Blaxland's Crossing Bridge, Wallacia NSW – Bearing Replacement
Ken Maxwell, Arcadis Australia Pacific, Sydney, Australia

ABSTRACT
The existing bridge (known as Blaxland’s Crossing) carries Silverdale Road over Nepean River at Wallacia on the western outskirts of Sydney and comprises a structurally continuous five span post-tensioned concrete girder superstructure with an overall length of 103.6 metres. The bridge was opened to traffic in 1966.

As the laminated neoprene bearings in this bridge have provided over 50 years of service, it was deemed by Wollondilly Shire Council that they had exceeded their anticipated design life, particularly as this bridge represents an early use of this type of bearing in Australia.

The following paper describes the load rating assessment of the superstructure briefly and the proposed bearing replacement system in detail, including the design and potential construction constraints presented by the unusual configuration of the bridge.

INTRODUCTION
This bridge comprises precast concrete segmental girders, framing between intermediate diaphragms (within spans), end diaphragms (at abutments) and headstocks (at piers), and was then post-tensioned to form structurally continuous lines of girders, from one end of the bridge to the other. All superstructure elements were precast, except for the deck slab and grouted joints at the girder/diaphragm and girder/headstock interfaces.

Figures 1 to 5 provide general details of Blaxland’s Crossing Bridge at Wallacia.

The piers are of unusual geometric configuration, being tapered walls that are parallel with the pier headstock at their top surface and twist to pile cap level (refer Figure 6). This seems to have been designed that way for flood flow purposes.

Figure 1 – Blaxland’s Crossing Bridge, Nepean River, Wallacia
Figure 2 – Bridge Elevation (extract from original bridge design drawings)

Figure 3 – Pier (extract from original bridge design drawings)

Figure 4 – Updated Superstructure Cross-Section (note revised services cavity at footway)
LOAD RATING

Although not noted on the original bridge design drawings, the bridge would likely had been designed for H20-S16-44 traffic loading, being the bridge design live loading applicable from 1948 to 1976, which is approximately equivalent to a 33 tonne semi-trailer. This loading is appreciably lower than the maximum current vehicle configuration that is allowed unrestricted access on public roads in NSW, being the 42.5 tonne semi-trailer.

Prior to investigating bearing replacement options, load rating of the bridge was undertaken as a desktop assessment, to ascertain the bridge’s theoretical load-carrying capacity. The aim was to investigate whether the bridge could theoretically carry the following two Higher Mass Limits (HML) traffic loadings: 45.5 tonne semi-trailer and a 68 tonne B-Doubles vehicle. If so, the replacement bearings would be designed for these traffic load cases.

This bridge is somewhat structurally complex, which required detailed structural analysis to confidently predict its theoretical load-carrying capacity, as well as its anticipated behaviour during the jacking operations for bearing replacement. This complexity includes continuity of prestressing, which was a novel approach for the time of its design and for the type of girder in use, the ‘warped’ pier shape, and the bridge articulation relying on cast-in ‘hairpin’ bars for superstructure restraint.

It was found that the existing superstructure could theoretically carry the proposed HML loadings, using AS 5100.5:2017 Bridge design Part 5: Concrete and AS 5100.7:2017 Bridge design Part 7: Bridge assessment as the basis for the analysis work. The vertical component of the draped post-tensioned Freyssinet cables in the girders was relied upon to enhance each girder’s theoretical shear capacity.
Initially, the size of the proposed replacement bearings was restricted to the geometric configuration of the existing bearings, as they are contained within upper and lower steel bearing plates having side downturn ‘keeper’ plates. As such, special laminated elastomeric bearing pads would have been required to be manufactured, as no currently available bearing pads correspond to the sizes of the existing bearings. Alternatively, the existing steel plate housings would have required to be modified.

Figure 6 – Pier 4 (note twisted configuration)

**BEARING REPLACEMENT DESIGN – PIERS**

**Issues**

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Figure 7 – Existing Superstructure Restraint System (at piers)
It is noted that the existing bridge was not designed to facilitate bearing replacement, unlike modern bridges, where this is now a design requirement. At each pier, there are interlocking ‘hairpin’ bars from the superstructure and substructure, connected via a 355 mm long, 32 mm diameter galvanised steel pin welded to the substructure ‘hairpin’ bars only, thereby linking the superstructure to the substructure (refer Figure 7). This was installed to prevent superstructure uplift and potential dislodgement during flood events on the Nepean River. However, this pin detail prevents any effective lifting of the superstructure required to allow decompression of the existing neoprene bearing pads and subsequent removal and replacement of the bearings.

Arcadis carried out a check and it showed that jacking the pier headstock on one side sufficiently to enable removal of the bearing, and pivoting about the restraint pin (located at the centre of each pier), would significantly overstress the pin connection, as well as the concrete pier headstock itself.

Based on the abovementioned findings, the only structurally feasible option to enable bearing replacement was to sever the superstructure/substructure connection system to allow an even uplift across the pier headstock. Consequently, a replacement restraint system would be required to be designed and installed.

As the bridge superstructure is structurally continuous across all five (5) spans, stresses will be introduced into the superstructure due to separate jacking events at the abutments and piers to remove the bearings. Superstructure jacking was modelled using ACES grillage analysis software by entering prescribed node displacements to simulate the superstructure jacking process. Checks were undertaken for overstressing of the bridge elements during the jacking activity.

Another constraint is the available vertical clearance between the underside of the pier headstock and the pier top surface, which is only 90 mm (approximately, according to the existing bridge drawings). At the abutments, this vertical clearance is around 115 mm.

Due to the arrangement of the existing upper and lower steel bearing plates, together with the fact that the vertical gaps between underside of superstructure and the tops of the abutments and piers should be maintained as per existing (ideally), the replacement bearings would be required to precisely match the existing laminated neoprene pad bearings in terms of thickness and plan dimensions. Therefore, matching the existing bearing’s geometric configuration would obviate any modification work required to install replacement bearings, including road surface levels.

For the replacement bearings, Arcadis investigated various Roads and Maritime Services-approved bearing types, namely laminated elastomeric pads, unreinforced elastomeric pads, pot-type bearings, and spherical bearings. The latter two (2) bearings types were discarded, as they are impracticable for retrofit projects with minimal headroom, as anchor bolts are required to be installed for base plate fixity. And unreinforced elastomeric pads possess insufficient load-carrying capacity for this project. This left the only option being laminated elastomeric pads.

There is a standard range of proprietary code-compliant (to AS 5100.4:2017 Bridge design Part 4: Bearings and deck joints) laminated elastomeric bearing pads available, however, none of these bearings matched the fixed geometric dimensions required of the replacement
bearings. As such, special-designed bearing pads would be required, or modification to the existing steel bearing plates would be required.

A variety of specially-designed laminated elastomeric pads were investigated, in terms of internal arrangements of embedded steel plates and corresponding internal rubber layer thicknesses. All combinations of steel plate/rubber layer thickness were assessed and none were found to be fully code-compliant in their design, failing several bearing design criteria. In fact, the existing bearings were found to theoretically fail the current bridge design code’s criteria for laminated elastomeric bearings.

Consequently, options were considered that would provide sufficient clearance such that compliant bearings could be installed, as follows:

- Permanently raise the bridge superstructure.
- Break back a portion of the tops of the piers and abutments.
- Construct/install new bearing supports extending off the existing piers.

It was found that the proposed elastomeric pad bearings were larger in plan area than the existing bearings and would require to be located on a wider ledge than the existing pier tops provide (refer Figure 8). The maximum permissible contact/bearing surface pressure was found to be limited by the narrow width of the piers (610 mm) and the proximity to the ends of the piers.

This was due to the bearing surface stress check as described in Clause 12.9 of AS 5100.5:2017 Bridge design Part 5: Concrete. According to the abovementioned clause, unless special confinement reinforcement is provided, the design bearing stress at a concrete surface shall not exceed:

$$\phi 0.9 f'_c \sqrt{\left(\frac{A_2}{A_1}\right)} \text{ or } \phi 1.8 f'_c$$

(whichever is less). Figure 9 defines $A_1$ and $A_2$.

![Figure 8 – Plan: Top of Existing Pier](image)

![Figure 9 – Extract (Fig. R10.17) from Building Code Requirements for Structural Concrete and Commentary (ACI 318M-05)](image)
Tender Design

Due to the limited bearing stress the existing pier top surface can theoretically resist, an option was developed to construct a cast in situ concrete support around the top of each pier for the replacement bearings, as shown in Figure 10 and Figure 12.

Figure 10 – Tender Design Arrangement

Figure 11 – Simplified Strut-and-Tie Model
The tender design was based on strut-and-tie structural behaviour. The geometry of the load offset to the dimensions of the headstock overhang essentially creates non-flexural/corbel element behaviour.

High-tensile steel bars were used as the ‘tie’ reinforcement in the strut-and-tie model, while a major diagonal concrete ‘strut’ (within the concrete) transfers load from the bearing location to the side face of the existing piers (representing the ‘support’). This structural system is shown in Figure 11.

This form of structural behaviour is covered by Section 7 and Clause 12.3 of AS 5100.5:2017 and would fit the Type I strut-and-tie model, whereby the vertical load from the bearing is carried to the support directly by a major strut.

**Alternative Design**

During the tender period, an alternative design was received by Wollondilly Shire Council from one of the tenderers, comprising hollow steel box brackets (with internal diaphragms) and external post-tensioned high-tensile steel bars to achieve a clamping force for the brackets onto the sides of the existing concrete piers.

The load-carrying mechanism of the clamped-on steel bearing support bracket system is based on developing sufficient frictional resistance at the steel bracket/concrete pier interface to counteract the vertical loads from the bridge bearings (denoted by V* in Figure 13). The load-carrying system is described in Figure 14.
PROPOSED SUPERSTRUCTURE RESTRAINT SYSTEM

Since the existing superstructure restraint system (refer Figure 7) is required to be severed, a new restraint arrangement had to be developed. The existing restraint, located at the centre of each pier will be replaced by interlocking steel ‘T’ sections, at each end of the extended pier headstocks (refer Figure 10 and Figure 15).
The restraint system was designed for both uplift forces and lateral forces, and to accommodate longitudinal superstructure movements by way of an elongated/slotted hole in the stem of the lower "T" section.

**BEARING REPLACEMENT DESIGN – ABUTMENTS**

The existing laminated neoprene bearings were designed to be replaced with identical-size laminated elastomeric bearing pads and in the same location on the existing abutment ledge, being directly below each of the three girders.
Figure 16 – Proposed Abutment Bearing Steel Restraint Frame: Plan (top)
These replacement bearings are not proprietary items with an Australian Standard number, but rather special-designed laminated elastomeric pads, as no Australian Standard bearing pad corresponded to the dimensions required.

A steel 'keeper' frame was designed to attach to the abutment and surround the bearing pads to prevent bearing ‘crawl’ (refer Figure 16).

**CONCLUSION**

Such a project probably should have initially been awarded as a design and construct contract, instead of a design-only engagement. As design engineers, we can develop options, however, only one is typically prepared for tender issue. Construction contractors are required to submit conforming tenders, however, are free to propose alternative design/s. This is what occurred for this project.

The Council-accepted alternative design certainly represents an economical scheme, without the need to core numerous holes into and through the piers. The use of fabricated cellular steel brackets to support the replacement bearings, apparently used on a similar bridge bearing replacement project in the ACT, possesses some clear advantages over cast in situ concrete construction. However, the following long-term issues should be considered with this type of system:

- Blaxland’s Crossing Bridge is often inundated in flood events. The exposed (thereby vulnerable) high-tensile clamping bars are primary structural elements and cannot tolerate any damage due to floating debris. Although this steel box bracket system has apparently been retrofitted to Caswell Drive bridge in the ACT, that bridge does not cross a flood-prone watercourse, rather another road.

- Post-tensioning force in the high-tensile bars shall be maintained over the design life, as a minimum clamping force is required to provide the frictional resistance to the applied loading, thereby preventing slippage of the brackets.

The tender design prepared by Arcadis, while requiring extensive work at the piers, represents a feasible bearing replacement solution. Once constructed, there would have been very little maintenance intervention required by Council over its life cycle.