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II

RAPPORT GÉNÉRAL / ARBEITSBERICHT / GENERAL REPORT

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The opening remarks at this morning's session pointed out the desirability and the hope that, as a result of interchange of experience, it might be possible to develop reasonably simple mathematical techniques for designing structures to cope with the effects of creep, shrinkage and temperature changes that would be as well agreed upon and at least as simple to apply as the well established and somewhat complicated methods for dealing with gravity loads.

Theme II for this second session is to consider how to apply the results of observations and measurements as previously discussed to the practical design of structures. This would deal not so much with the computational methods, because those are for tomorrow's program, but rather the influences these different parameters have in the design of structures.

You have heard Mr. Casado's introduction to this theme in which he summarized the current state of the art and many of the problems and gaps in our knowledge. It is my task to give you a summarization of the contributions for Theme II.

Professor Leonhardt of Stuttgart, Germany, following his own successful practice, recommends that by care in selecting materials, proportioning, and curing, the volumetric changes in the concrete can be minimized. He mentions gap-grading, small cement content, efficient curing, prohibiting loading of young concrete and other excellent suggestions. He also mentions selection of sections that behave well, guarding against excessive prestress. In difficult cases, compression reinforcement can be added. Many other practical suggestions are brought together in this excellent summary.

Mr. J. Aichhorn of Austria also has practical suggestions, such as selection of suitable sections, columns in framed bridges, amount of prestressing force, thermal insulation, cantilevered construction, and numerous similar precautions and design possibilities.

K. Ohno and M. Obata of Japan analyze multi-legged bents with buried tie beams, the former subjected to a single uniform temperature change and the latter to a different temperature change. Short term and long term effects are compared with measured values with good results.

M. F. Bauer of Austria selected the problem of a cantilevered beam with sometimes one, but usually two diagonal hangers, the beam carrying a uniform load for all or a part of its length for extended times. He concludes with suggestions that variations in tensioning can minimize the effects of shrinkage.

Two papers, one by B. Bresler, D. Helmick and L. V. Ramakrishna of California, U.S.A. and the other by K. Cederwall, L. Elfgren and A. Losberg of Sweden, concern themselves with analytical and experimental studies of eccentrically loaded relatively slender columns and compare the results quite satisfactorily.

H. Trost of Hannover, Germany develops a time-dependent relationship for the effects of creep and shrinkage in concrete and compares the results with test data. He suggests methods of application to actual structures.

C. A. Miller of Illinois, U.S.A. presents expressions for calculating deflections of beams due to creep and shrinkage and offers simplifying assumptions.

S. K. Gosh and M. Z. Cohn of Waterloo, Canada offer a non-linear analysis of structural concrete from time-dependent stress-strain relationships. A computer program appears to predict moment curve, time and deformations for long-time loads that agree with measured results.

M. A. Saeed and J. B. Kennedy of Windsor, Canada combine the various approaches including a fictitious modulus of elasticity to compute rotations and deflections for a simply supported prestressed concrete structure.

R. B. Warner of Australia also studies time-dependent stresses and deformations under sustained moment. Moment redistribution with time in double reinforced continuous beams is considerable even to the point that the ordinate of the stress block might reduce to zero or even become tension.

B. Fassel of France comments on problems of instability under sustained loading that this effect is not sudden failure but gradual yielding. Creep does sharply reduce this critical load.

J. Fauchart of France discusses the effect of creep and shrinkage on prefabricated, prestressed continuous girders.

It can be seen that we do know quite a bit about the behavior of beams and columns and something about frames, sometimes analytically, sometimes experimentally and sometimes by a combination. We could, therefore, hope to formulate procedures and agree upon design methods.

At the same time, we have available a considerable number of methods for by-passing or avoiding the more serious problems. Readers of the prepublications and these prepared discussions will doubtless agree on the following conclusions.

First, that the effects of volumetric changes can be very important. Structures have, and do, tear themselves apart. Engineers do attempt to cope with the problem, but mathematical procedures are not as well established as those for gravity loads.

Second, that there are several ways to minimize the problem.

(a) One is to cut the building into sections which can accommodate the anticipated changes.

(b) Another might well be to contain the entire structure within a prestressed ring, inducing internal compressions roughly comparable to the tensions anticipated from creep, shrinkage and temperature.

(c) Still another might be to free the structure entirely so that columns may move on their bases, beams slide upon their supports, even slabs upon their beams, so as to make the structure self-relieving.

(d) Still another way is to specify certain ranges of parameters and thereby certain unit values that would permit a reasonably close estimate of the volumetric changes which must be accommodated and then establish accepted mathematical procedures to determine the forces which must be resisted internally by the structure and transmitted from support to support.

If our Symposium brings to the attention of designers, and especially those who occasionally overlook these phenomena, the necessity for thinking about volumetric changes and trying to make some provisions to cope with them and not simply blithely forget about them, perhaps half of our task will have been accomplished. It is possible that experts never will agree upon just how to design for these volumetric changes but would prefer to keep it a highly individualized matter of judgment. It is, however, more likely that as the interchange of information goes on, we will be able to formulate our methods and procedures quite clearly, taking into account at least all of the major parameters and being able to develop calculations which another engineer in another country can understand and verify. Then it will no longer be necessary for building codes simply to say "take account of the effects of creep, shrinkage and temperature."

To draw what lessons we can from the American Concrete Institute's Symposium on the same subject held in New York last March, Bob Philleo, Chief of Concrete Research, Civil Work, U.S. Army and Chairman of ACI's Technical Activities Committee, will present a report of the principal accomplishments in New York.

II

Summary of the American Concrete Institute Symposium on Creep, Shrinkage and Temperature, New York, April 1970

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The purpose of the New York symposium was to identify the problem area in design of concrete structures produced by the effects of creep, shrinkage, and temperatures; to report and organize the research information available to assist in coping with the problem; and to outline practical design techniques. Accordingly, nine designers were invited either to discuss structures in which the effects of creep, shrinkage, or temperature had produced distress or to present design procedures for preventing the problem. In addition, ACI Committee 209 on Creep and Shrinkage in Concrete presented two state-of-the-art papers: one on the effect of concrete constituents, environment, and stress on the creep and shrinkage of concrete; and one on the prediction of creep, shrinkage and temperature effects in concrete structures. The list of papers and authors is given in the Appendix.

The first committee report on mechanisms of creep reported specific data or theories from 78 of the more than 1,500 references in the literature on the subject. Concrete was considered as consisting of aggregate, unhydrated cement, solid products of hydration including crystals and crystallites, and void space containing both strongly adsorbed and capillary water. The effect of each on creep and shrinkage was examined. Since it has been observed that dry concrete does not creep appreciably at normal stress levels, creep, like shrinkage, was attributed to the presence and movement of water. Since free water and most of the capillary water are relatively mobile and respond rapidly to pressure changes, creep was attributed to the water which is bonded to the hydrophillic solids comprising the gel. Such water responds slowly to mechanical or thermodynamic stumuli, but it tends to return to its original position upon removal of the stimuli unless the return is inhibited by permanent changes in the solid. The effect of aggregate and unhydrated cement particles is to restrain the movement. The effects of temperature and humidity, both as they affect hydration and moisture transfer between the concrete and its environment were considered. The section on the effect of stress on creep was largely a presentation of a large amount of empirical data although it was concluded that non-linearity of creep is attributable to bond-crack propagation.

The fact that volumetric changes do occur in concrete having been established, the second paper De Serio established the fact that such changes can damage structures. In a survey of case histories he described a parking garage in which a large seasonal temperature differential produced recurring cracks throughout the structure, a school on a clay foundation in which drying out of both the soil and the lower portion of the structure produced extensive structural damage, a school in which the walls were subjected to unanticipated torsional loading as a result of thermal and shrinkage volume changes in connecting members, and storage silos in which the large possible temperature changes between the inside and outside had not been adequately provided for.

The second report by Committee 209 was a synthesis of data from 56 sources presented as equations to predict creep or shrinkage strains for

54 conditions of age, loading, environment or concrete properties or configurations. The equations were supplemented by curves providing correction factors for yet other conditions.

The remaining papers were reports of practicing designers giving actual design techniques which they have found to be effective or of researchers reporting the actual behavior of structures to provide data for verifying design techniques.

Fintel and Khan presented a procedure for analyzing frames of multistory structures. The elastic and inelastic shortening of supports of each slab from the time of the casting were computed throughout the remaining construction period. An equivalent one-bay frame was used to facilitate the analysis. Charts were given to estimate the residual differential shortening for a practical range of ratios of axial column stiffness to flexural stiffness of the horizontal slab elements. From the residual differential movements the corresponding moments in the frame could be computed. Creep of the slab, it was noted, substantially reduced the frame moments due to differential shortening of supports.

Raths presented a method for computing stresses due to volume change in a multi-bay frame by repeatedly solving a reference single-bay frame in which the force build-up was varied from bay to bay in a systematic manner. He recommended the use of shearwalls for lateral stability since, when a frame is required to provide its own lateral stability, the required frame stabilityproduces an excessive build-up of axial volume change forces in the columns and beams.

Pauw reported on a method for predicting long-time deflections of a five-span continuously reinforced concrete box girder highway bridge which consisted essentially of dividing the instantaneous modulus of elasticity by 3 and by reducing laboratory shrinkage data by one-third. Calculated deflections agreed well with those of the prototype.

Pfeiffer and Magura reported the results of instruments mounted on columns and core walls of two very high concrete frames. They confirmed the validity of parallel laboratory tests.

Roll had been called upon to compute the deflections in an office building in which the beams were steel beams designed to act in a composite manner with the concrete floor above. His approach was a step-by-step calculation of long time increments of deflections produced by each step in the construction process. It was assumed that the principle of superposition was valid and that the increments were, therefore, additive. Deflections resulting from differential shrinkage and creep were calculated by the "composite section method" of Branson [(1)]. Results agreed well with the performance of the prototype.

Khan and Fintel discussed vertical creep, shrinkage and temperature effects which can occur in frames in excess of 30 stories in height. They recommend that:

1. By utilizing similar percentages of vertical reinforcement in adjacent columns, differential shortening can be kept to a minimum.

2. Where columns are located close to the shearwall, it is sometimes advisable to connect them by deep beams designed for load transfer from the shearwall to the adjacent columns;

3. Where the floor slab between the exterior columns and the interior shear-wall is expected to be greatly overstressed due to the

combined effect of creep, shrinkage and temperature of supports, a possible solution is to hinge the entire floor slab around the shearwall core in the upper floors;

4. It is usually desirable to detail the partitions to avoid cracking and loss of acoustical properties even if overstressing of the structure is not indicated;

5. Particular attention must be paid to the details for the exterior wall cladding and window frames, both vertically and horizontally to compensate for the effect of creep and shrinkage.

Martin and Acosta proposed an equation, taking into account environmental conditions and rigidity of frame members for determining the maximum allowable length of one-story concrete structures. The equation serves as a guide for joint spacing.

Rogers reported on the technique used to design for temperature changes in a reinforced concrete frame of a 540 foot long two-and-four story bakery structure in which no joints or cracks were permitted. By substantially increasing the design horizontal forces over those normally considered adequate and by casting floors in a checkerboard pattern to minimize the effects of early shrinkage and creep, a satisfactory structure was obtained.

CONCLUSIONS

That there is need to take into account in design the effects of creep, shrinkage, and temperature on concrete structures is no longer debated. The existence of these two symposia bear general witness to the proposition, and the papers by De Serio, Raths, and Roll offer specific testimony. Structures have been designed without regard to these phenomena to the distress of the owners.

Having recognized the problem, the purpose of the New York symposium was to provide guidance for designers. The papers submitted suggest that there are two available approaches:

(1) Design so as to avoid the problem;

(2) Learn to live with it.

Avoiding the Problem.

Virtually all designers have made some use of the first approach for years by including expansion or contraction joints in structures which extend more than a few dozen meters horizontally. The paper by Martin and Acosta helps to establish quantitative boundaries for the region in which this approach is necessary.

One of the most fascinating developments in the New York symposium was the approach recommended by Fintel and Khan in their paper on conceptual details. They deal with ultra-high-rise frames, which of all structures must be among those most vulnerable to the disease of differential volume changes. Yet even here they suggest that it is possible and expedient to design around the problem. To avoid the problem posed by differences in vertical movements between the exterior columns and the shearwall core, the slabs connecting them can be hinged around the shearwalls, at least in the upper stories. Differential movement among interior columns can be prevented if all such columns are designed to have identical steel percentages and volume-surface ratios. The only remaining unsolved problem is that of large interior columns close to shearwalls, and that one can almost be avoided in design by connecting them with a deep beam which, in effect, makes the columns part of the shearwall.

Raths discusses such items in precast-prestressed construction as avoiding tee-to-column fixity. If a tee is free to slide at one end, volume changes can be accommodated and, therefore, ignored. He also makes one of the significant generalizations of the symposium; excess frame stability conditions attract and result in the buildup of axial volume change forces in the columns and beams; there should be no more stability connections than required by design.

Finally, the approach of Rogers in designing a long horizontal structure, in which no joints were permissible, by over-reinforcing the members, may be considered a case of designing around the problem.

Living with the Problem.

Unfortunately, it is not possible to handle all design situations by clever techniques which circumvent the problem of volume changes. In all bridge design and in much building design it is necessary to control camber or deflections. Hinging slabs, adding steel, or providing sliding joints does nothing to tell the designer how much a member will deflect. Thus, it apparently is necessary to learn how the volume of concrete reacts to load, time, and environment and to organize the knowledge in a form useful to the designer. The greater part of the symposium was devoted to the second objective: learning to live with the volume change problem.

In its review of available knowledge Committee 209 explains in its first report that research on creep and shrinkage has been twofold:

(1) attempts to understand the basic mechanisms and causes of creep and shrinkage, and,

(2) attempts to develop empirical design methods. Accordingly, the review begins with a summary of the existing knowledge of hydrated cement as deduced by the methods of physical chemistry, reinforced by the latest scanning electron micrographs. The hydrate is seen as a colloidal material of high internal surface available to water which, therefore, is sensitive to volume changes under changing load or humidity. Aggregate is seen as an unyielding inclusion which restrains volume changes within the cement paste but which introduces other volume-change effects as a result of microcracks at paste-aggregate interfaces. These mechanisms are reasonable and, no doubt, correct. But when it comes to presenting data, all information is empirical. Apparently the 1500 papers on creep research in the literature have been unable to describe more than qualitatively the mechanism of creep. When useful data have been required, it has been necessary to test concrete containing aggregates of interest with various water-cement ratios, loads, ages of loading, and environments. Thus, the bulk of the review is a marshalling of these empirical data. Each of the succeeding papers is based on the authors' choice of the available empirical data.

Required Data.

An important question to the designer is: what data are necessary for a given job? In their paper on column analysis Fintel and Khan suggest that it is highly desirable to obtain creep and shrinkage data from specimens of the concrete mix to be used in the structure stored under job-site conditions. All of the authors, however including Fintel and Khan, assume that such a utopian ideal will seldom be realized and have devised design techniques based on data available in the literature.

In its second report Committee 209 assembled its voluminous data in a group of equations, ready for direct application by designers, covering a comprehensive list of problems from camber of shored composite beams to prestress loss. The equations tend to be complicated, but the terms are well catalogued so that the paper can serve a handbook function. Presumably, if one has a computer available he need write any given complicated equation only once. The preferred starting point for a designer is the modulus of elasticity of his concrete. If it is unknown, it can be estimated from the equation in the ACI Building Code which relates modulus of elasticity to unit weight and compressive strength. Information is provided to apply corrections to standard creep and shrinkage curves for age of loading (or exposure) humidity, cement content, slump, air content, aggregate fines, and thickness of section.

The approach of Fintel and Khan is similar in principle but is based on different data and utilizes different techniques for adjusting the data to non-standard conditions. They rely on Hickey's(2) work at the Bureau of Reclamation for relating creep to modulus of elasticity and on the CEB(3) recommendations for correcting for size of member. Rath's relies primarily on the data developed by Reichard(4) at the National Bureau of Standards with corrections for size of member as given by Hansen and Mattock(5).

Pauw, in a problem devoted entirely to calculation of deflections, adopts a somewhat different approach. He uses a lower "equivalent" modulus of elasticity to account for the effects of shrinkage and creep. Having selected the appropriate value of E, the problem can be solved by elastic methods. Roll, in another deflection problem, concludes that the "effective modulus of elasticity method" is not applicable to his problem because it involves shored construction. Although his work related to a structure in place, no reliable data on concrete properties were available other than core strength. Using that as a start he proceeded, essentially by the methods of the second report of Committee 209, to deduce the other properties needed for the analysis.

Perhaps the detail on which there is most disagreement among the contributors to the symposium is how to correct length-change data from small laboratory specimens to make them applicable to large structural members. Pauw arbitrarily reduces laboratory shrinkage by one-third. Martin and Acosta make a similar reduction for temperature length-change effects. Fintel and Khan use a curve which relates the correction to volume-surface ratios, but the relation is assumed to be independent of time. Raths uses a time-dependent correction factor which, within a single problem, varies from 0.48 to 0.92. Committee 209 steers a middle course by providing two curves related to minimum thickness of member. One is applicable for ages up to a year, while the other is applicable to ultimate creep or shrinkage. Raths' approach is the most realistic. The effect of large size is primarily to delay volume change by increasing the distances through which water must diffuse. The difference between length changes in large and small members is, therefore, time-dependent.

Choice of Design Approach

With the variety of approaches demonstrated, the questions arise: which approach is best, or does it make any difference? One means for evaluating different approaches is to solve the same problem by more than one method. In their paper on column analysis, Fintel and Khan analyze a 20 x 49 inch (50 x 125 cm) column constructed of 5,000 psi (36 megapascal) normal-weight concrete to which a load of 1335 kips (6 meganewtons) was added during a 293-day period beginning at an age of 28 days. Given below are the results obtained by Fintel and Khan and those obtained for the same column from the equations given by Committee 209:

	Creep Strain	Shrinkage	Total Creep plus Shrinkage
Fintel & Khan	265×10^{-6}	590×10^{-6}	885×10^{-6}
Subcommittee II	329	464	769

Although the agreement for creep and shrinkage alone leave something to be desired the two values for total inelastic shortening agree within 10% even though the estimates are based on different data and the methods used to correct for age of loading and size of member are entirely different. The actual structural significance of this difference is reduced considerably when the effect of reinforcement is introduced.

Another significant observation is the conclusion of Pauw that in using the effective-modulus method the deflection results are rather insensitive to the exact choice of modulus. He notes that in computing creep deflections a six-fold increase in the assumed ratio of the modulus of elasticity of steel to that of concrete increases the computed deflection by less than 75% and that shrinkage deflections are even less sensitive. He makes the further interesting observation that initial dead load deflections are more difficult to predict than long-time deflections. It is also noteworthy that with practically no data available Roll was able to reproduce analytically deflection performance in the field. Like Pauw he found that for certain purposes it made no difference whether calculations were based on assumed properties at an age of 14 days or 493 days.

Thus it may be concluded, at least tentatively, that although 6-inch (15 cm) cylinders made of different concretes may behave somewhat differently in the laboratory, by the time the results are modified to apply to structural-size members and the effect of reinforcement introduced, the differences are reduced to a tolerable level.

Recommendations.

The final question to be answered is : where do we go from New York? If, as has been suggested, it is advisable to have data on concrete to be used in the project before the design can be carried out with confidence, the traditional American system, which separates design and construction responsibilities is threatened, and the time required to execute a structure is increased. If so, the paper by Fintel and Khan on conceptual details should be required reading for all designers since it largely avoids the volume-change problem. But, as has been pointed out, such techniques do not deal with the deflection control problem. To provide complete control of inelastic volume changes, either the designers must assume a control over the selection of materials which is not normal American practice at present or the specifications must be complicated by inclusion of shrinkage and creep provisions.

Happily, the results reported at New York suggest that such advance information is not necessary. While the ignoring of creep, shrinkage, and temperature effects can lead to serious trouble, the results almost justify the generalization: "It makes no difference what you do as long as you do something." It is perhaps significant that the symposium only included techniques that worked. We did not hear from those who tried solutions that did not work. However, in all cases in which it was possible to check calculations against actual structural performance agreement was satisfactory. A variety of approaches based on a variety of data has demonstrated that actual behavior is only mildly sensitive to the considerable scatter in concrete volume change data. It is necessary only that the data be reasonable and the design procedure rational.

The question "where do we go from New York?" must be answered separately from the two interest groups: those who gather creep and shrinkage data, and those who must apply it in design. After 1500 research papers, one would like to conclude that we have all the basic data that are required. And in view of the conclusions stated above, perhaps enough information is now available to satisfy the requirements of reinforced concrete design. In the field of unreinforced mass concrete, however, where the long-time ultimate tensile strain is a matter of concern if cracking is to be avoided which might impair the stability of a structure and where the mitigating effect of reinforcing steel is not available, differences between materials are important. The empirical data available are not yet adequate. Hydrated cement paste is known to be the active ingredient in creep and shrinkage. A fairly inexpensive investigation should becapable of providing a comprehensive understanding of the behavior of paste taking into account quantitatively the available data from surface chemistry. Then, the relevant properties of aggregate may be introduced as they relate to the role of aggregate as an inclusion in the matrix. For the restraint function of aggregate, modulus of elasticity and Poisson's ratio are the relevant properties. For determining an aggregate's contribution to microcracking these same properties, or other equally easy to determine, may be adequate. While several investigators have approached the latter problem, the comprehensive study of paste is missing. Ideally, a one-day aggregate test should permit an accurate prediction of creep and shrinkage of concrete of any given quality under any set of load and ambient conditions. Not only would the needs of the mass concrete designer be met, but the designer of reinforced concrete would acquire the knowledge to permit him to set limiting values on pertinent properties of aggregates to insure that the concrete in the project is sufficiently like that assumed in the design.

As for the design techniques themselves, the New York symposium placed before designers several available procedures. Presumably the fittest will survive. It appears that design methods do not have to be elegant to be effective. Some of the methods might justifiably be simplified. The relatively simple approach of Committee 209 might also include relatively simple equations by elimination of some of the minor terms.

Finally, it is safe to predict that, no matter how firmly the engineering profession becomes committed to ultimate strength design, engineering students of the future will still have need to learn about transformed sections and the other essentials of working stress design in order to assure proper behavior of structures under service loads.

References

(1) Branson, D. E., " Time-Dependent Effects in Composite Concrete Beams," Journal of the American Concrete Institute, Vol. 61, No. 2, February 1964, pp. 213-230.

(2) Hickey, K. B., "Creep of Concrete Predicted from Elastic Modulus Tests," Report No. C-2142, Department of the Interior, Bureau of Reclamation, Denver, Jan. 1968, 27 pp.

(3) Recommendations for an International Code of Practice for Reinforced Concrete, Comite Europeen du Beton, Paris, 1964.

(4) Reichard, T. W., "Creep and Drying Shrinkage of Lightweight and Normal Weight Concretes," National Bureau of Standards, Monograph 74, March 4, 1964, U. S. Government Printing Office, Washington, D. C.

(5) Hansen, T. C. and Mattock, A. H., "Influence of Size and Shape of Member on the Shrinkage and Creep of Concrete," Journal of the American Concrete Institute, Vol. 63, No. 2, February 1966, pp. 267-290.

Appendix

List of papers at New York ACI Symposium on "Designing for Effects of Creep, Shrinkage and Temperature," April 17, 1970.

1. "Effect of Concrete Constituents, Environment, and Stress on the Creep and Shrinkage of Concrete" - Subcommittee I, ACI Committee 209.

2. "Thermal and Shrinkage Stresses - They Damage Structures" - James N. De Serio, consulting engineer, Buffalo, New York.

3. "Prediction of Creep, Shrinkage and Temperature Effects in Concrete Structures" - Subcommittee II, ACI Committee 209.

4. "Effects of Column Creep and Shrinkage in Tall Structures: Analysis for Differential Shortening of Columns and Field Observation of Structures" - Mark Fintel, director, Engineering Design and Standards Department, Research and Development Division, Portland Cement Association, Skokie, Illinois; and Fazlur R. Khan, chief structural engineer, Skidmore, Owings and Merrill, Chicago, Illinois.

5. "Designing for Axial Concrete Volume Changes" - Charles H. Raths, president, Raths, Mees and Johnson, Inc., Structural Engineers, Hinsdale, Illinois.

6. "Time-Dependent Deflections of a Box Girder Bridge" - Adrian Pauw, professor, Department of Civil Engineering, University of Missouri-Columbia, Columbia, Missouri.

7. "Measuring Performance in High-Rise Structures" - Donald W. Pfeifer, principal research engineer, Structural Research Section, Research and Development Division, Portland Cement Association, Skokie, Illinois; and Donald D. Magura, ABAM Engineers, Inc., Tacoma, Washington.

8. "Effects of Differential Shrinkage and Creep in Composite Steel-Concrete Structure" - Frederic Roll, professor of civil engineering, Towne School of Civil and Mechanical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania.

9. "Conceptual Details for Creep, Shrinkage and Temperature in Ultra High-Rise Buildings" - Fazlur R. Khan, chief structural engineer, Skidmore, Owings and Merrill, Chicago, Illinois; and Mark Fintel, director, Engineering Design and Standards Department, Research and Development Division, Portland Cement Association, Skokie, Illinois.

10. "Effect of Thermal Variations and Shrinkage on One-Story Reinforced Concrete Buildings" - Ignacio Martin, partner, and
2 Jose Acosta, structural engineer, Capacete-Martin & Associates, Consulting Engineers, San Juan, Puerto Rico.

11. "Temperature Changes on Reinforced Concrete Frame of a Bakery Structure" - Paul Rogers, structural engineering consultant, Chicago, Illinois.

12. "Summary" - Robert E. Philleo, chairman, Technical Activities Committee, and civil engineer, Office, Chief of Engineers, Washington, D. C.

SUMMARY

Nine designers were invited either to discuss structures in which the effects of creep, shrinkage, or temperature had produced distress, or to present design procedures for preventing the problem. An ACI committee presented available pertinent research data. The papers presented justified the conclusion that for reinforced concrete sufficient data and adequate design methods are now available to permit safe efficient design.

RESUME

Neuf ingénieurs ont été invités soit à présenter des constructions endommagées par les effets du fluage, du retrait ou de la température, soit à exposer des procédés de conception pour prévenir ces influences. Un comité de l'ACI a apporté d'utiles résultats de recherches, qui prouvent que l'on dispose maintenant de suffisamment de données et de méthodes de conception pour construire d'une manière sûre et efficace.

ZUSAMMENFASSUNG

Es wurden neun Ingenieure eingeladen, entweder um über Bauwerke zu diskutieren, in denen Kriechen, Schwinden oder Temperatur Verspannungen hervorgerufen hatten, oder um Berechnungsmethoden für solche Probleme darzulegen. Ein ACI-Ausschuss legte verfügbare Forschungsdaten vor..Die eingereichten Beiträge rechtfertigten die Schlussfolgerung, dass für Stahlbeton genügend Daten und entsprechende Entwurfsmethoden verfügbar sind, die einen sicheren und wirksamen Entwurf erlauben.