SYNOPSIS
Deck joints are simple elements in bridges but are heavily impacted by moving traffic. They are susceptible to damage and their repair is costly due to the need for lane closures and traffic control at the worksite with installation often being at night.

RTA realised the importance and organised large scale inspections of bridge deck joints starting from 1995. Over the years, the inspection method was modified to target specific features of deck joints. A computer module was developed to document the history of RTA joints and is used as a condition assessment tool. The Bridge Joint Assessment (BJA) Module assesses joint condition and performance rating using field inspection of several simple items, and can also be used for monitoring performance of a particular joint or joint type.

To minimize its risk, RTA mandated and implemented an approval process for proprietary deck joints for RTA bridges and those that will become property of RTA. RTA only allows use of unapproved joints when proven to comply with AS 5100.4. Lists of RTA approved bridge components and systems are published on RTA’s Internet site and are regularly updated.

RTA has taken action to discontinue or limit the use of specific expansion joint types, proprietary or otherwise, based on actual field performance. Its systematic approach for managing deck joints has been initiated to reduce maintenance costs and to safeguard the travelling public and RTA workers.

1 BRIDGE DECK JOINTS
The function of bridge deck joints is to provide a trafficable surface across permanent gaps in the bridge with the widths of such openings varying with environmental effects, loads and movements.

Bridge deck joints allow movements to take place to reduce development of secondary stresses in bridge superstructures and substructures. When movement is constrained or prevented, unacceptable stresses develop in the structure from temperature changes, traffic load effects, prestressing effects, concrete creep and shrinkage, foundation settlement, earth pressures, mining subsidence and/or earthquakes.

In addition to their basic function, deck joints have to carry high levels of repeated traffic loads and can be heavily impacted. AS 5100.4 requires that deck joints accommodate ultimate limit state (ULS) movements and be designed to a vertical load of A160 – single axle with dual wheels carrying 80 kN – with a concurrent longitudinal load of 35% of the vertical load. A 60% dynamic load allowance is applied except for modular joints for which specialist studies required. The resulting
load is multiplied by 1.8 for Ultimate, 1.0 for Serviceability and 0.6 for Fatigue Limit States.

Joints effectively undergo infinite fatigue cycles from heavy and repeated wheel load impacts. Design fatigue stresses need to be limited to fatigue limit values to sustain these live load cycles without damage.

Figure 1: Some Types of Bridge Deck Expansion Joints

Figure 1 shows some of the deck joint types used in NSW. Bridge deck joint failures can cause severe problems such as disruption of traffic, accidents and, in the worst
case, fatalities, if not properly designed, installed and maintained. Damaged bridge deck joints can result in damage to other bridge elements from water penetration.

Water leaking through bridge deck joints may damage superstructures and substructures, including bearings. When water reaches bearings and lower bridge elements, corrosion and structural degradation can occur and major maintenance problems may result. Steel truss bridges and many older bridges have suffered severe damage resulting from water leaking through expansion joints. Prevention of water leaks is an important joint performance indicator. Even though joints are rarely completely watertight, watertightness of bridge deck joints is emphasized by highway owners worldwide who specify performance tests for verifying watertightness.

The cost of joint replacement works is far greater than the cost of the supply of the joint itself, at around 10% - 20% of the total cost. The replacement or rehabilitation of joints invariably involves costly traffic management and personnel working under hazardous conditions, often at night, with high overall project costs. The better the joint, the more money saved over the life of the bridge, the less disruption to traffic and the safer are the travelling public and RTA workers.

2. INSPECTION AND INVESTIGATION OF DECK JOINTS

RTA realized the importance of bridge deck joints and initiated targeted large scale inspections since 1995. Deck joint surveys were conducted in 1995/96, 2003/2004, 2004/2005 and 2007 by RTA Bridge Engineering and Regional staff across New South Wales. RTA then developed a method for managing its deck joint assets.

Early inspections of deck joints were focused on the condition of expansion joints after some years of service. The joint inspection procedure has been gradually revised and currently stipulates assessment of 18 inspection items for each joint which are used to evaluate the joint condition and performance rating. Not all inspection items are assessed for all joints. The eighteen items and what percentages of the inspected joints were assessed for those items by RTA are shown in Table 1.

Out of these eighteen items, the first eleven items are defects rated at the following four levels:

• No defect/Minor;
• Moderate;
• High; and
• Severe.

The other seven items are for condition assessment rated as follows:

• Good (G) – All joint items do not require any unscheduled maintenance and the joint is in good working order;
• Satisfactory (S) – Some joint items require repair but the joint is in working order;
• Poor (P) – Some joint items require repair but the joint is still performing its basic function; and
- Failed (F) – Some or all joint items are damaged to such an extent that the joint is not performing its basic function.

Table 1: Response Details of Joint Inspection Items

<table>
<thead>
<tr>
<th>Item for Assessment</th>
<th>% of all RTA Joints*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage to adjacent deck/slab</td>
<td>84.0</td>
</tr>
<tr>
<td>Damage to nosing/ transition strip</td>
<td>52.5</td>
</tr>
<tr>
<td>Damage to retainer/ protection angles</td>
<td>34.7</td>
</tr>
<tr>
<td>Seal splitting/puncture/ tracking/flow</td>
<td>76.7</td>
</tr>
<tr>
<td>Joint debonding from blockout</td>
<td>76.4</td>
</tr>
<tr>
<td>Noise</td>
<td>86.1</td>
</tr>
<tr>
<td>Joint dislodgement/ seal sticking out</td>
<td>74.0</td>
</tr>
<tr>
<td>Misalignment/twisting/ jamming</td>
<td>75.3</td>
</tr>
<tr>
<td>Debris in joint</td>
<td>92.5</td>
</tr>
<tr>
<td>Leakage</td>
<td>74.3</td>
</tr>
<tr>
<td>Wear to anti-skid surface of joint</td>
<td>38.6</td>
</tr>
<tr>
<td>Bolting/anchorage</td>
<td>45.2</td>
</tr>
<tr>
<td>Riding quality</td>
<td>84.5</td>
</tr>
<tr>
<td>Joint movement capability</td>
<td>84.4</td>
</tr>
<tr>
<td>Kerbs</td>
<td>73.2</td>
</tr>
<tr>
<td>Members underneath</td>
<td>71.6</td>
</tr>
<tr>
<td>Protective coating</td>
<td>40.0</td>
</tr>
<tr>
<td>Overall condition</td>
<td>98.6</td>
</tr>
</tbody>
</table>

* Total number of joints in database: 1174

Most of the items shown in Table 1 were reported for more than 70% of the inspected joints. Only four items were reported for less than 50%. If only the recent investigations are used the numbers will be much higher. The high ratio of assessed items confirms the suitability of these items for inspection across the 16 different joint types inspected.
Analysis of the inspection data provides information on typical problems associated with different types of joints. For example, the most common problems associated with hot poured sealant joints are leakage, debris in joint, joint debonding from blockout, joint dislodgement/sealant sticking out, sealant splitting/ puncture/ tracking/ flow and damage to adjacent deck/slab.

Anchorage failures are a very common problem for deck expansion joints. RTA has carried out studies on methods for preventing loosening of bolts and nuts, determination of applicable loadings for new and rehabilitation joint designs, and design procedures for fingerplate type joints, socket head cap screws and through-bolt anchorages for anchor bolts through deck slabs. Figure 2 and Figure 3 show a sample of 2D and 3D finite element models used in one of these studies.

![Stress distribution after tensioning](image1.png)

a) Stress distribution after tensioning

![Stress distribution with tension plus applied wheel load](image2.png)

b) Stress distribution with tension plus applied wheel load

**Figure 2: Expansion Joint 2-D Model with Through-Bolt Anchorage**

**Figure 3: Expansion Joint 3-D Model with Through-Bolt Anchorage**
These studies have resulted in durable designs for bridge deck joint rehabilitation across NSW.

3. BRIDGE JOINT ASSESSMENT MODULE

As deck joints comprise several types with varying design lives, just assessing the condition of one sample of a type of joint at a specific time is not sufficient to evaluate the type’s superiority or otherwise compared to other joint types. While decisions for repair are made based on the condition of a specific joint, deck joint types should be rated based on field performance of a number of samples.

The assessment of condition and performance rating of deck joints is relevant for identifying the current status and field performance of a joint type. RTA developed its computerized Bridge Joint Assessment (BJA) Module for this purpose. The module can be used for monitoring performance of a particular joint or joint type over time.

Screen dumps of the BJA Module’s tabs are shown in Figures 4 and 5. The joint identification tab contains general details of a specific joint while the joint assessment tab contains input details of field ratings and computed assessment values.

![Figure 4: Bridge Joint Assessment Module Opening Screen](image-url)
Bridge inspectors print out blank joint inspection forms from the BJA Module before an inspection and report on as many details as possible, as explained earlier in this paper. These ratings are then used to evaluate the technical performance of the joint in four different performance categories; load, movement, condition of adjacent areas, and environment.

General features of each joint type are incorporated into the rating process by assigning values for ongoing maintenance cost and accessibility for repair/replacement.

The technical and general performance ratings are added to obtain the apparent rating of the specific joint to which is applied a composite modifier based on life in service, environmental severity and traffic counts to obtain its effective rating. Both apparent and effective ratings are used to rate the joint’s performance.

Sample assessment results are shown in Figure 5.

Valuable feedback from inspectors can be entered and viewed regarding joint history and other specific issues.

Reports with several output options can be output from the database, for further analysis for a single bridge, a range of bridges and all bridges for any RTA region or all of New South Wales.
The BJA Module helps with the selection of joints according to their performance, and allows easy retrieval of inspection data, making it a bridge asset management tool with great potential.

An increase of about 10 minutes of inspection time per bridge joint is required during bridge inspections to gather data for the BJA Module.

4. RTA APPROVAL PROCESS FOR PROPRIETARY DECK JOINTS

Deck joints are often supplied as proprietary items rather than being designed and fabricated one-off for the specific project. Their relative cost is small compared to the overall bridge cost but can have a large impact on the bridge's whole-of-life-cycle costs because of their effects on bridge maintenance costs.

It is prudent to aim for durable and trouble free deck joints when considering the consequences of failure and costs of repair. Faulty joints inconvenience motorists, can lead to accidents with, at worst, fatalities and costly litigation. RTA mandates the use of approved joint components wherever possible using suitable installation procedures.

As the repair of deck joints is costly due to the need for lane closures and traffic control at the worksite, to minimize its risk RTA has mandated and implemented an approval process for proprietary deck joints for RTA bridges and those that will become property of RTA. The approval process assesses a proprietary joint in terms of materials, quality control regime, performance, and installation and maintenance manuals. RTA only allows use of unapproved joints following proof of compliance with AS 5100.4.

The following details are required for submissions for RTA approval of bridge expansion joints:

i) Drawings detailing the expansion joint systems and any alterations required to the structure

ii) Joint opening and movement ranges

iii) Anchorage of joint to the deck

iv) Design calculations for all structural elements

v) Records of past usage, including the names of some bridges where the joints have been installed; together with the movement capability and installation date

vi) Specifications for all joint components

vii) Evidence, preferably in the form of test certificates from recognised testing organisations, verifying compliance with the following:

• The specifications for the joint components

• Relevant performance requirements detailed in AS 5100.4 Bridge design – Bearings and deck joints

• Requirements of the relevant RTA technical specification, if any

• Noise test reports where applicable of the performance of the system under traffic
viii) QA certification of materials and manufacture
ix) Procedure for installation
x) Construction tolerances
xi) Schedule of maintenance and expected system life

Suppliers submit information and details on their proprietary joints in accordance with the above RTA proforma. Submissions are evaluated for fitness for purpose, and the supplier advised accordingly. Further information about this approval process can be obtained from RTA Bridge Technical Direction BTD 2008/11. Once approved, the bridge deck expansion joints are included in RTA’s approved bridge components and systems lists available at:


In addition to the requirements of AS 5100.4, the following RTA bridge deck joint specifications have been developed to ensure robust and durable installed components with minimum bridge life-cycle costs.

- B241 – Manufacture and supply of minor steel items (Relevant to the fabricated fingerplate type joint)
- B310 – Compression seal expansion joints
- B312 – Cold applied elastomeric joint sealants
- B315 – Elastomeric strip seal expansion joints
- B316 – Modular bridge expansion joints
- B318 – Bonded metal-elastomer expansion joints
- B319 – Proprietary aluminium expansion joints

5. MAINTENANCE AND MANAGEMENT OF BRIDGE DECK JOINTS

Bridge deck joints need to be maintained starting from their installation and continued throughout the life of the bridge. Maintenance can comprise cleaning and washing of scuppers and joints, and removing debris, growth and silt, which is undertaken by road patrols or maintenance crews using simple equipment. Maintenance can also include replacing and repairing parts of the joints.

Maintenance of bridge deck joints ensures the safety of the travelling public, maintains the trafficability of the bridge at a serviceable level and minimizes the costs of repairs. Joint maintenance must be ongoing to rectify damage that may lead to serious consequences.

Maintenance or rehabilitation needs are identified by regular inspections and preventive measures implemented to maintain the quality and safety of the joint. Leaking water through joints should be diverted as early as possible to control damage to other bridge elements.
Figure 6: Photos of Modular Joint Replacement
Action has been taken to reduce RTA’s risks by banning or limiting the use of joints with identified problems. RTA has discontinued the use of cork or hose filled, hot poured sealant, moulded elastomer with strip seal, open gap without protection angles, semi-rigid epoxy and sliding steel plate joints. Sliding steel plate joints can still be used for other than road traffic such as pedestrians.

Some joints are only permitted for limited use based on site specific studies, these being asphaltic plug, bonded-metal elastomer, metal fingers bonded to elastomer and open gap with protection angles. As an example, the use of asphaltic plug expansion joints has been restricted even though they are easy to install and repair and provide a smooth, quiet and seamless road surface for traffic. These joints in NSW have been noted to soften in hot weather, to harden and crack in very cold weather, to rut or delaminate under heavy traffic, and to shove with longitudinal cracking under light traffic. They are also deficient when installed on lively bridges. The quality of these joints is highly dependant on the skill of the work crew operating under site constraints. As a result, these joints have been banned for new bridges and discouraged for maintenance and rehabilitation works except for locations where noise issues are predominant and there is no suitable alternative, in which case their installation, maintenance and replacement are carefully managed.

Maintenance works on joints have to be undertaken on a priority basis to effectively use scarce resources. Regular assessment of joints using the BJA Module will help to identify with minimal effort joints requiring immediate attention. The BJA Module plays a major role in selecting joints for rehabilitation with work priority being based on risk management techniques used by the Bridge Maintenance Planner.

6. SUMMARY

Bridge deck joint performance depends on the quality of the joint supplied, the skills of the bridge design engineer, the use of specialist installation contractors, the provision of robust anchorages and the establishment of effective maintenance programs. Maintenance programs include preventing water leakage to prevent damage to the remainder of the bridge, especially the bearings.

RTA’s bridge expansion joints are carefully selected in accordance with BTD 2008/10 and BTD 2008/11 considering the overall effect on the life cycle cost of the bridge. The lists of RTA approved bridge components and systems referred in BTD 2008/11 are kept current on RTA’s Internet site.

RTA understands the need to work together with specialist suppliers to provide safe and durable infrastructure for the community. RTA identifies problems associated with proprietary bridge components including bridge expansion joints and requires continuing improvements in those components from suppliers.

RTA’s BJA Module is an Oracle based application delivered through RTA’s Bridge Information System and, if necessary, can also be delivered as a standalone application. Use of a similar approach throughout Australasia will measure the performance of different deck joint types with a common yardstick and validate requests for improvements to joint performance.
REFERENCES


2. RTA Bridge Technical Direction BTD2008/10, Bridge Deck Joints

3. RTA Bridge Technical Direction BTD2008/11, Lists of RTA Approved Bridge Components and Systems