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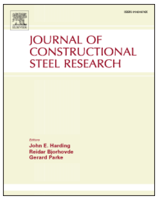

Review

Behaviour of thin-walled curved steel plates under generalised in-plane stresses: A review

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A B S T R A C T

Cylindrically curved plates are increasingly used in steel construction. In particular, there is a clear trend for their use in box-girder steel bridges with curved bottom flanges. However, there is a gap in standards dealing accurately with these types of structural elements under several arrangements of loadings and boundary conditions. This paper provides a state-of-the-art on the stability behaviour and design of cylindrically curved panels under generalised in-plane loading. A detailed review of the behaviour of curved panels subject to uniaxial compressive stresses, circumferential stresses, shear stresses and combined in-plane compressive stresses is presented, followed by a comparison of the design provisions of DNV and DNVGL standards with FEM numerical results obtained by the authors.

Contents

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1. Introduction

Despite the limited guidance on the structural behaviour of curved steel plates under generalised in-plane stresses and the lack of practical design rules from codes of practice, structural engineers are increasingly using this type of elements. Recently, Reis et al. [1] provided an exhaustive survey of steel bridges using curved bottom flanges. In their report, a total of 18 bridges with curved cross-sectional parts are described. In these box-girder bridges, the global curvature parameter (see Section 2) of the bottom flange varies from 1 up to 600. As an example, in Fig. 1, the cable-stayed Ebro River Pedestrian Bridge is illustrated during its erection process, showing a highly curved unstiffened bottom flange (global curvature parameter varying between 300 and 600).

The use of curved shapes in cross-sections (which are predominantly under compressive stresses but may also be subject to shear stresses) raises a problem: how can designers cope with mandatory/standardised safety levels when current design codes do not provide guidance on the design of curved plates? The only possible solution is the use of advanced Finite Element Analysis. However, its use requires experienced designers and a high level of understanding of computational tools to tackle with confidence complex stability driven problems.

Other authors have presented literature reviews of shell structures. For example, Schmidt [3] reviewed the main features of the stability design of shell structures. However, this state-of-the-art report is limited to shells of revolution. For the design of shells of revolution the reader is also referred to the ECCS publication no. 125 [4] and for a comparison of standards to [5].

Therefore, this paper presents a review of the stability behaviour of simply supported cylindrically curved panels under generalised in-plane stresses. After an introductory description of the geometry of cylindrically curved panel in Section 2, Sections 3 to 6 characterise the elastic critical and postbuckling behaviour of simply supported cylindrically curved panels (subject to uniaxial compressive stresses, circumferential compressive stresses, shear stresses and a combination of stresses, respectively). Subsequently, a review of the postbuckling and ultimate behaviour for cylindrically curved panels is provided, including the consideration of boundary conditions other than simply supported and loading conditions other than uniform compressive stresses. Finally, current design methodologies for the assessment of the resistance of structures incorporating curved panels are identified in Section 7. In particular, the design methods found in DNVGL [6] and DNV [7] are compared with numerical results obtained by the authors.

2. Geometry of the curved panel

Fig. 2 defines the relevant geometrical variables for the characterisation of a cylindrically curved panel is given as follows
where

- a is the length of the panel;
- a_{loc} is the length of the subpanel;
- b is the width of the panel;
- b_{loc} is the width of the subpanel;
- t is the thickness of the panel;
- R is the radius of curvature of the panel;
- φ is the sectorial angle of the panel;
- b_s is the width between longitudinal stiffeners;
- h_s is the height of the stiffener;
- t_s is thickness of the stiffener.

The aspect ratio is defined by the ratio between the panel's length by its width as shown in Eq. (1).

$$a = \frac{a}{b} \tag{1}$$

Fig. 1. Ebro River pedestrian bridge (cable-stayed bridge), Zaragoza, Spain [2]