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A Conceptual Codification of Codes

Codification conceptuelle des normes

Konzeptioneller Aufbau von Normen

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SUMMARY

After a short reminder of the anatomy of the design process, the scope and means of a design-code are reviewed. Subsequently, several basic features of a modern code are enumerated, together with indications of some contradictions; a proposal is made to overcome them. The lecture ends with a further response to some invited reports to the Colloquium.

RÉSUMÉ

Le processus général du dimensionnement est rappelé succintement; la nécessité et les buts d'une norme sont passés en revue, puis, plusieurs caractéristiques fondamentales d'une règlementation moderne sont énumérées et ceci conjointement à quelques situations contradictoires: une proposition est faite afin d'y remédier. L'article s'achève par quelques réponses à des contributions invitées au Colloque lui-même.

ZUSAMMENFASSUNG

Nach einer kurzen Betrachtung der Gliederung des Entwurfsprozesses wird ein Überblick über die Inhalte und die Regelarten von Bemessungsnormen gegeben. Dann werden verschiedene grundlegende Charakteristiken einer modernen Norm aufgezählt; dabei werden auch einige Widersprüche angedeutet, und ein Vorschlag zu ihrer Verminderung unterbreitet. Abschliessend werden weitere Antworten auf einige eingeladene Referate zum Kolloquium gegeben.

1. THE DESIGN PROCESS

a) It is worth, perhaps, to remind that **design** is a mental process, through which knowledge is transformated into production-drawings and specifications. Thus, as an interface between a set of pre-existing knowledge and a set of yet non-existing productive results, design is potentially a clearly **creative** endeavour.

b) To its end, design is based on **given** data, such as:
- Performance requirements of structural, functional, aesthetic and environmental nature.
- Acceptable probability of failure.
- Life-expectancy (indirectly given though)
- Assumptions on (future) level of quality assurance of construction, use and maintenance.

c) Design may make use of several **tools**, such as:
- Experience from similar situations
- Rules for conceptual design; intuitive procedures may intervene in original cases.
- Engineering models regarding local or global behaviour.
- Deemed to satisfy practical rules
- Numerical analysis
- (Eventually) Testing

How such a highly complex and frequently creative process may be assisted by "**Codes**"? And how the eventual risks of such a socially important activity can be faced?

2. CODES: SCOPES AND MEANS

a) These questions should be considered when formulating the **scope** of Codes:
- Public safety issue: Human lifes and enormous economical interests are at risk because of eventually defective designs. And, indeed, almost 50% of failures of any nature are due to incomplete or erroneous design. It is therefore understandable that design principles and basic design methods should be somehow "codified" in order to cover the broader interest of society. Such an inevitable l e g a l aspect has to be clearly understood by our profession.

- Designer's assistance: It has to be recognised that the entire design-industry is not in hands of the few very talented, experienced and creative Engineers. Yet, even those Engineers had passed a period when they were somehow g u i d e d. In this connection, a Code is but a substitute of the live guidance from more experienced persons; but an "un-personalised" guidance, in order to avoid strong non-scrutinised individual views. Thus, from this point of view, a Code should not limit itself in saying only "what not to do" ([1], p. 3).

- Check locus: An articulated ensemble of mutually supported design principles and compatible models, may also serve to identify lacunae, to inspire further research and to stimulate better design philosophies. From this point of view, Code-making may encourage further creative work.

b) Through which **processes** professional community may establish a Code?

- Synthesis: A long and patient process has to be established by a (as broad as possible) professional group, in order to select m a t u r e and well established knowledge ready for "codification". An optimum size of such a Group is sought: Relatively restricted ones are bound to disproportionate personal influences, whereas extremely large organisations may discourage much innovation.

- Scrutiny: A collective re-examination and consensus is needed in selecting available knowledge; and this is a fundamental process inspite of its delicate aspects.

- Calibration: Last but not least, a marriage with the past is to be contracted, so that continuity is secured; trial calculations and feeding back are a sine qua non step in this connection.

But a Code is a "too good to be true" business, needing quite a few further qualifications (yet, not without some degree of contradictoriness).

3. BASIC FEATURES OF A CODE

What follows may be considered as a wishful thinking; however, there is a clear tendency of actual Code-making towards these ideas. After all, it is through experience that such a categorisation of desired features was achieved.

3.1. Holistic design

Due to an understandable oversimplification, design is normally meant to be synonymous to structural analysis and dimensioning against l o a d s. Concurrent external actions, such as imposed deformations and physical-chemical actions, were underestimated or merely covered by means of unconnected and non-trasparent construction-rules [2]. Nowadays, a more holistic attitude (see [3] § 3.6) is taken; building materials and elements show a considerably different response to the synergetic effects of mechanical, physical and chemical actions. Consequently, modern Codes do contain broader guidance for a life-time design.

3.2. Conceptual comprehensiveness

Despite the fragmentaristic approach of just dimensioning some cross-sections, it is now made clear that a global **conceptual design** (which always precedes) should be appropriately backed by the Code. To this end, identification of structural systems, morphological rules and "preliminary dimensioning" (see [1], § 3), are subjects to be also codified. Thus, a sound s y s t e m securing "the efficient flow of forces throughout the structure" ([3] §1.2) will be submitted to the next step of design: "Refined check", to use Schlaich's terminology, will follow and will be backed by subsequent contents of the Code. But we should make clear that an ideal Code needs to elaborate on **two** distinctive levels of sophistication, correspondingly. However, this dual character of design is mainly apparent in original or outstanding structures; in designing everyday structures, previous experience and functional requirements lead directly to the preliminary shaping of the structure before its detailed check.

3.3. Rationality

It is recognised that a modern Code should not be a compilation of more or less authoritarian rules to be blindly followed by the designer. Instead, the following rational characteristics seem to be of paramount importance.

a) Performance oriented formulation is needed; thus, we first describe the desired behaviour. Any criteria to satisfy these requirements may very well change in time, whereas the required performances remain.

b) Physically sound models are needed now more than ever. This is the only way to achieve:

- compatibility within the Code (needed not only for elegance, but above all in order to avoid contradictions and gross errors)
- uniform applicability across apparently different "materials" (reinforced, prestressed and composite, as rightly pointed out in [3], §1.2).

c) Pluralism of design-means should be offered, provided that the conditions of their applicability will be clearly stated. Thus, a Code should be formulated in such a way that e.g. all methods for analysis may be usable, FEM included, following the same format and reliability scheme.

d) Uncertainties-proof: Rationality i.a. means "honesty" on the validity-limits of our working methods. Thus, all possible uncertainties of input data or of modelling should be appropriately counter-balanced by the Code, by means other than just numerical safety-factors. To this purpose, geometrical constrains, construction provisions, and/or limitations of extreme values of basic variables should be used instead. Minimal ductility provisions belong to this category of honesty-measures.

3.4. Transparency

Every design clause should be clearly connected to its **purpose**: Whenever a criterion is given (be it a model, a rule or a minimal measure), the scope of its use should be explicitly stated in connection with the satisfaction of a previously formulated requirement. Listing unconnected or unexplained rules, is a bad code-policy.

On the other hand, the limits of validity of each criterion should a l w a y s be given.

3.5. Pragmatism

In addition to the state-of-the-Art, a Code equally reflects the state-of-**capacities**: Current educational level, available computing facilities and broader technological means in construction industry, are also taken into account along the Code, and influence its degree of sophistication. Thus, it is absolutely legitimate that local traditions, educational habits and industrial particularities may differentiate a Code from region to region of the world. That there is a possibility and indeed a tendency towards a gradual harmonisation across the borders, this is another (wishful) story.

3.6. Logical format

a) Each section of the Code should be structured in a logical sequence, from the more general to the more specific ([4], p. 112).

b) First, the required behaviour of the structure (or of a component) is formulated and, subsequently, the means are given through which this behaviour may be achieved in design. In this connection, the following explanations may be needed:

- A structural **requirement** is meant to be a description of a desired behaviour of the structure, of a structural component or of a critical region of such a component. Thus, a requirement should not be understood as an "order" to the designer. The designer, having in mind the desired behaviour, will make use of the appropriate means in order to satisfy these requirements.

- And in doing so, he will be assisted by the Code offering corresponding **design criteria**; their application is meant to secure the satisfaction of the respective requirement, unless the designer wishes to use other means to the same purpose (but in such a case, he will take the responsibility to prove that the requirements are indeed satisfied).

  A "criterion" might be
  - the application of an appropriate engineering model
  - the use of a set of deemed-to-satisfy practical rules
  - the application of just some minimal measures
  - or a combination of them.

  Limits of validity of each criterion are also given.

3.7. Provisions on post-design issues

Codes should reconfirm the right of the designer to be informed on the following basic issues:

- What is the level of expected **quality** assurance scheme that the owner is willing to secure during construction?
- What is the **maintenance** policy expected during the use of the structure?

Several important decisions at the stage of conceptual design will depend on that kind of information: Sophistication and complexity of the technical solutions to be adopted, extend of durability measures to be taken (visitability of critical areas included), and the like.

I maintain that these are issues of fundamental technical and economical importance (with consequences on safety as well), which should be somehow institutionalised via appropriate provisions of the Code.

3.8. Efficiency

The final usefulness of a Code will depend on a sort of optimisation between several desired aspects. An isolated consideration of each of those aspects may easily destroy the equilibrium needed; Table 1 shows such an interplay: There are few of the desired characteristics of a Code which are not mutually contradictory.

	short and practical	complete and detailed	precise	comprehensible	open to developments
short and practical					
complete and detailed	no				
precise	no				
comprehensible	perhaps				
open to developments		no	perhaps		

Table 1

The contradictoriness of the several desired characteristics of a Code.
(——— no
------ perhaps)

There is only one way out of this conflict: Efficiency is gained by a set of regulatory documents rather than by just one. A Master Code, at higher level of sophistication, is needed, encompassing all types of structures and all design situations; separate documents, emanating from the central document but applicable only to well specified cases, will be shorter, and more practical.

The Master Code will be much more rational, model-based and open to future developments. The other regulatory documents will mainly be based on "rules" but in doubtful cases they may be occasionally "abandoned" in favour of the Master Code; in all cases, the same reliability is secured thanks to the rationality of the system. Last but not least, these sub-codes are to be more frequently modified in the course of time.

Much of the uneasiness we actually feel in the field of Codes will be remedied if such an approach is adopted. Otherwise, the "optimum" will be only a matter of personal taste...

4. COMMENTS

I thought I should have first elaborated on the broader concept of Codes before trying to submit some comments on the actual trends of Code-making in the field of Structural Concrete; here again, going from the general to the specific, offers several logical advantages.

4.1. The CEB-FIP Model Code 1990

Now that this vast collective endeavour is over (after an international effort of more that six years), I think I can be more objective about what we have achieved and what we have failed to do.

a) Among other things, the main innovative aspects of this document are the following:

- Structural concrete is above all "concrete", the basic material which governs the behaviour of the ensemble (see Fig. 1). It is hard to believe that only 6 pages were devoted to concrete in MC78. Now, a complete set of quantitative scrutinised knowledge on the mechanical and physical behaviour of concrete is included in 50 pages.

- Fundamental models of R.C. are described in the Code, both as an input for the subsequent chapters and as a guidance for advanced design beyond the Code. (It suffices to see how rudimentary are sometimes the input R.C. models used in **some** commercial computer-packages).

- Provisions are included for every type of analysis (linear, non-linear, plastic).

- Consistency of models for dimensioning is achieved to a certain extent: Critical regions (not cross-sections) are considered, with fully interactive M, N, V. Discontinuity regions or entire "plates" are treated more rationally.

- Prestressing is mainly handled as multifold e x t e r n a l forces.

- A complete and operational chapter on fatigue-design is included.

- Crack-width considerations are harmonised for both reinforced and prestressed concrete, whereas durability considerations are mostly uncoupled form crack-width values.

- An operational and explanatory chapter is provided covering the design for durability.

- Design by testing is rationally covered.

- A modernised chapter on practical construction is included.

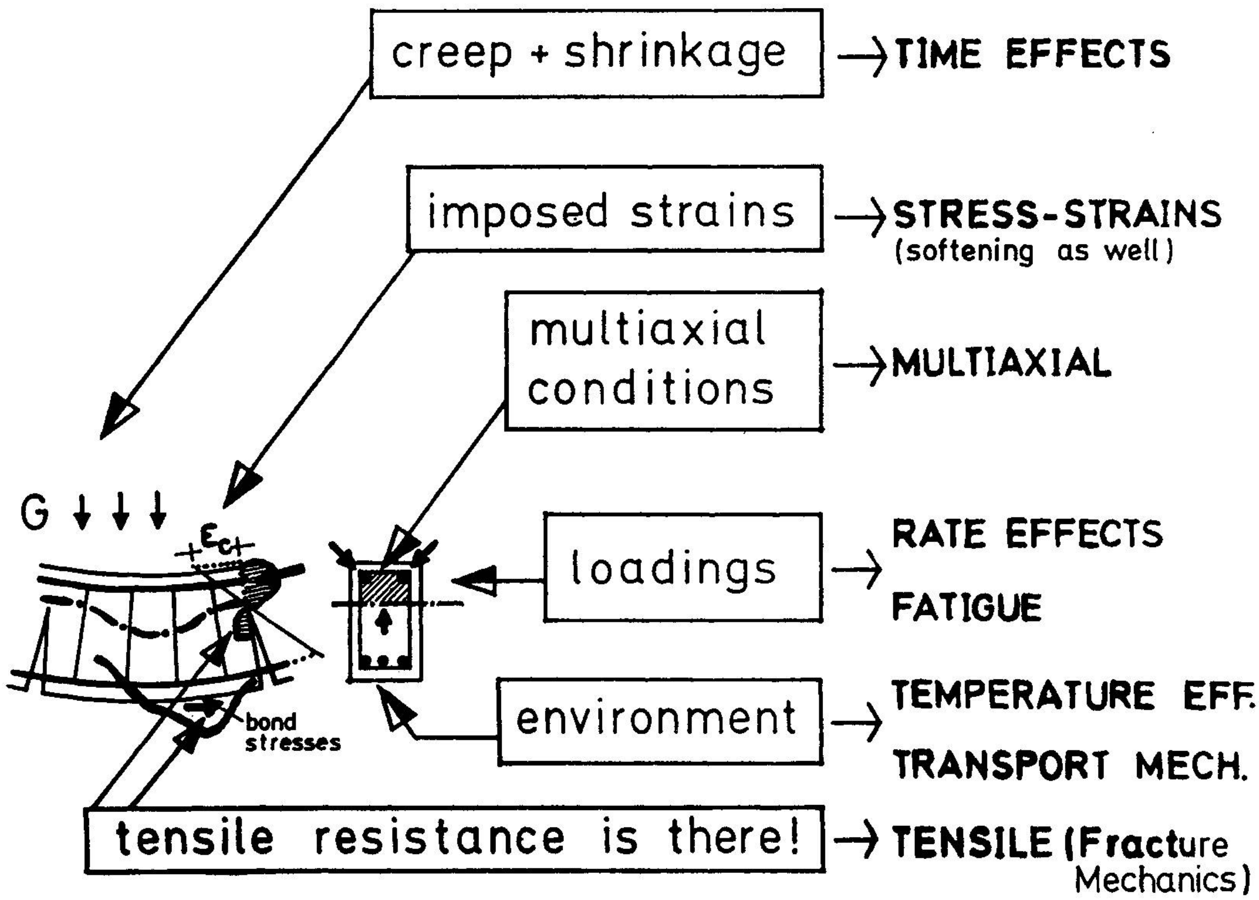

Fig. 1: Structural concrete is above all "concrete"; its properties govern everything and they must be described in details.

b) However, for the actual state of the art or for the actual state of possible consensus in an international document, I think we were less successful in the following areas:

- The design of plain (or slightly reinforced) concrete is far from being as rational and reliable as for the other types of Structural Concrete.

- Even the code-handling of prestressing is not yet as general and complete as it should be.
- The increasing use of truss-models across a multicracked medium, leaves some open problems of rationality and non-equivokalness.
- The reliability format of the Code is well established and calibrated for the most common case of the linear analysis of monodimensional building elements. However, when non-linear analysis is used and when (e.g. in "plate" elements) the concept of the critical region is not easily applicable, the problem seems unsettled: When and how mean values and/or factored characteristic values of material properties will be considered in the step by step process?
- The consequences of repeated (or cyclic) loading on i) the redistribution of action-effects and ii) the eventual strength degradation, are not covered.

Nevertheless, it may be said that the new CEB-FIP Model Code 90 goes along the correct lines of modern code-making, and it may be profitably completed and corrected during the few years to come.

4.2. Joint efforts

a) In view of this state of the art of code-making in the field of Structural Concrete, what is to be done in the near future?

- First, we should continue discussing the philosophy of Modelling and Codes, the way this very Colloquium of IABSE has shown.
- Second, in the opinion of this writer, the five MC90 main inadequacies mentioned in § 4.1.b, should be tackled in priority; CEB has a direct interest to instruct its newly structured Commissions to elaborate on them, whereas IABSE could possibly organise relevant Workshops on some of these major subjects.
- Third, we should be pragmatic, trying to understand the necessity for a patient development of the ideas of several schools of thought, up to a critical moment when:
  (i) the validity of some ideas has been broadly accepted in the professional community, and
  (ii) the operationality of the relevant methods in all design aspects has been proved.

Progress by its nature is a slow (and sometimes zig-zag) process.

b) Closing this lecture, and following the instructions of the Organisers, I wish to add further response to some of the very fruitful ideas offered in the Introductory Reports of this Colloquium; in the previous paragraphs, as well as in [5], I had already the opportunity to make some (mostly positive) comments.

- In fact ([3], §3.3) we need a unique ductility criterion for all cases of Structural Concrete; models predicting available "θ_{pl}" are the best way in doing so. A similar approach has been implemented in [6] via a required curvature ductility factor, valid for all structural cases.

True, "the designer should give priority to making sure that all load cases, all restraint cases, all equilibrium checks, and all possible instabilities are considered" ([3], §4.2). But how is this possible without precise analysis? Happily enough, our actual calculation tools are not based on "wild guesses".

- Some further explanations are needed on what is really new in the proposals ([3], §4.3) related to linear or non-linear FEA.

- The compressive fields approach or the strut and tie models have their own merits for what they offer for ULS checks under well specified conditions; they are not obliged to cover topics such as crack control or durability ([3], §4.4)! Even Physics was not that ambitious to unify all fields of forces. What we want in design is consistency of **appropriate** models, not uniqueness.

- I fully subscribe to the wish of exploring a consistent approach in selecting appropriate structural systems, together with respective educational aids ([3], §5.2).

- I am not sure that the most efficient and elegant way of doing things is that one International Association should prepare a "model for other organisations" ([3], § 6). The most pragmatic and indeed productive way is to come up with a joint effort, like for instance the common design principles prepared by CEB and ECCS (1985).

- I have very much appreciated at least two of the views formulated in [7], namely that "design should be made less sensitive" to time effects, and that we need one approach for crack spacing, crack width, stiffness and deflections.

- I welcome the view that ([1], § 3, § 4.1, p. 7) thanks to the computer oriented analysis and modelling, ("for refined review"), a preliminary simplified design (which offers a direct understanding of the overall behaviour) becomes now easier, (see also § 3.2 of this paper).

- Today, it is difficult to limit the well established concept of a truss to only the case of "compressive and tension chords parallel to the surfaces lines" ([1], p. 6). I submit we should use the general term "truss" in every model where force trajectories are substituted by one straight line.

- I friendly confess I was one of those ("code-makers running after cookbook recipes" ?, [1], § 4.2) trying to maximise the fruitfulness of strut- and -tie models in checking plate elements and discontinuity regions. To this end, we do not require a ready made solution ("recipe") but a non-equivokalness of the m e t h o d o l o g y; and we must anyway give it to the designer. It is only too obvious that the "inner flow of forces adjusts to the reinforcements' layout"; what is to be made explicit is, for a **given** steel pattern, the physical mechanisms which dictate the topology of the truss, out of a large variety of alternatives, all satisfying equilibrium; especially when no other analysis is available. But even in the case a complete elastic analysis is available, orientations of truss elements are known but a criterion for their density is still needed. That is why the designer needs an additional guidance, especially in some cases where compatibility cannot be overlooked. Similar additional guidance is needed on the exact geometry of nodes (especially in real life supports or loads). Of course, in case the method is used only for a preliminary dimensioning, all this information is not necessary.

But, happily enough, a considerable progress is being made in all these since the first Schlaich's publication in the CEB Bulletin 50, (1982). And this is a welcomed development.

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