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Observed Deflections of Reinforced Concrete Slab Systems, and Causes of Large Deflections

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Synopsis: This report is in two distinct parts

Part I is a summary of published studies on slab deflections (3 from Australia, 1 from Scotland, 1 from Sweden, 2 from U.S.). The summary focuses on construction practices and materials quality. Comparison of deflections calculated by various methods with actual long-term deflections is made in some cases.

Part II summarizes several construction problems and material deficiencies which can contribute to large long-term deflections. Focusing on large construction loads, the authors show

that construction loads may be considerably higher than design loads and that high construction loads cause high initial deflections because concrete has a lower modulus of elasticity when loaded at an early age. Furthermore, concrete creeps more when it is loaded at an early age, thereby causing additional high long-term deflections, even when construction loads are sustained only for a few days.

The authors then suggest a method of form removal and reshoring that has proved successful in the New York City area in preventing large slab deflections. Essentially, no more than an 8-foot slab span is left unsupported until a slab is mature.

A reader interested only in the Committee's findings and recommendations may proceed straight to Part II of the report.

Keywords: concrete construction; concrete slabs; creep properties; deflection; flat concrete plates; form removal; loads (forces); modulus of elasticity; reinforced concrete; shoring; shrinkage; two-way slabs.

Contents:

Part II

FACTORS CONTRIBUTING TO DEFLECTION PROBLEMS IN TWO-WAY REINFORCED CONCRETE SLABS

Part I

FIELD DEFLECTION MEASUREMENTS OF REINFORCED CONCRETE FLAT PLATES, FLAT SLABS AND BEAMS: A REVIEW OF LITERATURE

This part of the report reviews and summarizes the existing literature on field deflection measurements of reinforced concrete flat plates, flat slabs and beams.

INVESTIGATION A

Summary

Three experimental flat plat structures were erected at the Division of Building Research, Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia. The investigations were carried out under field conditions, the structures being completely exposed to the weather.

Structure Mark I consisted of an expanded shale concrete slab, 3-1/2 in. thick, spanning three bays of 9 ft in one direction and three bays of 12 ft in the other, with cantilevers 4 ft 6 in. long in this direction. The reinforcement was conventional individual plain round bars and was designed by the empirical design method given in ACI 318-56. The slab was carried on 16 steel columns of box section with a grillage type shear connection. The significant features of this structure were (1) span/depth ratios of 41 in one direction and 31 in the other; (2) the ratio 4:3 of the sides of the panels; and (3) the steel columns. The use of lightweight aggregate concrete was also an important feature Further, no edge beams or torsion reinforcement near the edge columns was used.

The long-term deflections reached "annoying" proportions. The slab was allowed to stand under its own weight for 8 months, during which time the deflection at the center of the middle panel increased by 0.62 in. This was 12 times the initial elastic deflection of 0.05 in. In a study of the long-term deformation of this structure it was suggested that about 20% of the increase at the center of the middle panel was due to differential settlement of inner and outer columns, about 40% was due to further cracking causing a reduction in stiffness, and to local bond slip, and about 40% to creep. This analysis also suggested that the increment of deflection due to creep was about 85% of the immediate deflection of a completely cracked slab..

In connection with the large long-term deformations, three features were pointed out. First, the structure was constructed of expanded shale concrete. Available evidence suggests that in concrete made with well-coated, expanded shale aggregate, the creep may in certain cases be 20% greater than for natural rock concrete at the same stress, which would be an insignificant contribution in this case. Secondly, the experimental structure was built in the summer, and during its early history was exposed regularly to high ambient temperatures and direct sunlight. It has been shown that creep is directly proportional to temperature, for set cement pastes. Finally, since the structure was outdoors, completely exposed, it was under widely fluctuating conditions of temperature and relative humidity. Creep and shrinkage under fluctuating conditions have been shown to be greater than under constant average conditions of storage.

Structure Mark II had 9-ft spans over two bays in one direction and three bays in the other. Cantilevers 3 ft long extended in the two-span direction. The slab was of expanded shale concrete and was intended to be 4-in. thick, but because of distortion of the formwork it was much thicker in some places. The concrete, supplied by an outside contractor, contained in error some dense basalt in addition to the expanded shale aggregate. These two factors combined to make the slab much stiffer than was intended and useless for studies of deformation. No attempt, therefore, was made to examine its deflection under imposed loading, and it was tested directly to destruction.

Structure Mark III, probably the first prestressed, post-tensioned flat plate in Australia, was allowed to stand under its own weight to obtain data on loss of prestress.

References

A.1a. "Experimental Flat Plate Structure of Expanded Shale Concrete," Constructional Review (Sydney), Vol. 33, No. 2, Feb. 1960, pp. 22-29.

A.1b. "Experimental Lightweight Flat Plate Structure, Part I - Measurements and Observations During Construction," Constructional Review (Sydney), Vol. 34, No. 1, Jan. 1961, pp. 21-32.

A.1c "Experimental Lightweight Flat Plate Structure, Part II - Deformations due to Self Weight," Constructional Review (Sydney), Vol. 34, No. 3, Mar. 1961, pp. 25-33.

A.1d. "Experimental Lightweight Flat Plate Structure, Part III - Long-Term Deformations," Constructional Review (Sydney), Vol. 34, No. 4, Apr. 1961, pp. 21-26.