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Anchor Bolt Behavior and Strength During Earthquakes

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ABSTRACT

This is the final report for NRC Contract No. NRC-03-92-05 ("Anchor Bolt Behavior and Strength During Earthquakes"). The objective of this project was to obtain technical information to verify, by testing, the adequacy of the assumption used in the US nuclear power plant designs that the behavior and strength of anchor bolts (cast-in-place, expansion, and bearing-type (undercut)) and their supporting concrete under seismic loads do not differ significantly from those for static conditions (Klingner 1991).

To that end, a research program was carried out on the dynamic behavior of anchors in concrete. In this report, that research program is described; the principal results are summarized; and the principal conclusions are given.

Four documents have already been submitted to the Nuclear Regulatory Commission, giving detailed results of this research: Rodriguez (1995); Hallowell (1996); Lotze (1996); and Zhang (1997). The intent of this report is to summarize and synthesize those previously submitted documents, and to guide the reader in obtaining more detailed information from them. Most of this report is adapted from those documents.

The research program comprised four tasks:

Task 1: Static and Dynamic Behavior of Single Tensile Anchors (250 tests)

Task 2: Static and Dynamic Behavior of Multiple Tensile Anchors (179 tests)

Task 3: Static and Dynamic Behavior of Near-Edge Anchors (150 tests)

Task 4: Static and Dynamic Behavior of Multiple-Anchor Connections (16 tests)

The anchors tested were selected based on their reported frequency of use in nuclear power plants in the US. Anchors included cast-in-place headed bolts, grouted headed bolts, two wedge-type expansion anchors, one sleeve-type expansion anchor, and two undercut anchors. Loading conditions included tension, shear, and combined tension and shear. Test variables included different concrete strengths and types, loading rate, and the presence of cracks.

The basic conclusions of the research are:

1) Under seismic-type loading, the capacities of most anchors tested in this study were at least as high as under quasi-static loading.
2) As a result, most anchors tested in this study, if designed for ductile behavior under quasi-static loading, would behave in a ductile manner under seismic-type loading as well.
3) The above conclusions are not true for wedge-type expansion anchors. These tend to pull out and pull through under dynamic loading. Wedge-type expansion anchors should be evaluated individually to determine their seismic adequacy.