PERFORMANCE OF MULTI-STORY R.C. STRUCTURAL SYSTEMS UNDER STRONG EARTHQUAKE MOTIONS

by

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SUMMARY

Ten-story R.C. models tested on University of Illinois Earthquake simulator are the domain for the discussions presented in this paper. An attempt is made to catalog parameters influencing seismic performance criteria. Displacements are chosen as a basis of evaluation of performance. Response relationships and characterisitcs are presented in order to point out the applicability of simple linear models and s.d.o.f. systems in evaluation of success of structural systems. The possibility of an algorithm that will aid the designer in his decision on success is outlined.

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OBJECT AND SCOPE

Relative performance of different structural systems still remains controversial and unaccounted for in the existing seismic codes and provisions, although such systems are widely used in multi-story R.C. buildings today.

Object of the current discussion is (a) to select response parameters related to performance, (b) to derive informing principles based on the relations of the parameters selected, (c) to be able to tell the structural designer how he should decide on the "success" of structural types of multistory R.C. structures subjected to strong earthquake motions.

Domain: The domain of this paper is ten story R.C. models that were subjected to simulated standard earthquake motions on the University of Illinois Simulator since 1974 (See Fig. 1). The test structures cover a range of structural systems as frames and modified frames (3-5); frame and wall system with varying stiffness distributións (1); Coupled-walls (2). Salient characteristics of test structures are that they have uniform stiffnesses (i.e. no abrubt changes along the height) and are aligned in the direction of the input motion. The structures were subjected to simulated motions of El-Centro 1940 N-S component and/or Taft 1952 N21E component. The time axis of the input motion is compressed by a factor of 2.5 so that structures are excited in the decreasing acceleration range of response spectra. The test runs were of increasing order in design intensity and multiples of design intensity.

SEISMIC PERFORMANCE CRITERIA

In order to be able to define performance or success of a structural system under strong earthquake motions; an attempt is made to compose a catalog of factors influencing seismic performance criteria. Aim is to select parameters that will identify performance.

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The listing is separated into 3 major categories, although each group is not independent of others. The groups are (a) Dynamic characteristics, (b) Damage (as state of damage and systems subjected to damage) (c) Response (as inferred and observed response). Under dynamic characteristics damping, frequency and apparent mode shape can be mentioned. Damage is a very broad criteria and is hard to quantify; but repairable damage state and pre-collapse state are of interest. Damage can also be subgrouped as structural damage, nonstructural damage and nonarchitectural damage. Response as an output from the structural system can be inferred in terms of parameters as, energy dissipation, softening, ductility, damage ratio, plasticity ratio (residual/yield displacement), shears/total shear, limit states and stability. Or more physically response can be observed as displacements, story drifts, residual displacements, cracking (width, type and pattern of cracks) and collapse. The chosen parameter to represent success of structures are displacements (and story drifts) coupled with dynamic characteristics of the structure. The reasons for the choice is that displacements are observed rather than inferred and they are readily applicable to m.d.o.f. systems. Drifts relate to cost and damage of the structures and the variations of displacement with respect to time and frequency can account for the remaining factors cited above.

OBSERVATIONS

Response Relationships. The relationships of response parameters (i.e. displacements) to parameters that are of concern for a design engineer is important. A designer would be interested in how intense the input motion is and how a particular structural system responds to input. Housner's Spectrum Intensity [Area under Spectral Velocity] is chosen as a measure of intensity of input motion for the intended comparison. This quantity is plotted against top level displacement (divided by height) in Fig. 2. The plot represents all the structures tested under test runs of increasing intensity. The points fall in an area closely surrounding the straight line drawn in the plot. The relationship indicates that the way input motion intensity is related to response is independent of structural configuration. Another interesting relationship to look at will be that of response at a given intensity of input motion: Displacements are related to the cost of materials (longitudinal steel and concrete) in Fig. 3. The cost of materials are not intended as an absolute quantity, since it is subject to change, but rather as a relative factor (It is normalized with respect to most expensive structure and plotted on y-axis) to combine quantities of concrete and steel. The expected relationship is the following: if more material is put into a structure to resist input motion better performance (drift) is expected in return. On the contrary the plot shows that there is no substantial difference in the response but the difference in materials is as high as 35%. In other words nothing is gained by putting more material into structures with frame and wall combinations.

Response Characteristics. The displacements are dominantly first mode and the waveforms are in phase at all levels. Also the displacements and moments have similar time histories. Apparent fundamental mode shape does not change in the successive test runs of increasing intensity because the damage is uniform along the height of structures. Linear models and characteristics are applicable for the design test run and the magnitude of maximum displacements, moments can be predicted using such models. The top level displacements and maximum interstory drifts have been used interchangably in the response relationships. This is explained through the apparent mode shapes presented in Fig. 4 for frames and wall systems with the same top level displacement for a given intensity (design) of input motion. The only difference seems to be that the maximum story drifts occur at upper level for wall system and at lower levels for frames.

CONCLUSION

The observed response characteristics indicate that the M.D.O.F. system can be reduced to a S.D.O.F. system (6) using displacement as a parameter. If the input motion characteristics (i.e. spectrum intensity) are related to dynamic characteristics (i.e. apparent fundamental frequency) a force-displacement envelope can be obtained for a given input motion. A simple hysteresis relationship (6) applicable to R.C. structures will enable the engineer to obtain displacement waveforms successfully, which can be used as a basis for seismic performance criteria for slender R.C. structural systems.

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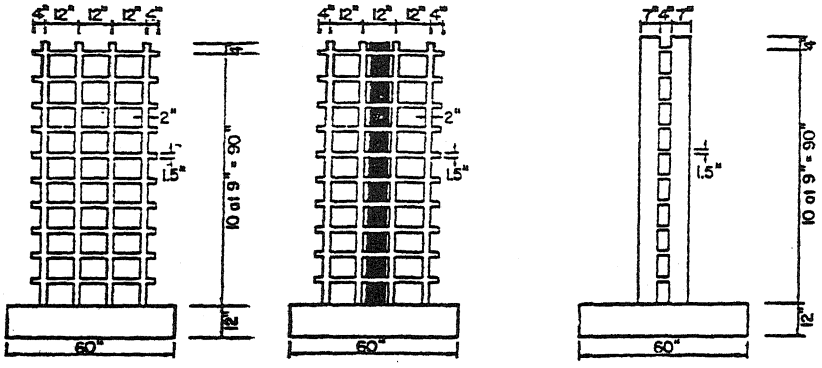

FRAMES FRAME & WALL COUPLED-WALL

FIG. 1 TEST STRUCTURES

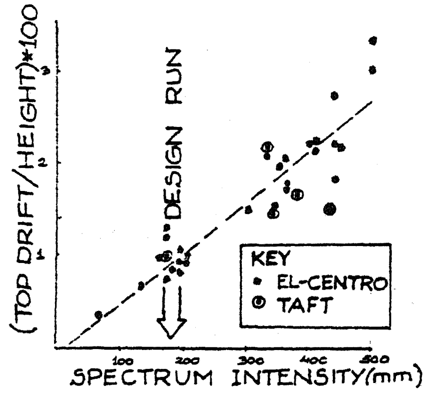

FIG. 2

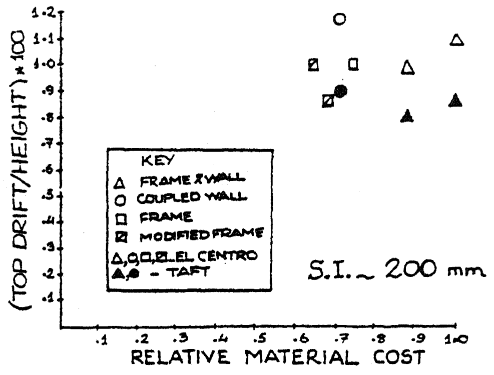

FIG. 3

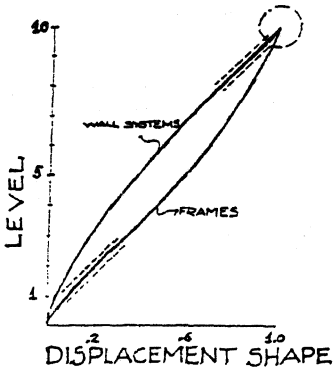

FIG. 4