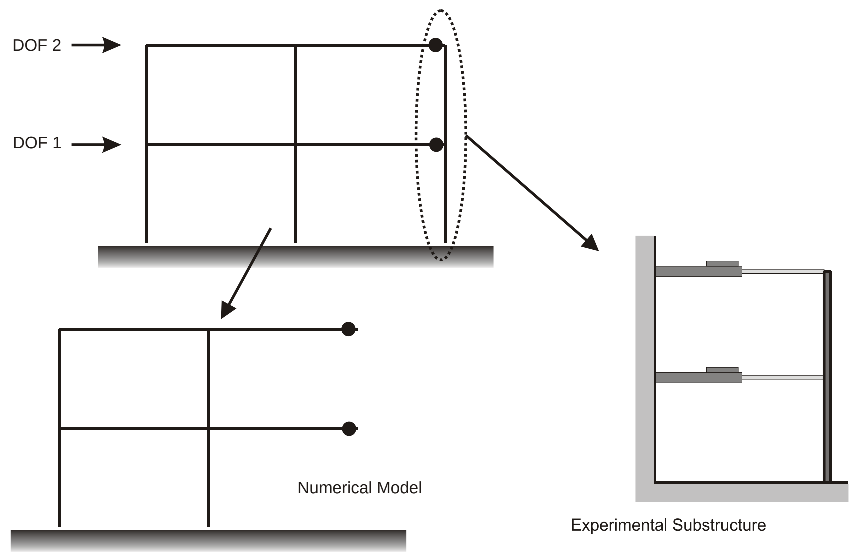
HOMEWORK PROBLEM #6
Substructure Pseudo-Dynamic Hybrid Simulation

Problem Statement:

Develop a structural model and test plan for a two-story two-bay structure for hybrid simulation and perform pretest analyses. The following figure shows a shear building with two degrees of freedom (rigid floors).



The experimental substructure available in SEESL has two degrees of freedom with the following stiffness and mass matrices:

$$\mathbf{K} = \begin{bmatrix} 27.7 & -8.5 \\ -8.5 & 3.9 \end{bmatrix} \text{kips/in} \qquad \mathbf{M} = \begin{bmatrix} 50 & 0 \\ 0 & 25 \end{bmatrix} \frac{\text{lb}}{\text{g}}$$

Mass and Stiffness matrices for numerical model should be selected to result in the desired natural periods of the test structure, which are recommended to be 0.6 or more for the first mode.

Actuators have a ±3-in stroke and a ±5-kip force capacity, and are able to perform acceptably up to a velocity of 20 in/s. The stiffness matrix may be adjusted by manipulating the number of coupons in the experimental setup. The yield displacement of each story is about 0.2 in.

Required Analysis:

A preliminary numerical simulation of the entire structure is necessary to ensure about the levels of force and displacement demands for the experimental setup. For this purpose, a linear simulation of the entire system will probably be sufficient.

The experimental substructure can be thought of as column, whose precise (nonlinear) behavior is to be determined through hybrid simulation. That is, the hybrid simulation will be nonlinear, and larger deformations will be expected.

Required Information for Hybrid Simulation:

After preliminary analyses, the following information should be provided to conduct a hybrid simulation:

Number of degrees of freedom,
Number of experimental degrees of freedom,
Numerical stiffness matrix,
Numerical mass matrix,
Inherent damping ratio of the numerical substructure,
Numerical damping matrix (for damping devices, if any),
Influence vector,
Transformation matrix for displacement from global coordinate system to
Command displacement factor
Measured force factor
Earthquake record and its scale factor

Note: The above scale factors for displacement and force are provided to achieve different hysteretic characteristics from the same experimental setup. Remember that scaling will equally scale the errors and measurement noises.

Information Format:

The attached MATLAB m-file illustrates a suitable format for the above-mentioned information. This file is generated for the 4-story structure presented in class, with degrees of freedom numbered from bottom to top. Only the first three sections contain information about the experimental substructure and should be provided.

Required:

(This homework will be performed jointly by all students in class)
Develop the information for the pseudo-dynamic test, perform the test with the assistance of Mr. Mehdi Ahmadizadeh, and prepare a report of the testing and its results.

Testing: December 1, 2008
Report Due; December 8, 2008

```
% ***General Information****
NDOF=4;                              % number of degrees of freedom
NACT=2;                              % number of actuators involved in the simulation
NPAR=2;                              % number of important parameters for formation of stiffness matrix

% ***NUMERICAL MODEL****
k1 = 5.543*2;                        % DOF 1    STORY 1 (two pairs of coupons)
k2 = 3.89;                           % DOF 2    STORY 2
l1=43;
l2=46;
l=l1+l2;

% ***NUMERICAL MODEL DATA***
MT = [7 0 0 0; 0 5 0 0; 0 0 3 0; 0 0 0 1]*1.25/g;     % Total mass matrix
ME=[0 0 0 0; 0 0.05 0 0; 0 0 0.025 0; 0 0 0 0]/g;      % Experimental Mass Matrix
K = [30 -12 0 0; -12 20 -8 0; 0 -8 12 -4; 0 0 -4 4];   % Global analytical stiffness
KEP = [k1*l1^2 0; 0 k2*l2^2];                          % Parameteric experimental stiffness in intrinsic coord. system
C=zeros(NDOF,NDOF);                                    % Analytical damping matrix
dr=0.05;                                                       % Damping ratio forstifness proportional damping
L=-MT*ones(NDOF,1);                                    % Influence vector for base motion

% COORDINATE SYSTEM TRANSFORMATIONS *****
TDGA=[-1 1 0 0; -1 0 1 0];           % Displacement from global to actuator cs ****
FDGA=1;                              % Displacement scale factor from global to actuator coordinates
FFAG=1;                              % Force scale factor from actuator to global coordinates
TDAP=[1/l1 0; -l/l1/l2 1/l2];        % Actuator displacements to parameter cs ***

% Simulated experimental model properties
Parameters.K1 = k1;                  % one column
Parameters.K2 = k2;                  % one column
Parameters.Uy = 0.20;
Parameters.Ep = 0.00;
Parameters.Ga = 0.45;
Parameters.Be = 0.55;
Parameters.N = 1.5;
massA=0.025;                         % Actuator weight (kips)
eyd=[Parameters.Uy; Parameters.Uy*3];  % experimental substructure yield displacement
```