McGill University
Department of Civil Engineering and Applied Mechanics
CIVE 603 – Structural Dynamics

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Homework #4 (Total Points 100/100)
Group Assignment: max. 2 students
Due Date, March 22nd 2018 by 4:00pm

Note: In addition to hard-copy submission, please submit your MATLAB codes and soft-copy of your assignment through mycourses.

Problem 1 (20 points)
Determine by the central difference method the deformation response $u(t)$ of an elasto-perfectly-plastic damped SDF system with T_n=0.5sec, ζ=5% and $\bar{f}_y = 0.125$ to the Canoga Park record that was recorded during the Northridge 1994 earthquake in urban California. This record was distributed in class as part of HW#3. Compute the following:

1. Deformation response $u(t)$ for $0<t<25$sec.
2. Force-deformation relation.
3. Compute the displacement-based ductility demand μ based on the response of the SDF system subjected to the Canoga Park record.

Problem 2 (10 points)
The lateral force-deformation relation of an SDF system is idealized as elastic-perfectly plastic. In the linear elastic range of vibration this SDF system has the following properties: lateral stiffness k=2.112 kips/in., and ζ=2%. The yield strength f_y=5.55kips and the lumped weight w = 5200lb. Determine the following:

1. Determine the natural period and damping ratio of this system vibrating at amplitudes smaller than u_y.
2. Can these properties be defined for motions at larger amplitudes? Explain your answer.
3. Determine $\bar{f}_y$ and R_y for this system subjected to the El Centro ground motion scaled up by a factor of 3.

Problem 3 (30 points)
Based on the program that you developed in Problem 1 that computes the inelastic response of elastoplastic SDF systems, compute the constant ductility absolute acceleration response spectra for the Canoga Park record for ζ=5% and for the following ductility levels, μ: 1, 1.5, 2, 4, 8.

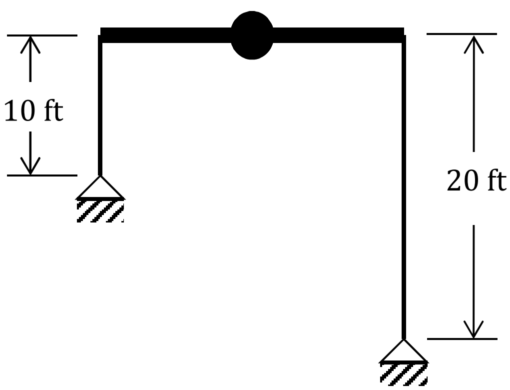
Problem 4 (15 points)

A small one-story reinforced concrete frame with a shear beam is assumed massless and supports a total load of 10 kips at the beam level. Each square column (section width and depth = 10 inch) is hinged at the base and has modulus of elasticity E = $3x10^3$ ksi (kips/in^2). Assume that the inherent damping ratio of the structure is 5%.

a) Determine the peak elastic response of this structure to ground motion characterized by the given design spectrum scaled to 0.25g peak ground acceleration. The response quantities of interest are the displacements at the top of the frame and the maximum bending moments in the short and long columns.

The structural engineer wants to reduce seismic-induced forces in the structure by utilizing following two alternative solutions:

b) By adding supplemental damping devices to the elastic SDF system. To this end, linear viscous dampers are added to the structure. The lateral supplemental damping coefficient provided by all supplemental damping devices is c_{sup} = 0.1 kip-sec/in. Determine the lateral deformation of the elastic structure equipped with supplemental damping devices.
c) By designing the SDF system inelastic such that it cannot exceed a displacement ductility demand, μ=4. Determine the lateral deformation and lateral force for which the SDF system should be designed.



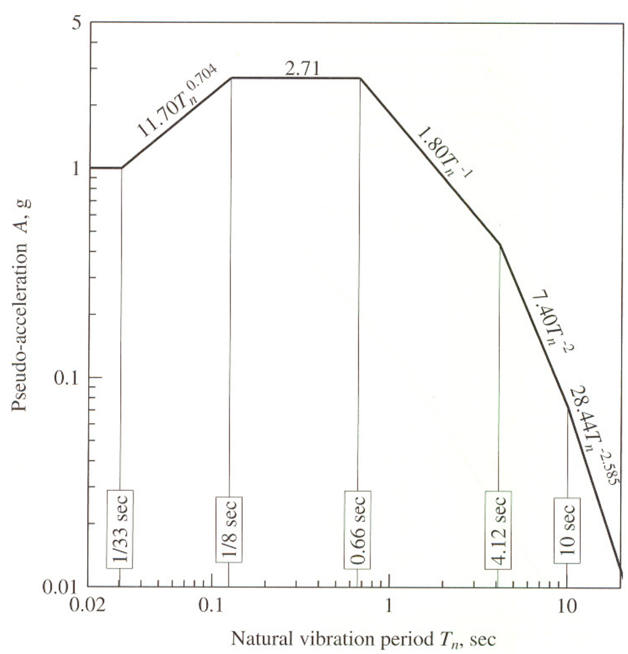


Figure 1a) RC frame b) 5% damped spectrum

Problem 5 (25 points)

A structural engineer is about to design a single story structure with weight W=200kips and height h=144-in., for earthquake loading. The engineer has to respect both safety and economy as part of the seismic design. The design options are as follows:

- T_n=0.5sec, reduction factor, R_y=2
- T_n=0.5sec, reduction factor, R_y=4
- T_n=1.0sec, reduction factor, R_y=2
- T_n=1.0sec, reduction factor, R_y=4

The record of interest is 'LomaPrieta.th', which was recorded during the Loma Prieta earthquake in California in 1989. The ground accelerations are in g and the time step of the recording is dt = 0.005 sec.

Part A
By utilizing the program that you developed, compute the response of the corresponding linear SDF systems with periods T_n=0.5sec and T_n=1.0sec. Report the maximum displacement and force demands, u_o, f_o, respectively, per case.

Part B
Assume that the effect of gravity on the SDF response is ignored and the hysteretic response of the various SDF systems is elastoplastic. By utilizing the program that you developed,

- Compute the displacement history and force-displacement relations of the four SDF systems for ζ=5%.
- Determine which of the four options should the structural engineer select and why? Your response should include concepts that we discussed during class with emphasis on displacement ductility demands and what does that mean in terms of structural damage.

Part C
Assume that the effect of gravity on the SDF response is now considered. This can be done through the stability coefficient, θ that we discussed in class. To this end, the hysteresis rule for elasto-plastic system should be modified to account for gravity effects. By utilizing the program that you developed,

- Compute the displacement history and force-displacement relations of the four SDF systems for ζ=5%.
- Determine which of the four options should the structural engineer select and why?

Hint: For PART C, the solution for displacement response history and force-displacement relation are shown below, for T_n=0.5sec, R_y=4. The solution was obtained by utilizing Newmark method with an analysis time step dt=0.0025 sec. Try to replicate the given solution by utilizing the program that you developed with central difference method and obtain the solution for remaining cases.

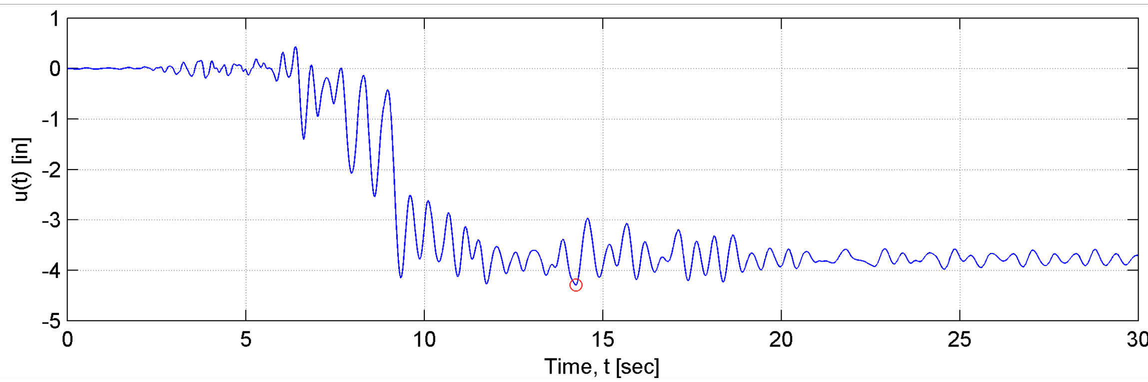


Figure 2a Response history, PART C, T_n = 0.5sec, R_y=4, ζ=5%.

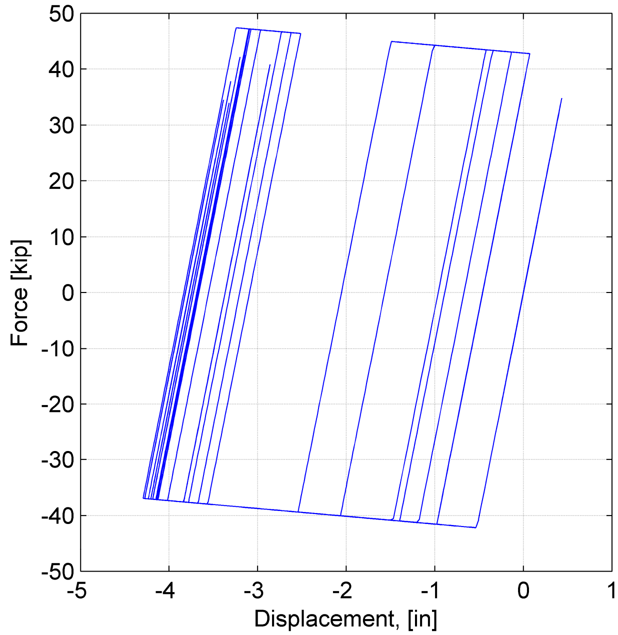


Figure 2b Force-displacement, PART C, T_n = 0.5sec, R_y=4, ζ=5%.