Problem 4 – Elastic Modal Analysis

Part A: Mode Shapes and Periods

Notes: Using effective seismic mass and moment frame members as specified in the "Introduction to the class building". The seismic mass does not include live loads. In this problem, we're analyzing only one 5 bay frame, so we need to apply half the effective seismic mass of the building to the frame. For these solutions, I have distributed the mass at each floor evenly over the nodes. (It would also make sense to distribute forces based on tributary area.)

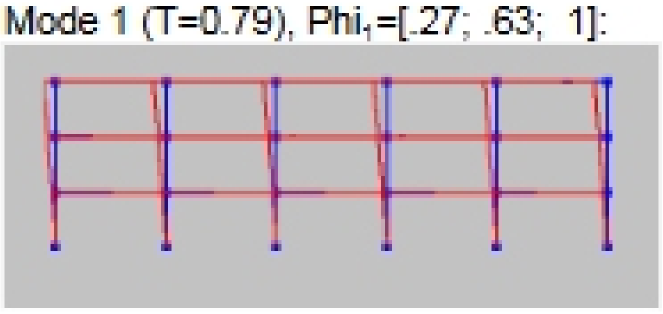
To avoid a third mode based on axial beam deflection, give the beams additional area (multiply by 10 or so). This will limit the analysis to modes in which the beams stay axially rigid and the columns move together, which is what we want for future modal analysis.

These solutions are based on a FEDEASLAB analysis.

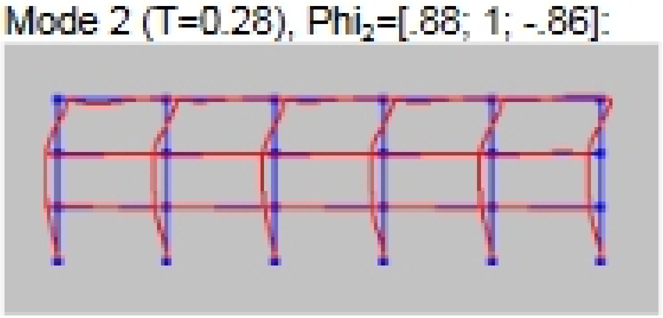
Analysis gives the following periods and mode shapes:

T_1=0.79
T_2=0.28
T_3=0.15

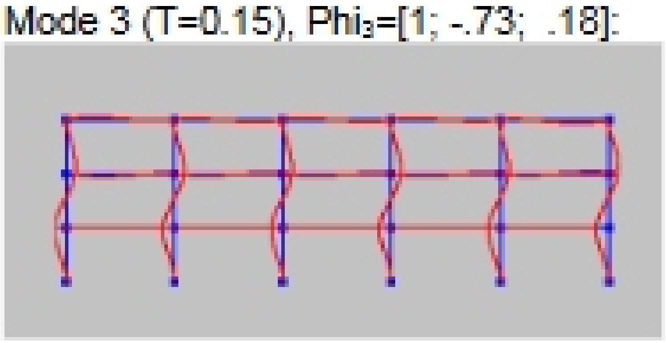
Mode 1 (T=0.79), Phi_1=[.27; .63; 1]:



Mode 2 (T=0.28), Phi_2=[.88; 1; -.86]:



Mode 3 (T=0.15), Phi_3=[1; -.73; .18]:



Part B: Period Comparison

The fundamental period predicted from analysis (T=0.79) is significantly longer than the code-based period (T=0.59). In this case, the code-based design was conservative in terms of forces (which is good!), and we can reduce our design forces by using a dynamic analysis. However, since the actual period is longer than the code-predicted period, the code with underestimate drifts. In a displacement based approach, the code will not tend to be conservative.

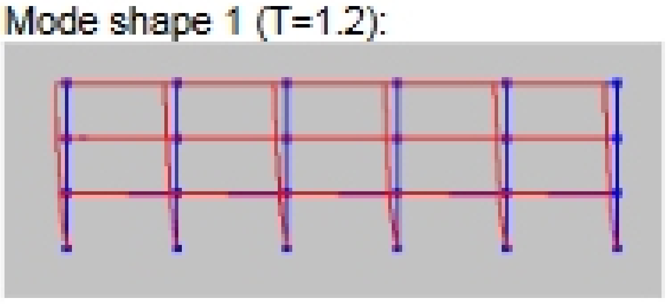
The mode shapes look quite similar. Both the code forces and the analysis fundamental mode are roughly linear, corresponding to a triangular equivalent force distribution.

Part C: Pinned columns

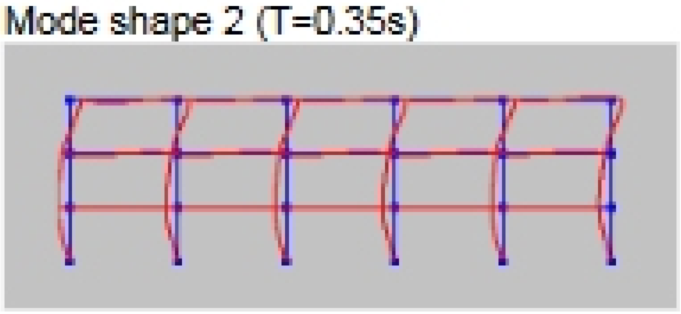
Analysis of the frame with pinned columns gives:

T_1=1.2s
T_2=0.35s
T_3=0.17s

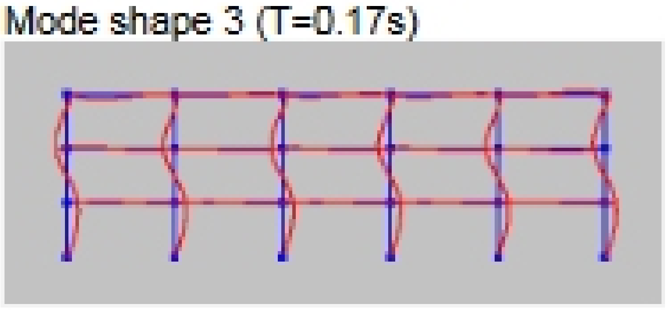
Mode shape 1 (T=1.2):



Mode shape 2 (T=0.35s)



Mode shape 3 (T=0.17s)



Allowing the column bases to rotate significantly lengthens the modes, particularly the first mode (by over 50%). It also changes the first mode shape to a less triangular and slightly more rectangular shape. Upper story displacements are reduced relative to lower story displacements. This concentrates displacements in the first story, which could lead to a soft story collapse mechanism.

Part D: Recalculate Base Shear

From Table 12.8-1, Cu is 1.4. Therefore, the upper limit on the period we can use is 1.4*0.59s=0.83s.

Since we calculated T=0.79s (lower than 0.83s), we can use our calculated value.

Therefore,

$Cs=S_{D1}/(TR/I)<=S_{DS}/(R/I)$
$Cs=.82/(.79*8)=0.13<=1.37/8=0.17$
Cs=0.13

$V=Cs*W=0.13*5876=764^K$

Base shear = 764^K

Analysis allowed us to reduce the design base shear from 1000K to 764K, or by about 24%. The ratio of base shears is 764/1000=0.764. The new base shear is 0.76*(code base shear).

Part E: Direction

Since the moment frame layout is different in the transverse and longitudinal directions, dynamic analysis will give us different design base shears in each direction. This makes sense, because base shear relates to the mode shapes, which depend on the layout and makeup of the structural system. This contrasts with the code-based approach, in which base shear is independent of direction. Our dynamic analysis will give more accurate results, which relate more directly to the structure we are studying.