Damage Identification in Steel Buildings Using Nonlinear Structural Models and Seismic Networks

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Damage identification methods applied to structures are motivated by dense and continuous building response data collected from low-cost strong-motion networks such as the Community Seismic Network. Damage in a structure is assigned by modifying the material properties in a targeted number of structural components. To account for the sparsity of the damage, L1 regularization techniques or sparse Bayesian learning tools are found to be suitable for identifying the location and severity of damage. In the vast majority of studies, such techniques have been applied to linear models of structures using modal properties as the measured quantities. In this study the damage identification problem is formulated in the time domain, and it is configured so that near-real-time strong motion acceleration time histories recorded by dense arrays can inform assessment of structural condition. Furthermore we extend these methods to handle model nonlinearities that reflect damage to the structure. Guided by observed steel-moment frame damage patterns, we consider the behavior of cracks in beam-column connections. For the structures under consideration, high-fidelity nonlinear finite element models are developed in OpenSees using force-based fiber elements, allowing for realistic behavior associated with the opening and closing of cracks to be incorporated into the modeling. The effectiveness of the proposed method is demonstrated using a number of different imposed damage scenarios and simulated acceleration data from a multi-story theoretical steel building as well as an existing, fully-instrumented 15-story building in downtown Los Angeles.