The development of an international codification for structural concrete with the CEB-FIP model codes

Michel **VIRLOGEUX**
President of the
Fédération Internationale du Béton

Michel Virlogeux, born in 1946, graduated 1970 at the Ecole Nationale des Ponts et Chaussées. Former head of the large bridges division of the SETRA, he designed many bridges among which the Normandie Bridge. Now independent consultant.

Joost **WALRAVEN**
Deputy President of the
Fédération Internationale du Béton

Joost Walraven, born in 1947, graduated 1972 from the Delft University of Technology. As research assistant he finished his PhD in 1980. Afterwards worked for Corsmit Consulting Engineers in the Hague, and was in 1985 appointed Professor of concrete structures at the Delft University of Technology.

Summary

This paper reminds the goals of the foundation of CEB and FIP in the beginning of the fifties, and evidences the evolution of codes which have been produced along the years mainly by CEB activities. The development of the Eurocodes on the basis of the CEB-FIP Model Code for Concrete Structures was a recognition of the previous work done by this organization. The recent merger between FIP and CEB makes the new Fédération Internationale du Béton, ***fib***, to a truly international association for structural concrete, with the task to develop an international design philosophy and model codes, recommendations and guidance far beyond any nationalistic approach.

1. Introduction

The development of a Concrete Model Code for Asia is of course of major importance considering the rapid development in the region, at present and in the future.

As ***fib*** officers, we encourage that such an initiative takes place within our association between its Asian members, either by using the ***fib***-expertise, or by creating a specific ***fib***-Model Code tailored to Asian conditions. Anyhow, ***fib*** felt extremely engaged when the Thailand group of IABSE decided to organize a specific Symposium in Phuket, and we are honoured to have been invited to give a keynote lecture on this decisive issue.

Of course it is of major importance that a real convergence between the different codes can be achieved. More and more an international market for construction is developing, with large international companies and gigantic projects, and it is a key issue that there should be a clear understanding between the different partners, including the local ones ; this is not possible without an internationally accepted design philosophy and standards. And if true competition is wanted, it is not acceptable any more that a particular codification could protect or favour certain designers or contractors of any specific nation or region.

We must develop a really international code philosophy, and this is one of the major goals of ***fib***.

2. CEB and FIP history

2.1. The Fédération Internationale de la Précontrainte, FIP, was founded in 1952 by the pioneers of prestressing – Freyssinet, Torroja, Magnel and many others – to develop this technique which was ignored by the majority of engineers, and which had not received enough attention from IABSE at the time. Being not conveniently considered by the existing bodies, these now famous pioneers founded their own association with its official address in Paris though the headquarters were installed from the beginning in England ; these headquarters were at first hosted by the Cement and Concrete Association at Wexham Springs, and later by the Institution of Structural Engineers in London.

The goals of FIP were clearly the dissemination of knowledge and the promotion of the prestressing philosophy, -design and -techniques on a world wide scale. FIP has been a really international association with member countries from the five continents.

FIP has been strongly supported by the inventors and industrialists of prestressing systems, and developed very practical activities including the preparation of state-of-the-art-reports and recommendations oriented to applications. For this reason, FIP attracted owners, designers and contractors and the FIP congresses have been the major events in the world of concrete every fourth year, as will be the ***fib*** congresses in the future.

2.2. The CEB was founded as Comité Européen du Béton (European Concrete Committee) in 1953, on the initiative of the French contractor Balency-Béarn. He and the co-founders Nennig, Base, Rüsch, Torroja and Wästlund, coming from contractors and research, had the vision that post-war Europe would need a common approach in concrete design and construction. Now, 45 years later, this is, inspite of all the progress made in creating a common market, not yet completely achieved ; but we can appreciate today how farsighted these founders have been.

Their greatest concern was the enormous disparity between codes in Europe, and their very limited scientific bases. Clearly, the goal of CEB has been from the start the development of a European code ; with the development of more scientific approaches as a first step and the harmonised preparation of a Model Code as a second and major step.

Since this is the precise theme of this presentation, we shall later regard more in detail the development of the CEB Model Codes, which was done in close relation with FIP. But we must not forget the intense scientific activity in the CEB Commissions, which led to the publication of some 250 Bulletins ; some of them have been a real breakthrough for the scientific and technical knowledge in the field concerned. We shall just cite the work on buckling, non-linear analysis of hyperstatic structures and shear behaviour.

2.3. During decades, the elaboration of international recommendations and Model Codes directly inspired national codes, producing step by step the desired convergence. Milestones were :

- 1964 First CEB International Recommendations, translated into 15 languages.
- 1968 UNESCO Code and Manual based on the 1964 Recommendations.
- 1970 CEB/FIP 2nd International Recommendations.
- 1974 CEB initiated an effort together with FIP, ECCS, CIB and RILEM to create an "International System of Unified Standard Codes of Practice for Structures".
- 1978 CEB/FIP Model Code (Vol. 1 and 2 of the above International System).
- 1985 CEB Model Code for Seismic design.
- 1990 2nd CEB/FIP Model Code.

Especially the two Model Codes were of great influence on many national codes and quite naturally served as a basis for the drafting of Eurocodes when the European Commission launched this activity : the necessity of pre-codification based on a thorough discussion of research results and experience from practice became once more evident.

With time, the CEB became more international with a new name for the same logo adopted in 1976: Comité-Euro international du Béton, since many countries outside Europe were interested in its activities and took part in them more and more frequently. And European countries also understood that Europe is only a part of the world and must be open to other continents.

2.4. Finally we must briefly evoke the merger between FIP and CEB.

It appeared more and more unlogical to have two different associations in the same field, and it was felt to be necessary to limit the number of events and meetings, the more as many members were working in both associations and could not maintain such a demanding involvement. It took a long time to merge the two associations, but the preparation time has been extremely useful since it helped understanding each other, making from this merger a great success.

We just want to add that the need for a closer international collaboration is not limited to CEB and FIP. The new ***fib*** is a member of the Liaison Committee of International Associations, and has developed – and will continue to develop – a privileged and friendly relation with IABSE as evidenced by our presence here.

3. The Model Codes

3.1. As already said, the concrete codes in Europe – and in the world – were dramatically different 40 years ago. An excellent example was given during the Quebec IABSE Symposium in 1974 : the bearing capacity of a reinforced concrete column has been evaluated considering second order effects in the different participating countries following their own code ; the values differed from 1 to 3 between the extremes. The need of common bases and philosophy was clear.

3.2. But the major input of the CEB codification activity has been the introduction of a new design philosophy on the basis of limit states.

Some researchers and pioneers foresaw the drawbacks of the traditional approaches more than 50 years ago, and began developing new safety concepts based on the notion of limit states and on partial safety factors. It is the great merit of CEB to have adopted, developed and introduced this new philosophy in its Model Code, pioneering in the field and being in advance as compared to all national codes and giving to concrete structures a leading position as compared to other materials. For this reason, the 1970 CEB/FIP International Recommendations are a historical reference as well as it has been a real model to many national codes in Europe. In 1985, Theodossios Tassios – then the CEB President – established that CEB strongly influenced the concrete codes in Belgium, Brazil, Finland, France, Greece, Italy, Portugal and Spain, and moderately influenced the concrete codes in China, Germany, Netherlands, United Kingdom, Switzerland, Turkey and Yugoslavia.

Safety concepts were developed in the seventies with semi-probabilistic approaches, and later-on real probabilistic analyses were made as a basis for a better evaluation of structural safety and for a more scientifically based definition of the partial safety factors.

3.3. With the two editions of the Model Code – in 1978 and 1990 – improved models were developed for a more accurate representation of the structural behaviour of reinforced and prestressed concrete structures, and new chapters were introduced to cover new fields. It could only be reproached to these Codes that they tried to cover all situations with too specific models, with as a consequence not enough difference between the major points and details. This could be a serious drawback for a real code, but it is only a small one for a Model Code.

3.4. Clearly, ***fib*** will have to fix its position for the future. Is it useful or not to prepare a new version of the Model Code, a ***fib*** Model Code now ? This would have some major advantages in our opinion, at least to develop a really international philosophy when several "regions" are now unifying their code : the American Code, ACI ; the Eurocodes already evoked ; and later the Concrete Model Code for Asia, theme of this Symposium. An international approach would have the merit of avoiding the development of unnecessary differences and of "regionalist" antagonisms as well as any tentative of impairing the competition through "regional" codes.

4. The goals for a new code

4.1. A good code must have several qualities ; it must be coherent, scientifically based, open-minded, transparent, simple, oriented to practice and flexible. This needs some comments.

4.2. We probably do not need to explain why a code must be "coherent" and "scientifically based": a code must be based on a clear and scientific theory, consistent and coherent, corresponding to a good representation of the structural behaviour, and of the material physics. We cannot accept specifications only justified by habits or tradition, which are not justified by a quantified analysis of a clear physical phenomenon.

4.3. A code must be "open-minded", which means that it cannot be based on a given theory excluding other ones. To take an example, many oppose now the "classical" approach and the "strut and tie" theory ; this is clearly a mistake and both approaches have advantages and fields of application. In addition the development of computer software will change the situation in the future – as it has already done though it has not been really recognized by codes –, allowing for more and more sophisticated non-linear analyses, including for example the prediction of the distribution of cracks in a three dimensional solid.

A code must be adapted to the different existing theories, making possible for the designer the use of the most appropriate one for his specific problem, or the most transparent one.

4.4. "Transparent" means that a code has not been prepared for those who made it but for those who will use it.

The ordinary users, who have not been involved in the redaction of the code, must understand its philosophy, and also the physical phenomenon behind each specification. This is a clear condition for an intelligent application of the code ; and more important for an understanding of its limits. A "blind" specification or formula cannot help ; it can be misunderstood or used outside its limits of validity. If the philosophy of the specification is clear for the designer, he will be able to see if something is outside the limits of his problem, and he can adapt the code to his need.

But it must be clear in the same time that a code – even a Model Code – is not an education book. This is an occasion to say that an association like ***fib*** certainly has to develop its activity in the education field and probably has – at least in our opinion – to prepare a Model Education Book on structural concrete, or perhaps education books of two different levels : a rather simple one for practitioners, and a more complete one for researchers and professors. This would be a great help for the redaction of a code, transferring detailed explanations to a more adapted document.

4.5. "Simple". Not forgetting the famous sentence by Albert Einstein : as simple as possible but not simpler.

This means that a code must not aim at covering 100% of the potential applications but only the most frequent ones, 99% of the practical cases. It is clear that exceptional structures – very large bridges, big offshore platforms etc...- need special provisions but are as well designed by very qualified teams of engineers which are able to adapt and complement standard specifications, provided that adapted comments clearly precise the limits of the specifications and that the design philosophy specified by the code is clear. Another possibility is that the code is complemented by a book of comments as was done on some occasions in some countries.

What must be very clear in the code is the philosophy, which is not to be confused with the application method which may be adapted or developed in specific applications, or changed with the development of software capacities. And finally, a code must not be a collection of specifications developed by researchers to promote their works. A code must be reduced to the essence, and specific problems related to such or such type of structures must be detailed in specific recommendations as was done by FIP.

4.6. "Oriented to practice" is very strong and clear. Codes are made to help designers to design properly and have no other purpose. They must be adapted to them.

4.7. Finally codes must be "flexible" to adapt to the technical evolution and to the evolution of materials. This is another reason to reduce them to the essence, to the basic philosophy and to the definition of the structural behaviour.

Codes must not prevent progress. And this is a major problem as we shall see.

5. New problems for concrete codes

5.1. The development of modern codes, model codes or application codes, is made difficult by new problems.

We have already evoked the development of new theories, or of new representations of the structural behaviour such as the modelisation with struts and ties. Very clearly this method has very large advantages, explaining and making logical what was only covered previously by the "règles de l'art" to use the French word, "règles de l'art" which were to be supplemented to the results of very simple analyses. This is why strut and tie models can be a simple and reliable tool to design the reinforcement of classical structural elements – like footings for a well known example – or regions in a structure. But for large and complicated structures, strut and tie models must be supported, or checked, by a FEM analysis – preferably non-linear – to establish the flow of forces which can be different for each loading case.

Clearly modern codes will have to be adapted to different approaches and be very flexible as regards modelisation.

5.2. At the same time, because of the rapid development of the computational capacities, there is a tendency to ask for more and more sophisticated analyses.

An excellent example can be given for seismic analysis. Some softwares can now evaluate the non-linear time history response of a concrete structure, as was recently shown for the Rion-Antirion Bridge. It is evident that those facilities will change the philosophy of seismic design.

Seismic codes must not forbid such a development, and modern codes must accept – in parallel with the now classical specifications based on the concept of capacity design, which includes many "règles de l'art" in fact – the emergence of new approaches which will replace, with a convenient frame, the more or less conventional specifications. The pre-definition of a behaviour coefficient, as an example, loses any significance when a non-linear time history of the dynamic response can be produced. Modern codes will have to allow for both approaches, the existing one being most probably favoured during many years for classical structures.

This is another occasion to say that codes must leave liberties to designers, specially for very large projects, and refrain from codifying what is under development. Codes must codify what is well mastered, and not prevent progress.

5.3. Finally, we must evoke the fantastic evolution of materials and specifically concrete.

In the pioneer applications of prestressed concrete by Freyssinet, the concrete strength was often about 50 MPa, obtained with extremely qualified manpower and with engineers on the site. With the enormous development of the scale of construction there has been a clear regression and in the seventies and eighties it was classical to limit the concrete strength between 30 and 40 MPa, partly due to the limited interest of the cement industry in the civil engineering market. Only the prefabrication industry pioneered high strength and high performance concrete.

Under the influence of several countries – and specially the Norwegian offshore industry – we have recently seen a fantastic development of concrete strength, up to 100 MPa. And some companies and engineers – like Bouygues in France in cooperation with Lafarge – are developing completely new materials, such as the reactive powder concrete which can have a compressive strength comparable to the strength of steel.

But the mechanical and physical characteristics and these different types of concrete cannot be compared, and cannot be evaluated from the same specifications. Even more, it is now possible to "design" a specific concrete for a given application : for example high strength and reduced shrinkage to fill pockets of concrete slabs in composite bridges. We now have a real development of "material design", of the design of the concrete itself which must be considered in the codes. Codes must be – once more – flexible enough to be applicable to these specific and special concretes. This is certainly not the simplest task.

6. Conclusion

It is clear that the development of adequate Model Codes is of significant importance. We know now that this awareness exists in Asia as well, and ***fib*** will be glad to cooperate with Asian countries in order to realize this ambitious goal.