INELASTIC SEISMIC RESPONSE OF AN EMBEDDED REACTOR BUILDING

By M. Chatterjee[I], Wayne W. H. Chen [II], and S. Loo[I]

SUMMARY

Inelastic seismic response of an embedded reinforced concrete Reactor Building is analyzed for a long duration strong earthquake. Five in-plane shear wall panels of the Reactor Building were found to show cracking. Inelastic behavior of the building due to localized cracking of the shear walls results in higher maximum relative displacements, increasing instantaneous acceleration of neighboring element masses and larger high frequency spectral acceleration.

INTRODUCTION

In many part of the world, it is economically infeasible to design important civil engineering structures to withstand strong earthquakes elastically. The ability of the structure to sustain dynamic load due to strong motion earthquake is dependent on its ductility and energy-absorbing capability which can be achieved by effective design and detailing. This paper presents the results of inelastic seismic analysis of an embedded reinforced concrete reactor building whose dynamic behaviour is governed by heavy concrete shear walls.

SEISMIC CRITERIA

The Reactor Building analyzed is 81 meters square in plan, 65 meters high and 20 meters embedded in mudstone with a shear wave velocity of 1,000 m/sec. The duration of the design artificial time history is 50 seconds. The design peak acceleration is 0.60 g.

I Bechtel Power Corporation, San Francisco, California, U.S.A.

II Research and Engineering, Bechtel National Inc., San Francisco, California, U.S.A.

ELASTIC ANALYSIS

Elastic analysis of the Reactor Building is performed (1) to provide a reference for comaprison in assessing the effect of inelastic behavior on the Reactor Building response and (2) to confirm that the effect of soil-structure interaction is being adequately simulated in analyzing the fixed-base building subjected to the interaction basemat response time histories. The nodal damping values used in the analyses are equal to the composite damping values of 2% of critical for steel members and 7% of critical for concrete members. The interaction basemat motions generated in the elastic analysis are then used for the subsequent inelastic analysis.

INELASTIC ANALYSIS

By taking advantage of building symmetry to reduce the computation effort, the analysis is performed for only one half of the Reactor Building (Fig. 1). The in-plane shear walls of the Reactor Building are modelled by twenty-one shear panel elements with nondegrading trilinear stress-strain relationships (Fig. 2). Fourteen stiffness degrading concrete beam and fourteen concrete beam-column elements are used to model the floor and the out-of-plane walls. The inelastic behavior of these structural components are represented by an elastic-perfectly plastic moment-curvature relationships. The internal structures and the roof truss system are modelled using fifteen steel beam-column elements. Five spring elements representing the RPV stabilizer, the shear lug and the PCV truss are assumed to be elastic.

The inelastic seismic analysis is performed using modified computer program ANSR-1 (Ref. 1) for seismic excitation of 0.60 g. The time step interval used is 0.005 second. The gravity load is first applied to calculate the initial deformation. The dynamic analysis is then performed using a step-wise integration of the incremental equations of motion with equilibrium correction. The Newmark constant average acceleration time integration scheme ($\beta = 1/4$, $\gamma = 1/2$, and $\delta = 0$) is used in the solution calculation. Structural damping is simulated by both the strain energy dissipated by the hysteretic action of the structural component and the mass and stiffness proportion viscous damping assigned to the material.

RESULTS OF INELASTIC ANALYSIS

The peak accelerations at the top of RPV and the Reactor Building are higher than those would be predicted by an elastic analysis. The acceleration response spectra shows additional high frequency responses at the top of the PCV and RPV in the inelastic analysis. These results indicate that the redistribution of the elastic strain energy at the onset of cracking possibly causes the increases in instantaneous accelerations of the neighboring elements masses. High frequency spectral accelerations observed in the spectra of the nodes indicated may be due to strain energy redistribution and/or the method of solution.

The comparison of the maximum relative displacements shows that the displacement response at all locations except the top of the basemat are higher than would be predicted by an elastic analysis. The observed behavior is believed to be caused by the cracking of shear wall elements which dissipate additional energy by hysteretic behavior. However, the reduction in stiffness results in higher nodal displacements in spite of the reduction in base shears. The other apparent effect of inelastic behavior is the reduction of shear stresses in the shear wall elements adjacent to the cracked elements, and the corresponding increase in shear forces and bending moments of the out-of-plane structural walls and floor beams.

CONCLUSIONS

(1) For the 0.60 g seismic excitation the Reactor Building shows cracking of five in-plane shear wall panels of the structure (Fig. 1). However, no yielding is induced in any of the cracked walls and all other structural components within the building remain in the elastic range of response.

(2) The following observations are believed to be due to localized cracking of the shear walls:

(a) Maximum relative displacements at all locations except the top of the basemat are increased.

(b) Redistribution of the elastic strain energy at the onset of cracking possibly causes an increase in instantaneous acceleration of neighboring element masses.

(c) High frequency spectral accelerations observed in the spectra of some of the nodes may be due to strain energy redistribution and/or the method of solution.

(d) Although reduction in the total base shear force was observed, it was not found to be appreciable.

REFERENCES

1. Mondkar, D. P. and Powell, G. H., "ANSR-1 General Purpose Program for Analysis of Nonlinear Structural Response," Earthquake Engineering Research Center, Report No. EERC 75-37,

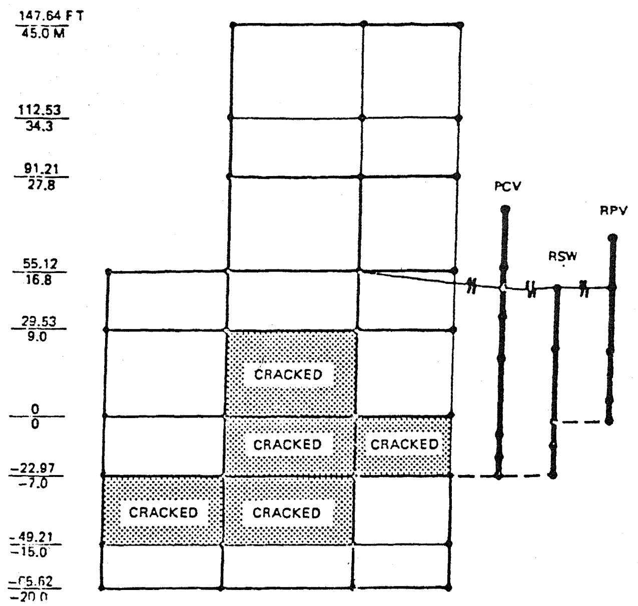

FIG. 1 2-D FINITE ELEMENT REACTOR BUILDING MODEL

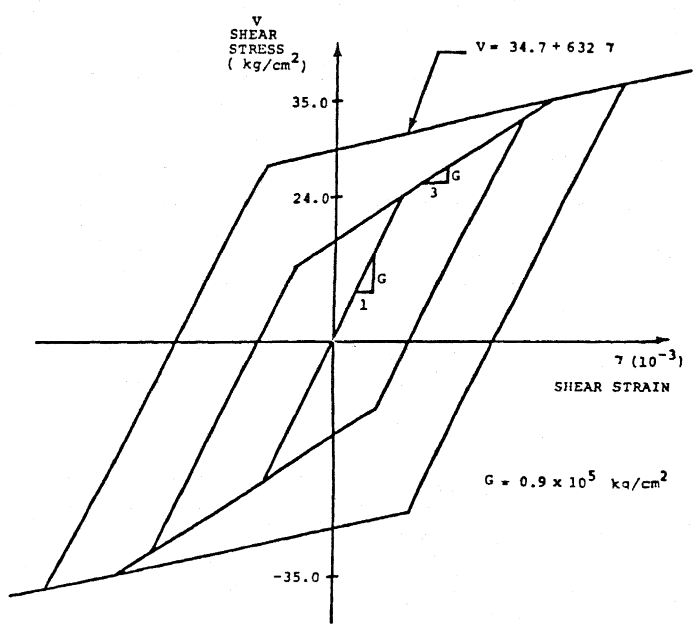

FIG. 2 HISTERETIC STRESS-STRAIN RELATIONSHIP FOR SHEAR WALLS