ANALYTICAL MODELS FOR RC FRAMES WITH STRENGTH AND STIFFNESS DEGRADATION

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Among the key enabling technologies for modern Performance-Based Earthquake Engineering are tools to simulate the nonlinear response of structural systems to collapse. Such simulation technologies are essential to advancing engineering practice beyond current empirical assessment methods to the stage of accurately modeling seismic response and damage to buildings and bridges. Recognizing the central role of computing technologies to performance based engineering, PEER (Pacific Earthquake Engineering Research Center) has embarked on the development of OpenSees (Open System for Earthquake Engineering Simulation) - a versatile computing environment that brings together geotechnical and structural analysis models in an object oriented framework. The specific focus of this project is to develop structural material and component models for simulating strength and stiffness degradation in reinforced-concrete structures, using the OpenSees platform.

This research project involves the development and implementation of structural models for performance assessment of reinforced concrete frames that exhibit strength and stiffness degradation. Emphasis is on generalized hinge models that are sufficiently accurate to capture behavior of degrading systems up to collapse, but still practical enough for simulating the response of realistic building and bridge structures. Several uniaxial materials and 2D beam-column models have been implemented in the OpenSees analysis platform and work is ongoing to refine these to capture degradation under the combined actions of bi-axial bending, axial and shear forces.

Class hierarchy for the element formulation, based on object oriented paradigm, has been developed such that a generic element class, *Element2D*, captures second-order response employing an updated Lagrangian formulation. All the elements derived from this class inherit this property while providing alternative schemes to model inelastic effects, like concentrated spring assemblies or yield surface in force space.

A range of yield surface models for steel, concrete filled tubes, and concrete sections are being developed such that any of them could be plugged into the inelastic beam column element. The yield surfaces model combined isotropic and kinematic behavior that captures hardening/softening through expansion/contraction of the yield surface. The stiffness components for the yield surface can be deteriorated based on cumulative plastic strain, shear and other damage parameters. Work is continuing to extend these basic implementations to include three-dimensional models and more elaborate history variables that can capture the hysteretic response observed in component tests and provide damage index data that feeds into performance assessment modules.