Mastering global quality by an interactive concept

Mastering Global Quality by an Interactive Concept

Maîtrise de la qualité globale à l'aide d'un concept interactif

Umfassende Qualitäts-Sicherung durch ein interaktives Konzept

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SUMMARY

Traditionally, the construction process is divided into different stages, each characterized by a typical quality assurance strategy that is related to the particular activities that take place. In this contribution the need for an interactive concept is emphasized as this is the only way to assure the global quality of a structure. To achieve this, it is necessary to investigate the relationships between the different construction stages, to indicate possible feed-backs and to identify information flows.

RÉSUMÉ

Traditionnellement, le processus de construction est divisé en différents stades, chacun d'eux étant caractérisé par sa propre stratégie d'assurance de la qualité et cela en fonction des activités particulières qui ont lieu. Dans cette contribution, l'accent est mis sur la nécessité d'une conception interactive, car c'est la seule façon d'assurer la qualité globale d'une construction. Pour y arriver il est nécessaire de chercher les relations entre les différents stades de construction, d'identifier et d'actualiser les flux d'informations.

ZUSAMMENFASSUNG

Der Bauprozess lässt sich in verschiedene Abschnitte gliedern, für die, entsprechend den unterschiedlichen Aktivitäten, jeweils ganz spezifische Strategien der Qualitätssicherung charakteristisch sind. Im folgenden Beitrag wird die Notwendigkeit eines interaktiven Konzepts hervorgehoben, welches allein die umfassende Qualität eines Bauwerkes sichern kann. Es ist deshalb notwendig, die Beziehung zwischen den verschiedenen Abschnitten des Bauprozesses zu untersuchen, die Möglichkeiten für Rückkopplungen anzugeben und die Informationsflüsse zu identifizieren.

1. THE CONSTRUCTION SCENARIO

As we are particularly interested in all types of interactions influencing the conception stage of a structure, it is necessary to establish a general *construction scenario*. The model given in fig.1 is certainly not complete, but it is, for our purpose, a sufficiently sophisticated reflection of reality. In stead of the "closed loop" pentagon that is used in [1], a linear model is deemed to be more suitable. Mainly two exterior sources of interaction affect the construction process.

From one side, the actions of nature constitute a system of random events that occur during the whole construction process. Although sometimes the extreme magnitudes of these events can be controlled or predicted, so that disastrous effects can be limited or reduced, we generally have to accept their occurrence. We use historical information and load surveys to elaborate appropriate safety formats.

The second class of exterior factors that influence the construction process is related to the social and natural environment. All human beings that will be affected by the existence of the structure, in particular the owner and the future users, express certain desires and expectations with respect to safety, serviceability and durability. These general and particular boundary conditions are treated in a formal way by building codes and professional experience, which are in fact the synthesis of information coming from innumerable realisations of similar projects.

Some of the most important types of feed-back are indicated in fig.1. Identification of all of them is not necessary and certainly not possible as an important number is hidden in customs and accepted procedures.

2. SOME BASIC CONCEPTS

In the title, some basic concepts are introduced that deserve some general comments before they are illustrated in detail in the following section.

2.1. The global quality

It is obvious that a global view on the quality level of the whole construction process should be available at the design stage. The following indications allow to set up a global appreciation.

The *global quality level* could roughly be obtained as an integral of contributions resulting from all stages or sub-stages of the construction process. However, in that way a mean value could result that conceals low and high quality levels, although this is what sometimes remains as the final impression of the owner.

To arrive at a more balanced appreciation, an extension of reliability formats could turn out to be useful. We define a quality function $q\ (\underline{X})$ similar to a limit state function and associate a quality index to each construction stage. To obtain the global quality index,the system has to be carefully modelled and serial and parallel connections have to be identified. This approach needs a judicious analysis of the construction process since certain dependencies exist between different stages. One aspect of dependency is that a deficiency of quality at one stage sometimes can be remedied during one of the successive stages. On the other hand however it can be amplified later on.

Although the practical application of this approach can be questioned, its main aim is to indicate that in practice, quality assurance is often too much differentiated. By this we mean that decisions are made separately for the different activities in the construction process and that the effect of a decision on

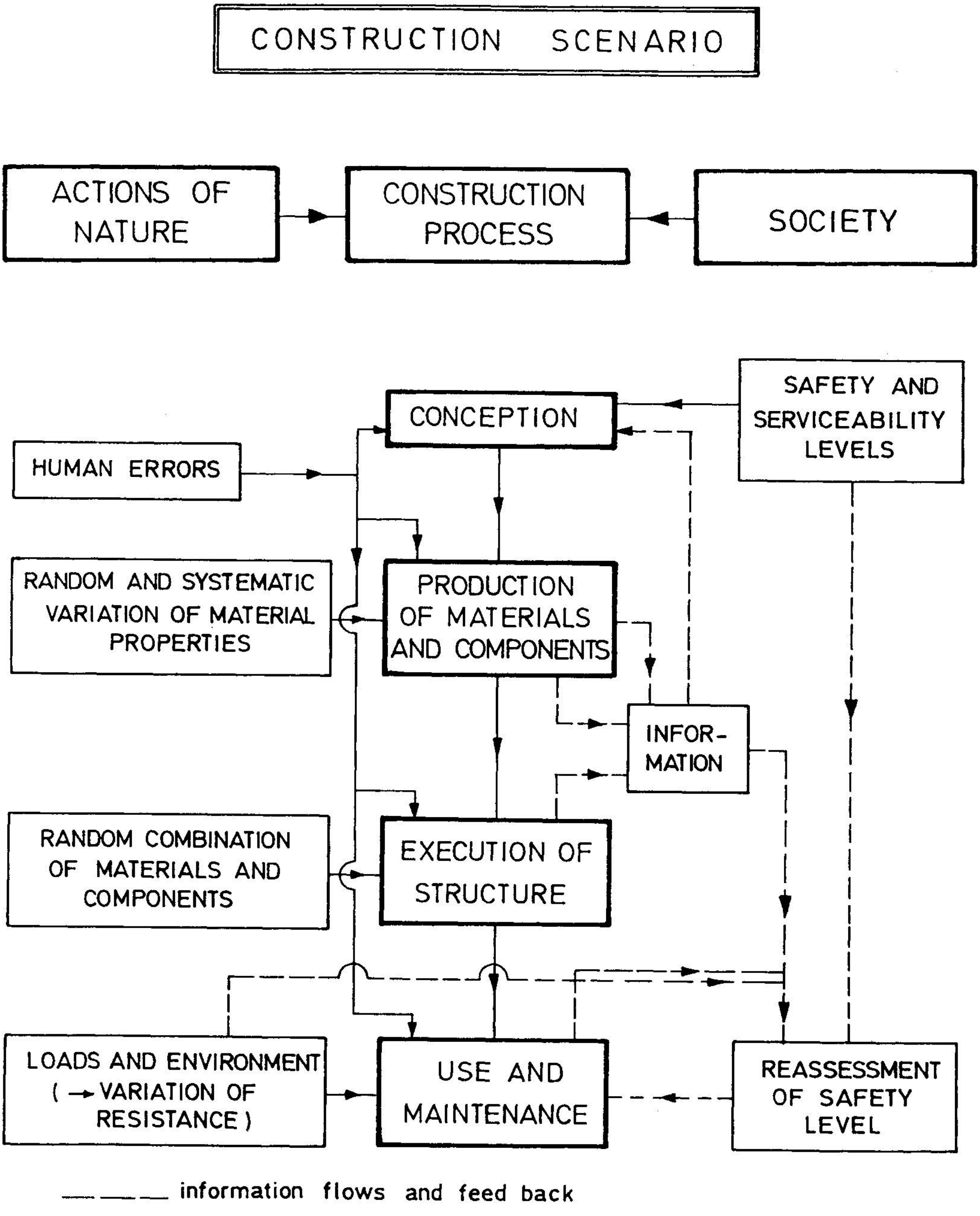

Fig.1 A simplified version of the construction scenario

the quality level of other activities is often ignored. This can lead to serious complications that are easily avoidable if appropriate planning at the design stage occurs.

These interactive aspects indicate the need for a global view, not only on the construction process but also on the quality level because it is precisely the global level that will determine the long term structural behaviour.

2.2. Conception of a structure

It is necessary to introduce the notion "conception of a structure" within the framework of this paper. As a first attempt, we could simply state that the conception of a structure includes planning and design. This definition is too limited however. The *conception of a structure* is the transformation or materialisation of the original idea into a real construction plan and execution guidelines. The conception of a structure gradually grows as more aspects are considered and more information becomes available. The final version has not only a static part that remains fixed during the execution stage, but has also a flexible part that is execution and time dependent. The interactive character is equally important in both parts and mainly depends on the number of feed - backs that exist and on the level at which they intervene. In this way the "conception" is not just a single stage in the construction process, but is integrated in and based on the whole construction scenario.

2.3. Quality mastering

An interactive conception of the construction process, automatically results in *"quality mastering"*, a notion that could be seen as a mature state of "quality assurance". Indeed, by assuring that a sufficient quality level will be obtained, we only look at the achievement of a predifined performance level, e.g. related to an execution stage or to supplied components or materials. With respect to the previously defined concepts "global quality" and "conception of structure", it is clear that we have to introduce quality strategies on a global or local scale, by making use of our knowledge concerning possible interactions, all types of information flows and data on production processes and execution schemes. Quality mastering reflects the insight we have in the activity we are dealing with and our ability to control the parameters that govern it. It follows that quality mastering also offers advantages in case of deficiencies, because it can easily offer alternative strategies.

One could also state that quality mastering leads to the most optimal solution of a construction process taking into occount in a flexible way the exterior constraints and boundary conditions that appear in the construction scenario.

3. PRACTICAL REALISATION OF AN INTERACTIVE CONCEPTION

In the following, different examples are discussed and some concepts are introduced to illustrate which events interact with the conception stage, in a direct or indirect way, and how these events influence the global quality of a structure.

3.1. Safety and serviceability criteria

a) The codified safety formats we use, are the reflection of the confrontation of existing structures with the actions of nature listed in the first column of fig.1. In fact they allow to forecast structural behaviour on the basis of engineering extrapolations of different types of information and experience, taking into account the requirements imposed by the social environment. The distinction between safety requirements (here related to the ultimate limit states) and serviceability requirements is not always clear. Moreover, a large degree of graduation and differentation exists.

b) Consider the case of concrete structures. Generally, crack limitation is considered as a serviceability limit state. In fact cracking influences corrosion and deterioration and hence affects durability, a property that is related to the way in which all limit states are affected by time. Mathematically it can be expressed by the evolution in time of structural reliability during the accepted reference period. In this way it is possible that certain serviceability limit states are less critical initially, but become decisive as the age of the structure increases. All things considered, cracking should not be interpreted as a serviceability limit state except perhaps for large crack widths that are not in agreement with structural aesthetics and that could alarm the public mind. Moreover, it is recognized nowadays that crack widths less than 0.4 mm generally are not dangerous with respect to durability [2]. Hence, graduation of maximum crack widths less than 0.4 mm as mentioned in [3], is only a conventional way of differentiating serviceability requirements without real physical background.

c) A remarkable example of the relativity of safety and serviceability is the Leaning Tower of Pisa (fig.2). Obviously, the probability of collapse is higher than all existing codes would allow. However, its serviceability as a "campanile" is not impaired since its impressive bell is still chiming perfectly. The presence of a local soil weakness underneath its foundation even increased its utility since it became a major touristic attraction. This exceptional example is not intended as an incentive to leave judgement of actual structures to our descendants but it illustrates that our value system can change in unexpected ways.

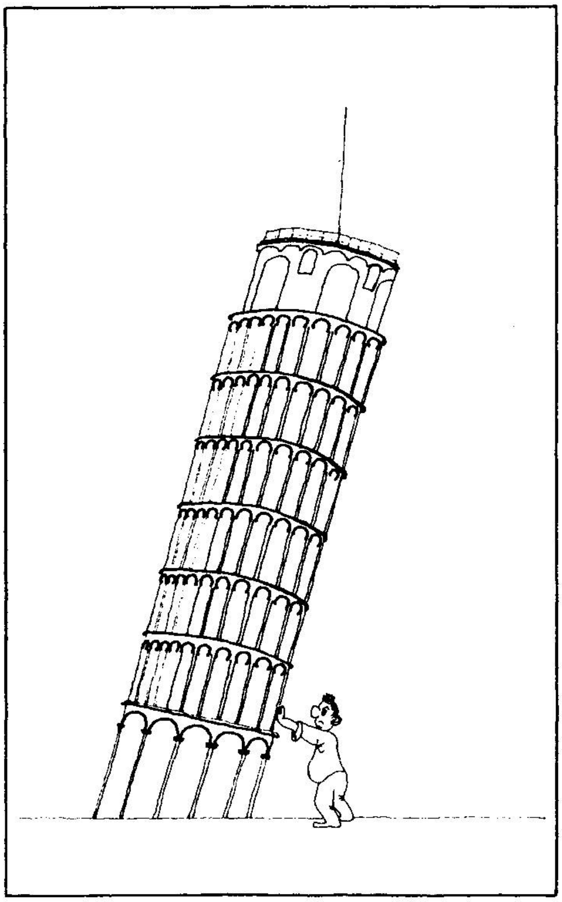

Fig.2

The relativity of reliability

d) Sometimes, new types of hazards arise that require the introduction of new safety regulations and that can even give rise to the use of new material combinations. In Belgium, regulations and research concerning fire resistance were thoroughly extended and updated as a consequence of a calamitous fire in a large shopping centre, causing the death of more than 200 people, some 20 years ago. Provisions for fire safety resulted in a wider application of composite steel - concrete columns since, by using concrete as a protective cover for steel columns, one can also benefit from its contribution to the column's bearing capacity.

e) In order to assure a sufficiently high global quality, it is clear that ambiguous and complicated design rules should be avoided as this may give rise to doubtful or illegitimate interpretations by the designer, generally in the sense that the most economical solution is retained.Often the consequences this solution has with respect to safety will not be investigated. The Belgian Standard for the design of concrete structures allows the application of limit state design as well as the allowable stress method. However, certain engineers use one method for a first limit state (e.g. bending) and the other method for a second limit state (e.g. shear), if this turns out to be more favourable. This approach reflects the poor "safety attitude" of certain designers.

3.2 Conceptual saturation and versatility of structures

a) Another interaction with society is related to the fact that our structures must be accepted by it and correspond with its needs. The appreciation that follows from succesful designs will result in a better motivation of designers and in the practical benefit of receiving more commissions.

To achieve this, it is often useful to introduce new concepts in order to avoid *"conceptual saturation"*. However, this should not result in an inordinate striving for novelties or for experiments with bizarre architectural compositions.

b) When the first tall buildings were erected, everyone was excited by the technical novelty of it. Later on it turned out that these structures, which had a very high environmental impact, became typical for a cool, impersonal grey style of building that often receives the label "steel, concrete and glass style". This caused the need for more harmonic structures (buildings, bridges, highways, ...) on a human scale and incorporated into the natural and historical environment. On the other hand this can lead to an exaggerated attention to detail whereas the global harmony is missing. This latter aspect is illustrated by the reflections of one of the members of the jury of the "Brickwork award for architecture" that is organized yearly in Belgium [4]. Considering the various contributions he writes : "Often there is no pronounced *Gestalt*, no immediately recognizable basic form, but rather a fashionable aftermath of juxtaposed spatial, physical, functional or technological elements" (fig.3). Again the "global quality" concept appears.

c) It is important that designers be fully aware of the mentioned conceptual saturation mentioned above, because the periodic renewal of the needs of the client and his evaluation pattern, determine in great measure the future of the building industry.

To cope with the future demands of the users, it is necessary to offer flexible and *versatile structures* not only with respect to serviceability requirements but also with respect to safety. To illustrate this latter aspect, we mention the growing interest in external prestressing of concrete bridges. This technique offers the advantage of easy removal of cables and allows to strengthen older bridges so that a heavier traffic load can be accomodated. By taking some necessary, yet simple precautions, the uncertain future demands can easily be coped with eventually .

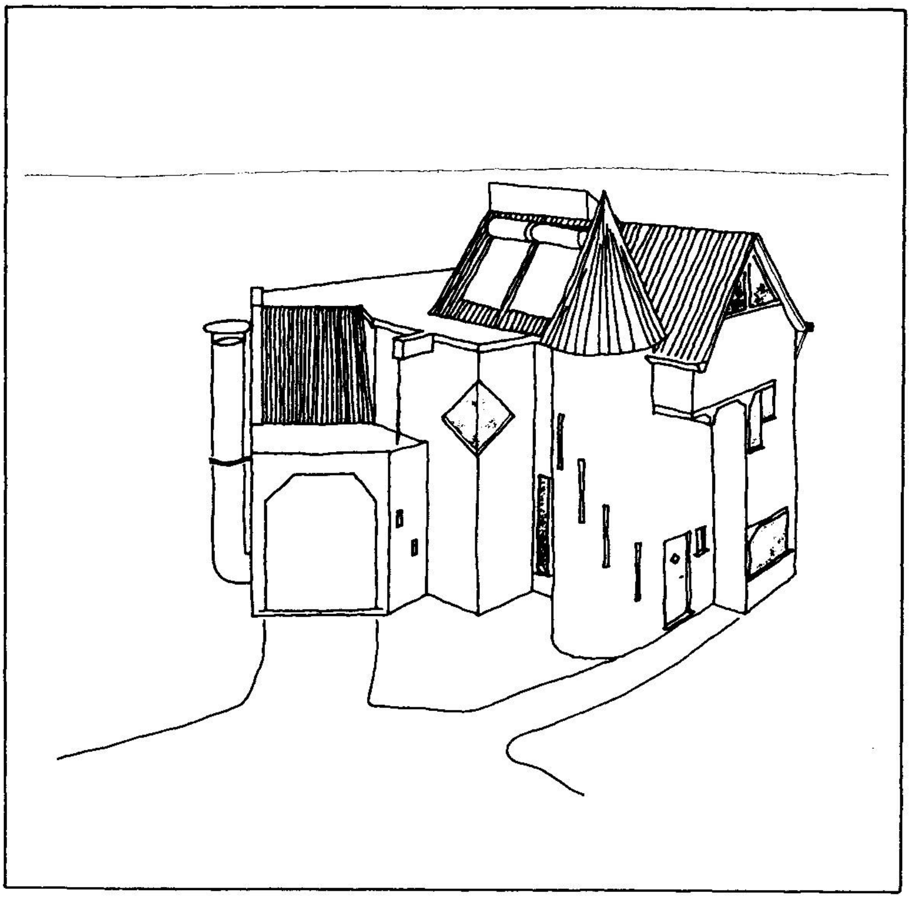

Fig.3 Architectural experiments versus global harmony (or quality) ?

Obviously we cannot proceed like the electronics industry and almost continuously create new needs by offering new or more performing products. This is related to the fact that the planned life-time of these goods is much lower than we are used to in building and in civil engineering, and that the total cost of structures is a large multiple of the cost of the products of the electronics industry (large mainframes excepted).

3.3 Interaction and communication between the different partners

a) Every partner involved in the construction process, projects the structure in his own realisation space. When the different resulting sub-spaces do not coincide, e.g. because the individual solutions are different, a compromise has to be reached in order to avoid lasting disagreements between the different parties. To avoid this situation, sufficient communication and exchange of information between the different partners is necessary already in the early stages.

b) This not only holds during the conception and execution stages but equally during the life-time of the structure. This latter aspect is strikingly illustrated by the example of a bridge failure discussed in [6]. The structure suddenly collapsed after 8 years of service. It turned out that failure occured because of dispersion of responsabilities between different agencies and departments of the Ministry of Public Works and because of a lack of communication between them.

c) At the conception stage, each party involved already thinks at the execution level and establishes its own optimal production strategy almost subconsciously. This optimal strategy results in a certain class of materials and a certain type of structure being applied in the major part of realisations just because they represent the most economical solution. As a consequence, a certain degree of standardization is established since alternative solutions or exceptional or novel structures generally appear more expensive. However, this is not necessarily so since in the neighbourhood of the minimum, the utility varies slowly. This general trend partly explains the traditional character of the building industry that is not very open to artistic inputs and new experiments. Let us quote [6] : *"L'art sème le désordre dans la vie..."*. Although we should not make the conception subordinate to execution, a beneficial interaction is desirable since,especially in difficult periods, the building industry really needs a sufficient number of technical innovations to remain competitive. One of the most innovative periods in the field of concrete structures was undoubtedly related to the development of prestressed concrete.

In the case of new materials, the higher costs are understandably caused by development, prooftesting and initially higher partial safety factors.

d) Sometimes the optimal solution follows from needs arising during the construction stage which have consequences with respect to design. Examples are the incremental launching method for bridge construction and the use of precast concrete slabs in buildings to reduce formwork costs. Both types of construction influence the design procedures (long term feed-back).

3.4 Human errors

In the following we point out how human errors reflect a kind of interaction with the past, but also with the future.

When considering human errors as an interaction with the past, we refer to experience that causes decreasing awareness and to routine that makes the inspection frequency no longer random or systematic but subjective and correlated with the production output.

When considering human errors as an interaction with the future, we consider the problems engineers were faced with by the introduction of new types of structures and the increase in dimensions of different common types of structures. Experience largely guided our capacity for extrapolation, but new phenomena appeared such as buckling, aeroelastic instability, temperature effects etc. These errors occur in the design stage but also erroneous actions in the operation stage are more likely to occur as structural complexity increases. Application of CAD and CAM offers the possibility to spend less time on routine activities and to focus attention on the particularities of complex systems. A possible disadvantage is that computer programs are generally developed for classical types of structures and that in this way innovation could be hampered.

4. CONCLUSIONS

- On the basis of a general construction scenario, it is investigated what types of interaction influence the conception stage of a structure. It is explained that the notion "conception of a structure" is broader than planning and design.
- It is emphasized that a global view on quality is necessary as it is found that in practice quality assurance is often too much differentiated.
- "Quality mastering" is introduced as a mature state of quality assurance.
- It is shown that a clear distinction between safety and serviceability

requirements is not always easy.

- An interactive conception is necessary in order to prevent conceptual saturation and to obtain versatile structures.
- Interaction between the different partners is discussed and it is pointed out that a certain degree of standardization almost automatically results.
- Finally, some aspects of human errors influencing the conception stage are summarized.

5. ACKNOWLEDGMENT

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6. REFERENCES

1. CEB, Quality Control and Quality Assurance for Concrete Structures, Bulletin d'Information No. 157, 1983.
2. SCHIESSL P., Admissible crack width in reinforced concrete structures, Preliminary Report, Vol.2, IABSE-FIP-CEB-RILEM-IASS Colloquium, Liège, June 1975.
3. CEB-FIP, Model Code for Concrete Structures, Volume II, 3rd Edition, 1978.
4. Baksteenprijs 1985 - Verslag van de jury (visie van J.Baele), Bouwen met baksteen, Nr.40, 1985.
5. VANDEPITTE D., Collapse of the Bridge at Pulle, Proceedings IABSE Workshop, Rigi 1983, IABSE Reports, Volume 47.
6. PORTOGHESI P., Au-delà de l'architecture moderne, L'Equerre, Paris,1981.

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