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DETERMINATION OF STABILITY MARGIN FOR FLEXIBLE SUBSTRUCTURES WITH LIMITED LATERAL DEFORMATION

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ABSTRACT

A variety of new approaches in seismic design of structures are based on adding to the flexibility and energy dissipation potentials of a structural system instead of relying on its ductility capacities. In this case higher flexibility reduces the level of lateral force on the structural system and energy dissipation controls its lateral deformation during earthquake excitation (Ziyaeifar, 2002). On the other hand, expanding the flexibility of a structural system is limited to its stability margin in sustaining vertical loads. In this work it is attempted to find the required level of stability margin for a flexible structure that its lateral deformation subjected to earthquake actions is restricted by damping forces. Such flexible structural systems (mass subsystems) are connected to a much stiffer structure (stiffness subsystems) by the means of large energy dissipaters for reducing their lateral deformation (Ziyaeifar et al., 2012). Similar arrangement of soft and stiff structural systems also exist in case of connecting two adjacent buildings with viscous dampers (Christenson et al., 2003; Yuji et al., 2004).

Increasing the flexibility of structural system and its natural period reduces the stability margin of the system (as described by Bernal, 1998). This can be understood from the inverse relationship between natural period and stability index of typical structural systems ($T = \alpha\lambda^{-\beta}$ where T is natural period of the system and λ is its stability index). Considering the role of lateral deformation of structural systems on their stability margin (due to *P*-Δ effect), the highest flexibility of mass subsystems has to be determined based on stability margin for the system at its expected lateral deformation (that is restricted by high damping forces).

METHODOLOGY

In this work, the results of typical pushover analyses (considering *P*-Δ effects) on some referenced frame systems (Bernal, 1992, 1998) have been used to find the stability margin for ultra-flexible substructures subjected to limited lateral deformation (to be used as Mass subsystems in seismic design of structures).

Results and Conclusion

Figure 1 represents the results of pushover analyses in terms of horizontal load and lateral deformation in a 4 story frame system. In this figure, Δ_e is the onset of nonlinear behavior in the system, Δ_y defines the nonlinear range of behavior in case of using a bilinear model and Δ_{ep} represents the point in which a uniform drop in lateral load capacity of the system can be identified. As shown in the figure, lowering lateral stiffness of the system increases its natural period and reduces its stability margin. According to this figure, a very soft structure with the natural period of $T = 3$ seconds has the minimum stability index of $\lambda = 4$ (based on the chosen code of practice (ASCE, 2005a, 2005b, 2010, 2017)). In this case lateral deformation of the system has to be limited to about $\Delta = 2\%$ drift margin at collapse prevention performance level for the system. A more conservative design for this structure suggests to reduce the natural period of the system to $T = 2.5$ second and add to its stability margin ($\lambda = 6$). In this case, lateral deformation of the system at collapse prevention goes to above $\Delta = 3.5\%$ level.

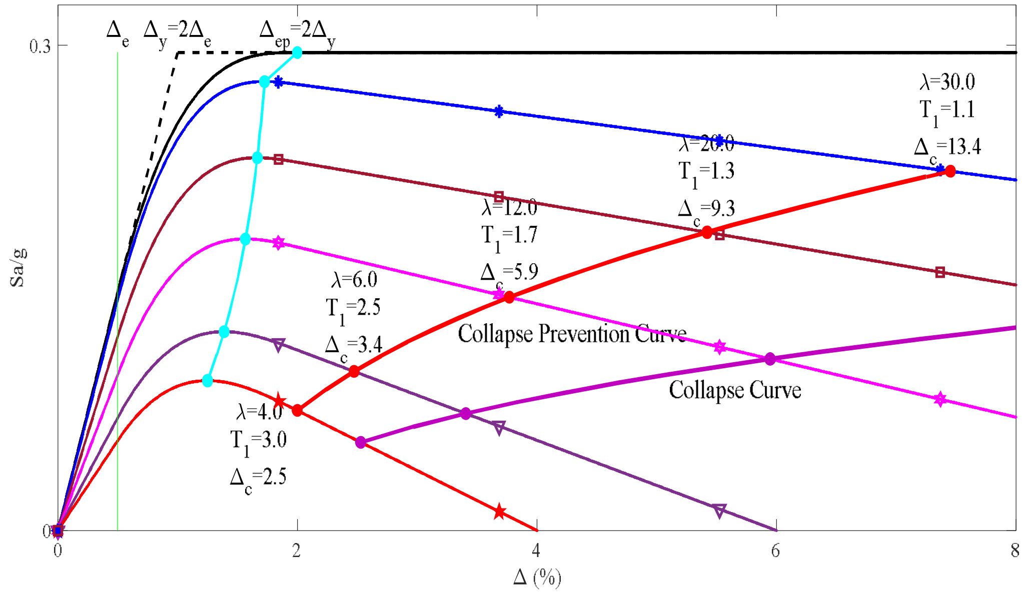

Figure 1. Pushover results for a typical 4 story frame structures.

In the paper, several relationships are presented to relate the structural flexibility and stability to its permissible lateral deformation at different performance levels. Such relationships are important in optimal design of soft mass subsystems subjected to earthquake actions.

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