University of California at Berkeley
Civil and Environmental Engineering

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Spring Semester 2009

CEE 227 -- Earthquake Resistant Design

Homework Assignments
(Target due date Feb. 12, 2009)

Problem 3 - Preliminary Code-based Estimate of Seismic Design Forces

You are now to get a quick idea of the level of design forces for which the building would be designed according to the equivalent lateral force procedure of ASCE 7-05, a current model building code. A copy of Chapter 11 and 12 of ASCE 7-05 related to seismic lateral load requirements is provided on the course web site.

This problem will give us a baseline against which to compare design forces obtained using other methods, and a set of values upon which to base some preliminary design calculations in subsequent problems. You are NOT expected to become an expert on these provisions.

a. Determine Seismic Base Shear for Design

The design Seismic Base Shear is computed using the equation 12.8-1 shown below:

$$V = C_s W$$

where W is the total effective weight of the structure (see section 12.7.2). The seismic response coefficient represents a simplified design response spectrum modified approximately to account for structural period as well as viscous and hysteretic damping by the structure. The value of C_s is given by

$$C_s = \frac{S_{D1}}{TR/I} \leq \frac{S_{DS}}{R/I} \qquad \text{(A)}$$

Where T is the approximate fundamental period given by Eq. 12.8-7 (or by Eq. 12.8-8, or alternative means), I is an importance factor taken here as unity to represent a typical building, R is a Response Modification Coefficient accounting for the viscous and inelastic energy capacity of the system and is taken here as 8, corresponding to a special steel moment resisting frame (see Table 12.2-1), and S_{D1} and S_{DS} are estimates of the spectral pseudo-acceleration values at structural periods of 1 sec and 0.2 seconds, respectively. Section 12.8.1.3 permits low-rise structures having a period less than 0.5 seconds to be designed with S_{DS} equal to 1.5.

The values of spectral pseudo-acceleration at 0.2s and 1.0s for a Maximum Considered Earthquake (MCE) having a 2% probability of exceedence in 50 years can be determined for Site Class B (Rock) from Figures 22-3 and 22-4, respectively. If you have difficulty reading the figures the values of S_S and S_1 are approximately, 2.06g and 0.82g, respectively. These values need to be adjusted to the design level (in California corresponding to about a 10% probability of exceedence in 50 years) by multiplying by 2/3, and adjusting for soil type. We will consider firm soil, or Site Class D. Thus, we need to find F_a from Table 11.4-1, and F_v from Table 11.4-2.

Thus, the values of S_{D1} and S_{DS} for use in equation A above are obtained from:

$$S_{DS} = \frac{2}{3} F_a S_S$$

$$S_{D1} = \frac{2}{3} F_v S_1$$

A previous analysis of the building owned by the company in Los Angeles has a period of 1.0 sec., based on an elastic dynamic analysis. As such, it provides a possible reasonable estimate of the fundamental period of the structure.

Determine the design seismic base shear for the structure considering a period given by:

i. Equation 12.8-7,
ii. Equation 12.8-8

This base shear may be further modified for systems with low redundancy. We will assume that the system is sufficiently redundant so that the value computed above can be used. The load factor, used for LRFD for seismic design is unity.

b. Determine floor level design forces and story shears

For this part of the problem use the base shear given by a(i) above, since it gives the lowest base shear for design. The forces applied on each floor **x** are given by F_x from Equations 12.8-11 and 12.8-12, which if combined give:

$$F_x = V \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

where w_x is the weight of floor level **x**, h_x is the elevation above the base of floor level **x**. The parameter k may be taken as 1 for T less than 0.5s, and as 2 for T greater than 2.5s. For our period, that is between these two extremes, you need to interpolate linearly the value of k.

The story level shears at level **x** can be determined from equilibrium as:

$$V_x = \sum_{i=x}^{n} F_i$$

The area under the shear diagram above the floor level in question may be used to determine floor level overturning moments.

c. Summary plots of results

Plot the story level forces, story shears and floor level overturning moments that will be used for design according to ASCE 7-05.

Do your results depend on which direction of the building you consider the loads are acting (transversely or longitudinally)?

Problem 4. Elastic Modal Analysis to Extract Periods and Mode Shapes

> For the following problem, you need to download and install a computer program such as Matlab, SAP, OpenSees Navigator, FEDEASlab, CSI Perform and so on. SAP is available on the department server.

ASCE 7-05 permits one to use a computed period for the fundamental mode in determining the base shear. However, the design base shear may not be less than that obtained by using a period equal to C_u (from Table 12.8-1) times the period from Equation 12.8-7. Generally, this gives a longer period, and thus a lower design force. Consequently, there is a tangible benefit for doing a dynamic analysis to determine periods and mode shapes.

If we consider the longitudinal direction of the building, there are two identical five-bay, moment-resisting frames located on the perimeter of the building. If we ignore torsion of the building about a vertical axis and assume the floor diaphragms are rigid in plane, we need only construct a 2D planar model of one frame, and consider half of the total inertial mass of structure applied to each frame. We will assume that the remainder of the framing in the building is pinned connected, and thus will ignore this gravity only framing at this point when evaluating the structures dynamic characteristics. Since we are only interested for this problem in transverse modes of vibration, you may disregard vertical loads and the vertical (or rotational) inertial effects. You need not include the penthouse in your numerical model.

a. Using a computer program of your choice, model one of the moment-resisting frames designed for Los Angeles, and determine its (three) elastic periods of vibration and mode shapes.
b. How does the your computed period for the first mode compare with those predicted by the two empirical equations in ASCE 7-05? How does the shape of the first mode you compute look compared to that implicitly assumed in the ASCE 7-05 code ($\mathbf{x}^k/(H)^k$ where H is the elevation of the roof)?
c. How do your answers to part ‘a’ change if the bases of the columns are pin connected to the foundations rather than being fixed? Fixed bases are expensive so this is a design alternative.
d. Using the lower of the computed fundamental period for the fixed base model, or C_u times the period estimated from Equation 12.8-7, what is the revised base shear you should design the building for. What is the ratio of the base shears computed using the dynamic analysis and using Equation 12.8-7.
e. If we use a dynamic analysis method to compute the base shear, will the design base shear be the same in the longitudinal and transverse directions?