Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 8 (1968)

Artikel: Effects of column temperature, creep and shrinkage in tall structures

Autor: Khan, Fazlur R. / Fintel, Mark

DOI: https://doi.org/10.5169/seals-8852

Effects of Column Temperature, Creep and Shrinkage in Tall Structures

Effets de la température, du fluage et du retrait dans les colonnes des structures élancées

Temperatur-, Schwind- und Kriecheinflüsse in Stützen hoher Bauwerke

FAZLUR R. KHAN
Associate Partner
Chief Structural Engineer
Skidmore, Owings & Merrill
Chicago, Illinois

MARK FINTEL
Director of
Engineering Design and Standards
Portland Cement Association
Skokie, Illinois

In recent years a large number of multi-story apartment and office buildings have been built in reinforced concrete. While in the low rise buildings the effects of temperature creep and shrinkage in the columns did not substantially control the stress or design of the structure, these otherwise secondary effects may become primary and must be considered in the analysis, design and detailing of the high-rise structure. The effects of temperature, creep and shrinkage in high-rise buildings are not only structural, but also architectural in that the exterior window wall details as well as the interior partition details must be designed to incorporate relative movements caused by these factors. A brief discussion of the philosophy for planning and design procedures of high-rise buildings subjected to these effects follows:

1. Temperature Effects. Exposed columns when subjected to seasonal temperature variations change their length relative to the interior columns which remain unchanged in a controlled environment. Furthermore, if the exterior columns have difference in size and are subjected to different average temperature due to the location of glass lines, there will be relative displacement between these adjacent columns when exposed to seasonal changes.

The philosophy of design of structure with exposed columns involves one of the two basic concepts: (a) To use an effective method of analysis and design and to develop details to accommodate large expected relative movements, or (b) To plan a building for a controlled temperature movement.

When for architectural or other reasons it is not possible to limit the relative movements between the exterior column and the interior column to a reasonable value, the structural system should be analyzed by a simple and effective method such as proposed by the authors in papers published in the ACI Journal (1, 2, 3). If the analysis indicates that the stresses are acceptable and can be designed for, then only the partition details should be developed to accommodate the expected maximum distortions. However, if the initial analysis indicates extremely high stresses in the upper floors it may be advisable to hinge the floor system at the exterior columns as was done in the 38-story Brunswick Building in Chicago.

If the exterior columns are unequal in size as was used for the One Shell Plaza Building in Houston, the analysis may indicate that the glass line should be controlled in a manner that the average temperature of all the columns is approximately the same.

2. Effects of Creep and Shrinkage. With increasing height of buildings, the importance of time dependent shortening of columns and shear walls becomes more critical due to the cummulative nature of such shortening. It is known that columns with varying percentage of reinforcement and varying volume-to-surface ratio will have different creep and shrinkage strains. Increasing the percentage of reinforcement and the volume-to-surface ratio reduces strains due to creep and shrinkage. In very tall structures where a large heavy reinforced column may be adjacent to a lightly reinforcing shear wall a differential inelastic shortening causes moments in the horizontal members and also a load redistribution from the shear wall to the column which has less creep and shrinkage.

Although a large amount of research information is available on shrinkage and creep, it is not directly applicable to column of high-rise buildings but are applicable to flexural elements only. In the construction of a high-rise building columns are loaded in as many increments as there are stories above the level under consideration. Such incremental loading over a long period of time makes a considerable difference in the magnitude of creep and consequently in the differential movement and load redistribution between adjacent columns.

The significance of incremental loading was first questioned during the design of the 52-story, 715' (218m) high One Shell Plaza Building in Houston, built entirely with high strength (6,000 psi & 4,500 psi) lightweight concrete. Theoretical work to predict incremental creep was then jointly undertaken by the authors, the results of which have been submitted to ACI for publication. The Portland Cement Association at the suggestion of the senior author, undertook a series of tests with incremental loading conducted under direct supervision of Dr. Eivind Hognestad and Mr. D. Pfeifer. These results clearly pointed out the difference between the incremental loading in a column and the full load applied to a beam. The test results confirmed the authors theoretical findings indicating that the overall time vs. strain characteristics due to incremental loading surprisingly resembles the theoretical linear curve made on the basis of elastic shortening at each incremental loading. The classical creep characteristic is almost non-existent.

This linear type of creep characteristic can be translated into an "equivalent creep modulus" and can then be used to determine load redistribution between adjacent columns or columns and shear walls. Such an analysis can be made by the use of the iterative method developed by the first author (4).

References. (1, 2, 3) "Effects of Column Exposure in Tall Structures" by: Fazlur R. Khan and Mark Fintel - Part 1, ACI Journal, December, 1965; Part 2, ACI Journal, August, 1966; Part 3, ACI Journal, February, 1968. (4) "On Some Special Problems of Analysis and Design of Shear Wall Structures" by: Fazlur R. Khan - Symposium on Tall Buildings, University of Southampton, England, April, 1966.

SUMMARY

It is concluded on the basis of previous discussion that even though further research is necessary, sufficient information is now available for the design of ultra high-rise buildings in reinforced concrete to take into consideration the temperature creep and shrinkage effects both for normal weight and lightweight concrete.

RÉSUMÉ

A la suite de discussions précédentes, et malgré la nécessité de pousser les recherches, on dispose de suffisamment d'informations à l'heure actuelle pour tenir compte des effets de température, de fluage et de retrait dans les colonnes en béton armé (normal ou extraléger), dans le dimensionnement de structures très élevées en béton armé.

ZUSAMMENFASSUNG

Auf Grund vorangegangener Diskussionen und trotz der Einsicht, dass weitere Studien unerlässlich sind, kann man behaupten, dass im Moment genug Informationsmaterial zur Verfügung steht, um Temperatur-, Kriech- und Schwindeinflüsse in den Stützen extrem hoher Stahlbetonbauten, sowohl mit Normal- als auch mit Leichtbeton, bei der Bemessung zu berücksichtigen.

Leere Seite
Blank page
Page vide