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16. Abstract (Limit: 200 words)
Research was conducted in the area of seismic behavior of frame-wall and infill frame structural systems investigating the seismic hysteretic behavior of R/C structural walls and the effects of engineered masonry infill panels on the seismic hysteretic behavior of ductile R/C frames. Integrated analytical and experimental studies were conducted in both investigations to develop practical methods for the aseismic design of combined frame-wall structural systems. In the studies of the hysteretic behavior of R/C structural walls the main objective of the analytical studies was to develop efficient computer programs for the analysis of multistory frame-wall structural systems. The experimental studies sought to obtain reliable data regarding the linear and nonlinear (particularly the hysteretic) behavior of frame-wall structural systems. The experimental program covered the testing of framed and frameless single and coupled wall systems. To conduct these experiments, a special loading facility was developed. Its principle feature is its ability to simulate pseudo-statically the dynamic loading conditions which could be induced in subassemblages of buildings during earthquake ground shaking. The experimental phase of the second investigation consisted of pseudo-static cyclic load tests on a series of 1/3-scale model subassemblages of the lower three stories of an eleven-story, three-bay frame with infills in the two outer bays. Its analytical phase was to develop and use theoretically sound macroscopic mathematical models capable of describing essential aspects of the observed hysteretic behavior of engineered infilled frame subassemblages subjected to pseudo-static cyclic lateral loads.

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National Science Foundation sponsored research in the area of seismic behavior of frame-wall and infill frame structural systems is ~~being con-~~ducted by studying the seismic hysteretic behavior of R/C structural walls and the effects of engineered masonry infill panels on the seismic hysteretic behavior of ductile R/C frames.

Hysteretic Behavior of R/C Structural Walls

The ultimate objective of this investigation is to develop practical methods for the aseismic design of combined frame-wall structural systems. To achieve this objective, integrated analytical and experimental studies are being conducted.[1] The main objective of the analytical studies is to develop efficient computer programs for the analysis of multistory frame-wall structural systems. The main objective of the experimental studies is to obtain reliable data regarding the linear and nonlinear (particularly the hysteretic) behavior of frame-wall structural systems. The experimental program covers the testing of framed and frameless single and coupled wall systems. To conduct these experiments, a special loading facility has been developed. The principal feature of this facility is its ability to simulate pseudo-statically the dynamic loading conditions which could be induced in subassemblages of buildings during earthquake ground shaking.[1]

A series of tests has been conducted on four 1/3-scale wall component models of the bottom three stories of a ten-story frame-wall system which was designed according to 1973 UBC provisions. The four specimens consisted of a 4-in. thick wall framed by two 10-in. sq. columns and a portion of 3-in. thick floor slabs. The only difference between the four specimens was in the way that the concrete of the edge members was confined. While spirals were used in specimens 1 and 2, square ties were used in specimens 3 and 4. Rather than simulate the critical load combinations of gravity and seismic loads as specified by the 1973 UBC, it was decided to investigate the behavior of these walls under the most critical load combination which could be developed in the case of an extreme earthquake ground shaking. To estimate this critical load combination, the prototype building was subjected to a series of analyses using different methods for evaluating the seismic forces. Considerable discrepancies between the resulting shear span values for the wall component were obtained, which point out not only the difficulties involved in selecting the critical combination of inertial forces, but also, the need for carefully interpreting results obtained in experimental investigations in terms of the actual seismic behavior of structures.

The testing procedure was as follows: The two axial forces necessary for simulating the effects of gravity forces were applied first. The effects of seismic forces were introduced following a different loading pattern in each of the specimens tested. The four specimens were subjected to cycles of full seismic force reversals in the working load range before being loaded in their inelastic range. In walls 1 and 3, the lateral force

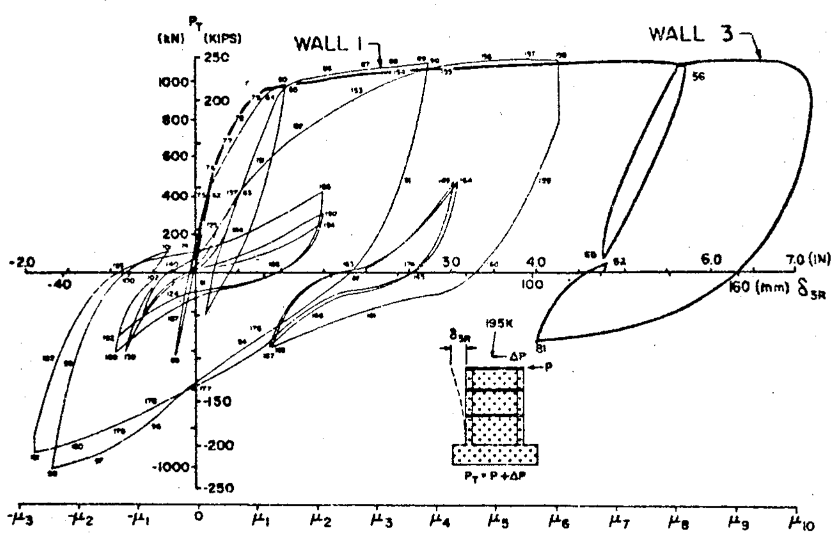

FIG. 1 P_T-δ_{3R} DIAGRAMS - WALLS 1 & 3

and change in column axial forces needed to reproduce the corresponding change in overturning moment were supposed to increase monotonically until a reduction in the lateral resistance could be observed. In the test of wall 1, however, a cycle with significant inelastic displacement reversal was introduced long before the drop in lateral resistance (Fig. 1). Walls 2 and 4 were subjected to a history of lateral shear and corresponding overturning moment that induced gradually increasing cycles of full reversal lateral displacement with at least three cycles at each displacement amplitude (Fig. 2).

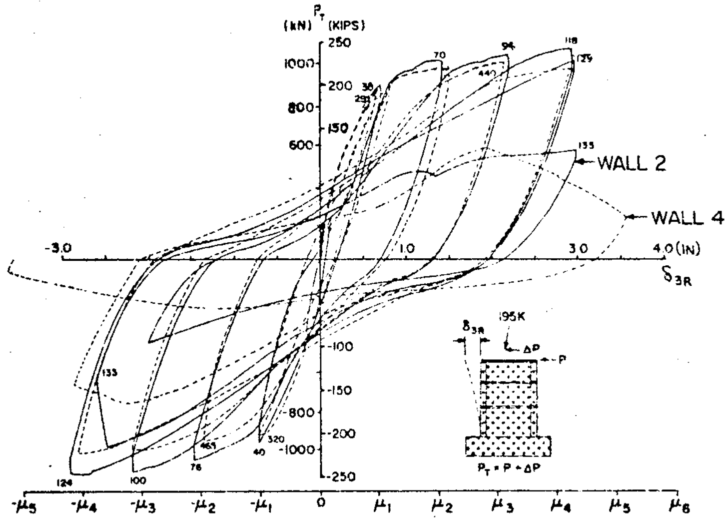

FIG. 2 P_T-δ_{3R} DIAGRAMS - WALLS 2 & 4

Figures 1 and 2 are composite graphs illustrating the overall response for the four specimens tested. These graphs facilitate evaluation of the two main variables of the tests already conducted, i.e., the effect of (1) cycling with reversal deformations versus monotonically increasing loads; and (2) different ways of confining concrete of edge members. Despite the limited amount of specimens tested, analysis of the data obtained enables the following observations to be formulated: (1) It is possible to design structural wall components capable of developing large ductilities even when subjected to full deformational reversals inducing nominal unit shear stresses up to $10\sqrt{f'_c}$. (2) Although the ductility was reduced significantly due to full reversals, this reduced ductility can be considered large enough to permit the development of energy absorption and energy dissipation capacities exceeding even those that would be demanded in the case of very severe earthquake shaking. (3) The closely spaced square ties were as effective as the spiral in confining the column concrete. (4) Present code specifications for design forces, load factors, and design and detailing of critical regions can lead to a wall design which considerably underestimates the amount of shear that can actually develop. In the next series of experiments, two specimens similar to those already tested, with the exception that no columns will be used as edge members, will be tested under monotonic and cyclic loading. A facility for testing coupling walls is presently being developed.

Hysteretic Behavior of Masonry Infilled Frames

Following an extensive literature survey, experimental and analytical studies were developed to determine the effect of engineered masonry infill panels on the seismic hysteretic behavior of R/C frames.[2] The experimental phase consists of pseudo-static cyclic load tests on a series of 1/3-scale model subassemblages of the lower three stories of an eleven-story, three-bay frame with infills in the two outer bays. Emphasis is placed on simulation of the proper force and displacement boundary conditions, and on the reinforcing details required to attain ductile frame action. The first series of tests just completed was conducted using the following models: (1) a bare frame (test #1); (2) this same bare frame, infilled with clay blocks after test #1; (3) a virgin frame, infilled with clay blocks; and (4) a virgin frame, infilled with concrete blocks. The infills were grouted in all cores.

In the design of these infilled frames, two basic design guidelines were adopted: (1) to maximize energy dissipation through distributed infill cracking, closely spaced horizontal and vertical reinforcement was used; and (2) to minimize the possibility of brittle frame failure which could result from panel falure, the frames were specially reinforced against shear, and the thickness of the infill was based on column shear resistance. Infilled frames designed and constructed according to these guidelines have several advantages over comparable bare frames, particularly if they may be subjected to severe ground motions: (1) Owing to the increased stiffness (500%) and strength (470%) provided by infills, behavior is greatly improved under service loads, moderate ground shaking, and even under the largest expected overload of standard live loads. (2) For severe ground motions demanding elastic base shears in excess of that corresponding to the bare frame collapse load, stiffness provided by infills significantly reduces the influence of P-Δ effects on seismic response. (3) For extreme ground motions demanding average story drifts in excess of 0.02, the engineered infilled frame is superior to the bare frame with respect to energy dissipation and resistance to incremental collapse.

The analytical phase of the investigation has two principal objectives: (1) to develop theoretically sound macroscopic mathematical models capable of describing essential aspects of the observed hysteretic behavior of engineered infilled frame subassemblages subjected to pseudo-static cyclic lateral loads; and (2) to use these mathematical models in analytical investigations of the effects of engineered infills on the overall seismic response of R/C structures. It is hoped that information gained from these experimental and analytical studies will be useful in the ongoing modification of pertinent design procedures and codes.

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