Annerley Road Bridge Strike Protection Beams

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ABSTRACT

Two existing railway bridges span over Annerley Road in Dutton Park, South East of Brisbane. The vertical clearance signposted for vehicles passing under the bridges is 3.7 metres. The bridges have been struck 23 times by high vehicles between 2002 and 2013. In order to protect the bridge superstructure from vehicle striking, Queensland Rail sought to install a strike protection beam on each side of the bridges. Queensland Rail awarded a contract to JF Hull Pty Ltd (JFH) for the design and construction of the protection beams. Kellogg Brown & Root (KBR) was engaged by JFH for the design component.

A key design challenge was the optimisation and location of the beams' structural elements to avoid clashes with the extensive existing underground utilities and services along Annerley Road. KBR worked through several protection beam options in consultation with Queensland Rail, Brisbane City Council and JFH, to deliver a design within the schedule and allocated budget.

Designed in accordance with AS 5100-2004, the protection beam structure is a frame with a steel box beam and steel box columns supported on a pile cap with cast-in-place bored piles. A finite element analysis was also performed to check high concentrated stresses in steel boxes due to an impact. The construction of the protection beams was completed in August 2014.

KBR designed the protection beams to allow offsite fabrication and facilitate installation within the tight construction timeframe which was limited to one night road closure per beam. For this innovative design, the project was awarded the 2015 Queensland CCF Earth Awards in Category 1.

KEYWORDS
Strike protection beam, box section, bored pile, pile cap, finite elements

INTRODUCTION

Bridge strikes can cause severe damage to the rail bridges and extreme traffic delays for road and rail users. In the worst case, the strikes can cause fatality to road users including cyclists and pedestrians. Queensland Rail is committed to find engineering solutions to reduce the likelihood of vehicle strikes on the rail bridges. One solution is to install protection beams on each approach to the low clearance rail bridge along with height clearance and detour signs to inform vehicle drivers.

Annerley Road bridges were the first bridge site to be implemented with the bridge strike protection beams with the $3.6 M program to prevent over-height vehicles colliding with the bridges. Queensland Rail engaged JF Hull Pty Ltd (JFH) for the design and construction of the protection beam. JHF engaged Kellogg Brown & Root (KBR) as the design engineer to complete the design and construction inspection of the protection beams. The key stakeholders were Queensland Rail and Brisbane City Council.

EXISTING SITE CONDITIONS

The Annerley Road rail bridges are dual single span structures spanning over Annerley Road between Park Road East and Park Road West. The southernmost of the two bridges is a steel truss bridge and the northernmost is a concrete arch bridge. The bridges carry electrified Brisbane suburban train services. The bridges are approximately 60° skewed to Annerley Road. The original signposted vertical clearance height was 3.80m under the bridges. Vertical clearance warning signs and road height gauges existed on both northern and southern approach of the bridges. Detour routes existed for over-height vehicles, which allowed them to turn off at Annerley Road without passing under the bridges. Overhead electrical wires and underground services such as water mains, stormwater drainage and telecommunication cables are present along Annerley Road and its footpaths.

Figure 1 – Aerial view of existing bridges and Annerley Road

Figure 2 – Side view of existing bridges (Looking north)

DESIGN OF PROTECTION BEAMS

KBR design engineers proposed the following options to the contractor and stakeholders for discussion:

- Option1: New protection structures to be built immediately adjacent on both sides of the bridges
- Option 2: The existing road height gauge supporting structures to be modified to the protection structures at their existing locations
- Option 3: The existing road height gauge supporting structures to be removed and replaced with new protection structures
- Option 4: The new protection structures to be installed spanning the entire roadway at suitable locations and existing road height gauges to be removed.
- Option 5: The new protection structures to be installed spanning one side of the roadway only using existing road medians

In addition to the options listed above, it was agreed that the protection structures for the bridges would be designed for ultimate loads in accordance with Clause 10.3, AS 5100.2 – 2004. A safety workshop was conducted with the contractor and stakeholders to ensure the risks and hazards associated with construction of the structures were eliminated or mitigated. The main safety-in-design aspects considered in the design included:

- **Structural strength of protection beams**: the beams shall withstand the impact load without structural failure. Collapse of the protection structures will cause damage to vehicles operating on the road and even injuries and deaths to road users.
- **Maintenance of protection beams**: the beams shall be designed to sustain multiple strikes over the 50 year design life. However, the beams shall be replaceable if they are severely damaged.
- **Geometry of protection beams**: vertical clearance to the protection beams shall be 20mm below the soffit of the bridges (currently 3.85m surveyed clearance to the soffit of the bridge) to ensure high vehicles to be completely stopped before they strike the bridges. The protection beams shall be built with no skew to the roadway on the side of traffic approaching; this is to avoid striking vehicles deflecting sideways and hitting road users such as cyclists and pedestrians.
- **Visibility of protection beams:** the beams shall be located away from existing traffic signals and tree branches and confirmed with site lines. Clearance height signs shall be provided on the beams and they shall be clearly visible.
- **Support locations:** the beam supports shall be located away from existing services, footpaths and private land. Relocation of existing services shall be minimised. Roadway widths shall not be compromised.
- **Construction methodology:** hazards on site shall be minimised. Construction of the protection beams shall be carried out in non-peak hours to minimise closure of Annerley Road which is one of the busiest road networks in the Brisbane suburbs.

While each proposed option has its advantages and disadvantages, after several discussions with the stakeholders, Option 4 was selected as the most acceptable solution for the protection structures.

The new structures span across the entire roadway and are located as close as possible to the bridges (Refer to Figure 1). As agreed with Queensland Rail and Brisbane City Council, it was unnecessary to provide a protection beam on Park Road East and Park Road West because high vehicles are likely to turn to Annerley Road at low speed and the risk of damage to the bridge structures due to an impact is low.

There was a significant period of concept design, assessment and stakeholder reviews to determine the ideal locations for the protection beams. Once the locations of the protection structures were established, the search for the existing underground services commenced.

It was important to eliminate the potential clash with existing underground services as relocation of the services would be costly. Potholes were dug in the proximity of the proposed locations (Figure 3) and underground services encountered, such as conduits, ducts, pipes and cables, were surveyed and recorded.

Figure 3 – Pothole excavation for services location on the northern approach

With this information, the KBR design team was able to finalise the location of the supporting structures for the protection beam on both approaches. On the northern approach, the protection beam was designed to be straight and square to the entire roadway. On the southern approach, due to the site constraint, the beam was proposed to be perpendicular to the roadway on the traffic inbound side and skewed (approximately 25°) to the roadway on the traffic outbound side (Figure 4). This allowed for the northern approach supporting post to be located within Queensland Rail property on the north-east corner.

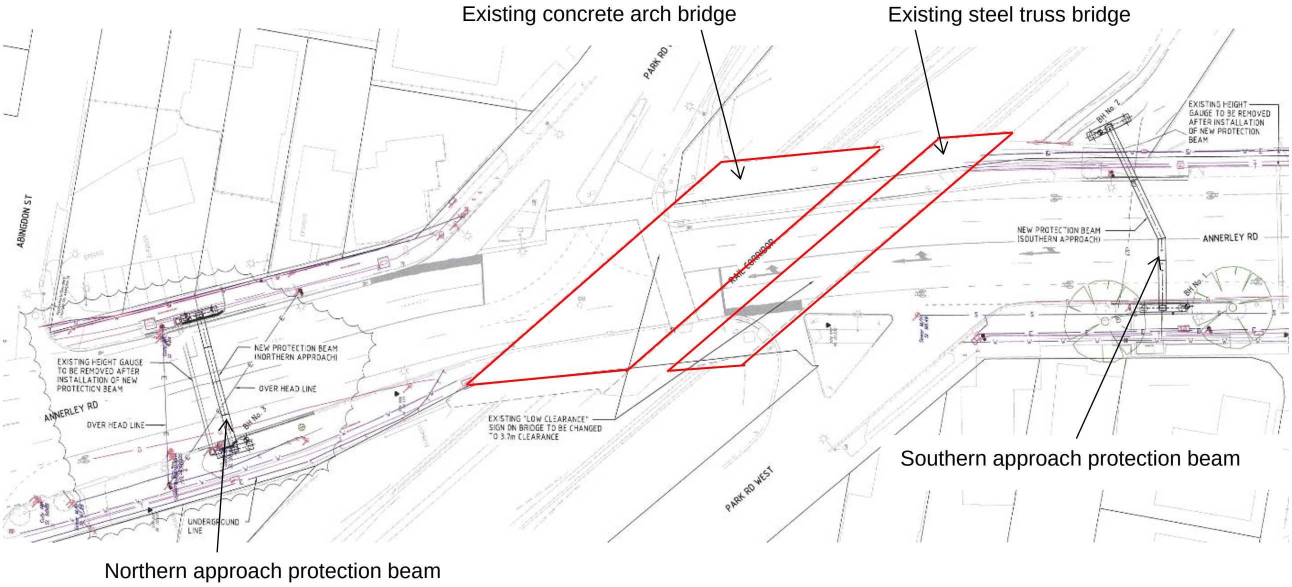

Figure 4 – General Layout Plan

The KBR design team considered three alternatives for the protection beams: beam with circular cross section, welded twin I-beams and welded plate box section. The drawback of the circular cross section was that fabrication of a customised circular hollow section beam would be a real challenge for the steel fabricator. Moreover, the circular cross section was unlikely to stop the over-height vehicles once it is struck.

The twin I-beam sections could be joined together by cross bracings to enhance their lateral bending capacity, however, there was a likelihood that the beam flanges may locally buckle in an impact. Repairs of damaged beam flanges would impose a significant challenging task to both Queensland Rail and Brisbane City Council.

The welded plate box section was adopted and agreed by Queensland Rail and the contractor. The box section is likely to stop the over-height vehicles and the cost of repair and maintenance of the beams would be minimal.

The steel structures were designed in accordance with AS 5100.6 – 2004. Each frame model was created for the northern and southern approach structure. The beam section required for the protection structure was a 1100x1100mm closed box consisting of four 20mm thick welded plates. Internal diaphragms of 16mm thick plate were required at 2000mm centre-to-centre to enhance torsional stiffness of the box. Due to the large size of steel structures, a finite element model (Figure 5) was generated for the southern approach structure. An analysis was carried out to determine any potential local buckling/yielding of steel plates under an impact load. From the finite element analysis, high concentrated stresses were discovered near the kink of the beam and in the vertical plate on the traffic approaching side. To resolve the problem of plate yielding, an additional 20mm thick plate was added in the kink and two internal horizontal stiffeners were supplemented to the vertical overstressed plates. The protection beams were designed not to have bolted splices and installation of the entire beams was intended.

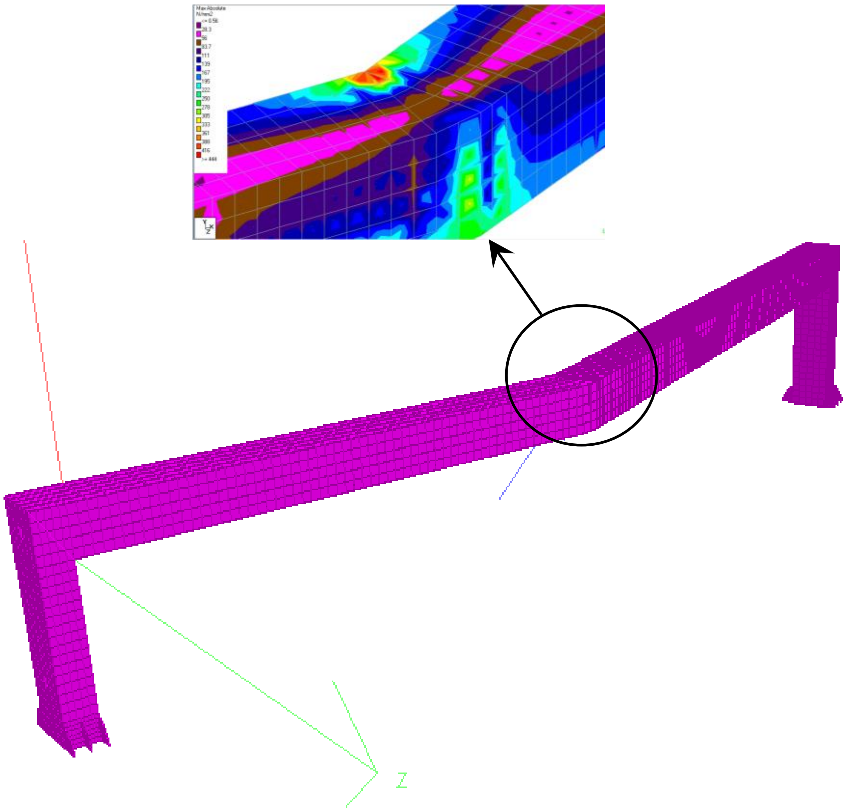

Figure 5 – Finite element model for southern approach beam

Two 1100x700mm rectangular columns were required to support each protection beam. Similarly, the columns were constructed of 20mm thick plates welded to all sides. The column sections also include internal diaphragms. The columns were bolted-spliced with the beams. Each column was rigidly connected to a reinforced concrete pile cap supported by three 900mm diameter bored piles.

The size of pile caps and piles was chosen to fit them in a restricted space which was determined during the survey of the existing underground services. All pile caps were designed with a rectangular section (1500mm deep x1200mm wide) except for the eastern pile cap of the northern approach beam. Due to the clash with the existing underground services, the piles were moved offset from column centreline and the pile cap was set to flash out to support the column (Figure 6). A 150mm diameter sewer main and four 100mm diameter Telstra ducts clashed with the pile cap and they were relocated.

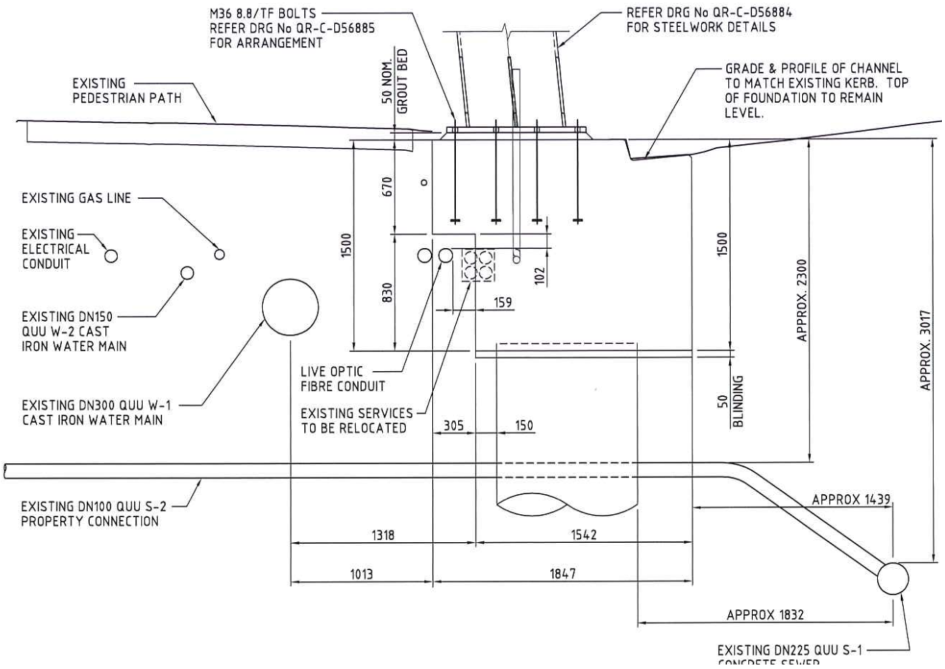

Figure 6 – Geometry of eastern pile cap for northern approach beam

FABRICATION AND INSTALLATION OF PROTECTION BEAMS

KBR along with Queensland Rail carried out routine inspections of the fabrication and installation of the protection beams. As significant potholing was carried out, designs were modified prior to construction works to either avoid underground services or relocate support locations away from highly populated areas. This allowed construction to be carried out without any major delays.

Figure 7 – Fabrication and Installation of Protection Beam

Due to the high impact loads, there was significant reinforcement in both the piles and pile caps. The engineering and construction teams collaborated closely during inspection and certification and to review and mitigate any arising clashes. All pile and pile cap reinforcement cages were inspected prior to installation, and then hold-down bolts including end plates were inspected along with reinforcement prior to concrete pours.

The two protection beams had significant welding requirements and therefore many inspections were carried out prior to hot-dip galvanising. Crucial components were the butt weld located at the kink of the southern approach beam and the base and splice plate joints/welds. The kink weld was likely to experience impact and was located near the centre/high bending zone of the beam. Heat stress at the base and splice plates needed to be quality controlled particularly with the number of stiffeners and size of the main welding.

Two fabricators were contracted for the protection beam fabrication to meet procurement timeframes. One fabrication workshop operated with machine welding, and the other was manual welding. Therefore, inspection techniques and hold points needed to be created for each workshop individually to ensure both welding techniques achieved a quality product.

All welded connections needed to be shop welded between the splice locations as site works were undertaken within one night shift and included the removal of height gauges, installation of beams and fixing of beam signage.

The protection beam posts were installed with only temporary traffic closures on Annerley road prior to the main beam installation works, with bolts tensioned during night works.

The close collaboration between the design and construction teams allowed for a design which facilitated the construction of each beam during an overnight construction period. For example, the location of the post splices were located parallel to the base plate and the beam was constructed using continuous 'L' plate at the haunches/hinges. This reduced risk and improved safety as the beams could be positioned, and the bolts tensioned, as the beams were supported by both the crane and the main posts (Figure 8).

Figure 8 – Beam to Post Connection

Construction works were carried out successfully and included delivery of the 20 - 29m long beams, crane lifts and bolt tensioning, road height clearance survey, beam splice connections (including 24/M36, 8.8/TB bolts at each splice), crane removal of existing steel height gauges and then installation of the vertical clearance warning signs.

KBR and Queensland Rail were onsite during the installation to provide engineering construction certificates and to resolve any construction issues, although none occurred.

STRIKE PROTECTION

The protection beams have successfully prevented over-height vehicles from striking the rail bridges since their installation in August 2014. The two protection beams have survived multiple strikes in the last three years. Two main beam strikes were reported. On 20 January 2016, a garbage truck driver failed to recognise a couple of important information such as his truck height and road clearance limit and the truck struck the southern protection beam. On 23 November 2016, a similar incident happened as a refrigerating truck hit the northern protection beam. The truck was severely damaged; however the protection beam was only slightly scratched and prevented any damage to the rail bridges and injury to the public.

Figure 9 – Northern approach beam during and after strike

CONCLUSION

The design of Annerley Road bridge strike protection beams encountered a number of challenges due to the nature of site and the safety requirements. By working closely with stakeholders and the contractor, the KBR design team was able to successfully complete the design within the allocated program and budget. From the day of completion of the protection beam construction, the structures have protected Annerley Road bridges from striking in both directions.

ACKNOWLEDEMENTS

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REFERENCES

AS 5100.2 - 2004, *Australian Standard, Bridge Design Part 2: Design loads*
AS 5100.6 - 2004, *Australian Standard, Bridge Design Part 6: Steel and Composite Construction*

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AUTHOR BIOGRAPHIES

Sunthara obtained his bachelor's degree in civil engineering in 1993 at the Kharkov Institute of Municipal Engineers in Ukraine. In 2000, he pursued a postgraduate study at the University of New South Wales in Sydney and obtained his master's degree in structural engineering. Sunthara has been working as a structural engineer in Cambodia and Australia. His main duties involve structural design of bridges and civil structures.

Pamela Howell is a senior structural engineer and project manager with over 10 years' experience in the engineering industry. Pamela obtained her bachelor degree in Civil Engineering (Honours) at the University of Queensland in 2005. She has worked on a variety of structural engineering projects embracing industrial, bridge, water and rail infrastructure. For this project, Pamela was the Project Manager for concept, preliminary and detailed design, as well as Structural Engineer during the Construction Phase Inspections.