

**Zeitschrift:** IABSE reports = Rapports AIPC = IVBH Berichte  
**Band:** 62 (1991)

**Artikel:** Impact of codes in practice  
**Autor:** Walther, René  
**DOI:** <https://doi.org/10.5169/seals-47721>

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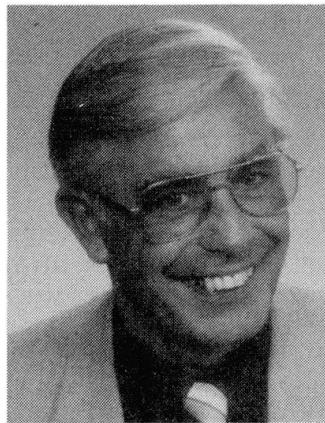
## Impact of Codes in Practice

### Impact des normes dans la pratique

### Auswirkungen der Normen auf den Entwurf

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#### **SUMMARY**

A symptom of misguided professional orientation is the inclusion of many details in our codes that fail to embrace a higher scientific standard. Codes should delineate basic principles and goals while leaving to the ingenuity and experience of the engineer the conceptualization and realization of the task. The distinction of serviceability and ultimate limit states, is one such basic design principle that can be further applied in conjunction with non-linear methods to arrive at more progressive monolithic construction. A uniform approach to structural concrete could certainly help to enhance the aim of good conceptual and aesthetical design.

#### **RÉSUMÉ**

La difficulté d'orientation des ingénieurs est accrue par la complexité et l'aspect détaillé de nos normes, qui ne permettent pas une approche scientifique de bon niveau. Les règlements devraient décrire les principes et les objectifs de base, laissant à l'ingénieur son génie et son expérience pour assurer la conception et la réalisation de l'objet. La distinction entre l'état de service et l'état limite ultime est un de ces principes de base qui, appliqué en conjonction avec des méthodes non linéaires, peut construire à la construction d'éléments monolithiques sans joints de dilatation. Une approche unique et uniforme du béton structural pourrait certainement favoriser le dimensionnement, tant pour un bonne conception que pour un aspect esthétique séduisant.

#### **ZUSAMMENFASSUNG**

Ausdruck einer unseligen Entwicklung im Ingenieurwesen ist, dass unsere Normenwerke immer komplexer und undurchsichtiger werden, Detailfragen regeln wollen und dabei ihr wissenschaftlicher Wert in keiner Weise erhöht wird. Normen sollten grundsätzliche Fragen regeln, ohne die Kreativität und den Pioniergeist des projektierenden und des ausführenden Ingenieurs einzuzugen. Die Unterscheidung von Gebrauchstauglichkeit und Tragfähigkeit eines Bauwerks, welche in den meisten modernen Normen Anwendung findet, ist eines der Prinzipien, das verbunden mit nichtlinearen Berechnungsmethoden zu modernen monolithischen Konstruktionen führt. Eine einheitliche Betrachtungsweise des Stahlbetonbaus sollte zu guten Entwürfen und ästhetisch überzeugenden Bauwerken führen.



## 1. GENERAL REMARKS

The making of codes inevitably implies the difficult task of finding a fair compromise between the noble aim of stating basic principles and the trivial necessity of specifying rules of good practice. In general discussions most everybody agrees that codes should not merely be manuals for technical personnel with little creative imagination, but should on the contrary convey the basic state of the art in a concise, yet general and flexible way.

However, when it comes to drafting codes many a researcher feels the irresistible urge to include his latest findings or professors their favorite topics while others consider it indispensable that codes go into minute details which are deemed necessary for competitive bidding and for reasons of legal implications. This tendency inevitably leads to ever more voluminous treatises and worse yet to a subdivision in many separate tomes for plain, partially prestressed and fully prestressed reinforced concrete, as well as for buildings, highway and railroad bridges, etc. One is tempted to paraphrase the famous saying of the British engineer Tredgold (1829) that the quality of structures is inversely proportional to the size of the codes needed for its realization 1).

Codes are indeed more than only helpful or necessary tools; to a certain extent they reflect an image of the whole profession, and this unfortunately is not anymore the best as far as civil engineering is concerned. We have come a long way since the times when masterbuilders were architects, engineers and artisans in one person, the great ones often speaking as equals to their rulers. Nowadays at inaugurations of or in publications about important bridges or structures the engineer is hardly ever mentioned, regardless of the extent of his contribution. Nothing shows the decline of the prestige of engineers more clearly than the fact that the task of designing the last bridge over the river Seine in Paris, and incidentally also one in Basel, was recently given to architects rather than to experienced bridge engineers, leading however, as was expected, to rather disappointing results.

It would certainly be a gross exaggeration to hold the excessive preoccupation of engineers with codes responsible for this unsatisfactory situation, but it is nevertheless a symptom of misguided professional orientation. If we continue to conceive our codes as comprehensive manuals, which must also be intelligible for the so-called average engineer or even draftsman, then it is a small wonder that we are often only called upon to calculate and to dimension structures conceived by others. And even this task can nowadays be performed by computers with the latest cry of implementing all the pertinent clauses of codes directly into computerized design programs.

If we wish to improve the reputation of our profession again, then we must have the courage to pursue it in a more progressive way and to place more emphasis on innovative conceptual design rather than on mere dimensioning of structures according to codes. One little step in the right direction would certainly be to raise the scientific standard of our codes, specifying essentially only basic principles and goals while leaving it to the creativity and experience of the engineers to translate this into innovative conceptual design. A concise unified code for structural concrete could undoubtedly be helpful in this respect.

## 2. SAFETY AND SERVICEABILITY

There is nowadays a nearly universal consensus that for modern conceptual design the two criteria, safety and serviceability, should be checked separately. The first is often referred to as ultimate-limit-state check (ULS), while the second is termed as serviceability-limit-state check (SLS). One of the drawbacks of the otherwise simple and straightforward concept of allowable stresses was that it tried to combine the two criteria in one, with neither of them being met in a really satisfactory manner.

However, even though the principle of two separate checks is stipulated in the introduction of most modern codes, this noble objective is often violated in subsequent chapters specifying the details of these verifications.

1) Original version: the stability of a building is inversely proportional to the science of the builder.

More often than not clauses concerning action effect to be taken into account for the ULS-check include factors for creep, shrinkage, relaxation, temperature effects, hyperstatic forces of prestress, etc. which at ultimate have in general no or, in exceptional cases, only limited influence.

Yet, it should be clearly recognized that the potential advantage of the new design philosophy lies in the clear distinction between safety and serviceability requirement. The fact that the phenomena mentioned above are in general relevant for serviceability considerations only can favorably be exploited in modern conceptual design. A great many structures could be built monolithically, that is without expansion joints or mechanical bearing devices, if appropriate measures are taken to ensure a satisfactory behavior at service loads and if the security check is then performed with non-linear methods such as the theory of plasticity which take duly into account that the effects of these phenomena have the tendency to disappear as the ultimate load is approached.

As an example we cite the 1 km long Felsenau Bridge built about 20 years ago in Berne, Switzerland (Fig. 1).

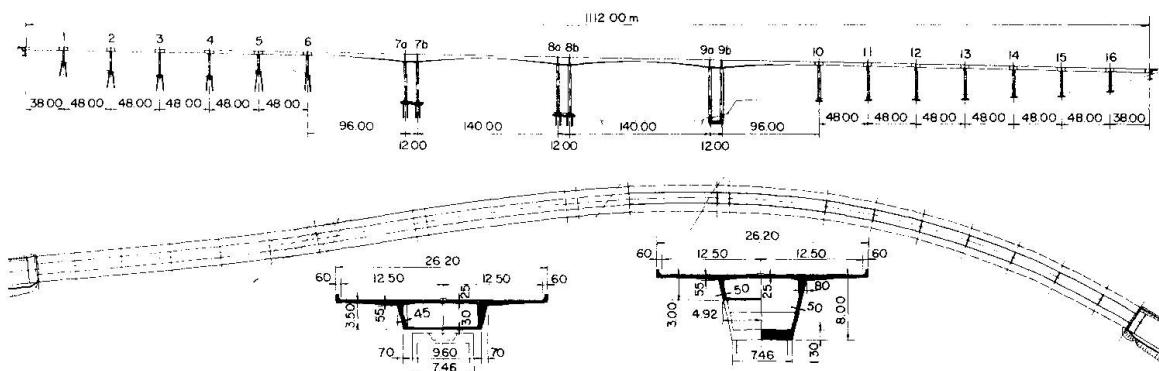


Fig. 1. Felsenau Bridge, Berne, Switzerland.

According to the codes in use at that time it was necessary to fit the piles of the side spans with gliding bearings. Nowadays one would probably prefer to connect these piles monolithically with the superstructure which would certainly be more economical and preferable from the point of view of maintenance.

Another example is the large storage building of the IKEA near Basel, Switzerland (Fig. 2).

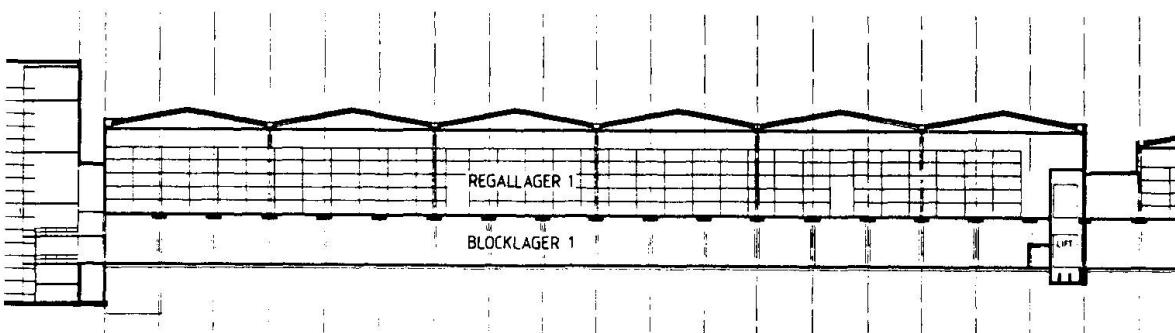


Fig. 2. IKEA Storage Building



In spite of the large size of this building, measuring 180 m in length and 85 m in width, the prestressed cast in-situ slabs do not have any expansion joints and were monolithically connected to the columns. This was only possible by using modern non-linear methods for the design and by profiting from the liberal spirit of the Swiss codes, which grant the engineer much freedom of action as long as he can prove the feasibility of his concept by scientifically sound methods and is willing to take the full responsibility of his endeavours.

By these examples it was tried to show that the separation of security and serviceability requirements is much more than abstract fancies of some theoretically inclined scientists. On the contrary, it enables qualified engineers to conceive their structures in a more appropriate and modern way.

As far as the so-called serviceability requirements are concerned, it has also to be admitted that the roots of many of them stem in reality from durability considerations, which in turn are related to safety.

One can rightly question if, for reasons of conceptual clarity, it might be better to treat durability separately as well. However, we should not erect somewhat scientific ivory towers which are of little help in practice. This holds also true for other topics in this field such as reliability-based design or probabilistic methods concerning safety and considerations of the lifetime of structures.

The essence of all these valuable approaches could and should be implemented in a concise form in the two major categories, one dealing broadly with structural safety and the other with the actual behavior of the structure during its anticipated lifetime, which may well, even if somewhat unprecisely, be termed as serviceability.

### 3. PRESTRESSING

Since the main objective of this Symposium is to deliberate over the benefits of a uniform approach to structural concrete it is indeed superfluous to discuss at length the futility of artificially divorcing reinforced from prestressed concrete of any degree. This only prevents many engineers from taking full advantage of the most appropriate means of improving the serviceability and durability of their structures by simply providing them with even moderate prestress, especially in building construction, where this procedure is far too scarcely used. Furthermore, most prestressed structures also comprise conventionally reinforced elements. Thus, it would seem rather nonsensical to have to refer to two different codes for one and the same structure.

On the other hand, there exist some diverging opinions as to how prestressing should be dealt with at service and ultimate level and, in particular, if the prestress should be considered as an internal or an external action effect.

From a purely theoretical point of view there can be no doubt that at service loads prestressing is definitely an internal action, which creates a state of self-equilibrating internal stresses (Fig. 3).

However, it can be expedient in education as well as for practical design to take advantage of the static equivalence of the prestressing force itself and its reaction effects on the concrete as is, for example, widely done with the so-called load balancing method. As long as one knows exactly what he is doing there is certainly nothing wrong with using such methods. However, they become rather cumbersome for cases with multiple and overlapping prestressing tendons, in particular if one forgets that prestressing cables produce not only deviation forces, but also sometimes eccentric anchorage forces. At any rate such considerations should not be implemented in codes, the mission of which is to specify principles but not to prescribe methods.

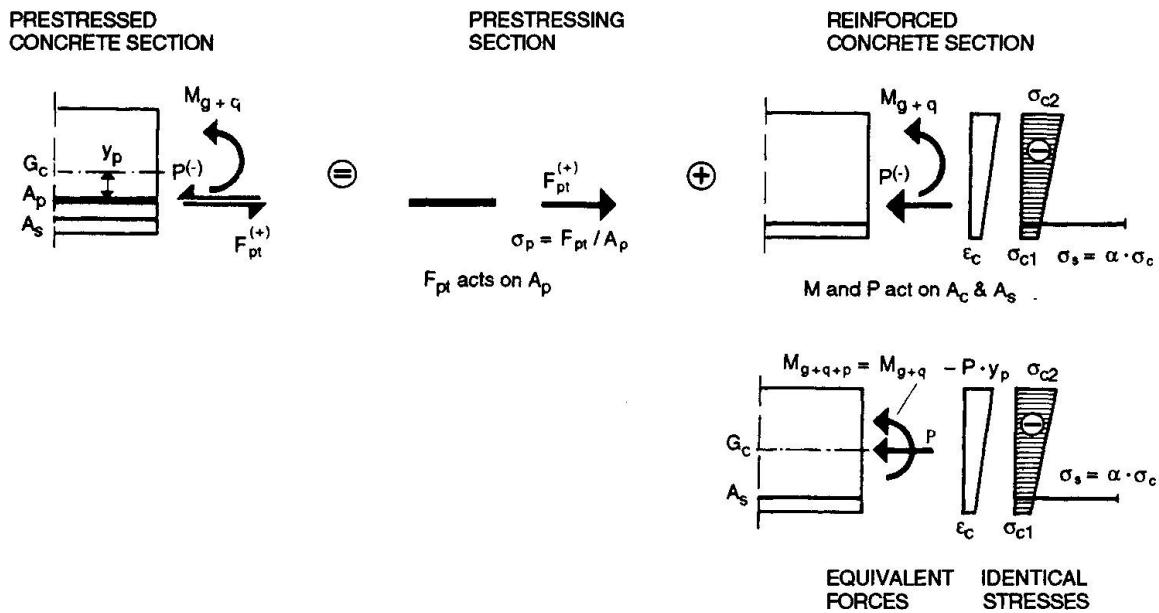


Fig. 3. Internal stresses and forces due to prestress

The question becomes considerably more involved when it comes to the ULS-check. Most of the codes today stipulate formulae of the type:

$$M_u > \gamma_Q M_Q + \gamma_p M_p^h$$

where:

$M_u$  ultimate moment at the section considered

$\gamma_Q M_Q$  moment due to load effects increased by the load factor (1.6-1.9)

$M_p^h$  hyperstatical (secondary) moment of prestress

$\gamma_p$  load factor of  $M_p^h$  (varying between 0.8 and 1.3 depending on the code considered).

Again it has to be stressed that the hyperstatical moments pertain to the elastic state and can no longer be clearly defined at the ultimate limit state due to the considerably moment redistribution which will have taken place. While the formula just mentioned may yield satisfactory results in most cases, there are others (inverted T-beams for example) Fig. 4, where the shifting of the moment closure line stipulated by the term  $\gamma_p M_p^h$  goes in the wrong direction. The resulting sectional safety factors  $\gamma$ , calculated backwards by assuming  $\gamma_p = 1$  (first line in the table of figure 4) and  $\gamma_p = 1.3$  (second line) clearly show the inconsistency of such approaches. Furthermore it is sometimes recommended to take  $\gamma_p = 0.8$  if  $M_p^h$  acts favourably and  $\gamma_p = 1.2$  in the unfavourable case, which means that the global system would not even satisfy the equilibrium conditions. No such ambiguities are met if one performs the ULS check by the statical method of the theory of plasticity, which clearly assesses the effective distribution of internal forces at ultimate load, and which leads to an identical global safety for a T and an inverted T-beam (last line in the table of figure 4) as it should correctly be.

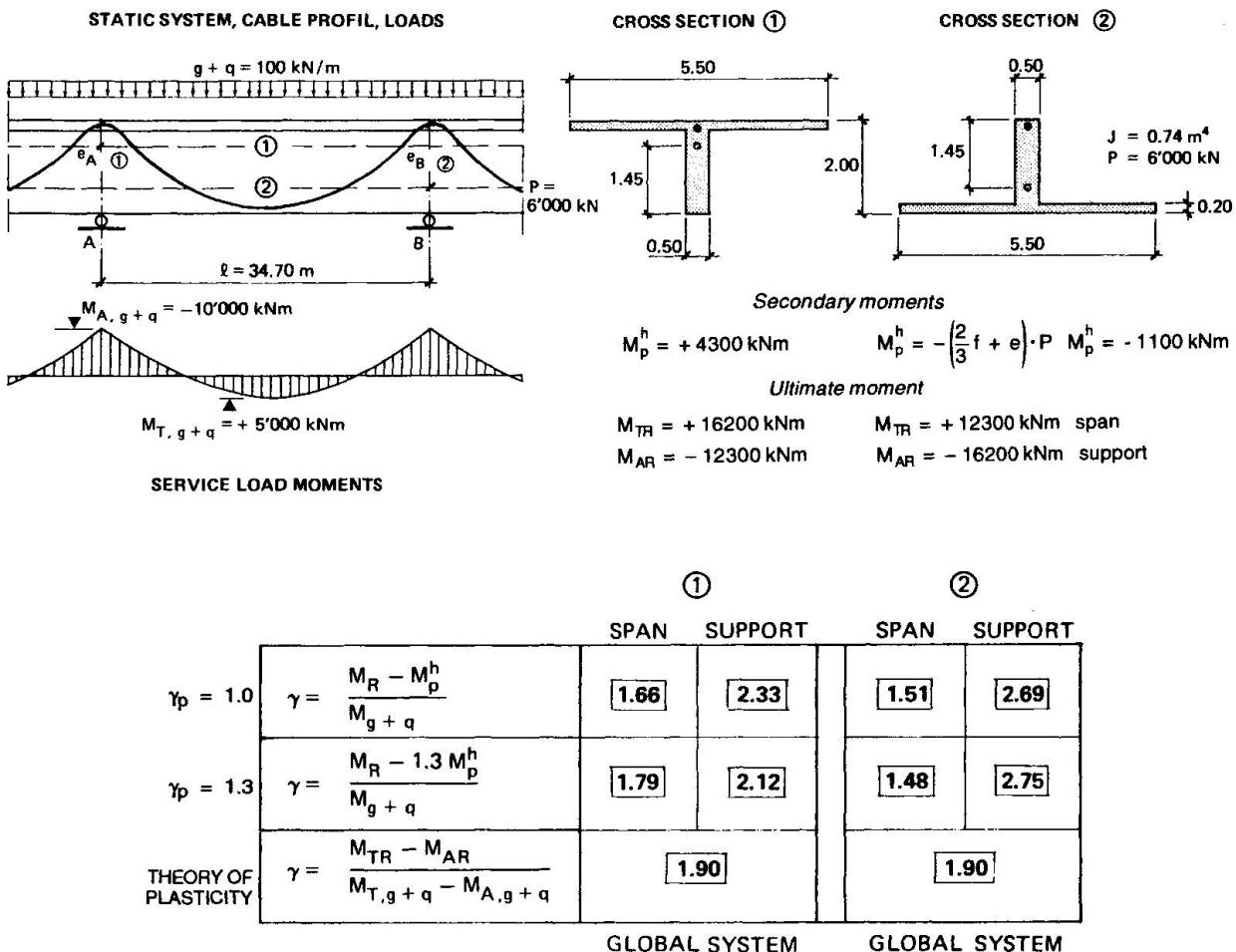


Fig. 4.

#### 4. DETAILING

Nowhere does the discrepancy between noble goals and practical necessities become more apparent than in the case of detailing. While a great many rules of proper detailing can indeed be derived from basic principles, there are others which result from long experimental and practical experience not always readily available to all engineers. Furthermore, they constitute sometimes a quality requirement which the owner may wish to impose. Concrete cover, bending radii, anchorage lengths and alike are striking examples of that category.

There is certainly nothing wrong if such details are specified in the codes. On the contrary, it frees the project engineer from dealing with rather tedious, albeit important matters. However, these rules should not be imposed as rigid commandments carved in stone, but rather be regarded as valuable yet flexible recommendations for everyday routine work. Here, as for codes in general, the overriding maxim must be that he who makes decisions has to assume the full responsibility for their consequences.

#### 5. LEGAL IMPLICATIONS

It is often argued that codes must be comprehensive and go into considerable details in order to put potential bidders on the same contractual and technological footing, especially in view of the ever growing international competition. This argument can certainly not be taken lightly, but it should also not be overestimated.

Above all it must be recognized that the economical aspects of modern building process depend much more on skillful conceptual design and the adroit choice of innovative, time-saving construction procedures than on provisions of codes, which influence mostly only secondary matters of material consumption. Furthermore, the questionable practice of blindly awarding the contract to the lowest bidder is fortunately slowly fading away, since it dawned to many owners that the initially cheapest solution is often not the most profitable one in a long run, not to speak of esthetical aspects which should undoubtedly occupy a more predominant place in our society. Aside from the topic treated here, we have all to strive to grant an ever greater importance to quality and esthetics of our structures.

Yet we have to concede that some code provisions may have considerable effects also on the economy of engineering structures. Take for example construction by incremental launching; the potential economy of this procedure depends very much on whether one requires full prestress during launching or whether some concrete tension stresses of say  $3 \text{ N/mm}^2$  are deemed acceptable, which reduces the prestressing forces needed during erection only quite significantly. Thus the question of whether or not and where such and similar provisions should be introduced, has to be pondered carefully. In our opinion certainly not in codes, the task of which must be to promulgate the objectives, but not to prescribe the methods to achieve them. Such and similar provisions should - if necessary - be included in the tender documents of a given project all by leaving the option for eventual alternatives open, if the designer and contractor are willing and capable to guarantee the required quality and safety criteria.

While for reasons of fair competition it is often unavoidable to go into considerable details, one must not believe that the quality of the structure to be built depends on the size or completeness of the specifications. In fact, a sly contractor can more easily find and exploit loopholes in prescriptions of minute details than violate general but rigorous requirements of quality and safety.

There can be no doubt that the liberal attitude towards codes and tendering advocated here requires both courage and competence from all parties involved.

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