Using *portal frame*, beam mid span and column mid height moments under lateral loads can be assumed zero. This approximation eliminates the need for a detailed moment distribution analysis.

Behavior of an external beam-column joint can be modeled as shown in figure 1. Since portal frame analysis is based on the assumption of zero moment at mid span of beam and mid height of column, these halves of the beam and column can be used with hinges at zero moment locations.

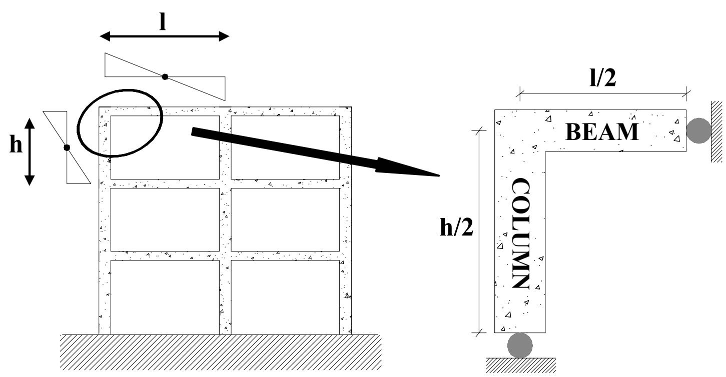


Figure 2

The purpose of this experiment is to determine of the behavior of a reinforced concrete "L" joint under simulated seismic loading. As shown in figure 2, test specimen consists of an exterior joint with fixed base. Cyclic load is applied to the tip of the beam with the jack.

If figures 1 and 2 are compared, it can be seen that experimental setup has different boundary conditions with the actual model. Modeled beam and column assumed to have hinges at the middle however column This change in the test specimen only changes the shear demand of the column. In real case (figure 1) there is a constant shear force on the column whereas in our test specimen, shear demand is equal to zero. Based on the assumption that shear strength of the column will be higher than the demand, this test setup reasonably reflects the behavior of a portal frame under seismic loading.

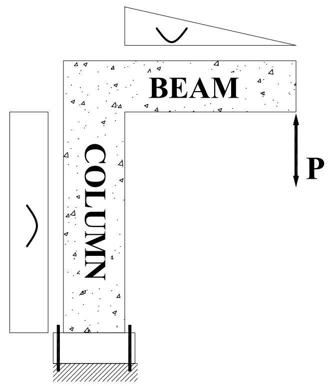


Figure 2

Joint Geometry & Boundary Conditions:

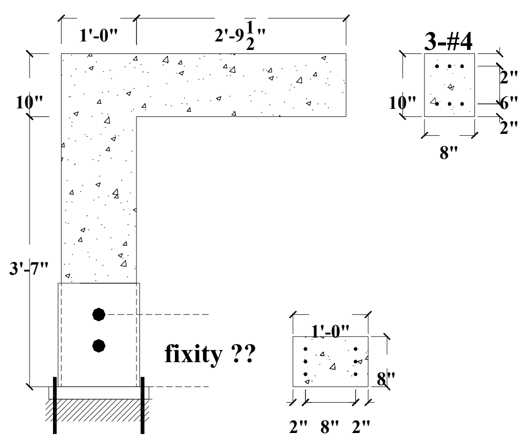
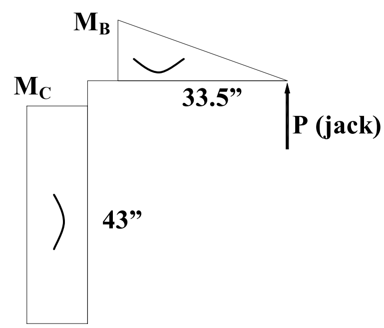


Figure 3



Centerline Dimensions

$$6"\cdot V_B + M_B - M_C = 0 \;\Rightarrow\; \qquad M_C = M_B + 6"\cdot V_B$$

Beam/Column Capacities:

Deflections:

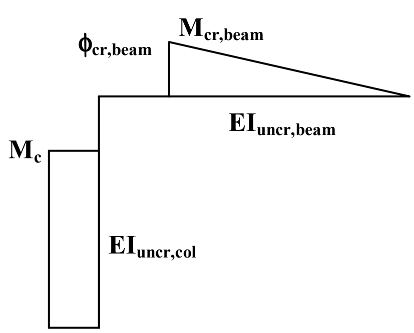
(a) Establish sequence of cracking, yielding, and ultimate in beam and column

a. Cracking in beam

Moment area method is used to calculate tip deflection of the beam. It should be noted that force applied to the beam causes rotation on the column as well as the beam. So tip deflection is affected by the rotations at both face of the joint: column and beam.

In order to calculate tip deflection:

- Plot moment diagram of the system.
- Calculate uncracked moment of inertia ($I_{uncracked} = I_g$) of both beam and column.
- Determine the curvatures ($\phi = M/EI$) at joint faces.
- Calculate the deflection by using the equation given below. Here first term represents the deflection caused by column rotation. Second term is the tip beam deflection with respect to a fixed end.



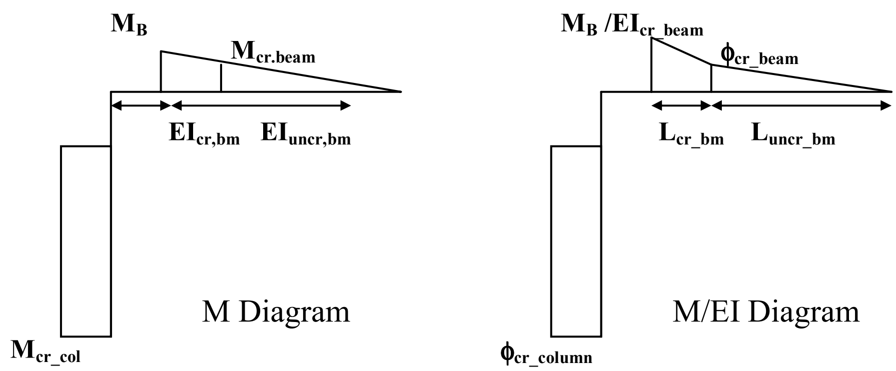
$$M_{cr\_beam} = \frac{f_r \cdot I_{g\_beam}}{c_{beam}}$$

$$\phi_{cr\_beam} = \frac{f_r}{E_c \cdot c_{beam}}$$

$$\delta_{crack\_beam} = \left[\left(\frac{M_{col}}{EI_{col}}\right) \cdot L_{col}\right] \cdot \left(L_{beam} + 6''\right) + \left[\left(\phi_{cr\_beam}\right) \cdot L_{beam} \cdot \frac{1}{2}\right] \cdot \frac{2}{3} \cdot L_{beam}$$

b. Cracking in Column

This step is basically the same as first one. Only difference is the cracked beam section. Since $M_{cr\_col} > M_{cr\_beam}$ when column reaches cracking moment, some part of the beam is already cracked.



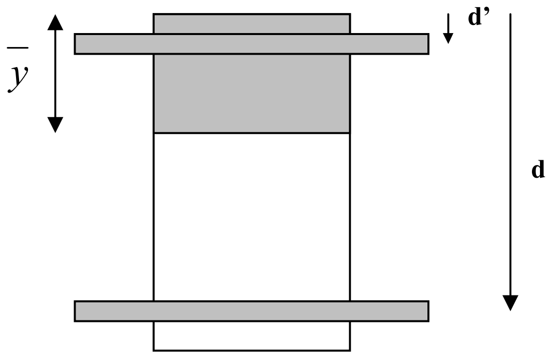
$$M_{cr\_column} = \frac{f_r \cdot I_{g\_column}}{c_{column}}$$

$$\phi_{cr\_column} = \frac{f_r}{E_c \cdot c_{column}}$$

$$\delta_{cr\_column} = \left[\phi_{cr\_column} \cdot L_{col}\right] \cdot \left(L_{beam} + 6"\right) + \left[\left(\phi_{cr\_beam}\right) \cdot L_{uncr\_bm} \cdot \frac{1}{2}\right] \cdot \frac{2}{3} \cdot L_{uncr\_bm}$$
$$+ \left(\phi_{cr\_beam}\right) \cdot L_{cr\_bm} \cdot \left(L_{uncr\_bm} + \frac{L_{cr\_bm}}{2}\right) + \left(\phi_{beam} - \phi_{cr\_beam}\right) \cdot \left(L_{uncr\_bm} + \frac{2 \cdot L_{cr\_bm}}{3}\right)$$

Beam Yielding:

Column curvature when beam yields can be calculated by dividing moment on column face by $E_c I_{cr}$. Moment of inertia for cracked cross section can be calculated using method of transformed sections as given below:



Section	y_i	A_i	$y_i \cdot A_i$
1	$\bar{y}/2$	$b \cdot \bar{y}$	$b \cdot \bar{y}^2/2$
2	d'	$A_S' \cdot (n-1)$	$A_S' \cdot (n-1) \cdot d'$
3	d	$A_S \cdot n$	$A_S \cdot n \cdot d$

$$\bar{y} = \frac{\sum y_i \cdot A_i}{\sum A_i}$$

$\bar{y}$ can be calculated by solving the quadratic equation.

Using $\bar{y}$, moment of inertia of the cracked cross section with respect to neutral axis is calculated as:

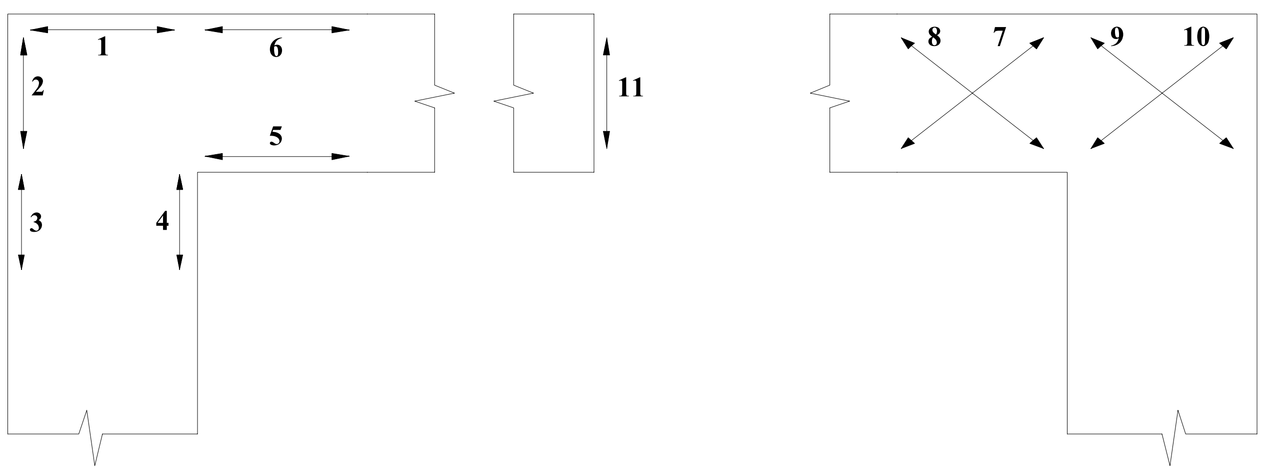
$$I_{cr} = \frac{1}{3} \cdot b \cdot \bar{y}^3 + (n-1) \cdot A_s' \cdot (\bar{y} - d')^2 + n \cdot A_s \cdot (d - \bar{y})^2$$

Instrumentation:

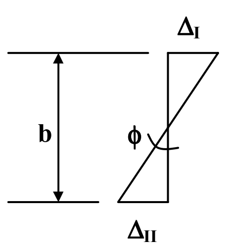
LVDT's are used to convert linear deformations to voltages which are recorded by the DAQ program during the experiment.

A load cell is used to measure the applied load and is recorded in kips by the computer.

Positions of LVDT's are given in the figure below. **It has vital importance to note down the location of each LVDT's start and end points.**



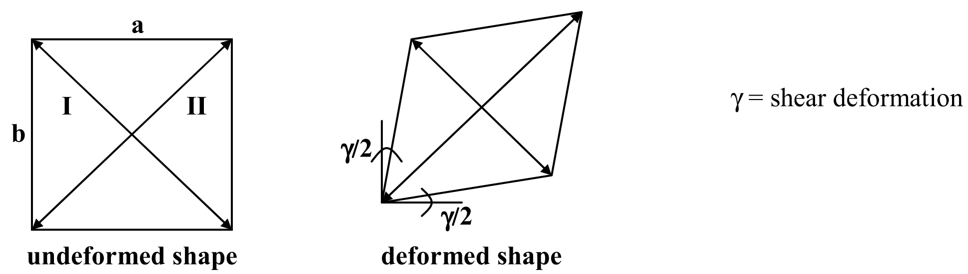
Transducer #'s 3,4,5 and 6 are used to measure curvature as follows:



Δ_I and Δ_{II} are deformations measured by two LVDT's in parallel.

Curvature is needed in order to plot Moment-Curvature curves.

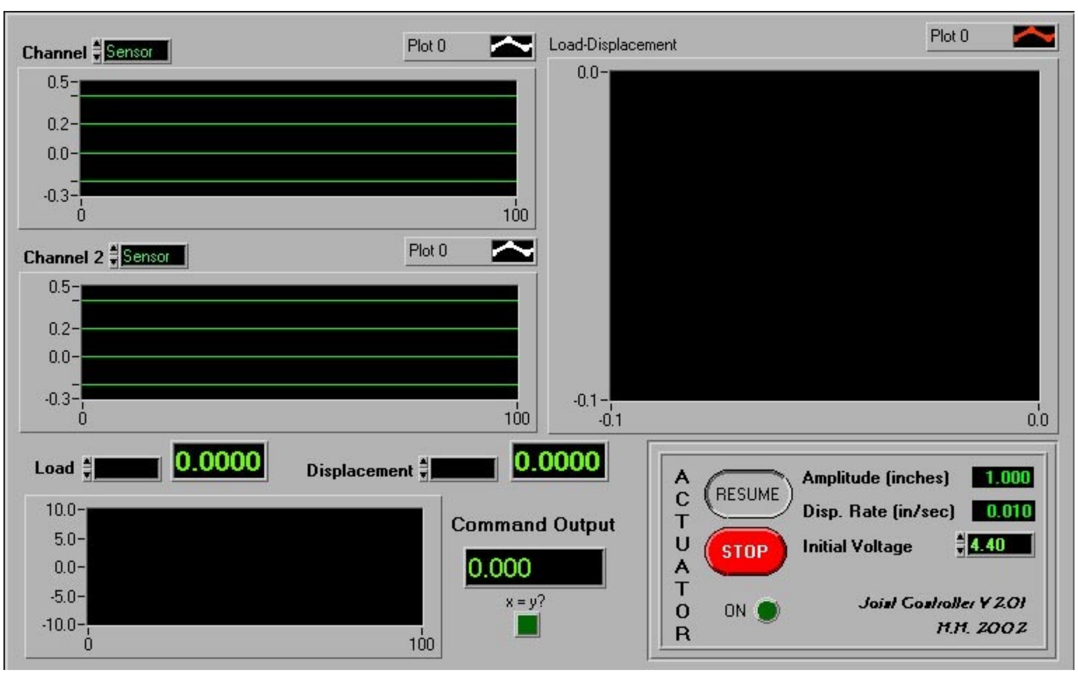
#'s 7,8,9 and 10 are used measure shear deformation.



γ is computed as $\gamma = \frac{(\Delta_I - \Delta_{II}) \cdot \sqrt{a^2 + b^2}}{2 \cdot a \cdot b}$ where Δ_I , Δ_{II} are deformations of LVDT's I and II (+) lengthening and (-) shortening.

Note in the typical shear calculations I=8 and II=7 or I=9 and II=10.

LVDT's 1 and 2 is used to measure the slip of longitudinal bars in joint region and transducer #11 is used to measure tip deflections.



Data acquisition and movement of hydraulic jack are controlled by a LABVIEW virtual instrument. Program windows is given below. Amplitude and disp. rate must be entered by the user. For smaller displacement levels ($\delta_y/4$ and $\delta_y/2$), displacement rates between 0.002-0.005 are appropriate. For δ_y , $2\delta_y$ and $4\delta_y$, displacement rate can be increased to 0.01 to 0.05. It is recommended not to use displacement rates greater than 0.05.