CEE 227 -- Earthquake Resistant Design

We will not see how higher modes effect nonlinear response later in the course, but as we saw in earlier assignments, the archetype structure responds primarily in its first mode. For the moment, it will suffice to consider only the first mode in the following problems.

It is also worth noting in passing that the structure's dynamic characteristics being used here are still trial values based on member sizes resulting from the 2005 ASCE-7 design, and will thus change when we revise the design of the structure to reflect the new design spectra and criteria we are using. Thus, the overall design process is iterative and, consequently, a high degree of accuracy is not required at this stage. Nonetheless, these modal values provide a good starting point to assess the feasibility of our structure, and to conduct preliminary proportioning. In practice, the whole process will be repeated with new modal values (periods and mode shapes based on new member sizes) and revised masses until we converge upon an acceptable design satisfying all of our performance criteria.

Problem 13 - Estimation of Inelastic Design Forces/Displacements

For this problem, assume the archetype structure responds only in its first mode (a single degree of freedom system), and to have a period, mass, modal and other characteristics considered previously.

a. Considering the 50% in 30-year earthquake hazard spectrum developed in Problem 11 for 3% viscous damping, determine:
   i. The story shears should we consider to design the structure for our continued occupancy requirements? Assume the structure remains elastic.
   ii. What are the expected floor displacements and inter-story drifts (expressed in inches (or cm) as well as in the form of an interstory drift index obtained by dividing the interstory displacement by the corresponding story height)?

b. Here we will look at some of our results in part a.
   i. How do your estimates of drift (in part a (ii)) for the 50% in 30-year hazard compare to a typical upper bound value for protection of partitions, such as 0.0025 times the story height? This drift is indicative of displacements that would start to cause damage to displacement sensitive nonstructural elements.
   ii. If you want to reduce your computed drifts by 10%, qualitatively suggest what would you do to the structure (e.g., change mass, stiffness, damping, etc. and roughly by how much)?

iii. What would you want to do to your elastic system conceptually, if you needed to reduce the accelerations in the structure by 10%?

> *Note:* We are not looking for a precise quantitative answer here, but an observation on what would be the most effective aspect of the structural system to change. For example, see how to interpret a Newmark-Hall or other spectrum in Section 6 in the class notes to achieve your desired results. This approach is quite useful, but if you use more complicated spectral shapes (like Borzorgnia and Campbell) this is not so easy, but can be done using Matlab or a piece of graph paper.

Problem 14

The structure must simultaneously satisfy our design criteria for collapse prevention. Thus, we will now consider the elastic spectrum from Problem 9 targeted for the 2% in 50-year (MCE) hazard level ground motion and the soil conditions at the site.

Consider a basic case where a maximum displacement ductility of 6 is to be targeted. This is a large ductility value, but we are targeting collapse prevention as our design criteria for this rare event. Other conditions (e.g., soil, periods, and so on) are the same as specified in the earlier assignments. However, in Prob. 11e, you identified the maximum permitted value of R such that the structure can satisfy the continued occupancy performance criteria. Since we want to achieve this criteria, the maximum value of target ductility should be larger than the smaller of (i) 6 or (ii) the ductility value corresponding to R_{max} computed in Problem 11(e).

> *Note:* If we were to use the 10% in 50-year event, we would most likely use smaller allowable design ductility, such as 3 or 4, depending on the materials, details, and performance criteria adopted. You need not develop a spectrum for this case.

a. Use Newmark and Hall's method for modifying the elastic response spectrum you generated in Problem 9 to account for inelastic action. ***Important:*** Show both the force and displacement spectrum.

b. For the estimated period of the structure, what are the pseudo-spectral acceleration and spectral displacement corresponding to the first mode?

c. Use these values in exactly the same manner as in Problem 13 (part a) above to estimate the story level shears, the maximum floor level lateral displacements, and the interstory drifts. Note, by using use the spectral pseudo-accelerations corresponding to your target ductility, you will obtain the force acting on the structure when you would like it to yield. The displacement of the structure corresponding to the yield force is the yield displacement. Thus, the maximum displacement of the structure is the yield displacement times the target ductility factor.

d. Repeat part b, and estimate the spectral pseudo-accelerations and displacements at the fundamental period of the structure using:
   i. Use the method suggested by Miranda (this is representative of statistically derived methods)
   ii. Use the method suggested by Riddel, Hildalgo and Cruz (this is representative of simplified methods).
   iii. Use Newmark and Hall's method (this was done above in part b, but you need to include it here to do part iv below!).
   iv. Comment on the similarities and differences between R and γ values obtained using these different procedures. Comment on the advantages and disadvantages associated with using the different procedures.

e. Comment on how your answer to Part "c" would change if you use one of the other methods (such as Miranda's method) instead of Newmark and Hall's method. Just outline the steps in the process, or draw and discuss a simple sketch. You need not do any calculations!

f. Comment on how your computed interstory drifts in Part "c" compare to a value of 4% interstory drift. This value is viewed as an upper bound for the interstory drift capacity of prequalified welded steel moment connections before significant connection fracture occurs. If you exceed this drift value, you will have to reduce the lateral displacements. We will discuss optimal methods of doing this later. The result will generally be a stiffer structure, with a different (lower) natural period (and this will change our computed lateral forces and displacements). Thus, we have an iterative process here.

Problem 15

Here we are going to use the computer program and the model you used previously to compute the periods and mode shapes of the structure. For this problem, prepare a table in which you enter the maximum moment and shear in any (a) beam at each floor, and the maximum moment and shear at each story in the (b) interior columns and (c) exterior columns. We do not need moment or shear diagrams, because we will make the beams at a floor equal in size. Similarly, the interior columns at a story will likewise be equal, as would be the two exterior columns.

a. Considering gravity loads, compute the moments and shears in all members, as well as axial load in columns. Consider the LFRD load combination 1.2D+1.6L

b. Consider the spectrum in Problem 13 for the 50% in 30-year event, and compute the critical moments, shears and axial loads in the frame members. For continued occupancy the elements should remain elastic (i.e., just yield) for the moments, shears and axial loads associated with the LFRD load combinations:

   1.2D+L+E