Elastic-, inelastic and plastic buckling of curved shear webs in closed box girders with vertical stiffeners

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Abstract

Curved steel panels are widely used in structures such as ships, aircrafts and bridges. During the last decades, plates with an out-of-plane curvature in the cross-section of the bridge are being used, partly to increase the aesthetics. The elastic buckling behaviour of curved plates is not covered by standards of codes for bridge design, resulting in rather conservative solutions. In the current research, there is investigated how curved steel panels used as a web panel in a closed box girder interacts with shear and bending stresses. Therefore, a double symmetric box is numerical simulated in a three point bending test. The first mode shape found by a LBA is used as an initial geometric imperfection, in order to trigger buckling of the webs. It is proven that when increasing the curvature while keeping a similar slenderness ratio, the buckling mode of a plate can change from elastic to inelastic and even plastic buckling. This behaviour is found back in the webs of the closed steel sections. Slender curved plates have an equal load-deflection path as their straight variant. Inelastic and plastic buckling of the webs results yield zones in the web, eventually combined with geometric deformations. The girders with curved webs are sensitive to imperfections in such a way that slender curved panels have a large reduction in initial stiffness with increasing amplitude. On the other hand, moderate or thick curved panels remain their initial stiffness but have a reduction in their ultimate load capacity.

Keywords: Curved panels, Box girders, Plate girders, Slenderness classification, Imperfection sensitivity, Shear Buckling

1 Introduction

Curved steel panels are widely used in structures such as ships, aircrafts and bridges. During the last decades, plates with an out-of-plane curvature in the cross-section of the bridge are being used, partly to increase the aesthetics. Despite the use in actually build bridges, no structural standard is covering a design method yet. However, the research towards the stability of curved panels started in 1937 by D. M. A. Leggett [1], expanded by Batdorf [2,3] during the ’40. He introduced the Z parameter (equation 1), used to determine a critical buckling coefficient k_s for a single curved plate. This coefficient is used to find the critical elastic buckling force. The Z parameter depends on the curvature radii r, the evolved length of the plate b, the plate thickness t and the poisons coefficient μ.

$$Z = \frac{b^2}{rt}\sqrt{1-\mu^2} \tag{1}$$

Over time, more parameters influencing the (in)stability of curved plates are investigated [4;5;6]. With the use of finite element modelling, it is shown that imperfections play an important role in the bearing capacity of such a plate. Curved plates are more sensitive to imperfections than flat

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