Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 37 (1982)

Artikel: Fatigue design concept of the ECCS

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DOI: https://doi.org/10.5169/seals-28889

Fatigue Design Concept of the ECCS

Concept du dimensionnement à la fatigue de la CECM

Konzept des Ermüdungsnachweises gemäss der EKS

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SUMMARY
The scope and aims of the European Convention for Constructional Steelwork (ECCS) are indicated, its technical activities are outlined, the interactive efforts with other organizations and its contribution to the development of Eurocodes 1 and 3 are shown. The main portion of the paper is devoted to describe the major options retained for the ECCS Recommendation for the Fatigue Design of Structures: stress range concept, parallel S-N curves, cumulative damage rule, fatigue load models for highway and railroad bridges, safety concept.

RESUME
Cet exposé résume les différents domaines d'activité de la Convention Européenne de la Construction Métallique (CECM), ses buts, ses activités techniques, ses actions réciproques avec d'autres organisations et sa contribution au développement des Eurocodes 1 et 3. La majeure partie de l'exposé est une description des principaux paramètres retenus dans la Recommandation de la CECM, soit: différence de contraintes, courbes de résistance à la fatigue parallèles, lois du cumul des dommages, modèles de charges pour ponts-routes et ponts-rails, concept de sécurité.

ZUSAMMENFASSUNG
Umfang und Ziele der Europäischen Konvention für Stahlbau (EKS) sowie ihre technischen Tätigkeiten, die interaktiven Bemühungen mit anderen Organisationen und ihr Beitrag zur Entwicklung von Eurocode 1 und 3 sind dargestellt. Im weiteren werden die wesentlichen Parameter umschrieben, welche für die EKS Empfehlung gewählt wurden: Konzept der Spannungsdoppelamplitude, Parallelität der Ermüdungsfestigkeitslinien, kumulative Schädigungshypothese, Lastmodelle für Strassen- und Eisenbahnbrücken, Sicherheitskonzept.

1. SCOPE AND AIMS OF ECCS

Founded in 1955, on the initiative of Switzerland and France, the European Convention for Constructional Steelwork comprises at present, 15 European member countries and two non-European associate member countries, Japan and the United States of America.

Among its aims, which were defined in its constitution over a quarter of a century ago, the most important are :

- the undertaking of common research and investigation leading to the publication of results in a form directly applicable by designers and structural steel manufacturers for the advancement of the steel construction industry,
- the preparation of recommendations and guidelines with a view to an international harmonisation of standards and codes in the field of steel construction,
- the promotion of coordination and co-operation with other European and international organisations concerned with construction, standardisation and testing of materials.

Since its very beginning, the ECCS has worked on technical matters relevant to the quality, safety and economy of steel construction. This still constitutes the main part of its activity today.

Among the main considerations that have guided ECCS activities are :

- the conviction that technical progress leading to up-to-date methods of design and fabrication is the key to efficient and economic structures,
- the awareness of the need for international, unified rules in view of the increasing inter-penetration of markets,
- the wish to put together the experience, knowledge and working capacity of experts from various countries in order to obtain the most rational recommendations in the field of structural design.

In this perspective technical committees and working groups have been formed to deal with specific subjects. Their members are experts chosen from the professions, the academic or research world and in many cases, government departments. These committees have always worked together most successfully and responded to the demands of our time.

It would not be in line with the theme of this Colloquium to give a complete description of the activities of ECCS in the technical field. Therefore, only a few of its main objectives and achievements shall be mentioned before presenting the ECCS involvement and activity on fatigue.

2. TECHNICAL ACTIVITIES OF ECCS

The following lists the ECCS Technical Committees that are actively dealing with structural problems and related matters :

TC1	Structural Safety
TC2	Aluminium Alloy Structures
TC3	Fire Safety
TC6	Fatigue
TC7	Cold-Formed Thin-Walled Sheet Steel in Buildings
TC8	Structural Stability
TC10	Bolted and Welded Connections
TC11	Fabrication and Erection
TC12	Wind
TC13	Seismic Actions

As an example, the field of structural stability, which is of fundamental importance for the study of steel and other metal structures may be mentioned. To put an end to the enormous discrepancy which existed between the column curves of various countries, a large experimental (more than 1'000 columns) and theoretical research programme was carried out by TC8 with the aim of obtaining the best possible unified treatment of the problem. The results were presented at the International Colloquium on Column Strength, sponsored by IABSE, ECCS, CRCJ and SSRC, in Paris in 1972 [1] and in the Introductory Report to the Second International Colloquium on Stability [2] Tokyo 1976, Liège, Washington, Budapest 1977). Three noteworthy aspects of the whole research, that are also common to other ECCS programmes, are :

- for the first time a probabilistic approach has been adopted for a major experimental investigation on structural stability,
- the strict international co-operation between laboratories of eight countries under the supervision of the ECCS Technical Committees,
- the success of the whole co-operation as shown by the improvements in most national codes.

The ECCS technical activities have also covered certain fields that are not specifically related to steel structures, but nevertheless relevant to structural design. The best example is the preparation and the publication of "The Recommendations for the Calculation of Wind Effects on Buildings and Structures" [3] which is a most up-to-date document on this matter. It contains a specially studied wind map of Western Europe, which ignores national borders, as wind does, and has a full set of aerodynamic factors. An ISO Recommendation on wind loading, currently under preparation, follows closely this Recommendation, as do various National Standards also under preparation.

These two examples, stability and wind, illustrate the type of activities of ECCS and their influence upon national and international codes or recommendations.

Most of the studies carried out by ECCS have been included in the "European Recommendations for Steel Construction" published in 1978 [4] in the format of a practical code with commentaries on each article. These recommendations had a great influence on the preparation of many national codes and formed the basis of the "European Code for Steel Construction" (Eurocode 3). This has been prepared in the framework of the harmonisation of codes for structural design promoted by the Commission of the European Communities. In connection with this I would like to mention another ECCS publication "Composite Structures" [5] prepared in the format of a model code by a Joint CEB, ECCS, FIP committee which will certainly be the major reference for the "European Code for Composite Construction" (Eurocode 4).

3. ECCS RECOMMENDATION FOR FATIGUE DESIGN

The 1978 ECCS Recommendations [4] covered only statically loaded structures. A great effort with regard to fatigue was therefore still necessary on a European level to include bridges, crane girders, and other structures subjected to fatigue. A new technical committee, TC6 "Fatigue", was founded in 1979 under the chairmanship of Prof. Dr. Manfred A. Hirt, Switzerland. The task of this committee is to harmonize the available modern concepts, to have a common set of rules applicable to various types of structures and to have a philosophy of safety in line with statically designed structures.

When this new committee started its work, a first proposal [6] was already available that had been prepared by committee TC9 "Welded Connections". This proposal was restricted to welded elements, but it included the results of much of the modern research. It had not yet obtained general acceptance mostly because of a large discrepancy in the state of knowledge and historically motivated differences in points of view of some member countries.

Committee TC6 has already come up with a new proposal [7] retaining many ideas of the previous document, adding new elements, and taking advantage of the progress achieved in other organizations, such as UIC, IIW, and a few national codes. This international co-operation, which is instrumental from the point of view of achieving harmonization, acts mainly as a means to dispense information on an international level. All this ensured that the new document [7] would achieve wide acceptance. In addition, it was the basis for the chapter on fatigue incorporated in the first draft of Eurocode 3 [8].

3.1. Scope and goals of the fatigue recommendation

The aim of the fatigue recommandation is to give detailed information not only on the fatigue strength of welded and bolted structural details but also to include a basic safety concept as well as load models that can be used for general fatigue evaluations. It is obvious that this is a very ambitions intention since not all information needed is available to date. Therefore, the recommendations are divided in two distinct parts : the basic chapters and the appendices. The chapters contain the major rules and clauses based on generally accepted concepts where as the appendices provide detailed information and numerical values. These appendices may be adapted more easily and more rapidly with improved knowledge.

It is beyond the scope of the present paper to describe in detail all clauses of the ECCS Recommendations for fatigue design, so only some of the basic concepts shall be mentioned. Much input information was obtained from References [9] [10] [11], as well as from various working documents prepared by members or guests of Committee TC6.

It might be interesting to add that committee TC2 "Aluminium Structures" participates actively in the preparation of these fatigue recommendations through its TWG 2.4. The main purpose of this co-operation being to adopt, as far as possible, the same concept for aluminium structures.

3.2. Constant amplitude fatigue strength

After almost a century of research in this field, it was only around 1970 that, for the first time, the results of statistically evaluated test data of a comprehensive study were published [12]. These were immediately introduced in some USA specifications. The results were based on beam tests and provided a new insight into the fatigue strength of structural elements. In particular, it was found that :

- stress range is the governing parameter for the fatigue life of structural details,
- the type of structural detail used is of prime importance for the fatigue strength,
- minimum stress, stress ratio, and even grade of steel do not significantly affect the fatigue strength, in the vast majority structural applications.

In the wake of these findings, many analyses and re-analyses of the USA and additional European data yielded similar fatigue strength curves. Everybody believed his curves to be the true ones and it became readily apparent that no harmonization was possible. It is to the merit of Prof. Siebke to have proposed, mostly through his work in the UIC code writing, a different approach : define a set of equidistant fatigue strength curves which can accommodate fatigue test data as well as national differences of workmanship or even interpretation or classification of structural details.

At the present time, the curves shown in FIGURE 1 are proposed to become the "European Fatigue Strength Curves" similarly to the buckling curves. It is most fortunate that IIW [12] has opted to include these same curves, permitting thus an international agreement.

The classification of the structural details has yet to be finalized and will probably follow quite closely the proposal by IIW. However, it is the aim of ECCS to show the structural details in such a way that the designer realizes rapidly whether a detail is good or bad, and what corrective measures have to be taken to improve a bad detail. The structural details will be grouped as welded or non-welded and the former divided into non-load and load transmitting welds. Such a presentation is schematically shown in FIGURE 2. In short, the designer should be motivated to design and not to go into extreme lengths of sophisticated computations.

3.3. Cumulative damage rules

It is proposed that stress-time histories be evaluated using Rainflow counting or any other method which permits adequate definition of stress ranges. Cumulative damage is calculated according to Palmgren-Miner's rule and based on the fatigue

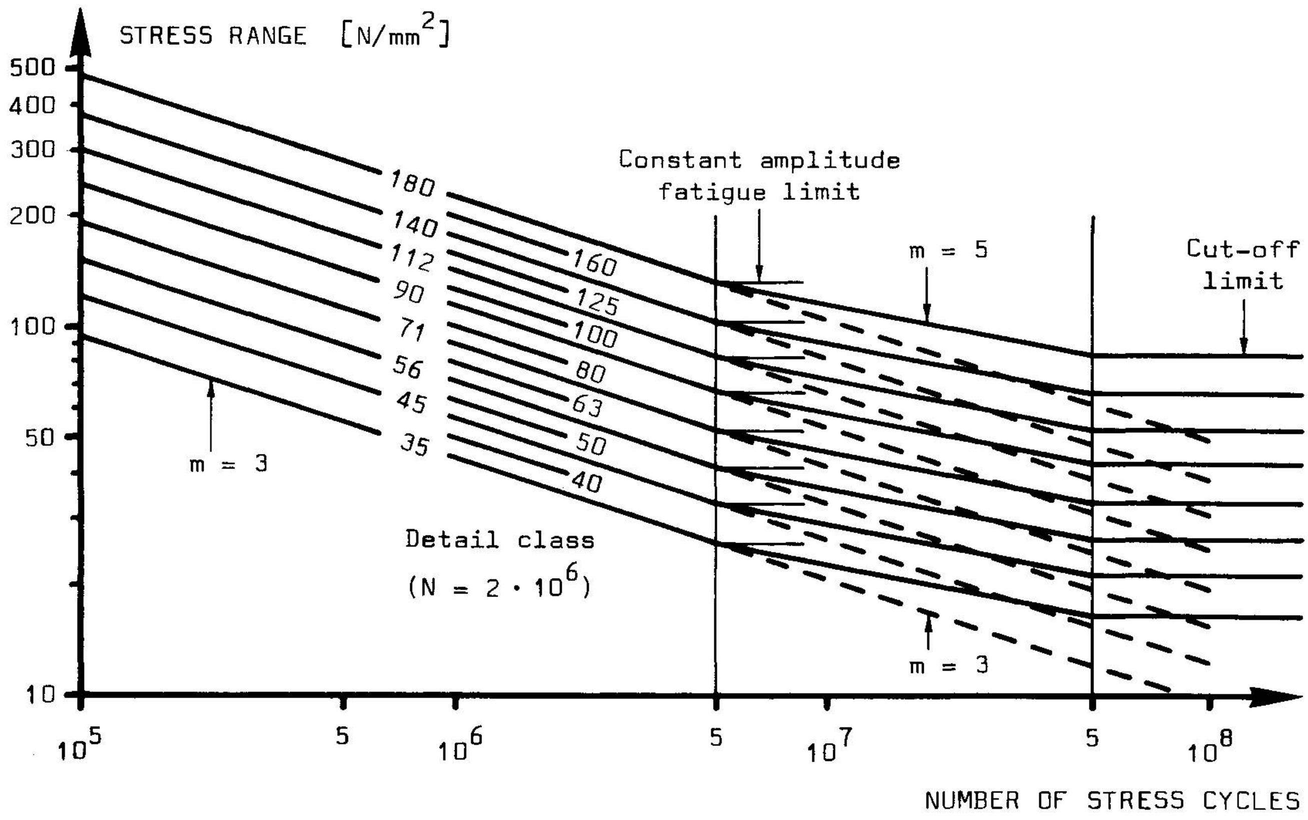

FIGURE 1 : ECCS proposal for "European Fatigue Strength Curves" representing mean minus two standard deviations [7].

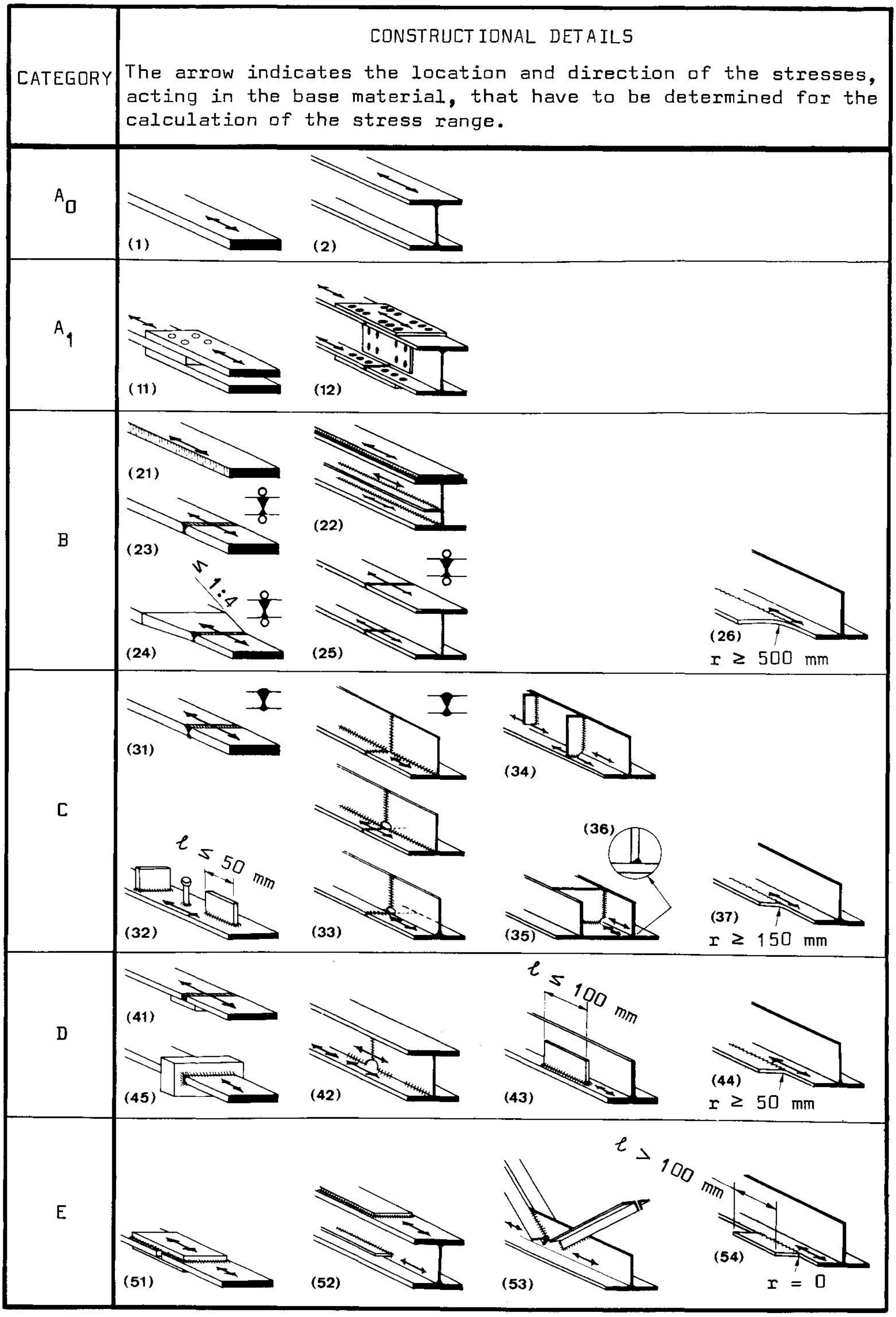

FIGURE 2 : Example for the classification of typical constructional details in fatigue categories [10].

strength curves defined in FIGURE 1. One should note that the fact of having parallel lines greatly simplifies the designer's work.

If all stress cycles fall below the fatigue limit, it is assumed that no fatigue damage will occur. When the spectrum is such that a part of it lies above the fatigue limit, three approximations are possible :

1.- A simplified approach, being on the safe side, which disregards the fatigue limit and uses fatigue curves extended below the limit.

2.- A modified curve, having a slope of 5, below the fatigue limit, which may be used for this part of the spectrum.

3.- Fracture mechanics methods may be used.

It should be stressed that fatigue strength and cumulative damage are only a part of the problem and thus the simplifications given are acceptable. This becomes even more obvious when considering all the other assumptions with regards to loads and impact factors.

3.4. Fatigue loads

The description of loads has long been a neglected part of fatigue codes. In fact, much more research has been done, and is still being done, to establish strength rather than investigating loads and load effects. This, incidentally, is equally true for statically loaded structures. Nevertheless it seems possible to describe generalized load models for railway bridges, highway bridges and crane gantry girders, among others. More information on this will be provided in other sessions of this Colloquium.

It should be recognized that it is much more sensible to define loads and load models instead of directly imposing stress range spectra. In fact, a given load, say a train, will cause completely different stress spectra when crossing long or short span bridges. Thus for any given bridge, different stress spectra will be obtained for different structural elements. The same is true for highway bridges where sometimes the total vehicle weight, or the axle loads, or a combination of both become dominant.

All this does not imply that the engineers have to calculate stress spectra in all circumstances. It is feasible to give standard correlation functions for typical influence lines of typical structures based on standard statical analysis. This work can be done, and has been done, in different national codes [9] [10] and the results are available.

3.5. Safety concept

This is probably still the most difficult problem of modern fatigue codes. Much research has recently been done in the fields of safety and reliability of statically loaded structures. However, only a little information is available for structures under fatigue loading. Early attempts to solve the problem have used statistical distributions of equivalent stress ranges and fatigue strength. Recent studies should provide us with additional information to specify numerical values for load and strength factors applicable for fatigue design.

4. CONCLUSIONS

The present draft of the ECCS fatigue recommendations [7] will be modified in some details. However, the main concept can probably be retained since it represents a general concensus of most of the advanced research groups and code writing bodies. ECCS would like to express its thanks to all national and international organizations for their willingness to co-operate and to harmonize their concepts. Special thanks are extended to the many persons inside and outside of ECCS who have spent much time and effort to improve the quality of the recommendations. It is hoped that the final draft will be available by the end of 1982.

It is of prime importance that Europe is not flooded with a multitude of different, or different looking codes, edited by various groups or organizations. The task of design engineers, working at home or abroad, has to be simplified. One way of achieving this goal is to give one, and only one set of rules. We hope that IABSE may continue to provide an adequate platform for discussion which will eventually lead to the desired harmonization.

REFERENCES

[1] International Colloquium on Column Strength, Proceedings. IABSE, Zurich, Reports of the Working Commissions, vol. 23, 1975.

[2] Second International Colloquium on Stability, Introductory Report. ECCS, Brussels, 1976.

[3] Recommendations for the Calculation of Wind Effects on Buildings and Structures. ECCS, Brussels, 1978.

[4] European Recommendations for Steel Construction. ECCS, Brussels, 1978.

[5] Composite Structures, ECCS. The Construction Press, London, 1981.

[6] European recommendations for the design, fabrication and inspection of welded steel structures with fatigue loads. ECCS TC9, Brussels, 1978 (draft).

[7] Recommendations for the fatigue design of structures. ECCS TC6, Brussels, 1981 (second draft).

[8] European Code for Steel Construction, Eurocode 3. Commission of the European Communities, Brussels, 1981 (draft).

[9] Steel, concrete and composite bridges. BS 5400, Part 10 : Code of practice for fatigue. BSI, London, 1980.

[10] Swiss Standard SIA 161 : Steel structures. SIA, Zurich, 1981.

[11] Design recommendations for cyclic loaded welded steel structures. IIW, Paris, Document JWG-XIII-XV-53-81, 1981.

[12] FISHER, J. W. et al. Effect of Weldments on the Fatigue Strength of Steel Beams. NCHRP Report 102, Highway Research Board, Washington D.C., 1970.