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EC 2: Concrete Structures. Overview – Basic Design Concept

EC 2: Ouvrages en béton. Exposé – Principes de base pour le calcul

EC 2: Betontragwerke. Übersicht – Allgemeines Bemessungskonzept

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SUMMARY

Eurocode 2 is the main part of the European Regulation System for the design and execution of buildings and civil engineering works in plain, reinforced and prestressed concrete. The basic elements of the design concept in EC 2 are presented.

RESUME

L'Eurocode 2 constitue l'élément principal du futur système de réglementation pour le calcul et l'exécution des bâtiments et des ouvrages de génie civil en béton, béton armé et béton précontraint. Les principes de base de l'EC 2 pour la vérification des structures sont présentés.

ZUSAMMENFASSUNG

Eurocode 2 ist der zentrale Bestandteil des künftigen europäischen Regelwerks für den Entwurf und die Ausführung von Tragwerken aus unbewehrtem Beton, Stahl- oder Spannbeton. Die Hauptelemente des Bemessungskonzepts werden erläutert.

1 EUROCODE 2 AND THE EUROPEAN REGULATION SYSTEM FOR CONCRETE STRUCTURES

Eurocode 2 [1] is part of the future European Regulation System for the design of buildings and civil engineering works in plain, reinforced and prestressed concrete (Fig. 1). It is concerned with the essential requirements for resistance, serviceability and durability of concrete structures. Execution is covered to the extent that is necessary to indicate the quality of the construction materials and products which should be used and the standard of workmanship on site needed to comply with the assumptions of the design rules.

The work on EC2 started in 1979 and was originally based on the CEB/FIP Model Code 1978 [2]. A first important step was the publication a first draft for EC2 [3] in 1984, issued in form of a Technical Report. The CEC-Member States were invited to comment on it. In 1985, about 1500 pages of partly very detailed comments have been received. They were assessed in 1986 and 1987 by the Editorial Group for Eurocode 2 chaired by Professor Franco LEVI (Italy). At the end of 1989, a revised final Draft for EC2 was approved by this Group and submitted to Sub-Committee 2 (SC2) of TC250 of CEN which was formed in 1990. After a slight editorial improvement of this Draft, EC2 was issued in form of a European Pre-Standard ENV at the end of 1991 [1].

EC2 Part 1 therefore is the result of a sound discussion of more than 10 years on a European level involving numerous specialists in the specific areas. It can be therefore assumed that EC2 Part 1 reflects to a large extent the state-of-the-art in the individual CEC-Member States.

2 SCOPE OF EC2 PART 1; DEVELOPMENT OF FURTHER PARTS

EC2 Part 1 (Fig. 2) gives the *general* basis for the design of buildings and civil engineering works in reinforced and prestressed concrete made with normal weight aggregates. In addition, Part 1 gives detailed rules which are mainly applicable to ordinary buildings. The applicability of these rules may be limited, for practical reasons or due to simplifications. The use of the relevant rules and any limits of applicability are explained in the text where necessary.

In particular, Part 1 of EC2 does actually not cover

- the resistance to fire;
- particular aspects of special types of buildings (such as tall buildings);
- particular aspects of special types of civil engineering works (e.g. viaducts, bridges, dams, pressure vessels, off-shore platforms or liquid-retaining structures);
- no-fines and aerated concrete elements, and those made with heavy aggregate or containing structural steel (future Eurocode 4).

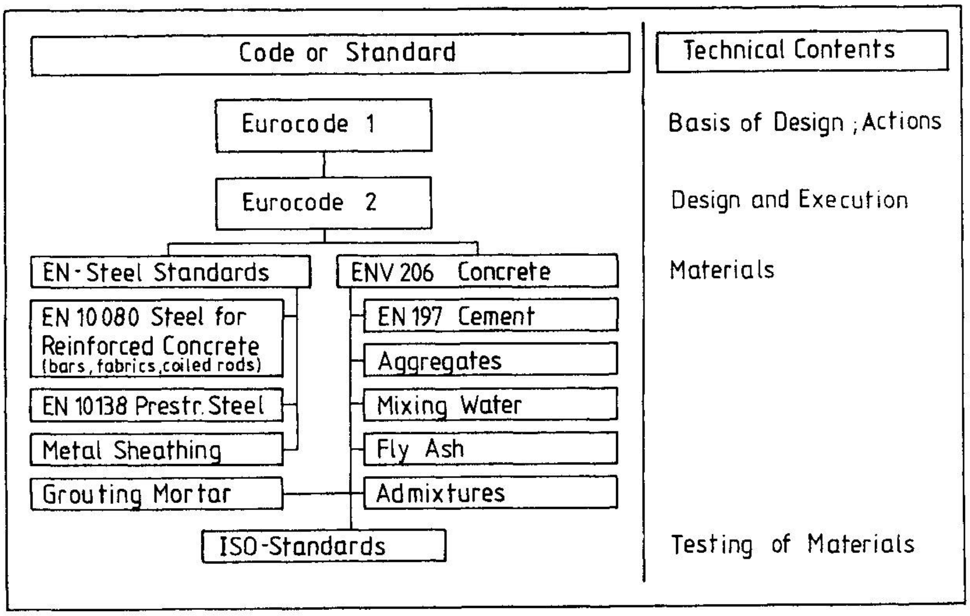

Fig. 1: Future Regulation System for Concrete Structures

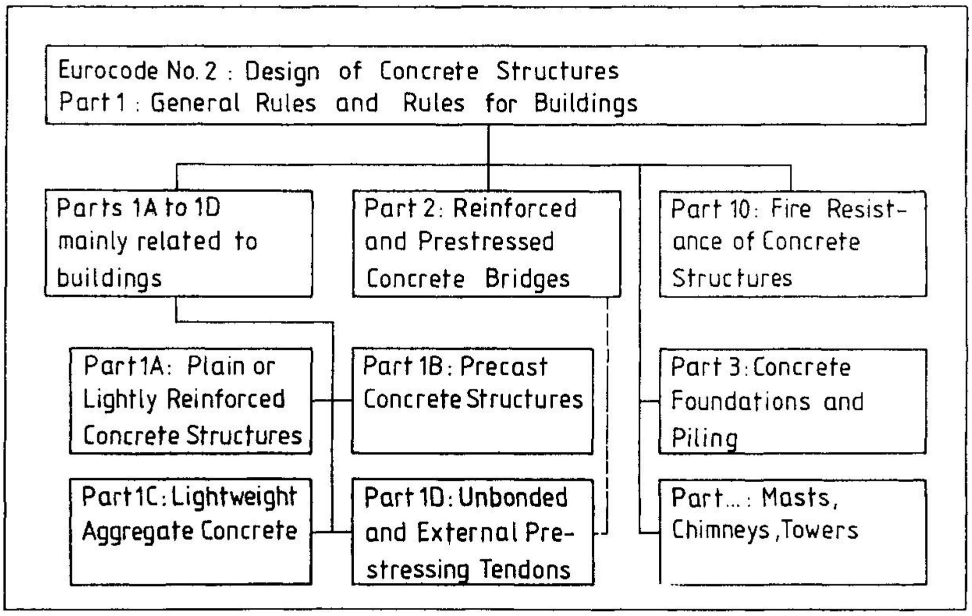

Fig. 2: Future Structure of Eurocode 2

Due to this limited scope of Part 1, EC2 will be supplemented by further Parts which will complement or adapt it for particular aspects of special types of building or civil engineering works, special methods of construction and for certain other aspects of design which are of general practical importance.

Further Parts of EC2 are actually being prepared by CEN/TC250/SC2 on the basis of mandates in the following areas (Fig. 2):

Part 1A: Plain or lightly reinforced concrete structures;
Part 1B: Precast concrete elements and structures;
Part 1C: The use of lightweight aggregate concrete;
Part 1D: The use of unbonded and external prestressing tendons;
Part 10: Fire resistance of concrete structures;
Part 2: Reinforced and prestressed concrete bridges.

These Parts will be issued in form of European Pre-Standards (ENV) in 1993 (Part 1A - 1D, Part 10) and 1994 respectively (Part 2).

High priority is given by CEN/TC205/SC2 to the following Parts of EC2 which will hopefully be included in the working programme for 1993 and 1994:

Part 3: Concrete foundations and piling;
Part 4: Containments and retaining structures;
Part X: Design assisted by testing; material related aspect

as well as a Mandate for the maintenance and further development of EC2 [1].

This demonstrates that the issue of ENV 1992-1-1 [1] is only a first step towards a harmonized European regulation system for concrete structures (Fig. 1) and futher, important steps have to follow.

3 HARMONIZATION PROBLEMS; PRINCIPLES AND RULES FOR APPLICATION; INDICATIVE VALUES

Concrete construction has in all European countries a long tradition. The result is that - even when based on the same physical model - the individual design rules and practices are likely to differ significantly (Fig. 3). The main objective of EC2 therefore was *not* the *total* unification of the design rules but a *gradual* harmonization. This aim was achieved by

- the publication of EC2 in form of a European Pre-Standard (ENV) (Fig. 4);
- the distinction between *Principles* and *Rules for Application*;
- the use of *indicative* numerical values.

The *Principles* comprise:

- general statements and definitions for which there is *no alternative*, as well as

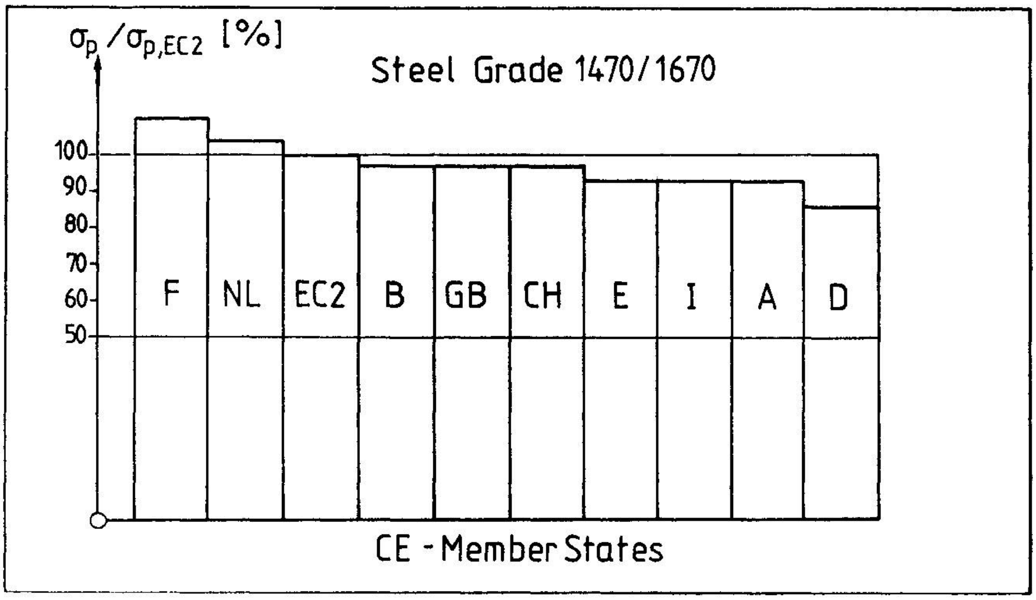

Fig. 3: Comparison of the admissible stresses σ_p in prestressing tendons

7.6 Implementation

7.6.1 Members shall make the ENV available at national level in an appropriate form promptly and announce its existence in the same way as for EN/HD.

7.6.2 Existing conflicting national standards may be kept in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

Fig. 4: CEN-Rules for the implementation of European Pre-Standards (ENV)

- requirements and analytical models for which no alternative is permitted unless specificalyl stated.

The *Application Rules* are generally recognised rules which follow the Principles and satisfy their requirements. However, it is permissible to use *alternative* rules different from the Application Rules in EC2, provided that it can be shown that the alternative rules accord with the relevant Principles and that they are at least equivalent with regard to the resistance, serviceability and durability achieved with the present Eurocode 2.

A second tool for the gradual harmonization of design rules is the use of indicative values, e.g. of numerical values identified by ⎣⎦ in the text (Fig. 5). Other values may be specified by the CEN Member States, for example in the National Application Documents (NAD, see Section 5).

4 GENERAL DESIGN CONCEPT - LIMIT STATES; DURABILITY REQUIREMENTS

According to the "Model Chapter 2.1" common to all Eurocodes, structures shall be designed and constructed in such a way that they are suited to their intended use throughout their anticipated service life, taking economic aspects into account.

Consequently, concrete structures shall

- sustain all mechanical actions with an adequate degree of reliability and
- be adequately resistant to chemical, biological, climatic and similar actions.

In their intended use, concrete structures shall also

- with an adequate degree of reliability sustain specified actions in serviceability conditions - without a decrease in their utility.

These general requirements concerning the ultimate bearing capacity and serviceability also include durability. They are quantified in EC2-Chapter

4 Section and Member Design

in particular in Sub-Chapters (see Fig. 6)

4.1 Durability Requirements
4.3 Ultimate Limit States

and

4.4 Serviceability Limit States.

Additional informations for the avoidance of damages by hazards to an extent disproportionate to the original cause are subject of Chapter

1.3 Assumptions

P(3) Numerical values identified by $\sqcup$ are given as indications. Other values may be specified by Member States.

Example: Admissible Prestressing Force

$$F_p = \sigma_{pm0} \cdot A_p = \boxed{0{,}75} \cdot f_{pk} \cdot A_p \text{ or } \boxed{0{,}85} \cdot f_{p0.1k} \cdot A_p$$

Fig. 5: The use of indicative values

1 Introduction

2 Basis of Design
- **2.1 Fundamental Requirements**
- **2.2 Definition and Classification**
- **2.3 Design Requirements**
- **2.4 Durability**
- **2.5 Analysis**

3 Material Properties
- **3.1 Concrete**
- **3.2 Reinforcing Steel**
- **3.3 Prestressing Steel**
- **3.4 Prestressing Devices**

4 Section and Member Design
- **4.1 Durability Requirements**
- **4.2 Design Data**
- **4.3 Ultimate Limit States**
- **4.4 Serviceability Limit States**

5 Detailing Provisions

6 Construction and Workmanship

7 Quality Control

Appendices

Fig. 6: Contents list of EC2 Part 1

5 Detailing Provisions

and in particular of Sub-Chapter

5.5 Limitation of Damage Due to Accidental Actions

which contains rules for the design and detailing of tie systems.

The Ultimate Limit States (ULS) covered by EC2-Chapter 4.3 include the

4.3.1 ULS for Bending and Longitudinal Force
4.3.2 Shear
4.3.3 Torsion (including combined effects of actions)
4.3.4 Punching
4.3.5 ULS Induced by Structural Deformations (Buckling).

In these ULS, it shall be verified that

$$S_d \left[\Sigma \gamma_G * G_k + \gamma_Q * Q_{k,1} + \sum_{i>1} \gamma_Q * \Psi_0 * Q_{k,i} + \gamma_P * P_k\right]$$

$$\leq R_d \left[\frac{f_{ck}}{\gamma_c}; \frac{f_{yk}}{\gamma_s}; \frac{f_{pk}}{\gamma_s} \right] \qquad (1)$$

where

S_d	design value of an internal force or moment
R_d	corresponding design resistance
G_k	characteristic value of permanent actions
$Q_{k,1}$	characteristic value of one of the variable actions
$Q_{k,i}$	characteristic value of the other variable actions
P_k	characteristic value of prestressing force
$\gamma_G, \gamma_Q, \gamma_P$	partial safety coefficient for permanent actions, variable actions and for the actions due to prestress
Ψ_0	combination factor
f_{ck}, f_{yk}, f_{pk}	characteristic strength of concrete, reinforcing steel and prestressing steel respectively
γ_c, γ_s	partial safety coefficient for concrete and steel.

Values for the coefficients γ_G, γ_Q, γ_P, γ_c and γ_s are shown in Table 1. with regard to imposed deformations Q_{IND}, where non-linear methods of analysis are used, the factors for variable actions Q_k given in Table 1 apply. For a linear calculation, these factors for unfavorable effects should be reduced by 20 % (i.e. $\gamma_{IND} = \gamma_Q = 1{,}2$).

Values for the combination factor Ψ_0 will be found in the future Eurocode 1 "Basis of Design and Actions on Structures".

In the Serviceability Limit States (SLS), it shall be verified that

$$E_d \leq C_d \tag{2}$$

or

$$E_d \leq R_d \tag{3}$$

where

C_d denotes a nominal value or a function of design properties of the concrete structure under consideration

E_d in the design effect of actions, determined on the basis of the relevant load combination, e.g. of the rare, frequent or quasi-permanent combination of load.

Table 1: Safety coefficients for fundamental combinations

Safety coefficient for	unfavorable effect	favorable effect
1	2	3
permanent actions G_k	$\gamma_G = 1,35$	$\gamma_G = 1,0$
variable actions Q_k	$\gamma_Q = 1,50$	$\gamma_Q = 0$
prestressing force P_k 1)	$\gamma_P = 1,2$ or $1,0$	$\gamma_P = 0,9$ or $1,0$
concrete	$\gamma_c = 1,50$	---
reinforcing and prestressing steel	$\gamma_s = 1,15$	---

1) these values will be applied according to the relevant clauses in EC2.

A verification according to equations (2) and (3) is necessary in the following Serviceability Limit States:

4.4.1 Limitation of Stresses under Serviceability Conditions
4.4.2 Limit States of Cracking
4.4.3 Limit States of Deformation.

According to Clause 4.4.3.1 in EC2, the appearance, general utility and durability of concrete structures may be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi-permanent loads exceeds $l_{eff}/250$ (l_{eff}: effective span). In addition, deflections may cause damage to partitions, to members attached to, or in contact with the member considered if they exceed the value $l_{eff}/500$. Experience shows that these limits may govern design and detailing of structural concrete members mainly subjected to bending.

Durability is also an important design criterion in EC2. For this reason, Sub-Chapter

4.1 Durability Requirements

was included which summarizes in form of a "Checklist" all parameters which are likely to impair the longterm behaviour of concrete structures. These parameters concern the

- actions, in particular the actions due to the environmental conditions;
- design (cover to reinforcement)
- materials, in particular the composition of concrete;
- construction (curing periods, compaction of the concrete).

In addition to the design rules, Chapters

6 Construction and Workmanship

and

7 Quality Control

provide a series of minimum specification requirements for the standard of workmanship and quality control which must be achieved on site in order to ensure that the design assumptions of EC2 are valid and hence that the intended levels of safety, serviceability and durability will be attained.

5 ASSESSMENT OF THE DESIGN CONCEPT IN EC2; NATIONAL APPLICATIONS

In comparison with the existing design codes in the CEN-Member States, EC2 may lead to more economic solutions (Fig. 7), in particular in design situations where the Ultimate Limit States are predominant.

For a general assessment of the design concept of EC2 it should be noted, however, that design and detailing of concrete structures may be governed either by the ULS or by the SLS (Fig. 8). For this reason a final answer to the question whether or not EC2 leads to more economic results in comparison with the relevant national Codes cannot be given.

For the maintenance and future development of EC2, *practical* experience is necessary. Forthis reason, the CEN-Member States are requested to apply EC2 on a trial basis and in parallel to their national Codes and Standards.

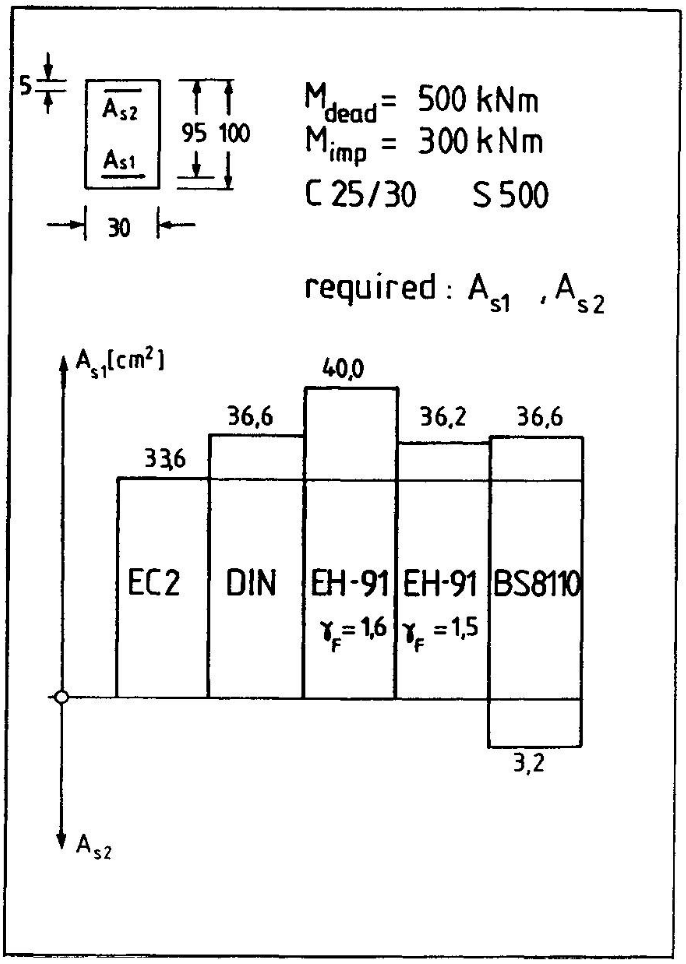

Fig. 7: Comparison of Design Results according to EC2, DIN 1045, BS 8110 and the Spanish Code EH-91

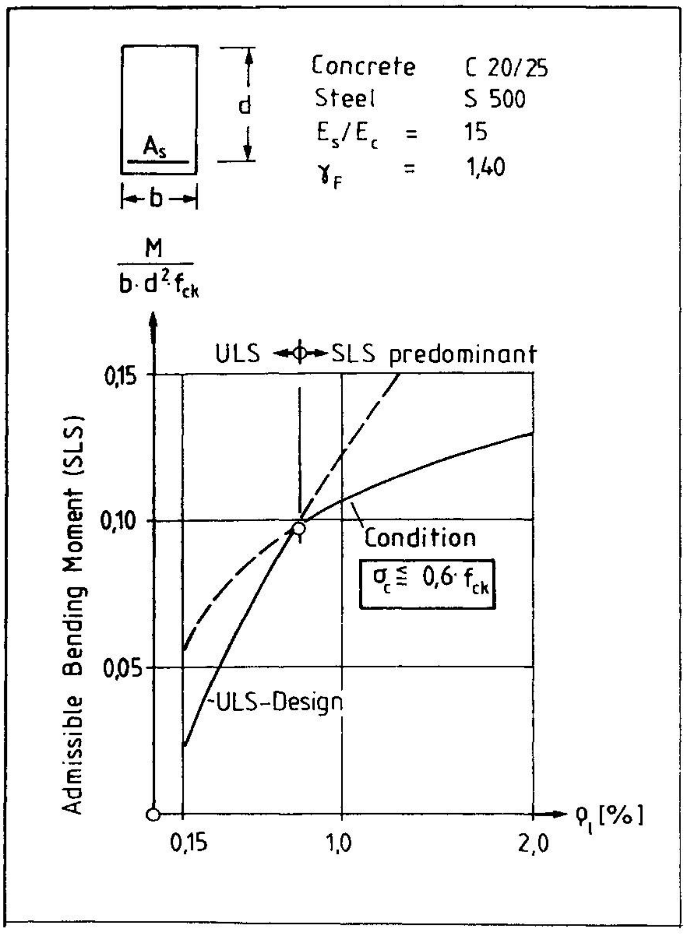

Fig. 8: Link between ULS- and SLS conditions in the design concept of EC2

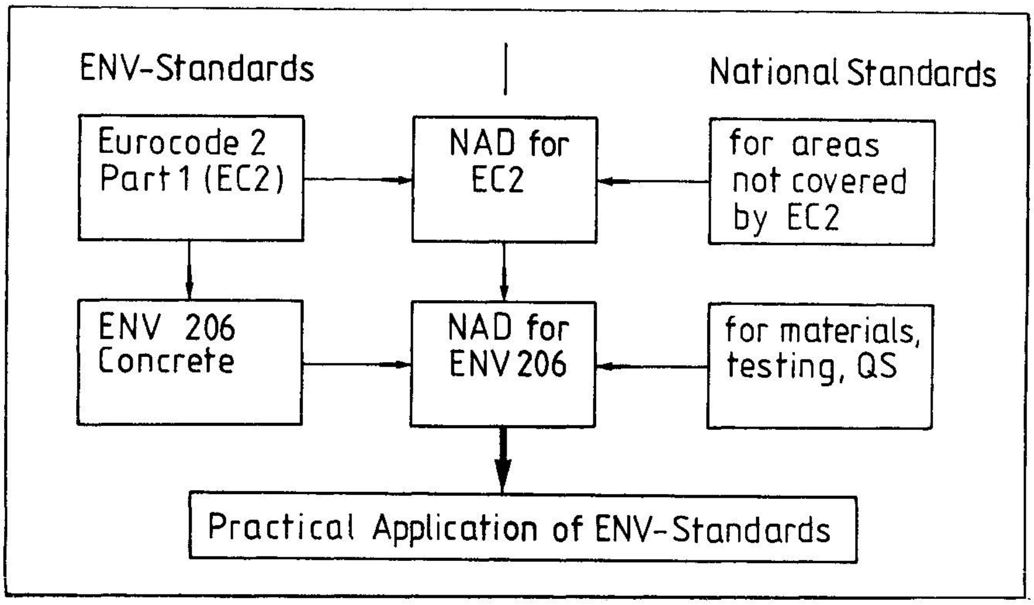

Fig. 9: National Application Documents for the Practical Use of EC2

However, many of the harmonized supporting standards for EC2 (see Fig. 1), such as, for example, Eurocode 1 giving values for actions to be taken into account, will not be available by the time when ENV 1992-1-1 [1] is issued. It is therefore anticipated that National Application Documents (NAD) giving definitive values for safety elements, referencing compatible supporting standards and providing national guidance on the application of this Pre-Standard, will be issued by each member country or its Standards Organisation. The Principle is shown in Fig. 9.

CONCLUSIONS

The issue of Eurocode 2 [1] is a first important step to harmonized European regulations for design and construction of concrete structures. However, for the implementation of the European internal market, further supporting Codes and Standards are necessary. For their development, the input from the profession is needed. Therefore, all engineers are invited to contribute to this within their field of activity.

REFERENCES

[1] ENV 1992-1-1: Eurocode 2: Design of Concrete Structures - Part 1: General Rules and Rules for Buildings (December 1991).

[2] CEB-FIP Model Code for Concrete Structures 1978. CEB-Bulletin d'Information 124/125. Paris 1978.

[3] Commission of European Communities: Eurocode No. 2: Common Unified Rules for Concrete Structures. Report EUR 8848 DE, EN, FR. Brüssel 1984.