PROBABILISTIC SEISMIC ASSESSMENT OF ACCELERATION DEMANDS IN MULTI-STORY BUILDINGS

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Previous earthquakes have shown that nonstructural components are major contributors to the damage and therefore repair costs in buildings. In moderate earthquakes where structures do not see a lot of damage, there can be significant damage in nonstructural components. Looking at cost distribution of commercial buildings shows that about 70 percent of the total cost is spent on nonstructural components and thus, in the event of an moderate earthquake where the structure remains safe and almost with no damage, the owner has to pay a lot of money to repair the nonstructural components. Many of the nonstructural components such as suspended ceiling and most of mechanical and electrical equipments are sensitive to acceleration and not interstory drift and therefore estimation of floor acceleration demands which leads to better design of acceleration sensitive components can improve the performance of buildings.

In moderate earthquakes, the main structure may remain elastic or practically elastic while nonstructural components may experience significant damage and therefore study of acceleration demands in linear structures seems crucial. To study the acceleration demands in linear structures, the structure is approximated with a continuum model consisted of two cantilever shear and flexural beams. This model not only is helpful for rapid estimation of response but also provides an effective tool for parametric study. The model is fully defined with fundamental period of the structure (T_1), lateral stiffness ratio or the ratio of shear to flexural behavior (α_0) and modal damping ratio (ξ). Approximate dynamic characteristics of the building such as period of higher modes, modal participation factors and mode shapes obtained by the model then used to estimate the floor acceleration demands in a time history analysis or spectral method. The accuracy of the method has been verified by comparing the acceleration demands of a few instrumented buildings subjected to previous earthquakes with those obtained from the model. Results show that although the method is very simple and fast, it captures the acceleration response even when the higher modes dominate the response while current seismic provisions recommend a linear variation of peak floor acceleration and a typical floor response spectrum regardless of dynamic characteristics of buildings.

The simplified model mentioned above has also been used to perform parametric study of peak floor acceleration and floor response spectra. A wide rage of structures with fundamental period of vibration from 0.5 to 4.0 s, lateral stiffness ratio from 0 (flexural behavior) to 20 (shear behavior) and different damping ratio for main and secondary system were subjected to a set of ground motions recorded on firm soils. Effect of each parameter on acceleration demands has been investigated. Several parameters such as mean, standard deviation and probability distribution of response have been looked and results show that dynamic characteristics have significant effect on acceleration demands while this is neglected in design codes.

As part of our study, we have studied different ground motion intensity measures and their effectiveness in predicting peak floor acceleration demands. The common intensity measure used in the field of earthquake engineering is spectral acceleration at first period of the structure. The logic behind this is that displacement demands are mainly dominated by the first mode and therefore use of $S_a(T_1)$ leads to small dispersions of response. When the response parameter of interest is acceleration, $S_a(T_1)$ produces large dispersions because of significant contribution of higher modes. The results show that peak ground acceleration is a better representative of ground motion for estimation of floor acceleration.

To conclude the study of floor acceleration demands in linear structures, a spectral method was developed to estimate absolute floor acceleration. The method is based on combination of modal responses considering the correlations between modes and also correlation of ground and modal responses and also peak factors. A parametric study with parameters same as those mentioned earlier was performed to evaluate the accuracy of the method. Comparison of the peak floor accelerations obtained from time history analysis and spectral method show that the spectral method with the formulation proposed in this study can predict effectively the peak floor acceleration demands of structures with all range of parameters.

To extend the study into nonlinear structures, a series of structures with different dynamic properties were modeled as single bay generic frames. The parameters include number of stories, beam to column stiffness ratios, rigidity of the structure and damping ratio of the secondary system. The frames were designed according to the current seismic codes. The ground motions are applied to the structures using incremental dynamic analysis (IDA) method. The results are being processed now which provide valuable information to relate the acceleration demands including peak floor accelerations and floor response spectra to structural parameters as well as the level of nonlinearity of the main structure.