MODELING OF SLABS IN SEISMIC ANALYSIS OF NUCLEAR POWER PLANT BUILDINGS

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SUMMARY

Seismic structural analysis is an essential aspect of nuclear power plant design and entails mathematical modeling of buildings. These safety related buildings are generally complex structural systems. With the exception of the containment, the buildings are typically low aspect ratio, box-like reinforced concrete structures with thick walls and slabs. The slabs are supported by shear walls, beams and columns. Three-dimensional stiffness, inertia and damping characteristics of these structures are represented in analytical models to adequately evaluate seismic responses for structural design and equipment qualification. The so-called stick model consisting of lumped masses interconnected by weightless elastic beams is traditionally used. Significant eccentricities are considered by providing rigid horizontal beams between the floor mass points and stiffness centers. Implicit in this approach is the assumption that the floor slabs are infinitely rigid. It is well known that distribution of lateral loads in buildings depends on the stiffnesses of slabs relative to those of the vertical load resisting elements and not on the absolute slab stiffnesses. Recent tests of multi-story buildings subjected to dynamic loading indicate substantial deformation of floor slabs and hence interaction between slabs and vertical load carrying system. The purpose of this study is to evaluate the rigid slab assumption in modeling of nuclear power plant buildings and to present practical methods to consider slab flexibility in seismic analysis.

Ideally, three-dimensional finite element dynamic analysis should be used to accurately evaluate the seismic response of structures. However, it is a well recognized fact that presently, such an analysis would be prohibitively expensive, if not impossible. Simpler and more practical methods are used in the present investigation. Briefly, floor slabs are represented as shear beams between the supporting walls which are modeled as vertical beams. This coupled system is subjected to seismic ground excitations. Typical buildings founded on rock and soil are analyzed with fixed base and compliance representations, respectively. Over-all structural responses including three translational and three rotational accelerations are computed at each floor mass point of the model. In case of soil foundation, translations and rotations of the structure base are included. Results of the study indicate (1) traditional stick model generally yields satisfactory over-all acceleration responses of buildings (2) lateral force distribution in shear walls with rigid slab assumption can result in significant errors, e.g., possible under-design of interior shear walls, and (3) local slab amplifications, both horizontal and vertical, are significant when slabs have long spans, large openings and/or relatively small thicknesses.

Based on the results of this investigation, the following analytical approach for the seismic analysis of nuclear power plant buildings appears appropriate and practical:

1. Dynamic analysis of stick model to determine over-all acceleration responses.
2. Static three-dimensional analysis using the finite element representation of the building and inertia loads due to acceleration responses.
3. Subsystem seismic analysis approach for local slab amplifications by simple spring-mass or detailed finite element models depending on the complexity of slab geometry, support conditions and equipment locations.