EVALUATION OF APPROXIMATE NONLINEAR PROCEDURES FOR MATCHING OBSERVED RESPONSE OF A SHEAR WALL STRUCTURE

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Recent focus on simplified procedures in performance-based seismic engineering has led to comprehensive research that has resulted in improved response estimation techniques applicable for buildings with regular features. The nuclear engineering community has initiated research to investigate the validity of simplified displacement based procedures for near field response of stiff structures built for nuclear facilities. In view of this, a series of benchmark shaking table experiments were carried out in the Saclay Nuclear Center, France. One particular specimen, CAMUS1, has been further studied numerically under a coordinated research program sponsored by the International Atomic Energy Agency (IAEA) and JRC. This specimen is a 1/3-scale model of a 5-story reinforced concrete building, a typically representative example for stiff nuclear structures. In the first phase of the investigations, a reliable and representative analytical model of the tested specimen was developed based on the successful duplication of physical conditions and loadings imposed during the tests. The experimentally measured results were predicted numerically with a reasonable level of accuracy\(^1\). This article is complementary to the first phase, and deals with the analytical assessment of the seismic response of the CAMUS1 under a suite of fifty-five ground motion records. The ground motion set selected for the study contains representative far and near field earthquake excitations recorded in firm soils. The results are examined to assess efficiency and validity of the approximate nonlinear static analysis procedures for these types of structures.

The analytical model used in the non-linear dynamic analyses is a realistic duplication of a specimen used in the experimental program, so the results obtained from these analyses were considered “exact” with high level of confidence.

1. Response Analyses of the Structure

The selected ground motions were applied to the model and various response parameters from nonlinear time history analyses were determined using ANSYS\(^2\). The top floor displacements of the structure obtained from these analyses were compared with the results of pushover analyses performed for three lateral load patterns as presented in Figure 1. In the first loading shape called modal push pattern, a vertical distribution proportional to the shape of the fundamental mode and story masses in the plane of the shear wall was used. Next a triangular lateral load pattern representing the contribution of each story mass to the inertia force relative to the sum of inertia forces was utilized. Lastly, a uniform distribution consisting of lateral forces at each level proportional to the total mass at these levels was used.


As evidenced in Figure 1 for structures dominantly responding in fundamental mode, while the modal load pattern can be considered as the lower bound for the seismically induced base shear, uniform load pattern acts as an upper bound for the base shear. The pushover curve corresponding to the triangular load pattern was approximated by an equivalent bilinear curve in order to predict the nonlinear response using simplified procedures that are based on the SDOF approximations. A number of widely used procedures including the Capacity Spectrum Method of ATC-40 (CSM), Displacement Coefficient Method of FEMA 356 (DCM) and the nonlinear analysis of the SDOF were employed. As an alternative approach the substitute damping proposed by Gulkan and Sozen\(^3\) was used in conjunction with the CSM to predict the top floor displacement of the MDOF system. The results presented in Figure 2 indicated that the CSM when used with the substitute damping yields the best results while the CSM of ATC resulted in the worst estimates of the inelastic displacement demand.

The article presents comparisons between the “closed form” results and those obtained from simpler models.

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\(^3\) Gulkan, P. and Sozen, M., A., [1974], “Inelastic Response of Reinforced Concrete Structures to Earthquake Motions”, ACI Journal, December, pp.604-610
Figure 2. Comparison of exact and approximate roof displacements

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