RESPONSE OF THREE-STORY REINFORCED CONCRETE FRAMES SUBJECTED TO SIMULATED EARTHQUAKE MOTIONS

by

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SYNOPSIS

The inelastic response of small-scale three-story one-bay reinforced concrete frames to earthquake motions was investigated through experimental and analytical studies. The test specimens withstood, without collapse, base motions with maximum accelerations approximately six times the calculated base shear coefficient corresponding to the formation of collapse mechanism. Calculated linearly elastic response was not favorable in predicting the measured maximum response. Calculated nonlinear response showed reasonable agreement with the measured response.

EXPERIMENTAL STUDY

Each test specimen (Fig. 1) consisted of two identical reinforced concrete frames carrying approximately 1960 lb weight (including the weight of the specimen) at each beam level, and was subjected to a series of simulated earthquake motions in one horizontal direction parallel to the planes of the frames on the University of Illinois Earthquake Simulator(2). High-early-strength cement (Type III), fine lake sand and Wabash River sand (mix proportion of 1:1:4 by dry weight, water cement ratio of 0.7, and compressive strength of 5,050 psi) were used. Number 2 deformed bars (yield and ultimate stresses of 42,600 and 66,500 psi) were used as longitudinal reinforcement. All frame members and joint cores were provided with web reinforcement to carry the entire expected shear.

The intensity of base motion was increased from one earthquake run to another, maximum base accelerations ranging from one-half to six times the calculated base shear coefficient at formation of collapse mechanism (elasto-plastic limit analysis). Observed behavior of the test specimens is summarized as follows: (a) The fundamental frequency of a specimen varied from approximately 80 percent of the calculated elastic natural frequency before the test to 25 percent at the end of the last test run. (b) The maximum first-level displacement was approximately one-twentieth of the story height, approximately 10 times the yield deflection calculated for the collapse mechanism. (c) The measured maximum base shear was approximately 1.3 times the calculated base shear assuming yield moments at the top and bottom of the first-story columns (clear height), but was less than the calculated value assuming ultimate moments in the same locations. (d) The first-story column developed a net tensile force which would not be predicted without considering strain hardening of reinforcement. (e) Total displacement range at each level increased almost linearly with the intensity of base motion.

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ANALYTICAL STUDY

The measured response was compared with calculated linearly elastic and nonlinear dynamic responses. Linearly elastic dynamic response was calculated for initial uncracked and fully cracked stiffnesses, with a critical damping factor of 5 percent for all three modes. Comparison of calculated elastic response to that measured (Fig. 2) is summarized as follows: (a) The calculated maximum accelerations (both uncracked and fully cracked stiffnesses) at all three levels agreed favorably at low intensity base motions, but deviated from the measurements at moderate and high intensity base motions because of cracking and yielding in the specimen. (b) The calculated maximum displacements (fully cracked stiffness) at the third level agreed favorably. However, the comparison at the first and second levels was poor. (c) The calculated maximum displacements (uncracked stiffness) ranged from one- to two-thirds of those measured.

An inelastic dynamic analysis was developed which recognized (a) cracking of concrete, (b) yielding and strain hardening of reinforcement, (c) bond slip of tensile reinforcement, and (d) rigid joint cores. Hysteresis was based on Takeda (3). The damping was assumed to be proportional to the stiffness with a critical damping factor of 2 percent at the elastic stage. Comparison of calculated response with that measured is summarized as follows: (a) Large oscillations were favorably simulated by analytical model (Fig. 4). (b) The analytical model predicted closely the maximum response of the test specimen (Fig. 3).

Although the nonlinear analysis method developed is not efficacious to be used in design, it can be useful in making studies of the behavior of reinforced concrete frame structures to earthquake motions toward the development of simplified design methods.

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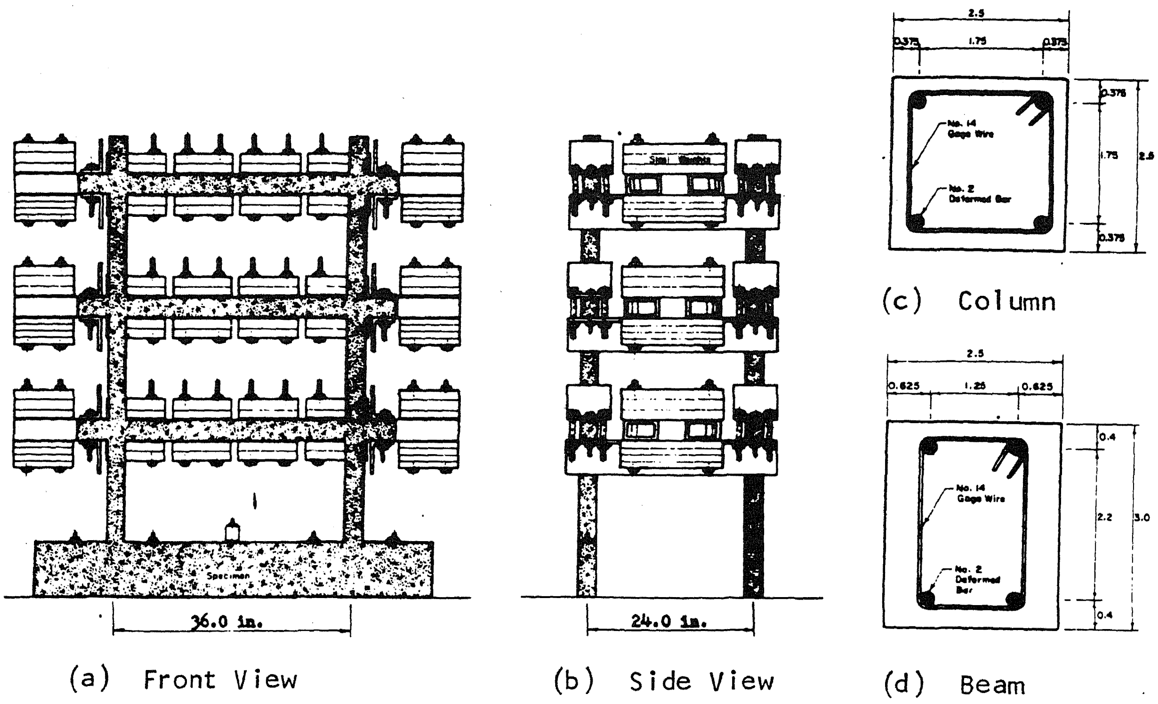

Fig. 1 Three-Story Reinforced Concrete Test Frames

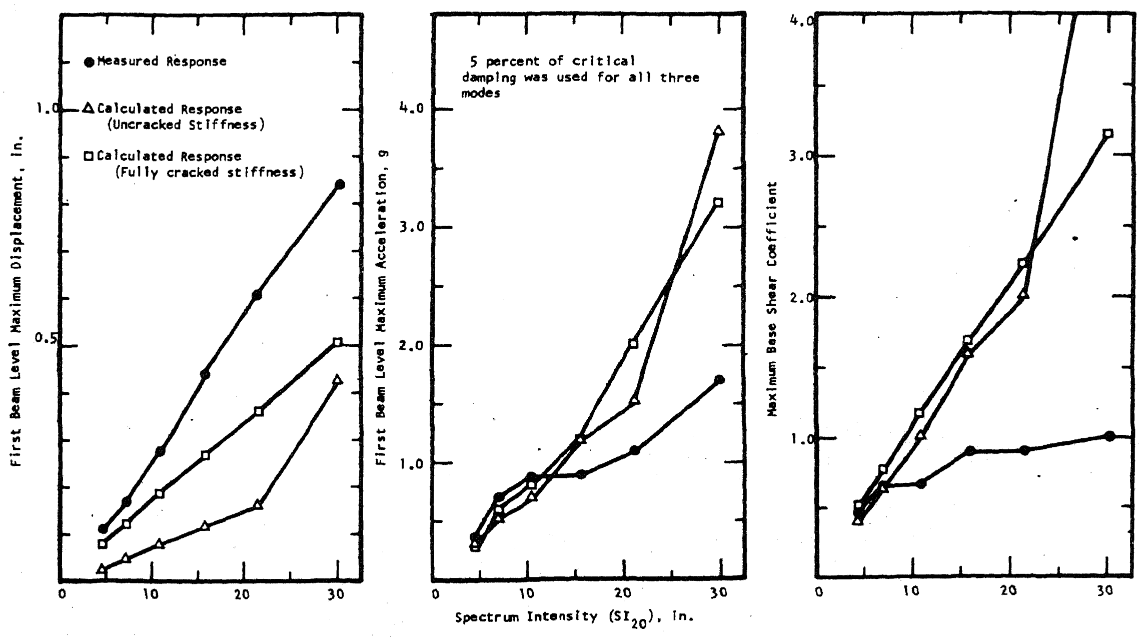

Fig. 2 Measured and Calculated (Linearly Elastic Analysis) Maximum Response

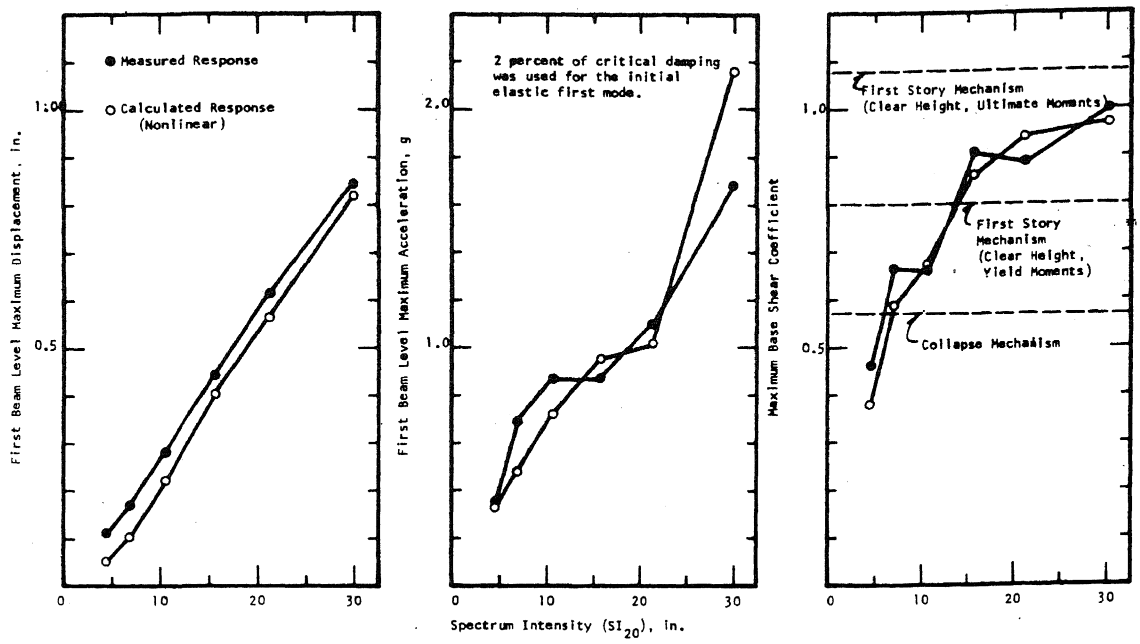

Fig. 3 Measured and Calculated (Nonlinear Analysis) Maximum Response

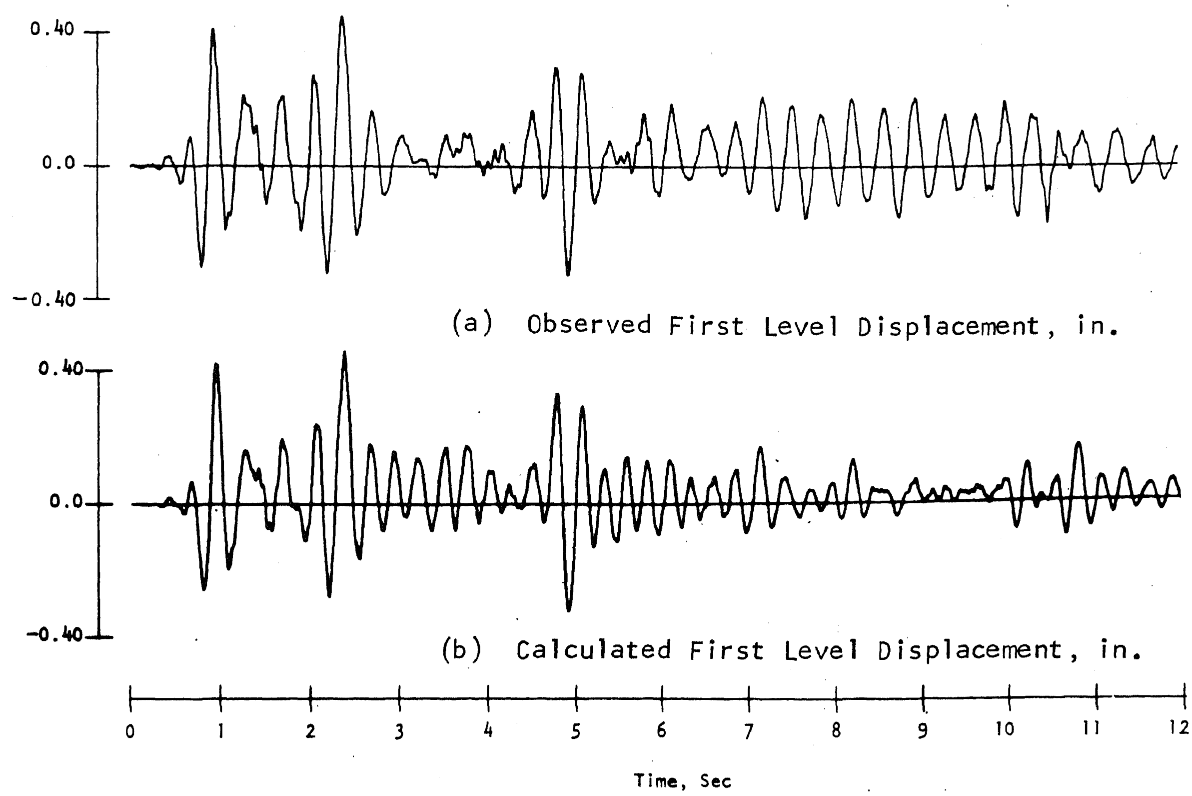

Fig. 4 Comparison of Measured and Calculated (Nonlinear Analysis) Displacement Waveforms