Near-Fault Effect on Seismic Performance of 3D Reinforced Concrete Complex Structures

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Abstract

Disastrous earthquakes caused heavy casualties and structural damages. It is found from the earthquake reconnaissance that the behavior of 3D reinforced concrete (RC) complex structures is very difficult to be predicted, especially when they are subjected to near-fault ground motions. The 3D RC complex structures can be visualized as assemblies of beam-column, membrane and shell elements. Numerous studies have been performed to understand the behavior of structural elements. The behavior of a whole structure can be predicted if the behavior of each element is thoroughly understood. This lecture presents the development of a finite element analysis (FEA) program to predict the nonlinear behavior of 3D RC complex structures. The developed program is first validated by several large-scale structural tests, and is then employed to investigate the near-fault effect on seismic performance of both nuclear containment vessel and irregular 2-story RC building.

A 2-node beam-column element and its constitutive models have been developed at UC Berkeley. A 4-node membrane element and its constitutive models have been developed at the University of Houston (UH). More recently, at UH an 8-node iso-parametric curved shell element and its constitutive models have also been developed. In the formulation of membrane and shell elements, we utilize the UH-developed Cyclic Softened Membrane Model and develop the constitutive relation modules. To form a FEA program (called Simulation of Concrete Structures, SCS), the constitutive relation modules and the analysis procedure were implemented into a finite element program

development framework, OpenSees developed at UC Berkeley. Several large-scale structural tests were employed to validate the developed FEA program, including panels subjected to pure shear or combination of shear and bending, circular and rectangular hollow bridge columns, cylindrical tanks, nuclear containment vessel and irregular RC building subjected to reversed cyclic loading.

Generally speaking, the near-fault earthquakes have different characteristics when compared to the far-field earthquake. Unlike the far-field earthquake in which the main frequency content of the earthquake is more distributed, the main frequency content of the near-fault earthquake is more concentrated in a very low-frequency region. The near-fault earthquake also has a pulse like configuration in its time velocity record which introduces large input energy to the structure in a short period of time. To investigate the near-fault effect on the seismic performance of complex 3D reinforced concrete structures, both the nuclear containment vessel and irregular 2-story RC building are employed. Using the developed FEA program, nonlinear time history analyses were performed for both structures subjected to near-fault or far-field ground motions. The following was found from the analytical results. Due to the low natural periods possessed by both structures, the seismic responses of both structures are governed by the far-field ground motion in the elastic region. When the stiffness of the structures decreases, causing the natural period of the structures to increase, the responses of both structures are governed by the near-fault ground motion in the inelastic region. It is observed that the near-fault ground motion causes much greater damages to the structures due to larger displacements, higher energy dissipation, and hence requires greater structural ductility demand. Therefore, to resist near-fault ground motions on the RC structures, a super ductile behavior of materials needs to be ensured.