bridges in Phase 2.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Cost	Evaluation
A	Inappropriate route due to the talus layer on the slope that repeatedly collapses at the back of the abutment.	—	×
B	Feasible route. It is the similar to C in road alignment. However, this is more economical because bridge length is about 10m shorter than route C.	1.00	○
C	Feasible route. Although it road alignment is the similar to that of route C, the bridge length is about 5m longer, so this route is considered to be uneconomical.	1.10	△

(3) Abutment Position and Hindrance

Both abutments (A1 on the Wangdi Phodrang side and A2 on the Dumphu side) can be installed at a relatively flat spot. Based on the findings of the topographical survey, if the bridge length is as short as possible within the dead water region in order to be protected by the abutment of the present bridge during a flood, the bridge length becomes approximately 40m.

(4) Topographic, Geological and Hydrological Conditions and Foundation

The geological composition at the bridge site is riverbed sediment and former talus layer in the upper section. The former talus layer (30<N≦50 gravel layer) is desirable as the load supporting stratum. Although spread foundation is desirable due to the deep talus layer at both abutment locations, a foundation such as an open caisson method will also be examined. The bridge is periodically dredged due to accumulation of boulders transported during flood time. In addition, since the water level rose to the present bridge surface during a flood in 2007, the vertical clearance from this water level (EL+526m) will be raised 1.0m so that the surface elevation of the bridge will increase.

(5) Requirements for Superstructure Types

Due to the relatively gentle riverbed, heavy machinery from the national highway can enter and vertical clearance is approximately 6m, so temporary supports can be installed. Therefore, each of (a) temporary supports with openings in the the river ＋launching method, (b) temporary supports ＋ crane erection or (c) an all staging method can be adopted. However, it is impossible to adopt PC-T girders since there is no space to temporarily install an erection or main girder between the front of the abutment and the national highway in the direction of bridge axis.

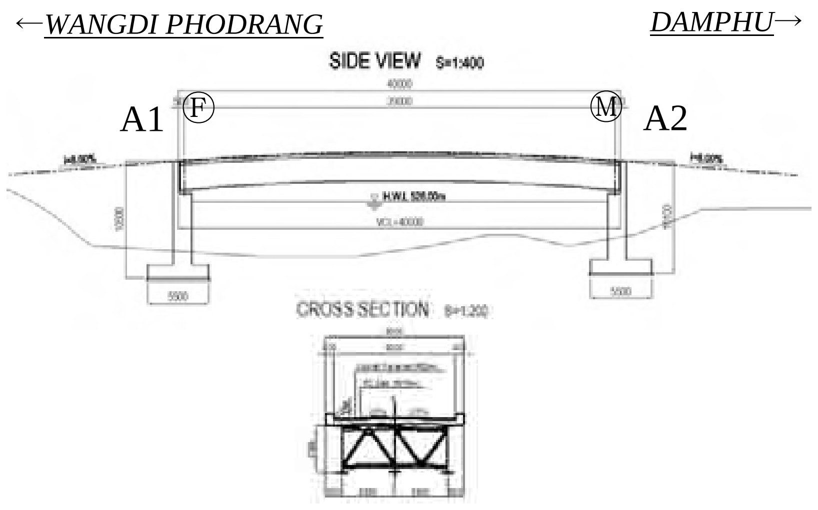
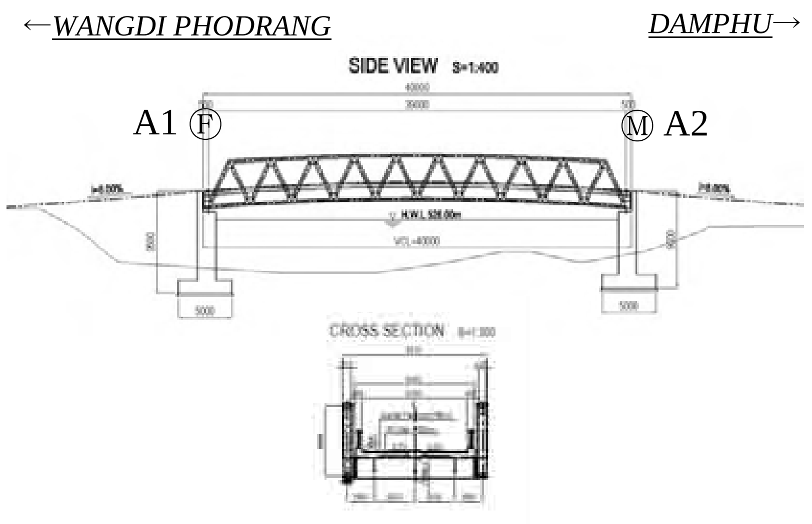
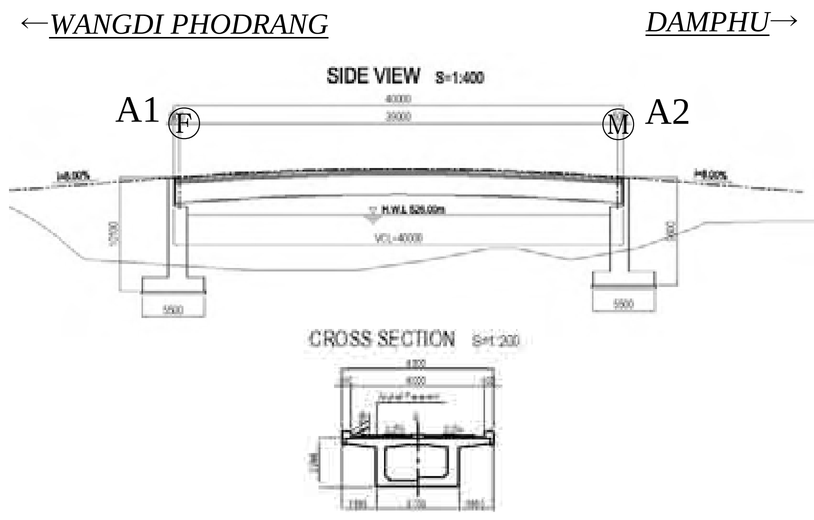
(6) Possible Superstructure Types (First Selection Results)

In case of the span length is approximately 40m, although the following four bridge types can be considered based on the past records, etc., from the results of the first selection in accordance with the above-mentioned requirements, the three bridge types will be compared and examined as shown in the following table.

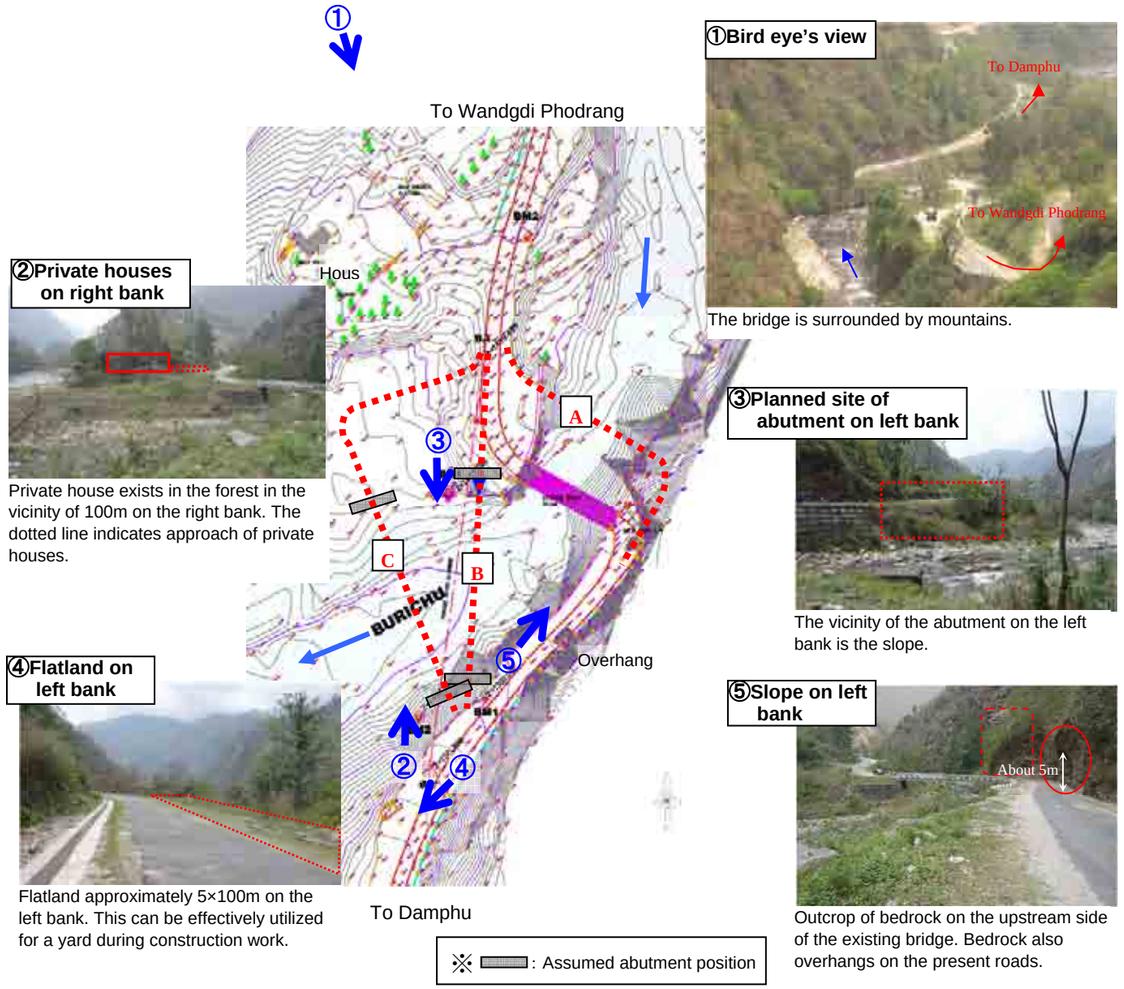
Bridge Type	Summary	Evaluation
1) **Composite simple steel I girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○
2) **Simple steel pony truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) PC post tensioning T girder bridge	Excluded from the examination due to lack of space for launching girders manufactured at the yard on both banks.	×
4) **Simple PC box girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○

(7) Bridge Type Study (NYARACHU Bridge)

Comparison of three bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

Bridge Type		Case-1 Composite Steel I Girder Bridge	Case-2 Simple Steel Pony Truss Bridge	Case-3 Simple PC Box Girder Bridge
General View				
Bridge Outline		➢ Superstructure: Composite simple steel I girder bridge utilizing weathering steel ➢ Substructure: Inverted T-type spread foundation or open caisson foundation as the former talus layer is a bearing support layer on both A1 and A2 abutments is desirable. ➢ Structural problem: No structural problems arise due to the bridge type and from the post results. ➢ Approach road: When considering HWL, elevation of the bridge surface will be higher than the present bridge; vertical curve will be inserted by adopting 8% of the maximum grade. ➢ Vertical clearance: As vertical clearance, the minimum 1.0m from HWL will be secured.	➢ Superstructure: Simple pony truss bridge utilizing weathering steel ➢ Substructure: Same as on the left. However, abutment width will be approximately 10m. ➢ Structural problem: Bhutan has five experiences of this bridge type. So no structural problem will arise. ➢ Approach road: Same as on the left ➢ Vertical clearance: Same as on the left	➢ Superstructure: Simple post tension type PC box girder bridge ➢ Substructure: Same as on the left. However, abutment width will be 6.8m, which is the smallest. ➢ No structural problems will arise because member-related risk can be avoided since specified concrete design strength will be 30N/mm2. ➢ Approach road: Same as on the left ➢ Vertical clearance: Same as on the left ➢
Evaluation Item	Workability	➢ Although transportation difficulty will arise due to higher steel elements compared to the pony truss bridge, web plate height will be 2.2m, so no problems will arise. ➢ Although rigidity during the bridge construction is less than that of a pony truss bridge, the number of members is less and the construction period is shorter.	➢ Steel elements are small in size and advantageous to transportation. ➢ Since the number of steel elements becomes greater, the construction period is slightly longer.	➢ Construction through an all staging method is possible by working only in the dry season. ➢ Since most of construction materials can be locally procured in Bhutan, it is unnecessary to transport large materials for constructing girders at site. ➢ A construction period is slightly longer than that of a steel bridge.
	Construction Period	The total construction period will be 22 months.	The total construction period will be 22 months.	The total construction period will be 22 months.
	Construction Cost	1.205 times	1.307 times	1.000 (basis)
	Maintenance	➢ Since stable rust will settle by utilizing weathering steel, a repainting is unnecessary so that maintenance can be minimized.	➢ Same as on the left	➢ The durability is basically superior., so maintenance cost will be the lowest.
Overall Evaluation		➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the second highest among the three proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 2	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the highest among the three proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 3	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the cheapest among the three proposed bridges. ➢ Maintainability will be the most superior. 1

4. Burichu Bridge



①Bird eye's view

The bridge is surrounded by mountains.

②Private houses on right bank

Private house exists in the forest in the vicinity of 100m on the right bank. The dotted line indicates approach of private houses.

③Planned site of abutment on left bank

The vicinity of the abutment on the left bank is the slope.

④Flatland on left bank

Flatland approximately 5×100m on the left bank. This can be effectively utilized for a yard during construction work.

⑤Slope on left bank

Outcrop of bedrock on the upstream side of the existing bridge. Bedrock also overhangs on the present roads.

※ : Assumed abutment position

(1) Site Conditions

1) Located approximately 63km from Wangdi Phodrang.
2) The main stream of Sunkosh River flows in the vicinity of 180m on the valley side of the present bridge. The riverbed is 2m higher at 1 to 2% of inclination than the main stream. Although the water depth rose approximately 3m at flood time, the river channel is stable.
3) Private house exists in the vicinity of 100m on the right bank. Although the approach of private house may be utilized as lot for the approach road, it is within the RoW of DoR, and so no problems will arise.
4) Since there is flatland of approximately 5m wide×100m in length before and after the existing bridge, this can be effectively utilized for a yard during construction work.
5) Overhang rock approximately 5m overhead exists in the vicinity of 25m on the left bank of the existing bridge.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Cost	Evaluation
A	Impossible due to no lot for road because bluff bedrock slope exists on the left bank.	—	×
B	Feasible route. This is an ideal route with reasonable alignment. The impact (fear of collapse) resulting from excavation on the exiting retaining wall is expected, alignment avoiding the existing retaining wall is preferred. Since the bridge length will be about 50m, the construction range will be smaller than that of route C. Therefore, this will be more economical than route C.	1.00	○
C	Feasible route. The aim is to construct a square bridge by crossing at right angles to the river. Although the bridge length will be about 50m, the approach road will be extremely longer than route B so construction range becomes wider. Consequently, this will be less economical than route C.	1.10	△

(3) Abutment Position and Hindrance

Since the proposed location of the abutment (A1) on the Wangdi Phodrang side is surrounded by approximately a 6m retaining wall and the river section appears clear, it will be installed on the land side from the existing retaining wall. On the other hand, the scheduled location of the abutment A2 on the Dumphu side will be installed in a dead water region that will be provided by the abutment of the present bridge. As the result, the bridge length will be approximately 50m.

(4) Topographic, Geological and Hydrological Conditions and Foundation

Since the geological composition on the bridge site is different on the A1 side and A2 side, the composition on the A1 side is the former talus layer and gneiss layer in the upper section from the top; whereas, that on the A2 side is terrace deposits and gneiss layer from the top. As for the supporting stratum, the former talus layer and terrace deposit (30<N≦50 gravel layer) can be selected, so spread foundation is desirable for both abutments. In due consideration of collision of debris flow and boulders on the bridge piers, the piers will not be installed. Since the high water level is EL+1494m based on the flood mark and hearing survey, even if the surface height is determined from the elevation of the present road, the allowance under the girders is sufficient.

(5) Requirements for Superstructure Types

Due to the relatively gentle riverbed, heavy machinery from the national highway can enter and the vertical clearance is approximately 10m or less, so temporary supports can be installed during the dry season. Therefore, each one of (a) temporary supports with openings in the river ＋launching method, (b) temporary supports ＋ crane erection or (c) an all staging method can be adopted.

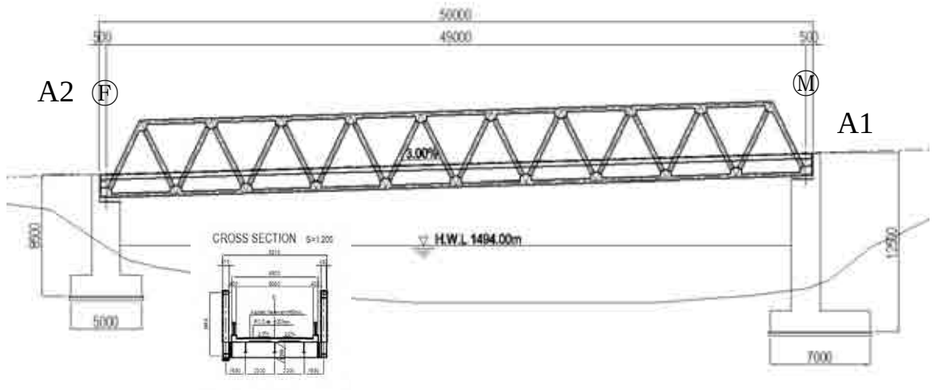
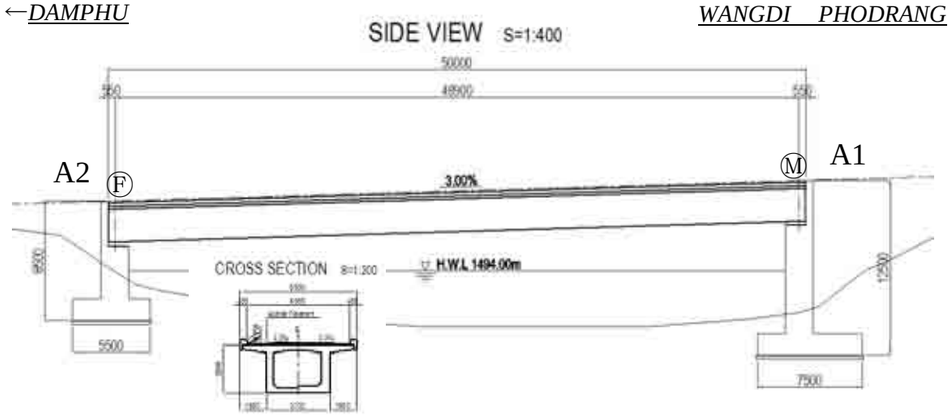
(6) Possible Superstructure Types (First Selection Results)

In case the span length is approximately 50m, although the following four bridge types can be considered based on the results, etc., as the results of the first selection in accordance with the above-mentioned requirements, two bridge types will be compared and examined as shown in the following table.

Bridge Type	Summary	Evaluation
1) Composite simple steel I girder bridge	Largest class structure (bridge length of 45m or longer). Inappropriate because it is uneconomical.	×
2) **Simple steel pony truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) **Simple PC box girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○
4) Simple RC through-type arch bridge	Structure and construction is more complicated than (3) PC-BOX (girder bridge) so that construction will be clearly be uneconomical. So this will be excluded from the type for comparison.	×

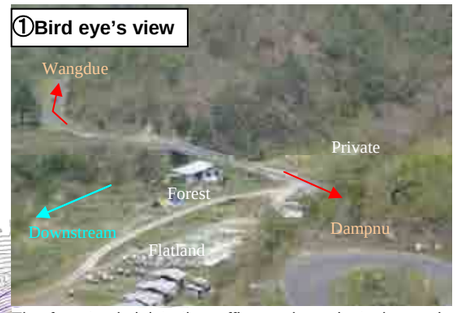
(7) Bridge Type Study (BURICHU Bridge)

Comparison of two bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

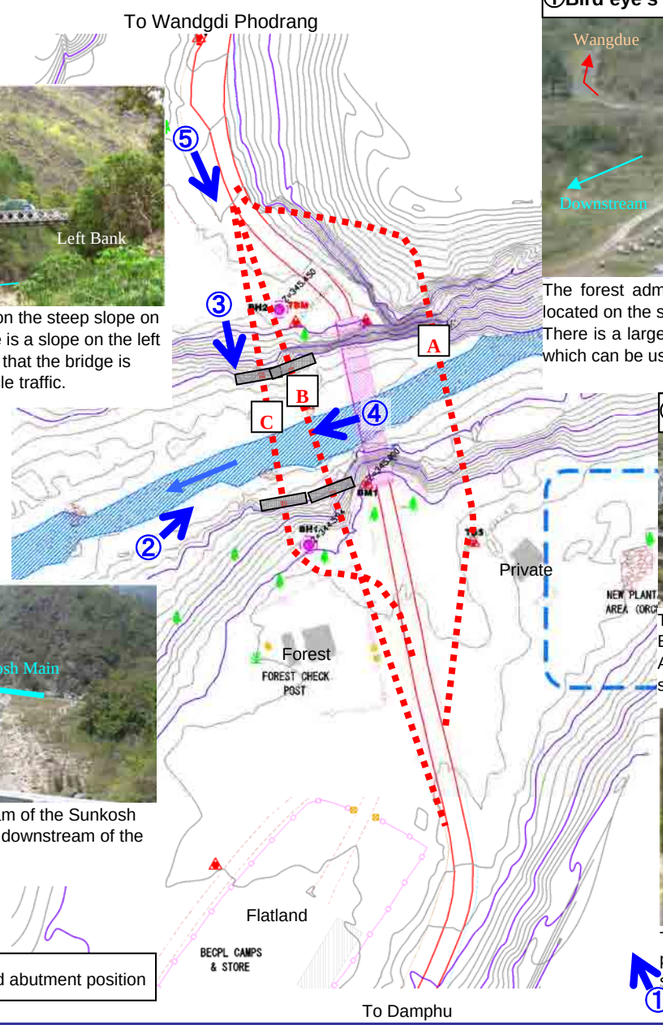
Bridge Type		Case-1 Simple Steel Pony Truss Bridge	Case-2 Simple PC Box Girder Bridge
General View		←*DAMPHU* SIDE VIEW S=1:400 *WANGDI PHODRANG* 	←*DAMPHU* SIDE VIEW S=1:400 *WANGDI PHODRANG* 
Bridge Outline		➢ Superstructure: Simple pony truss bridge utilizing weathering steel ➢ Substructure: A spread foundation method will be prominent for both A1 and A2 abutments. Abutment width will be 10.0m, which is wider than that of a simple PC box girder bridge. ➢ Structural problem: Bhutan has five experiences of this bridge type, so no structural problem will arise. ➢ Approach road: A surface elevation will conform to the present road elevation and grade will be 3.0%. ➢ Vertical clearance: A vertical clearance will be approximately 3.4m (＞1.0m), which is sufficient..	➢ Superstructure: Simple post tension type PC box girder bridge ➢ Substructure: Same as on the left. However, abutment width will be 6.8m, which is the minimum. ➢ No structural problems will arise because member-related risk can be avoided since specified concrete design strength will be 30N/mm2. ➢ Approach road: Same as on the left ➢ Vertical clearance: Vertical clearance will be approximately 2.0m (＞1.0m), which is sufficient.
Evaluation Item	Workability	➢ Steel elements are small in size and advantageous to transportation. ➢ Since the number of elements will be greater, construction period will be slightly longer.	➢ Construction through an all staging method is possible by working only in the dry season. ➢ Since most of construction materials can be locally procured in Bhutan, it is not necessary to transport large materials for constructing girders at site. ➢ Construction period is slightly longer than that of a steel bridge.
	Construction Period	The total construction period will be 22 months.	The total construction period will be 22 months.
	Construction Cost	1.316 times	1.000 (basis)
	Maintenance	➢ As stable rust will settle by utilizing weathering steel, a repainting is unnecessary so that maintenance can be minimized.	➢ Durability is basically superior. So maintenance will be the lowest.
Overall Evaluation		➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the second highest among the two proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 2	➢ Same as on the left ➢ This will be cheaper than the pony truss type. ➢ There is no difference in maintenance. 1

5. Chanchey Bridge

Outcrop of bedrock on the steep slope on the right bank. There is a slope on the left bank. It can be seen that the bridge is sagging due to vehicle traffic.

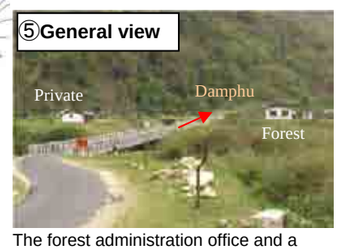


The forest administration office and a private house is located on the side of the existing bridge on the left bank. There is a large area of flatland in the back of the office, which can be used for a yard during construction work.



There is a forest administration office on routes B and C. There is a high possibility of relocation. Abutments will be installed on the slope on the side of the existing retaining wall.

It joins the main stream of the Sunkosh River at a spot 280m downstream of the existing bridge.



The forest administration office and a private house is located on the immediate side of the existing bridge.

※ ▭: Assumed abutment position

(1) Site Conditions

1) Located approximately 69km from Wangdi Phodrang.
2) The main stream of Sunkosh River flows in the vicinity of 280m on the valley side of the present bridge. The riverbed is 2m higher at 2 to 3% of inclination than the main stream. Although the water depth rose approximately 3m at the flood time, the river section appears clear so that the river channel is stable.
3) The forest administration office and the private house is located in the vicinity of 20m on the left bank. Since both land and building of the office are owned by the government, as an occasion arises, a possibility of relocation was confirmed.
4) There is the vast flatland in the back of the forest administration office on the left bank, which is utilized for a stock yard of other projects. This place can be effectively utilized for a yard at the time of construction work.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Cost	Evaluation
A	Impossible due to lack of space because bluff bedrock slope exists on the left bank.	—	×
B	Feasible route. This is an ideal route a reasonable alignment. An approach road is shortened by moving alignment to slightly left. It is confirmed that no problems would arise because the forest administration office is owned by the government.	1.00	○
C	Feasible route. Route aimed at the shortest approach road. A steep curve must be created after the straight line of this route, so there is a high possibility of traffic accidents or congestion. This alignment is therefore not favorable.	1.00	△

(3) Abutment Position and Hindrance

Since the proposed location of the abutment (A1) on the Wangdi Phodrang side is surrounded by approximately 15m retaining wall and river section is clear, it will be installed on the land side from the existing retaining wall. On the other hand, the scheduled location of the abutment A2 on the Dumphu side will be installed in a dead water region that will be provided by the abutment in the river of the present bridge. As the result, the bridge length will be approximately 45m. The forest administration office on the Dumphu side should be relocated.

(4) Topographic, Geological and Hydrological Conditions and Foundation

The geological composition on the bridge spot at both A1 and A2 sides is terrace deposit. As for the supporting stratum, terrace deposit (30<N≦50 gravel layer) can be selected, so spread foundation is desirable for both abutments. In due consideration of the collision of debris flow or boulders on the bridge piers, the piers will not be installed. Since the high water level is EL+336m based on the flood mark and hearing survey, even if the surface height is decided by the elevation of the present road, the clearance under girders is sufficient.

(5) Requirements for Superstructure Types

Although the vertical clearance is approximately 6m, since heavy machinery from the national highway can enter due to relatively gentle riverbed, temporary supports can be installed during the dry season. Therefore, each one of (a) temporary supports that with openings in the river ＋launching method, (b) temporary supports ＋ crane erection or (c) an all staging method can be adopted.

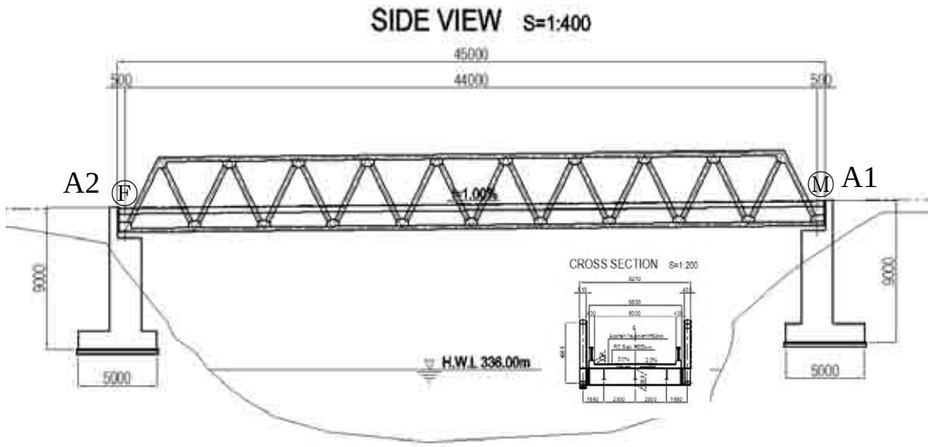
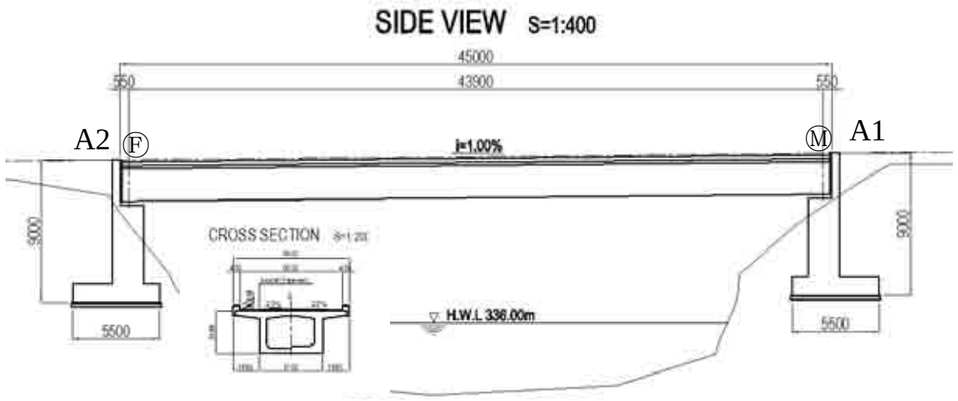
(6) Possible Superstructure Types (First Selection Results)

In case the span length is approximately 45m, although the following four bridge types can be considered based on the past records, etc., from the results of the first selection in accordance with the above-mentioned requirements, two bridge types will be compared and examined as shown in the following table.

Bridge Type	Summary	Evaluation
1) Composite simple steel I girder bridge	Largest class structure (bridge length of 45m or longer). Inappropriate because it is uneconomical.	×
2) **Simple steel pony truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) **Simple PC box girder bridge**	Bridge type that is feasible to construct at the bridge construction position	○
4) Simple RC through-type arch bridge	Structure and construction is more complicated than (3) PC-BOX (girder bridge) so that a construction will be clearly uneconomical.	×

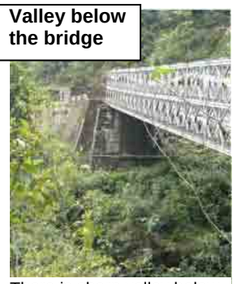
(7) Bridge Type Study (CHANCHEY Bridge)

Comparison of two bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

Bridge Type		Case-1 Simple Steel Pony Truss Bridge	Case-2 Simple PC Box Girder Bridge
General View			
Bridge Outline		➢ Superstructure: Simple pony truss bridge utilizing weathering steel with no structural problems ➢ Substructure: A spread foundation method will be influential for both A1 and A2 abutments as the former talus layer is a bearing support layer. Abutment width will be 10.0m, which is comparatively wider than that of a simple PC box girder bridge. ➢ Structural problem: Bhutan has five experiences of this bridge type, so no structural problem will arise. ➢ Approach road: Elevation of the bridge surface will conform to the present road elevation and grade will be 1.0%. Same as on the left ➢ Vertical clearance: A vertical clearance will be approximately 8.8m (＞1.0m), which is sufficient.	➢ Superstructure: Simple post tension type PC box girder bridge ➢ Substructure: Same as on the left. However, abutment width will be 6.8m, which is the minimum. ➢ No structural problems will arise because member-related risk can be avoided since specified concrete design strength will be 30N/mm2. ➢ Approach road: Same as on the left ➢ Vertical clearance: Vertical clearance will be approximately 7.6m (＞1.0m), which is sufficient.
Evaluation Item	Workability	➢ Steel elements are small and advantageous to transport. ➢ Since the number of members will be greater, construction period will be slightly longer.	➢ Construction through an all staging method is possible by working only in the dry season. ➢ Since most of construction materials can be locally procured in Bhutan, it is unnecessary to transport large materials for constructing girders at site. ➢ A construction period is slightly longer than that of a steel bridge.
	Construction Period	The total construction period will be 22 months.	The total construction period will be 22 months.
	Construction Cost	1.267 times	1.000 (standard)
	Maintenance	➢ As stable rust will settle by utilizing weathering steel, a repainting is unnecessary so that maintenance can be minimized.	➢ Durability is basically superior. So maintenance will be the lowest.
General Evaluation		➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be the second highest among the two proposed bridges. ➢ By utilizing weathering steel, there is no difference in maintenance. 2	➢ Same as on the left ➢ It is cheaper than a pony truss type. ➢ There is little difference in maintenance. 1

6. Loring Bridge

① Valley below the bridge



There is sharp valley below the bridge.

② Waterfall on mountain side

Waterfall on mountain side. More waterfalls in addition to this during the rainy season.

③ General view

There is a steep slope at the back and sharp valley below the bridge.

④Debris pit on right bank

Debris pits on the right bank. The abutments will be installed by avoiding these.

⑤Waterfall during the rainy season

More waterfalls arise in the back of the bridge during the rainy season.

⑥Open-cut rock

Open-cut rock on the left bank. The abutments will be installed after cutting the rock.

(1) Site Conditions

1) Located approximately 18km from Sarpang. This is fairly away from other five bridges.
2) The mountain side of the existing bridge is surrounded by a few waterfalls and the steep slope containing debris pits and presents land form of the steep valley exceeding 50m of the depth on the valley side.
3) Since the number and amount of waterfalls increases in the rainy season, falling stones from the talus in the vicinity frequently occur. In addition, water comes into the road and hinders traffic.
4) Flatland hardly exists along the road and in the vicinity of the bridge, so a construction yard will be limited. In addition to narrow road in the vicinity, some points are predicted not to secure an enough width of an approach road sufficiently. In such a manner, the construction of Loring Bridge faces extremely severe conditions.

(2) Route Study

The following 3 routes can be considered.

Route	Summary	Cost	Evaluation
A	Impossible because a few debris pits exist on the route and the route is buried under the waterfalls.	–	×
B	Feasible route. There is no fear of mudslides due to the bedrock slope before and after the bridge. This is the ideal route for this bridge.	1.00	○
C	Feasible route. However, due to debris pits on the slope in the back of the abutments on the right bank, there is a fear of bridge damage from mudslides or suspension of traffic. Thus, this route is greatly inferior to route B in traffic safety.	1.00	×

(3) Abutment Position and Hindrance

The abutment (A1) at Dumphu side, which is sandwiched between, does not have much space due to the towering cliff and steep valley. Accordingly, for the purpose of securing location for the abutment and installing it in front (forward) as much as possible, abutment will be installed by excavating rock on the valley side of the present road. The abutment on the Sarpang side will be constructed on the slope on the valley side of the present road in order to secure traffic on the present road and to smooth the approach road. In this case, the bridge length will be approximately 70m. Natural ground at the back of the abutment should be excavaed in order to secure the width of an approach road on the Dumphu side.

(4) Topographic, Geological and Hydrological Conditions and Foundation

Due to the outcropping of gneiss on the A1 abutment side, spread foundation will be selected. On the A2 abutment side, the former talus layer is thinly accumulated and gneiss exists underneath. Since the supporting stratum is inclined at approximately 45° on the valley side, gneiss will be selected for supporting stratum. As the excavation of the A2 abutment side may be extended to the national highway, although spread foundation will be applied in principle, caisson pile method will be also examined.

(5) Requirements for Superstructure Types

There is a deep valley under the girders and a steep slope, so it is difficult to install temporary supports. In addition, cranes cannot enter under the bridge and will be utilized only for approach areas on both sides. Accordingly, a cable election ＋ vertical hanging construction can be considered as a bridge construction method.

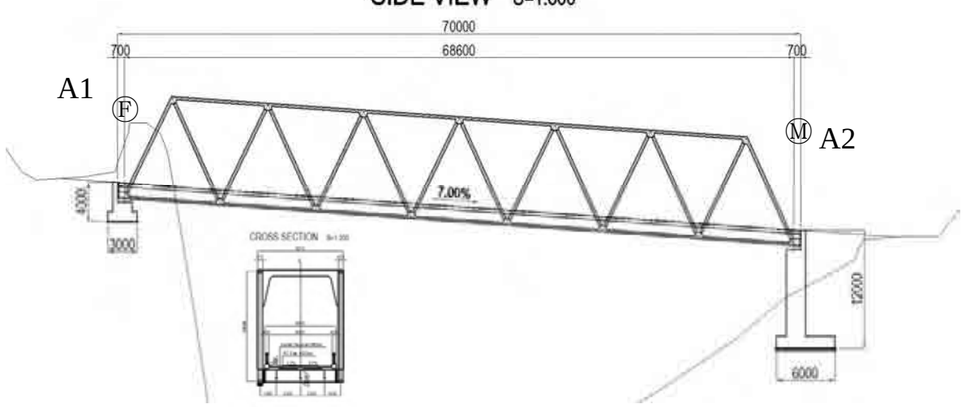
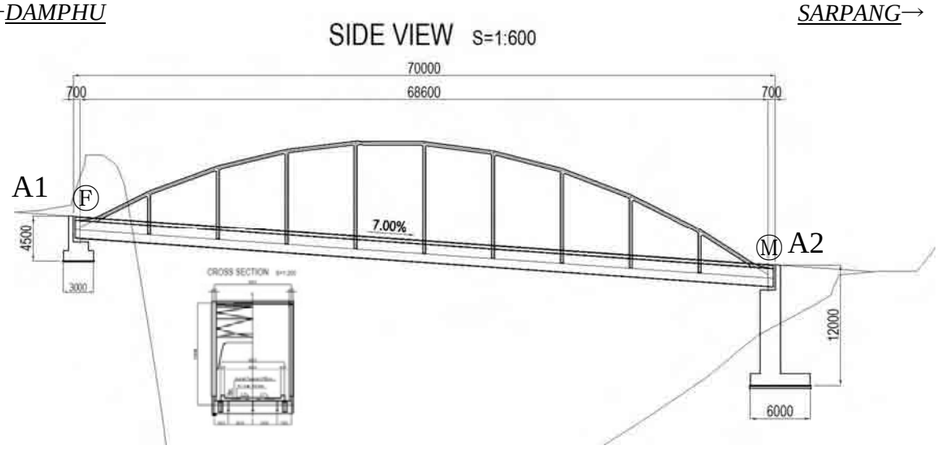
(6) Possible Superstructure Types (First Selection Results)

In case a span length is approximately 70m, although the following four bridge types can be considered based on the past records, etc., as the results of the first selection in accordance with the above-mentioned requirements, two bridge types will be compared and examined as shown in the following table.

Bridge Type	Summary	Evaluation
1) **Simple steel through-type truss bridge**	Bridge type that is feasible to construct at the bridge construction position	○
2) **Simple Steel Langer bridge**	Bridge type that is feasible to construct at the bridge construction position	○
3) Simple steel through-type arch bridge	Due to curved members, one block during transportation becomes larger. The transport route until this bridge is narrow and many overhangs (about 3m) exist, so there are so many topographical limits. Thus, this type in which transportation blockage is great is not appropriate. This type will be excluded from the examination.	×
4) Simple RC through-type arch bridge	Impossible to construct this type, because it becomes impossible to build timber for bridge erection due to steep valley and deep land formations.	×

(7) Bridge Type Study (LORING Bridge)

Comparison of two bridges under consideration at the construction site from the viewpoint of workability and economic efficiency

Bridge Type		Case-1 Simple Steel Through-Type Truss Bridge	Case-2 Simple Steel Langer Bridge
General View		←*DAMPHU* SIDE VIEW S=1:600 *SARPANG*→ 	←*DAMPHU* SIDE VIEW S=1:600 *SARPANG*→ 
Bridge Outline		➢ Superstructure: Simple steel through type truss bridge utilizing weathering steel ➢ Substructure: Spread foundation will be applied on the A1 abutment on bed rock, whereas, a spread foundation or caisson pile method will be applied on the A2 abutment on the former talus layer. ➢ Structural problem: No structural problems arise due to the many past projects. ➢ Approach road: The slope face on the A1 side should be excavated on a large scale in order to secure the minimum curve radius. In addition, a maximum grade of approximately 7% as a longitudinal grade will be adopted since the present road elevation is different. ➢ Vertical clearance: Vertical clearance will be sufficient due to the deep valley.	➢ Superstructure: Simple Langer bridge utilizing weathering steel ➢ Substructure: Same as on the left ➢ Structural problem: Bhutan has four past experiences of this bridge type, so no structural problems will arise. ➢ Approach road: Same as on the left ➢ Vertical clearance: Same as on the left
Evaluation Item	Workability	➢ It is difficult to install temporary supports due to the deep valley and steep slope at the bridge construction site. Consequently, since the use of cranes will be limited only to the back of the abutment of both sides, a cable erection vertical hanging construction method can be considered. Rock anchors will be installed halfway up the mountain as cable anchors. ➢ The number of steel elements will be larger than that of a Langer bridge.	➢ Same as on the left ➢ The number of members will be smaller than that of a truss bridge, which is advantageous.
	Construction Period	The total construction period will be 24 months.	The total construction period will be 24 months.
	Construction Cost	1.046 times.	1.000 (basis)
	Maintenance	➢ As stable rust will settle by utilizing weathering steel, a repainting is unnecessary so that maintenance can be minimized.	➢ Same as on the left
General Evaluation		➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be inferior to that of a Langer bridge. ➢ By utilizing weathering steel, there is no difference in maintenance. 2	➢ There is little difference in structural property, workability and construction period. ➢ Construction cost will be cheaper than that of a truss bridge. ➢ By utilizing weathering steel, there is no difference in maintenance. 1