INSTRUMENTAL ASSESMENT OF THE PREDICTIVE CAPABILITY OF NONLINEAR STATIC ANALYSIS PROCEDURES FOR SEISMIC EVALUATION OF BUILDINGS

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Abstract

The recorded responses of five reinforced concrete buildings to real earthquakes are used to evaluate the predictive capability of nonlinear static procedures (NSPs). NSP predictions of response parameters such as inter-story drift and story shears are compared with the response reconstructed from the measurements. Response reconstruction is carried out by blending measured acceleration signals and model based information, using an observer, a mathematical structure from control theory. The buildings are represented by 3D nonlinear Finite Element models with elastic stiffness updated from eigenproperties identified from small amplitude response. The fidelity of the models for behavior at large amplitudes is validated by contrasting time history predictions with measured strong motion acceleration response.

The study involved two major tasks; 1) application of the NSP to predict the response parameters and 2) estimation of the response from sparse acceleration measurements. The 1st task is a routine engineering application of NSP's with particular ground motion spectra replacing the general response spectrum used in the standard procedures. The second task hinges on the estimation of the response at the floors that are not instrumented. Traditional cubic spline (CS) interpolation and various techniques from state estimation were tried in a pilot analytical study to determine how to most reliably reconstruct the response. It was found that the CS interpolation, albeit adequate in most cases, lead to undue error sometimes and for this reason the reconstruction was carried out using a state-space observer. The basic theory of the observer, a linear system that combines model based information with the measurements, is described in detail in the paper.

The results indicate that when data from all the stories are treated in a single batch the ratio of the estimated response to the NSP predictions has a mean that varies from {1.03 to 1.13} for shears and from {1.06 to 1.31} for inter-story drift. The corresponding upper bounds of the 95% confidence intervals, assuming a lognormal distribution, are: {1.71 to 1.87} and {2.32 to 2.51}. When only the data from the lower half of the building are considered the mean of the shear and the drift ratios vary from {0.98 to 1.10} and {0.87 to 1.16}. The upper bounds of the 95% confidence intervals are {1.39 to 1.60} for shear, and for inter-story drift {1.38 to 1.70}. As can be seen, and one anticipates from theoretical considerations, the prediction accuracy of NSP is found to be significantly higher in the lower levels of the buildings considered. Differences in the predictive capability between the various NSP modalities, however, proved to be statistically insignificant.

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