Department of Roads
Ministry of Works and Human Settlement
Royal Government of Bhutan

Preparatory Survey Report on Project for Restoration and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan

July 2011

Japan International Cooperation Agency

INGEROSEC Corporation

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey on the Reconstruction and Improvement of Vital Infrastructure for Cyclone Disaster in the Kingdom of Bhutan, and organized a survey team headed by Mr. Takeo MOGAMI of INGEROSEC Corporation from November 2010 to June 2011.

The survey team held a series of discussions with the officials concerned of the Royal Government of Bhutan, and conducted field investigations. As a result of further studies in Japan, 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.

Finally, I wish to express my sincere appreciation to the officials concerned of the Royal Government of Bhutan for their close cooperation extended to the survey team.

July 2011

Mr. Kiyofumi Konishi
Director General,
Economic Infrastructure Department
Japan International Cooperation Agency

SUMMARY

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1. Outline of the Country

The Kingdom of Bhutan (hereinafter referred to as "Bhutan") is a landlocked country that lies adjacent to the Tibet Autonomous Region in the southwestern part of China and the state of Assam in the northeastern part of India. In the northern part of the country are the Himalaya Mountains, with altitudes of over 7,000m. Several rivers run southwards from the mountains, forming deep valleys up to 150km long and joining the Brahmaputra River in Assam, India.

The climate of Bhutan is temperate. It consists of the monsoon season from June to September in which precipitation is high, and the dry season, from November to March. The remaining months belong to the intermediate season. The temperature drops close to -5℃ in the winter months of December and January, and rises to around 25℃ in summer, around July.

The population of Bhutan is 671,000 (2009; the Royal Government of Bhutan, hereinafter referred to as "RGB") and the capital is Thimphu. With respect to the economy, the gross national income (GNI) is 2,020 US$ per capita (2009; World Bank), which remains low in comparison with neighboring countries; but social conditions are stable as the economic growth rate in recent years has been 5.0% (2008; RGB) and the un-employment rate has remained at the relatively low level of 4% (2010; RGB). With about 80% of imports and exports coming from or going to India, Bhutan has close connections with its neighbor, India.

2. Background, History and Outline of the Project

Since the land of Bhutan is in steep mountain ranges for the most part, roads and bridges provide the most important means of traffic and transportation. However, more than 20% of the households in the country cannot reach a vehicle road on foot in less than half a day. Insufficient maintenance condition and absolute shortage of roads are the biggest obstacles to development in Bhutan, impeding access to social services and market especially in the rural area. Therefore, development of safe and efficient road networks and bridges is essential to the socioeconomic development of Bhutan.

In fact, to cope with such problems, the Royal Government of Bhutan has set up the 10th Five-Year Plan (2008-2013), which advocates the importance of balanced development of the urban and rural areas and strategic infrastructure development and designate repair and maintenance of arterial roads, development of access road networks in the rural area, maintenance and repair of existing roads and bridges and reconstruction of existing bridges as priority issues.

Cyclone Aila, which struck South Asia on the 26th and 27th May 2009, brought torrential rains to Bhutan and 320 died that is the largest number in the first half of the year. It is reported that, including India and Bangladesh, more than 100,000 people escaped and more than 100,000 houses had been damaged by the cyclone. In spite of the assistance announced by India, Denmark, Austria and UN etc. after the

disaster, reconstruction had not shown a significant progress although nearly two years had passed since then. The residents are still deprived of access to facilities necessary for daily life.

Reference shall also be made regarding the natural conditions of Bhutan that there is a glacier lake in the upper reaches of the Mandechhu River and this being the case the possibility of a GLOF (Glacier Lake Outburst Flood) occurring in the future cannot be denied, and that Bhutan is in the hazardous area of earthquakes. In addition, the road traffic is closed by landslides and floods during the rainy season and by road surface freezing and snow mantle. Thus, the life of Bhutanese people is greatly affected by the natural conditions.

Under these circumstances, in September 2009, RGV requested Japan to implement a grant aid program, the "Program for Reconstruction of Vital Infrastructures Damaged by Cyclone Aila". In response to this request, the local office of the Japan International Cooperation Agency (JICA) carried out a survey to verify the relevance of the program as a grant aid program of Japan. In the survey, JICA defined the target of the program as the rebuilding of bridges, and carried out a screening study to identify the bridges requiring urgent attention. Following to the survey, JICA decided to implement a project formulation survey and carried out "The Preliminary Survey for the Reconstruction of Vital Infrastructures Damaged by Cyclone Aila" from August to September 2010. On the basis of the results of this survey, JICA made the decision to implement the "Preparatory Survey for Reconstruction of Vital Infrastructures Damaged by Cyclone Aila" on the nine bridges most urgently in need of reconstruction.

This Project, which involves the construction of bridges at Dolkhola and Jigmiling on the National Highway No. 5 and Mandechu (Reotala), Kela and Jangbi on the access road connecting to the National Highway No. 4, is expected to contribute to the improvement of access for local residents by restoring the bridges that were destroyed by a cyclone and the securing of access to provide for the cyclones that may hit this area in the future. In these constructions, replacement of the existing bridges at Dolkola and Jigmiling with permanent ones and substructure work in the construction of temporary bridges at Mandecchu (Reotala), Kela and Jangbi in this project should be covered by the grant aid scheme.

In "Bhutan 2020" (constituted in 1999), the national development outline of Bhutan, the renovation of the trunk roads and the construction of the feeder roads (branch roads accessing to trunk roads) so that all Bhutanese people can access to the trunk roads in half a day are stated as the objectives. The construction of feeder roads of municipality level is also stated in "Road Sector Master Plan (2007 – 2027)". In addition, it is stated in "the 10th Five-Year Plan (2008 – 2013)" that "Access to the trunk roads shall not be more than 2 hours (the objective has been upwardly revised according to the rapid progress of development)" and that renovation of the trunk roads, reinforcement of feeder roads, maintenance and repair of the existing roads & bridges and replacement etc. As stated above, this project corresponds to the long-term, the mid-term and the short-term development policies of Bhutan.

3. Selection of the Bridges to be Covered by the Project

Among nine bridges that were scheduled to be surveyed, No. 3 Naja/Geling Haa Chhu Suspension Bridge and No. 21 Chanchey Bridge were excluded for the following reasons. Thus, it was decided to carry out the survey on seven bridges.

(1) No. 3 Naja/Geling Haa Chhu Suspension Bridge

Construction of a new bridge has already started at a point 75m upstream of the existing bridge.

(2) No. 21 Chanchey Bridge

Preparations are underway to construct a new bridge (Bailey bridge) at a point 800m upstream of the existing bridge.

For the above-mentioned reasons, seven bridges were selected as the scope of survey from nine bridges. The priorities of the site were determined as shown in Table 1 by evaluating these seven bridges in terms of urgency, benefit, importance of the road, possibility of being damaged in the event of a disaster of an equivalent scale, and degree of difficulty in construction. The priority is in order of No.9 Mandechhu (Reotala) Bridge, No. 17 Dolkhola Bridge, No. 18 Jigmiling Bridge, No. 19 Kela Bridge and No. 20 Jangbi Bridge. No. 16 Dzongkhachulum Bridge and No. 5 Tshendona Bridge were judged to be of less necessity of reconstruction. Thus, the top five prioritized bridges were determined to be covered by the grant aid project.

Table 1 Site Priorities

No	Bridge name	Urgency	Scale of beneficiaries	Importance of the route	Possibility of suffering damage caused by a similar disaster	Difficulty of construction (implementation by the Bhutanese side)	Score	Rank
9	Mandechhu (Reotala) bridge	◎	◎	◎	◎	◎	15	1st
17	Dolkhola bridge	○	◎	◎	◎	◎	14	2nd
18	Jigmiling bridge	○	◎	◎	◎	◎	14	2nd
19	Kela bridge	○	○	◎	△	○	10	4th
20	Jangbi bridge	○	○	◎	△	○	10	5th
16	Dzongkhachulum bridge	×	○	◎	△	○	8	6th
5	Tshendona bridge	×	△	△	△	△	4	7th

◎: 3 points, ○: 2 points, △: 1 point, ×: 0 point

※ Bridges with the same score are ranked in order of urgency.

※ No.19 is ranked the 4th, because it is creakier than No.20.

Bridges to be covered by the project

This project aims to rebuild two bridges on National Highway No.5 by replacing the present temporary bridges with permanent ones. With respect to the three bridges on the farm road connecting to the National Highway No. 4, temporary bridges will be built, and the substructure works will be implemented by Japanese side.

Bridges covered by this grant aid project are as follows.

- Two bridges on National Highway No. 5:
  1) Dolkhola Bridge 2) Jigmiling Bridge
- Three bridges on the farm road connecting to the National Highway No. 4:
  1) Mandechhu (Reotala) Bridge 2) Kela Bridge 3) Jangbi Bridge

4. Outline of the Survey Results and Project Details

JICA dispatched a preparatory survey team to Bhutan from November 9th to December 25th, 2010. In consultation with the officials and associates of the Royal Government of Bhutan, the survey team carried out a field reconnaissance of the target area of the project, studying the current status of the bridges included in the request and the progress of procedures regarding environmental and social considerations, in order to confirm the urgency and necessity for the reconstruction of the bridges. After returning to Japan, the survey team developed a plan for the reconstruction of the bridges. Explanation of and consultation on the outline of the grant aid project took place in Bhutan from January 22nd to 29th, 2011 in order to reach a basic agreement with the Royal Government of Bhutan. In addition, explanation of and consultation on the outline design plan were carried out from June 1st to June 10th, 2011 and the basic agreement was obtained from the Royal Government of Bhutan.

5. Design Policy

5-1 Bridges on National Highway No. 5

National Highway No.5, on which the bridges covered by this survey are located, is an important route running through the developing area in the southern plain of the country. On National Highway No. 5, "Wakleytar Bridge" has been reconstructed under the grant aid program of Japan, The Project for Reconstruction of Bridges (Phase II), to replace the temporary Bailey suspension bridge with a permanent bridge. In addition, under the Project for Reconstruction of Bridges (Phase III) that is currently being implemented, reconstruction work is under way for Lawaka Bridge, Basochu Bridge, Bhurichu Bridge, Nyarachu Bridge, Chanchey Bridge and Loring Bridge. Besides, five bridges 30m or less in length are also being rebuilt on the same route by the Bhutanese side. However, Dolkhola Bridge and Jigmiling Bridge, located between Gelephu and Sarpang in the southern part of the same route, are still Bailey bridges. These bridges are highly likely to be washed away in the event of a similar disaster as Cyclone Aila. Therefore, it is very important to include them in the project. The survey revealed that

these two bridges with load limit of 18t maximum and a width of 3.27 m do not allow the safe and smooth passage of vehicular traffic due to damage caused by distortion as well as abrasion and corrosion of the structures. Also, traces of erosion are observed in the foundations of the bridge abutments.

These two bridges have a high possibility to become bottlenecks obstructing the steady transportation of people and commodities as the traffic volume, particularly of large vehicles, is expected to increase as the development program of the areas in the south progresses. Therefore, the reconstruction will be significant in ensuring safe and smooth traffic on National Highway No.5.

The basic design policies are as follows:

- Since the two bridges covered by the project were found in the field survey to be more than 30m in length, there are some difficulties for the Bhutanese side to reconstruct them, given Bhutan's experience in similar projects, topographical conditions, procurement situation, etc. Therefore, reconstruction should be carried out as a grant aid project of Japan.
- According to the "Road Survey & Design Manual", which is the road standard in Bhutan, the width of National Highway No. 5 should be 7.0m. Thus the effective width should not be less than 7.0 m, in order to ensure ease of passage, safety and continuity.
- As it is assumed that there will be large-vehicle traffic on National Highway No.5 for the transportation of materials and equipment for the Punatshangchu hydropower project, in addition to Class A as prescribed by the Indian Roads Congress (IRC) standard, the Royal Government of Bhutan has established a new standard, 70R (wheeled), as the live load intensity for the design of bridges on the National Highway, taking into account large-vehicle traffic. Therefore, the standards "Class A live load" and "70R (wheeled)" should be used in designing the bridges.
- The design and construction plan should be examined so as to obtain maximum benefit for minimum cost.

5-2 Bridges on the Farm Road along National Highway No. 4

The area, where No.9 Mandechhu (Reotala) Bridge, No. No. 19 Kela Bridge and No. 20 Jangbi Bridge on the farm road connecting to the National Highway No.4 are located, is considered to be the least developed area. As these three bridges are on the community road indispensable for the people live around the area, the construction has been prioritized issue since the 9th Five-Year Plan. However, the Mandechhu (Reotala) Bridge constructed during the 9th Five-Year Plan was washed away by the cyclone, and as for the construction of Kela Bridge and Jangbi Bridge, the project itself has not been implemented due to the restrictions such as budget etc., and only the temporary pedestrian bridges are provided for the use of people live around the area up to now. Therefore, reconstruction of these bridges will greatly contribute to restoration and improvement of the people's life, helping them in acquisition

of daily commodities and transportation of agricultural products and such. It will also significantly contribute to the achievement of one of the objectives of the 10th Five-Year Plan, specifically, to make trunk roads accessible within two hours.

The basic design policies are as follows:

- With respect to the superstructure of the three bridges, taking into consideration the length of the bridges, it was decided to adopt a Bailey bridge design for Kela Bridge and Jangbi Bridge and a Bailey suspension bridge design for Mandechhu (Reotala) Bridge. As Bhutan has an adequate track record in building Bailey bridges and Bailey suspension bridges and the capability to do so, the superstructures should be built by the Bhutanese side.
- Collapsed bridge abutments and bridge piers remained at the target sites. The results of the survey showed that the quality of the substructure (concrete construction) built by the contractor in Bhutan was improper. Therefore, it was decided that the substructure work should be carried out by the Japanese side.
- According to the design standards for Bailey bridges in Bhutan, the width should be 3.277m and the design load should be Class 24R. This project also adopts these standards. If the materials currently used for Bailey bridges are diverted, the allowable load should be Class 18R.
- Considering the damage by flooding caused by Cyclone Aila, etc., an appropriate margin was set of the vertical clearance. Also, revetment work was designed so as to protect the bridge abutments. A request was sent to the Bhutanese side to take the design of Mandechhu (Reotala) Bridge into account in the construction of new bridges over the Wandigang River, which merges with another river at a point downstream of Mandechhu (Reotala) Bridge.

6. Details and Scale

Table 2 shows the outlines of the replacement bridges.

6-1 Two bridges on National Highway No. 5

Table 2 Outlines of the Replacement Bridges

Bridge Name	Dolkhola Bridge	Jigmiling Bridge
Bridge structure	2-span PC joining simple post-tensioned T-girder bridge	2-span PC joining simple post-tensioned T-girder bridge
Bridge length	70.0m (230FT)	70.0m (230FT)
Span length	35.0m (115FT)	35.0m (115FT)
Girder height	2.1m×4 main girders	2.1m×4 main girders
Width	7.0m (2 lanes)	7.0m (2 lanes)
Foundation structure	Spread foundation (Abutments A1 and A2 and Pier P1)	Spread foundation (Abutments A1 and A2 and Pier P1)
Main material	PC main girder concrete (σ_{ck}=30N/mm^2) RC concrete (σ_{ck}=21N/mm^2)	PC main girder concrete (σ_{ck}=30N/mm^2) RC concrete (σ_{ck}=21N/mm^2)
Method to erect superstructure	Erection girder method	Erection girder method
Notes	Responsibilities of the Bhutanese side: Removal • Bridge superstructure • Bridge abutment on both riverbanks • Existing revetment on the right bank • Embankment at the access road on the right bank	Responsibilities of the Bhutanese side: Removal • Bridge superstructure • Bridge abutment on the right bank • Bridge pier

6-2 Three bridges on Farm Roads along National Highway No. 4

Table 3 Outlines of the Replacement bridges

Bridge Name	Mandechhu (Reotala) Bridge	Kela Bridge	Jangbi Bridge
Bridge structure	Bailey suspension bridge	Bailey bridge	Bailey bridge
Bridge length	103.7m (340FT)	49.532m (163FT)	49.532m (163FT)
Span length	97.6m (320FT)	48.768m (160FT)	48.768m (160FT)
Width	3.277m (one lane)	3.277m (one lane)	3.277m (one lane)
Foundation structure	Spread foundation (Abutments A1 and A2)	Spread foundation (Abutments A1 and A2)	Spread foundation (Abutments A1 and A2)
Main material	Steel for beams of Bailey bridge concrete (σck=21N/mm2 (Abutment))	Steel for beams of Bailey bridge concrete (σck=18N/mm2 (Abutment))	Steel for beams of Bailey bridge concrete (σck=18N/mm2 (Abutment))
Method to erect superstructure	Cable erection/vertical suspension method	Launching method with a support in the middle	Launching method with a support in the middle
Notes	The construction is to be handed over to the Bhutanese side after the substructure and revetment works in the scope of the works of the Japanese side have been completed. Material procurement and construction of the superstructure should be carried out by the Bhutanese side.	The construction is to be handed over to the Bhutanese side after the substructure works in the scope of the works of the Japanese side have been completed. Material procurement and construction of the superstructure should be carried out by the Bhutanese side.	The construction is to be handed over to the Bhutanese side after the substructure works in the scope of the works of the Japanese side have been completed. Material procurement and construction of the superstructure should be carried out by the Bhutanese side.

7. Construction Period and Estimated Cost of the Project

If this project is implemented as a grant aid project of Japan, the project cost to be borne by the Bhutanese side is estimated 1.83 hundred million yen. The total construction period is estimated to be 26 months, including the bidding process (7 months for execution of design and 19 months for construction).

8. Project Evaluation

The relevance and effectiveness of this project are demonstrated as follows:

8-1 Relevance

This project aims to reconstruct the existing bridges on the farm road connecting with National Highway No. 4 and the existing bridges on National Highway No. 5 that were damaged by Cyclone Aila and form bottlenecks to the flow of commodities and people. The project involves Japanese assistance and the construction of the superstructure of the Bailey bridges by Bhutan, which will not only improve the ease of passage and safety of the bridges in order to boost the movement of people and commodities, resulting in the development of the local economy, but will also greatly contribute to the achievement of one of the objectives of the 10th Five-Year Plan of Bhutan, namely, to make arterial roads accessible within two hours. At the same time, it will assist in the transportation of materials and equipment for the implementation of a variety of national projects in the southern part of the country.

With respect to environmental and social considerations, it is possible to minimize the social impact by monitoring the construction work appropriately and by taking due care to alleviate the environmental burden in the implementation of the construction work.

Of the bridges covered by this project, two bridges on National Highway No. 5 cannot be reconstructed independently by Bhutan, in view of the length of the bridge and Bhutan's track record and procurement situation. As far as the three bridges on the farm road are concerned, the superstructures should be constructed by Bhutan, as the country's track record and investigative situation pose no problems. With respect to the substructure, on the other hand, the survey revealed a problem in quality control and it is considered inappropriate to have the substructure of these bridges constructed by Bhutan. Therefore, the substructure construction should be covered by the grant aid program of Japan.

8-2 Effectiveness

(1) Quantitative Effects

1) The Two Bridges on National Highway No. 5 (Dolkhola Bridge and Jigmiling Bridge)

The load-carrying capacity of both bridges on the National Highway No. 5 (Dolkhola Bridge and Jigmiling Bridge) will be increased from 18t (at present) to 40t. Benefited by this increase of the load-carrying capacity of two bridges, it is expected that large-vehicles passing the capital city Thimphu for the central city in the southern region Gelephu will choose to take the route on National Highway No. 1 and No. 5 with a travelling distance of about 260km which is approx 120km shorter than the

present route on National Highway No. 2 with a travelling distance of about 380km. As a result, the travelling time will be shortened by approx. 4 hours.

2) Three Bridges along National Highway No. 4 (Mandechhu (Reotala) Bridge, Kela Bridge and Jangbi Bridge)

The reconstruction of the bridges will boost the flow of people and commodities, conferring a benefit to about 3500 residents in the villages on the opposite bank of the rivers spanned by the three bridges. Coupled with the improvement of the farm road, it will greatly contribute to the achievement of one of the objectives of the 10th Five-Year Plan, namely to make arterial roads accessible within two hours.

(2) Qualitative Effects

1) The Two Bridges on National Highway No. 5 (Dolkhola Bridge and Jigmiling Bridge)

The reconstruction of the bridges will improve the ease of passage on National Highway No. 5 and activate the movement of people and distribution of commodities, and contribute to the development of the local economy. It will also ensure the smooth traffic of National Highways even in a time of serious disaster equivalent to Cyclone Aila. More details of qualitative effects are shown below.

- The load-carrying capacity of the bridges will be increased to a large extent, and it is expected that the traffic of large-vehicles will become activated.
- The reconstruction will increase not only the load-carrying capacity but also the width of the bridges, and it is expected that the ease of passage and the safety on the bridges will also be improved.
- Moreover, the reconstruction of the bridges will contribute to the development projects of the areas along National Highway No. 5 and in the south, such as the construction of the Punatshangchu hydropower plant (presently under construction), industrial park, new international airport and a second east-west highway, as it will facilitate the transportation of the materials and equipment necessary for the implementation of these projects.

2) Three Bridges along National Highway No. 4 (Mandechhu (Reotala) Bridge, Kela Bridge and Jangbi Bridge)

The reconstruction of the bridges will dramatically improve the traffic convenience and activate the movement of people and distribution of commodities, and contributes to the improvement of life in the area. More details of qualitative effects are shown below.

- The damage by the cyclone Aila will be restored.
- The reconstruction of the bailey suspension bridge and the bailey bridge will enable the traffic of vehicles.
- The access of the local residents to the administrative services, the medical services and the educational institutions will be retrieved.
- The access to the market will be improved.

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