

Selection of Option for Replacement of Major Bridge Expansion Joints

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SYNOPSIS

Large bridges usually have large expansion joints to cater for movements due to concrete shrinkage and creep and temperature variations. When these joints wear out, the selection of a replacement option needs to consider a range of factors, including bridge articulation, traffic volumes, and future maintenance. The process of selecting the replacement option is discussed, using as examples the actual and planned replacement of joints for two major road bridges in NSW, at Pheasants Nest on the F5 South-Western Freeway south of Sydney and Mooney Mooney Creek on the F3 Sydney/Newcastle Freeway, north of Sydney. Issues associated with the reasons for joint replacement, delivery of the project, and replacement joint design and installation are discussed. Suggestions for avoiding similar problems with expansion joints in the future are offered.

1 BACKGROUND

1.1 Situation

The modular expansion joints of the twin bridges on the F5 at Pheasants Nest south of Sydney and of the twin bridges on the F3 over Mooney Mooney Creek north of Sydney had been experiencing failures of centrebeams and support bar components for a number of years. Ongoing maintenance had been carried out to keep the joints in service in a safe condition. These repairs comprised emergency weld repairs under traffic, securing broken ends of support bars, welding of additional plates to the sides of failed centrebeams, replacement of failed support bar bearings etc. all under most difficult, cramped and noisy conditions.

1.2 Reasons

1.2.1 Pheasants Nest twin bridges

The Pheasants Nest bridges were opened in December 1980. The bridges are 305m long twin identical statically determinate balanced cantilever concrete box girder bridges, with a central expansion joint. Soon after opening, unexpected sagging of the cantilevers occurred due to creep effects. At the tips of the cantilevers, a cusp formed, and consequently pronounced impact loadings on the joints occurred from the high speed truck traffic. Under those conditions, the joints' weaknesses were exposed. To correct the excessive sagging of the

cantilevers, an asphalt correction was applied, and in the mid-1990s external post-tensioning was installed to lift the cantilevers. To match the asphalt correction, steel plates were welded to the tops of the joint centrebeams, with holes matching the seal anchor bolts locations provided in those plates. However, these holes acted as stress concentrations, and some time after welding the centrebeams fractured at some of the hole locations, after which mild steel plates were welded on both sides of fractured or severely cracked centrebeams.

Cropping of the webs at the ends of some support bars at the pivot of the swivel joints during joint fabrication resulted in early failure of some of the flanges of those bars, necessitating temporary maintenance to support the support bars. However, the cumulative damage that occurred to the joints led to the decision in mid-2002 to replace the joints, as unexpected failure of the joints could pose a severe hazard to traffic.



*State of Pheasants Nest
southbound bridge expansion
joint before replacement*

1.2.2 Mooney Mooney Creek twin bridges

The Mooney Mooney Creek bridges were opened to traffic in December 1986. The bridges are 485m long twin identical statically indeterminate balanced cantilever concrete box girder bridges, with an expansion joint at one end only. Problems with the joints were discovered during inspections in 2002, and temporary remedial work was carried out to keep the joints safe in service. The problems appear to have arisen from poor fabrication, in that centrebeam to support bar welds were undersize and undercut, and from maintenance issues resulting in failed/missing support bar bearings not being replaced as they were dislodged. The missing bearings resulted in the unsupported parts of the joint being quickly damaged by the heavy truck traffic, which resulted in rapid joint deterioration.

The remedial works carried out included replacement of missing bearings, and welding of mild steel plates to the sides of failing centre beams. The condition of the joints and the cost

of the remedial works resulted in the decision to explore the options available for replacing the joints.

1.3 Necessity for action

Due to the cost of ongoing repairs, usually by nightwork under traffic, and the hazards posed to traffic by the failing joints, the decision was made in mid-2002 to investigate the feasibility of replacement of the joints for both sets of bridges, and options for doing this.

2 RTA RESPONSE

The gravity of the situation was conveyed to the responsible positions in the RTA's corporate directorate, and Federal funding of around \$3M was obtained for the works at Pheasants Nest and about \$4M for the works at Mooney Mooney Creek.

3 FORMATION OF COMMITTEE

Following the decision made in mid-2002 to explore the feasibility of replacing the joints, a four person committee was formed to explore the available options, comprising the Bridge Maintenance Planners from the RTA's Wollongong and Newcastle offices, and staff from the RTA's Bridge Section and Road and Bridge Technology Section.

4 STRUCTURAL ANALYSIS

The first task performed in the joint rehabilitation process was a structural analysis of the bridges, taking into account past and future time dependent effects from concrete creep and shrinkage, and prestressing relaxation. The structural models were only of a complexity needed for calculation of serviceability and ultimate joint movements under all loading conditions, including traffic live loads.

The bridge analysis was carried out using a two-dimensional frame model. The analyses were calibrated using survey data taken at intervals after construction.

The survey data from the Pheasants Nests bridges was useful, as a number of readings had been taken over a relatively long period of time, given the problems experienced with the sagging of the cantilever tips, and the verification surveys of the effects of the external post-tensioning. This survey data enabled a confident prediction of ultimate joint displacements.

The survey data from the Mooney Mooney Creek bridges was less extensive, but was still useful for calibrating the design model.

The design temperature ranges were estimated from the Australian Bridge Design Code, adjusted for lags and moderations due to the large sizes of the bridge elements. The traffic loads were in accordance with the Australian Bridge Design Code.

5 RANGE OF FEASIBLE OPTIONS

Once the required displacements of the joints had been calculated, the joint options available to provide those displacements were reviewed, taking into account the constraints applying at each of the sites.

5.1 Pheasants Nest twin bridges

As the Pheasants Nest bridge joints are located in the centre of the bridges, at the ends of relatively flexible cantilevers, it became obvious that the only options available to provide the required joint movements were a:

- a. rehabilitation of the existing joint; or
- b. complete replacement with a new specially designed modular joint; or
- c. replacement with a new fingerplate type joint.

The joints had to provide a large relative rotational capacity between the opposing sides as well as the vertical and horizontal movements. The joints also had to fit within the available limited depth of the variable depth deck cantilevers.

Once the available options were identified, concepts for implementing each option were designed, to a stage suitable for assessing the practicality, advantages, drawbacks and cost estimates of each.

Sketches were prepared for each concept, ready for presenting to the committee for assessment and selection for implementation.

5.2 Mooney Mooney Creek twin bridges

The options available for the Mooney Mooney Creek bridges were not subject to the same constraints insofar as joint movements were concerned. The constraints were more a function of the volume of traffic and its conditions and the steep grades at the site. The longer length of the bridges also affected the options available, in that a simple cantilevered fingerplate was impractical due to the long length of fingers required for the range of movement and to span the joint gap.

The options available were a:

- a. complete replacement with a conventional modular joint; or
- b. replacement with a supported cantilever fingerplate type joint.

The option of rehabilitation of the existing joint was not practical as the configuration of the existing joint was such that new support bars could not be placed in position without destroying the support boxes.

The main requirement of the replacement joints was the capacity for large translational movements. Rotations were not an issue as the joints are located at the abutment ends of deep box girders. There were no constraints on joint depth, as the joints are located within deep blockouts in the abutment walls and deck end cross girders. The translation bearings at the abutment are on the same grade as the road surface.

A real constraint was the necessity of providing a safe surface for any cyclists using the freeway, as the grade at this location is about 5.5%, compared to that at the Pheasants Nest bridges of about 1.6%.

Again, concept designs were prepared for committee assessment and selection of option.

6 SELECTION OF REPLACEMENT OPTION BY COMMITTEE

The concept designs for the joints were presented on separate occasions for each set of twin bridges to the committee for discussion, assessment and selection of option.

The committee discussed the concepts, and tabulated the advantages and disadvantages of each with respect to traffic impact, ease of construction, future maintenance requirements, hazards to cyclists, supply times and suitability for the site.

The options selected were for:

- a. Pheasants Nest bridges – the fingerplate type joint, due to the extreme relative rotations of the joint, and the suitability for installation with minimum disturbance to the existing concrete of the deck cantilevers.
- b. Mooney Mooney Creek bridges – full width modular joint replacement because of the need to prevent water ingress to the abutment cavity and to avoid the hazards to cyclists on the steep grades posed by a fingerplate type joint.

7 PROPOSAL TO RTA CLIENTS

The alternatives for the joint rehabilitations, together with the case for the selection of the recommended option were presented to the RTA's Regional Managers in Wollongong and Newcastle, with their concurrence obtained relatively quickly. Their agreement was expedited by the hazards posed by further deterioration in the condition of the joints, and the costs of keeping them serviceable.

8 TRAFFIC IMPACTS AND COSTS

The traffic impacts of joint replacements on large bridges can be severe, as usually these bridges form part of the main route between large population centres.

8.1 Pheasants Nest twin bridges

The Pheasants Nest bridges carry traffic between Sydney and Canberra, Melbourne and the south-western parts of NSW. A large proportion of the traffic comprises semi-trailers and other trucks.

Following a study of diversion possibilities, and the effects of moving traffic on the cantilever movements, it was decided that the bridge would be completely closed to traffic, and the four lanes merged to three lanes on the other bridge during the works. As the bridges had originally been designed for three lanes, the impact of this traffic arrangement on the structures was minimal, with the most impact and costs coming from the diversion arrangements.

The final cost of the work was about \$2.3M, excluding the costs of resheeting the asphalt wearing surface.

8.2 Mooney Mooney Creek twin bridges

The Mooney Mooney Creek bridges carry traffic between Sydney and Newcastle, the NSW Central Coast dormitory suburbs and the coastal part of northern NSW. The traffic volumes were extremely high, currently about 35,000 vehicles per day per carriageway, with about 5% heavy vehicles. Any delays during peak travel times on the Freeway can cause long delays. Hence, it was decided that complete closure of the bridges was impractical, except for a short period in the middle of the night to lift the joints into position, and for final adjustments to its position prior to concreting.

Use of temporary steel coverplates and asphalt transitions to take the traffic over the joints whilst part of the work area was exposed was accepted as the most practical and low cost option. Most costs of the work are in the provisions for traffic and costs associated with night work.

The estimate of cost for the work is currently about \$2.55M.

9 FUNDING

The work was fully funded under the National Highways Maintenance Program, as both sets of bridges are on the National Highway.

10 PROJECT DELIVERY

The Pheasants Nest bridges joint replacements were carried out using separate supply and installation contracts, using local contractors selected by open tender.

The Mooney Mooney Creek bridges are being replaced under a combination of separate supply contracts for the joints, with installation under single invitation contract by the RTA's

Hunter Road Services organisation, to control the costs associated with traffic control and night work, and to give flexibility to deal with unexpected contingencies.

10.1 Need for flexibility

With rehabilitation and maintenance works, the need for flexibility whilst the contract is underway is paramount, to enable quick resolution of problems and issues that invariably arise.

This flexibility can be achieved through careful selection of contractors and the Principal's site staff. An adversarial approach is not desirable, and must be avoided by appropriate delegation of decision making to experienced personnel

10.2 Expert client

The more experienced the Principal's client, the more issues can be anticipated and planned out in advance. Practical experience and understanding of bridge behaviour is essential, together with the ability to work as part of a team, involving the ability to consult, advise, liaise, problem solve, and make decisions.

11 INSTALLATION ISSUES

The Pheasants Nest bridges joints have been replaced, the southbound in September 2003 and the northbound in November 2003.

There were two problems associated with the installation, the first avoidable at design and drafting stage, the second not assessable until the work was underway. The costs and delays incurred were significant and frustrating. The RTA paid the contractor its costs and delays associated with resolving the problems.

11.1 Rapid response to problems

Once the problems became apparent on site, a rapid response was required to minimise delays and costs, while not causing flow-on effects on the future performance of the joints.

11.1.1 *Designer availability*

Once the two problems became apparent to the personnel on site, the Regional Bridge Maintenance Planner was informed, and after a site inspection formulated a draft solution, and confirmed the appropriateness of the solution with the design manager.

The appropriateness of the solution was reviewed by the designers, and suggestions for improvement made. The solution was then discussed between the design manager and the Bridge Maintenance Planner, and the decision made to implement it.

Quick and reliable communications were essential to facilitate the process of arriving at the solution.

11.1.2 Mobile phones, faxes and e:mail

The communication tools of mobile phones, faxes, laptop computers with access to the RTA network and e:mail systems are essential in today's working environment.

11.1.3 Need for prior and thorough drawing review on site

The problems encountered on the Pheasants Nest bridge project highlighted the need to critically review prior to issue the design drawings, with cross-reference back to the works-as-executed drawings for the bridge. The drawings for the existing joint were found to be in error at the end of the joint rehabilitation works, with this error not realised until after the works had almost been completed.

Due to the discrepancies in the drawings of the original joints, the holes drilled for the new fingerplate joint clashed at some locations with the sides of the support boxes, causing core barrel breakages and subsequent delays.

These issues highlighted the need to check and confirm as correct all dimensions on the works-as-executed drawings of both the bridge and the existing joint, at and around the joint, prior to issue of the rehabilitation drawings. This may necessitate local demolition of concrete to expose hidden steel components.

12 OUTCOMES AND PROJECT COSTS

The Pheasants Nest bridges modular expansion joints have both been replaced with new fabricated steel fingerplate type joints, with no accidents, at a total cost of about \$2.3M.

The joint supply costs of about \$350,000 represented about 15% of the total project cost. The errors in design imposed extra costs of \$70,000, or 3%.

13 AVOIDING SIMILAR FUTURE PROBLEMS WITH CURRENT PROJECTS

Attention should be paid to ensure the bridge design conforms to the bridge design code, and represents current world best practices, and that the construction conforms to the design.

At Pheasants Nest, unbalanced prestressing forces and bridge articulation were major contributors to the premature failure of the joints. If not for the formation of the pronounced cusp at the joint location, the problems with the joint may not have become apparent until

much later after the end of construction. The joint when fabricated and supplied should have been checked for conformity to the joint design drawings, as the use of incorrect dimensions for the support boxes may have contributed to early joint failure, as cropping of the some support bar webs led to fracture of the flanges at the bearings.

Attention should also be given to the supply, including particular attention to fabrication, of expansion joints. These bridge components are the most severely loaded parts of the bridges, from continual passage of axles of vehicles, notably trucks. Defects in fabrication will result in premature failure. Use of approved expansion joints with proven history of performance from reputable suppliers with rigorous quality systems, and with surveillance by the Principal at critical stages of fabrication, will eliminate most problems. It is far better to pay slightly more during initial construction for a better quality joint, then pay replacement costs down the track for a new joint, the cost of which comprises only about 15% of the rectification works.

If a suitable specification exists in the construction contract documents, then the Superintendent should strongly resist any moves by the Contractor to provide a cheaper, lesser quality joint, as in the end such a joint will cost the Authority far more than the marginal savings offered by the Contractor.

14 ACKNOWLEDGMENT

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15 DISCLAIMER

The opinions expressed in this paper are entirely those of the author, and do not necessarily represent the policy of the RTA.