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EC 4: Relationship to Eurocodes 1, 2 and 3

EC 4: Lien avec les Eurocodes 1, 2 et 3

EC 4: Beziehung zu den Eurocode 1, 2 und 3

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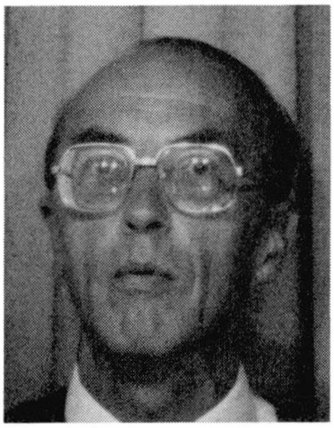

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SUMMARY

Eurocode 4 Part 1.1 has many relations with Eurocodes 2 and 3. These relations are numerous and very complex, both technically and editorially. For chapter 1 the main problems were editorial. In chapter 2 the specific aspects of composite structures resulted in some rules additional to the model clauses, and others adjusting the reliability format. Chapter 8 was established in accordance with a draft Part 1 B of Eurocode 2. Annexe A dealing with reference documents is very provisional.

RESUME

L'Eurocode 4 (Partie 1.1) est principalement lié aux Eurocodes 2 et 3. Ces relations sont nombreuses et très complexes, techniquement aussi bien que rédactionnellement. Pour le chapitre 1 les principaux problèmes étaient rédactionnels. Dans le chapitre 2 les aspects spécifiques des structures mixtes ont donné lieu à des règles additionnelles aux clauses modèles, et à d'autres règles ajustant le format de fiabilité. Le chapitre 8 fut établi pour être en accord avec un projet de Partie 1 B de l'Eurocode 2. L'annexe A traitant des documents de référence est très provisoire.

ZUSAMMENFASSUNG

Eurocode 4, Teil 1.1 ist hauptsächlich mit EC 2 und EC 3 verknüpft, wobei die Bezüge technisch als auch editorisch zahlreich und kompliziert sind. Im Kapitel 1 waren sie vor allem editorischer Natur. Im Kapitel 2 verlangten die Besonderheiten von Verbundtragwerken einige zusätzliche Regeln im Vergleich zu den Musterparagraphen und Anpassungen der Zuverlässigkeitskriterien. Kapitel 8 wurde in Übereinstimmung mit dem Entwurf von EC 2, Teil 1 B aufgestellt. Der Anhang A über Referenzdokumente ist noch rudimentär.

1. RELATIONS WITH EUROCODES 1, 2, 3

The obvious need of consistency throughout the set of Eurocodes has been particularly important and critical for EC 4. Its critical character resulted from the fact that EC 2 and 3 (Parts 1.1) were not totally consistent together on a series of details and remained under revision up to the end of 1991. These difficulties were a supplementary reason for publishing the Eurocodes first as ENV.

Since the beginning of the work on EC 4, EC 1 has been deeply modified in its scope (see the reports on EC 1). This had however no consequence on EC 4 Part 1.1 because the reliability format has not been modified. At present the only references made by EC 4 to EC 1 are for the representative values of actions and have a general character, and in clause 2.2.5 for an application rule on simple load arrangements which maybe will be finally transferred to EC 1.

The relations with EC 2 and 3 are much more complex. Only the main or most typical examples are given below.

There were first some minor numerical discrepancies which, although identified rather soon, could not been avoided at the ENV stage :
- the modulus of elasticity of steels E_s was 210 GPa in EC 3 (the most precise value) and 200 GPa in EC 2 (a simple value chosen for a property that is not identical for all steels) ; 210 GPa was chosen for EC 4
- the thermal expansion coefficients were also different for the various steels and for the concrete ; simple values were chosen for these minor coefficients in EC 4.

More difficult was the fact that EC 2 and 3 did not refer to the same degree of plastification in bending nor to identical types (and terminology) of structural analyses (see the report on chapter 4).

It has still to be mentioned that the Chapter 8 of EC 4 on floors with precast concrete slabs had to refer not to Part 1.1 of EC 2, but to Part 1B which was still under discussion at the end of 1991.

2. CHAPTER 1 OF EUROCODE 4

As for most of the ECn Part 1.1, this introductory chapter is based on a model text established by the past Coordination Group. Only what is specific for EC 4 is mentioned below.

The clause 1.1.2 is very specific and mainly deals with two problems :
- what are the status of the various Annexes ? This question will become very important only at the EN stage. It was however already carefully considered, first to clarify it as a guidance for the experimental uses of EC 4 as ENV, and also to provide a serious

basis of discussion for the transformation of EC 4 into an EN. This revision will obviously have to take also into account the consequences of further events
- what is not covered by the present version of EC 4 ? This is important for a complete understanding of the content and for contractual uses of this EC. The contractual importance will increase at the EN stage (application of the European Directive 89 440 on contracts for public construction works).

The clause 1.4.2 which supplements the common clause 1.4.1 by the special terms used in EC 4 Part 1.1 is rather developed for two reasons :
- there should be adopted, commonly after selection, a series of terms coming separately from EC 2 and 3. As mentioned in an ENV Note, a better consistency across EC 2 and 3 has still to be achieved on the denomination of the various types of analyses
- a composite structure is more complex than a concrete or steel structure and even than both together, as well because it needs supplementary elements and concepts (relating especially to shear connection and connection of members), as because its construction process (propped or not) usually has various consequences on the design.

We strongly recommend to use carefully the Eurocode terminology in applications and discussions, in order to avoid misunderstandings. The clause 1.6 finally, dealing with symbols, had to establish a consistent set of symbols starting from EC 2 and 3. This harmonization was not a very difficult task, but the result shall be considered as intended only for the applications of EC 4 Part 1.1 because the limited contents of the alphabets do not make it possible to envisage a complete and unique set of symbols for all ECs. For example the subscript p is used in EC 4 Part 1.1 for profiled steel sheeting while in EC 2 it is used for prestressing steel.

3. CHAPTER 2 OF EUROCODE 4

For this chapter also, which deals with basis of design and is based on a model text, only what is specific for EC 4 is mentioned below.

Clause 2.2.1.1 mentions limit states relating to the shear connection, and clause 2.2.1.2 requires the identification and consideration of specific transient situations during the construction process.

Clauses 2.2.2.1 and 2.2.2.2 require to take into account the action of the shrinkage of the concrete and classify its effects (with the effects of temperature differences, if relevant), as primary and secondary, having different consequences in the verifications.

At this occasion it can be mentioned that the shrinkage has generally small effects on the design of composite structures for buildings. On the other hand its magnitude depends on many parameters, some of which are not precisely known at the time of the design and (this is operationally worse) are different from one member to another. Finally its effects are blurred by the effects of temperature differences which are still more imprecisely known. For this reason, and as confirmed by a long and wide practice in several countries, simplified rules including modular ratios have been included in Chapter 3 (clauses 3.1.3 and 3.1.4.2) for the shrinkage and also, for the same reasons, for the consideration of the creep, to be used freely in common cases. It is hoped that the text is flexible enough to be considered as an acceptable compromise between very various national opinions in this respect.

For the static equilibrium EC 3 has been recently modified : the associated $GAMMA_F$ factors have been proportionally increased in order to make it possible to include a resistance as a complement in the limit state equation. The Project Team has considered this modification as useful and has introduced it in EC 4 (clauses 2.3.2.3 and 2.3.3.1). It shall however be recognized that no set of constant GAMMA, factors can be fully appropriate for the treatment of all static equilibria which can be very various.

The most difficult problems were met for the format of $GAMMA_M$ factors, their conditions of use and their numerical values. This first results from the fact that, for sound technical reasons, there are substantial discrepancies between the corresponding rules given in EC 2 and 3.

In the most general case a material factor $GAMMA_M$ given in ECs may be subdivided into several partial factors, as

$$GAMMA_M = GAMMA_{Rd}\ ETA\ GAMMA_m \quad \text{where}$$

- $GAMMA_{Rd}$ relates to model uncertainty of a resistance R and in practice, in EC 2, covers also geometrical uncertainties

- ETA is a conversion factor (essentially for concrete) covering the difference between the strength measured on standardized specimens and the strength in the structure

- $GAMMA_m$ relates to the scattering of the strength of standardized specimens.

It can be seen that normally a design resistance should be written

$$R_d = (1/GAMMA_{Rd})\ R\ (f_k/ETA\ GAMMA_m)$$

For a steel element ETA is generally equal to 1, $GAMMA_{Rd}$ and $GAMMA_m$ should not be very different from 1 and R is proportional to f_k, which makes strong simplifications fully acceptable.

For a composite element three strengths f_{ck}, f_{sk} and f_y generally intervene in R which generally is not even a linear function of them because of the shift of the neutral axis when the forces and moments applied to a cross section vary. Consequently strong simplifications such as practiced in EC 3 are not possible in EC 4.

Further difficulties resulted from the fact that the values of $GAMMA_c$ (for concrete), $GAMMA_s$ (for reinforcing steels) and $GAMMA_a$ (for structural steel) given in EC 2 and 3 are not directly comparable together for many reasons, e.g. :

- $GAMMA_c$ given in EC 2 refers to rupture (at 28 days), refers to a partial plastification and includes a subtantial part taking into account an imprecision on the location of reinforcing bars

- $GAMMA_a$ given in EC 3 refers to the yield, refers to a total plastification and takes on various values depending on the risk of local buckling (and if relevant on the presence of bolt or rivet holes).

The values given in these ECs are also widely pragmatic.

Besides the various strengths intervene very differently in various resistances (e.g. in columns and in hogging and sagging resistances in beams). For this reason "true" values of GAMMA factors cannot exist in a code : only values acceptable within limited fields of application can be provided.

It shall be clear that the choice of the numerical values was not, at the time EC 4 Part 1 was in preparation, the main aim of the document, because at the ENV stage all GAMMA values in ECs had to be boxed which means that they are only indicative and that the decisions should be taken at the national level.

At the same time the drafting panel was not ignoring that some $GAMMA_M$ values given in EC 2 and 3 remained subjected to contests which probably will lead to further discussions. Considering this situation, the EC 4 panel did not want to make it still more confused by giving in EC 4 new values, and kept in EC 4 the $GAMMA_M$ values provided in EC 2 and 3, having only checked by referring to the pratice, that they could be considered as sufficiently safe. This judgement was later confirmed by some theoretical researches which demonstrated, in some particular cases, that in spite of the differences between steel and composite structures, the level of safety resulting from EC 4 was numerically consistent with that of EC 3.

It can still be mentioned that the $GAMMA_M$ factors to be applied to material properties other than strengths have been specified more explicitly in EC 4 than in other Eurocodes.
Finally a partial factor very important for composite structures is the $GAMMA_M$ factor to be used for shear connection.

In Eurocode 3, the partial safety factor $GAMMA_M$ for resistance of steel connections is generally given as 1.25, though there are a few exceptions. The various expressions for bolts, welds, etc., that emerged from statistical calibration were scaled up or down to enable a single value of $GAMMA_M$ to be used, for the convenience of designers.

In Eurocode 4 Part 1.1, the design resistance of a welded stud shear connector is similarly found by dividing the characteristic resistance by a factor $GAMMA_v$, also taken as 1.25 :

$$P_{Rd} = P_k/GAMMA_v$$

This is done even though P_k is in some cases proportional to the ultimate tensile strength of the material of the stud, and in others to the cylinder strength of the concrete. Thus, the factors $GAMMA_a$ and $GAMMA_c$ for concrete and steel are not used. This procedure is an exception to that described above. It reflects the complex interaction between deformation of steel and concrete that determines the resistance of a stud.

Where the influences of steel and concrete are more distinct (e.g. for block-and-hoop connectors), the usual partial safety factors $GAMMA_a$, $GAMMA_c$, and $GAMMA_s$ are used.

4. CHAPTER 8 OF EUROCODE 4

This chapter, which deals with floors with precast concrete slabs for buildings, had to be drafted at a time where Part 1B of EC 2 was far from its finalization and before the revision of ENV 206 was undertaken. It should therefore be revised before the publication of EC 4 as EN. It should be also expected that in any case its content might have to be supplemented by some specifications particular to any particular project.

The content of this chapter is solely intended for slabs to be used as or in top members of composite beams for buildings, while Part 1B of EC 2 has a more general scope. It is therefore mainly devoted to the consideration of joints between such slabs and to the consequences of the shear connection.

The numerical values of the $GAMMA_M$ factors applicable for prefabricated concrete slabs and their conditions of applicability were at this time under discussion within TC 250 SC 2. It was not considered to be appropriate to deal separately with this problem in EC 4. These values will in any case be "boxed" in EC 4 as in EC 2.

5. ANNEX A TO EUROCODE 4

This Annex, at the present stage indicative and very provisional, was intended to define the relations of EC 4 Part 1.1 with other documents which include standards but possibly also other documents (e.g. European approvals for shear connectors).

As for other Eurocodes a general difficulty resulted from the fact that most documents likely to be referred to are not available at the present time, some of them being in preparation but not yet finalized so that their full compatibility with EC 4 cannot yet be certified. The situation in this respect will widely evolve during the ENV period, and it has to be coped with by the relevant authorities through the National Application Documents, themselves having a transitory and evolving character.