Experimental and Analytical Modeling of Unbraced Multipanel Concrete Frames

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This paper summarizes the physical and analytical modeling of a series of unbraced multipanel concrete frames. These frames had four columns of unequal stiffnesses and were loaded with beam, column, and lateral loads. The objectives of the test series were to study the behavior and redistribution capability of highly indeterminate concrete frames under realistic loading combinations, to assess the applicability and accuracy of current design procedures, and to develop correct analytical modeling techniques for the nonlinear analysis of frames.

This paper documents the experimental test procedures, the data interpretation methods, and the nonlinear analysis program used to model the frames. The data interpretation and nonlinear analysis relied heavily on axial load-moment-curvature (P-M-θ) relationships verified in a companion series of isolated columns tested under controlled deformation loading. The analytical modeling procedure approximated the demonstrated ductile rotations in critical column regions by inserting equivalent plastic hinges. Overall, the analytical program accurately predicted the load-deflection behavior, yield locations, sequence of yielding, and load levels at yielding.

Keywords: axial loads; bending moments; columns (supports); frames; long columns; reinforced concrete; research; structural analysis; tied columns.

This paper documents the analytical and experimental procedures used in a multipanel frame study which investigates behavior as called for by Wood. Other reports in this series provide complete summaries of results. This paper contains a fuller documentation of the methods used.

In a previous paper in this series, tests of cantilever columns under controlled lateral deformation demonstrated that the actual P-M-θ relationships for heavily loaded, lightly tied concrete columns are not as brittle as previously indicated, but are nearly flat-topped and exhibit significant ductility. An analytical procedure was developed which closely predicted the relationships observed. The concrete crushing strains in that test series ranged between 0.0096 and 0.0160 in./in., far in excess of the generally assumed strain limit of 0.003 in./in. Ultimate strain equation predictions indicated that the significantly higher ultimate strain values were principally due to the presence of appreciable moment gradients. These gradients, however, are typical of gradients in unbraced frames under combined loadings.

Almost all earlier experimental studies investigating the moment redistribution capability of reinforced concrete structures concentrated on continuous beams or lightly loaded single-bay portal frames with axial loads less than 20 percent of the member axial capacity. Although these tests provided valuable information concerning the ductility of beam-type specimens, they provided almost no information concerning the behavior of important members with high axial loads. Many interior columns in multistory buildings have factored axial loads ranging from 60 to 80 percent of the pure axial capacity of the members.

Full redistribution of moments, creating a collapse mechanism, has been achieved in most normally reinforced and prestressed continuous beams having low or medium percentages of reinforcement. As shown in Fig. 1, most investigations of unbraced portal frames have used only beam loads or beam loads in addition to a lateral load. Richard and Lazaro [Fig. 1(a)], Ernst, et al. [Fig. 1(b)], and Cranston [Fig. 1(c)], indicated that full redistribution of moments was obtained. Cranston emphasized that additional research was required for frames with more redundancies and with heavily loaded columns. Gupta

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