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OVERALL STABILITY OF STEEL WEB-TAPERED MEMBERS

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Abstract. Efficient analytical-numerical method for the calculation ultimate capacity of thin-walled steel web-tapered members under biaxial loading is presented. It allows to determine ultimate loads and displacements faster than using FEM. Results made by presented method for three loading schemes are demonstrated.

1. Introduction

The use of web-tapered members in frames can reduce the consumption of steel up to 30% in comparison with prismatic members. However, frames composed of web-tapered members haven't obtained wide distribution in Russia because of the lack of information about stability in the national design codes. Therefore, an analytical-numerical method for solving stability problems is presented in the paper. This method allows carrying out the member's overall stability analysis in the elasto-plastic range rapidly and precisely enough.

2. Computational model

Member's boundary conditions at both ends: bending about the major and minor-axis is free, the torsion is prevented but the warping is unrestrained. Member's extraction from the plane frame is conducting by its out-of-plane effective length. To carry out this extraction it is needed to make in-plane non-linear analysis of the frame (without taking torsion into consideration). The aim of this analysis is to find second-order bending moments M_{y0}, M_{y1} and compressive force N at the ends of the member at any loading level.

Figure 1 represents loading case for bar element: compressive force is applied with eccentricities about both axes $e_{y0} = M_{y0} / N$, $e_{y1} = M_{y1} / N$, $e_{x0} = e_{x1} = l_{ef,y} / 750 + i_y^{mid} / 20$. The latter imply all the imperfections which could occur during fabrication and erection processes.

3. Solution method

The solution of the problem is based on the V.Z. Vlasov second-order theory of thin-walled members [1], extended by B.M. Broude [2] and E.A. Beilin [3] to the case when it is necessary to take into account the difference of the fibers' curvatures and the slopes associated with the torsion. In view of this fact the three differential equation system of equilibrium [3] (after the pre-integration of the first two) will be:

$$\begin{cases} EJ_x^* v'' + N^0 v - M_y^0 \theta + M_z^0 u' = -M_x^0 \\ EJ_y^* u'' + N^0 u + M_x^0 \theta - M_z^0 v' = -M_y^0 \\ \left[\dfrac{EJ_\omega^*}{\left(h_\omega^*\right)^2} \left(\theta h_\omega^*\right)'' \right]'' h_\omega^* - \left[GJ_k^* \theta' \right]' - M_y^0 v'' + M_x^0 u'' + \left[i_p^{2^*} N^0 \theta' \right]' = 0, \end{cases} \tag{1}$$

dashed – when there is $m_{x0} = 0$ at the smaller end (Scheme 2), dash-dot correspond to the case when the eccentricities are opposite in direction at the ends (Scheme 3).

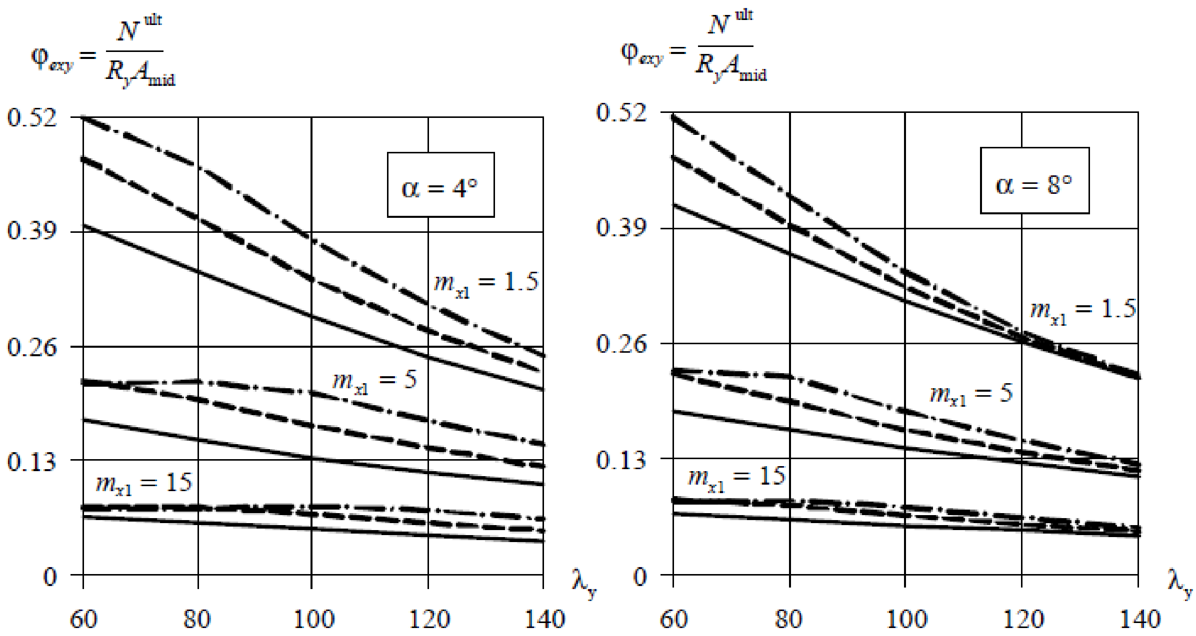

Fig. 2. The results of the study for the three loading cases.

The graphs in Fig. 2 reveal that when the non-dimensional eccentricities are equal, the load carrying capacity is considerably higher for the schemes 2 and 3 than for the scheme 1. However, with the growth of slenderness these differences become insignificant.

5. Conclusions

The use of analytical-numerical method when the buckled shapes are determined numerically allows to study the overall stability of the web-tapered members quite fast and precisely enough. Thus, the results of this investigation can be widely applied in structural steel design.

References

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