Assessment and Upgrading of Steel Bridges using Finite Element Modelling

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Summary

This paper describes how Finite Element (FE) modelling techniques can assist in the assessment (rating) and upgrading of steel bridges of various types. Global and local modelling options are considered with reference to several projects, in particular the West Gate Bridge in Melbourne, Australia. The use of different analysis assumptions, element types, eigenvalue and nonlinear analysis functions to achieve greater load rating capacity is outlined, identifying examples of good practise and drawing on international codes and literature for recommendations.

Keywords: bridge; assessment; rating; modelling; corrosion; nonlinear; eigenvalue; buckling

1. Introduction

Bridges which are deemed substandard by use of simplified approaches can sometimes be shown to be adequate when more advanced approaches are employed. Since the cost and disruption caused by interventions can be very significant, approaches which would not perhaps be regarded as cost-effective for new designs can be justified. This paper considers aspects of FE modelling in the context of the assessment and upgrading of steel bridges.

2. Global modelling approaches

Analysis approaches for some common bridge types including truss, half-through girders, beam and slab bridges and box girders are described. The importance of boundary conditions is discussed.

Truss bridges are considered with reference to appropriate end fixities for the different limit states including fatigue. An analysis by Benesch for the Michigan DOT (Cut River Bridge) is cited as an example where a more sophisticated model gave an improved load distribution for a structure which might on first sight appear to have low redundancy.

U-frame bridges are considered with reference to those existing structures which may fall outside of the scope of codes of practice or for which the codified rules may be over-conservative. Modelling suggestions are made and pertinent references given.

Beam and slab structures are considered with the options of grillage modelling, plate-eccentric-beam (PEB) modelling and full 3D analysis set out, with particular reference to guidance recently published in the USA.

Box girder bridges are considered with the focus falling on Flint & Neill's FE modelling and analysis of the West Gate Bridge in Melbourne

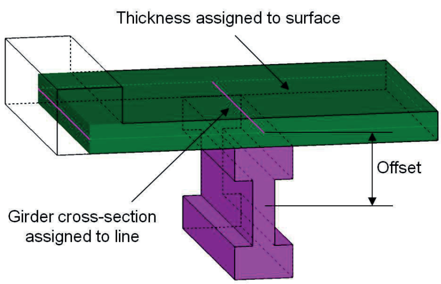

Fig. 1: Part of plate-eccentric-beam model

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for increased vehicle loading.

3. Corrosion

The uncertainty associated with the severity of corrosion in an existing structure and how this can be handled in analysis and member resistance calculations is discussed and pragmatic suggestions made.

4. Localised modelling

The use of standalone or embedded local models, for detailed stress analysis of non-standard structural details (bearings, connections, anchorages etc) or structures with significant discontinuities, is discussed. The West Gate Bridge Upgrade project is discussed further in this context, with particular reference to practical ways of obtaining the appropriate boundary conditions for a local model.

5. Use of nonlinear analyses

Recommendations from international texts on the worth of nonlinear analysis in bridge assessment work are summarized, together with practical advice on the approach to be taken by the engineer. Material, boundary and geometric nonlinearity are considered.

5.1 Buckling analyses

Buckling is considered with reference to code of practice rules, elastic buckling and means of obtaining a realistic assessment of buckling failure load and mode. Emphasis is given on means by which the expected result can be bounded, in order to help engineers gain confidence, rather than lose it, as they adopt more sophisticated analysis approaches.

Results from studies comparing approaches to predicting buckling loads are outlined. Information relating to initial imperfections which should be included in analyses is drawn together from international sources.

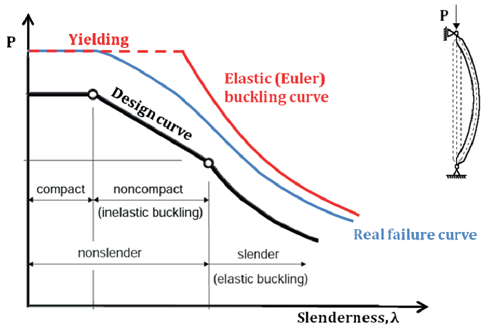

Fig. 2: Theoretical, real and codified buckling curves

6. Summary

This paper emphasises that the staged approach for assessment enables the engineer to gain a good understanding of the behaviour of the structure in question and the parameters of most significance. Conclusions are reached in the following areas:

1. Appropriate element selection based on structure type.
2. Importance of support stiffness etc in global analysis.
3. Use of local models, boundary conditions and embedded local models.
4. Usefulness of nonlinear analyses, efficient ways of approaching such analyses and ways to gain confidence in the results.

Examples of good practise, citations to relevant clauses of international codes and literature are made throughout the paper.