MICROMECHANICAL SIMULATION OF EARTHQUAKE-INDUCED FRACTURES IN STEEL STRUCTURES

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Characterized by high-strain low-cycle conditions, earthquake-induced fractures are quite different from low-strain high-cycle fatigue fractures that have been extensively studied in bridges and mechanical components. The high-strain low cycle fatigue associated with earthquakes involves even fewer cycles (less than ten or twenty) than conventional low cycle fatigue. This can be termed as ultra-low-cycle fatigue (ULCF). Traditional techniques to analyze and predict such behavior are not nearly as well developed as those for other limit states. Computationally intensive micromechanical models, which aim to capture the fundamental mechanism of the process, show great promise in predicting failure due to inelastic fracture and ultra-low-cycle fatigue commonly seen during earthquakes. This research develops and applies computational methods for simulating inelastic earthquake-induced fractures with an emphasis on ductile crack initiation due to monotonic or cyclic loading. The scope of the research includes complementary computational (finite element) and experimental studies that utilize state-of-the-art fracture and micromechanical models to analyze failures. A large variety of tests (and complementary finite element analyses) are carried out on seven different varieties of steel. The experiments include monotonic and cyclic stress-strain tests for materials, standard fracture tests, smooth notched fracture tests, as well as pull-plate tests that resemble structural configurations. Based on the simulation results and tests, models for the low-cycle fatigue situation are developed after identifying mechanisms that lead to such failures. The study (1) validates monotonic micromechanical models for structural steels and makes recommendations for their use (2) generates material toughness data for a variety of structural steels (3) proposes new mechanisms for ULCF (4) develops new micromechanical models for ULCF based on these mechanisms (5) uses experiments similar to structural details to validate the micromechanical models and (6) comments on the limitations of such approaches and makes recommendations for future research.