Use of Finite Element Buckling Analyses for Steel Bridges

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Abstract

Collapse of steel bridges during construction can occur as a result of a global buckling behaviour which may be overlooked when using member resistance checks such as those in the Eurocodes. Furthermore, existing structures that were not constructed to modern tolerances cannot be safely assessed for buckling using modern design codes.

This paper describes how finite element analysis can be used to help. It draws on recommendations in the recently published NCHRP Report 725 [1], exploring the problem of global buckling modes and when these should be of concern to the designer. Use of FE analysis for member resistances is also discussed in terms of approaches which may be appropriate for historical structures.

Keywords: steel, bridges, computational methods, codes and standards, assessment / repair

1 Introduction

Buckling analyses performed using Finite Elements (FE) may be elastic or nonlinear. Elastic buckling analyses give results which may be used in member resistance calculations in codes of practice, and – crucially – can be used to identify 'global' buckling modes not routinely identified when carrying out such checks. Nonlinear buckling analyses may also be useful in certain cases, such as when considering existing structures which have details and tolerances that fall outside modern standards. This paper explores the practical applications for both of these buckling analysis options.

2 Elastic buckling analyses using FE

In FE analyses, the real or potentially real object is idealised as a series of 'elements', connected at nodes. For analysis of bridge structures in 3D, the most commonly used elements are beam elements – suitable when a member is long in comparison to its cross-sectional dimensions; and shell elements – suitable when a member has plan dimensions which are large in comparison to its thickness. FE models may use mixed elements and can be used to analyse members or whole structures, considering non-standard details, support conditions and load arrangements as necessary.

In the FE solution, a stiffness matrix is constructed, based upon the member dimensions, material properties and support conditions. When combined with the loading, a linear static analysis can be performed. Alternatively, an elastic buckling analysis can be carried out, determining the eigenvalues of the stress-stiffness matrix and the corresponding eigenvectors.

The eigenvalues obtained from an elastic buckling analysis each give the factor, α_{cr}, by which the applied loading would have to be increased to cause elastic instability in the corresponding mode (determined from the relevant eigenvector).

Due to material plasticity, initial imperfections (including out-of straightness and residual

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