

CASE STUDY: REFURBISHMENT OF DETERIORATED BRIDGE DECK EXPANSION JOINT IN SUBURBAN AREA

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ABSTRACT

An expansion joint can be defined as a device to support the surfacing, or to provide a running surface, across an expansion gap on a bridge structure. Typically expansion gaps are installed between adjacent spans of a bridge deck or between a bridge deck and an abutment.

Due to the exposure of expansion joints to traffic loads, heat and cold, and atmospheric corrosion they tend to deteriorate faster than other bridge components and require several replacements during the expected life span of a bridge.

In this case the existing sliding finger joint plate joint at the northern abutment of Judd Street Bridge in South Perth was significantly deteriorated, the secure anchorage of some male plates and the waterproofing had failed. In addition the longitudinal grade creating a level difference between the bridge deck and the abutment approach slab during the colder seasons caused noticeable noise emission.

There was a quest for a solution that would require the least amount of demolition and construction works and is watertight, flexible in all directions and does emit minimal noise. After evaluating several options the design engineer and Main Roads Western Australia (MRWA) as the asset owner have decided to install a Flexible Plug Joint due to its various technical advantages discussed further in this paper. After removal of the existing finger plates this joint was installed in 4 x 8hr night shifts with next to no traffic disturbance during the day.

Extensive in-house and independent testing provided enough confidence to designers and asset owners. Successful applications and track records in over 20 countries worldwide in extreme high to extreme low temperatures demonstrates the durability and long term benefits of this joint. The certified service life (in accordance with European Technical Approval ETA-12/0260) of the joint is 15 years, with an expected service life of 30 years, thus keeping "Total Life-Cycle costs" considerably down. The new Flexible Plug Expansion Joint System achieves a completely new benchmark in terms of quality and working life.

This paper will examine the project and the benefits of this type of joint system.

INTRODUCTION

Life-cycle cost (LCC) considerations are recognised as having a high priority in the responsible management of any construction project or asset. A great deal has been written to assist engineers and owners in the assessment of life-cycle issues, and the field of bridges is no exception - for example, with the report "Bridge life-cycle cost analysis" (Hawk et al. 2003), published by the Transportation Research Board of the American National Research Council as Report 483 of the National Cooperative Highway Research Program (NCHRP). However, in spite of this recognition, expected actions have regrettably not yet translated into consistent practice to a large extent.

The field of bridge expansion joints is even more specialised than that of bridges in general. Therefore, it is no surprise that limited guidance is available to decision makers when considering TLCC while choosing an expansion joint. More than often, a solution that does not prove to be cost effective over the life cycle of the bridge is selected due to availability in certain geographical areas or driven by upfront capital costs.

Such solutions deteriorate faster if accompanied by lack of proper and periodic maintenance and significantly increase the indirect costs to the environment and wider society. E.g. wastage of resources,

noise emissions, and – probably most significantly – costs to the economy due to traffic congestion. Moreover, the performance of the expansion joints has a knock-on effect to maintenance costs of other components of the structure.

THE PROBLEM

Bridge 1009 (Judd Street Bridge) carries traffic from Mill Point Road onto the Kwinana Freeway via elevation over the Kwinana Freeway and Perth-Mandurah Rail Line. The bridge is located in South Perth, close to Perth CBD and has an average annual daily traffic of more than 10,000 vehicles per day. The bridge superstructure is a post tensioned voided box girder and has a total length of approximately 158m (5 spans). The superstructure has a total width of 8.80m. The bridge was constructed circa 1977 and is a MRWA structure. The bridge is fixed at Abutment 1 and has a sliding finger plate expansion joint at Abutment 2. The sliding finger plate joint was deteriorated to an extent where maintaining it further was not a feasible option (refer to Plate 1, 2 and 3). The damage to substructure and other bridge components associated with deteriorated deck joint is also evident from plate 4 and 5.

The post tension anchor locations on this bridge was the main driver for selecting a suitable replacement product. The original finger plates were tied-down into cast-in ferrules using M16 bolts. The cast-in ferrules were installed in various depth, at the location of the post tension anchor end blocks with a depth of 54mm below the 86mm recess for the plates to avoid any interference. The post tension anchor plates are located 225mm from the expansion joint gap and the anchor head cap has a 40mm cover. Because of the close proximity of the post tension anchor blocks to the top surface and the expansion joint gap breaking back the concrete diaphragm to install a cast-in option was regarded as high risk and discarded.

Installation of any available finger plate expansion joint using post installed concrete anchor design and satisfying AS5100.4 requirements proved to be impossible because of the geometric restrictions caused by the post tension anchor end blocks. Installation of reinforced elastomeric expansion joints was considered but discarded due to the known short lifespan.

Other reviewed joint types could not satisfy the required total 82mm longitudinal movement allowance at SLS and 103mm at ULS with a vertical component due to the longitudinal grade.



Plate 1: Overall Joint Condition



Plate 2: Level difference between male and female finger plates – safety hazard



Plate 3: Tie-down bolts missing



Plate 4: Damage to Bridge bearing underneath due to leaking joint



Plate 5: Damage to Bridge bearing underneath due to leaking joint

THE SOLUTION

After considering multiple products and ruling them out because they did either not satisfy Australian Standards or geometric constraints the new generation Flexible Plug Expansion Joint was selected by the designer and the asset owner. Some minor adjustments to the original product were required to satisfy Australian Standards and to ensure safe anchorage could be achieved within the geometrical restraints.

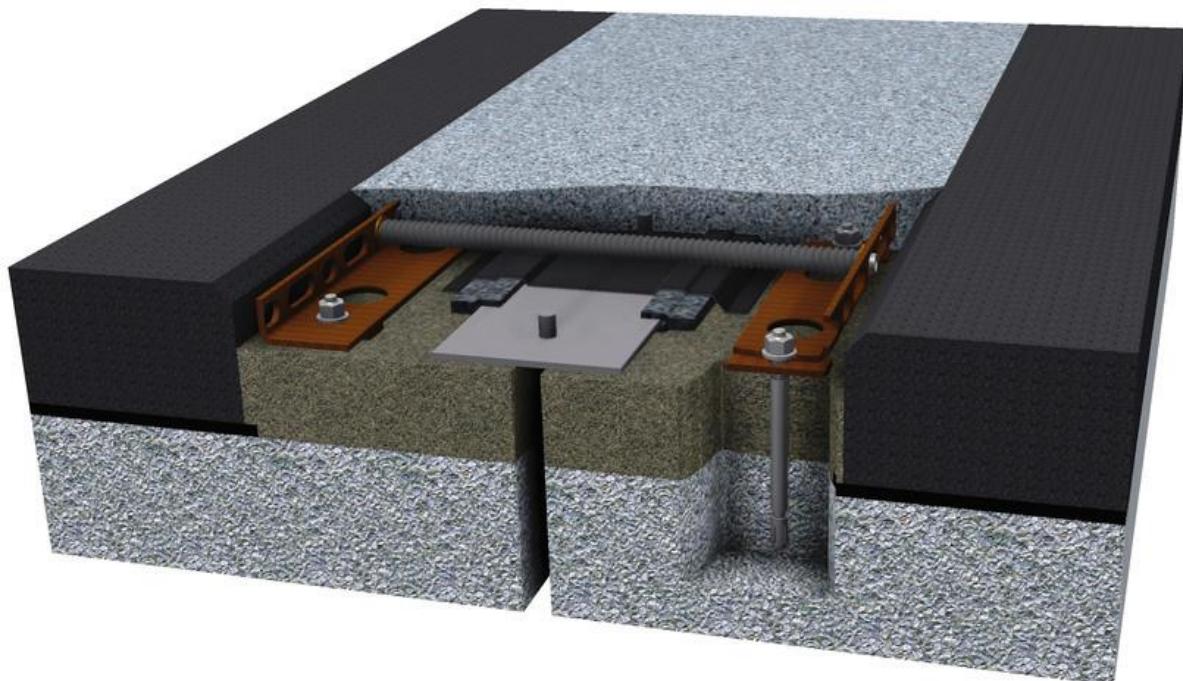


Plate 6: Typical cross section of new flexible plug joint

The Principle

Traditional bituminous based expansion joint materials have several disadvantages. Softer materials with lower reaction forces are not sufficiently stable and deform plastically at high temperatures and traffic loads (especially when vehicles are braking). By contrast, harder material has higher reaction forces – causing surface de-bonding at lower temperatures which leads to leakages. Varying quality due to proper mixture and temperature during installation (at appr. 180 °C / 356 °F) and limitation to small movements frequently cause problems.

The elasto-plastic behaviour of bituminous mixtures causes permanent loads (e. g. ballast gravel) to sink into the material (rutting). For this reason, conventional bituminous plug joints are not suitable for e.g. railway bridges with ballast beds, whereas Advanced Polymeric Flexible plug joints are.

New flexible PU material (developed in cooperation with leading chemical industries) and special joint design have solved the above mentioned problems. Additionally, it is a unique solution for the design of integral bridges as a crack-free link between bridge and abutment.

Characteristics

This joint uses a durable fully elastic material with an enormous tear resistance and low reaction forces. Perforated steel angles within the PU-material help to accommodate horizontal braking and reaction forces and allow for a clean bond between surfaces free of leakages from ingressing water. The new material has an exceptionally long lifespan and is resistant to wear and environmental and chemical influences. Its working life is substantially higher than that of most roadway surface materials. The original PU material has a long history of use as waterproofing for roofs and has been constantly improved over the years. The material has shown test values of 650% elongation before breaking (compared to 350-400% for standard rubber), which makes the material a perfect choice for use in expansion joint systems. PU material can be cast for nearly any joint shape (e. g. upstands, skew, T and X joints, etc.). The two-component material is mixed in complete packing units at ambient temperature, thus avoiding the possibility of on-site mixing failures. Processing is possible at temperatures between 5 °C and 35 °C virtually independent of humidity. The joint can be driven over after a few hours. Full functionality of the joint is given in a temperature range between -50 °C and 70 °C (-58 °F and 158 °F), which is a major improvement over bituminous plug joints. The flexible plug expansion joint system is a complete new development based on elastic polymers and a further development of the traditional asphaltic plug joint, whereby disadvantages of the traditional bituminous plug joint (e. g. de-bonding, plastic deformation, rutting, overload due to standing traffic, etc.) can be eliminated.

THE PROJECT

Tremendous amount of traffic management and planning was conducted by the contractor and the road authority personnel beforehand to ensure that removal of existing joint and installation of new joint goes as smoothly as possible minimising the day time traffic disruptions. The whole replacement operation was completed in 4 x ~8 hour's night shifts. A step by step brief of the whole process is explained below:

Night 1 & 2:

All the teams involved gathered just after 8:00pm on the site and a safety briefing with detailed site induction was completed. The planned process for removal of existing joint with backup actions (if required) and installation of new joint was briefly explained to all involved.

Step 1: The first step was started by unbolting the exiting anchor bolts. Due to very high degree of deterioration plan B was activated and the bolts were Oxy-Cut from their position and the shanks were ground off to the bottom of the recess, as shown in Plate 7 and 8.



Plate 7: Oxy-Acetylene flame cutting was used to remove existing damaged anchor bolts

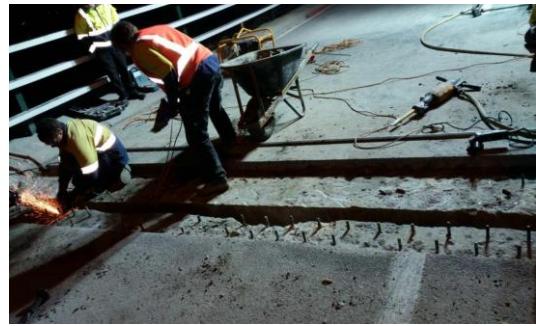


Plate 8: Remaining bolt shanks were ground off to the bottom of the recess.

Step 2: Surface of the recess left after removal of the existing joint was prepared level to be as close as possible to the design dimensions of the new joint system. Plate 9.

Step 3: The expansion gap between abutment and bridge deck was measured to verify the required quantities of the new joint system components. Plate 10.



Plate 9: Remaining bolt shanks were ground off flush with the recess



Plate 10: Verification of the expansion gap

Step 4: The kerb cover plates were carefully removed and a suitable recess for joint “upstand” was formed in the kerb area. Plate 11.



Plate 11: Recess formation in the kerb area

Step 5: The prepared recess was then sand blasted (Photos of sand blasting cannot be captured due to safe distance requirements). And the whole recess was covered with a heavy duty road plate secured at one end for the day time traffic.

Night 3:

After usual toolbox meeting and tasks briefing the works presumed on 3rd night to carry out below steps;

Step 6: The recess surfaces were applied with the bonding primer RW98 to ensure the anticipated bonding between existing concrete and new Polymeric Concrete Sub structure. 100% surface coverage, rate of application and precise curing time before application of Polymeric concrete is utmost important for developing strong bond. Plate 12.

Step 7: A high strength Polymeric Concrete RW42 was then used to form the perfectly flat recess bottom and strong transition beams on either side of the joint. The special Polymeric concrete is a Rapid curing high strength compound that develops its anticipated strength very fast. Plate 13.



Plate12: Application of primer RW98 to the recess surface with the recess



Plate13: Formation of recess using high strength polymer concrete RW-42

Product Explanation: RW42 is a 2-component, fast-reactive, highly filled PMMA-based (polymethyl methacrylate) repair and levelling mortar with a formulated filler mix. The Key Characteristics of the RW42 Polymeric concrete are listed below;

- Easy to apply -Can also be applied at sub-zero temperatures
- Fast-curing Thermoplastic behaviour
- Stable under pressure
- Abrasion-resistant
- Watertight (subject to correct intermediate compression)
- Resistant to frost and de-icing salt
- Largely resistant to acids, alkali solutions and diesel
- UV-, hydrolysis- and alkali-resistant and Solvent-free

Reaction times

	Reaction times RW42 (bei 20 °C, 3 % Katalysator)
Pot life	approx. 15 minutes
Rain-proof after	approx. 30 minutes
Can be walked on / overcoated after	approx. 1 hour
Curing time	approx. 3 hour

Higher temperatures will reduce reaction times, while lower temperatures will increase reaction times.

Night 4:

After usual toolbox meeting and tasks briefing the works presumed on 4th night to carry out below steps;

Step 8: The bridging steel plate and perforated angles were placed on the recess. The holes for hold down anchors were drilled into the substructure and cleaned with pressurised air (Plate 14,15). Only guide anchors were inserted in the pre-drilled holes.

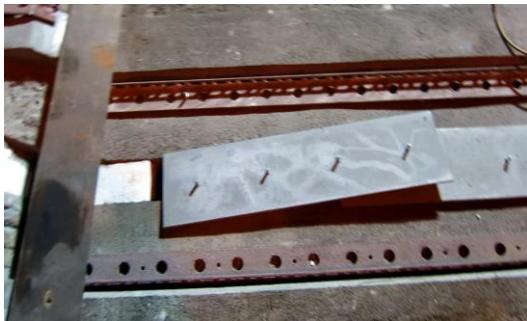


Plate 14: Placement of Steel plate and Perforated Angles



Plate 45: Installation of hold down anchors

Step 9: Preparation of the elastic compound RW60: Material was mixed according to the technical instructions. The first layer was poured with a thickness of about 1 cm. Then the perforated angles were positioned over the guide anchors and the rest of the hold down anchors were installed and tightened.

The cover plates were placed centrally over the structural gap. The separation foil was installed on top of the cover plates. The second layer was installed to a maximum level matching the bottom of the holes of the perforated angle. Plates 16 - 19.

The product requires installation of at least 3 joint meters at once. Should longer interruptions of installation occur (longer than 12 hours) or installation covers only one lane, then the connecting surfaces are always to be coated with RW 91P – Primer flexible plug material.



Plate 56: Preparing the RW60 elastic compound



Plate 67: Pouring first layer of RW60 elastic compound

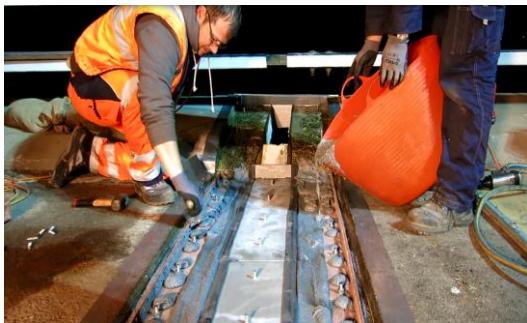


Plate 78: Pouring second layer of RW60 elastic compound

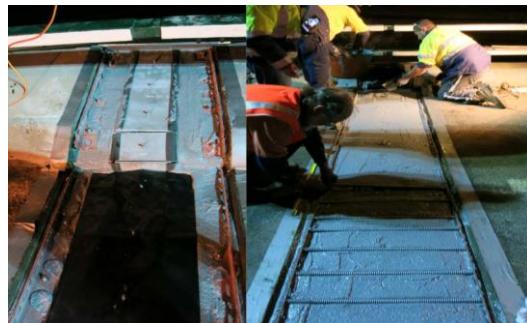


Plate 88: Pouring second layer of RW60 elastic compound

Product Explanation: For joints with more than 50mm movement capacity a separation foil and support bars for load transfer are required (Plate 19). Support bars (Plate 16) are a set of two hollow telescopic steel tubes loaded with internal springs, that allows traffic load transfer in wider joint systems (>50mm movement capacity) and also helps providing restoring forces to the joint. These bars connect two perforated angles on either side of the joint. The bars are covered with a corrugated PVC sleeve to allow movement and to separate the metal from elastic plug.

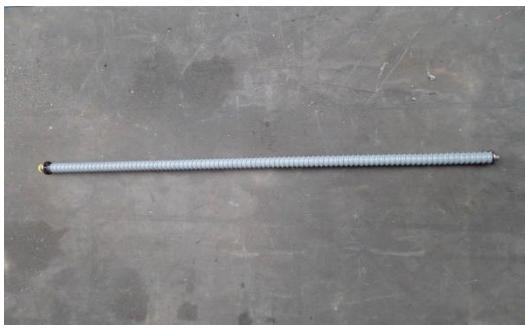


Plate 20: Support Bars for joint PA90



Plate 9: Final layer of elastic compound RW60

Step 10: Once all the support bars were installed, the final layer of the flexible plug material is poured in place and levelled with levelling tool. Plate 21.

Product Explanation: *The carriageway can be opened for traffic over the newly installed joint after 12 hours curing of the PU plug material installed, provided that ambient temperature during and after installation is not less than 25° C. For lower temperatures the curing time shall be increased.*

Step 11: After the PU plug material was cured, the kerb area was be poured with the new PU material. The minimum formwork is required to profile the kerb. Plate 22.



Plate 22: Formwork and elastic compound RW60 placed in kerb



Plate 23 Completed expansion joint opened for traffic area

Depending on the kerb details, various options are available for the kerb areas, e.g. Cover plates to allow service ducts etc.

After removing the formwork the joint was complete and could be opened for traffic the following morning. Plate 23.

CONCLUSION

From the overall design, selection and installation process of this joint following unique benefits of Flexible Polymeric Plug joint are strongly highlighted;

- Absence of mechanical wearing parts, exceptionally long service life can be anticipated
- Virtually no maintenance required – except localised repairs in case of accidental damage
- Very speedy Installation process – sometime overnight
- Possibility of sequential, lane-by-lane, installation with minimal impact on traffic
- Minimum concrete breakout required – no invasion in structural deck concrete
- Post installed mechanical anchors with a minimum depth of 75mm are sufficient
- Continuous surface, flush to the asphalting on either side, on the deck ensures zero noise emissions
- Wide range of movement possible - Total movements of 15–135 mm
- 100 % watertight along the deck.