Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 65 (1992)

Artikel: A steel Eurocode for innovative structural engineers

Autor: Sedlacek, Gerhard

DOI: https://doi.org/10.5169/seals-50046

EC3: A Steel Eurocode for Innovative Structural Engineers

EC3: Un Eurocode en vue du projet de structures en acier innovatrices

EC3: Ein Eurocode für innovative Entwürfe in Stahl

Gerhard SEDLACEK
Prof. Dr.
RWTH Aachen
Aachen, Germany

Gerhard Sedlacek, born in 1939, is Professor for Steel Construction at the RWTH Aachen. He has been Technical Secretary of the Eurocode 3 Editorial Group.

SUMMARY

After pointing out that the design rules in Eurocode 3 have been developed on the basis of test results some examples for such rules are given which demonstrate the compromise between sophisticated design models with close approximation to the actual physical behaviour of the structure and the user-friendly simplified design models that have been proposed. Some new design rules for frame structures, hollow section lattice structures and plate girders are presented.

RESUME

Après avoir rappelé que les règles de dimensionnement de l'Eurocode 3 ont été établies sur la base de résultats d'essais, l'article présente quelques exemples illustrant ces règles basées sur un compromis entre des modèles de calculs très élaborés, cherchant à représenter exactement le comportement physique de la structure d'une part, et des modèles de calculs simplifiés, d'utilisation pratique, d'autre part. De nouvelles règles de calcul sont présentées pour les structures en cadres, à profil creux et les poutres composées.

ZUSAMMENFASSUNG

Nach Hinweis auf die Entwicklung der Bemessungsregeln im Eurocode 3 anhand von Versuchsresultaten wird an einigen Beispielen gezeigt, wie ein Kompromiss zwischen möglichst grosser Nähe der Bemessungsmodelle zum wirklichen Verhalten der Konstruktion und einer nutzerfreundlichen Vereinfachung gesucht wurde. Dabei wird auf die neuartige Bemessung von Rahmentragwerken, von Hohlprofilkonstruktionen und von Blechträgern eingegangen.

1. INTRODUCTION

Eurocode 3 is a limit state design code in which principles and rules for serviceability limit state and ultimate limit state verifications are given.

These limit states are referred to physical phenomena as e.g.

- the exceedance of values for deflections or vibrations that may limit the serviceability or
- the collapse or other form of structural failure that may endanger the safety of people and thus be regarded as ultimate limit.

Thus the attainment of limit states can be proved by tests. On the other hand available test results can be used to develop strength functions and functions for the resistance of members and systems, and it is evident that these functions are the better the more accurately they can predict the ultimate strengths of members in tests.

This however produces a dilemma: In general a mechanical model with a good prediction (expressed in terms of a small mean value deviation and a small scatter, see fig. 1a) is more complex and sophisticated (e.g. a finite element model). The advantage of such a model is that from the test evaluation (see the paper "Eurocode 3: A Eurocode for Reliable Steel Structures) only smallγ_M-values are derived that lead to economical design values with sufficient reliability. A simplier model however, in which certain unlinearities and parameters in view of better usability are omitted, may produce larger deviations between predictions and test results. It then will be punished by larger γ_M-factors and hence will be less economical, fig. 1b.

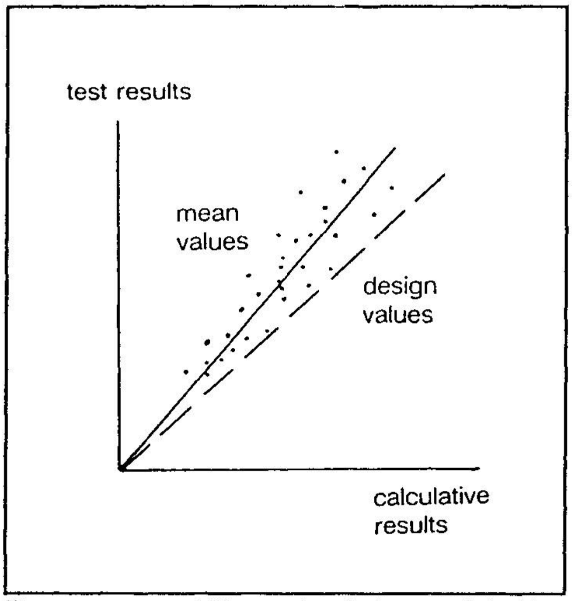


Figure 1a: Effects of a design model with a good test prediction.

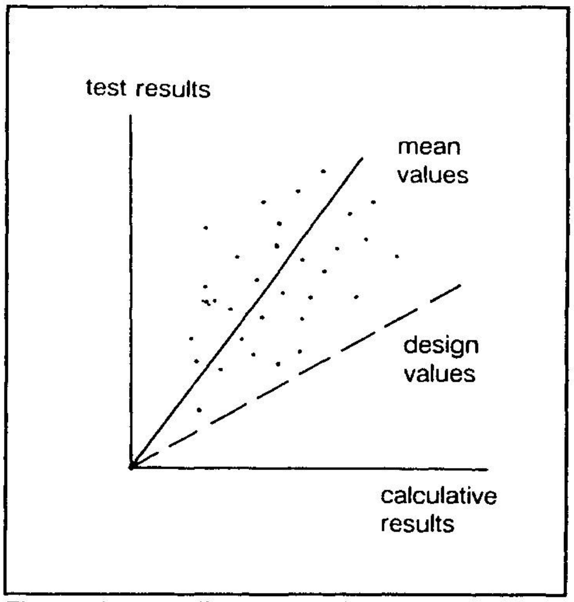


Figure 1b: Effects of a design model with a moderate test prediction.

The rules in Eurocode 3 present a compromise; the intension was to keep them accurate enough to make them economical and clear and simple enough to ensure their userfriendliness. In many cases both more detailed and more simple conservative approaches have been presented to allow the user to choose.

In any case the development of strength and resistance models on the basis of test-evaluations allowed to include the most recent world wide test results in the works and to reach the justification of new rules and rules for new types of structures and structural detailing for Eurocode 3.

In the following some examples for such rules are given. Their justification is given in the relevant background documents to Eurocode 3 [1].

2. ANALYSIS MODELS FOR FRAMES

2.1 General procedure

In general spacial frame structures may be separated into several plane frames, fig. 2, that may be considered as laterally supported at the spacial nodes.

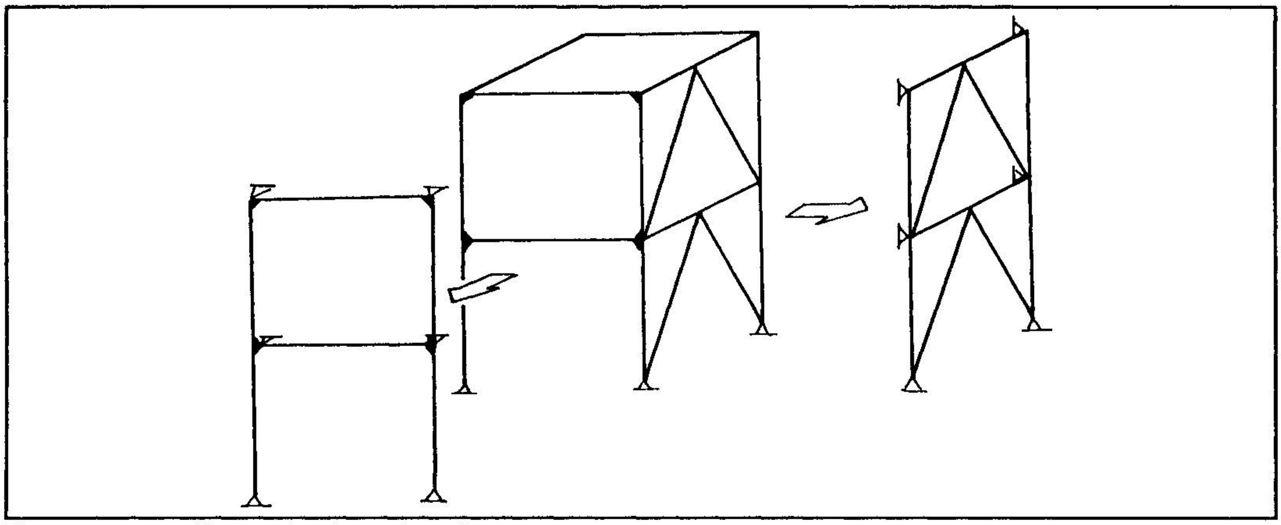


Figure 2: Separation into plane frames.

For the inplane loading of these plane frames in the first step out of plane deflections between the lateral supports are neglected and only the inplane monoaxial action effects are determined.

In the second step the individual members of the plane frame between the lateral supports, i. e. the beams and the columns, are separated from the plane frame, to consider lateral buckling and lateral torsional buckling, under monoaxial bending and compression, fig. 3. Members which are common to two different frames, e. g. columns, may be verified for biaxial bending and compression.

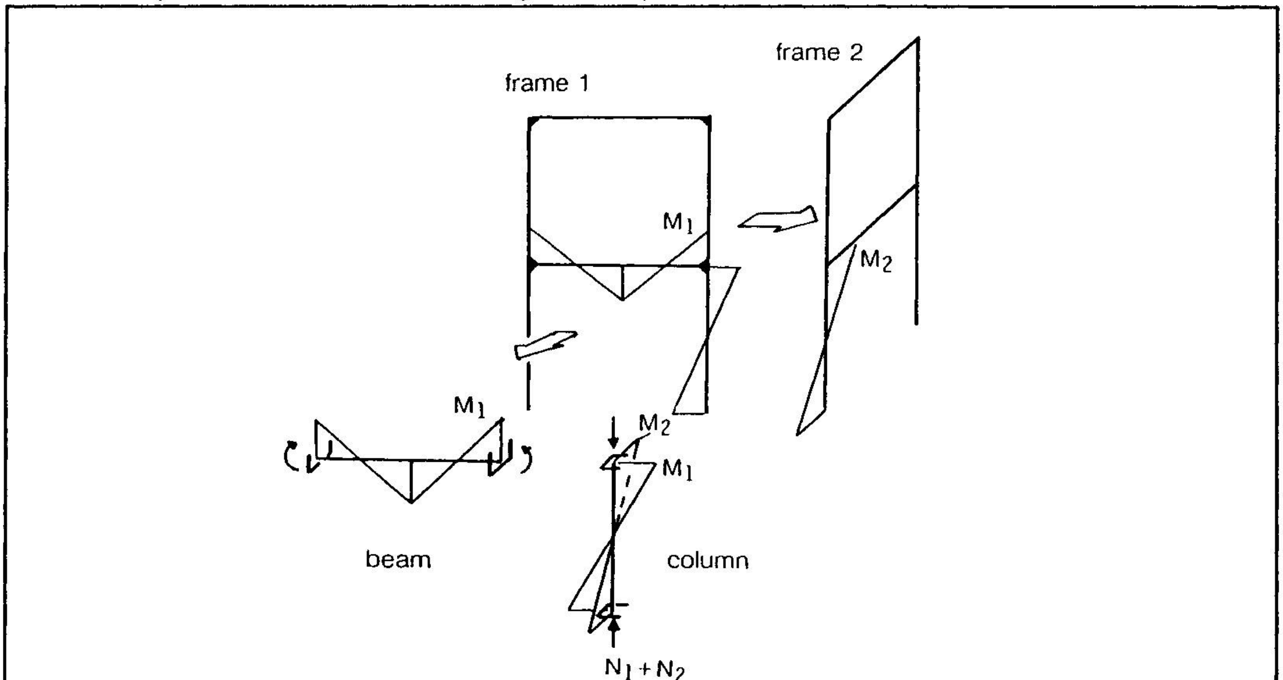


Figure 3

2.2 Plastic or elastic models

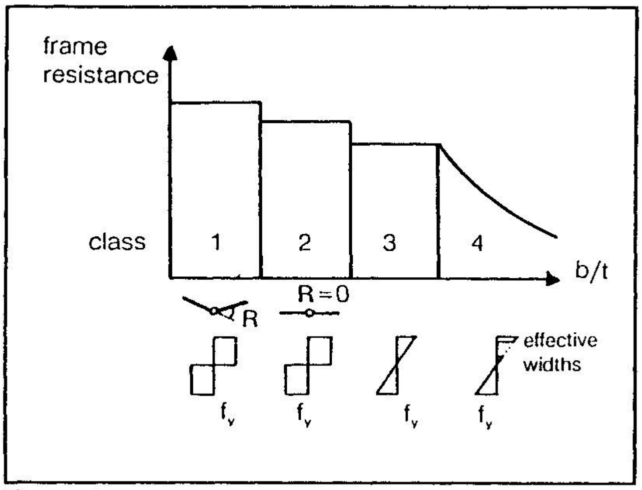


Figure 4

The model for the first step inplane analysis of the frame depends on the type of failure of the most stressed zones of the members.
The type of failure is classified by the slenderness b/t of the flanges of the cross section in compression, fig. 4. Class 1 sections allow for the use of the plastic hinge method with moment redistributions, class 2, 3 and 4 for elastic analysis methods with different levels of resistance of the cross sections.

Eurocode 3 allows to bypass the limiting b/t ratios for class 1 sections when the plastic hinge analysis is justified by an additional check of the rotation capacity R of the cross sections in plastic hinges, fig. 5. Guidance for this check is given in [2].

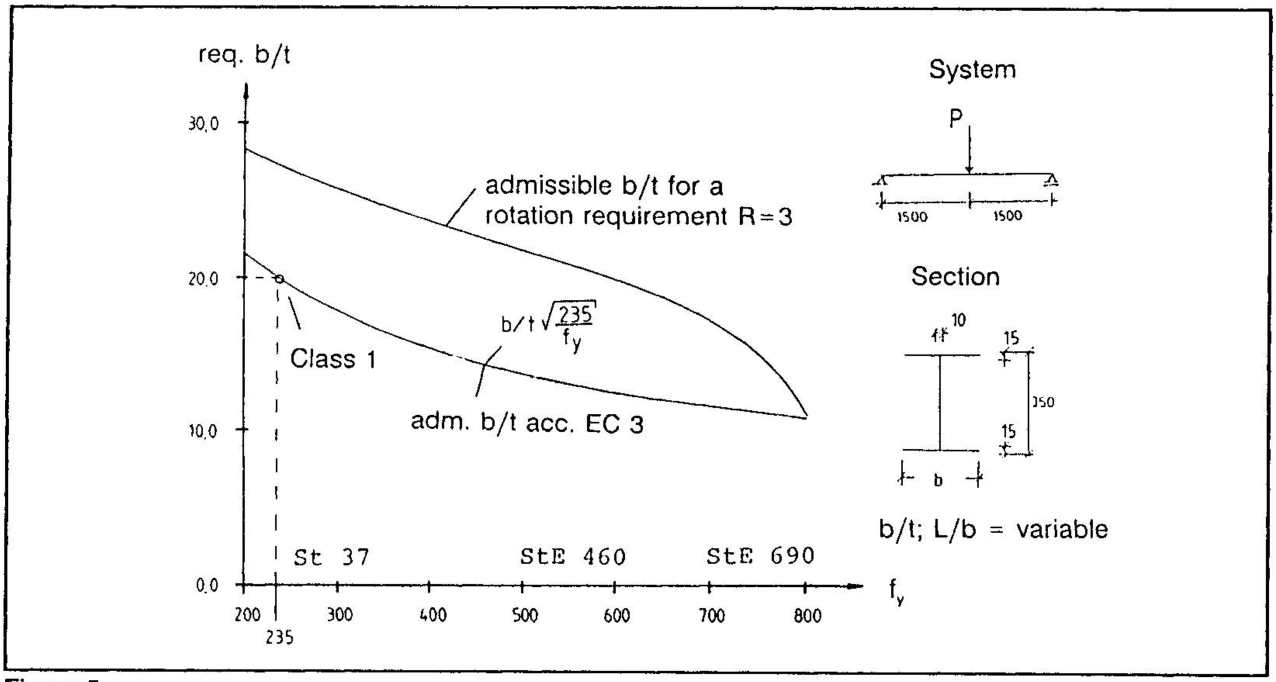


Figure 5

2.3 1st or 2nd order theory

The question whether in the first step elastic or plastic analysis 1st order or 2nd order theory has to be used can be easily answered in Eurocode 3 by considering the '10%-criterion': When from the action effects calculated with the 1st order theory a sway deformation ψ_1 is obtained that fulfills

$$\psi_1 \leq 10\ \% \ \frac{H_1}{V}$$

where H_1 = shear force in a frame storey
V = vertical load in a frame storey

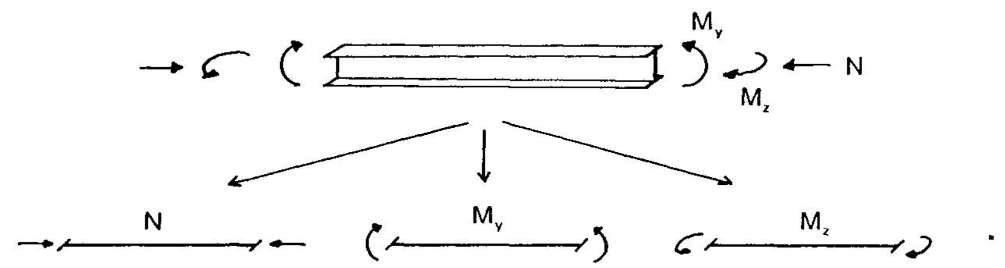
the results of the 1st order theory may be used.

This criteron also works for inhouse-structures, where no wind action has to be applied, because the shear force H_1 also contains the effects of initial sway imperfections $\psi_o \cdot V$ that have to be considered for all frames.

The 10%-criterion allows the majority of frames to be calculated with 1st order theory.

2.4 Buckling and torsional buckling verifications of members

For the buckling and torsional buckling verifications of members according to step 2 of the general procedure interaction formulae have been derived, fig. 6, that represent the best fit approximation to the design values from test results.



$$\frac{N_{Sd}}{\chi\, N_{pl,Rd}} + k_y \frac{M_{y,Sd}}{\chi_{LT}\, M_{pl\ y,Rd}} + k_z \frac{M_{z,Sd}}{M_{pl\ z,Rd}} < 1$$

column | beam 'M_y' | beam 'M_z'

Figure 6: Interaction formulae for lateral-torsional buckling.

In case the boundary conditions of members are such, that individual members cannot be separated from the frames, e. g. for portal frames where unsufficient support is given at the knee-points, see fig. 7, Eurocode 3 offers the following alternative procedure to the interaction formulae in fig. 6:

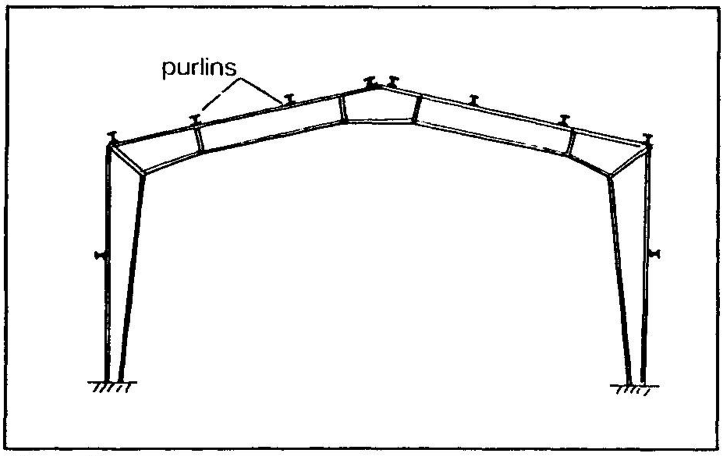


Figure 7

In the first step the inplane safety factor γ_{pl} of the frame with inplane response only (lateral deflections neglected) is calculated using the relevant elastic or plastic method (see clause 2.2). In the second step the out of plane safety factor γ_{crit} for lateral torsional buckling using a hyperelastic frame model is determined. From the overall slenderness

$\bar{\lambda} = \sqrt{\frac{\gamma_{pl}}{\gamma_{crit}}}$ of the frame, which includes the interaction effects of compression and bending moments, the reduction factor χ_c is obtained from the European buckling curve c that gives the overall safety factor $\gamma_u = \chi_c \cdot \gamma_{pl}$.

For the 2nd step of this procedure in general a computer program is needed, that takes the local restraints due to the connections with purlins and the distorsions of the cross section into account. Fig. 8 gives an example for a thin walled cross section that may be used for such frames. Detailed information on the strength verifications of such frames are given in Annex A of Eurocode 3.

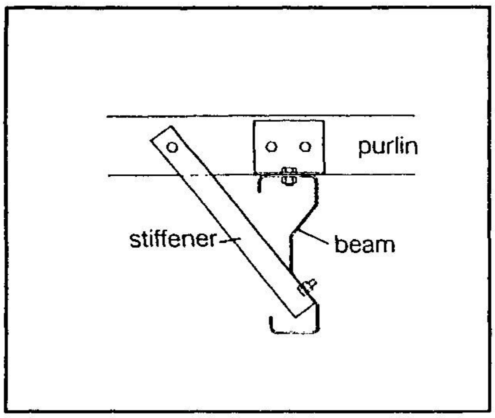


Figure 8

3. SPECIAL RULES FOR HOLLOW SECTION LATTICE STRUCTURES

Hollow section lattice structures are more and more used for roof structures, columns etc. They offer a good architectural appearance and request due to their reduced surface low maintenance.

The key for economical design of hollow section lattice structures is even more than in other areas the appropriate design of connections. Fig. 9 gives a survey on the possibilities specified in Eurocode 3 Annex K, where resistance rules are available.

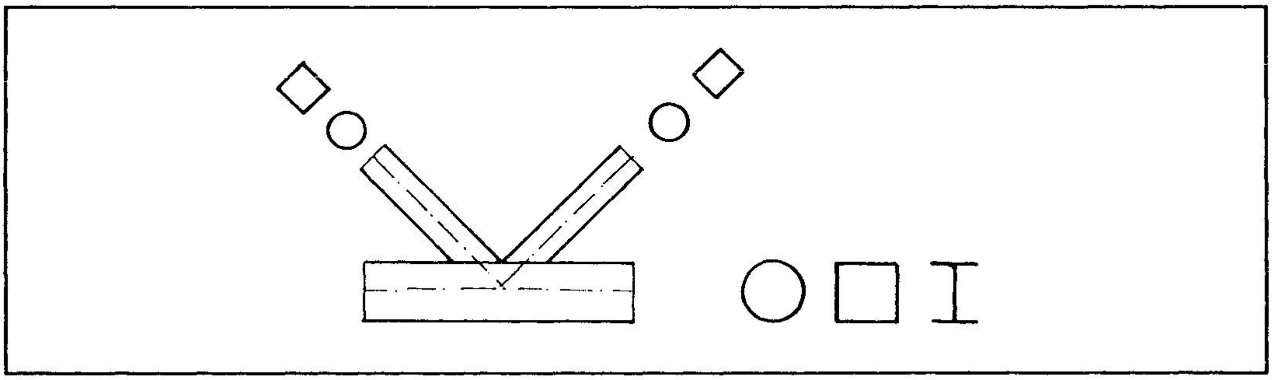


Figure 9

4. PLATED GIRDERS

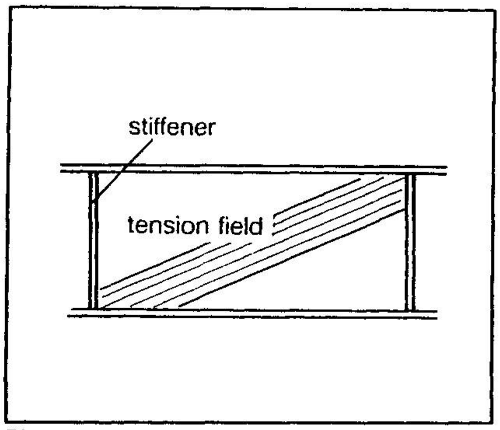


Figure 10

For plated girders two cases are dealt with in Eurocode 3:

- webs without transverse stiffeners,
- webs with transverse stiffeners.

The shear buckling resistance of webs without transverse stiffeners may be obtained by a simple postcritical method using a buckling curve $\tau = f(\bar{\lambda}_w)$

For webs with transverse stiffeners a tension field method may be used, where the total strength has two components :

- the residual shear buckling strength which is independent on any flanges
- the strength of the tension field which allows for the strengths of the flanges, fig. 10.

In the course of the development of design rules for bridges these rules are being further developed and extended.

REFERENCES

[1] CEN European Committee for Standardisation: Eurocode 3: Design of Steel Structures, ENV 1993-1, Febr. 1992

[2] Spangemacher, R.: "Zum Rotationsverhalten von Stahlkonstruktionen, die nach dem Traglastverfahren berechnet werden", Diss. RWTH Aachen, 1992