INFLUENCE OF INITIAL IMPERFECTIONS ON THE COLLAPSE BEHAVIOUR OF BOX-COLUMNS

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In this work the analysis of the post-buckling state in the elasto-plastic range of a box-column subjected to uniform compression in the elasto-plastic range is presented. The problem is investigated using Rayleigh-Ritz variational method. The stress-strains relations in the plastic range are determined on the basis of the flow theory of plasticity. The proposed method is a combination of analytical and numerical solutions. Different material stress-strain curves and initial imperfections such: out-of-flatness and residual stresses are taken into account. The load-shortening curves for column of different geometrical parameters and material properties are shown in diagrams.

1.Introduction.

Many works have been devoted to the post-buckling analysis of thin-walled box-column subjected to different types of loading in the elastic range (3). It is known that to determine the ultimate strength of such girders the analysis of the post-buckling behaviour must be carried out into the plastic range. In aiming to determine the ultimate strength (maximum load carrying capacity) of a plated structure it is necessary to consider geometrical nonlinearities (large deflections) and physical nonlinearities (plastic strains). Therefore the analysis becomes complicated as far as the mathematical solutions are concerned. It is known that initial imperfections (initial out-of-flatness and residual stresses) appearing in real structures reduce the load carrying capacity and must be taken into account during analysis. First attempts of determination of maximum load carrying capacity for girders and columns started in the sixties. Those works were based on the approximate solutions for elasto-plastic plates, the interaction between girder walls was neglected. Among others, Graves-Smith's work (1),in which the analysis of post-buckling behaviour in the elasto-plastic range of a rectangular column has been presented, is very distinguished. In the previous works the author has demonstrated load-shortening curves in the elasto-plastic range for plates (2) and box-column (5), initially unflat, subjected to uniform compression. The aim of this paper is to analyse the post-buckling state of a rectangular column working in the elasto-plastic range. The present research extends this work to materials having a rounded stress-strain curve which exhibits continuous strain hardening. In the analysis residual stresses and HAZ softening are taken into account.

2. Main assumptions and constitutive relations.

The column section contained between nodal lines is considered. Due to the axial shortening S the column walls buckle elastically and when the deflections are more pronounced, some parts of plates become plastic. The column cross-section has two axes of symmetry. The column dimensions and coordinate systems are shown in Fig.1.

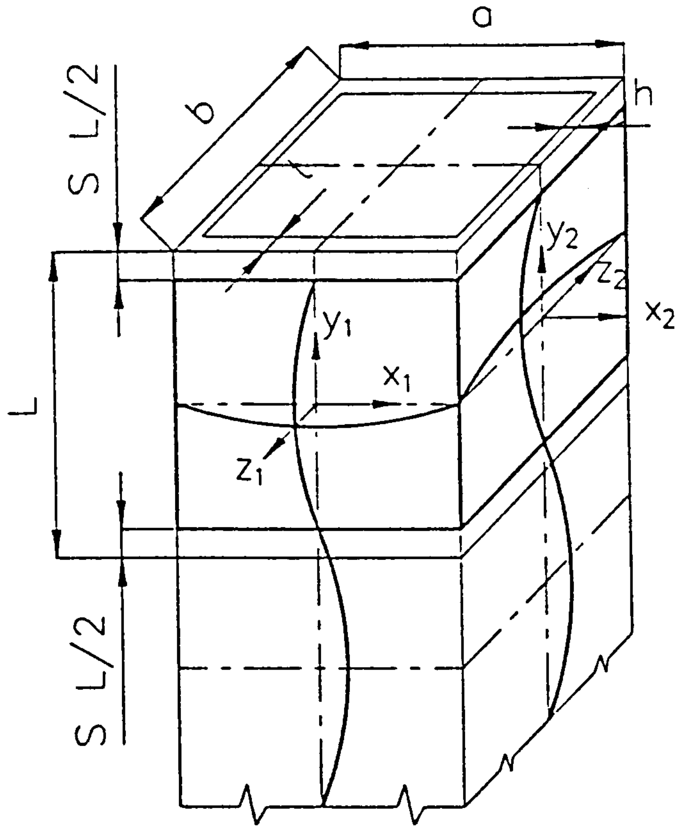


Fig.1. Box-column dimensions and coordinate systems.

The analysis is based on the large deflection plate theory and it is assumed that the material is isotropic. The usual assumptions of the non-linear plate theory are imposed. Substituting the expressions for deflections into the von Karman-Marguerre equations and taking into account Hooke's law and boundary conditions, the strains at any point of component plates can be found in the elastic range.

In the plastic range following assumptions are made:

- the material is isotropic, with non-linear strain hardening and obeys Huber-Mises Yield Criterion
- all assumptions of large deflection plate theory still hold
- the forms of displacement functions are the same in the elastic and plastic range
- according to the plastic flow theory, the plastic strain increments are described by the Prandtl-Reuss equations.

It was proved by Graves-Smith in his work (4) that it is possible to apply the variational method to the elasto-plastic plates undergoing finite deflections. This method has been used in many works. The value of energy increment is calculated numerically, next, the numerical minimisation of the energy functional is performed versus independent deflection parameters. The average stress corresponding to the load applied to the column is obtained numerically, using the Principle of Virtual Work.

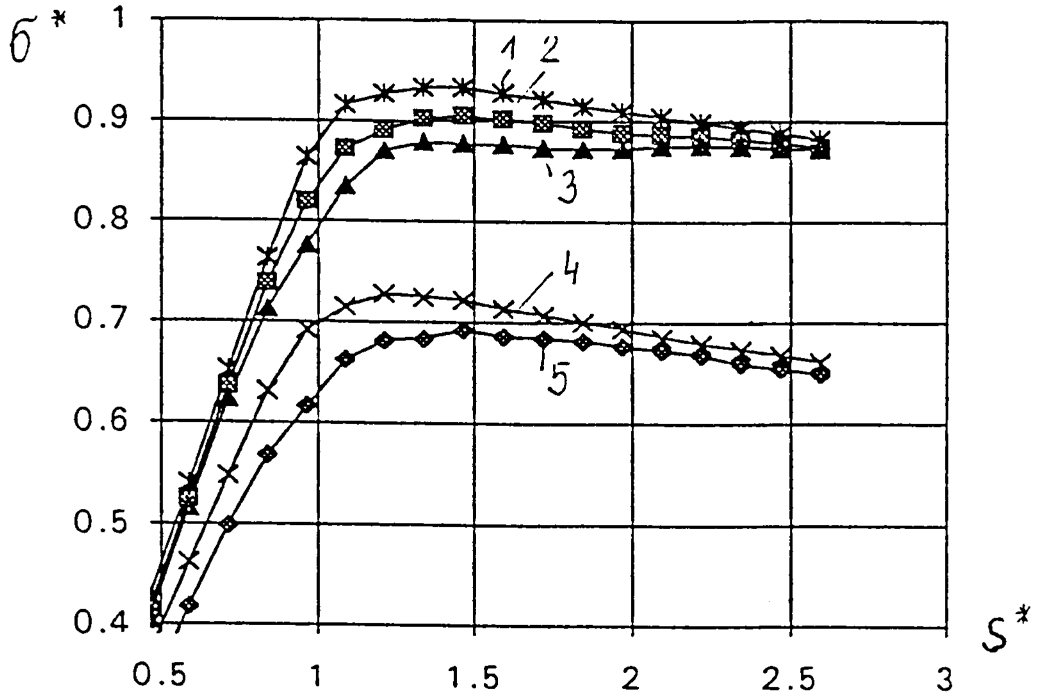
3. Material stress-strain curve, residual stresses.

In the studies concerning the stability of structures in the elasto-plastic range it is essential to describe the shape of the uniaxial stress-strain curve of a material. As is known from the mechanics of materials the experimental uniaxial tension test is the simplest way to obtain the actual relation between stress σ and strain ε. Accurate analytical description of a stress - strain seems to be almost impossible or would require very sophisticated mathematical functions which in turn could complicate the solution of a problem. In the theory of plasticity a lot of approximated (σ-ε) relations are proposed. In this paper two types of relationships have been considered : Needleman-Tvergaard formula for materials having gradual yield and elastic-perfectly plastic relation for mild steel.

Plates which are parts of thin-walled structures are subjected to many manufacturing processes which are sources of initial geometrical imperfections and residual stresses. These processes are very complicated and difficult to measure or to describe in an analytical way. The influence of residual stresses on the elasto-plastic stability of thin plates have been found to be significant. The analyses have been concerned with a set of residual stresses acting in the direction of the applied load and produced by welds laid simultaneously along the unloaded edges. It follows from the experiments that along welded edges of a box-girder , the stresses are equal to the yield limit and are tensile, while in the middle zones of plates they are compressive. Moreover a uniform distribution of these stresses through the thickness of a plate is observed, which allows one to treat the residual stresses as membrane stresses. In the present work a rectangular block of distribution of residual stresses is taken into account in the analysis (c - with of residual tension block at one edge).

4.Results of numerical calculations.

The results of numerical calculations are presented in figures as non-dimensional relationships between the average stress σ^* and the shortening S^* of column.



Curve	L/a	L/b	L/t	h/t	$\bar{f}_{0i}$	
1	1	1	50	2	0.5	$\sigma_r=0$
2	1	1	50	2	0.5	c=3t c=1.5h
3	1	1	50	2	0.5	c=3t, c=3h
4	1	1	50	1	0.5	$\sigma_r=0$
5	1	1	50	1	0.5	c=3t, c=3h

E=205000 MPa $\nu=0.3$ $\sigma_Y=245$ MPa

Fig.2. Influence of residual stresses and HAZ softening on L-S curves.

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