THE NEW AS 5100 – PART 8, REHABILITATION AND STRENGTHENING

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ABSTRACT

AS 5100 was originally developed for the design of new bridges. There are however, approximately 20,000 existing bridges in Australia. Although Part 7 of the Standard relates to the strength rating of existing bridges, the existing AS 5100 generally does not refer to the specific applications of design and construction for the repair, rehabilitation, strengthening or widening of existing bridges. Following numerous requests from industry, this has been addressed with the introduction of Part 8, “Rehabilitation and strengthening of existing bridges”, which will form part of the new revised AS 5100.

This paper summarises the content of the new Part 8 and addresses for existing bridges: condition assessment, methods of repair, rehabilitation and strengthening for concrete, steel, timber and masonry structures plus specific requirements for bearings, deck joints, barriers and culverts. Particular requirements for carbon fibre strengthening and cathodic protection are also provided.

INTRODUCTION

It is intended that Part 8 will set out minimum requirements and procedures to:

• Repair or rehabilitate in order to restore a structure to its original or intended level of service
• Extend the remaining service life of the structure
• Strengthen to restore capacity due to structural deterioration
• Strengthen to increase capacity for live load (such as in response to a proposed increase in vehicle loads), barrier loading, collision loading, earthquake loading and other loading
• Change the function of a structure (such as a road bridge to a pedestrian/cyclist bridge)
• Widen an existing structure

It is noted that the existing bridge will have been designed to the Code current at the time, and this may not be the same as the current standard. Part 8 provides guidance to the Authority who may direct that a lesser design loading be adopted where a series of listed conditions can be shown to apply.

For the planning and design stages of bridge rehabilitation or strengthening, Part 8 lists a number of items which need to be considered, as a minimum. Requirements are also provided for the frequency of bridge inspections.

The following sections summarise some of the proposed key components of Part 8.

Concrete structures

This Section includes specific requirements for assessment for cathodic protection and assessment of fire damaged concrete. Procedures are provided for crack repair and repair of concrete in general. Guidance is provided for the waterproofing of bridge decks by sheet membranes or spray applied solvent free waterproof membranes.

Both red rust corrosion (characterised by good oxygen availability and expansive corrosion product) and black rust corrosion (characterised by limited oxygen availability and often non expansive corrosion product) are addressed.
Assessment techniques and requirements described include:

- Chloride analysis
- Carbonation
- Potential mapping
- Electrical resistivity
- Concrete cover
- Delamination and crack width measurement
- Core sampling
- Corrosion rate measurement
- Alkali aggregate assessment

Details provided addressing strengthening include fibre reinforced polymers, steel plating, external/transverse post tensioning, reinforced concrete deck overlay and reinforced concrete jacketing systems.

**Steel structures**

Causes of steel deterioration covered in detail in this Section include: corrosion, permanent deformations, cracking and loose connections. Details are provided for different test methods including: visual, hammer test, magnetic gauges, radiographic testing, ultrasonic testing, magnetic particle testing, acoustic emission and laboratory analysis of steel samples.

The distinction between old and modern steels, and wrought iron and cast iron is very important in rehabilitation or strengthening design, and in the consideration of weldability. Guidance is provided to assist in the material identification.

Provisions are provided for the cathodic protection of steel structures for applications where the structure is buried or submerged, using either the galvanic anode or impressed current system.

When subjected to fire, steel and its associated connections, may lose strength with increasing temperature, and on cooling can show a loss of both yield strength and tensile strength. At high temperatures, steel is also subject to significant elongation, which may also lead to adverse impacts, especially if it is restrained. Guidance is provided in the assessment of steel members which have been subject to, or suspected of being subject to, high temperatures.

Requirements are provided for the assessment and repair of surface protection systems, rivet replacement and replacing cracked plates and sections. Strengthening steel structures generally comprises fitting stronger replacement steel elements or supplementary elements by either welding or mechanically fastening. Due to potential issues with weldability and fatigue life, connection using mechanical fastening is preferred.

Steel over-bridges are particularly vulnerable to damage from over height vehicles passing under. This Section of the Code addresses repairs and strengthening to major components such as girders or truss members and minor components such as bracing members affected by such damage.

Details are provided for the strengthening of steel bridges by the use of straight strands or bars applied near the bottom flange, or by providing a composite connection to the concrete where applicable.

**Timber structures**

Causes for the deterioration of timber structures discussed in this Section include: structural overload, splitting due to shrinkage, insect attack (termites and marine borers), fungal attack (rot), weathering and fire. These are described, together with methods of assessment including
visual inspection, inspection under transient loading, inspection using timber boring, nuclear densometer and resistograph (drill resistance) testing.

Requirements are provided for common remedial and temporary repairs including splicing of timber piles, providing additional girders and providing a concrete overlay. Due to uncertainties in long-term composite action between overlays and timber decks, concrete overlays are not considered to contribute to strength or stiffness in the longitudinal direction, and should be ignored in strength calculations for the timber girders.

The remaining life of timber members can be significantly extended with appropriate protection, and recommendations are provided for flashing and preservative application.

For longer term rehabilitation, the Code specifically addresses replacement of timber piers, stress laminated timber decks and component replacement. It is noted that all timber components need to be ordered by specifying the size, strength grade, seasoning requirements (green, 12 months air dried or kiln dried) and durability class. If unseasoned or air dried timber is required, then a larger size must be specified (add 5%) to cover shrinkage of the timber as it seasons with time.

Masonry structures

Methods of assessment of masonry structures is described including visual inspection techniques, identification of leaf separation, crack width measurements and surveys, requirements for core sampling and various methods of non-destructive testing including ground-penetrating radar, ultrasonic pulse velocity and impact echo.

Guidance is provided for the inspection and assessment of fire damaged masonry.

As most masonry structures are unreinforced, the effect of cracking can change established load paths and also reduce the structural capacity. Data is provided on crack repair, noting in particular the need to delineate between active and non-active cracks, and to determine the cause of cracking before any repairs are undertaken.

Recommendations are made for the repair of fretting, the repair of damage to jointing mortar and the repair of damage to masonry units.

Strengthening of masonry structures may be undertaken by using various materials and techniques including steel plating, external/transverse post tensioning, reinforced concrete deck overlay and reinforced concrete jacketing systems. These methods are described in some detail. The need for a structural analysis to determine the level of overloading or underdesign for the in-service load conditions is noted, to ensure that the strengthened structure meets the minimum requirements for serviceability, strength and durability.

Bearings

Bearings may require repair due to deterioration, with damage caused by a number of factors that may include deficiencies in the original design, supply or installation, actual bridge loadings and environmental conditions. It is noted that the causes of deterioration need to be identified, and proposals provided for arresting and preventing further deterioration of existing and newly repaired bearings.

The code addresses options for the bearing repair as follows:

- Rehabilitate existing bearings.
- Replace with like-for-like bearings.
- Replace with different types of bearings.

Specific requirements are noted for the site work including provisions for work under traffic, jacking of the span and accommodating thermal movements at temporary supports.
Deck joints

It is noted that deck joints may require repair as a result of a deficiency in their original design or supply or installation; wheel impacts on joint gaps made wider by abutment movement, concrete creep and shrinkage and environmental conditions or, for public safety.

Guidance is provided for the inspection and condition assessment of deck joints. The need to clearly identify the extent and causes of deterioration of the deck joints is essential, particularly when consideration is being made to replace the joint with one of the same type.

Constraints that need to be considered when developing repair options are listed, and these include; cost of rehabilitation or replacement of the joints, availability of joints requiring replacement, whether like-for-like or of a different type, potential for work to be performed off-site to minimise on-site activities, timing of the deck joint repair work with respect to bridge traffic and traffic management and disruptions during repairs.

Barriers

This Section covers the inspection, assessment and repair of existing bridge barriers. It also provides for the assessment of barrier performance levels, to be used in the consideration for the design of replacement traffic barriers.

Since the release of AS 5100 in April 2004, the design of replacement traffic barriers on existing bridges has been affected by the generally higher barrier design loads specified. Most bridges built before 2005 have been designed using barrier loads significantly less than those specified in AS 5100.2 e.g. for regular performance level. This situation is further complicated if the required barrier performance level is more severe than regular performance level.

The Code now provides a procedure to allow a risk assessment for the bridge site to be undertaken, as an appendix within Part 8. If, based on the risk assessment, the bridge cannot be economically strengthened to cater for the required barrier performance level then the highest barrier performance level achievable within the economic constraints applicable to the site is proposed, consistent with the direction of the Authority.

It is noted that if the required barrier performance level cannot be provided, then consideration should be given to eliminating or mitigating the hazards identified as part of the risk assessment.

Culverts

This Section covers the repair, rehabilitation and strengthening of concrete, corrugated steel and corrugated aluminium culverts, including arches, with clear spans (or design diameters) extending from 1800 mm and up to 6000 mm. These culverts generally comprise buried structures subject to fill loading and live loads from road and railway traffic and may have a primary function for drainage (not under pressure), pedestrian access, vehicular access, fauna crossings and grade separation.

Abrasion of the culvert surface due to cavitation and wear from sediment bed load is an important criterion in the assessment of condition. Damaged joints are a focal point for cavitation initiation which may result in concrete removal and progressive failure of reinforcement. Corroded joints in metal culverts can result in ingress of backfill material and settlement of the above roadway or railway surface.

Requirements are provided for condition assessment of culverts and for their repair, rehabilitation and strengthening, depending on their material and type.

Carbon fibre strengthening

Part 8 introduces guidelines for the use, the application, and the design of carbon fibre in the strengthening of existing concrete bridges. The use of these methods is predicated upon achieving the minimum concrete pull-off strength of 1.5 MPa as measured by ASTM D7522/D7522 M-09.

It is a requirement that a trial application on a test area of the actual substrate of not less than 1.5 m² shall be conducted prior to the commencement of FRP strengthening work. The test area shall be prepared and strengthened to satisfy all the requirements of the material manufacturer’s recommendations, unless otherwise specified in the relevant section in Part 8. If the trial application is successful, the installation of the FRPC strengthening system can then proceed.

In order for FRP strengthening to be considered, the unstrengthened structural member, without FRP reinforcement, needs to have sufficient capacity to resist a level of load comprising 1.1 (serviceability design load for permanent effects) + 0.75 (serviceability design load for transient or thermal effects).

Cathodic protection

A normative appendix is provided to cover the cathodic protection (CP) of steel in reinforced concrete structures which are atmospherically exposed, buried or submerged. These requirements apply to both new and existing structures, including relevant inspection and testing and acceptance criteria for both normal reinforcement and prestressed reinforcement embedded in concrete.

CONCLUSIONS

This paper presents an overview of the draft Part 8, which will form part of the new revised AS 5100. It sets out minimum requirements and procedures for rehabilitating and strengthening of existing bridges including concrete, steel, timber and masonry structures plus specific requirements for bearings, deck joints, barriers and culverts. Particular requirements for carbon fibre strengthening and cathodic protection are also provided.

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