1992 AUSTROADS Bridge Design Code

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ABSTRACT

The 1992 AUSTROADS Bridge Design Code has been developed in limit states format. As such, it will allow the strength of bridges to be determined on a consistent rational basis for the relevant applied loadings and material properties.

Satisfaction of the strength requirements of the Code will ensure that a bridge will not fail in its expected lifetime. Satisfaction of the serviceability requirements will minimise maintenance resource requirements by ensuring the performance of new bridges throughout their life and by identifying potential inadequacies in existing bridges at an early stage, thus allowing more effective remedial treatment.

The Code has a background in overseas bridge code developments and also through links with complementary Australian Standards. Significant variations in the Code provisions from the existing NAASRA 1976 Bridge Design Specifications are described.

The new Code will be a valuable resource to assist bridge designers to provide even better solutions to the bridge engineering challenges of the future.
The 1992 AUSTROADS Bridge Design Code has now been published and is available for purchase through ARRB. This Code has been prepared to replace the 1976 NAASRA Bridge Design Specification. The major change in the 1992 Code has been its development in limit states format. The limit states concept, as compared with the previously used working stress concept, applies safety factors to loads and resistances rather than to stresses. This approach allows rationalisation of load effects, related to the confidence with which various loads can be predicted and enables consistency in the use of materials, related to the confidence with which various materials properties can be determined.

In the presentation of the 1992 Bridge Design Code, AUSTROADS have made considerable effort to produce Code and Commentary volumes which are uniquely recognisable as Australian. In addition, the individual Code Sections are identified by the use of different colours whilst the Commentary Sections are in complementary colours.

The design motif of the ‘dreamtime’ bridge linking Australia, developed by designer Ken Andrews, of Andartica, provides a most appropriate symbolism for this Code. More important, however, are the contents of the Code, and the impact these contents will have on the design and analysis of road bridges in Australia.

**Scope of Code**

The current publication contains Code Sections 1 to 5, as listed below, together with Commentaries on each of these sections. Commentaries have not been provided with previous editions of the Code.

Section 1: General
Section 2: Design Loads
Section 3: Foundations
Section 4: Bearings and Deck Joints
Section 5: Concrete

Publication of Section 6: Steel, and Section 7: Temporary Works, will follow at the end of the year. In the interim, design of steel bridges may either be to existing rules or be based on the British Bridge Code BS5400, and the design of temporary works can be to relevant Australian Standards.
Potential benefits from application of 1992 Bridge Design Code

For new bridges, the 1992 Code will enable:
(i) consistency in the use of materials;
(ii) rational prediction of loads;
(iii) control of serviceability and durability with minimal maintenance;
(iv) confidence in the ultimate strength over the lifetime of the structure.

For existing bridges, the 1992 Code will enable:
(i) the identification of potential strength reserves, which may justify increases in both general load limits and permit load limits;
(ii) the identification of serviceability inadequacies, which may allow early remedial treatment.

Background to the Code

Prior to 1976, the editions of the NAASRA Bridge Design Code were closely based on the AASHTO Bridge Design Code.

The 1976 NAASRA Bridge Design Specification (Current Code) was the first attempt to develop a Code for local requirements and conditions.

The limit states concept of design has been promoted for many years as a process which gives a more rational determination of design loads and allows a more consistent choice of materials properties.

The pioneering work in the development of a limit states Code for Bridge Design was carried out by the Ontario Department of Transportation in the late 1970s and early 80s.

The Ontario work was a reaction to very conservative theoretical assessments of bridge load carrying capacities, which resulted in major load constraints on the Ontario road network. The limit states Code allowed the determination of load-carrying capacities which were more in keeping with real life experience.

Concurrent with the development of the AUSTROADS Bridge Design Code in limit states format, Standards Australia were also moving to develop their major design codes (steel, concrete, etc.) in limit states format.

Work on the development of an edition of the Bridge Design Code in limit states format commenced in 1979, with the formation of a steering committee which included representatives from each of the State Road Authorities, from consulting engineers and from academics.

This steering committee gave initial guidance and direction in the development of the Code and its work provided the bases for the subsequent specialist working groups formed to develop the various sections of the Code.

These working groups also had representatives from external specialists as well as State Road Authority personnel.

In order to ensure consistency of philosophy and presentation with related Australian Standards, members of working groups have represented AUSTROADS on Standards Association of Australia Design Standard committees.

The Draft Code was subject to significant examination and proofing by State Road Authorities and private design consulting firms during 1987 and 1988, with reports on these studies being presented to workshop sessions of the Australian Road Research Board Conference in Canberra in August 1988.

The public comment from this process has been taken into account in the subsequent revision of the Draft Code.

Subsequently, a final technical review was carried out by an eminent retired bridge engineer, Mr G. Marsh, former Director, (Design) Main Roads Department, Western Australia and a policy review was carried out by a State Road Authority, the Main Roads Department, Western Australia, with comment from these reviews being incorporated into the final documents.

What are the limits? What are the states?

Structural behaviour needs to be predicted with confidence for two 'states' — the ultimate 'states', and the serviceability 'states'.

For the ultimate 'states', limits are set and have to be satisfied for strength (including collapse and failure) and stability (including loss of equilibrium and overturning).

For the serviceability 'states', limits are set and have to be satisfied for deformations, deflections, vibration, cracking and spalling.
For bridges, the relevant limit states are related to the effects of loading (self weight, dead loads and live loads) in conjunction with environmental effects such as wind, heating, cooling, flooding, scour, earthquake and the effects of material degradation such as corrosion, fatigue, creep, shrinkage, chloride penetration, carbonation, alkali-aggregate reaction, rot and termite attack.

In the design process the calculated ultimate strength and stability capacities must be greater than the ultimate load effects (i.e. the sum of the actual individual load effects, each multiplied by an appropriate ultimate load factor) to ensure that the structure will not fail in its expected lifetime.

Similarly, the calculated serviceability capacities must be greater than the serviceability load effects (i.e. the sum of the actual individual load effects, each multiplied by an appropriate serviceability load factor), to ensure that the structure will be serviceable during its expected lifetime with minimum maintenance and with control on deflection, cracking, fatigue, vibration and durability.

**Code sections**

Some comments on the sections of the code follow.

**General**

*Section 1: General,* outlines general principles for the use of the Code and provides an understanding of the basis of the limit states design process. The information provided also gives some comfort in that the determination of the serviceability limit states will generally follow existing design practices.

The article on waterways and flood design principles introduces the requirement for the need to ensure strength and stability under the design ultimate flood effects, including debris. This article also introduces the concept of the need to consider the hydraulic capacity of the total flooded cross section (bridge and approach embankments) for the design ultimate limit state flood (2000-year return period).

The article on traffic barriers defines four levels of service, with the Level 1 barrier being used where absolute containment of vehicles is required for the protection of vehicle occupants and also for the protection of other persons, vehicles or property under the bridge. Level 2 barriers are for an intermediate level of service, corresponding to the design requirements for traffic barriers in the 1976 Bridge Design Specifications. Level 3 barriers correspond to flexible W-beam guard-rails and Level 4 is no barrier at all, as might be appropriate for a low traffic-volume crossing which can be submerged by floods.

**Design Loads**

*Section 2: Design Loads,* sets out the design loads, forces and effects. Provision is made for the design engineer to vary loads on the basis of engineering measurements and calculations, provided the general principles of design in Section 1 are complied with.

This section nominates the load factors to be used for design actions for both serviceability and ultimate limit states.

In comparison with the 1976 Bridge Design Specification, the T44 Truck Loading remains unchanged and the L44 lane loading is similar except that the associated concentrated load has been set at 150 kN for both moment and shear effects. The A14 axle has been deleted and replaced by a W7 wheel load for localised effects.

The abnormal vehicle load has been replaced by a heavy load platform (HLP) which is significantly heavier. A HLP gross weight of 320 tonne is applied as the general case for principle routes. The 400 tonne HLP is applicable to special designated routes, as determined by the road authority. The load factor applicable to the HLP loadings depends on the degree of control over the actual mass of permit vehicles and their passage as exercised by the State Road Authority. The State Road Authority may vary the load factor depending on the degree of control exercised.

In comparative designs carried out with the above design loads, for some structures the HLP loading has been the controlling load.

The impact factor has been replaced by the dynamic load allowance, adapted from the Ontario Code. The dynamic load allowance has a maximum value of 0.4, depending on the natural frequency of the superstructure.

Braking forces are significantly increased on the 1976 values and are a function of that length of the structure resisting the force. In addition, a minimum lateral restraint requirement has been introduced to resist unaccounted for lateral forces not catered for in the design.
Loadings are introduced to account for collisions on bridge supports from road traffic, rail traffic and shipping.

Earthquake loadings are at this stage unchanged from 1976 but these will be reconsidered when the SAA revision of the Earthquake Code is complete. Earthquake effects can be increased by upgrading the zone classification.

Foundations

The major change in Section 3: Foundations is the development of a philosophy of emphasising the nexus between the extent of foundation investigation and the confidence in the assessed foundation capacity. By this means, the designer has the flexibility to balance the cost of investigation work with the cost of the foundation, with an appropriate confidence in the performance of the foundation. Such an approach takes advantage of improved technology both in foundation investigation and also in the assessment of driven pile capacities.

This approach will result in more responsibility on the designer in assessing the nature of the site and the consequences of variations, rather than relying on the lowest common denominator approach previously applied to standard piles. A consequence of the philosophy should be an increased use of ‘test piles’ to assess capacity at the pre-tender stage.

Bearings And Deck Joints

As well as a conversion to limit state format Section 4: Bearings and Deck Joints, represents a major updating and revision of the rules for the design of deck joints and bridge bearings.

The rules for elastomeric bearings have been completely revised. The shear deflection capacity has been significantly increased. The vertical load capacity (rated load) for ‘thin’ bearings has been significantly increased. However for ‘tall’ bearings the rated load has remained unchanged.

The rotation capacity of elastomeric bearings has been increased. The NAASRA 1976 rules forced designers to select tall bearings to satisfy rotation limits, but this sometimes caused other problems due to their low shear stiffness and relative instability.

The new rules should result in the selection of smaller, more economical bearings.

The design specifications for pot bearings and contact sliding surfaces have been updated to reflect current practice and allow increased load capacities.

The loading and design requirements for deck joints have been clarified, particularly for finger plate joints and other fabricated joints, where the distribution of load to the anchorages has been more fully considered.

The allowable open gap width for deck joints has been increased to conform to international standards. This will permit, where large movement capability is required, the selection of modular (multi-element) deck joints with a smaller number of elements.

Concrete

Section 5: Concrete, unifies design rules for reinforced concrete, ‘partially prestressed’ concrete and ‘fully prestressed’ concrete. This section is also compatible and to a high degree uniform with the AS 3600 (1988), Concrete Structures.

The emphasis on certain articles has been changed. Rules that were presented in a fragmented way or where insufficient guidance was provided by the NAASRA 1976 Code, such as those for durability, materials properties and analysis of beams, slabs and columns, are treated prominently in the new Section 5.

Durability

Rules for design for durability of concrete in the new Code will probably result in more dramatic changes of design practice than any other provisions included in this document.

Since the publication of the previous NAASRA Bridge Design Specification some 15 years ago, durability has become a major issue in the industry due to problems associated with corrosion of reinforcement and tendons and degradation of concrete surfaces, particularly in areas of high exposure, e.g. structures exposed to salt water or salt spray.

All the durability provisions, previously scattered throughout various articles of the Code, are concentrated and placed at the beginning of the concrete design section to signify the effect the new rules are expected to have on design. The durability requirements result in concrete strengths which in many cases will be higher than would otherwise be required for strength. The strength required for
durability is therefore determined initially. It is then appropriate to enter the strength design calculations with the minimum acceptable concrete strength as determined for durability.

Unlike the previous Code, the new provisions for durability are related to a wide range of defined exposure classifications. In general the rules governing durability are tighter than comparable rules in the previous Code; for higher exposure classifications the new requirements are much more stringent. The new rules respond to the developments over the last 10 to 15 years related to the gradual changes in the composition of concrete mixes. These mixes now, as a result of the much more finely ground cementitious materials used, contain less cementitious materials by weight for concrete of a given strength, and therefore do not provide the same degree of protection to reinforcement.

For higher exposure classification it is now mandatory to specify minimum cement content and maximum water/cement ratio. Although the latter is difficult to measure in the field, it is still recognised as a reliable measure of the ability of concrete to protect reinforcement.

Materials properties

The new Code attempts to avoid the tendency of the previous specification to give precise values of material properties. This has been done to avoid misinterpretation by less experienced users as to the accuracy of these values. The Code introduces a concept of guaranteed minimum capacity to resist loads by linking the concept of strength reduction factors and ultimate state load factors. For serviceability limit states the emphasis is on materials test values or current local knowledge; the curves or formulae are given with the emphasis on bands of uncertainty for all material properties. The Code and the accompanying Commentary encourages the designer to examine the sensitivity of possible variations in material properties. The information on creep and shrinkage of concrete emphasizes the dependence, among other influences, on the type of aggregate used.

Methods of Structural Analysis

The new Code requires that analysis must be carried out for all relevant limit states; the difference is particularly obvious for reinforced concrete which, to satisfy the requirement of NAASRA 1976, was analysed for working stresses only.

For reinforced concrete the new Code allows redistribution of moments at the strength ultimate limit state of up to 30 per cent of design moment. The removal of the stress limitation at serviceability limit states is expected to result in significant savings of reinforcing steel.

Other provisions of the new Code include:

- An increase of the limit of the stress increment in prestressing steel to 200MPa (The 1981 Addendum to NAASRA 1976 limited this increase to 120 MPa)
- Design of reinforced concrete is completely different from 1976 NAASRA in that design is for the ultimate strength limit state and there are no particular checks for stresses at the serviceability limit state. There are checks for other serviceability limit states viz. cracking and deflection.
- Design for shear, torsion and suspension reinforcement are very similar for both prestressed and reinforced concrete. Truss analogy method is used and for shear and torsion, a flatter truss angle is allowed than the 45° implied in NAASRA 1976. This should result in more economical design as a proportion of stirrups may be replaced by additional longitudinal reinforcement which is more economical to supply and fix.

Design of Columns

The working stress method of design in NAASRA 1976 had been abandoned by many designers long before the drafting of the relevant parts of the new Code. The method required by the new Code is similar but somewhat different to the one published in AS 3600. The majority of framed structures will be analysed by first-order methods of linear analysis, e.g. it will be assumed that changes of geometry under loading will have negligible effect on bending moments and shear forces. Second-order methods of analysis, of iterative nature, will be used for slender columns where changes of geometry cannot be safely ignored.

Summary

Section 5 provides a basis for rational and economical design of concrete bridges. The integration of design rules for reinforced, partially and fully prestressed concrete will remove the remaining artificial barriers between ‘partially’ and ‘fully prestressed’ concrete.
Conclusion

The Code has had a long gestation period. The time taken to produce the Code reflects the limited resources applied by the member authorities. The fact that it has been produced at all is a tribute to the dedication of a few working group members who have devoted countless hours of their own time. It is understood that the production cost of the Ontario Code was of the order of $3 million.

Contributors who deserve particular acknowledgement are the convenors of the various working groups:

Section 1: General and Section 2: Loads
Dr John Fenwick
Department of Transport, Queensland

Section 3: Foundations
Bob Meggs
VIC ROADS, Victoria

Section 4: Bearings
John Lloyd (deceased)
Department of Housing and Construction
Canberra
Mark Bennett
Roads and Traffic Authority, New South Wales

Section 5: Concrete
John Zavesky
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The significant driving force behind the development of the Code over many years was Gil Marsh, formerly Director, Design, Main Roads Department, Western Australia. Gil was the convenor of the NAASRA Steering Committee during the important formation years and, in his retirement, was engaged as the technical editor. The contribution he has made cannot be overstated.

It is anticipated that the 1992 AUSTROADS Bridge Design Code, in addition to being an attractive addition to the bookshelves of bridge designers around Australia, will be a valuable resource to assist these bridge designers in the provision of even better solutions to the bridge engineering challenges of the future.

Note:

The AUSTROADS Bridge Design Code is available for purchase from Don Merritt at ARRB for $134 (including postage in Australia)
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