International Journal of Bridge Engineering (IJBE), Vol. 5, No. 1, (2017), pp. 11-20

INSPECTION AND MAINTENANCE DESIGN OF STEEL BRIDGE

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ABSTRACT: Bridges are the major elements of road network which should always be in good working condition. Good working conditions can be achieved by routine, periodic and emergency maintenance after the bridge construction. For this study Bokse River Bridge is selected which is located in Jalbire village development committee of Sindhupalchok district along the Balephi (Arniko Highway-Asian Highway) to Jalbire in Nepal. For the inspection and maintenance of bridge the work is divided into two major parts namely desk study and field work. The relevant data related to the bridge was collected during desk study then in the field study the detail survey was done. IRC: SP: 74-2007, Guidelines for Repair and Rehabilitation of Steel Bridges was used for the maintenance of the bridge. Based on the inspection of the structural elements of the Bokse River Bridge, the bridge is in poor condition and needs attention as soon as possible. In this paper, inspection of bridge, geological condition, maintenance design and preventive measures are discussed in detail.

KEYWORDS: Maintenance; Inclined Legged; Steel Bridge; Nepal.

1 INTRODUCTION

Bridges are the major elements of road network which should always be in better working condition. Better working conditions can be achieved by routine, periodic and emergency maintenance after the bridge construction. For this study Bokse River Bridge is selected. Bokse River is located in Jalbire village development committee of Sindhupalchok District along the Balephi (Arniko Highway-Asian Highway) to Jalbire in Nepal as shown in Fig. 1. Initially there was a pedestrian suspension bridge only for people and cattle. At the time of development of Baramchi hydropower project, this motorable bridge was constructed. Bokse River Bridge is an inclined legged steel frame bridge integrated with reinforced cement concrete abutment. The road is classified as village road as per Nepal Road Standard [12] having half portion of bituminous surface and half of gravel surface. It is a key route for the transportation of goods and travelling through rural areas of Sindhupalchok district in Nepal. The

bridge facilitates more than hundreds of vehicles and pedestrians in a day. The bridge seems old and some emergency maintenance and repairs are required. The main problem of the bridge is corrosion in structural component. The corrosion on the steel part is due to human excreta and solid waste dumped in the members. Similarly, concrete spalling in the slab are also seen. The bridge is in the full authorization of District Development Committee Sindhupalchowk which takes the responsibility of its management and maintenance.

The objective of this work is to find the overall condition of bridge and suggest the repair and maintenance by special inspection and assessment of the bridge condition. The major task is to carry out all necessary de-tails of bridge inspection, assessment of repairs and remedial measures of the maintenance works including geological and geotechnical investigations and necessary laboratory testing.

Figure 1. Location of Bokse River Bridge

1.1 Bridge site location

The Bokse River Bridge at Sindhupalchowk joins the rural area of the district. The bridge crosses the Bokse River linking Jalbire (Right) and Jalbire (Left). Geographically, the bridge is located at 85°46'4.83"E, 27°48'32.35"N which is shown in Fig. 2.

Figure 2. Geographical Location of Bokse River Bridge

1.2 Description of the Bridge

- Span Layout and Structural Types:

Bokse River Bridge is a single span bridges having 14.40 m length. There are four longitudinal girders and Seventeen cross girders. The arrangement of the Bokse River Bridge is shown in the Fig. 3 below:

Figure 3. Structure of the Bokse River Bridge

- Deck System:

The bridge deck has only steel plate and no wearing course surface for the traffic movement and no footpath for pedestrian in the carriage way. Steel plates are rested on the cross and longitudinal girders and size of the cross girders are

lesser than longitudinal girders.

- Substructures and foundation:

It seems that both the abutments are rested on the soil and it is hard to predict foundation of all the substructures.

2 METHOLODOGY

For the inspection and maintenance of bridge the work is divided into two major parts namely desk study and field work. The relevant data related to the bridge was collected during desk study and then in the field study the detail survey was done. The details about the methodology are illustrated below.

2.1 Desk Study

In order to make the special inspection, the desk study was done on the basis of the available existing documents which were relevant to this study. The main documents studied at this stage were as follows:

a) Bridge Inventory Record Cards:
   The study work had referred to the Bridge Inventory Record Cards. Basic information regarding the location of the bridge site, length, number of span, carriageway width, footpath of the bridge, type of bridge, deck and foundation, running surface, etc. was recorded. Any provision of utilities such as electricity, telephone, water supply lines were also noted from the record cards.
b) Guidelines for Inspection and Maintenance of Bridges:
   Prior to the field inspection, thorough consultation of the Guidelines for Inspection and Maintenance of Bridges developed by the District Development Committee was done. Methodology for the inspection of bridges was provided by those guidelines and the maintenance requirement was identified. The methods of recording and implementing the maintenance activities in the field and the practical problems that may arise while implementing such works were also described by those guidelines.
c) Previous Maintenance Reports:
   No previous maintenance activities were available at the bridge unit except the regular routine maintenance; no major maintenance seemed to have been carried out in the past.
d) Maps:
   Topographic map had been referred to identify the location of the bridge site, catchment area of the river and the general topographical characteristics of the whole area including detailed bridge site area. Similarly, the google map of the area was studied.

Besides, the information was also collected from other informal sources such as enquiry with the local people, passengers, media etc. to know the prevailing serviceability and functionality of the bridge.

However, as already mentioned in limitations of the study, the documents related to the design, specifications and the technology adopted during construction were not available.

2.2 Field Work

The Field works for special Instruction works of the Bokse River Bridge generally comprises the following works that had been carried out at site.

a) Inspection of each part of the bridge and its condition thoroughly

- Bridge Inspection and Recording:
  Using Inspection Manual published by Department of Road (DoR) which was made available by Bridge Project as a guide, appropriate inspection report forms were completed. The condition, extent and urgency of maintenance were noted in the form. All the components of the bridge were inspected one by one and the items requiring maintenance were recorded in appropriate forms/ sheets. None of the component was left without inspection. Relevant field sketches of the general arrangement showing locations of various components of the bridge, steel structure showing different members with their joints, nut bolts etc. were also pre-pared. Separate inspection forms other than those suggested in the Manual have been used for field records.
- Bridge condition Assessment and Evaluation:
  On the basis of the inspection made at the field, existing condition of bridge had been assessed in detail to identify any defect/ damage in the bridge. The evaluation of maintenance needs had been made in terms of existing condition of the bridge, extent of defect /damage to a particular item and its urgency to execute re-medial or repair works so that the serviceability and safety conditions of the bridges for the existing and anticipated future volume in its estimated service life is guaranteed.
- River Training and bank protection works:
  Available free board, river flow and bank condition, and any instability features of the river banks had been studied during the inspection. Maintenance requirement of existing river training or bank protection works and also the need of additional ones as per the prevailing bank condition have had assessed.
- Geo-technical Assessment:
  Geotechnical aspects of the bridge site had been studied during the inspection. General slope condition and its stability near the foundation and its surrounding, general soil/rock type, river bank and slope stability of the bridge site were also observed during the field visit.

b) Design of Maintenance Works:

Under the maintenance design work of the proposed bridge, the drawing and calculation of the members of the bridge to be rectified or replaced including all

other maintenance required items had been thoroughly studied and presented in the drawing, estimate and report. Maintenance design and drawing of the bridge had been carried out as per the investigation and observation made on the bridge site.

c) Design of Ancillary structure Maintenance:

Observation and finding of the bridge inspection work had been included in the previous chapter including the proposed design and items of works to be executed. The bill of quantities of the maintenance work had been prepared and included in the cost estimate.

d) Preparation of General Arrangement and other Relevant Drawings:

A General arrangement of the existing bridge had been prepared and all the relevant features such as bank conditions, slope conditions and any other features that had relevance in undertaking maintenance / safety of the bridge has been shown in the drawing. The general arrangement prepared during the design and construction of the bridge will be as base map for the future reference to execute the maintenance works. As the relevant bridge related design and drawings of the proposed bridge were not available, the drawing and design had been prepared by noting down existing features of the bridge and ground conditions.

3 DETAIL BRIDGE INSPECTION

According the bridge Inspection results the condition of the bridge is rated as poor condition and need atten-tion within 6 months (generally before the monsoon or in the present fiscal year) to stop the further degrada-tion of the bridge. The main problem of the bridge are deflection of steel plate, corrosion in lower chords, connections, gusset plates, buckling of cross girders, poor function of nut bolts and problems in approach slab.

The condition of the each parts of the bridge has been briefly described below:

3.1 Superstructure

- Decking System (Steel Plate):
  From the inspection, steel plates are deflected and not in good condition. The plates are buckled, joints are disconnected and rusted. The conditions of decking system are shown in Figure 4.
- Footpath:
  There is no footpath at the both sides of the carriageway. People are walking at the side of the carriageway.
- Main Girder:
  The main girders are rusted but there is no problem with the deflection and buckling of main girder.

Figure 4. Condition of Decking System

- Cross Girders:
  Cross girders are buckled and rusted, so all cross girders are need to be replaced.
- Stringer Beam:
  Stringer beams are buckled and rusted, so all stringers are needed to be replaced.
- Railings:
  Railings are in good conditions.
- Approach Slab:
  All the concrete in approach slab are spalled and rebar were exposed.

Figure 5. Concrete spalling in approach slab

3.2 Substructure

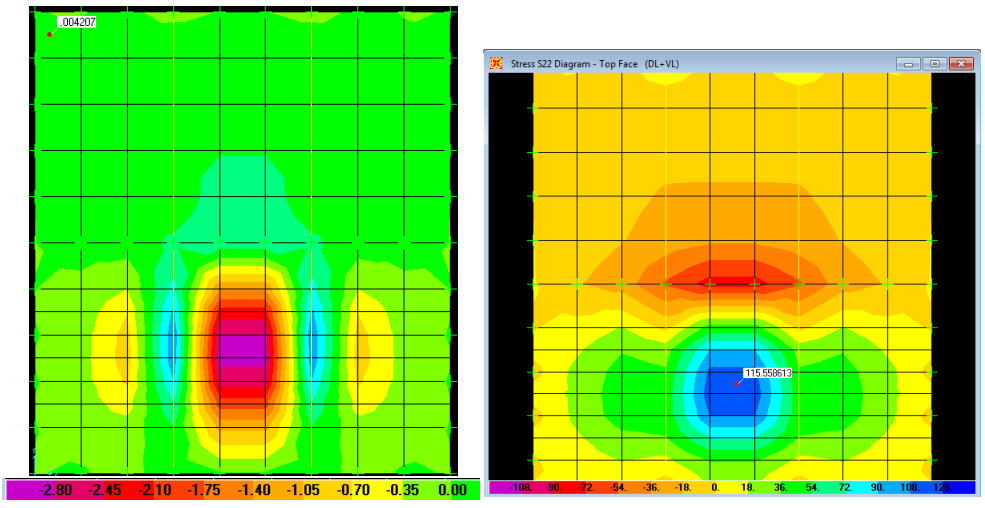
- Abutments:
  Both Abutments are in good condition. No maintenance is needed. But Abutments caps are covered with solid waste.
- Foundation:
  All the abutment foundations are buried and from the visual inspection it is in good condition.

4 DETAIL MAINTENANCE DESIGN

From the detail inspection, it was clear that the thickness of chequered plate was not enough and the connection to the stringers was not proper. For the maintenance design of this bridge, decking system were analyzed and designed separately and then connected to the bridge. For the live load IRC 6: 2010 [1] was used. IRC class A load was used as live load.

The spacing of cross girder are at every 900 mm and the stringer are also at a spacing of 900 mm. Again ISA 65x65x6 was used on the bottom of the chequered plate to at the rate of 300 mm to subdivide the plate area to make it stiff. The wheel of IRC A class load was placed between this section so as to achieve critical bending moment and shear. For the finite element analysis of this bridge SAP 2000 was used.

From the finite element analysis it showed that the demand of the load is 2.93 KNm and the capacity of the plate was 10.8 KNm in bending and for the shear the demand was 119.09 N/mm^2 and the capacity was 150 N/mm^2 as shown in Figure 6.



(a) **(b)**

Figure 6. (a) Moment contour, (b) Stress Contour

A 3D model was built in SAP 2000 for detailed finite element analysis of the Bokse River Bridge as shown in Figure 7.

For the stringer beams ISMB 150 were used. From the detailed finite element analysis it shows that the section modulus required for stringer was 14774.95 N/mm^3 and the capacity was 96853.34 N/mm^3. For the shear, the demand was 32.249 N/mm^2 and the capacity was 85 N/mm^2.

Similarly for the cross girders ISMB 150 were used. From analysis it shows that the section modulus required for cross girder was 24491.2mm^3 and the capacity was 96853.34 mm^3. For the shear the demand was 52.702 N/mm^2 and the capacity was 85 N/mm^2.

For the main girders ISMB 300 was used whose sectional capacity was 57357.30 mm^3 and the demand was 29926.67 mm^3 in flexure and 53.333 N/mm^2 was the stress demand and 85 N/mm^2 was the capacity in shear. For the deflection, maximum deflection was 2.35 mm and the allowable deflection was 4.50 mm. Hence from the analysis we can say that the main girder was safe.

For the approach slab, it has to be reconstructed. For the other parts of bridge, rusting should be removed by using sand ballasting methods. Vegetation should be removed.

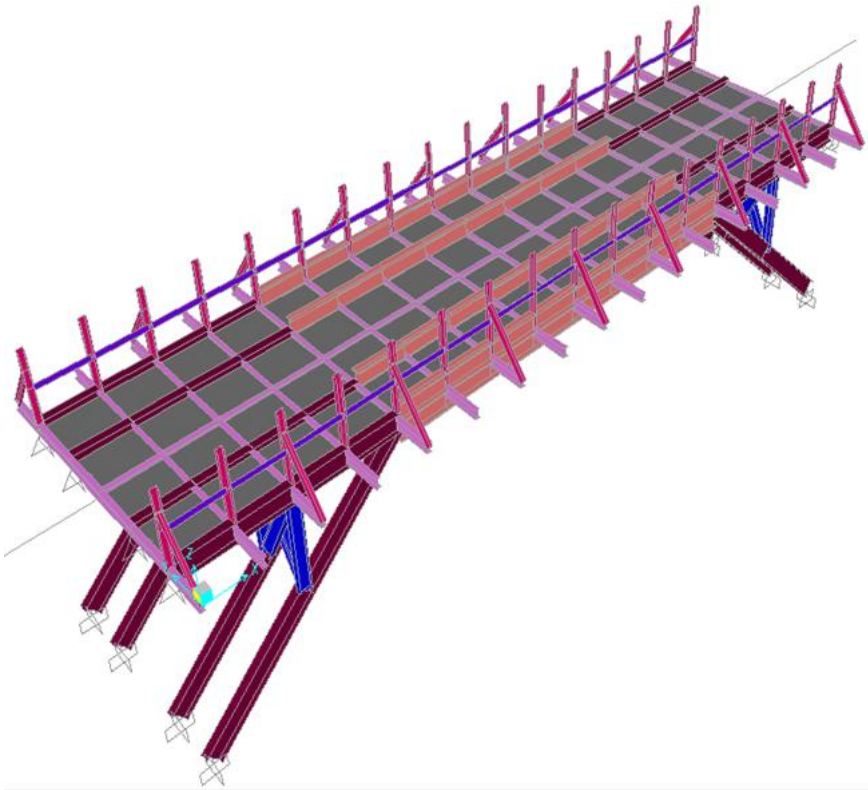


Figure 7. Detailed 3 D model of bridge for analysis

5 CONCLUSIONS

Based on the inspection of the structural elements of the Bokse River Bridge, the bridge is in poor condition and needs attention as soon as possible. From the repair and maintenance of the bridge, life of the bridge can be extended.

- The repair and maintenance program are recommended as follows:
- Replace the Steel plate, cross girders, stringers, and damaged gusset plates of different size, damaged seat angles, damaged / malfunctioning nut bolts
- Chiseling and Epoxy grouting in concrete spalling portion.
- Sand blasting and painting in the bridge.

ACKNOWLEDGMENTS

The work was supported by Digicon Engineering Consults P. Ltd. and Rural Infrastructure Developers Consultants P. Ltd. The author is grateful to these supporting institutions and greatly thankful to Er. Subin Desar for his valuable suggestion.

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