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Distress in the old brick masonry bridges of Bangladesh Railway and remedial measure with a new approach - a case study

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Abstract

Most of the bridges of Bangladesh Railway are almost 100 years old and are decaying; becoming vulnerable to the safe movement of the rolling stocks. Whenever cracks or settlements develop in a bridge, speed restrictions are being imposed, followed by the partial or complete rebuilding of the bridge with the conventional temporary arrangement or, temporary diversion. This process of the conventional method of repair, construction, and reconstruction of distressed railway bridges involves time, money, and risk. In this case study a new approach is introduced as an intermittent maintenance technique for the sectected brick masonry railway bridges of the Chattogram-Laksam section. First, selected bridges are inspected carefully to identify the causes of the distress and cracks. The cracks in bed blocks, brick masonry abutment walls, wing walls, and piers are then repaired by using epoxy injection, bonding agent, micro-concrete, etc., and monitored at regular intervals. However, no distortion of the alignment and settlement are recorded after more than two years of observation. It is concluded that cracks in the pier, bed blocks, and abutment wall of the old brick masonry bridges can successfully be repaired with the new approach/intermittent maintenance technique which will be beneficial for the concerned authorities.
***Keywords**: Over-aged bridges; Bangladesh Railway; Partial and Complete Rebuilding; Temporary arrangements; New repair approach.*

1 Introduction

Railway bridges are considered a valuable capital asset not only because of the heavy investment engaged in constructing or replacing them but also because some of them form part of the historic and cultural heritage of a country. However, no engineering structures including the railway bridges are endowed with eternal life. Lack of day-to-day, periodic, and special maintenance work generally results in reduced life and deterioration in the bridge structure. Therefore, it is essential to prolong the life of structures by identifying the cause of distress, selecting appropriate repair methods, and rehabilitating them wherever necessary. According to Issa et al. (2005), the proper repair of cracks depends on knowing the causes and selecting the repair procedures that take these causes into account; otherwise, the repair may only be temporary. Successful long-term repair procedures must attack the causes of the cracks as well as the cracks. According to Lin et al. (2014), due to the considerable associated costs, the reduction of maintenance requirements for bridge abutments is highly demanding and a topic of worldwide interest. The phenomenon is the same for other parts like the pier, wing wall, bed block, etc. of the brick masonry railway bridges. Bridge deterioration has become a widespread problem throughout the railway transportation infrastructure of Bangladesh. Exploration and implementation of cost-effective, reliable, and appropriate need-based repair technology and materials are necessary to ensure safety during the full-service lives of the existing bridges is essential (Ainge and Steven, 2012). Regular maintenance along with special attention needed to maintain the safety of the bridges. Regular maintenance works like pointing and cement grouting are done for the small-scale distortion of brickworks and cracks. According to the Bridge Rehabilitation and Strengthening Manual 2018, RHD, Bangladesh, routine/regular Maintenance works are carried out to prevent the bridge from suffering further deterioration. Intermittent repair, maintenance, and strengthening works are demanded for the moderate cracks, protective works, and distortion of

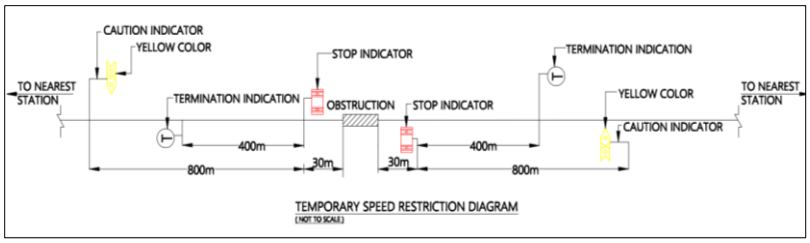
brickworks of the substructures with no distress/settlement in the foundation. However, when cracks in the abutments and pier are developed due to the settlement of the foundation then heavy repair works like partial rebuilding/strengthening works or, complete rebuilding are required. This includes the ultimate and serviceability limit state when the structure of abutments, wing wall, and pier become unstable. According to Hong and Lee (2009), the serviceability limit state occurs when an abutment fails due to factors such as deterioration or deformation. The main causes involve vibration, cracking, and lateral movement. Examples of such ultimate limit states include overall instability, sliding, overturning, and capacity failure (Movahedifar and Bolouri, 2012). In Bangladesh railway intermittent maintenance of the bridges is not practiced, irregularly regular maintenance and ultimate replacement/reconstruction are practiced. Whenever cracks or settlements develop on a bridge, speed restrictions are imposed, followed by the partial or complete rebuilding of the bridge with the conventional temporary arrangement or, temporary diversion. This process of the conventional method of repair, construction, and reconstruction of distressed railway bridges involves time, money, and risk along with a breach of the schedule of train movement as a dead stop is imposed. As a consequence, a complete block of railway tracks is required during the making and dismantling of the temporary arrangements. The situation leads to a shortfall of punctuality, creates a hazardous situation in train operations, and an unpleasant feeling for the passengers that their safety may be endangered. Bangladesh Railway experienced several train accidents due failure of the temporary arrangements. According to Almeida (2016), the use of epoxy resins by injection or just by sealing constitutes the most common solution for crack repair. Even in Bangladesh Roads and Highway Department uses such techniques for repair and maintenance work of RCC bridges. In contrast, epoxy injection, micro-concrete, polymer mortar, and bonding agents are rarely used for crack repair, repair of loose joints, and strengthening of masonry structures, especially never been tried in masonry bridges of Bangladesh Railway. This case study involves the use of an intermittent maintenance technique with epoxy injection, micro-concrete, and bonding agent to repair cracks and loose joints along with strengthening work with RCC jacketing of distressed brick masonry bridges of Chattogram-Laksam section of Bangladesh Railway.

2 Conventional Practice of Railway Bridge Maintenance in Bangladesh

Conventional repair and maintenance of the Brick masonry bridge include pointing, cement grouting, RCC jacketing of the pier, partial rebuilding, and complete rebuilding of the bridges which involve a considerable amount of money and time. Again, during conventional repair dead stop is imposed, then trains to move at a restricted speed over a particular area with the conventional temporary arrangement or, temporary diversion. In case of complete re-building, the existing bridges are completely dismantled, and for partial re-building, the affected portion of the bridge structures are dismantled after proper installation of the temporary arrangements or, construction of the diversion line as required with appropriate speed restriction. The temporary arrangement is the temporary structural arrangement provided at the distressed railway bridges to facilitate train movement at restricted speed over the bridge imposing no load on the distressed railway bridges during its maintenance like partial rebuilding or complete rebuilding. In this technique, bolder, drum sheet, cc cribs, wooden sleepers, and unserviceable rails are used to make a temporary foundation to support RS Joist/existing girder to carry and transfer the load to the earth, coming from railway traffic through rail and sleepers with appropriate speed restriction with dead stop as shown in Figure 1(a,b,c). Figure 1(a) describe the practical situation of partial rebuilding with temporary arrangement, whereas Figure 1(b) represent complete rebuilding bridge with temporary arrangement and Figure 1(c) shows schematic speed restriction diagram required for partial as well as complete rebuilding of railway bridge in Bangladesh.One the other hand temporary diversion is constructed to maintain the train services uninterrupted during line maintenance, upgradation work or to accommodate engineering works. In Bangladesh railway temporary diversion is commonly used for the reconstruction of bridges where the temporary arrangement is not enough to serve the purpose.

a)The Temporary Arrangement

b) Complete rebuilding of a bridge (RCC box culvert)



c) Schematic diagram of temporary speed restriction (Dead Stop)

Figure 1: Speed restriction diagram, temporary arrangement, and complete rebuilding of bridge.

3 Background of the new approach to Repair the Bridges

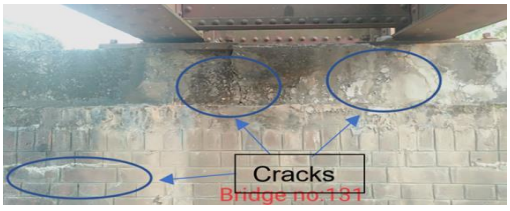
During the scheduled inspection in December 2020, it was found that 7 numbers of bridges in between the Chattogram-Laksham section require immediate attention as cracks had developed badly in the brick abutment wall, piers, and the RCC bed block. As a conventional approach, it was decided, three bridges for complete rebuilding and four for partial rebuilding. Both approaches require temporary arrangement/ temporary diversion and dead stops with a speed restriction. Considering the average 5 minutes loss at each bridge was counted a total of 35 minutes would have been required for those bridges if decided for partial rebuilding and reconstruction along with the huge sum of money. However, considering existing two dead stops between the Chattogram-Laksham section counting a total of 8 dead stops, and some speed restrictions due to the ALDLP project between the section of Dhaka-Chattogram. In this situation, the cost, and loss of a total of 60 minutes in the Dhaka-Chattogram section was unbearable for Bangladesh Railway. Higher authority demanded to repair of the bridges without dead stop and speed restrictions which provide the opportunity for the author to apply a new approach to the repair of those bridges.

3.1 Field observation of selected bridges and discussion

The case study considered in this paper is the brick masonry bridge no. 102 (up), 111(up), 131(up & down), 209(up), 210 (up), and 221(up) between the Chattogram-Laksam section with cracks on the abutment wall, piers, and bed blocks upon visual inspection. First careful inspection of the selected bridges is done with the visual observation of approaches, superstructures, substructures, floor, soils, etc. Loose joints and cracks in the bed block, abutment wall, and wing wall are observed and some pictures of bridges with cracks are shown in Figure (a,b,c,d).

a) Cracks in Bed block, abutment, and wing wall (111up)

b) Horizontal and vertical cracks in Abutment (221 up)



d) Cracks in Pier wall and Bed block (131 up)

d) Cracks in Bed block (Bridge No. 131 dn)

Figure 2: Bridges with cracks in the abutment wall, piers, wing wall, and bed blocks

4 New approach to crack repair and strengthening (intermittent maintenance) of the brick masonry bridges of Bangladesh Railway

The approach applied for this case study for the repair of cracks, loose joint, hollowness, and strengthening are not new for brick masonry structures but first for Bangladesh Railway. The repair method selected following the Indian Bridge Manual 1998 (updated on 14.01.2020), Bridge Rehabilitation and Strengthening Manual (2018) for Roads and Highways Department of Bangladesh, according to the cause and type, extend of cracks and de-stresses of bridges as identified during field observation. The material used for the repair works is selected as per the method, type, and intensity of distress (cracks, loose joints, etc.). The essential parameters considered for deciding upon a repair material are low shrinkage, setting/hardening, workability, bond strength, surface interlocking system, mechanical bonding, curing requirement, low air, and water permeability, Cost, durability, non-degradable or non-biodegradable, etc. Considering the parameters required for repair materials, method, and observed distresses in the bridges, bonding agents, micro-concrete, epoxy materials, polymer-modified mortar, etc. are selected along with an appropriate method to repair the cracks and other distresses of the bridges included in this case study. First of all removal of vegetation growth, all loose and foreign materials, and surface treatments of brick or concrete surface are commonly done for the selected bridges by scrapping, wire brushing, grinding, and finally washing with low-pressure power water jet washing (less than 400 psi) as shown in Figure .

a) Scrapping, wire brushing etc. (B/N-131)

b) Cleaning with low pressure water jet(B/N-131)

Figure 3: Surface preparation of the brick masonry railway bridges

Loose brick joints are repaired by the application of shrinkage compensating polymer modified mortar with compressive strength of 60 MPa, ASTM C109 for filling grooves, and cleaned the spillage/ spread over with a wet sponge before it dries up. For diagonal, angular, and horizontal cracks on the brick abutment wall or, pier U-shaped groove cuts are made along all such cracks to a size of 15 x 15 mm/10x 10mm width followed by cleaning with an air blower, water wash, and then left for overnight. First, on the surface of the groove, styrene-butadiene copolymer emulsion slurry and cement in a 1:1 ratio were applied followed by the application of polymer-modified repair mortar to fill the groove. The injection Nipples of 12mm diameter or Nozzle of suitable size were arranged by drilling the surface and fixed with an instantaneous setting cementitious compound. Then the cementitious single component injection grout/slurry is applied by pressure to be pumped from the lowest level of the port through the nipple/nozzle and proceed towards the upper level, continued for all ports till refusal / oozes out from adjacent port as shown in Figure . The nozzle/nipple was removed after 24-48 hours of application by cutting it and filling the gap with an instantaneous setting cementitious compound. To repair the bed block and side joint, low viscosity epoxy resin injection grout complies with ASTM-C 881-78, Type 3, grade 1, class B is used in stages with grout pump. However, the bed block with a prominent crack was repaired by applying a bonding agent to prepare the old concrete surface and micro concrete to fill the void with hand the pump.

b) Bridge No. 221(up) b) Bridge No. 102 (up) a) Bridge No.111(up)

Figure 4: Repair of loose brick joints and horizontal, diagonal, and vertical cracks of pier and abutment

Bed block repair by injection of the Low Viscosity Epoxy Resin Injection Grout is shown in Figure (a, b) and that is done by using a bonding agent and micro concrete is shown in Figure (c). After conducting an experimental study Santos et al. (2012) opined that, when a hunk of fresh concrete is cast against a hardened substrate, the improvement of the surface roughness has a significant role in achieving the bond strength and the use of a bonding agent is advantageous which leads to higher values of the bond strength.

a) Bridge No. 111(up) b) Bridge No.131(dn) c) Bridge No. 131 (up)

Figure 5 : Bed block cracks repaired by low viscosity epoxy resin injection grout, bonding agent and micro-concrete

As the decision of the higher authority and to provide confidence about safety, abutment and/or pier of bridge no 102(up), 111(up), 131(up &dn), 209 are covered with RCC jacketing and that of bridge no 210 (up), 221(up) are left uncover after crack repair work. However, RCC Jacketing was not instantaneously done after the crack repairs work, there was a time gap which was different for those bridges. It is to be noted that the abutment wall is the first time jacketed in the history of Bangladesh Railway, although such practice is done commonly in Indian Railways. The method of RCC jacketing of the pier is modified from the conventional practice of Bangladesh Railway with the concept of the Indian Railway Bridge Manual, 1998. Previously, only the portion above the ground level used to be Jacketed, and had no connection with the foundation of the pier, thus not strengthened the pier properly.

5 Observations and Discussion

The bridges repaired in this case study are monitored regularly and searched for new crack development at two months intervals and the settlement is monitored at six months intervals, recorded subsequently. For the measurement of settlement, corresponding benchmarks are installed at each bridge. For each bridge, two benchmarks are installed during repair work, and the height of the top surface of the bed block is measured with the concerned benchmark by the leveling machine and recorded accordingly (**Error! Reference source not found.**). Such measurement is taken at every six-month interval and recorded to investigate the settlement. During these observations, no settlement is recorded and no crack is observed since repair work is done on those bridges. However, angular cracks are observed in the wing wall of bridge no.209, not in the repaired location but about 1.5 feet away six months after the completion of the repair work. After careful observation and analysis, the reason is identified as the settlement of the wing wall's foundation. So that particular wing needs to be re-constructed. As mentioned earlier cracks and other distress in bridges are repaired first, then are covered by RCC Jacketing at different times. Therefore, the repaired surface of all the bridges was uncovered before RCC Jacketing work nearly for a year but no visual cracks were identified during the inspection, neither along the previous crack nor in other areas. Moreover, for Bridge no 210(up) and 221(up) without RCC jacketing, three years have already passed from the completion of the repair work to the last inspection, and still no visual cracks or distortions and settlements are recorded. This indicates that the foundations of the bridges are intact, and no settlement is encountered which also reveals that RCC Jacketing may have been avoided.

Figure 7 Measurement of Settlement of Bridge No. 131 (up) on 15.06.2023

6 Conclusion

The findings of the present study reveal that the approach of application bonding agent, epoxy injection, polymer mortar, and micro concrete in case of distress/crack repair railway bridges of Bangladesh have a strong prospect over the conventional practice in this arena considering cost, safety, and valuable time. The conventional practice inherited from the Bish Railway company being 100 years old, is outdated definitely. During these 100 years, a lot of new technologies and materials have evolved in this field concerned with more safety, economy, strength, durability, workability, etc. The method, materials, and technology should be need-based and according to the actual situation and field demand. Since in Dhaka-Chattogram, Chattogram- Dohazari, Akhaura-Sylhet, and Dhaka-Dewanganj Bazar sections, most of the railway line is under some study project, and some projects are under implementation, some awaiting the implementation of Dual Gauge Double line/ Dual Gauge line in this area. So, in this situation complete re-building/ partial re-building may prove ineffective and loss of money as the railway alinement can be changed, may pass beside the newly completed re-build bridges. The present study reveals that the intermittent maintenance technique is effective for the repair of cracks and distress in brick masonry railway bridges and is well supported by the theories as well as practice in other countries. Further, the approach will be more effective considering the cost, safety, and time if unnecessary RCC jacketing is avoided based on the cause of cracks. The results and effectiveness of this intermittent repair technique have already been identified and appreciated by the authority of the Bangladesh Railway. Seven bridges in the Akhauara-Sylhel section were repaired with this method in 2022, another fourteen numbers of bridges of the same section and six bridges of Chattogram-Fani are in process of the intermittent repair with the same technique used in the case study avoiding the RCC jacketing as recommended by the study.

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