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The Ultimate Load of Monosymmetric Sections due to Lateral Torsional Buckling

Calcul de la charge ultime de sections monosymétriques en tenant compte du déversement

Traglasten von einfach-symmetrischen Profilen unter Berücksichtigung des Kippens

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1. INTRODUCTION

Structural members loaded by transverse loads and moments acting in the plane of greatest stiffness may also twist and deform laterally as shown in fig.1. The most general case includes initial imperfections of a bar or eccentricities of the loads and inelastic material behaviour, fig.2.

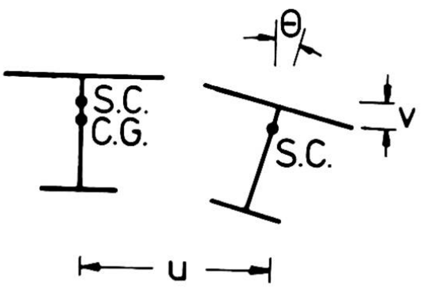

fig.1

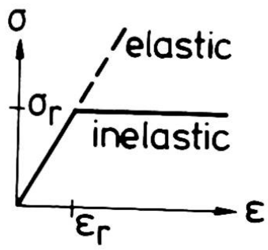

fig.2

Solutions for this problem of lateral torsional buckling are well known for the elastic behaviour, including monosymmetric sections. For inelastic material behaviour solutions are known only recently ([1] - [6]), most of them for double symmetrical sections. For monosymmetric sections only single results are known ([2], [4]).

2. THEORETICAL SOLUTION

The used theoretical solution is an approach for the inelastic material behaviour. It takes into consideration the elastic-plastic stress-strain relationship (fig.2), the spread of the plastic zones in the longitudinal direction of the beam-column, residual stresses and the alteration of the position of the shear centre due to plastification.

At first there is investigated a solution using the theory of elasticity. If the greatest stress in the most unfavourable fibre of the section exceeds the yield stress, this must be taken into account by iteration. Thus the spread of plastification in the section, the alteration of deformations and twist are considered. The ultimate strength is reached when equilibrium between external and internal forces is no longer possible.

This solution is described properly in literature ([2], [3], [4], [7]).

	St 37 σ_y=240 N/mm²	StE 70 σ_y=700 N/mm²
780·8 (web), 500·20 (upper flange), 400·15 (lower flange) [mm]	1769	5159
780·8 (web), 400·20 (upper flange), 400·20 (lower flange) [mm]	1828	5331

Table 1: Full plastic moments [kNm]

3. RESULTS

For getting numerical results, there are investigated a monosymmetric and a double symmetrical section with equal area and height. The loading is assumed as concentrated load, because the most unfavourable case of constant end moments are seldom given in practical members. The level of application of the load is the upper flange. The end conditions correspond to simple support in the lateral plane. This means that lateral deflection and twist are prevented but no resistence is provided against either lateral bending or warping.

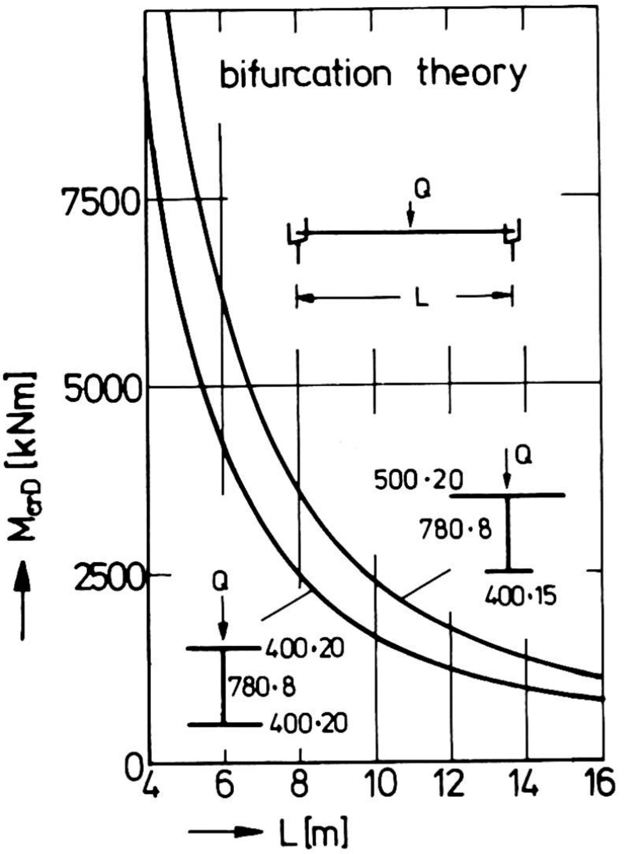

fig.3

The greatest capacity of the section is given by the full plastic moment, [8]. The results are given in table 1. It is seen, that the symmetric section gives the greater maximum capacity, but the difference does not exceed 3%.

The monosymmetric section is the better one, if the bifurcation theory is used (fig.3). The reason is, that the compression flange, which may buckle, get a greater area, the center of gravity and the shear center have a smaller distance to the compression flange and therefore it is clear, that the critical load increases. The differences amount to 45% related to the double symmetrical section.

The ultimate load carrying capacity is seen in fig.4. In addition mild steel St 37 and high strength steel StE 70 are compared. They are drawn in a nondimensional way. The parameters are M/M_{Pl} and $\bar{\lambda}$. M is the given moment of the beam, taking into account the load enhancement factor. M_{Pl} means the full plastic moment (table 1). The value of $\bar{\lambda}$ depends on the yield stress and the critical moment due to lateral torsional buckling. For each length of the beam $\bar{\lambda}$ can be calculated using table 1 and fig.3.

The value of the residual stresses was chosen to a maximum compression value of $\sigma_{rc} \cong 120$ N/mm².

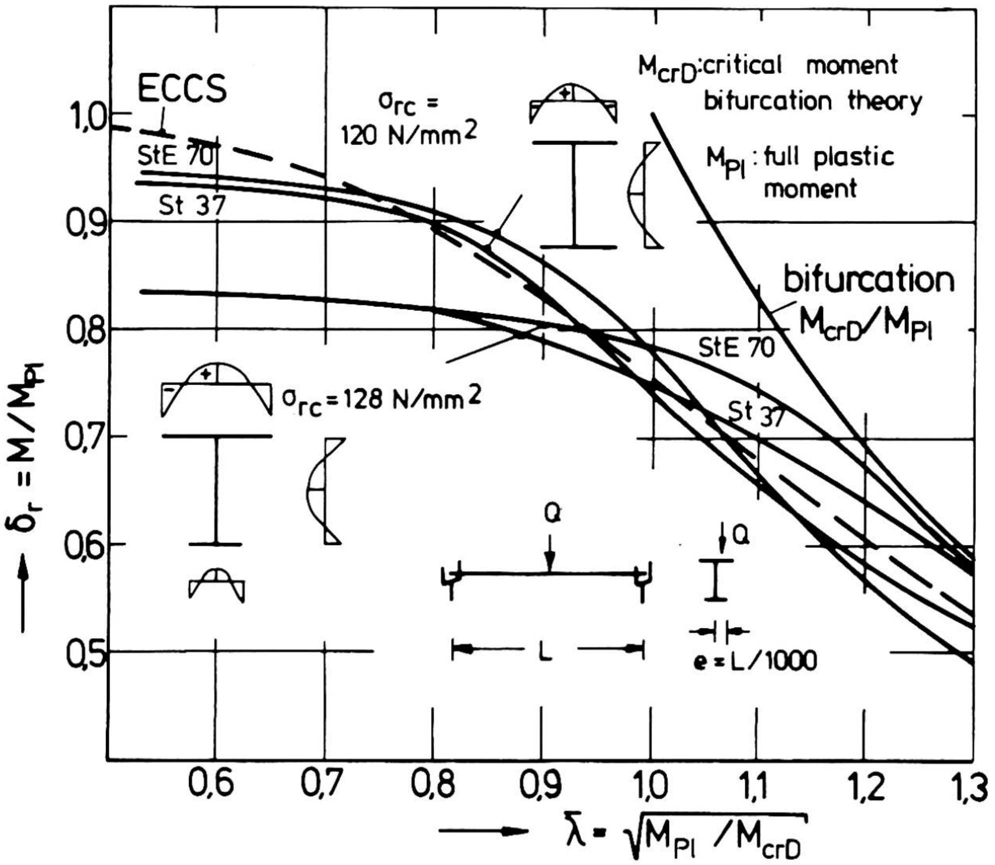

fig.4: Utimate load carrying capacity

That means for steel St 37 50% of the nominal yield stress. Even for the high strength steel StE 70 the same value for the residual stresses was chosen.

Some interesting results are seen in fig.4. It is seen, that for small values $\bar{\lambda} \lesssim 1,0$, that means small values L of the length, the ultimate load of the monosymmetric section lies significantly below that of the double symmetrical section. In the region of $\bar{\lambda} \gtrsim 1,0$ it is contrary, but the differences are a great deal smaller. The differences between St 37 and StE 70 are small, they exceed not more than 8%.

The curves for the double symmetrical section give a satisfying agreement to the new ECCS-curve [9], which should be valid only for double symmetrical sections. For the monosymmetric section the ECCS-curve may be used for $\bar{\lambda}>1,0$.

In addition a comparison is made to the elastic theory of second order. This theory is usually used if there is no possibility to calculate the real ultimate strength. Using this theory the assumption is made that the load carrying capacity is reached when at the most unfavourable point of the beam the yield stress σ_y is reached.

In the present case there are 3 types of normal stresses taken into account. These stresses are originated from moments about the strong axis, moments about the weak axis and warping moments.

The used calculation method is the energy method. The computer program was kindly given by D.BAMM, it is similar to these discribed in [3], [4].

The results are given in fig.5. It is seen that the shape of the curves is similar using the ultimate strength method or the elastic second order theory.

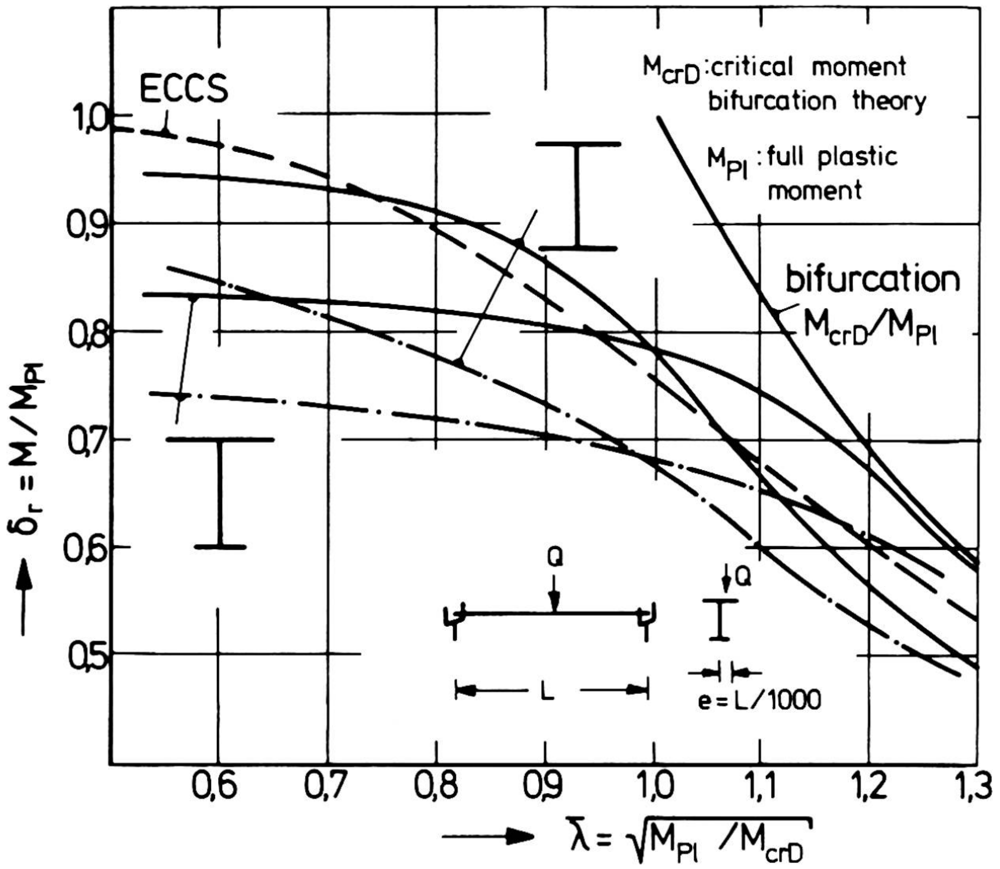

fig.5: load carrying capacity StE 70
—— ultimate strength
—·— second order theory, $\sigma_{cr} = \sigma_y$

But in the whole region of $\bar{\lambda}$ is a great reserve from reaching the yield stress at the most unfavourable point to the load carrying capacity, where the cross section is partly yielded.

Therefore from the economical point of view it is usefull to use the ultimate strength method or as an approximation using the method given in [6].

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SUMMARY

The paper deals with the load carrying capacity of monosymmetric sections taking into account lateral torsional buckling. Numerical results are calculated for a double symmetrical and a mono symmetrical cross section with equal height and area. From the results is seen, that the ultimate load of the monosymmetric cross section is smaller than that of the doublesymmetric cross section. The ECCS recommendation curve should only be used for monosymmetric cross-sections, if the length of the bar is great.

RESUME

L'article traite de la résistance ultime de sections monosymétriques en tenant compte du déversement. Des résultats numériques sont calculés pour des profils à symétrie double ou simple ayant des hauteurs et des surfaces égales. Les résultats montrent que la résistance ultime du profil monosymétrique dans le domaine plastique est inférieure à celle du profil à symétrie double. Pour des sections monosymétriques, les courbes des recommendations CECM ne doivent être appliquées que lorsque l'élancement est grand.

ZUSAMMENFASSUNG

Der Beitrag beschäftigt sich mit der Traglast von einfach-symmetrischen Profilen im Hinblick auf das Stabilitätsproblem des Kippens. Zahlenmässige Ergebnisse werden für ein doppelt-symmetrisches Profil und ein einfach-symmetrisches Profil mit gleicher Höhe und Fläche angegeben. Aus den Ergebnissen ist zu ersehen, dass im plastischen Bereich die Traglast des einfach-symmetrischen Profils unter der des doppelt-symmetrischen liegt. Die Bemessungskurve der EKS-Empfehlungen darf für einfach-symmetrische Profile nur benutzt werden, wenn die Stablänge gross ist.

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