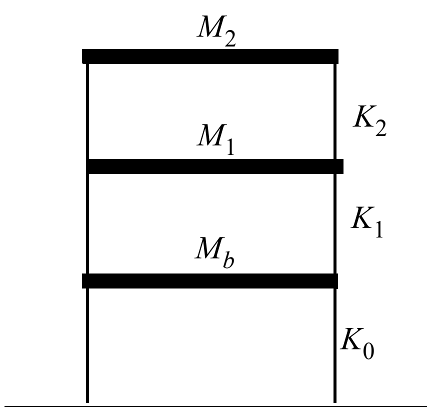
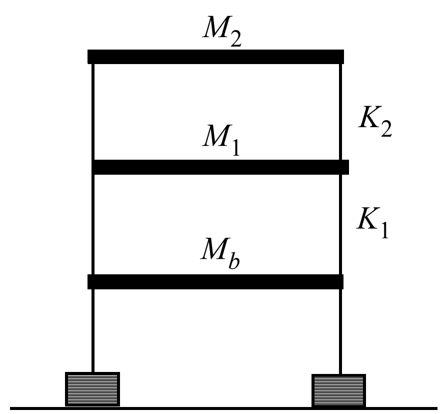
CEE 247 EARTHQUAKE HAZARD MITIGATION
Final Project

A three-story shear-type RC building is to be retrofitted with isolation devices at its first story. The un-retrofitted building can be idealized into a three-degree freedom linear system, whose mass and stiffness properties are shown in Figure below. The structural damping is approximated with Rayleigh damping, whose parameters are determined based on 2% modal damping for the first two modes. The footprint of the building is about 18m by 18m and the total height of the building is 12m with 4m story height. *Use SI units for all your calculations and results*.



Fixed-Base Structure



Isolated Structure

$M_1 = M_2 = M_b = 325000kg$ $K_1 = K_2 = K_0 = 300MN/m$

1. The design earthquake motions include 7 ground motions (listed in Table 1 below) recorded in past earthquakes in California. Their data files as well as plot files are posted on Bruin Learn. Construct 5% damping response spectrum (relative displacement and total acceleration) for each individual earthquake and the averaged response spectrum based on all 7 earthquakes. Use the response spectrum as the guidance to choose the target isolation period of the base-isolated building. When isolation is used, the base story is replaced with the isolation devices whose behavior is nonlinear.

2. Formulate the equation of motion for the fixed-base building using the relative displacements to ground as unknowns (i.e., u_{s0}, u_{s1} and u_{s2} represents the relative displacement of base story, first story and the second story to the ground respectively). Obtain the natural

periods and natural modes of the fixed-base building. Construct a linear time history analysis program in MATLAB for the fixed-base building using the built in ODE solver. Verify the solutions of your program by comparing to results obtained by the modal analysis or Newmark method. Compute the inter-story drifts, floor total accelerations and base shears under the design earthquake motions.

Table 1. Earthquake records selected for design and simulation

Record Station	**Earthquake**	**Magnitude** M_w	**Distance to Fault (km)**	**Peak Acceleration (g)**	**Peak Velocity (m/s)**
Pacoima Dam	1971 San Fernando	6.6	8.5	1.17	1.14
El Centro Array #5	1979 Imperial Valley	6.4	30.4	0.38	0.99
El Centro Array #7	1979 Imperial Valley	6.4	29.4	0.46	1.13
Lucerne Valley	1992 Landers	7.3	42.0	0.71	1.36
Rinaldi	1994 Northridge	6.7	9.9	0.89	1.75
Sylmar	1994 Northridge	6.7	12.3	0.73	1.22
Newhall	1994 Northridge	6.7	20.2	0.59	0.96

3. Conduct a sample bearing design for the building based on the target isolation period and the design displacement from Part 1. You need to provide the number of bearings needed, type of bearing, dimensions of bearing and nonlinear mechanical properties of the bearing for numerical analysis along with all applicable model parameters.

4. Formulate the equations of motion for the base-isolated building using the relative displacements to ground as unknowns (i.e., u_{s1} and u_{s2} represents the relative displacement of the first story and the second story to the ground respectively while u_b represents the relative displacement in isolator to ground). Construct a nonlinear time history analysis program in MATLAB for base-isolated building where Bouc-Wen model is used to model the nonlinear behavior of isolation devices. Use your program to compute the inter-story drifts, floor total accelerations and the base shears of the building above the isolation layer and compare with the fixed-base building case. Compute the displacement and shear in the isolation unit.

5. In order to achieve the optimum design, the design objective is to minimize a force quantity, which is a function of both the peak top floor absolute acceleration and bearing displacement as defined by $f(\ddot{U}_2, u_b) = Q + 2K_p|u_b| + M_2|\ddot{U}_2|$, where Q is the characteristic strength of the isolator, K_p is the post-yielding stiffness of the isolator and $\ddot{U}_2$ is the total

acceleration at the second floor. Adjust the mechanical properties of the bearing and conduct the nonlinear time history analysis to improve your building performance. Report the best design you can come up with including their mechanical properties and the associated force functions based on computed response quantities under each earthquake.

6. Prepare a written report and submit it before 11:59PM on June 14, 2022. The main body of the report should be written like a technical paper, including abstract, problem statement, approach, representative results and summary or conclusion. Appendices may be used to provide supporting data, hand calculations and MATLAB programs developed. The final grade will be based on: 1) accuracy and completeness of the work (65%); 2) efficiency of the design (i.e. how good is your design compared with others) (15%); and 3) presentation and organization of the material (20%). Submit all your MATLAB code and Excel sheet (if applicable) in a single zip file on Bruin Learn along with your report.