Out-of-plane buckling of arches with rectangular cross-sections and curved webs

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Abstract

Contemporary arch bridges are mostly designed as slender structures. Due to the presence of mainly compressive forces in the arches, the bridge may become prone to out-of-plane buckling. The main purpose of this research is to examine the influence of the geometric properties of a cross-section of the arch on this behaviour. To this end, a detailed FEM model of an arch bridge is built and validated by the results of a measurement programme. Thereafter, the critical buckling load is examined by numerical and analytical analyses. Furthermore, the influence of the plate thickness and the introduction of a cross-sectional curvature in the web on the buckling behaviour is evaluated. From that, it can be concluded that the relationship between the critical load and moment of inertia around the weak axis of the arch is linear, and in addition independent of the shape of the cross-section. Nevertheless, a cross-sectional curvature in the web shows the most potential in terms of structural efficiency.

Keywords: Arch Buckling, FEM, Curved Plates, Structural Efficiency

1 Introduction

The use of slender steel structures in bridge engineering has been rising over the years due to their aesthetical value and structural efficiency. Arch bridge behaviour is typically governed by compression forces. Consequently, in combination with a slender design, the arches are vulnerable to buckling instabilities. In general, the governing loads act in the plane of the arch, which is reflected by the stiffness properties of the cross-section. Therefore, out-of-plane buckling can become dominant if no measures are taken to obstruct such deformations. Striving for structural efficiency, an engineer intends to minimize material use, without affecting the quality. To this end, numerical and experimental research is performed to obtain a better understanding of the out-of-plane buckling behaviour of arches [1]. These studies are extended by analysing the influence of geometric imperfections [2][3]. However, knowledge of the impact of the geometric properties on the global instability modes of arches is still limited. Therefore, a railway bridge in Bruges (Figure 1) is examined. The bridge is a steel arch bridge consisting of three arches supporting an orthotropic deck.

Figure 1: Railway bridge with three arches [6]

The structure is fully modelled in a FE software and compared with results obtained from a measurement campaign on the actual bridge. Once the model is verified, the aim is to express the design buckling resistance in terms of structural efficiency of different geometrical parameters of a cross-section of the central arch. To this end,

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