Zeitschrift: IABSE reports of the working commissions = Rapports des commissions de travail AIPC = IVBH Berichte der Arbeitskommissionen

Band: 34 (1981)

Rubrik: Discussion - Session 3, part 2

Nutzungsbedingungen

Die ETH-Bibliothek ist die Anbieterin der digitalisierten Zeitschriften auf E-Periodica. Sie besitzt keine Urheberrechte an den Zeitschriften und ist nicht verantwortlich für deren Inhalte. Die Rechte liegen in der Regel bei den Herausgebern beziehungsweise den externen Rechteinhabern. Das Veröffentlichen von Bildern in Print- und Online-Publikationen sowie auf Social Media-Kanälen oder Webseiten ist nur mit vorheriger Genehmigung der Rechteinhaber erlaubt. Mehr erfahren

Conditions d'utilisation

L'ETH Library est le fournisseur des revues numérisées. Elle ne détient aucun droit d'auteur sur les revues et n'est pas responsable de leur contenu. En règle générale, les droits sont détenus par les éditeurs ou les détenteurs de droits externes. La reproduction d'images dans des publications imprimées ou en ligne ainsi que sur des canaux de médias sociaux ou des sites web n'est autorisée qu'avec l'accord préalable des détenteurs des droits. En savoir plus

Terms of use

The ETH Library is the provider of the digitised journals. It does not own any copyrights to the journals and is not responsible for their content. The rights usually lie with the publishers or the external rights holders. Publishing images in print and online publications, as well as on social media channels or websites, is only permitted with the prior consent of the rights holders. Find out more

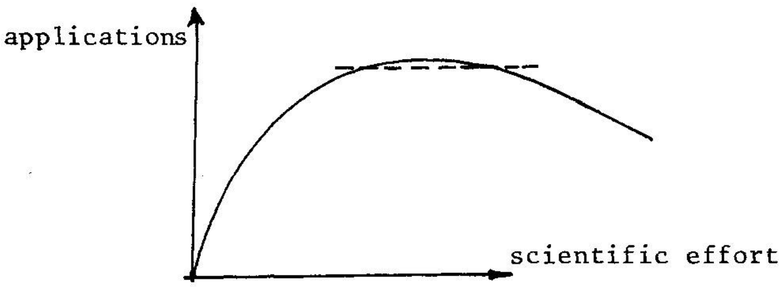
Download PDF: 05.09.2025

ETH-Bibliothek Zürich, E-Periodica, https://www.e-periodica.ch

Session 3, part 2: Applications and Experimental Verifications

Introduction by B.W. van der Vlugt, chairman (The Netherlands)

The first two days of this conference we have listened to the specialists on modelling of material properties, structures, mathematics. Now we are focussing on the questions of how this modelling can be interpreted and verified by experiments. A bridge is constructed over the gap between numerical specialism and the specialism on materials and structures; I think that it is one of the great successes of this conference that this gap between the two groups is bridged more and more. There is, however, another gap between the scientists on one side and the group of normal designers, who need simple rules, on the other side. The concern about this was this morning already expressed by Prof. Gerstle.
The designers rely fully on the rules, provided by the scientists. However, a common characteristic of scientists is that they are never sure of anything. Nevertheless they should provide simple and sound design rules, and suggestions for detailing, basing themselves on the tools that we have at the moment even for complicated fields of earthquakes, impact and cyclic loading, fire resistance. What happens if the scientists disregard this aspect of their task is illustrated by the following figure, respresenting the applications as a function of scientific effort. As you see, I have copied the stress-strain diagram, quite familiar to us.



As it is seen we can reach a situation in which an increment of scientific effort may not any more result in more applications and can even have a negative effect on these applications. Although making codes is primarily the task of institutes like CEB or ACI, rather than IABSE, we should not forget that we can all contribute to an amelioration of this situation.

Abstract on a practical application of the subject of Session 3

Non-Linear Behaviour of a Large Highway Superstructure in Berlin

Horst Falkner
Dr.-Ing., Partner

Ulf Hinke
Dipl.-Ing.

Leonhardt und Andrä, Consulting Engineers
Stuttgart, Federal Republic of Germany

1. General
In West-Berlin a 15-storey appartment building with two Autobahn tunnels passing through about 600 m suffered large deformations due to unexpected settlements (Fig. 1).
The structure consists of 77 three-legged stiff wall-frames placed in a distance of 6,4 m, carrying a total load of35.000 kN (Fig. 2).

2. Analysis of the structure
In order to get the most realistic and economical design value for the structure, it was decided to make a precheck by using three different approaches of analysis on the structure:
- Finite-Element approach (Fig. 3);
- Frame analysis by linear theory;
- Model analysis on a plexiglas model (Fig. 4).

The most important result of the different approaches was the governing influence of the different elastic soil behaviour between the inner and outer supports.

Having absolutely stiff supports of the three-legged frame we obtain a support moment -23 MNm. Due to the elastic behaviour of the soil we obtain a moment of +23 MNm corresponding to a differential settlement of 7 mm. Hence only 7 mm produce a variation of the support-moment of 46 MNm, which corresponds to about 200% of the initial value (Fig. 5).

With this analysis, the fundamental question for the structure and its design was solved. Measurements and observations showed that the structure over a length of 85% corresponds to the design values.

However, in a local area of 70 m length sudden differential settlements between the inner and the outer supports have been observed.
The irregular settlements led to final values which exceeded the initial design values by a factor 4 to 6. From this the main question arose: "What will happen to the stiff structure designed for a differential settlement of 7 mm, but being subjected in reality to a value up to 40 mm?"

3. Non-linear behaviour of the wall frame
Because it was not possible to reinforce the structure, there was the responsibility of checking the structure using refined methods of analysis considering the following conditions:
- The amount of restraint actions depends substantially on the time sequence and the absolute values of differential settlements.
- The change of the structure from the uncracked State I into cracked State II depending on the tensile strength of the concrete was observed.
- A substantial contribution to the deformation of wall structures is the contribution due to shear in State I, but even more in State II.
- Material data such as moduli of elasticity, and tensile and compression strength were checked.

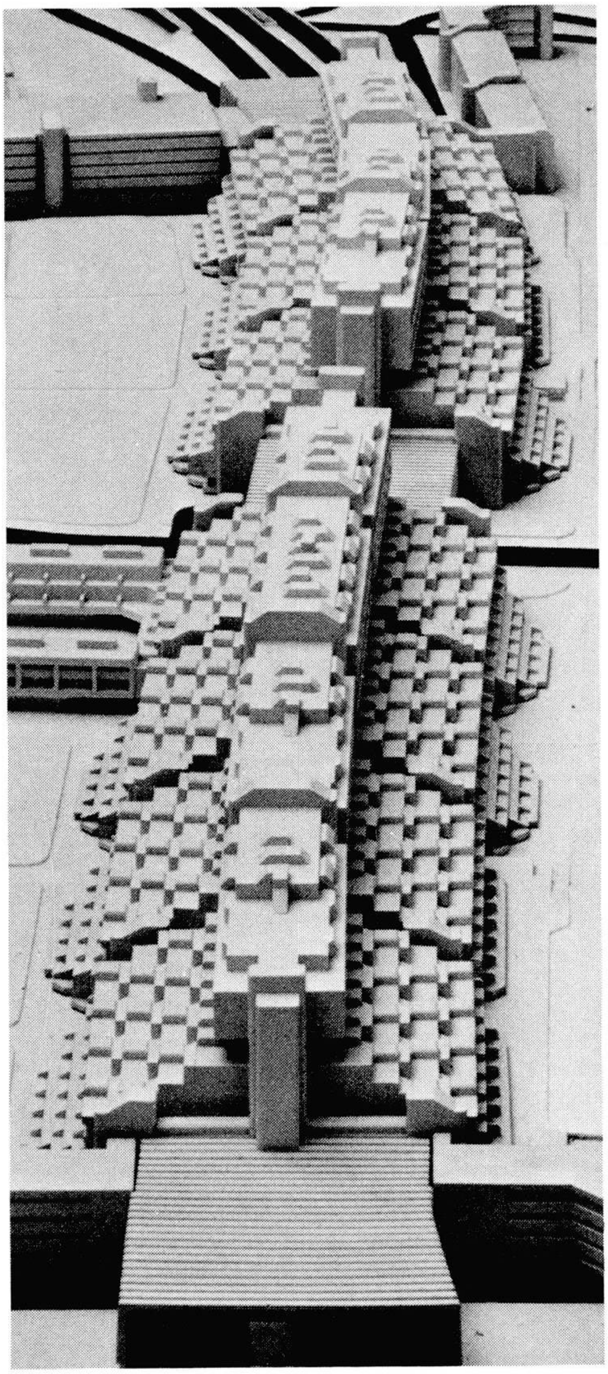


Fig. 1 Model of the SAB-Project

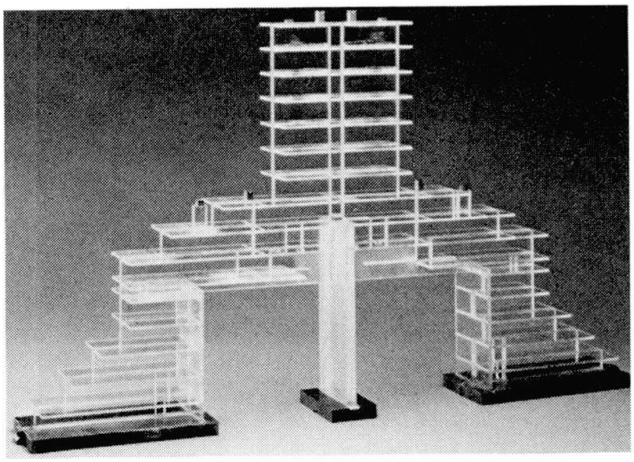


Fig. 4 Plexiglas model

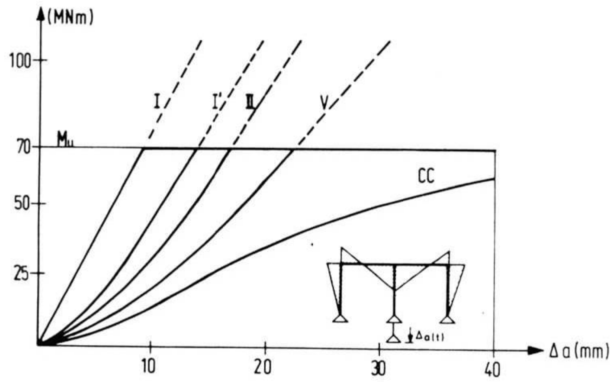


Fig. 6 Structure responses to differential settlements

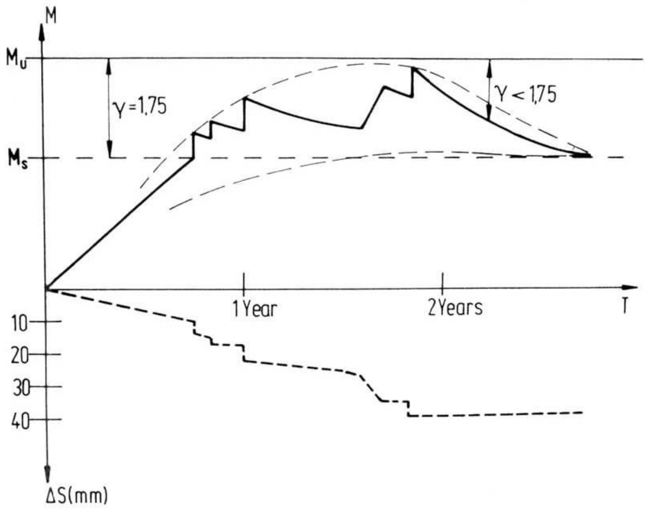


Fig. 7 Time depending restraint actions due to settlements

- In order to define the restraint actions of one year old concrete, it was important to know the creep and the relaxation behaviour. Therefore laboratory investigations were executed.
- Definitely one of the main tasks of the analysis was to define the existing factor of safety against ultimate strength behaviour.

In Fig. 6 the distribution of the actions of a relevant section of the structure is shown as a function of the differential settlements under consideration of the various influences as mentioned above.

With alle these data it was possible to prove that the structure would be able to deform by a factor 4 to 6 times bigger compared to values established by elastic analysis. It could be shown theoretically as well as by practical observations at the structure that these large deformations could be carried by the structure without permanent damages.

The actions in the structure might possibly have led to the development as shown in Fig. 7. This means that in certain stages of settlement the structure was subjected to such high restraint actions, that it came close to its ultimate carrying capacity.

Today, however, after it was possible to stabilize the settlements by cement injections into the ground it can be stated definitely that the stiff wall frame structure could withstand differential settlements of 40 mm. After grouting some large cracks the structure now behaves perfectly under service conditions.

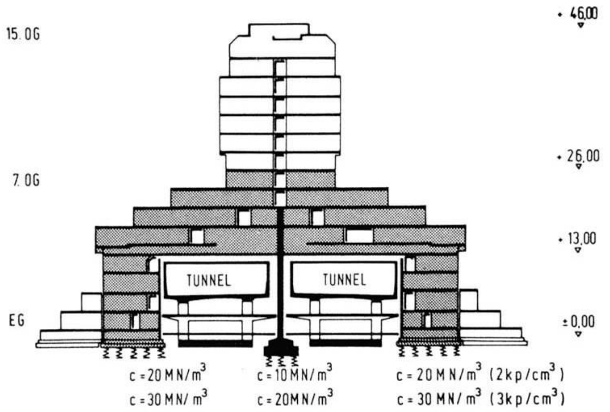


Fig. 2 Cross section of the wall frame structure, foundation moduli

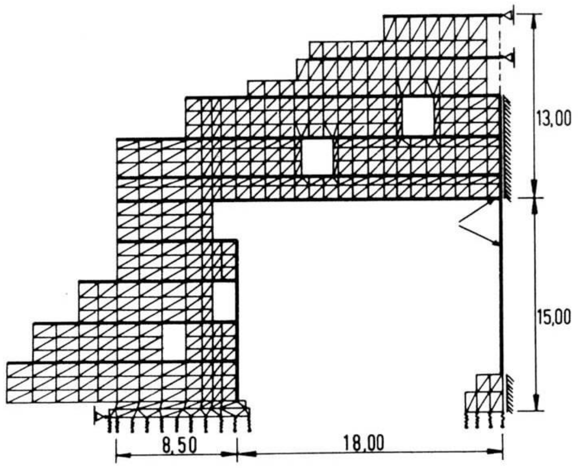


Fig. 3 Layout of the Finite-Elements.

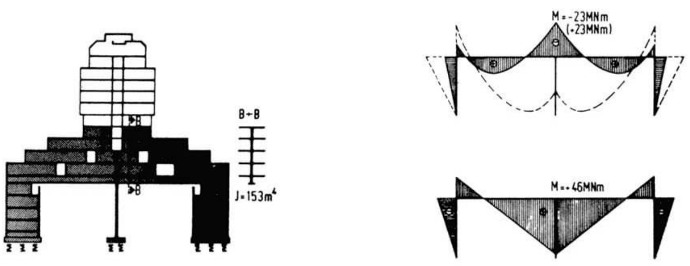


Fig. 5 Variation of the support-moment due to elastic supports.

DISCUSSION

Session 3, part 2: Applications and Experimental Verifications

Paper by Ketchum/Scordelis, U.S.A.

Jávor (Czechoslovakia): In section 4.6 of the presentation it is seen that the results of the calculation are in general agreement with the observed behaviour. If we consider however structures, which are not of a classical shape, as analysed here by Prof. Scordelis, but for instance prefabricated cantilevered box girders, we can meet differences between theory and practice. Whereas a finite element analysis displays equal strains for all corners of the cross-section, in reality measurements show that there are considerable differences, which can be well observed after stabilization of the main creep, so after about two years. These differences in strain are caused by the effect of temperature gradients on creep, shrinkage, prestressing losses etc., which is not taken into account by such a computer analysis.

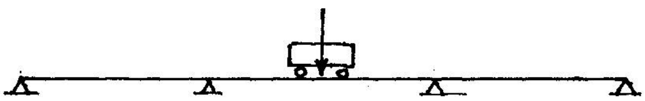
Scordelis: Deformations of such kind can be predicted by this computer program if you know what the input is as far as load history, temperature history etc., are concerned. If you do not know these effects, you have to adopt a lower bound and an upper bound for these values, put it into the computer program and see how it will vary. Furtheron, it is not possible to predict detailed stresses in concrete structures; however, we can predict overall force distributions, and that is what we are primarily interested in.

Van der Vlugt (The Netherlands): In general it is possible to take such temperature effects on box girder bridges into account, but then you need another type of computer program. The program used here can only analyse structures which can be linearized.

Scordelis: As mentioned in the paper, the computer program can perform a non-linear geometric material and time-dependent analysis of reinforced and prestressed concrete planar frames, subjected to any load or temperature history.

Ingvarson (Sweden): What was meant by the statement that the bridge has a 7-fold overload capacity?

Scordelis: It is meant that, if the bridge is designed in such a way that one truck can be resisted (see Fig.), the real capacity is 7 trucks, placed one upon another, so that it is seen that the design is very conservative.

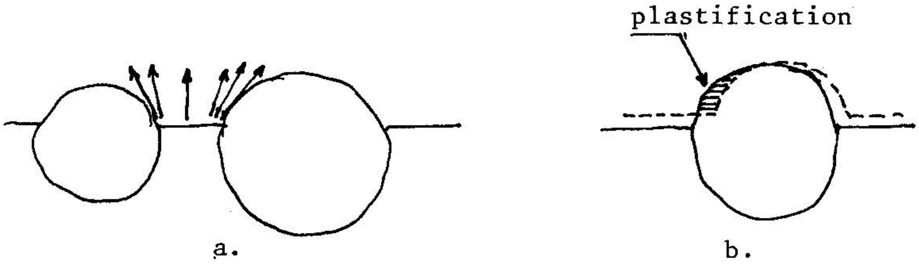


Ingvarson (Sweden): However, from a probabilistic point of view it is possible that a situation occurs in which the bridge is loaded by a combination of trucks, driving one after another along the whole bridge. In that case the safety will not be as high as a factor 7.

Scordelis: The safety of this span will not be violated by what is put on the other spans. So what I meant is really that 7 trucks are placed on top of each other.

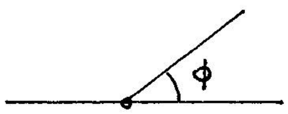
Paper by Razaqpur/Ghali, Canada

Walraven (The Netherlands): During his presentation Prof. Ghali raised the question whether it is possible that, at zero crack width, a shear displacement between the crack faces can occur. In this respect I do not agree with the statement of Dr. Gambarova and Prof. Bazant, that the first displacement of the crack faces should also be vertical to the crack. The structure of the utmost part of a crack face, on microlevel, is characterized by particles, which extend for a minor part from the crack faces (Fig. a).



So there is a certain range of freedom as far as the crack opening direction is concerned. Only a limited number of particles will be found providing planes of resistance, perfectly perpendicular to the crack plane (Fig. b). In such a case deformation of the relatively soft matrix will occur, so that shear displacement is not prevented. So from a physical point of view we can expect a shear displacement component to occur already at zero-crack width. This was also confirmed by our tests.

Braestrup (Denmark): I would like to support the comment by Walraven. I think also that from a physical point of view there is no reason why the crack displacement could not immediately have a shearing component. If we have a plane strain situation, then, according to the plastic model, the angle ϕ , in the figure, cannot be smaller than the angle of friction; ϕ will be the dilatancy angle. If we consider a plane stress situation, there is no reason why we cannot start immediately with pure shear, but in that case the resistance of the concrete is equal to half the compressive strength, thus pure shearing is very energy consuming. Therefore, the concrete would prefer a deformation which is more perpendicular to the discontinuity.



Van der Vlugt (The Netherlands): I think that in the case of smeared-out cracks it will be very difficult to establish this direction, because you have to combine the displacements of an unknown number of cracks and the deformation of the sound concrete between the cracks.

Ghali: Aggregate interlock can be important in some cases, but in many cases it is not. A shear displacement parallel to the crack sould occur in order to get aggregate interlock, but in many, so-called shear loading conditions, it actually ends up by having a crack in the principal direction, and the movement in the crack will be just simply widening without producing any aggregate interlock at all, so that the smeared-crack approach still can do the job perfectly.

Discussion on non-orally presented papers

Paper by Lorrain/Pinglot/Suhud, France

Van der Vlugt (The Netherlands): It is mentioned that the cracking moment of prestressed concrete is influenced by the reduction of the tensile strength of the concrete due to creep. Is this correct or a misprint?

Lorrain: Indeed, it should be the reduction of the concrete compressive strength by creep.

CLOSURE OF THE COLLOQUIUM

Prof.Dr.-Ing. H.W. Reinhardt
Delft University of Technology, Delft, The Netherlands

At the end of the colloquium we should try to balance accounts, i.e. we should look at the aims of the colloquium and compare the expectations with the results. May I cite some statements of the preliminary invitation to this colloquium:

"Structural theories have been based on experimental research without any full understanding of the internal force transfer. There is a need for more generality in the outcome of research. This can be reached by concentrating on elementary basic models which describe the characteristic properties of the materials involved."

Further:

"The modern high speed computer has stimulated new numerical techniques of which the finite element method proves to be the most promising one.... For a complicated load history the method provides the desired detailed information on the internal force transfer. However, this numerical approach relies upon the proper material behaviour being available."

Now the main statement:

"It is the aim of the colloquium to stimulate the synthesis of experimental investigation and numerical analysis of reinforced concrete structures."

Experimental investigation can have different meanings: the investigation of materials with subsequent deduction of material laws - constitutive relations - or the investigation of structures with subsequent verification of numerical models. Both aspects have been treated in the last three days. On the first day we heard about modelling of material behaviour. It was emphasized that micro-aspects should be taken into account in order to describe concrete behaviour properly. Micro-aspects are the process zone around the crack tip, the strain softening, the crack dilatancy. As fracture criteria, it was proposed, methods should be preferred which are based on strain or fracture energy rather than on stress or strength. We learned also that plain concrete does not exhibit the typical feature of a plastic material, namely a yield plateau, and that therefore the application of plasticity theory on concrete should be done with care.

Later on there have been other models presented which use tensile strength as a failure criterion or critical stress intensity factors which may not be exceeded. A whole palet of material models for concrete has been presented, and all of them pretend to be suitable.
An engineer who is no real specialist, must become crazy having the choice of so many possibilities because he must ask, why this variety?
There are various explanations possible: it may not be so important what material model is used or, for special cases a special model has to be established. What Hooke's law has made so powerful was the fact that it could be applied to any material, any structure under arbitrary conditions.

Let us keep in mind that human beings need to have not too many philosophies, and that applies also to engineers. Professor Gerstle said it in a condensed form: "If you don't need the complications, don't use them". I got the impression that we are in a rapidly and immensely growing jungle which should be cultivated, even if in the future much more powerful computers will be available.
The only difficulty is that the cultivators do not yet agree together.

I wonder whether agreement can be achieved as long as basic experimental results are missing which should be inserted into the models: realistic bond slip behaviour, shear resistance, fracture mechanics of concrete in compression and shear, strain rate effects on mechanical properties. On the other hand, there are so many experiments carried out and documented in the literature, that more experiments are perhaps superfluous. But if experiments should be done, they should be done after thorough theoretical examination and the results should be worked out in a way that they can be used by the analyst.
From this, you could prove a kind of predominance of the analyst over the material scientist. We think that the analyst who likes to refine his methods, must take care that he does not loose the contact with building practice. Today, we use high quality concrete, but couldn't we be forced to use waste material or garbage as aggregate for making concrete, and how useful are then our refined material models?
This brings me to another point which has been mentioned during the colloquium, but as I think, in a low voice. That is the scatter of the mechanical properties of material. We are discussing the problem where the first crack will occur in a beam with equal shrinkage stresses.
According to the theory, at a certain instant at any point an equal crack should occur, and that would mean that the tensile zone must crumble into a thousand pieces in one instant. Concrete knows better because all parts of the concrete are a little bit different.
In normal practice it is even worse, as Prof. Eibl pointed out; if you order a certain concrete quality, the mixing plant guarantees a certain minimum value which may well be exceeded.
This value is tested on 28 days age, but what about further hydration.
The same is true for reinforcing steel which may have higher yield stress and fracture strength. These facts imply that we have to think carefully and critically about all sophisticated models. More research should be done in order to cultivate the jungle - which as such is very nice but a little impractical - and to establish appropriate tools for the necessary tasks.

The question arises: "What is appropriate?" I agree with Professor Meyer who stated that the best technology should be used - I understand material and numerical models and high speed computers - if the public has to be protected against severe danger.
For instance, against dynamic effects from earthquakes, tornados, missile impacts, air blasts.
On the other hand, daily work of a structural engineer is to design structures in such a way that they can carry dead loads and normal live loads. I think that also for these engineers advanced mechanics is an appropriate tool, only in a somewhat different way. Modern regulations and standards which he has to use, can be based on finite element sensitivity analyses rather than on limited experimental data. Tables, plots and graphs will

also in the future be normal tools of daily practice and educational aids because engineers are highly sensitive to visual perception.
We are dealing with an applied science, that means applied to concrete problems which arise in the technical world. Or, expressed somewhat differently, this science serves the society and the topics of the science are derivatives of the demands of the people. From that, the best method is that which provides the best results within the least time for the least cost.
Let us come back to the aim of the colloquium; namely: to stimulate the synthesis of experimental investigation and numerical analysis of reinforced concrete structures. Did we reach the goal? I am sure we did, and for several reasons:

- outstanding personalities in the fields of materials and numerical methods have exchanged knowledge and ideas about the way to treat difficult problems;
- many papers have dealt with both aspects: materials and analysis;
- a great number of participants has learned a lot about current developments;
- research needs have been formulated by different disciplines;
- it was shown that there is a lot of material knowledge which should be prepared in such a way that the analyst can use it;
- different parties agreed to have a check of their capabilities. I strongly support the proposal by Professor Collins of a blind test and I am looking forward to know the "Mike Collins Award Winner" for the best prediction.

Ladies and Gentlemen,

On behalf of the organizing committee I would like to thank all of you for your attendance at this colloquium. We had very good speakers who have presented their papers with enthusiasm. Thanks to all of them.
I think the invited reporters have done a very good job, not only during these three days, but also in preparing the introductory report which has served as a guideline for the authors. Thank you very much for your effort which has stimulated so many authors and which has inspired the audience. I am also very grateful to the chairmen of the technical sessions for introducing the speakers, for leading the discussion and watching the time schedule. We have appreciated all contributions to the discussions.

We are proud of this colloquium and we wish that all of you have the idea that you have attended an interesting and useful meeting.

By this, I close the scientific part of the colloquium.

Leere Seite
Blank page
Page vide