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Axially and transversely loaded Timoshenko and laced built-up columns with arbitrary supports

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ABSTRACT

The two main effects that should be taken into account in the design of built-up columns are the shearing effect due to their reduced shear rigidity and the interaction between global and local buckling modes in the presence of imperfections. EC3 considers such columns as Timoshenko members for accounting for shear deformation and provides guidance for the calculation of their collapse load under axial compression only for the simply supported case.

In the present work an approximate analytical procedure for the calculation of the maximum 2nd order bending moment along imperfect Timoshenko members with arbitrary rotational and translational boundary conditions under combined axial and lateral external loading is formulated. The procedure is verified by means of geometrically nonlinear numerical analyses with the use of shear deformable beam elements. This method is then used for the evaluation of the maximum actions due to combined axial and lateral loading along laced built-up columns with various end conditions accounting also for initial imperfections. Incorporating the 2nd order bending moments in an interaction equation specifically formulated for laced built-up columns, the collapse load is calculated. Analytically obtained results based on the proposed method are compared with the ones found from geometrically and materially nonlinear imperfection analyses (GMNIA) of laced built-up columns modeled using either beam or shell elements. The accuracy of the analytical results is found to be very satisfactory. Due to its simplicity and accuracy the proposed method is a useful tool for the design of laced built-up columns in structural engineering practice.

1. Introduction

Built-up columns are often used in steel buildings and bridges providing economical solutions in cases of large spans and/or heavy loads. Depending on the way that the flanges are connected to each other, they can be grouped into two main categories: laced and battened built-up columns. The category that will be investigated in the present work is the first one, in which diagonal bars are used for connecting the flanges (Fig. 1(a) and (b)).

In the design of built-up columns additional effects should be taken into account, which differentiate them from other structural members. The first one is related to the significant and detrimental influence of shear deformation which was initially incorporated in their structural analysis by Engesser [12]. The Quebec Bridge failure in 1907 was attributed to the buckling of a built-up diagonal and pointed out the significance of this effect. Since then many researchers such as Nanni [25], Ziegler [32], Gjelsvik [16], Bazant [8], [9] dealt with this problem and more details can be found in many structural textbooks, such as the ones of Bleich [10], Timoshenko and Gere [30] and Bazant and Cedolin [7]. Banerjee and Williams [6] explained the reason why the elastic buckling load of members with springs of different rotational stiffness at their ends cannot be obtained from the general equation suggested by Engesser [12] and used by Eurocode 3 [13]. The effect of end stay plates on simply supported built-up columns was examined by Gjelsvik [15] by considering a layered sandwich cross-section and using a sixth order differential equation. This method was expanded for other possible boundary conditions by Paul [27] and experimental findings showed good agreement with analytical results [26]. Wang et al. [31] proposed an 8 by 8 matrix, providing exact stability criteria for Timoshenko columns with intermediate and end concentrated axial loads. Hashemi et al. [17] compared the elastic buckling loads of battened columns with end stay plates obtained analytically with experimental results. They concluded that Engesser's method is always on the safe side. The same authors [18] compared experimental collapse loads of simply-supported battened built-up columns with the ones found analytically with the use of Ayrton–Perry method and the ultimate strength curve method. Aristizabal-Ochoa [2] proposed a stability matrix for evaluating the elastic buckling load of Timoshenko members and second order slope-deflection equations based on Haringx's approach [3]; He, then, compared available methods for the calculation of the elastic critical buckling load of Timoshenko members [5]. Gengshu et al. [14] used Engesser's method to investigate the buckling of dual shear-

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