NACOE
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FINAL REPORT

Project Title: AS/ISO 13822 Framing Investigation into the Assessment of Deck Unit Bridge and Transverse Stressing Bar Deficiencies (A variation of S29)

ARRB Project No: PRG17026

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SUMMARY

Within the NACoE program, a number of research projects have been initiated to tackle the issues related to the assessment of existing deck unit (DU) bridges and transverse stressing bar (TSB) deficiencies, including S3, S29 and S32. While much of the required work has already been undertaken variously in these projects, this work has yet to benefit from the framing inherent in the AS/ISO 13822 process. The intention is that this framing will focus the recommendations of each project on the TMR core objectives, provide comprehensive linking of all three projects, and extract greater value from all three projects, and from the asset base.

This framing investigation has been conducted as a variation to the NACOE S29 project '*Deck unit bridge deck analysis under live load – development of improved guidance/specification for calibrated grillage models*'. This document provides the context and reports the preliminary findings from this framing investigation, including assessment objectives and scenarios. Preliminary recommendations have been made, including the approaches to load rating of existing DU bridges and other opportunities to manage assets. This investigation also identified gaps in the TSB deficiency research that need to be tackled in a future project.

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1 BACKGROUND

1.1 Operational Context

The Queensland Department of Transport and Main Roads (TMR) currently manages approximately 3000 bridges, of which more than 1300 (43%) are transversely stressed deck unit (DU) bridges. Many of these DU bridges have been in TMR service since the 1960s. During that period, design concepts have evolved, design loads have increased as have typical spans (to accommodate improved economic efficiency). Transverse stressing bar (TSB) design requirements have also increased. Within the bounds of this variability, servicing and maintenance issues are reasonably predictable and understood. Standard TMR management precautions include Level 1 inspections (TMR 2016 *Structures Inspection Manual*), servicing, and Level 2 inspections. TSB deficiencies typically identified during these precautionary activities include:

1. missing TSBs
2. corroded TSBs.

TMR has a general (although not officially documented) mitigation process that includes a response to circumstances where TSBs are believed to be compromised on a bridge.

1.2 Engineering Context

While PSC DU bridges have generally performed well:

1. standard numerical assessment of these bridges has flagged inadequate capacity for the access of C48 cranes on a number of bridges, which resulted in travel restrictions
2. circumstances have arisen reasonably regularly where the integrity of transverse stressing bars has been brought into question as discussed in Section 1.1. This raises concerns about the integrity and resilience of these bridges
3. a similar set of concerns arises when bridge widening is contemplated for these bridges.

Concerns in relation to these issues have been on the TMR agenda for many years, and these concerns resulted (among other activities) in the formulation of three NACoE projects. Extracts from the proposals of these NACoE projects are provided in Appendix A to provide context to the formulation of each project, namely:

1. S3 – Deck unit bridge deck analysis under live load
2. S29 – Deck unit bridge deck analysis under live load – development of improved guidance/specification for calibrated grillage models
3. S32 - Review of transverse stressing bar replacement techniques.

During the course of S3, an opportunity arose to test bridge behaviour on a network bridge scheduled for demolition (Sandgate Rd Bridge). The objective of this test was to investigate the behaviour of the bridge (particularly the lateral load distribution between the DUs) when the TSBs were progressively severed (refer to Section 4.2.2). The project was varied to include this activity, and a report (PRG16022-Sandgate Rd bridge testing – GUN bridge test report) was generated.

While the S3 project scope has been completed, the GUN test report has not been fully signed off for a number of reasons, mostly centring on how to frame the results of the test, and provide appropriate recommendations based on the test outcomes.

1.3 Assessment Context

The discussion in Section 1.2 focusses on predicting structural behaviour, typically for the purpose of developing a load rating methodology, in accordance with the assessment section of the bridge design standard – AS 5100.7 *Bridge assessment,* which is based on design principles. In contrast, AS/ISO 13822 *Basis for design of structures: assessment of existing structures* is a standard specifically developed for the assessment of existing structures. The concept of structural assessment in AS/ISO 13822 is much broader than that of AS 5100.7 and incorporates factors such as:

1. asset business case
2. functional performance
3. understanding risk and available precautions and mitigations
4. operational management opportunities, including understanding and managing actual performance.

Given that transversely stressed DU bridges constitute more than 43% of the TMR bridge stock, and that they are generally considered functionally adequate, there is a strong business case to optimise their performance and risk, given that their cost profile has largely been established through prior investment.

Individual PSC DU structural behaviour is relatively well understood and has been the subject of extensive research. The structural behaviour of DU bridges is less certain because a number of load paths are possible with respect to load sharing between adjacent units, and these are not necessarily consistent for different bridge configurations, or at all load levels. Adding to this uncertainty, many of the older deck units are subject to Alkali-Silica Reaction (ASR) deterioration (with uncertain effects on capacity and durability). In addition, there is an upward trend in desired operating loads for much of the bridge stock.

The fundamental nature of the concerns that have originated all three above mentioned NACoE projects relates to the assessment of existing transversely stressed DU bridges (although the value of the work may extend beyond that). In this context, AS/ISO 13822 defines the following core process:

1. define assessment objectives
2. define context (capture typical scenarios)
3. preliminary analysis
4. detailed analysis
5. reporting and recommendations (to address stated objectives).

While much of the required work in (3) and (4) above has already been undertaken variously in S3, S29, and S32, this work has yet to benefit from the framing inherent in the AS/ISO 13822 process. The contention is that this framing will:

1. focus the recommendations of each of the above projects on the TMR core objectives
2. provide comprehensive linking of all three projects
3. extract greater value from all three projects, and from the asset base.

However, this approach will require retrospectively applying the above AS/ISO 13822 process. It is proposed that this be undertaken in two steps, namely a preliminary study and gap analysis to demonstrate the indicative outcome (documented in this report), followed by comprehensive application of the process, including addressing issues identified in the gap analysis.

1.4 Plan

Based on the above contexts, an action plan was prepared to pursue the above three NACoE projects, as follows:

1. The current S29 scope was paused because it can be better targeted inside an AS/ISO 13822 framed project.
2. A variation was approved for S29 with the following broad attributes:
   (a) 'Park' the current scope such that it will be re-commenced once the framing has better targeted the required activities.
   (b) Undertake a preliminary AS/ISO 13822 framing activity across S3, S29, and S32 and prepare a summary report that will be used to inform related external stakeholders and for validation within TMR. This will facilitate:
      2.b.1. Application of the preliminary AS/ISO 13822 process, placing the GUN test report in context
      2.b.2. Sign off of the GUN test report (including any adjustments required from (2.b.1)).
   (c) Undertake a gap analysis to identify required activities from (b) above that have not already been undertaken as part of S3, S29, or S32 or (b). This will form the basis for a 19/20 NACoE project to comprehensively combine the finding of all three projects under a single AS/ISO 13822 framework.

2 ASSESSMENT OBJECTIVES

Question: What are the assessment objectives for existing transversely stressed DU bridges in general, and for DU bridges with transverse stressing bar (TSB) deficiencies (demonstrated or suspected)?

AS/ISO 13822 defines assessment as '*a set of activities performed in order to verify the reliability of an existing structure for future use'*. In light of this definition, it is required that the objective of the assessment of an existing DU bridge in terms of its required future structural performance be specified in consultation with TMR (the owner), based on a set of performance levels, with details given as follows (cl. 4.1):

1. *Safety performance level, which provides appropriate safety for the users of the structure*, i.e. ensuring no catastrophic failure of the bridge occurs with the passage of traffic (e.g. heavy vehicles).
2. *Continued function performance level, which provides continued function for special structures such as hospitals, communication buildings or key bridges, in the event of an earthquake, impact, or other foreseen hazard*. This requirement is site specific and does not apply generally across the TMR DU bridge population, although it may apply in specific circumstances.
3. *Special performance requirements of the client related to property protection (economic loss) or serviceability. The level of this performance is generally based on life cycle cost and special functional requirements.* This requirement may be interpreted as a requirement to avoid significant reduction in asset life under operating conditions, unless such a reduction is substantiated as appropriate for a specific business case.

While recognising that specific sites may have particular requirements, the desired outcome of this project is to define a comprehensive response protocol for DU bridges where a need for assessment has arisen (e.g. TSB deficiencies have been identified or are suspected). The response protocol is focused on assessment of the asset and identification of management options rather than design code compliance.

3 SCENARIOS

Question: What scenarios are relevant to provide framing for assessment?

TMR DU bridges can be considered functionally adequate based on 50+ years in service, i.e. they have been through a half of their design life without significant failure events due to TSB deficiency being recorded. Both operational and failure scenarios are of interest to the assessment as summarised in this Section.

Scenarios related to a change in structural conditions (cl. 4.4) should be determined to *identify possible critical situations for the structure. The identification of scenarios represents the basis for the assessment and design of interventions to be taken to ensure structural safety and serviceability*. This process should be based on the understanding of:

- actual performance vs current theoretical estimate: observations/records based on normal operations and behavioural testing indicate good performance, while theoretical estimates indicate substandard (very conservative).
- bridge failure mechanisms.
- opportunities to manage failure risks (likelihood and consequence).

3.1 Operational Scenario Examples

The following typical operational scenarios have been identified on TMR existing bridges:

- TSB corrosion: typically occurrs due to the presence of water which relates to situations with blocked scuppers, bridge cross-fall, and at end of span. This is normally coupled with ASR cracking on the DUs when water comes in through ASR cracks and causes the TSB to corrode. In these cases, the TSB sections within 1–2 external units may be lost due to corrosion. It is not known if the remaining TSB sections (within the internal DUs) are still intact, or how this affects the integrity of the whole structure.
- A number of TSB are compromised or found to be missing. It is hard to determine (the performance of the bridge) if a bar is lost. Basic tests have been used to run a current through the bar to test if the bar is integral. (The S32 project is intended to provide some insight in these cases).
- Missing TSBs due to design/construction errors or omissions.

Three L2 inspection reports of 3 bridges with TSB issues have been taken as examples of these operational scenarios. In all three cases, the ends of a number of TSBs were corroded and came loose. When one TSB on one span has this defect, all DUs on the span were rated in CS4 and a recommendation was made to replace the broken TSB (Figure 3.1–Figure 3.3).

However, no further development of structure distress has been observed or recorded as a result of the identified TSB deficiencies on the above bridges. It is not known how the defects found in 2010 on Bridge ID 7330, for example, have been rectified.

Figure 3.1: End 1 stress bar broken, Bridge ID 625 (Oct 2016 L2 inspection)

Figure 3.2: Broken sections of TSB on Bridge ID 7330 (Jun 2010 L2 inspection)

Figure 3.3: Bridge ID 41393 (Feb 2018 L2 inspection)

Full length crack running from A1 to A2 down bridge centreline

First TSB on RHS was broken

3.2 Failure Scenarios

Two ‘failure’ scenarios have been identified as being relevant to bridge assessment for these types of bridges:

1. Structural behaviour under monotonically increasing load, eventually causing structural collapse. This was a core focus of the S3 and S29 projects as formulated.
2. Defect propagation under near service loads. This concern is motivated by knowledge of damage to a plank bridge in NSW (near Murrurundi and Goulburn) in NSW approximately 25 years ago. The general circumstances surrounding these bridges were that the bridge concept had been extensively tested and developed prior to construction of these bridge types, yet a brittle and progressive failure mode primarily driven by service loads developed, such that it was difficult to remediate the bridge, and it is understood that the bridges may have been replaced (well before intended).

Interpretation of field test results (particularly for the GUN test) would vary significantly for the above two failure scenarios. While a systematic investigation has not been undertaken, no failure events under either of the above scenarios have been reported on the TMR bridge stock, however as highlighted in Section 1.3, there is considerable uncertainty associated with this outcome, and it should not be assumed.

4 TMR RESPONSE TO TSB DEFICIENCIES

Question: What are the response options where scenarios of TSB deficiencies (for each scenario describe operational issues, response options and failure mechanisms) are identified?

4.1 Current TMR TSB Deficiency Response

4.1.1 Existing Bridge Context

Existing bridges where TSB deficiencies are suspected occur in the following operational context:

1. Bridge condition is monitored through regular inspections; therefore, any significant deterioration of the structure is reported and can be rectified in a timely manner.
2. No historical record has been identified where all TSBs are lost at any point in time.

Ongoing operation of a bridge with suspected TSB integrity should minimise intervention while ensuring the safety performance, and this is achieved by:

1. periodic verification of the integrity of the structure through its service life via inspection, monitoring and maintenance activities;
2. managing the risks of overloading by the enforcement of vehicle loads (heavy traffic) that use the bridge (not bridge-specific).

4.1.2 Existing Structure Investigation and Response

Currently, a L3 investigation or TSB replacement is recommended in L2 inspection reports if a section of TSB is lost. Therefore, different scenarios need to be investigated to identify critical scenarios such as which is more critical: a short span or long span losing 1-2 bars? Generally, the following principles apply for further investigation:

- When TSBs are lost, for a long span, the rule of thumb is if 30% or more no. of bars on one span is lost then a prevention action is triggered.
- Checking the integrity of TSBs.
- If a bar is lost at the end of a span and if mortar is intact then dowel action can be assumed.

4.1.3 Bridge Widening/New DU Bridges under Construction

In a bridge widening context, during construction the load transfer mechanism between DUs is influenced by:

- Mortar joints have not gained sufficient strength.
- TSBs have not been installed or stressed.

Therefore, the individual DUs on a new widening or a new DU structure under construction with early age (i.e. under strength) mortar joints or unstressed/not installed TSBs will work independently from each other if they have to carry loads, since a transverse load transfer mechanism has not been formed. Any intention to put loads on this incomplete structure will need to assume no load sharing between DUs. This supports the MRTS74 (2018) requirement that ‘no construction plant or vehicles shall be placed on the erected units before the completion of transverse stressing and until the grout in the transverse stressing holes has attained a minimum age of two days’.

4.2 TMR TSB Research

Refer to Appendix A for details of the 3 NACoE projects S3, S29 and S32. Key findings from these projects are summarised in the following sections.

4.2.1 Testing of a DU Bridge to Destruction

As part of the NACoE S3 project, a partial bridge was built in a laboratory using decommissioned DUs and KU for testing to destruction. Key observations from this testing program include:

1. At service load level the TSBs did not engage in taking any load. This is due to the fact that the TSBs were located at mid-depth of DUs, and the transverse load transfer relied on the mortar joints between the DUs. The TSBs only started taking load at a very high load level which was close to the ultimate load.
2. Destructive test results indicate that once the KU failed (cracked), the load is redistributed to adjacent DUs, and the structure can continue to take additional significant loads due to the presence of the TSBs which hold the units together.
3. When some DUs failed, the whole bridge deck was still held in place. A sudden, high consequence failure will probably only occur when the individual DUs or a small group of DUs carry loads separately, i.e. when the TSBs are lost, and the mortar joints between them are totally cracked.

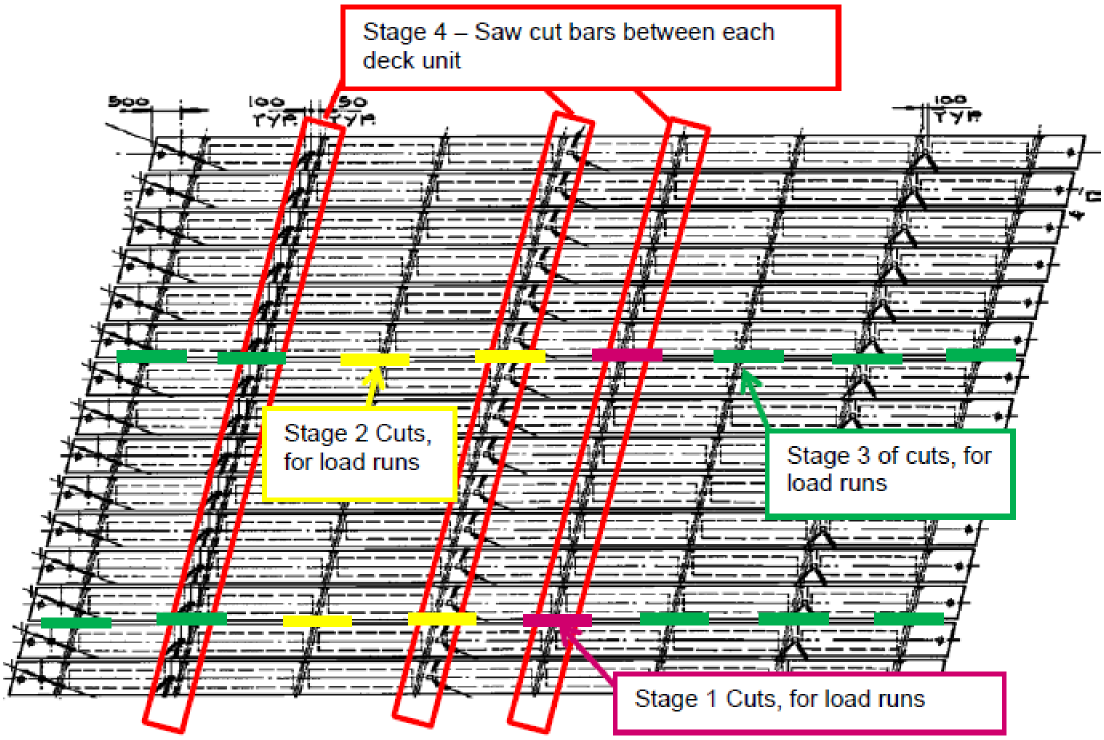
4.2.2 GUN Sandgate Rd Bridge Load Test Scenarios

The following observations were derived from the load test of Sandgate Rd Bridge:

- During testing, the test vehicle travelled back and forth on the bridge in a short period of time (about 60 runs in 2 days).
- As the TSBs were severed, the mortar joints around the TSB were also cut (noting that a 1.0 m dia. rotary blade was used to saw cut the mortar and TSB).
- The mortar joints away from the cutting area remained intact, therefore they still contribute to the load transfer mechanism between the DUs.
- In the final testing stage (Stage 4 – see Figure 4.1), all bars along 2 mortar joints (out of 14 joints) and all joints along 3 TSBs (of out 8 TSBs) were cut. The reduction in the area of mortar along a joint is 34%. In comparison to the whole deck, the reduction is 16%.
- The TSBs were bonded, therefore, a certain level of prestress remained in the uncut sections of TSBs.
- In addition, observations from the lab test indicate that (Section 4.2.1) the TSBs did not engage in taking load at service load levels (due to its location at the mid-depth of the DUs). They only started taking loads at very high load levels which are close to the ultimate load. Therefore, at service loads, the main transverse load transfer mechanism was through the mortar joint.
- Given the above observations, for Sandgate Rd at the final testing stage (Stage 4, where the TSBs were lost at some locations and all TSBs were damaged – see Figure 4.1), there were still substantial areas of mortar joints that remained intact. The stiffness in the transverse direction which relies on the mortar joints was still sufficient for the load transfer between the DUs. Therefore, it supports the observations and measured data from the tests.
- However, it is likely that the integrity of the uncut TSB sections and mortar joints would be lost gradually under the dynamic impact of traffic, should the bridge continue to be open for traffic after the test was completed. Since the TSBs were already cut, there was nothing to hold the units together, and further failure of the mortar joints would likely propagate from the

cutting areas under service loads. The DUs would eventually work individually and might fail in the similar pattern as reported on Murrurundi Bridge in NSW.

Figure 4.1: Sandgate Rd Bridge: TSB severing schedule sections of TSBs during the load test



4.3 Preliminary Recommendations

4.3.1 Load Rating of Existing DU Bridges (S29)

It is recommended that load rating of existing DU bridges (detailed assessment – AS/ISO 13822 cl. 4.6) be carried out based on:

1. determination of actual bridge geometry and material properties obtained from detailed inspection and material testing (cl. 4.6.3)
2. determination of actions, i.e. operational/largest heavy vehicle loads that may use the bridge (cl. 4.6.3), e.g. by WIM (weigh-in-motion) data.
3. determination of properties of the structure, i.e. load testing of structure to *measure its properties and/or to predict the load-bearing capacity when other approaches such as detailed structural analysis or inspection alone do not provide clear indication or have failed to demonstrate adequate structural reliability* (cl. 6.4.4).

4.3.2 Other Opportunities to Manage Assets

Management of assets that are otherwise considered efficient can be facilitated by operational data including past records. The following opportunities may be applicable in this case:

1. It is suggested that a number of DU bridges with high volumes of heavy traffic be selected to investigate recorded historical TSB issues. Investigation can be conducted by engaging the relevant bridge managers to identify the issues, the response to rectifying the issues, outcomes and if possible, the allocated budget.

2. In order to investigate the long-term effects of TSB deficiencies on the performance/capacity of the bridge, it is suggested that a number of bridges with known TSB defects be left untreated and closely monitored.
3. Future L2 inspection regime for DU bridges should include particular attention to reporting on the TSB-related issues such as TSB deficiencies, longitudinal cracks and flexural cracking of KUs.
4. Performance measures may include: inspection (any cracking in the mortar joints, disintegration of DUs, cracking in critical component, e.g. KU), monitoring (propagation of cracking/damage on the mortar joints), testing (integrity of the existing TSBs, behavioural load test), and restoring the design condition (replacement of damaged TSBs).

4.3.3 Interim Recommendations

Based on the AS/SIO 13822 framing investigation and the work undertaken within the NACOE S3, S29 and S32 projects, the following recommendations are made:

1. GUN bridge test report: given that the GUN bridge test program demonstrated a reduction in the lateral load distribution of service loads when TSBs are removed, it is recommended that this represents the in-service incremental damage and should not be considered acceptable on TMR bridges.
2. A separate report providing recommendations for modelling of DU bridge in the elastic range is to be prepared within S29.

5 ADDITIONAL INVESTIGATIONS IDENTIFIED IN GAP ANALYSIS

Question: What further investigations are required to deliver the identified assessment objectives for DU bridges with TSB deficiencies?

5.1 Identified Gaps

The following gaps have been identified regarding TSB deficiencies:

- An international literature review of the issues related to longitudinal cracks and transverse prestressing components of similar bridge types.
- With 50+ years in service of TMR DU bridges, a data analysis of TMR records may identify DU bridges with historical issues with TSBs, evidence of longitudinal cracking, and differential movement between DUs. Historical records may also be available on the rectifying actions and associated outcomes.
- Review of S3, S29 and S32 findings cognisant of the objectives identified in Section 2.
- Provide some recommendations on modelling the behaviour of DU bridges in the inelastic range.
- Also consider anything that may be beneficial for the design of new DU bridges.

5.2 Recommendations for Future Works

This report is preliminary based on the above analysis. It is recommended that a proposal for a future year project be developed to address the above identified gaps.

REFERENCES

Department of Transport and Main Roads 2016, 'Structures inspection manual', TMR, Brisbane, Queensland.

Standards Australia

AS 5100.7:2017, *Bridge design: bridge assessment*.

AS/ISO 13822:2005 (R2016), *Basis for design of structures: assessment of existing structures*.

APPENDIX A ORIGINAL NACOE PROJECT PROPOSAL EXTRACTS

A.1 S3 – Deck Unit Bridge Deck Analysis Under Live Load

Background

TMR currently manages approximately 3000 bridges, of which more than 1300 are transversely stressed DU bridges. These bridges would have been designed to the applicable bridge design code of the time. In addition, heavy vehicle access has been provided in accordance with various load rating assessments and National Access Schemes over the years.

TMR has undertaken a structural assessment of the freight network to determine if the structural capacity exceeds the current as-of-right access (GML/HML, B-double or road train) and permit vehicles. This assessment is based on the current code, as distinct from the code that the bridge was designed to. In the intervening period there have been a number of changes to codes including:

- correction of a worldwide error in the calculation of shear capacity in concrete in the 1960's and 1970's
- amendment to capacity reduction factors
- changes to design load combination factors
- changes to dynamic factors
- changes to structural capacity (for example, shear)
- changes to minimum shear reinforcement required.

Of the 1300 DU bridges, 548 have restriction for access to a 48 tonne crane. This restriction means that 48 tonne cranes need to travel on longer routes or be placed on a float. The consequence of these restrictions is to increase the cost of undertaking work within Queensland. However, the condition and in-service performance of these restricted structures often do not reflect the outcomes of the assessment results which indicate overloading. In the absence of targeted research, these restrictions must be maintained in the interests of prudent asset and risk management procedures.

Objectives

This project seeks to address the disparities between theoretical assessment and in-service performance of deck unit (DU) bridges in order to provide input for developing consistent guidelines for analysis. This will improve the accuracy of rating and assessment results with significant potential savings for deferred strengthening/refurbishment of DU bridges currently assessed as being sub-standard.

Specifically, the purpose of this project is to develop:

1. practical methodologies and procedures for instrumenting and load testing this type of bridge
2. calibration of computer models with actual performance
3. improve understanding of transverse distribution of live load
4. consistent guidelines with respect to the assessment of these bridges
5. verification of individual DU capacity through controlled laboratory testing
6. input to TMR guidelines with respect to the structural capacity assessment.

The project will be examining the following factors:

- actual concrete strength due to strength gain with time compared to the design strength
- actual reinforcing steel strength
- testing to examine the actual shear capacity compared to code design capacity.

It is anticipated that these parameters will be able to demonstrate significant increases in structural capacity compared to the theoretical design capacity.

Current status & deliverables

Testing program has been completed. Deliverables include:

1. behavioural testing of an in-service bridge (Canal Creek Bridge) – 1960s design era
2. destructive testing of decommissioned DU and KU in shear and bending
3. destructive testing of a partial DU bridge built in the lab
4. material testing for concrete, prestressing strands and reinforcement.

Sign off for Year 4 report is pending due to issues related to Sandgate Rd overpass load test report.

A.2 GUN Sandgate Rd Bridge Testing

Background

This is a variation of S3.

Transversely stressed precast concrete DU bridges have been in service since the late 1950's and represent a dominant and large portion of the road bridges in Queensland for small and medium spans. Despite their widespread use, the behaviour of these bridges is not fully understood.

TMR desires to gain confidence in the load distribution behaviour when the transverse bars are damaged or there is substantial loss of the section. This will allow:

- wider application across the state on the numerous existing DU bridges
- to establish guidelines and development of methodologies to evaluate this loss in strength to be applied on multiple bridges across the network, in preparation of maintenance strategies
- develop knowledge surrounding the behaviour of bridge spans when transverse bars are released and can be applied to widening bridges under live traffic. Increased knowledge of bridge behaviour can lead to reduced traffic restrictions during widening operations of DU bridges. This can result in reduced associated traffic management costs, and reduced distribution to the network during projects.

A wider scope TMR and ARRB research project exists which would benefit from data from testing during deconstruction of a DU bridge. The proposed deconstruction of the Sandgate Road Northbound bridge provides an opportunity to destructively test a DU structure. The three northern spans of Sandgate Road NB (BR08) have been targeted for the testing work due to their location away from traffic and current work areas.

Objectives

The primary objectives of this project are to:

- test and monitor the load carrying reduction of a DU structure in the event of TSB breaking

- identify NDT suppliers (or systems) that can accurately advise TMR of TSBs that are in a condition state that requires removal i.e. a nominal % of corrosion or grout loss that TMR deems significant
- utilise load testing to assist in determining the percentage loss of section in a TSB that warrants the replacement of the TSB.

Anticipated benefits

There are significant benefits to TMR and Queensland, as follows:

- improvements in the quality of data used to assign risk ratings to DU bridge assets on the road network
- increased knowledge of load distribution across the TSB
- increased knowledge of the behaviour of the structure and load capacity when a TSB is damaged
- enables the development of a methodology to evaluate loss in strength to be applied on multiple bridges across the network for development of maintenance strategies
- development of knowledge surrounding the behaviour of bridge spans when transverse bars are released which can be applied to widening bridges under live traffic. Increased knowledge of bridge behaviour could lead to reduced traffic restrictions during widening operations of DU bridges. This could result in reduced associated traffic management costs and reduced distribution to the network during projects
- non-destructive extraction of the DUs and subsequent destructive testing of these components improves the understanding of the transverse behaviour and kerb performance of DUs and effect of kerb barriers
- conducting the research on the GUN project may save time and reduce impacts to the community through utilising a bridge (Sandgate Road NB) that will be closed to traffic and demolished
- benefits to other projects in terms of providing more certainty around bridge performance which may allow bridges to be retained instead of demolished
- there are quality benefits to other projects in terms of having more certainty around bridge capacity
- develop knowledge of the available NDT systems and their accuracy. This will increase the confidence in the use of these systems for their wider application across Queensland on existing infrastructure, especially in preparation for widenings. This could avoid the need for costly rehabilitation works on DU bridge assets, enabling the expenditure of funds more effectively on critical assets
- increased knowledge of the changes to NDT data when a transverse stress bar is damaged or experiences a substantial loss of section
- this research will allow TMR to establish criteria for NDT suppliers to be TMR certified to accurately test TSB’s
- this research may lead to the potential for current network restrictions to be relaxed or removed, allowing for freer movement of freight and the economic benefits associated with this
- it will also allow TMR to make better informed and more targeted decisions around maintenance interventions. This will allow TMR to recognize additional residual life in structures and reduce unnecessary/excessive maintenance requirements.

Current status and deliverables

Behavioural testing of Sandgate Rd overpass – built 1985 - under undamaged condition and gradual severing of TSBs.

Sign off of the test report is pending due to issues related to the interpretation of the test outcomes.

A.3 S29 – Deck Unit Bridge Deck Analysis Under Live Load – Development of Improved Guidance/Specification for Calibrated Grillage Models

Background

As part of the NACOE project *S3 Deck Unit Bridge Deck Analysis under Live Load*, an extensive test program has been conducted including performance load tests of an in-service bridge, destructive tests of individual decommissioned deck units (DU) and kerb units (KU), and full-scale performance load tests and ultimate load test of a bridge built in the laboratory. In addition to improving understanding of how DU bridges perform, the results from this load test program have provided valuable inputs for theoretical model calibration.

Objectives

This project aims at calibrating a computer grillage model for the theoretical assessment of DU bridges using past TMR research outcomes and field measurement data obtained within the NACOE project *S3 Deck Unit Bridge Deck Analysis under Live Load*. Actual responses of in-service bridges and actual ultimate strength/capacity of DUs determined through load testing will be used to calibrate grillage models. The project will take into account the following measured data:

- lateral load distribution between units under serviceability loads and higher load levels
- ultimate sectional capacity of individual units
- concrete strength due to strength gain with time compared to the design strength
- actual prestressing steel strength
- prestressed losses.

Using field measurements, the calibrated model will provide more reliable and realistic assessment results. In addition, it is anticipated that using the measured data, it will be able to demonstrate significant increases in structural capacity compared to the theoretical design capacity. As a result, the discrepancies between theoretical prediction and actual behaviour of DU bridges would be reduced.

Specifically, the purpose of this project is to provide an improved grillage model for theoretical assessment of DU bridges and revise the current TMR guideline S02 Annexure Modelling Deck Unit Bridge Superstructure for Tier 1 Assessments.

Current status and deliverables

A grillage model calibration has been successfully completed for serviceability load test data.

Further works include:

- Calibration of computer model for ultimate load test data (parked).
- AS/ISO 13822 investigation
- Gap analysis.

A.4 S32 – Review of Transverse Stressing Bar Replacement Techniques

Background

Transverse stressing bars are an integral component in DU bridges that assist with the load distribution between adjacent DUs. These components are susceptible to deterioration, particularly when not installed correctly and/or in extreme environments. Failure of bars may be detrimental to the performance of these structures and consequentially, when failures are identified through the inspection process it is necessary to remove the damaged bar and replace it. Additionally, when it is necessary to widen structures, transverse stressing bars must be extended and/or replaced. This is problematic as the bars are typically grouted in place once installed and tensioned.

While various techniques have been employed there are currently no documented procedures for rehabilitation/repair treatments for the removal and replacement of damaged/defective transverse stressing bars.

The project was placed on hold while information was being collected across a number of Departmental stakeholders. It has come to light that there is a lack of quality assurance documentation available due to the nature of the minor works and rehabilitation contracts used.

A significant opportunity has arisen to extend the project to witness a bar extraction and to investigate the effectiveness of predicting TSB condition using Non Destructive Testing (NDT) methods. The bridge in question is the Cattle creek bridge which is being replaced as part of the Cattle to Frances Creek Bruce Highway Upgrade Project. This will significantly assist in the development of the specification while presenting an important opportunity to evaluate NDT methods.

NDT is a tool that has been promoted as being effective to determine if TSBs are broken, damaged or significantly corroded. The costs to replace TSBs are very high and so any tools that can help ensure that replacement is necessary will ensure that the Departments budget is spent wisely. Results of NDT on TSB condition have been mixed to date and this additional work will assist to develop a solid working knowledge of NDT methods for evaluating TSB.

Objectives

The intent of this project is to establish current procedures for the removal and replacement of transverse stressing bars in situ and prepare appropriate method statements and technical specifications.

Current status and deliverables

Field work on Cattle Creek Bridge completed Aug 2018 including NDT and coring for the TSBs. Further works include:

- Review TMR’s TSB replacement projects within the last 10 years
- Review of international practice
- Assess NDT data vs actual condition for Cattle Creek and Sandgate Rd bridges
- Prepare draft MRTS including method statement and specifications.