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EC3: A Steel Eurocode for Practical Structural Engineers

EC3: Un Eurocode d'utilisation pratique pour les structures en acier

EC3: Ein Eurocode als eine praxisorientierte Stahlbaunorm

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SUMMARY

The Eurocode 3 has been drafted, within the agreed parameters for Eurocodes, to be an user-friendly aid for practical structural engineers. The success of this is confirmed by a report on comparative design studies. Some of the editorial features adopted for useability are described. Mention is also made of various design aids, including two simplified versions of the code.

RESUME

Dans les limites des paramètres des Eurocodes, l'Eurocode 3 a été préparé afin d'en permettre une utilisation simple par l'ingénieur civil de la pratique. Le succès de cette réalisation est confirmé par des études comparatives de projets. Quelques caractéristiques de présentation pratique et simplifiée sont décrites. L'article mentionne quelques aides de calcul, y compris deux versions simplifiées de la norme.

ZUSAMMENFASSUNG

Innerhalb der Vorgaben für Eurocodes wurde der EC 3 als anwenderfreundliches Instrument für praktisch tätige Ingenieure entworfen. Den Erfolg dieser Bemühungen belegt ein Bericht über vergleichbare Bemessungsstudien. Einige wichtige Merkmale für den leichteren Gebrauch werden beschrieben. Ferner werden verschiedene Bemessungsmittel erwähnt, darunter zwei vereinfachte Versionen der Norm.

1. INTRODUCTION

The ultimate purpose of any design standard must be to serve as a tool for the practical structural engineer. Today a modern Euro-Engineer will recognise the need for:

- Limit States philosophy, practically applied
- Computer Aided Design, in appropriate cases
- a personal Data Bank to access relevant criteria, from the wealth of information available
- procedures for design and for execution, strictly governed by Quality Assurance criteria

It is against this background the new Eurocodes should be judged.

2. CONTENT AND SEQUENCE

The design sequence adopted in EC3 seems to be both sensible and realistic for practical application : first the basic assumptions and general structural analysis, then verification of sections and of member stability, finally connection design. This suits both the organization of work in the design office and the presentation of formal calculations for approval.

All generally recognised methods of analysis are permitted, under adequate safeguards, including plastic and elastic-plastic methods, thus setting designers free to choose what is most appropriate to a given situation. Similarly all types of joint, including semi-rigid, are permitted, provided that the details are consistent with the design assumptions. Practical and robust structures are encouraged by the explicit recognition of the need to consider practical tolerances in construction. Straightforward rules include such considerations in the structural analysis, and these rules are linked to the specification of reasonable but strict tolerances. These tolerances are outlined for designers in the EC3 Chapter on Fabrication and Erection and then expanded in detail in the forthcoming companion CEN Standard "Execution of Steel Structures".

Recognition is given to the practical role that may be played by testing of actual full-scale components in appropriate cases. However the need for testing of prototypes is an exception and for general routine work the traditional practice of design by calculation alone is retained.

The inclusion of a Chapter on Fatigue in Part 1 of EC3 arises from its dual role, comprising General Rules as well as Rules for Buildings. EC3: Part 1 is intended to be complete only for Buildings, but its contents are also intended to be valid, whilst not necessarily complete, for any other structures such as bridges, towers or silos. It is not intended to imply that buildings generally need a fatigue check, but rather it is provided for use in those limited specialised cases where fatigue may be a relevant design criterion. The Fatigue rules are in Part 1 because they apply to all types of structure. The subsequent parts of Eurocode 3 will cover in detail any additional rules that are specific to particular types of structures.

3. PRECEDENTS

Whilst EC3 itself has only recently become available, (though the work started 15 years ago and various drafts have circulated), a major source for its technical contents has been the pre-normative work represented by the long-range activities of the ECCS Technical Committees, as well as the pioneering pre-harmonisation of the ECCS Recommendations, originally addressed to national code-writing bodies but in the event the fore-runner of this European Standard.

The ECCS Recommendations were in fact published in 1978 and were discussed both before and after that date in various international meetings. The involvement of Engineers from the industry in all ECCS activities, along with researchers and academics, has served to ensure that the resulting design rules are useable and lead to practical solutions.

Similarly the influence on a worldwide scale of the Structural Stability Research Council (SSRC) can be detected within the contents of Chapter 5 Ultimate Limit States, albeit with a European rather than an American flavour.

The only real deficiency is the temporary absence of many of the CEN Reference Standards needed for the application of EC3. As an interim measure this has been covered by the National Application Documents (NAD) issued to permit the trial use of the ENV version of EC3 : Part 1. These give alternative equivalent national standards and also specify the required national values for the partial safety factors.

4. CALIBRATION AND TRIAL CALCULATIONS

The calibrations to determine recommended "boxed" values for the partial safety factors are a topic for another contribution. However at least in some cases comparisons with existing practice in various countries were also made, in collaboration with ECCS Technical Committees.

Useability aspects were also checked by trial calculations. Some were ad-hoc, but at the public enquiry stage some countries carried out complete design examples which were also compared to the use of their national codes.

Considerations of completeness and useability were the principal topics for complete design studies carried out as the final editing of EC3 progressed, by CEDIC, the then existing organisation of Consulting Engineers for the EEC countries, now superseded by EFCA which also covers the EFTA countries. A number of recently completed buildings in a variety of countries were chosen and the design was re-checked according to EC3. These buildings were selected so as to be reasonably challenging in terms of testing the availability of appropriate code provisions, whilst also being reasonably representative of best modern practice.

The development of CEDIC's reports on these studies interacted with the development of the final editing of EC3, so that comments made in their initial report were found to have already been acted upon, in terms of code improvement, by the time the final report [1] was prepared. Thus the final conclusion could be reached that EC3 is "sufficiently clear, transparent and comprehensible for practising engineers".

One result of this has been that the National Application Documents for the trial use of the ENV version of EC3 Part 1 mostly call for only marginal variations to the recommended "boxed" values of the partial safety factors. There is thus real hope that harmonised values can eventually be achieved by voluntary agreement, after the EC1 harmonised loadings are available.

A further testimony to the practical nature of EC3 is the adoption of large portions of its contents into proposed new versions of national standards, both in Switzerland and in the Netherlands.

It would of course be foolish to suggest that any new code is perfect or not capable of further improvement. The drafters of EC3 are at least as conscious as anyone else of the need for review. The 3 year ENV period offers the possibility of extensive trial use in practical design situations. It is greatly to be hoped that practising designers will take advantage of this opportunity to try out EC3 in current design work and to feed back their experience (whether good or bad) with any suggestions for improvements.

5. USEABILITY ASPECTS

The CEDIC report also expressed satisfaction with "the division....(of the text)....with some of the extensive calculation procedures presented as annexes". This has been adopted for certain aspects which are not necessarily applicable to every design, in order to aid the clarity and ease of locating the relevant basic requirements. This has proved to be such a practical feature that it has been suggested it could be taken even farther, for example by moving "Built-up members" into an annex, and perhaps this will be considered at the next stage of development.

A similar motive of improving useability, by keeping lengthy detailed procedures out of the main text, has led to the use of "Figures" containing text and formulae as well as diagrams (or even without any diagrams) to describe the necessary provisions, such as those for "average yield strength" of cold-formed hollow sections or for "stabilizing forces" in bracing systems. This too is an editorial device which could perhaps be used even more extensively in the future development of this — and maybe other — Eurocodes.

The detailed Application Rules necessary to develop the Principles of economic joint design for semi-rigid beam-to-column connections and for the connections of tubular ("hollow section" members are particularly extensive. In the case of beam-to-column connections, tabulated "Procedures" have been introduced to clarify exactly how the various checks are intended to fit together into a logical and efficient sequence of design steps.

In the case of tubular connections, tables illustrated by sketches have been used to list the design expressions relevant to various cases. This recognises the ability of designers to identify the item they require more readily by reference to sketches. A comparable approach has also been adopted for the determination of "detail categories" for Fatigue, where the appropriate table is selected by reference to the title, but the numerical values are selected by reference to sketches, amplified by descriptive text.

An aspect which should add to the useability of this code compared to others, once designers gain familiarity with its novel features, is the inclusion of a specific method for examining the adequacy of a bracing system in terms of both its resistance to stabilizing forces and its stiffness, including the influence of this stiffness on the magnitudes of the stabilizing forces to be resisted and the effects of external loads on the efficiency of the bracing system.

Other features that may be considered as useful, depending on which other code the Eurocode is compared with, include the following provisions:

- simple alternative method for load combinations
- alternative method for resistance of a fillet weld
- economic alternative method for shear buckling resistance
- guidance on choice of steel quality to avoid brittle fracture
- specific fabrication and erection tolerances
- guidance on slip resistant connections with high strength bolts

All these aspects, plus several of the features of EC3 already mentioned, including systematic treatment of frame imperfections, choice of analysis methods, procedures for connection design etc, are listed as potential advantages for the designer in the CEDIC report. Of course there is more still that could be done, as in any code, but the needs of the user have been a major consideration throughout the preparation of Eurocode 3, within the constraints of the agreed style and format, the need to adopt common Chapters in all Eurocodes and the editorial rules of CEN.

6. SIMPLIFIED VERSIONS

6.1 Introduction

Several people, including the writers of the CEDIC report, have identified the need for measures to assist the introduction and acceptance of the Eurocodes into everyday design practice. Whilst the comprehensiveness and freedom of choice for the designer are welcomed, the need is seen to give simple guidance on the appropriate methods to adopt in common cases, at least until designers become more familiar with those options and features that are novel for them.

6.2 Essentials of Eurocode 3

The ECCS have published a shortened version of EC3, together with additional tables and other practical information and design aids, in their publication No 65, "Essentials of Eurocode 3 : Design Manual for Steel Structures in Building" (E-EC3) [2]. It is intended as a design aid to facilitate the use of EC3 : Part 1 during the ENV period, and contains only those rules "that are likely to be needed for daily practical design work". This has led to the omission of plastic analysis, second-order analysis and semi-rigid joints. As an ECCS document, although produced initially in English, it is written on a pan-European basis; remaining as general as possible, but giving lists of "boxed" values extracted from available NAD's.

E-EC3 is intended to be used by designers who have studied at least the relevant portions of EC3. It is intended to serve as an aide-memoire both for the essentials of the Eurocode provisions themselves and for other necessary design information, including tables and figures which can be treated as "deemed to satisfy" the rules of EC3. In all cases of doubt, or for items not covered, EC3 and the relevant NAD must be consulted. E-EC3 is not intended to be used independently of the Eurocode itself.

6.3 Concise Eurocode 3

"The Concise EC3" (C-EC3) [3] is a different type of simplified version published by The Steel Construction Institute (SCI). It has a number of features in common with E-EC3 and the two drafting groups worked in close collaboration. The emphasis is however different, in that C-EC3 is a shortened version of EC3, limited in its scope to cover only those types of building structures that can currently be designed using a modern national code. It excludes frames where second-order analysis is necessary and does not cover elastic-plastic analysis or semi-rigid joints.

The C-EC3 is a self-contained, stand-alone design code. Its purpose is to introduce designers to the provisions of EC3 by building on familiar ground. Within its own more limited scope it can be used independently of EC3, yet it will produce designs that also comply fully with the Eurocode itself. However it is not intended as a complete substitute for EC3 and direct reference to the Eurocode will be more appropriate in cases where the need for maximum economy warrants the use of the most refined available approach.

The initial version of the Concise version, like the Essentials, has been produced in English; unlike the ECCS document the initial version of the SCI document is tailored specifically for designers in the UK. It incorporates all the requirements of the UK NAD as well as the values for all the boxed values applicable to buildings to be constructed in the UK. It is intended to also produce versions for use in other countries, depending on demand and other logistic considerations.

The Concise version contains only design rules, presented in easy-to-use form, but not design guidance or design aids as such, as these will be available separately. To maximise the ease of transition for designers currently accustomed to British Standards, the Eurocode wording has been modified. However the Eurocode symbols and axis conventions have been adopted.

Some of the clauses have been re-sequenced; in particular in Chapter 5, the main design chapter, the clauses have been grouped according to type of member (beams, columns etc) as in a British Standard, rather than according to phenomenon (cross-section yielding, member buckling etc) as in Eurocode 3. Generally however the C-EC3 follows the sequence in which topics appear in EC3 in order to help users to become more familiar with the Eurocode. It is hoped that as familiarity and confidence increase, users of the C-EC3 will soon wish to progress to the full EC3 in order to take advantage of its more advanced and economic methods in appropriate cases.

A number of user-friendly figures and tables have been included giving ready-reference values, as in a British Standard, such as strut buckling stresses corresponding to the normal slenderness ratio ℓ/i. Such values do of course need to be specific to each strength grade of steel and even though only two grades are included, the resulting tables are fairly voluminous (which is why a more compact treatment is used in EC3), but are liked by designers, at least in the UK.

7. DESIGN AIDS

For the cost-effective application of any set of design rules, various tables and other types of design aids are generally agreed to be important for efficiency. Traditions vary even within one country, and particularly between countries. However the following hierarchical list of possible design aids is probably fairly representative of an acceptable set of design documents:

- Simple code for everyday design [E-EC3 Essentials or C-EC3 Concise EC3]
- Design Guides for Buildings [Various Design Guides]
- Design Aids for Beams, Columns etc. [Design tables and charts]
- Section Dimensions and Properties [Tables of dimensions and properties]
- Design Examples [Simple, complete and practical examples]
- Explanatory Commentary [Background Documents etc]
- User's Handbook [Design manual]
- Design Textbooks [Educational material based on the Code]

Most, if not all, of these are already available or soon will be, at least in some countries. Design examples have been prepared by ECCS, CIDECT and SCI and the other usual national sources. In addition international teams have been collaborating on the production of user-friendly design software. The fact that EC3 has been found amenable to the production of all these documents and computer programs is a further indication that even at the present ENV stage it is a well-ordered document, well suited for use by practical structural engineers.

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