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Buckling behavior of stiffened plate under biaxial compression and shear

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Abstract

The structural elements in steel and composite bridges are sensitive to stability problems due to their large dimensions. Mainly, resulting elements are thin plates falling under the design requirements provided by EN1993-1-5. Due to the results of recent scientific papers regarding the unstiffened plates under biaxial stress, the review of the buckling proof formats for stiffened plates under biaxial loading was needed. The article gives an overview of buckling proof formats according to EN 1993-1-5 for steel and composite bridge and it is limited to the usual method of reduced stresses in Germany. For a given example, this paper discusses whether the proposed approach in the literature is also appropriate for the case of stiffened panels. One method for the buckling verification according to the effective width method of plates under biaxial compression and shear will be proposed.

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Keywords: plate buckling; biaxial compression; shear; panel; stiffeners;

1. Introduction

The elements of steel and composite bridges are generally imposed by the buckling verifications. The usual design method of reduced stress was regulated in 2003 by DIN Technical Report 103 (DIN-Fachbericht 103) [1], in Germany. Along with the effective width method, the reduced stress method represents the buckling proof formats according to EN 1993-1-5 [2] for steel and composite bridges.

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The results of recent scientific papers regarding the unstiffened plates under biaxial stress [3] suggests that the review of the buckling proof formats for stiffened plates under biaxial loading is needed.

The article gives an overview of buckling proof formats according to EN 1993-1-5 [2] for steel and composite bridges, limited to the usual method of reduced stress, in Germany, introduced in 2003 by DIN Technical Report 103. In this paper it is discussed if the proposed approach in [3] is also appropriate to the case of stiffened panels. Based on [12] and [13] one method for the buckling verification according to the effective width method of plates under biaxial compression and shear will be proposed.

2. Buckling verification according to EN 1993-1-5

The background of the design methods in EN 1993-1-5 [2] is represented by the development of the Eurocodes, which brought together various European design cultures. In most European countries, partly exclusively, the method of effective widths is applied. This describes the load bearing behavior of buckling plates realistic and takes into account both post-critical load bearing behavior and stress rearrangements within a cross section. Compared to the method of reduced stresses the concept of effective widths leads to more economical results, but it may also have the consequence that by repeatedly forming small bumps (called web-breathing) fatigue damage occurs.

In Germany the reservations against the method of effective widths come from the higher computational complexity (load case dependent cross-sections) and the lower flexibility in the application (non-rectangular buckling panels are not covered by the method).

The reduced stress method which is applied in Germany considers the post-critical load bearing reserves in a lesser extent and does not especially allow any stress redistribution within the cross-section. The following represents the details of the method of reduced stress.

In EN 1993-1-5 section 10 [2] the method of reduced stress for both single load and combination of loads is regulated. In this method the post-critical load bearing reserves of the cross section are not fully activated and stress redistribution is disregarded. This method is thus not economical in high-rise buildings, but produces robust results and applies to complex geometries. The quintessence of the buckling checks according to method of reduced stresses is the equation (10.5) in [2] reproduced as Eq. (1):

$$\left(\frac{\sigma_{x,Ed}}{\rho_{cx}\, f_{y,k}/\gamma_{M1}}\right)^2+\left(\frac{\sigma_{z,Ed}}{\rho_{cz}\, f_{y,k}/\gamma_{M1}}\right)^2-\left(\frac{\sigma_{x,Ed}}{\rho_{cx}\, f_{y,k}/\gamma_{M1}}\right)\left(\frac{\sigma_{z,Ed}}{\rho_{cz}\, f_{y,k}/\gamma_{M1}}\right)+3\left(\frac{\tau_{Ed}}{\chi_w\, f_{y,k}/\gamma_{M1}}\right)^2\le 1 \qquad (1)$$

The relation corresponds to the verification of the equivalent stress, modified by the corresponding reduction factor ρ_{cx}, ρ_{cz} and χ_w, to avoid buckling. The condition in Eq. (1) is applied for the entire panels with their single panels and subpanels in the longitudinal direction of the bridge (see Fig. 1).

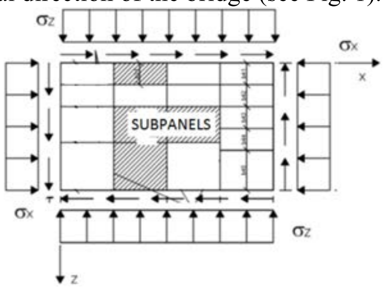

Fig. 1. Buckling panel and stresses [4].

In contrast to the procedure according to DIN 18800-3 [4], the reduction factors are calculated with a "global" slenderness, which takes simultaneously all stress components into account, Eq. (2).