Renewal of modular expansion joints - an innovative approach that minimises impacts on traffic and on the main bridge structure

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Summary

An innovative method for the replacement of an old modular expansion joint in a concrete structure is presented: the "box-in-box" method. It requires only the replacement of dynamically loaded parts of the joint, and thus offers several advantages over traditional full-replacement techniques. In particular, it saves the need to break out concreted-in parts of the joint and to place new reinforcement and concrete. Costs are therefore reduced, disruption to traffic is minimised, and structural impacts on what might otherwise be a perfectly sound structure are avoided. And the approach is environmentally friendly, minimising not only the use of new materials and the construction effort required, but also the various impacts of traffic congestion during the works.

Keywords: Modular expansion joint, renewal, replacement, minimum time, impact on structure

1. Introduction

Expansion joint renewal is a source of considerable expense to bridge owners and can cause enormous disruption to traffic– both impacts which should be minimised during the life of any structure. The best way to do this is to use only high-quality, properly designed and well detailed expansion joints, and ideally ones which have proven their performance on many structures over a period of many years. This will ensure that maintenance and repair efforts will be minimised during the life of the joint, and that the frequency of major replacement projects can be reduced thanks to a longer service life. But where significant movements must be accommodated, even the best, most perfectly designed and detailed joint is likely to require replacement several times during the life of the main structure. This is because the joint is far lighter and less robust than the bridge as a whole, yet subjected to fatigue loading with the passing of every vehicle [1].

When the time comes to replace such an expansion joint, a full new joint must generally be supplied and installed - after complete removal of the existing joint and any parts of the bridge deck to which it was connected. In the case of a modular joint in a concrete bridge deck, this traditionally required breaking out of significant quantities of concrete at each side of the bridge gap, and placing of new reinforcement and concrete around the new joint. But a method has recently been optimised which saves this effort, bringing a number of benefits. This method is described below.

2. The modular expansion joint

Modular expansion joints have a great deal to offer to bridge designers and constructors, thanks to their ability to facilitate very large longitudinal movements and (depending on their design) their great flexibility - no other type of joint can accommodate longitudinal movements of two metres or more while also facilitating transverse and vertical movements, and rotations about all axes. The design of the joint of one supplier is illustrated by Figures 1 to 6 below.

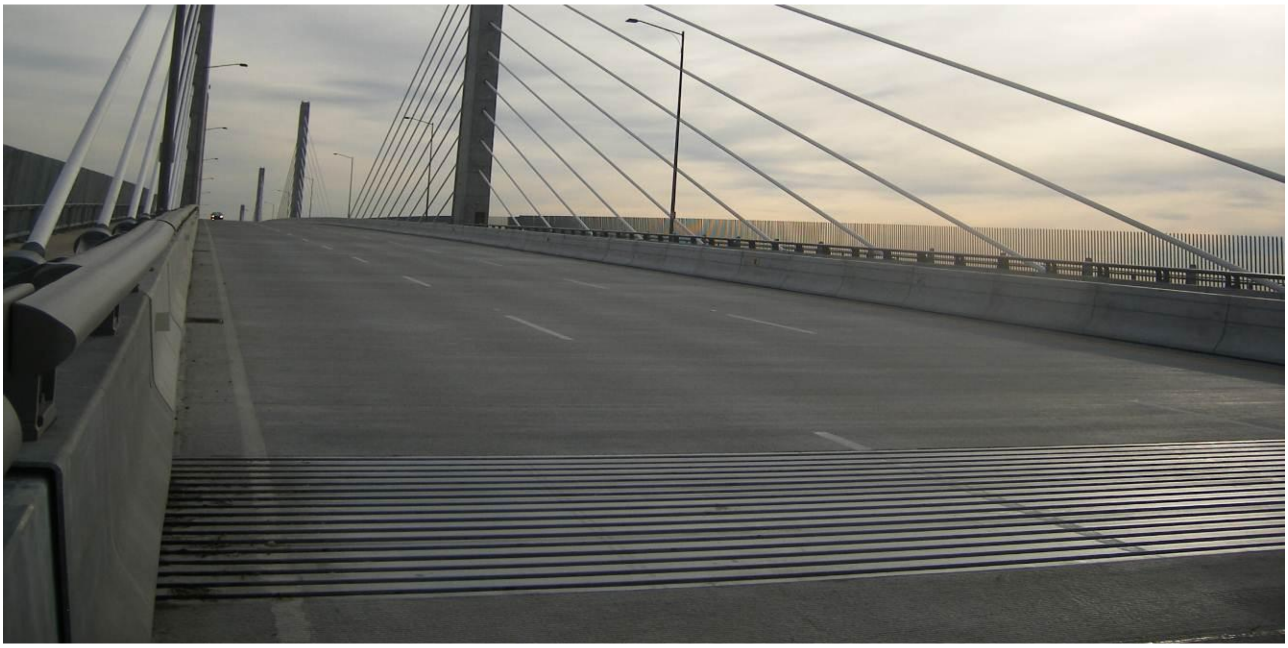

Fig. 1: A large modular expansion joint at one end of the deck of a cable stayed bridge

A modular expansion joint contains on its surface a number of lamella beams which divide the movement gap at the end of a bridge deck into smaller individual gaps. Each gap is typically permitted (by national standards) to facilitate 80 mm of longitudinal movement, so the number of gaps required in the joint can be calculated by dividing the total movement requirement of the joint by this figure. The joint in Figure 1, for example, has 17 gaps and can thus accommodate 17 x 80 = 1,360 mm of longitudinal movement. Further examples which show the joint's structure are presented in Figures 2 and 3.

Fig. 2: A 27-gap modular joint prior to installation on the Run Yang Bridge, China

Fig. 3: A modular joint during lifting into position on the Lillebaelt Bridge, Denmark

The structure of the joint is shown in more detail in Figures 4 and 5. The lamella beams are connected by elastomeric sealing profiles to form a watertight unit, preventing the passage of water through the joint and preventing damage to the structure beneath. They are supported by perpendicularly orientated beams underneath, typically spaced approximately 1.6 metres apart (as can be seen in Figures 2 and 3), along which the lamella beams slide. These beams, known as support bars or cross-beams, span between steel boxes in the deck at each side of the bridge's movement gap (as shown in Figure 5). The support bar slides into and out of the box at one side (or in some cases, boxes at both sides) as the bridge gap closes and opens.

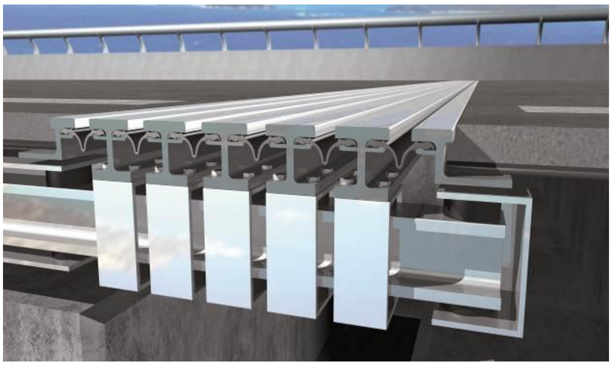

Fig. 4: Schematic section of a 6-gap modular joint. The lamella beams on the surface slide along support bars, which span between boxes at each side of the movement gap

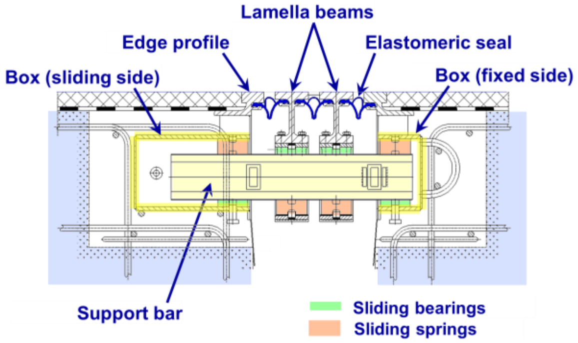

Fig. 5: Cross-section of a 3-gap modular joint, showing its main components – including a support bar and the boxes at its ends

Fig. 6: View of an installed 5-gap modular joint, from beneath

The support bars and their support components are thus critical elements of the mechanical structure which make the modular joint so versatile. Figure 6 shows an installed joint, viewed from beneath, with its support bars themselves supported by the boxes that are concreted in place.

3. The "box-in-box" method for modular joint replacement

Recognising that the parts of a modular joint which are concreted in are not subjected to dynamic loading, it may be concluded that it will not be necessary to replace those parts in most cases – saving the effort of breaking out the concreted-in parts and the traffic disruption caused while the structure is partially demolished and reconstructed. As an added benefit, this approach also avoids weakening what might otherwise be a perfectly sound structure.

3.1 Step-by-step description of basic procedure

The method is described with reference to a recently executed project to renovate a modular joint on the Simbach-Braunau bridge across the River Inn on the German-Austrian border. After a respectable service life, the modular expansion joints of this concrete bridge were found during inspections to be in need of replacement. However, apart from this, the bridge was determined to be in good condition. The owner was thus keen to avoid weakening it, and of course to minimise the time, effort and expense of the works.

Fig. 7: The existing 3-gap modular joint

Having undertaken an initial inspection and analysis, it was concluded that the project presented an ideal opportunity to implement the newly developed "box-in-box" method, which could optimally achieve these objectives. A phased approach would be implemented, as described in Section 3.2.

The initial analysis also established, as is often the case, that the movement demands of the expansion joint had reduced substantially since the original joint was installed. This is primarily due to the fact that the irreversible creep and shrinkage movements have already taken place and do not need to be accommodated any more. In this case, it was concluded that the existing 3-gap joint could be replaced with a 2-gap one, significantly reducing both initial and maintenance costs.

Step 1: Removal of asphalt at each side of joint

First, the asphalt adjacent to the joint along each side was removed, exposing the top of the support bar boxes. It also exposed the rest of the steel of the existing joint's substructure which would be retained, enabling sandblasting and corrosion protection works to be carried out, and presented an opportunity to address the rutting which had deformed the asphalt over the years.

Step 2: Removal of the old joint (less substructure)

The sealing profiles and lamella beams were then removed, providing access to the support bars beneath. Following cutting and removal of the steel lids of the support bar boxes, and of the parts of the concreted-in steel edge beams directly above the support bars (see Figure 9), the support bars could also be lifted out.

Fig. 8: Removal of the lamella beams of the old joint, following removal of asphalt

Fig. 9: Cutting of the steel edge profile at each side of the joint, at each cross-beam location

Step 3: Cleaning of retained steel and application of corrosion protection

After scraping away of any rust and loose corrosion protection, the remaining steel was inspected to ensure it was still serviceable. Having confirmed that it was, it was sandblasted and treated with corrosion protection, with a base coat applied to all steel and additional intermediate and surface coats to all areas that would not be subjected to welding.

Fig. 10: View of the retained substructure following completion of cutting and removal

Step 4: Inserting of the new joint framework

The new framework, consisting of lamella beam, support bars, support bar boxes and all connected components, could then be lifted into position (Figure 11), with the support bar boxes located inside the cut-open boxes of the old joint (Figure 12). Adjustments were made as required to ensure that any settlements and rotations which may have developed across the existing joint would not adversely affect the new joint. The new boxes were continuously welded, right around their edges, to the inside of the existing boxes. The welds were then sandblasted and applied with a base coat of corrosion protection.

Fig. 11: Lifting in of the new structure, consisting of a lamella beam and connected support bars, complete with boxes

Fig. 12: View of a support bar box of the new joint, placed inside the larger support bar box of the old joint and welded all around

Step 5: Filling of voids between old and new boxes

After fixing of shuttering as required at the free end of each old box, the voids between the old and new boxes were filled with non-shrink mortar (Figure 13). This ensures that the driving surface will not suffer from rutting in years to come.

Fig. 13: View of one new support bar and its boxes, following placing of mortar to fill out the voids between new and old boxes

Fig. 14: View of joint following securing in place, before re-instatement of edge profiles

Step 6: Formation of steel edge profiles

Following removal of shuttering, the vertical plate sections, which had been cut away to allow insertion of the new support bars, were welded back in position (Figure 15). New parts were then welded to the vertical plates (Figure 16), creating a new edge profile for connection of the sealing profiles.

Fig. 15: The vertical plate of the edge profile at one side of the joint has been welded back in place

Fig. 16: Completion of a new edge profile with the addition of a new part into which the edge of an elastomeric seal will be inserted

Step 7: Completion of corrosion protection

After sandblasting of the new welds, the application of corrosion protection to all areas was completed.

Fig. 17: Joint during application of corrosion protection

Fig. 18: Joint following insertion of sealing profiles

Step 8: Insertion of sealing profiles

The elastomeric sealing profiles were then inserted between the edge and lamella beams, and final cosmetic works carried out on the expansion joint.

Step 9: Reinstatement of carriageway

Finally, the waterproofing membrane was reinstated (Figure 19) with connections to the edge profiles at each side of the joint, and asphalt laid to complete the new driving surface.

Fig. 19: Application of waterproofing to bridge deck at each side of the new joint

Fig. 20: Joint section following placing of asphalt at each side

3.2 Phased approach to minimise impact on traffic

Although the "box-in-box" method greatly reduces the impact on traffic (as well as on the structure and the owner's finances), lane closures are unavoidable and disruption to traffic can be significant. To minimise such disruption, the work can be carried out in phases, with the expansion joint on only one side of the bridge deck being replaced at a time. In this way, the bridge can remain in service, avoiding the need for long traffic detours.

This option was utilised at the Simbach-Braunau bridge to minimise the impact on traffic. Having closed one half of the bridge (Figure 21), the lamella beams on the joint's surface were cut in the middle, and the procedure described in Section 3.1 was implemented on the joint at the closed side of the bridge. After repeating the process on the second side of the bridge, the lamella beams of the two sides were welded together (Figure 22), enabling the entire new joint to be put in service and the full width of the bridge to be re-opened to traffic.

Fig. 21: Phased approach to further reduce the impact on traffic – with work carried out one lane at a time

Fig. 22: View of joint following completion of first phase, before asphalting to finish second phase. The elastomeric sealing profiles (on left) have yet to be inserted in the second section

Even with the two-phase approach that was adopted, the entire renovation project took just 15 days, from closure of the first half of the bridge until clearing of the site, and had minimal impact on traffic. The direct costs of the project were also minimised – not only as a result of the considerably smaller scope of expansion joint supply, but also due to the much reduced break-out and installation time and effort required.

4. Conclusions

Adoption of the “box-in-box” method for modular joint replacement offers many benefits, and requires only that the new joint which is to be installed can be designed to suit the retained parts of the old one. This is particularly important in relation to the locations of the support bars of the new joint, which must be designed to fit (complete with new boxes) into the boxes in which the support bars of the old joint were located.

Implementation of the method saves a great deal of effort – in particular, in the breaking out of concreted-in parts of the joint and the placing of new reinforcement and concrete. It also greatly reduces the disruption to traffic that is caused by these works, especially considering the concrete curing time that is saved. The impact on what might otherwise be a perfectly sound structure is also minimised, with unnecessary damage to deck concrete and reinforcement avoided. And the approach is environmentally friendly, minimising not only the use of new materials and the construction effort required, but also the various impacts of traffic congestion during the works. It is thus clear that this innovative approach to expansion joint renewal should be seriously considered whenever modular joints are to be replaced on existing structures.

References

[1] SPULER, T., LOEHRER, R., O’SUILLEABHAIN, C., “Life-cycle considerations in the selection and design of bridge expansion joints”, *Proc. IABSE Congress on Innovative Infrastructures towards human urbanism*, Seoul, September 2012