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Renovation of two century-old steel truss railway bridges to increase the vertical clearance

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ABSTRACT: Bangladesh Railway Bridge No. 23 - Boral Bridge and Bridge No. 24 - Koidanga Bridge were constructed about a hundred years ago, during the construction of Hardinge Bridge. The singe track bridges are still functioning well as railway bridges. Main spans of these bridges are through type steel truss structures. The internal vertical clearance from the railway track to the top planer wind bracing is just adequate for passage of a single deck train. Bangladesh Railway in its plan to modernize the rail routes also thinks to introduce larger couches that would require increase of vertical clearance. In this context, in the first attempt, the feasibility of increasing the vertical clearance (main truss depth) of these two old bridges by 1.6 m is considered. This requires removal of existing top lateral bracing and installing a rigid frame system overhead. As-built strength of the steel of old bridges were checked by extracting steel samples and performing laboratory tests to assess the stress-strain responses. A check for weldability between old and new steel had been the other issue to be addressed. A structural truss form is proposed and a work methodology is chalked out to implement the work keeping the tracks partially operational taking work windows. The study shows that increment in vertical load for the structural alteration work is marginal. Thus renovation scheme is adequate to carry the vertical load. Wind load on the altered structure increases resulting in higher stresses and deformations in the members of the bridges. However, the increased deformations and stresses are found to be within acceptable limits for the members and bearings of the bridges.

1 INTRODUCTION

Bangladesh Railway Bridge No. 23- Boral Bridge (24°12'52.32"N; 89°22'45.39"E) and Bridge No. 24 - Koidanga Bridge (24°13'41.85"N, 89°25'13.07"E) were constructed about a hundred years ago at a similar time of the construction of Hardinge Bridge (Gales 1918). The bridges are still functioning well for the Bangladesh Railway (see Figure 1 for the geographic locations). Boral bridge (Figure 2) is located at the upazilla town of Bhangura while the Koidanga Bridge is located about 4.5 km north-east to Boral bridge on the same railway track (Figure 3). Main spans of these bridges are through type steel truss structures. Boral Bridge has three similar spans supported on caissons. Koidanga Bridge has two spans. The internal vertical clearance from the railway track to the top planer wind bracing is just adequate for passage of the trains leaving no additional headroom clearance. During festivals, rush hours and other vacation times, overcrowding occurs in the trains and many people, though not legal, forced to travel on the roof of the coaches. For the above two bridges, the clearance between the top of the railway coach and the top wind bracing had not been enough for roof-top traveling by people which resulted many casualties in the past. Bangladesh Railway, when thinking at the same time to increase the vertical clearances of many old bridges, the renovation of these two bridges got a priority to avoid casualties and also to check on site feasibilities for such renovation attempts. This paper presents the renovation strategy, design, measures considered to be observed during implementation and construction time experiences. Due to soft alluvium deposits of the sites (Alam et al. 1990), both the bridges were founded on caisson foundations.

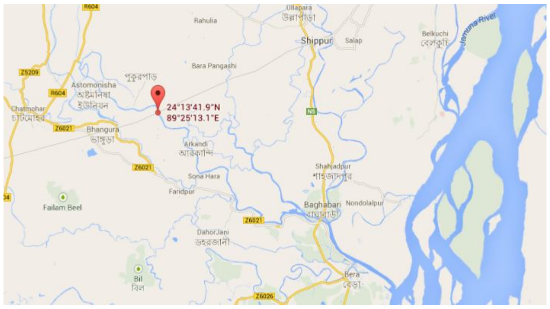

Figure 1. Bridge Locations. Source: Google Maps

Figure 2. Boral Bridge

Figure 3. Koidanga Bridge

2 RENOVATION STRATAGY

Removal of the top wind bracings of an existing railway steel truss bridge and installing a new bracing system with greater vertical clearance without affecting the vertical load carrying capacity of the trusses is undoubtedly a specialized kind of job requiring a thorough understanding of the structural behavior of the 100-year old structure. In order to get a first-hand idea about the existing condition of the bridges, the bridge superstructures were thoroughly inspected. Due to the absence of any design drawings for these bridges, it was necessary to survey the bridges thoroughly and prepare as-built drawings for the major elements of the superstructure. In this context, the preparation of as-built drawing for major members for member sizes, engineering analysis and design detailing for the top bracing replacement work was done (Figure 4).

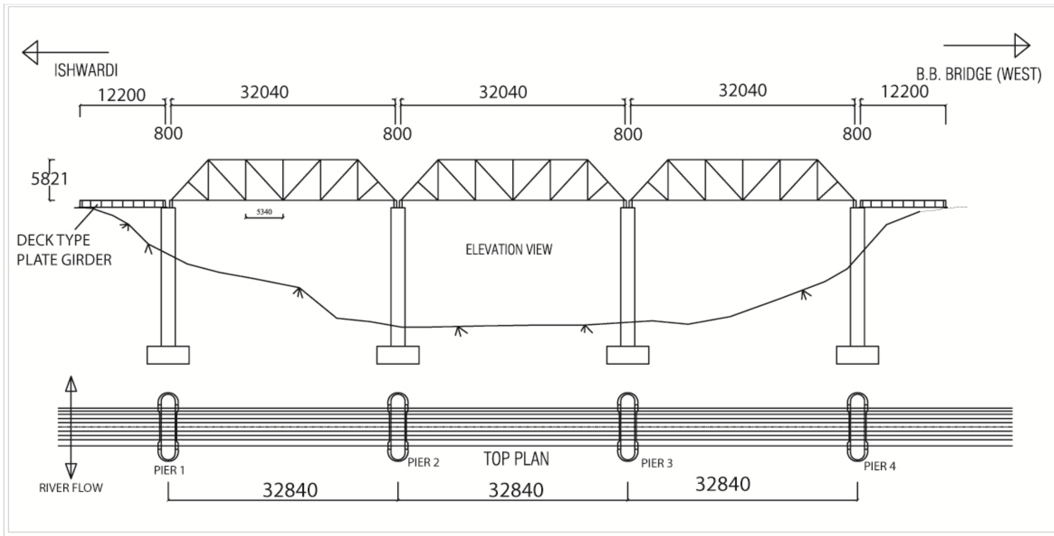

Figure 4. General dimensions of Boral Bridge and span arrangements

The railway bridges served for about 100 years. It was therefore considered to check the residual ductility of the existing members to ascertain any loss due to fatigue that might have taken place due to use over the time. Figure 5 presents a typical stress strain response of the steel extracted from the main load bearing members of the bridge. It shows the yield strength to be of the order of 300 MPa and ultimate elongation around 3%. No vertical sag in the existing bridge was noticed.

In view of this, the design team decided to depend on the existing main truss for carrying vertical load. However, to increase the desired clearance, the existing top chord bracings and wind portals that mainly cater for resisting wind loads (lateral loads) were considered to be removed after installing a wind force resisting system above the existing system.

To achieve the above scenario, first, appropriate welding methodology to connect the new members with the old members were considered. Secondly, the structural detailing to connect the new top bracing with the existing top chord was considered in detail so that the capacity of the existing top chord is not reduced.

The existing bearing system and connections were recommended to be surveyed in details to assure those to be correctly in place, none are missing and the existing bearings are functional through regular maintenance.

3 DESIGN

An illustration of the existing top plan bracing and the suggested new bracing system is shown in Figure 6. Three dimensional finite element models of the structural system of a typical span of the existing bridge was developed to find out the stresses in members due to different combinations of vertical load and wind load. Site specific wind load was assigned according to design wind speeds suggested in Bangladesh National Building Code (BNBC 2006). Numerical models for the bridge span after renovation were also developed. The member stresses and support reactions between the old and new system were compared. Material properties of the existing members have been assigned based on the tension tests performed (Figure 5). Adequacy of capacity of the renovated configuration was checked against AISC ASD 2005 provisions.

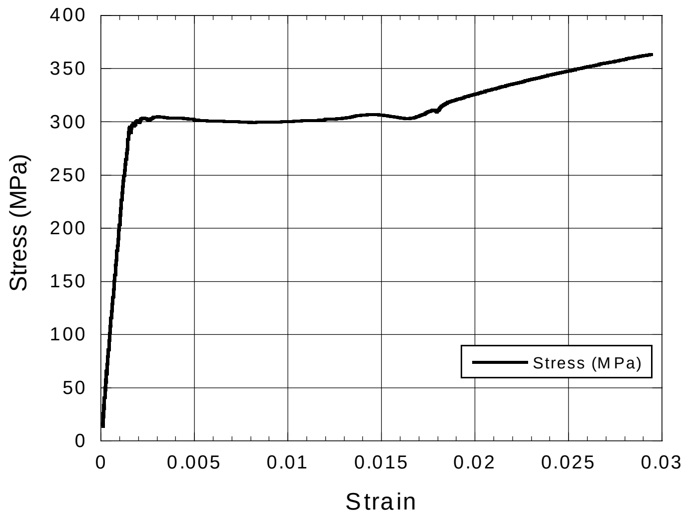

Figure 5. Stress-strain response of existing members

The analyses concluded that increment in vertical load for the renovation work is marginal. Thus renovation scheme is adequate to carry the vertical load. Wind load on the renovated structures is increased resulting in higher stresses and deformations in the members of the bridges. However, the increased deformations and stresses are found to be within acceptable limits for the members and bearings of the bridges.

It was conceived that the renovation works may be conducted after a thorough inspection survey of the connection details of the superstructure and regular maintenance of the support bearings. In the inspection it was emphasized to ensure that the conditions of the bearings and connections are adequate, no components are missing and no crack is present.

It was noted to be extremely important that capacity of the existing members of the bridges should in no circumstances be impaired while conducting the renovation works. Especially net area of the top chords must not be reduced while attaching the rigid frame to the existing bridge. It is strongly recommended that the new (proposed) top bracing system be first attached to the original (existing) top-chord of the truss by means of welding only. Thereafter, the old top bracing system may be detached by means of gas-arc cutting.

4 CONSTRUCTION

Figures 7-9 shows the different phases of construction of renovation works in Boral and Koidanga Bridges. Figure 8 particularly illustrates the increased clearance in Koidanga Bridge after removal of the old top chord bracing system. Figure 10 illustrates the connection details between the old and new members done through welding. The whole work was being done in different work windows on daily basis keeping the rail tracks operational for the rest of the day

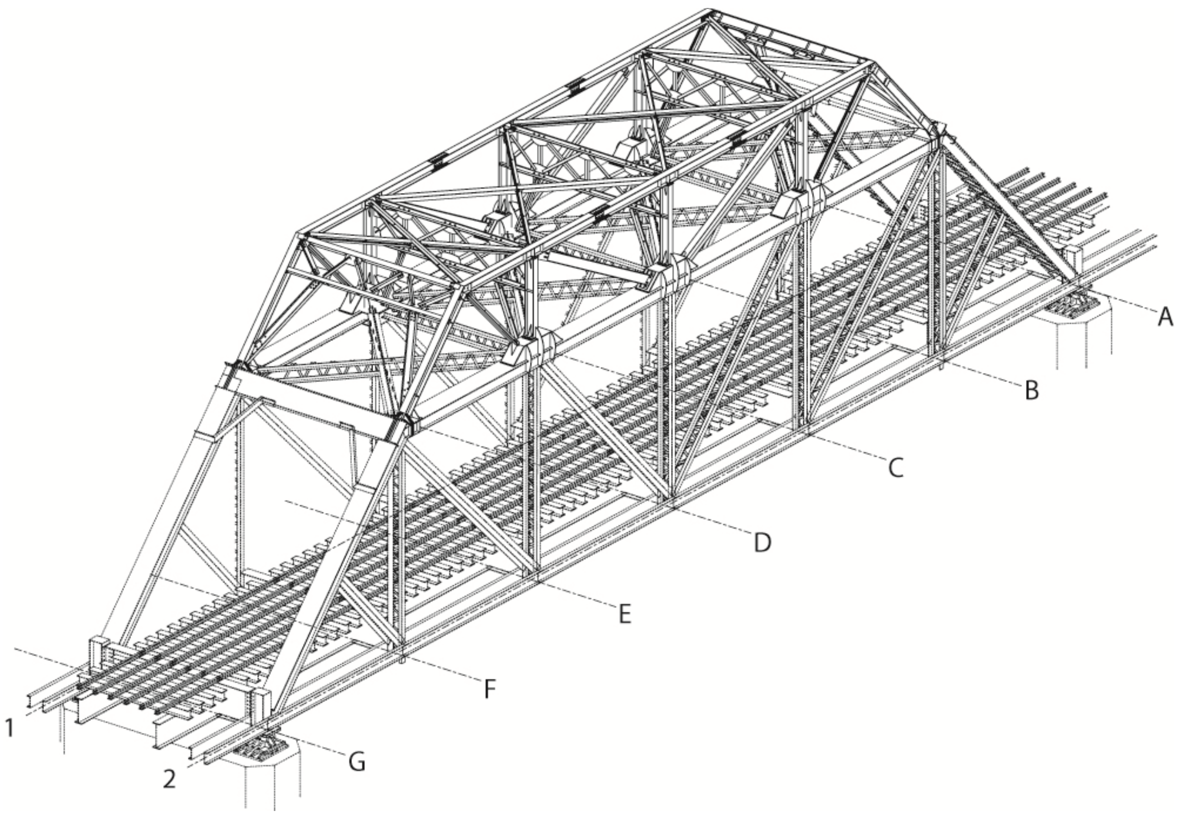

Figure 6. Post-survey reconstructed shop drawings and renovation plan for a typical span

Figure 7. Boral bridge after installation of new top chord bracing system.

Figure 8. Koidanga Bridge after instillation of the new top chord bracing system.

Figure 9. A view of the new top chord bracing system after installation above the old bracing system.

Figure 10. Details of under-construction connection between the existing top chord and the new member

5 CONCLUSIONS

Bangladesh Railway at present does not have any alternate route to detour the trains to provide an uninterrupted time slot to install the proposed rigid framing on top of the existing truss system. Rather, providing small time slots was making the progress of work slower than anticipated. The situation was getting worsened with the irregular time schedules of the trains that were in operation due to many other secondary factors. In spite of all those difficulties, the design team felt it of utmost importance to ascertain the in-situ capacity of an existing steel structure that has no as-built drawings in its record, no well documented maintenance and inspection records but seemed to possess a proven track record of satisfactory service over a period of a century. The renovation work of the two century-old railway through type truss bridges to increase the internal vertical clearance has been evaluated for structural adequacy and durability. The proposed methodology for installing the new rigid framing system on top of the existing system and then removing the existing plan bracing has been thoroughly scrutinized. It has been found that the proposed rigid framing system is structurally adequate and the methodology of attaching the new framing on the old truss by welding is safe and adequate.

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