RELIABILITY-BASED DESIGN OF NUCLEAR CONTAINMENT STRUCTURES

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SUMMARY

In the design of nuclear containment structures, several loads and load combinations are currently considered. Although the design loads and their combinations appear logically chosen, the uncertainties in the loads and resistances are not explicitly included in this selection. At present, there is no procedure available for calculating the reliability of containment structures and for assigning consistent load factors for specified reliabilities. The research currently underway (present paper) addresses this problem in a quantitative manner. A methodology for reliability-based design of containment structures is presented in this paper. Major aspects of this study are: probabilistic assessment of loads and material properties, determination of critical locations and failure modes, and calculation of the system reliability from cross-sectional reliabilities and their correlations.

Available data on different materials (concrete, reinforcing steel and prestressing steel) and loads (tornado, earthquake and accident pressure) have been analyzed to derive their probability distributions. Combinations of loads have been postulated considering their variabilities in time. The maximum total load effect in a combination is calculated taking into account the individual loads and their variabilities.

For a typical prestressed concrete containment, three critical locations have been identified for failure mode analysis: junction of base slab and cylindrical wall, junction of dome and wall, and containment penetrations. The corresponding failure modes of flexure, radial shear, tangential shear and combined flexure and compression are studied.

The reliability of a cross section is calculated using the probability distributions of resistance and load effect acting at the cross section. A second-moment approach is employed to calculate this cross-sectional reliability. The reliability of the containment structural system is evaluated based on the weakest link theory taking into account the statistical correlations in resistance of different cross sections and in load effects acting on them. Consistent load factors are derived for the postulated load combinations for specified reliability by formulating a nonlinear programming problem.

The procedure is illustrated for a typical prestressed concrete PWR containment.