Assignment 4: Problem Statement

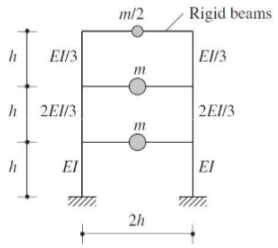
28 February 2022 10:24

CE 629A: Earthquake Analysis and Design of Structures
Assignment #4: Response History Analysis of Multistory Buildings
Due Monday, March 7, 2022

Problem 1

The three-story shear frame shown in Fig. 1 is excited in the horizontal direction by the El Centro ground motion that you used earlier. The properties of the frame are noted in the figure.

(a) Determine the natural vibration frequencies and mode shapes.
(b) Determine the modal expansion of the effective earthquake forces.
(c) Determine the effective modal masses and modal heights. Summarize them in a figure.
(d) Determine the SDF system responses $D_n(t)$ and $A_n(t)$ using any time-stepping method of your choice with an appropriate value of Δt; plot $D_n(t)$ and $A_n(t)$.
(e) For each natural mode, calculate as a function of time the following response quantities: (i) the roof displacement, (ii) the 3rd-story shear, (iii) the base shear, and (iii) the base overturning moment. Combine the modal contributions to each of the response quantities to obtain the total response; determine the peak value of the total responses. For each of the response quantities, plot the modal responses and total response in one figure and identify the peak responses in the same figure.



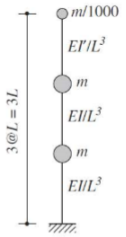
$m = 45$ tonne
$h = 4$ m
$E = 200$ GPa
$I = 5.8 \times 10^{-4}$ m^4
$\zeta_n = 5\%$ for all modes

Fig. 1: Problem 1

Problem 2

Fig. 2 shows a cantilever tower with three lumped masses. Note that the top mass and its supporting element are an appendage to the main tower. The properties of the system are noted in the figure. The system is subject to the same El Centro ground motion.

(a) Determine the natural vibration periods and modes; sketch the modes.
(b) Expand the effective earthquake forces into their modal components and show this expansion graphically.
(c) Compute the modal static responses for three quantities: (i) the displacement of the appendage mass, (ii) the shear force at the base of the appendage, and (iii) the shear force at the base of the tower.
(d) What can you predict about the relative values of modal contributions to each of the response quantity from the results of parts (a) and (c)?
(e) Determine the SDF system responses $D_n(t)$ and $A_n(t)$ using a numerical time-stepping method of your choice with an appropriate Δt.
(f) For each vibration mode calculate and plot as a function of time the three response quantities mentioned in Part (c). Determine the peak value of each modal response.
(g) Calculate and plot as a function of time the total values of the three response quantities; determine the peak values of the total responses.
(h) Compute the seismic coefficients (defined as the peak shear force normalized by the weight) for the appendage and the tower. Why is the seismic coefficient for the appendage much larger than for the tower?



$m = 85$ tonne
$EI = 2.8 \times 10^5$ kN-m^2
$EI' = 31.7$ kN-m^2
$L = 3$ m
$\zeta_n = 5\%$ for all modes

Fig. 2: Problem 2

Problem 3:

Read Section 13.3 of Chopra and solve the problem below.

Fig. 3 shows a one-story, unsymmetric-plan system. The system is excited by ground motion $\ddot{u}_{gy}(t)$ in the y-direction.

(a) Formulate the equations of motion; determine the natural frequencies and mode shapes.

(b) Expand the effective earthquake forces in terms of their modal components and show this expansion graphically.

(c) Verify that $\sum_{n=1}^{2N} M_n^* = \sum_{j=1}^{N} m_j$ and $\sum_{n=1}^{2N} l_{On}^* = 0$, where N is the number of floors, M_n^* base shear effective nth mode modal mass, and l_{on}^* is the nth mode modal static base torque.

(d) Determine the displacement u_y and rotation u_θ of the slab in terms of $D_n(t)$.

(e) Determine the base shear and base torque in terms of $A_n(t)$.

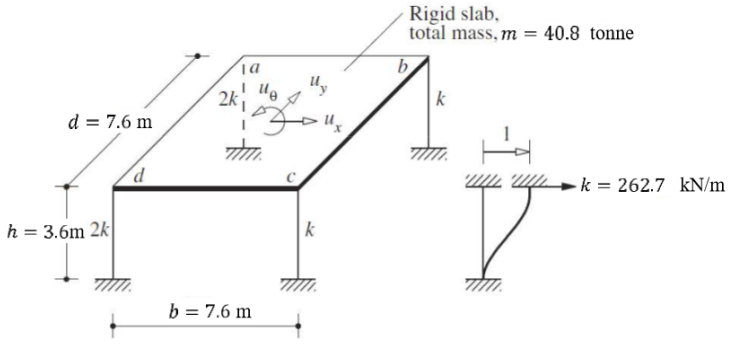


Fig. 3: Problem 3