Replacement of Damaged Bridge Barriers at Pimpama Bridge: A Risk Based Approach

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Abstract

In the evening of November 2024, a truck collided with the westbound barrier of the Pimpama Bridge. The barrier was unable to contain the vehicle, with the final position of the truck vertical in the creek below. Thankfully, there we no fatalities.

The City of Gold Coast (CGC) engaged SMEC to assess the damage and prepare detailed design documentation for the bridge barrier replacement and other associated works. The damage to the bridge was limited to the westbound lane bridge barrier, which had been destroyed, with minor cosmetic damage to the bridge kerb.

As the bridge was constructed 60 years prior, the bridge barriers and approach guardrails were not compliant with current bridge and road safety barrier standards with respect to both geometry and loading. The design of the new barriers followed a risk-based approach with close collaboration between CGC and SMEC. Bespoke design details and documented design exceptions were prepared to provide a rational and fit-for-purpose solution resulting in an overall improvement for road user safety compared with the original configuration.

Construction was successfully completed and the bridge re-opened in September 2025.

1.0 Introduction

In November 2024, a heavy vehicle collision resulted in complete failure of the westbound bridge barrier on Pimpama Jacobs Well Road Bridge No. 1 (Figure 1), allowing the vehicle to breach the containment system and fall into the creek below (Figure 2). While the incident did not result in fatalities, it highlighted the limitations of legacy bridge barriers designed under historic loading standards and raised immediate concerns regarding road user safety, operational continuity, and asset integrity.

The bridge, originally constructed in the mid-1960s, features post-and-rail barriers and approach guardrails that pre-date contemporary vehicle containment requirements. As is typical for bridges of this era, the structural capacity of the superstructure and kerb units is significantly lower than that required to support modern AS 5100 barrier performance levels. In such circumstances, strict compliance with new-build standards is often impractical and may unintentionally increase risk by transferring impact forces into primary structural elements.

This paper presents the engineering assessment, decision-making framework, and final design adopted for the barrier replacement and associated remediation works, including pile encasement and approach guardrail transitions.

Figure 1. Location map of Pimpama Jacobs Well Road Bridge No 1 (image courtesy of Metromap)

Figure 2. Bridge site immediately after accident

2.0 Existing Bridge History and Design Details

The Pimpama Jacobs Well Road bridge No. 1 is two-lane, two-way transversely stressed deck unit bridge over the Pimpama River at the Gold Coast. The bridge was designed in 1962 and constructed by TMR circa 1965. It is currently owned and managed by City of Gold Coast (CGC).

The bridge is supported by reinforced concrete headstocks with 5 driven square piles at abutments and 6 driven square piles at piers. Of the 12 pier piles, 8 had existing concrete encasements, however details and installation date were unknown.

The existing bridge barrier comprises galvanised wrought iron (GWI) bridge rails that are 89 mm dia (3.5" bore) with concrete posts constructed to TMR Std Drg 889. Concrete post spacing varies and is generally described as 3.05 m (10") for Spans 1 and 3, and 2.667 m (8'9") for Span 2.

W-beam approach barriers measuring approximately 17 m long had been retrofitted to the structure at a point in time after construction. The W-beams were connected to the concrete end post. No drawings were available relating to the W-beam connection installation works.

In October 2023, a Level 3 Engineering Inspection was undertaken due to defects flagged during a routine Level 2 inspection, and to ascertain the residual life of the bridge components. The salient observation from the Level 3 inspection was all 4 un-encased piles had severe etching below typical water levels due to long-term exposure to mildly acidic water in the river, and 1 pile had a large spall with corroded reinforcement visible. Concrete testing showed elevated chlorides due to partially tidal nature of the river. Only minor defects were observed to the remainder of bridge components.

3.0 Barrier Incident and City Response

On 18 November 2024 at approximately 11:43 pm a rigid body truck collided with the westbound bridge barrier which was unable to contain the vehicle (Figure 3). There were no fatalities or serious injuries, and the cause of the incident is understood to be under investigation.

The bridge was initially shut to all traffic immediately following the incident. Once the site was made safe and the vehicle had been removed, the road was reopened under temporary single lane traffic with stop/go traffic signals and water-filled barriers (Figure 4). This traffic arrangement would remain in place until September 2025.

Following the incident, the City of Gold Coast engaged SMEC to assess the damage and to rapidly develop a replacement barrier solution that would materially improve safety outcomes while remaining compatible with the existing structure.

Figure 3. Left, Bridge barrier before the accident, Right, Bridge barrier

Figure 4. Temporary Traffic Control

4.0 Replacement Barrier Selection and Design

The starting position for a replacement barrier design is to develop an outcome conforming with the requirements of AS 5100. However, many existing bridges such as Pimpama Jacobs Well Road bridge No. 1 have post and rail barriers with limited original design capacity.

As a result, these bridges typically have insufficient capacity to install a replacement barrier that complies with current AS 5100 barrier performance requirements for new bridge design and construction. In these situations, AS 5100.1 Clause 14.5.1 allows the relevant road authority to approve a replacement barrier performance level which differs from the standard required for new bridge design.

4.1 Design Criteria to Current Code for New Works

A barrier performance level risk assessment was undertaken in accordance with AS 5100.1 to establish the required barrier performance for a notional new bridge at this location. The assessment considered site-specific factors including road classification, traffic volume, operating speed, alignment, and the consequences of vehicle containment failure.

On the basis of this assessment, a Regular Performance barrier system would be required for compliance with the current requirements of AS 5100.

4.2 Likely Original Design Loads

The original drawings indicate that the structure was designed in 1962 for H20S16-44 vehicle loading. It is likely that the design standard used was the 1958 Highway Bridge Design Specification published by the Conference of State Road Authorities (later forming NAASRA - National Association of Australian State Road Authorities).

On this basis, the original bridge railing was designed to resist the following simultaneous loads:

- 150 lbs/ft transversely (2.19 kN/m)
- 100 lbs/ft vertical (1.46 kN/m)

For comparison, loads applied to new bridge design are specified in AS 5100.2 Table 12.2.2 as:

- 150 kN transversely for Low Performance barriers (TL2)
- 300 kN transversely for Regular Performance barriers (TL4)

- 600 kN transversely for Medium Performance barriers (TL5)

The original design forces are substantially lower than current barrier design forces. Any new AS 5100 barrier system will offer a substantial improvement in vehicle containment compared to the existing system.

4.3 Capacity of Bridge Superstructure with Proposed New Barrier

In the event of a vehicle impact, the cost of replacing barrier is significantly less than the cost associated with repairing primary bridge members such as deck units. Therefore, it is critical that the existing bridge does not fail before the replacement barrier.

To assess the bridge performance under a regular performance impact load, a review of the likely structural capacity was undertaken. The critical failure case was found to be the existing kerb units for concrete cone failure induced by forces in the barrier bolt fixings.

Impact forces were applied to the barriers and distributed through the bridge rails into the posts in accordance with AS 5100.2 Clause 12.2.2 using the methodology described in Austroads AP-R445-13 Standardised Bridge Barrier Designs (Figure 5).

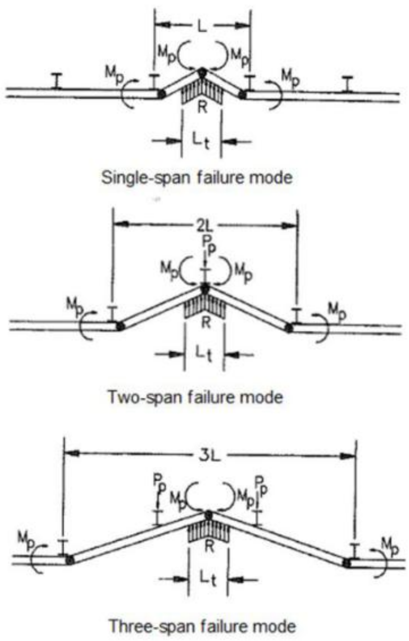

Figure 5. Possible failure modes for post and rail with failure of 1, 2 or 3 spans of posts (Source: Austroads AP-R445-13 Standardised Bridge Barrier Designs / AASHTO LRFD Bridge Design Specifications)

Resulting bolt tension forces were used to undertake a concrete cone failure assessment in accordance with AS 5100.5 Clause 14.3. The assessment concluded that:

- The existing bridge is unable to resist the impact forces associated with a new Regular Performance barrier.
- A Low Performance barrier would not exceed the bridge capacity and is an acceptable structural outcome.

4.4 New Barrier Performance Level

Performance barrier, the Pimpama Jacobs Well Road bridge No. 1 is an existing structure and does not have the required structural capacity to resist forces associated with this level of barrier containment.

AS 5100.1 Clause 14.5.1 highlights that for bridge rehabilitation projects it is often not possible to achieve an outcome fully aligned with new bridge design and construction criteria.

To assist with qualifying how this clause should be interpreted, TMR standards were referred to on the basis that they represent a major Queensland road authority with recognised pre-defined outcomes. The TMR Design Criteria for Bridges and Other Structures (DCBOS) sets the minimum barrier performance level as 50% of a Low Performance barrier.

The analysis showed that the bridge could exceed the minimum criteria and achieve 100% of the impact forces associated with a low performance system. On this basis, it was agreed that the replacement barrier would adopt a low performance level which is compliant with AS 5100.1 Clause 14.5.1 and aligns with the expected outcomes for barrier replacement works by other Queensland road authorities such as TMR, as documented in the DCBOS.

Additional factors which have influenced the recommendation for a Low Performance barrier outcome are:

1. The bridge is nearing the end of its design life and is approximately 60 years old with an expected total service life of 80 to 100 years.
2. An assessment of the existing structure was undertaken which confirmed a new replacement barrier with a regular performance level cannot be accommodated without strengthening the bridge.
3. Strengthening of the bridge to achieve a higher barrier performance level is not considered practical, or economically viable.

4. The new barrier will be significantly stronger than the existing barrier.
5. There has only been one bridge barrier crash incident based on a review of available crash data which extends over the last 15 years. There were no unusual or unexpected characteristics associated with the incident that would warrant adjustment to the new barrier assessment process.
6. The low barrier performance level provides the highest possible barrier containment level. A review of TMR documentation, as a key Queensland road authority, identified a reduced Low Performance barrier level is within acceptable TMR design outcomes.
7. For barrier replacement works where the criteria of new bridge design cannot be met, AS 5100.1 Clause 14.5.1 allows the relevant authority to determine an appropriate barrier performance level.

5.0 Structural Design for Replacement Barrier

Two parallel 250 x 150 RHS rails were adopted to comply with AS 5100.1 Cl 14.6.2, ensuring the clear opening between rails is less than 380 mm and that the front face of the rails is within 25 mm of the concrete kerb vertical face.

For the posts, 150 SHS members were chosen to provide a uniform visual outcome with other bridges on the network. 150 SHS posts are of similar geometry to the existing bridge posts and are aligned with the post sizes shown in TMR Std Drg 2200 "Post and Rail Traffic Barriers – Regular Performance".

Where possible, connections and detailing followed TMR Std Drg 2200 to provide a standardised outcome consistent with other structures on the network (Figure 6).

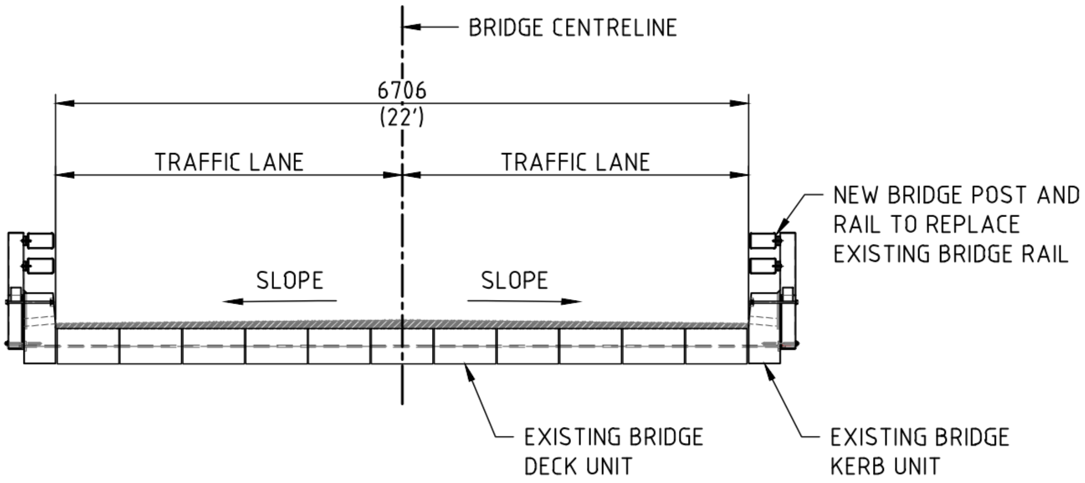

Figure 6. Post and rail configuration

The existing bridge kerb capacity is the limiting factor for the new barrier design. The section size chosen for the posts was driven by geometric reasons and is inherently greater than the capacity of the kerb unit.

In the event of a future vehicle collision, it is significantly more time and cost effective to replace steel bridge barriers than it is to undertake remediation of primary structural members such as kerb units. On this basis, the barrier posts were designed with a fuse connection to ensure the barrier fails before the kerb unit (Figure 7).

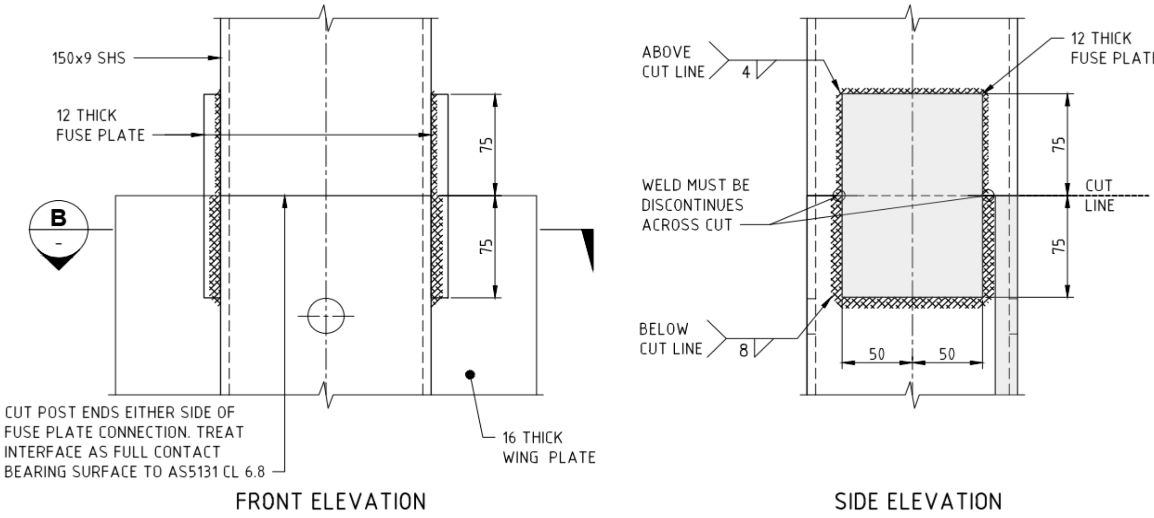

Figure 7. Fuse connection detail

Fuse connections are often used on road signage in exposed locations to create a controlled failure mechanism in the event of a collision.

The fuse connection developed for Pimpama Jacobs Well Road bridge No. 1 was designed to fail along the weld line. The fuse connection weld size and length iteratively refined to achieve the low performance vehicle impact resistance. The connection was designed using hand calculations and verified independent using Strand7 FEA and IDEA StatiCa FEA models (Figure 8 & Figure 9).

The anchor bolt tension force under this load case was 52 kN representing 59% utilisation, indicating that the fuse connection will be the point of failure in the event of a vehicle impact.

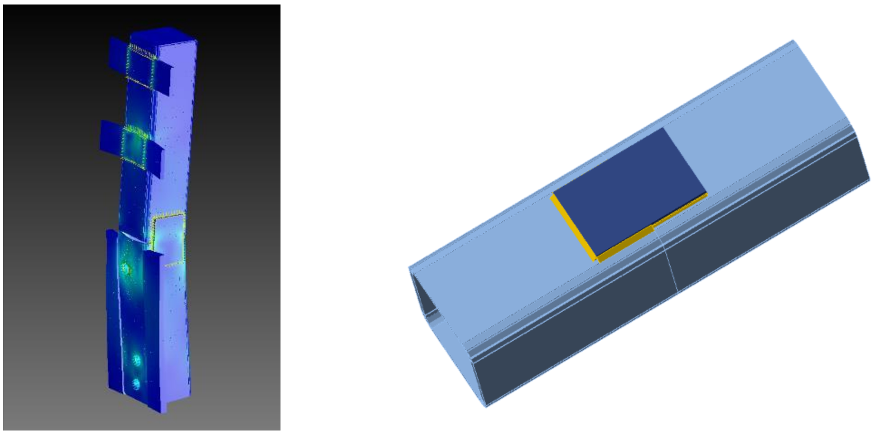

Figure 8. Left, Strand7 model of new barrier post, Right, IDEA StatiCa model of fuse connection in post

Figure 9. Installed bridge barrier

6.0 Transition to Approach Guardrails

Review of the bridge approaches identified several constraints that limited their suitability for integration into the new replacement barrier configuration. The key constraints were:

1. **Horizontal tie-in**: Existing W-beam located with an offset from the horizontal plane of the kerb. The offset varied at each of the four end points from 103 mm to 183 mm (Figure 10). This is a hazard for vehicles that are in contact with the existing road barrier during a collision. The vehicle is directed into the bridge kerb instead of being directed along the front of the bridge kerb.

2. **Vertical tie-in**: W-beam approach barriers, particularly on the southern side of the bridge were measured from survey as 490-500 mm above FSL at the edge of the pavement, ~250 mm lower than the minimum required height of 787 mm.

The nature of these constraints prevented the new bridge barrier design from connecting directly into the existing approach barriers and an options assessment was undertaken to identify the preferred treatment outcome.

The options assessment identified the preferred outcome to be installing a guardrail transition segment between existing guardrail and bridge barrier. This outcome was chosen as an interim guardrail solution to allow barrier replacement works to occur now and allow CGC to complete a full upgrade to the approaches as part of future works.

The bridge barriers were designed to accommodate the guardrail transition and were connected to the existing concrete end posts using the existing barrier bolts holes for the new barrier top rail. Two new holes were drilled for the bottom rail, and to allow flexibility in construction tolerances, the new barrier rail holes were tapped on-site (Figure 11).

Figure 10. Typical existing approach barrier to bridge connection

Figure 11. Installed guardrail transition in end post

7.0 Pile Encasement Design

It was identified the bridge relies on the piles to resist lateral vehicle forces imposed by impact to the replacement bridge barriers. For this reason, rectification of the 4 un-encased piles was included in the project.

The design objective was to restore the original design capacity of the pier piles and mitigate future corrosion of the original pile reinforcement. This was achieved by:

- Removing all unsound concrete.
- Augmenting (i.e. lap welding) existing reinforcement where >20% cross section loss has occurred.
- Providing cathodic protection to the existing pile reinforcement.
- Constructing a reinforced concrete encasement with a permanent formwork system.

The encasement was designed as a non-structural element, providing durability protection to the cathodic protection anodes and existing pile. Reinforcement was provided for control of cracking and core confinement to AS 5100.5. Ligatures were detailed with hooks to facilitate installation sequencing and were positioned away from the cathodic protection anodes to ensure clearance for micro-concrete compaction (Figure 12).

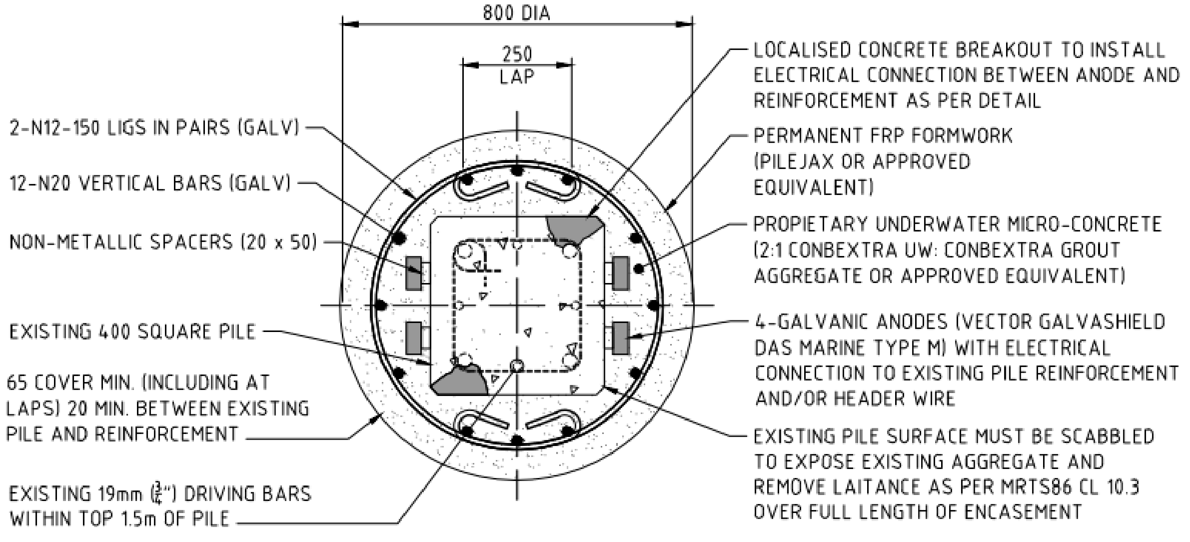

Figure 12. Pile encasement design section

7.1 Cathodic Protection

A cathodic protection system was incorporated into the design to protect the original pile reinforcement from future corrosion risks. A galvanic anode cathodic protection system (GACP) has been utilised instead of an impressed current cathodic protection system (ICCP) due to the significant reduction in on-going monitoring and maintenance. Features of the design included:

- Design life ≥30 years using a conservative initial current density of 40 mA/m^2 and a maintenance current density of 15 mA/m^2 (Figure 13).
- Highly turbid water made underwater diving works very difficult, hence electrical connection of anodes to existing reinforcement is only above water level. The anodes were interconnected below water level by a header wire.
- 2 electrical connections were nominated per pile, balancing redundancy and minimising damage to the existing pile. A conductor bar was included to avoid the need for reinforcement to be exposed for each anode connection location.
- The new galvanised reinforcement cage was intentionally electrically isolated from the original pile reinforcement to reduce the steel surface area to be protected by the anodes.

The nominated anodes (Vector Galvashield DAS Marine Type M) were specified due to their suitability for use in a tidal environment within concrete pile encasements.

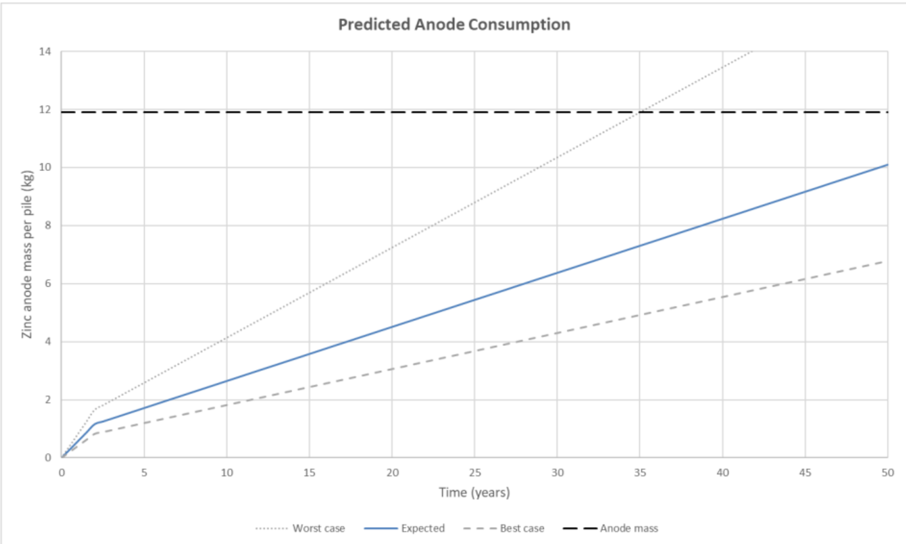

Figure 13. Galvanic anode consumption over design life

7.2 Encasement and Grout

The design of the encasement and grout considered the following:

- A permanent formwork system (jackets) was nominated, with several suitable options provided depending on Contractor / CGC preference and lead times.
- The extent of encasement was nominated at ~100-200 mm below the existing bed level. These levels were chosen to minimise excessive excavation of the existing bed.

A proprietary underwater micro-concrete (Fosroc Conbextra UW / Conbextra Grout aggregate @ 2:1 ratio) was nominated to fill the annulus between the existing pile and permanent formwork. Discussions with the product supplier resulted in the inclusion of aggregate in the grout to manage the risk of excessive heat and shrinkage. The product supplier advised this blended product is readily pumpable and the properties are largely unchanged, and compatibility with the nominated galvanic anodes was maintained.

Figure 14 shows various stages of the pile encasement installation.

Figure 14. Pile encasement installation in progress

8.0 Risk Analysis and Documentation

To document justification for acceptance of the replacement barrier and retention of the existing approach guardrails, design exception reports were prepared.

8.1 Bridge Barrier Capacity

The design exception report demonstrated a defensible, evidence-based engineering outcome founded on a robust, standards-aligned risk assessment. A site-specific evaluation was undertaken in accordance with AS 5100.1 Appendix A, incorporating traffic demand, heavy vehicle proportions, speed environment, geometry, under-bridge land use, and historical crash data. While this assessment indicated that a Regular Performance barrier would have been required for a new bridge at the site, detailed structural capacity checks confirmed that the existing superstructure could not safely accommodate the associated impact loads.

Quantitative assessment of barrier load transfer identified a high likelihood of brittle failure in legacy kerb and anchorage elements if a higher-performance barrier were installed, thereby increasing the consequence of impact from sacrificial barrier damage to potential damage to primary bridge components. On this basis, strict compliance with new bridge design and construction criteria was shown to increase overall risk rather than reduce it.

Application of AS 5100.1 Clause 14.5.1 enabled a holistic risk evaluation considering remaining service life, crash history, cost–benefit, and the practicability of strengthening. Strengthening was demonstrated to be impractical and uneconomic, and unlikely to provide proportionate risk reduction. Adoption of a Low Performance barrier therefore represented the highest practicable containment level that materially improved safety while preserving the intended hierarchy of failure.

The conclusions were supported by analytical assessment, sensitivity checks, and alignment with established road authority practices, providing a transparent and auditable basis for acceptance of the design exception.

8.2 Approach Guardrails and Connection

The design exception report for the bridge approach barriers documented a risk-managed, evidence-based justification for adopting a non-compliant interim treatment under constrained conditions. A structured assessment was undertaken in accordance with Austroads Guide to Road Design Part 6 and AS 3845, identifying multiple pre-existing non-compliances:

- Inadequate length of need.
- Non-MASH-tested barrier products and terminals based on the installation configuration.
- Insufficient offsets.
- Non-traversable runout areas.
- Installation on steep embankment slopes.

Crash history, roadside hazard risk ratings, traffic speed environment, and site geometry were explicitly considered.

Options analysis demonstrated that a fully compliant solution would have required extensive embankment widening, extended guardrail lengths, and significant earthworks, introducing disproportionate cost, constructability risk, potential flood impacts, and reduced roadside recovery widths. These factors were shown to outweigh the marginal safety benefit achievable under the project's emergency scope.

The adopted option was selected as the lowest-risk practicable outcome that avoided worsening existing conditions, maintained traffic operation, and enabled timely reinstatement of barrier functionality following a serious impact event. Residual risks were clearly articulated and mitigated through supplementary treatments, monitoring, and a defined commitment to future upgrade as part of the planned intersection works.

Overall, the report presented a transparent, auditable justification that balanced safety, constructability, and whole-of-life risk consistent with accepted engineering risk management principles.

8.3 Design Exception Reports Approval Process

The development and acceptance of the design exceptions were achieved through a structured and iterative collaboration between SMEC and CGC, underpinned by the City's formal design exception approval framework and delegated road authority process. Initial assessments by SMEC identified key constraints associated with the existing bridge superstructure and approach conditions, which informed preliminary risk evaluations and concept options. These findings were progressively reviewed with CGC through technical workshops and targeted engineering discussions, where assumptions, risk inputs, and mitigation strategies were tested and refined.

The design exception reports were iteratively updated to reflect this joint review process, incorporating feedback on safety risk, constructability, whole-of-life considerations, and alignment with CGC's risk management principles.

This collaborative process ensured that both the bridge barrier and approach guardrail treatments were not only technically justified, but also consistent with the CGC governance requirements for transparent, evidence-based decision-making.

Final agreement on the appropriate design exceptions was reached following endorsement through the delegated authority pathway, providing a clear, auditable basis for acceptance of solutions that balance compliance, risk, and practicality, while delivering a net improvement in overall safety outcomes.

9.0 Barrier Construction and Lessons Learnt

Construction was completed by Raw Worx Pty Ltd between May and August 2025.

Key lessons learnt from the design and construction were as follows:

- Many legacy bridges were designed for loading regimes well below current barrier standards and cannot practically be upgraded to full contemporary compliance. Applying a formal risk-based assessment allows safety outcomes to be improved in a manner proportionate to structural capacity, traffic exposure, crash history, and remaining service life, while avoiding unnecessary strengthening works that offer limited net benefit.
- Replacement barriers should be designed so that failure occurs in the barrier system rather than in primary structural elements. Incorporating deliberate sacrificial mechanisms ensures that future impacts result in repairable damage to replaceable components, preserving the integrity of deck and kerb units and reducing both disruption and long-term asset risk.
- Where site constraints prevent full compliance, design exceptions must be clearly documented. Any interim measures should be framed as temporary, with a defined pathway and commitment to achieve full compliance through planned future upgrades, preventing residual risk from becoming permanent.
- Designing appropriate tolerances into remediation works on existing bridges is essential. This was particularly evident when fixing to the existing tombstones where actual reinforcement locations varied significantly from the design drawings.
- Early and continuous collaboration between CGC and SMEC was critical to achieving a defensible and practical outcome. Establishing clear communication channels and engaging in iterative technical reviews ensured that constraints, risks, and assumptions were collectively understood and challenged, enabling timely refinement of the design exceptions and alignment with CGC's risk based decision-making and approval processes.

A constructability issue was uncovered only after the barriers had been designed, shop drawings prepared, and components fabricated and delivered to site. The rail connector bolts at the rail joint assembly were unable to be installed at the end terminal, as it was fabricated as a single piece as there was inadequate space for the bolt to be installed (Figure 15). A simple solution of using a single long threaded rod with an appropriate nut arrangement was proposed by the Contractor, which proved to be a simple solution which met the design intent.

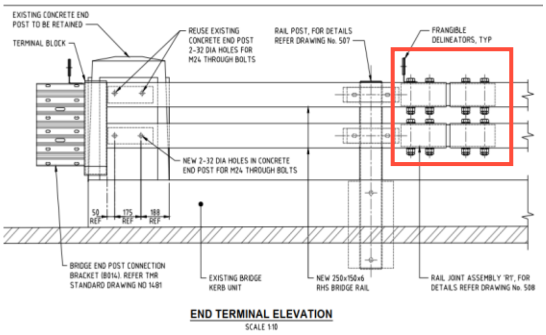

Figure 15. Bolt unable to be put through hole in barrier

10.0 Conclusion

The replacement of the damaged barriers at Pimpama Jacobs Well Road Bridge No. 1 demonstrated the effective application of a risk-based approach to bridge rehabilitation where full compliance with contemporary standards was not achievable. Assessment confirmed that although a Regular Performance barrier would have been required for a new bridge at this location, the existing superstructure lacked the capacity to safely sustain the associated impact loads without disproportionate strengthening. In this context, strict application of new-build criteria would have increased overall risk by transferring impact forces into primary structural elements.

Adoption of a Low Performance barrier in accordance with AS 5100.1 Clause 14.5.1 was shown to represent the highest practicable level of vehicle containment compatible with the existing structure. The selected solution provided a substantial improvement over the legacy barrier system, preserved the hierarchy of failure through deliberate sacrificial detailing, and safeguarded primary bridge components. Supplementary works, including pile encasement and carefully detailed guardrail transitions, further enhanced the structural robustness and durability of the asset.

This project reinforced that many legacy bridges cannot be economically or practically upgraded to full modern standards, and that improved safety outcomes were best achieved through transparent, evidence-based engineering judgement. Clear documentation of design exceptions, alignment with recognised road authority practices, and consideration of whole-of-life risk were critical to delivering a defensible and proportionate outcome.

The approach adopted provides a practical template for similar barrier replacement projects across ageing bridge networks.

11.0 References

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13.0 Author Biographies

Matt Duncanson leads SMEC's Asset Management and Materials Technology team for QLD. He was the project and design manager for the bridge barrier replacement.

Matt is a motivated and driven Principal Structural & Materials engineer with over 13 years' experience in the investigation and rehabilitation of bridges.

Tim Gibson is part of the SMEC bridges team and was the structural engineer for the replacement of the damaged barriers on the Pimpama Bridge.

Tim is an enthusiastic Associate Bridge engineer with over 10 years' experience and a passion for delivering innovative bridge designs and rehabilitations.

Tiffany Parker is the Coordinator Transport Structures for the City of Gold Coast. She is a Structural Engineer with 25+ years' experience across government and the private sector.

Tiffany is currently leading the structures team in the tactical asset management of the City's bridges.

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