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Replacement of expansion joints of 2nd Hooghly bridge, Kolkata

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ABSTRACT: Vidyasagar Setu (2nd Hooghly Bridge), the first major cable-stayed bridge in Indiawasput to service in 1992. The bridge is heavily trafficked. Main cable stay portion of the bridge was equipped with-Matt (Slab seal) expansion joint at one end an 11-cell Modular Expansion Joint of 880mm of movement capacity at the other end, which was also the first application of large modular joint in India. Condition of the Modular joint deteriorated over time and finally got damaged to an extent that immediate replacement became necessary. Replacement of the existing expansion joint, particularly the Modular joint involves challenges in defining proper traffic management, safety assurance, appropriate technical solution and work methodologyas blocking of any carriageway for a long duration is not possible and the large movement modular joint of 11 cells is required to be placed also in a lane by lane manner, ensuring an uninterrupted flow of traffic.

1 INTRODUCTION

Vidyasagar Setu (commonly known as 2nd Hooghly Bridge), is the first cable-stayed major bridge in India. The bridge was constructed over two decades, during 70s and 80s and was finally opened to traffic in the year 1992. In spite of an extremely long construction period, it was one of the longest span bridges of its type in Asia, at the time of its construction. It links the twin cities f Kolkata and Howrah, spanning over the river Hooghly, the main branch of the river Ganga. This magnificent structure, “A Poetry in Steel and Concrete” was planned to connect Kolkata with its suburbs and vast hinterland of huge industrial and agricultural importance as the second major link after Rabindra Setu (Howrah Bridge) which was constructed in 1943 at 1.5 km upstream. The bridge caters to almost 90,000 vehicles per day and thus in turn has an immense impact on the socio-economic life of the citizens.

1.1 *The Bridge*

The cable stay bridge portion is nearly 823meters long with a central span of 457.20 meters between two “A” frame pylons. Total deck width of 35meters is divided in dual-carriageway separated by a median strip with each carriageway comprising of three lanes. A cross-fall of 2% is maintained across each carriageway to facilitate surface run-off and 4% camber gradient is maintained in the longitudinal direction to match a central vertical curve of 5000m radius. This is a composite construction in steel and concrete comprising of built-up steel girder system with 230mm thick RCC deck slab.

Figure 1. Vidyasagar Setu (commonly known as 2nd Hooghly Bridge)

1.2 *Expansion Joints*

The bridge deck is restrained along both longitudinal and transverse direction through bearing supports at Kolkata end and only along transverse direction at Howrah end, allowing longitudinal movement of full length of the main cable stay bridge portion at that end. Kolkata end expansion joint was therefore required to cater for the movement contribution only from the approach part and is limited to 230mm while the Howrah end joint was required to be designed for a huge longitudinal movement of 880 mm, contributed primarily by the main cable stay bridge. Accordingly, at Kolkata end, Slab seal (matt type) expansion joint was used based on the availability in India at that time but for Howrah end, because of the large movement demand, 11 cell Modular strip seal expansion joint with total movement capacity of 880mm was provided and was required to be imported from Germany.

2 THE PROBLEM

About a year back, the bridge authority undertook a comprehensive inspection of the bridge with an aim to estimate its structural health and to enhance the operational life. Based on the findings of the inspection and assessment of the condition of major bridge components, a decision was taken to replace the expansion joints of the main bridge portion.

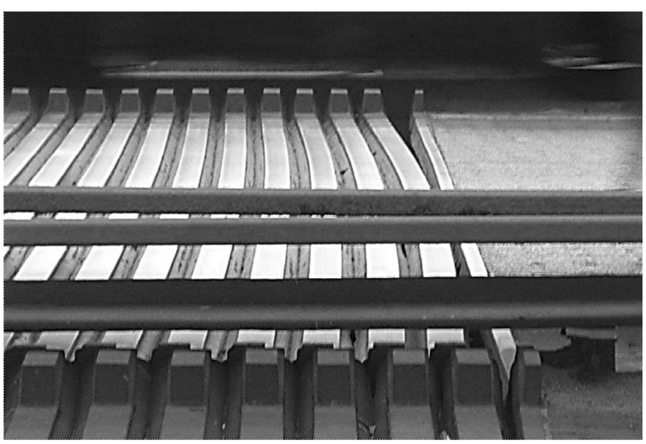

Figure 2. Existing Modular joint in distressed condition

Existing modular joint at Howrah end was of swivel-joist type 11 cell modular joint. Structural behaviour and performance of the joint started to deteriorate within 10 years from opening of the bridge to traffic. The moveable parts of the mechanical steering system of Swivel-Joist type modular joint which controls the gap width of the modules and maintains uniformity of gap with expansion and contraction of the joint, were getting jammed, hindering free movement of the joint. Jamming of the moving parts caused locked-in stresses in the system and as an effect the top lamella beams were found to be bent in plan with non-uniform gaps between modules. The severity of the problem grew fast with time and finally the lamella were snapped into pieces to relieve the huge accumulated locked-in stress built up over time. The situation was so grave that the existing joint was required to be buried under steel cover plates to facilitate traffic movement and it almost became an emergency for the bridge owner to replace the joint as early as possible.

Figure 3. Existing Slab Seal (matt) joint

On the contrary, the joint installed at Kolkata end, which was of rubberised matt (Slab seal) type, were found to be still in workable condition with signs of wear and tear at the top rubber surface facing road traffic. There was no serious structural damage to the joint which might be hazardous to the traffic. However, since the joint had served for more than two decades and crossed the design service life of 15 years and showed signs of weathering and ageing of rubber as well as wear and tear causing local exposure of internal steel parts, it was decided to replace this joint as well.

3 CHALLENGES

Replacing expansion joints of a bridge in service always brings in several challenges. The challenges become multidimensional, when it is a heavily trafficked major bridge in service with average daily traffic volume of about 90,000 vehicles; when the bridge is of sophisticated cable stay construction with composite deck and approaches made of concrete; when the joint to be replaced is a modular joint of very large movement.

3.1 *Keeping Uninterrupted Traffic Flow*

Heavy traffic volume on the bridge demanded a robust and fool-proof traffic management plan so that free flow of traffic is allowed on the bridge while replacement work would take place. It is therefore inevitable that the joint replacement has to be done in a lane by lane manner i.e. to take up activity of replacement at one lane of a carriage way at a time and allowing traffic over the other two lanes of the same carriageway. Replacement activity involves removal of existing joint as well as placing of new joint. Sequence planning of lane by lane work of removal and lane by lane work of placement of new joint also involves considerable complexity, particularly for modular joints as the top lamella beams are of single piece over the entire carriageway width for each of the carriageways.

3.2 *Complexity of the Bridge Structure*

The average daily movement of the bridge is about 200mm which is not only clearly perceptible but also highly significant particularly for the installation of new joint as the position of supports and width of the joint are changing when work is being done in a lane by lane activity. The joints are located between the cable stay deck, a composite construction with steel girder and concrete deck at bridge side and the approach viaduct structure made of pre-stressed concrete. This involves not only well thought out and careful technique of lane by lane removal of existing joint from steel support structure at main bridge side and concrete structure at approach side of the joint without damaging main structural components of the bridge but also involves complex detailing of the new joint for steel connection at one end and concrete connection at the other end of the joint.

3.3 *Complexity of the Joint Types*

Replacement of slab seal joints at Kolkata end of the bridge involves little difficulty as the elastomeric slab units are modular in nature and are replaceable easily from top with new slab unit and the challenge is limited only to the traffic management requirement.

Complexity in replacement of modular joint at Howrah end is manifold. The modular joint to be replaced is a large movement joint with considerable width at the top. Facilitating traffic over the gap width created after removal of the existing joints would require robust and strong enabling structure in form of temporary bridge plates capable to accommodate daily thermal movement. Large plan dimension of the joist boxes of the existing joint at concrete connection end requires controlled dismantling of pre-stressed concrete structure for removal of existing joint and also detailing and placing of new reinforcing bars to achieve desired strength for the new concrete connection. Complexity also involves detailing of the joint in tandem with the lane by lane installation procedure of the joint and at the same time keeping full length of lamella beams over all the three lanes of entire carriageway width avoiding butt weld connection of lamella beams. In addition, the connection detail of the joint is different at both side of the joint with steel connection detail at one end and concrete connection at the other end. Connection at the steel girder end is even more challenging to ensure minimal interference and involvement of fabrication with the existing steel girders.

4 FEATURES OF NEW JOINTS

4.1 *Matt (Slab Seal) Joint at Kolkata End*

Only the elastomeric slab units of the Matt (Slab seal) joint were required to be replaced after inspection and it was found possible to use slab units of same model and brand. Since the embedded steel housing were found to be in good condition even after more than two decades of service the entire replacement work could be done in a non-invasive way. This proves the efficacy of the Elastomeric Matt joint for midrange movement capacity not only from the durability point of view but also for the ease of replacement. The new slab units have improved abrasion resistance, better flexibility and strength.

4.2 *Modular Strip Seal Joint at Howrah End*

The new modular strip seal expansion joint used is a 4th generation modular joint. Unlike rigid and intolerant mechanical steering system of the existing joint, the new joint uses elastic steering systems, which is a natural and forgiving system and helps to avoid the constraint forces due to unforeseen movements or obstacles. This special feature of the new joint will help to avoid the problem faced by the existing joint.

Figure 4. Independent Load transfer and Gap control System of proposed joint

The new joint is made of bolted connection and avoids welded connections which not only improves the durability of the joint against fatigue but also helps to facilitate replacement of joint components easily and quickly. Sleek shape and construction of the joist box helps to provide adequate reinforcement bars with proper detail for concrete connection. The most important feature of the new joint is that the support system and gap control steering systems are independent of each other. This unique feature is of primary importance in detailing the new joint in a manner such that the support system of the joint of one carriageway may be placed in 3 parts to meet the lane by lane placement requirement and then the lamella beams complete with steering system are placed in single piece for full length and are connected to the support system avoiding any welded connection of lamella beams at site.

5 EXECUTION OF REPLACEMENT WORK

5.1 *Traffic Management System*

The temporary traffic management and control system that has been adopted on bridge during the replacement activity is elaborate and adequate keeping provision for smooth and hassle free traffic movement and at the same time ensuring safety to the motorist and the workers. Mitigating emergency situations like fire break-out or break-down of vehicles have also been planned beforehand. The guiding principle of the traffic management system is to reduce the number of conflict point by establishing a stream-flow of traffic on bridge. The traffic management system has been developed in the following phases:

5.1.1 *Planning phase*

This involves traffic volume study to determine the classified hourly traffic volume and average daily traffic volume by analysis of data supplied by the Owner. The vehicular characteristic varies widely between day and night demanding separate study for both the phases.

5.1.2 *Design phase*

Based on the volume study and mandatory clearances as per IRC regulation a basic layout plan has been prepared to mitigate the situation taking into consideration the basic principle stated above. It is recommended to keep the entire activity lane within the working zone preceded by adequate approach transition and advance warning zone. Due to ease of handling, Steel barricades and concrete delineators are used to separate the traffic control zone from the surrounding as and when required.

5.1.3 *Implementation phase*

Implementing Temporary traffic management and control in practice is found to be an uphill task particularly in situation with a daily traffic volume of 90000 vehicles and peak hourly volume of 4000 PCU. The Plan has been thoroughly scrutinized by the officers of the State Traffic control and their recommendations suitably incorporated in the plan before implementing.

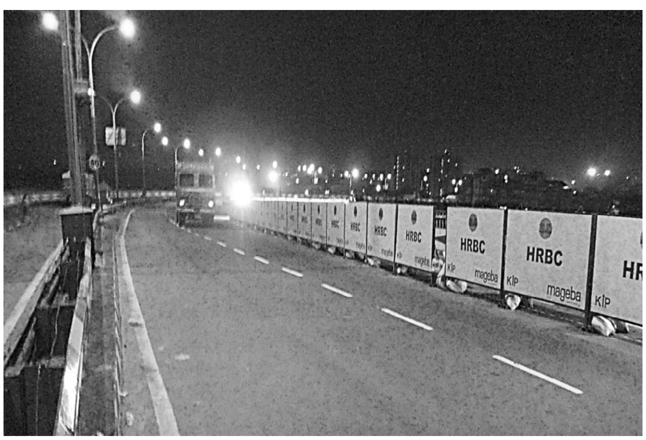

Figure 5. Temporary traffic Control on Vidyasagar Setu

Deploying adequate number of trained Flagmen under the supervision of senior Flag Marshalls, erecting informative, prohibitive or warning signage , placing barricades and delineators as per the basic layout plan was instrumental in implementing the robust traffic management and control.

5.1.4 *Operation and maintenance phase*

This is to ensure that the traffic management plan as implemented is being abided by the working crew, the responsible flagmen and marshals to maintain disciplined flow of traffic on bridge. Relevant checklist control is made which has been instrumental in imposing discipline at site.

5.1.5 *Enabling structure*
The bridging plate is designed as a simply supported span of 3.5m capable of withstanding Class AA wheeled loading as per IRC regulation.

Figure 6. Traffic plying over Bridging Plate

The support system of the plate is capable of accommodating the diurnal movement of the bridge due to thermal variation with one end being restrained to both longitudinal and transverse movements. The selection of economic section helps easy handling during placing and removal operations. The surface of the plate facing the traffic is made skid proof. Adequate head-way space is kept underneath the plate. The circular vertical profile of the plate accompanied with transition curves at either ends by flexible bituminous course help easy manoeuvring of vehicles.

5.1.6 *Mitigating emergency situations*
Towing equipment and necessary fire-fighting arrangements are made available on bridge throughout the implementation phase. Lastly since the traffic management and control system has to encounter unforeseen situations so reserve resources are to be maintained to mitigate such undesirable occurrences.

5.2 *Replacement of Matt (Slab Seal) Joint*

Owing to the strikingly remarkable features of the matt it can be replaced in a non-invasive manner in the following sequences:

5.2.1 *Removal of the existing slabs*
This involves unfastening the fastener system holding the pad firmly to steel housing underneath.

Figure 7. Recess of matt joint after removal of slabs

5.2.2 *Surface preparation*

The steel housing is cleaned thoroughly by in-situ sand blasting removing scales, rusts and other substances prior to the application of anti-corrosive treatment. The corrosion protection system has been designed for severe exposure. Furthermore, the threads of the tapped hole holding the primary fasteners have been made good for fastening the new bolts.

Figure 8. Prepared surface for placing new slabs

5.2.3 *Placing of the slab*

Prior to placement of new slabs the steel housing has been neatly cleaned by compressed air. The new slabs are placed in position keeping the centre of the slot in the pad and the centre of the hole in the housing as close as possible. Temperature plays a key role in this regard. Mechanical lever system may also be used for proper positioning of the slabs, otherwise.

Figure 9. Fixing of new slabs in position

The slotted hole in the slab is capable of undermining the differences within a tolerance range. So precision has to be adopted to avoid cumulative differences. After being positioned properly, the fastener accessories are fastened in their respective position in an orderly manner. Care has been taken so that male-female groove of one slab and the immediate adjacent one develops a mechanical water-tight interlocking. Waterproofing sealant has been applied at all possible locations, susceptible to water-leakage, to make the system perfectly water-tight.

Finally, prior to opening of the lane to traffic, trial run using light commercial vehicles is made and only after satisfactory results the lane is opened to traffic.

5.3 *Replacement of Modular Joint*

The lane by lane replacement of modular joint is a multi-fold activity done in different phases as stated below:

5.3.1 *Removal of existing joint*

The existing swivel type joint was detailed with fixed joist box at the steel connection end and with movable joist box at the concrete end. Due to the swivel geometry of the joint the selection of the segment to be removed has be done judiciously. Auxiliary support system has been devised to hold the free end of the lamella beams. The lamella beams and supporting frames are then removed in an orderly manner.

Figure 10. Removal of existing joint

The concrete is then dismantled to remove the large joist box structure. Adequate precision and control has been imposed during dismantling work keeping in consideration the PSC girder system of the viaduct portion.

5.3.2 *Surface preparation*

The process of surface preparation becomes versatile since the new joint will be supported between the steel girder of the main bridge and the concrete recess of the via-duct. Separate preparatory process has been adopted to make both surfaces ready to accept the new joint.

Figure 11. Surface preparation of the steel side of Modular joint

For the steel side of the main girder, localised grinding activity followed by an anti-corrosive treatment have been done complying with the severe exposure condition. However, on the concrete side, the recess preparation is far more elaborate. This involves cleaning the cut-out concrete edges neatly, removing loosely adhered articles with chiselling tools, chipping of the base and placing adequate rebar held or anchored firmly in position imparting flexural and shear strength to the section. This has been designed as sufficient to withstand the force responses of the new structure.

Figure 12. Prepared concrete recess of new Modular joint

Figure 13. Support interface of Modular joint

5.3.3 *Developing new support system*

A new support interface is introduced at the prepared surface of the steel side to minimise the interference and involvement of fabrication with the existing steel girders, and at the same time developing the load transmission mechanism through the existing bracket systems of the main girder.

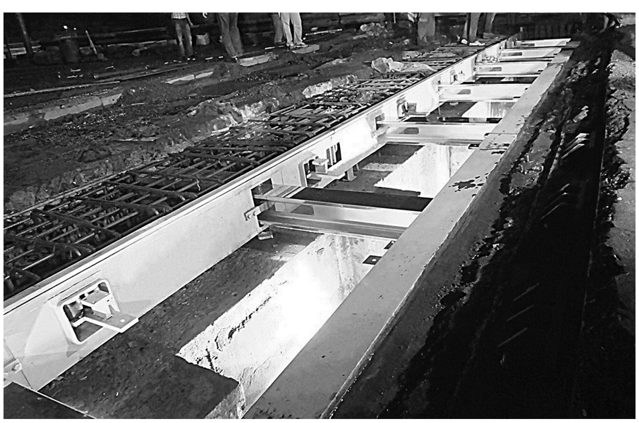

Figure 14. Support system of Modular joint installed at site

5.3.4 *Lowering of the support system*

The support system of the modular joint is then lowered and put to position as marked on the bridge. A robust holding system has been developed to avoid any type of local or system distortion. A strict quality control system is devised to monitor that the level and line of each joint segment are in line with the subsequent or preceding one and vice-versa, at the same time matching the bridge gradient in either direction. After obtaining necessary clearances from the quality control welding of the support system of the joint to the support interface is permitted. Welding sequence is also a very important aspect in this regard. And finally the joist-boxes in the concrete recesses are held in position with help of reinforcing bars.

Figure 15. Positioning of Lamella beam assembly

5.3.5 *Lowering of lamella beams*

After successful completion of the preceding activity in all the lanes of the carriageway, the entire lamella assembly of full length as that of the entire carriageway width, fitted with the complete steering system, is lowered and placed over the Joist beams of the support system already installed. The lamellas are now ready to be fastened with the Joist beams of the support system in their respective locations. Final connection of the joint has been established at the steel side by completing all required welding.

5.3.6 *Concreting and curing*

Controlled grade concrete of define strength and workability is adopted for the project. Development of early strength guides the selection of plasticisers for the design mix. Prior to pouring of concrete, bonding agents were applied in prescribed manner to the neatly prepared concrete recess. Desired compaction is attained by using mechanical vibrators. After initial setting time of couple of hours, traffic was allowed over the bridging plate spanning over the installed joint and new concrete .The concrete is then cured adequately before removal of the bridging plate and exposing the new joint and the concrete back to full traffic.

6 CONCLUSIONS

Expansion joint is a key functional component particularly for long span bridges. Replacement work of expansion joint on a major and busy bridge in service is extremely complex, particularly for the time constraint in execution maintaining undisrupted traffic flow. The most difficult part is to foresee hurdles from all corners and to design the work procedure in a manner so that there is no unforeseen surprise during the actual execution of work.

In the subject case, replacement work has been taken up for a very large expansion joint for the first time in India with precise planning and has been carried out through well coordinated execution within the estimated time, posing least trouble to the traffic. Vidyasagar Setu, the lifeline of Kolkata, has got rejuvenated through this refurbishment work. It is expected that the experience and knowledge gathered through this work will not only remain as precedence but also will provide reference for similar challenging work to be taken up in future.