AN ENERGY SPECTRUM METHOD FOR SEISMIC EVALUATION OF STRUCTURES

Subhash C. Goel[1], Wen-Cheng Liao[2], and Sutat Leelataviwat[3]

[1]*Professor Emeritus of Civil Engineering, University of Michigan, Ann Arbor, MI, USA*
[2]*Doctoral Student, University of Michigan, Ann Arbor, MI, USA*
[3]*Assistant Professor, King Mongkut's University of Technology, Thonbury, Thailand*

ABSTRACT

Seismic evaluation of structures generally involves determination of displacement demands from which story drifts, and component forces and deformations for specified hazard levels can be obtained for comparison with available capacities. A number of methods have been proposed by investigators in the past some of which are also used in current practice, such as MPA, FEMA 440, and Capacity Spectrum. Those methods generally involve non-linear pushover analyses. This paper presents adaptation of an energy based method that has been recently developed and successfully used by Goel et al., for design purposes, called Performance-Based Plastic Design (PBPD) method. In the PBPD method the design base shear for selected hazard level is determined by equating the work needed to push the structure monotonically up to a selected target drift to the corresponding energy demand of an equivalent SDOF oscillator. It turns out that the same work-energy equation can also be used to estimate seismic demands for existing structures. In this approach the skeleton force-displacement (capacity) curve of the structure is converted into energy-displacement plot (E_c) which is superimposed over the corresponding energy demand plot (E_d) for the specified hazard level to determine the expected peak displacement demand, Figure 1.

The method is applied to a number of example multistory steel and RC building structures of different heights with excellent results. The results are also compared with those obtained from time-history analyses as well as by using methods in current practice. Evaluation of RC structures presents special challenge due to their complex and degrading ("pinched") hysteretic behavior. This aspect is taken care of by making appropriate modification in constructing the energy demand curve, E_d. Sample results of a 20-story code-compliant RC moment frame from ATC 63 Project are shown in Figure 2. It can be seen that the drift demand estimates given by the energy spectrum method ($E_c = E_d$) are generally quite close to those obtained from time-history analysis using representative ground motion records. This can be considered as a very good correlation between the results given by an approximate method with those from more precise analysis.

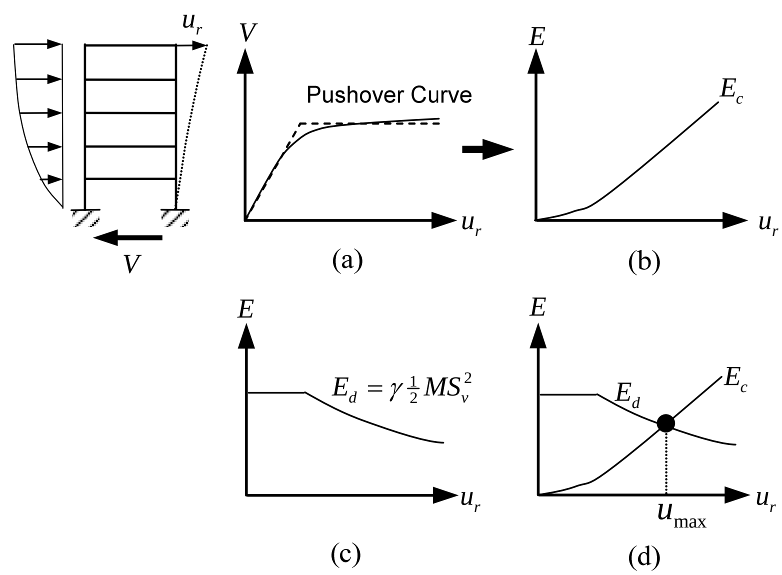

Figure 1. Proposed energy spectrum evaluation method for MDOF systems: (a) Push-over curve, (b) Energy-displacement capacity diagram, (c) Energy demand diagram, and (d) Determination of displacement demand

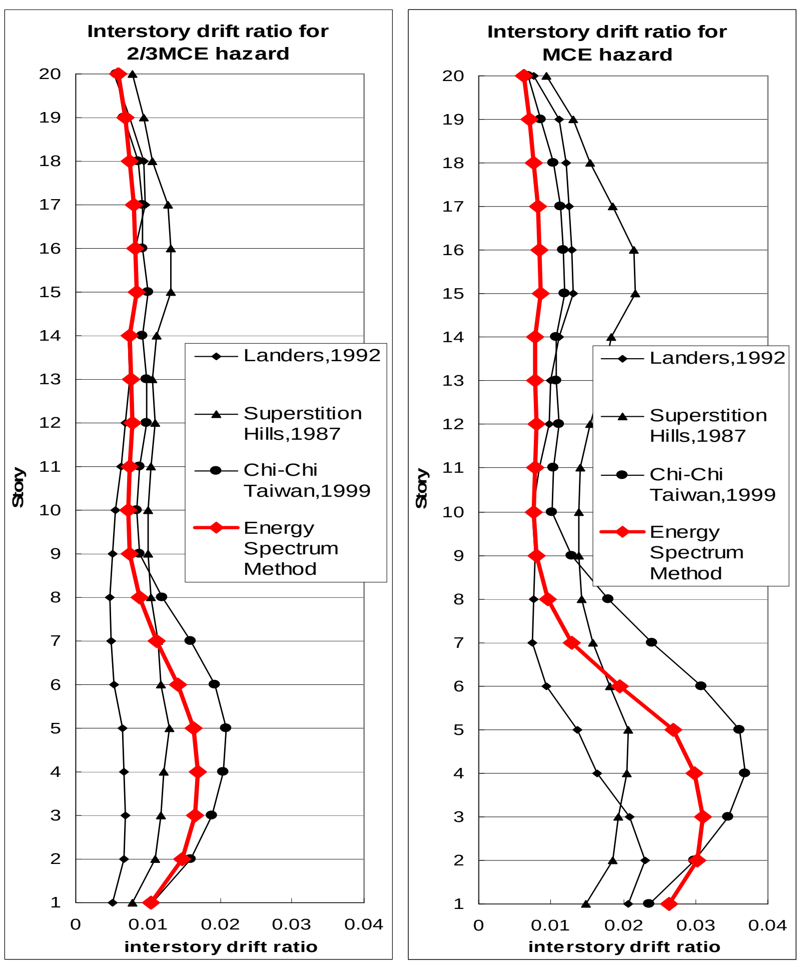

Figure 2. Comparison of interstory drift ratios of 20-story code-compliant RC moment frame derived from energy spectrum method with time-history analysis results.