RAILWAYS OF AUSTRALIA BRIDGE DESIGN MANUAL

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SUMMARY

The Railways Systems in Australia design bridges carrying rail traffic to the 1974 ANZRC Bridge Design Manual. The design rules in that manual are under review, and this paper sets out some of the reasons for the update, and the relevance of the proposed Manual to the revised AUSTROADS Bridge Design Specification now reaching publication stage.

KEYWORDS

ANZRC, Bridge, Code, Design, Railway.
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Ross Best is Engineering Manager Structures in the State Rail Authority of NSW with long experience in design and maintenance of structures, especially in the bridge area. Ross is also Co-ordinator of a Railways of Australia sub-committee directing the updating and review of the Railway Bridge Design Manual, having been one of the intersystem group involved in preparation of the 1974 edition. The Structures Unit is responsible for setting and monitoring standards in the bridge area, and a universal Bridge Code is a long-term goal.
SYNOPSIS

The Railways Systems in Australia design bridges carrying rail traffic to the ANZRC Bridge Design Manual 1974. The design rules in that manual are under review, and this paper sets out some of the reasons for the update, and the relevance of the proposed Manual to the revised Bridge Design Specification now reaching publication stage.

BACKGROUND

The history of railway bridge design and construction in Australia has followed the classical engineering path of using available local materials where possible, and importing overseas materials where span or complexity precluded the local product. In New South Wales, the oldest State System, early designs followed British practice under the Engineer-in-Chief John Whitton, now referred to as the "Father of the NSW Railways". Later designs, especially for the larger wrought iron lattice truss bridges, originated in the U.S.A. Unfortunately, design details of those 19th and early 20th century bridges have not been preserved.

Of later years, local design rules based on either British or American practice were developed independently and used by the various State Systems, but with little or no co-ordination between systems. Live loadings followed either an overseas standard, or used the current heaviest steam locomotive in service. Impact factors have varied similarly.

In 1974, following a great deal of joint investigation work, principally by the three Eastern States, the Australian and New Zealand Railways Conferences Railway Bridge Design Manual was published. It was patterned almost exclusively, and deliberately, on the American Railway Engineering Association (AREA) Manual which was - and is - a comprehensive handbook of engineering practice covering many facets of railway activities. Some State Systems had been designing bridges to the AREA Manual for many years, and had found it generally applicable to local conditions. The 1974 Manual included only four chapters:

1. Loading on Railway Bridges
2. Steel Bridges
3. Reinforced Concrete Bridges
4. Prestressed Concrete Bridges

It was always intended that further chapters would be added, and that the loose-leaf Manual would be updated as AREA rules changed. Unfortunately, neither action occurred, and the original edition remains unchanged, and partly out of date with the current AREA Manual (1990).
NEED FOR REVIEW

One of the motivators for the 1974 Bridge Design Manual was that Design Consultants were becoming involved in Railway Bridge Design, and the various Systems had no easily obtainable reference manual to be included in the design brief. Whilst the ANZRC Manual (1974) satisfied the basic requirements of Underbridge (rail) design, other areas such as Overbridges (road), Footbridges, Timber Bridges, Retaining Walls, and load rating of existing bridges, were not covered. For the missing chapters, each System set its own standards, although the NAASRA (1976) Specification was used widely by the States.

From the early 1980's several unsuccessful attempts were made to undertake individual revisions of the Manual, using in-house resources. Eventually, in 1988, an intersystem Steering Committee was set up to determine how progress could be achieved, and to consider basic approaches to a revision, such as the change from Working Stress design to Limit State analysis. This latter format presented some difficulty, since the "parent" AREA code was not intended to change for at least another five years.

It was resolved to invite initial expressions of interest from seven Consultants known to have expertise in the field of Bridge Design, especially as applied to railway structures. The Consultants were requested to respond with:

- An expression of interest
- An outline of the approach to be followed
- A general statement on a fee structure
- Special skills of expertise of staff relevant to the preparation and production of Codes of Practice
- Expertise which could be co-opted for specific parts
- An indication of the resources available to undertake the work.

Following extensive discussion of the submissions received, a short list was further considered, after which Maunsell Pty Ltd was selected to Project Manage the revision. To date, two stages of a 5 Stage programme have been completed, as detailed later in this paper.

APPROACH ADOPTED FOR CODE REVISION

The approach followed by Maunsell was to consider the revision sub-divided into five stages. This approach would enable the Rail Authorities to have appropriate review points.
Each stage also defines the scope and project costs for the following stage.

Stage 1 - Appraisal

This initial stage was to present recommendations to the client for the Manual Format and Scope.

The major issues considered during this first stage were:-

(i) that the Code would be in limit states format.

(ii) whether the New Code would be a stand alone document and if not, what degree of dependence would there be on other codes.

(iii) which existing codes would be used as a basis for the revised code.

(iv) what would be the scope of the code (for budgetary reasons, sections on timber and rating of existing structures are currently not included).

(v) the format of the code and the publication of a commentary concurrently with the code.

Stage 2 - "First Drafts"

After consideration of the Stage 1 report, the Railways of Australia (ROA) requested Maunsell to proceed with consideration of "First Drafts", based as closely as possible on the latest draft AUSTROADS Code. Primarily this Stage involved identifying those areas of the AUSTROADS Code which either did not specifically cover or were not directly applicable to Railway Bridges.

Comments on some sections of the code are given in the Appendix. Clause numbering is similar to AUSTROADS.

Stage 3 - Final Drafts

This stage, yet to commence, is to produce the final drafts of the code. The primary task in this stage is for specialist sub-consultants to carry out research in those areas of the code indicated previously in order to finalise the required code clauses.

Because of budgetary constraints, this stage has now been further sub-divided in order to minimise those areas where external sub-consultants are used and utilise the resources of the various Rail Authorities where possible. Stage 3A will be more closely defining these areas.

Stage 4 - Calibration

The fourth stage of the revision is to carry out calibration exercises and refine load factors.
Stage 5 - Publication

This stage will involve final printing and publication of the document.

CONCLUSION

This paper briefly outlines the current status of the revision to the ANZRC Bridge Code (1974).

It is intended that this code align with the new AUSTROADS Code. Some revisions will be necessary to satisfy special requirements for rail bridges.

Discussion from the Bridge Design Community is encouraged.

REFERENCES


1. **SECTION 1 - GENERAL PRINCIPLES OF DESIGN**

1.1 **SCOPE**

A general statement setting out the scope of the Code has been included.

This Code applies to railway bridges in Australia. If the Code is to extend to bridges in New Zealand then additional requirements may be required, in particular for Seismic Design.

The Code is for bridges of conventional form and having spans up to 100m. The current version of ANZRC is for spans of 120m, but the limit of 100m is suggested because this aligns with AUSTROADS.

1.2 **GENERAL PRINCIPLES**

This section of the Code, which is almost identical to AUSTROADS, sets out the bases of design and defines the main concepts.

The Code defines the design life of the bridge structure to be 100 years. However this does not necessarily mean that a bridge designed in accordance with the Code will no longer be fit for its purpose after 100 years, nor that it will continue to be serviceable for that length of time without adequate and regular inspection and maintenance. The design life is considered when statistically deriving the design loads. AUSTROADS assumes a 100 year design life and so for consistency, 100 years is recommended for ROA. If it is considered that a larger factor of safety is required for rail bridges then this is taken into account in the partial safety factors on loads.

1.3 **WATERWAYS AND FLOOD DESIGN PRINCIPLES**

The waterway design for a bridge must be related to the serviceability requirement of the rail network.

If a particular route is required to have a performance level which only has one interruption every 20 years, and if there are a large number of crossings of water catchments along the route, then it is possible that each crossing may have to be designed for a flood with a return interval greater than 100 years.

Rail bridges must be considered as a link in an entire system because there is often no suitable alternative route if one part of the system becomes unserviceable.
2. **SECTION 2 - DESIGN LOADS**

2.1 **GENERAL**

The section sets out the general loading requirements and has been based on AUSTROADS.

Full details of all loadings and special requirements for a bridge must be shown on the bridge drawings.

2.2 **DEAD LOADS**

This section is based on AUSTROADS, although review of other parts of the Code may lead to revised load factors for certain railway effects such as fatigue and to cover known variations in things such as ballast quantities.

2.3 **RAILWAY LOADINGS**

The current design loading specified in ANZRC is a metric version of the Cooper loading, which was derived from AREA and has been in use for a number of years.

The loading in ANZRC is for a metric Cooper M250 (denoting maximum axle load of 250 KN). Different Authorities apply factors to this loading to account for the actual loading on their systems.

Although it is advantageous to maintain the form of the design railway loading because it has been in use for a long time, the aim of the Code is to provide consistent factors of safety for bridges under current (and expected) operating loads. Consequently the form and magnitude of the live loads must be investigated to ensure the most appropriate live load is adopted. This may or may not be the same as the current loading, and the benefits of using a loading which gives more consistency will be weighed against the changes.

A study of the live loads in use and the load factors necessary to be used in the Code must be undertaken. In conjunction with this study, the merits of alternative railway live load configurations will be studied.

2.5 **HORIZONTAL FORCES DUE TO RAILWAY LOADING**

The load factors chosen will align with the load factors for vertical live load.

Nosing and lurching will be considered under impact effects.

2.5.5 **Effect of Trackwork on Structures**

This clause needs to be amplified in the Commentary to include indicative loads for various situations.
2.6 DERAILMENT LOADS

The effects of a train derailment, and the forces which may arise in rectifying the situation, are included. This includes impact on upstands, overturning effects of eccentric trains and local deck loads applied jacking trains back onto the rails etc.

2.7 WIND LOADS

This section of the Code is based on AUSTROADS, but has also included for wind on live load as a serviceability load, since trains can provide a wind barrier which is virtually continuous across a long structure.

2.8 THERMAL EFFECTS

This section is based on the AUSTROADS Code. The extreme shade air temperature diagram has not yet been published.

The effect of ballast on the temperature differentials in a bridge deck should be considered and additional research may be required.

It is expected that it will be conservative to assume a temperature distribution through the ballast similar to the distribution in AUSTROADS for a concrete deck, and the effective top surface temperature may be substantially reduced. Account must be taken of the possibility of a reduced depth of ballast.

2.8 EARTH PRESSURE

The equivalent additional depth of fill indicated in the AUSTROADS Code accounts for traffic live loads behind retaining walls and abutments.

A similar relationship will have to be derived for the railway loading adopted in the New Railway Code.

Earth pressure loadings are given in Section 4 of the AUSTROADS Code.

2.9 LOAD COMBINATIONS

This clause follows the philosophy of the AUSTROADS Code.

The values for "k" in Clause 2.17.2 of AUSTROADS for the serviceability limit state load combinations will have to be checked during the calibration stage.

2.10 LOADS ON ANCILLARY STRUCTURES

Loads shall have to be specified on ancillary structures such as catenary support and signal structures.
These loadings are required both for the design of the ancillary structure and for design of a bridge supporting such a structure.

3. FOUNDATIONS

The AUSTROADS Code has been used as the basis for the foundations section.

Some areas requiring further investigation are:-

(a) Water Pressure

No water pressure allowance is made for free draining structures.

Some allowance could be made where the drainage system may become impaired by clogging or breakage (eg. with time or subsequent reworking).

(b) Cyclic Loading

There is currently no mention of cyclic loading in AUSTROADS. This may become important in some retaining structures.

(c) Reference to AS 2159 - Piling Code

The Australian Standard AS 2159, the Piling Code, is currently under revision and a draft has been prepared.

The ROA Code should consider any changes to the Piling Code.

(d) Cast in Place Concrete Piles

A minimum diameter of 600mm is given. This would seem to automatically exclude Grout Piles, which could be economical on smaller bridges.

A section on Grout Piles should be included.

4. CONCRETE

The base document for this section of the Code is Section 5 of the draft AUSTROADS Code.

Additional work is required with respect to the following topics to ensure the Code is appropriate for use as a railway bridge code.
(a) Durability

The cover requirements for elements given in the latest draft of AUSTROADS allow the use of 25mm cover in the most favourable exposure conditions. We believe this could be too low for a railway bridge and 35mm may be more appropriate (which is in line with the current version of ANZRC).

The cover and concrete design for classifications U and C also require consideration. Instances can be seen of tidal zone bridge concrete, with strengths of greater than 35 MPa and having cover of 60mm plus failing by spalling and sheet delamination.

(b) Crack Control

The latest draft AUSTROADS Code needs to be examined in relationship to crack control of reinforced beams and slabs.

This is a subject that has been studied in depth over the last few years and needs review in relation to the acceptability of partial prestress and taking account ballast on concrete decks.

(c) Partial Prestress

The appropriate limiting stress increment for railway bridges must be determined.

Partial prestress and its applicability to railway loading conditions has been reviewed recently in Switzerland, in relation to fatigue in concrete structures. This research will be reviewed as part of this issue.

A related issues which has been discussed recently is the question of fretting fatigue of prestressing tendons in steel ducts.

(d) Vibration

AUSTROADS applies span to depth limits as a deemed to comply clause for vibration. The need for a vibration control is questioned, given that the applicability of the Code is only up to 160 kph.

(e) Stray Current Corrosion

A clause is necessary to cover this topic, with more detail and references to be provided in the commentary. This essentially will be a statement of good design principles to overcome potential problems in this regard. References are currently being researched and the advice of railway authorities will be sought.

(f) Detailing

It is considered that some additional detailing aspects (eg, cover and spacing of tendons; details to cater for differential shrinkage, waterproofing and earthquake...
resistance details) could be improved. Recommendations from other Codes such as BS 5400 will be reviewed for inclusion in this Section.

The commentary for AUSTROADS is understood to be based on the commentary to AS 3600. This may have to be amplified to cover the topics relevant to railway bridges.

5. STEEL

Section 7 of the AUSTROADS Draft Code deals with steel and composite bridges. It is drafted in Limit State Format, and is very similar to the new Australian Steel Structures Code (As 4100) which has only just been issued.

AS4100 represents the first major conceptual revision to the Steel Structures Code since 1968, with the main alterations being:-

- It is written in Limit States Format
- It is intended to cover bridges
- New sections cover Brittle Fracture, Fire, Earthquake and Modifications of Existing Structures
- Major technical revision in the design of members for bending, compression, tension and combined actions
- It incorporates a tiered approach to design.

AS4100 also represents three years of development since the draft of Section 7 of AUSTROADS was prepared in 1987. The sections dealing with Fire, Earthquake, Fabrication, Erection and the Modification of Existing Structures are not covered in AUSTROADS. However the AUSTROADS Code has sections which are not included in AS4100 in regard to the design of composite beams, Composite Box Girders (which is still to be drafted), Transverse Members and Steel and Cast Iron for Bridge Bearings.

The current status of Section 7 of the Draft AUSTROADS Bridge Code in regard to its applicability to the ANZRC revision can be summarised as follows:-

- It forms an appropriate basis for the ANZRC Code.
- It may need to be altered to include some extra material from AS4100.
- It needs to be reviewed in the light of the experience which will be accumulated in the next few months.
- Minor editorial changes will be required to allow for use by Rail Authorities, to specifically mention through girders etc.

In addition there are certain aspects of the steel section of the AUSTROADS Draft which should be reviewed in a fundamental way. These include:-

Appropriate Load Factors for Rail Bridges
The effect of rail loadings on the composite action of bridges, design of shear studs etc.

The requirements for fatigue, which may need to be made more stringent for rail bridge designs.

6. BEARINGS AND EXPANSION JOINTS

(a) Bearings

The rule for bridge bearing design in AUSTROADS can be applied to rail bridges with the addition of a clause on electrical isolation of bearings and the amendments of the clause dealing with anchorage of bearings to allow for the reduction in the frictional restraint offered by electrical insulation laminates.

The final draft of this Section will include details of the electrical insulating properties of the industrial laminates used for isolation.

(b) Deck Joints

The design requirements for deck joints given in Section 8.14 of AUSTROADS are not directly applicable to rail bridges.

New clauses dealing with design loads and anchorage of deck joint will need to be written during the final drafting stage.