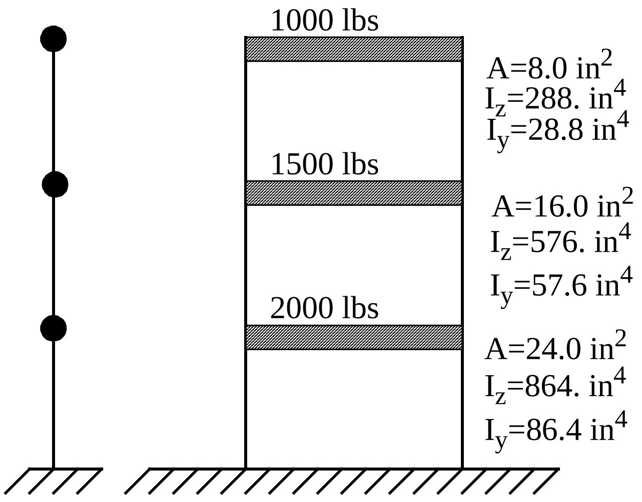
LESSON 14

Shock Analysis of a 3-Story Structure



Note: Only the I_z contributes to the stiffness of the building since the model is restrained in and out of plane.

Objectives:

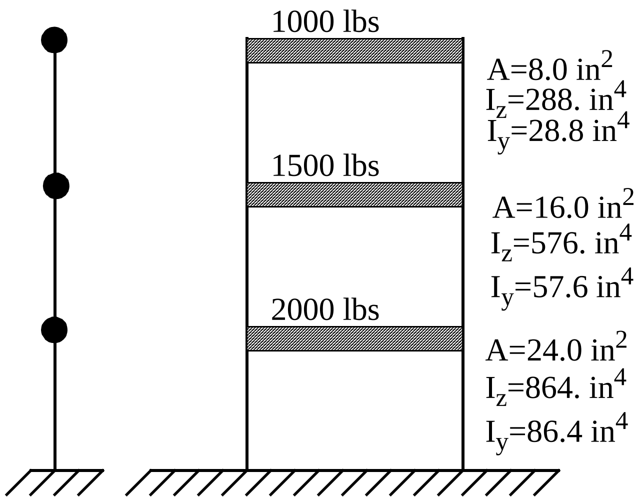
- Create a model of a 3-story building using p3.
- Set up and analyze a response spectrum analysis.
- Compare results to hand solution.

Exercise Description:

The 3-story structure shown in the figure below is idealized by modelling the floors as point masses and the stiffness of the columns combined into a single beam for each level. This simplification is valid for this case because the loading is in the x direction only, and the axial stiffness of the floors is several orders of magnitude greater than the bending stiffness of the columns.

A seismic input, expressed as applied velocities in the X direction, is applied to the model. Each floor is 10 feet high, and all have material properties of steel (see below). Mass and stiffness below are given in the figure below.

This solution is solved in two steps: modal analysis to compute eigenvalues and eigenvectors, followed by a response spectrum analysis using modal superposition method.



Note: Only the I_z contributes to the stiffness of the building since the model is restrained in and out of plane.

E = 30 E+6 lb/in^2

ν = 0.30

Story height = 10 feet = 120 inches

Velocity vs. Frequency:

Frequency	Velocity
0.731	**20.88**
1.563	**16.92**
2.320	**14.40**

Base Excitation direction <1 0 0>

Exercise Procedure:

1. Create a new database named **seismic.db.**

File/New ...

New Database Name: **seismic.db**

OK

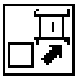
In the New Model Preference form set the *Analysis Code* to **MSC/ADVANCED_FEA.**

Analysis Code: **MSC/ADVANCED_FEA**

OK

2. Create the geometry that will represent the building.

First, turn on the entity labels using the following toolbar icon:

 **Show Labels**

◆ **Geometry**

Action: **Create**

Object: **Curve**

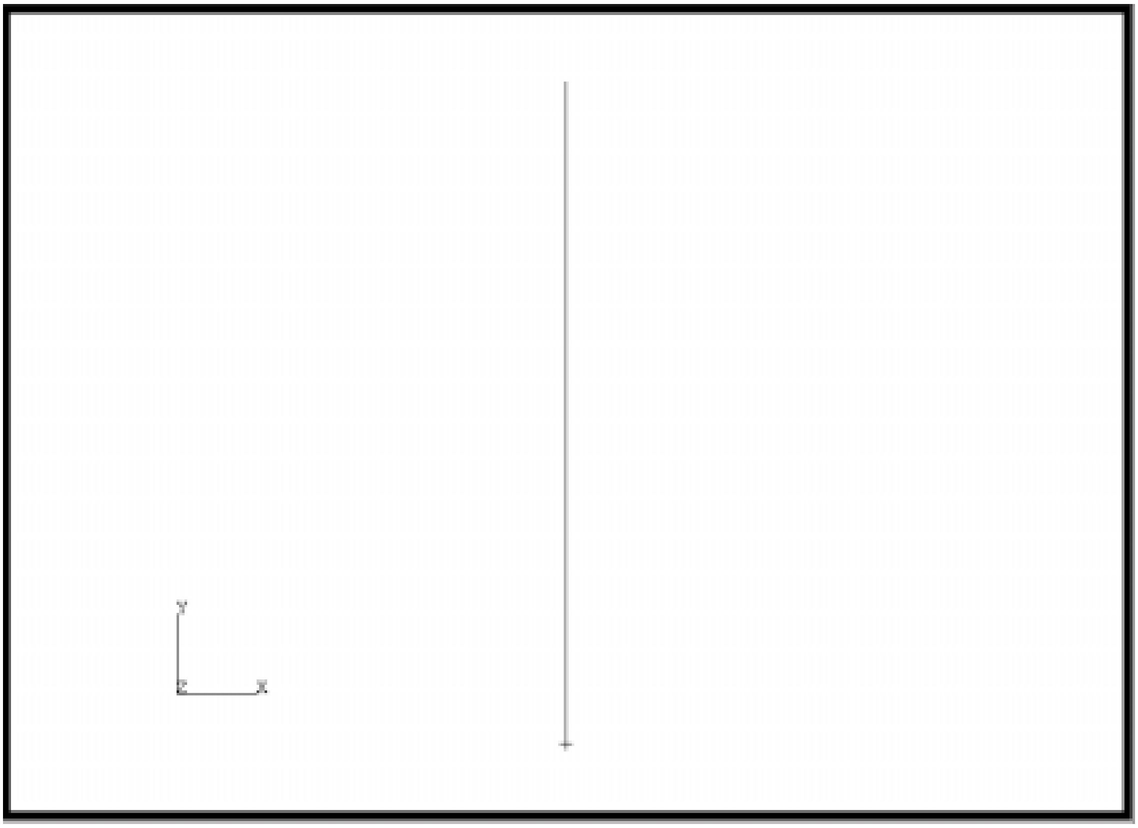
Method: **XYZ**

Vector Coordinate list: **[0, 360, 0]**

Origin Coordinate list: **[0, 0, 0]**

Apply

A line should appear in your viewport as follows:



3. Create a 3 bar mesh on this curve. Divide the total length by 3 and enter it in the Global Edge Length.

◆ **Finite Elements**

Action:	**Create**
Object:	**Mesh**
Type:	**Curve**
Global Edge Length:	**120**
Curve List:	**Curve 1**

Apply

4. Now create a point element at the three top nodes.

◆ **Finite Elements**

Action:	**Create**
Object:	**Element**

Method: **Edit**

Shape: **Point**

Topology: **Point**

Node 1: **Node 2:4**

Apply

5. Next, fix all degrees of freedom on the bottom node and all but the X translational on the other three nodes.

◆ **Loads/BCs**

Action: **Create**

Object: **Displacement**

Type: **Nodal**

New Set Name: **bar**

Input Data...

Translational <T1 T2 T3>: **< 0, 0, 0 >**

Rotational <R1 R2 R3>: **< 0, 0, 0 >**

OK

Select Application Region...

Geometry Filter: ◆ **FEM**

Select Nodes: **Node 1**

Add

OK

Apply

New Set Name: **bars**

Input Data...

Translational <T1 T2 T3>: **< , 0, 0 >**

Rotational <R1 R2 R3>: **< 0, 0, 0 >**

OK

Select Application Region...

Geometry Filter: ◆ **FEM**

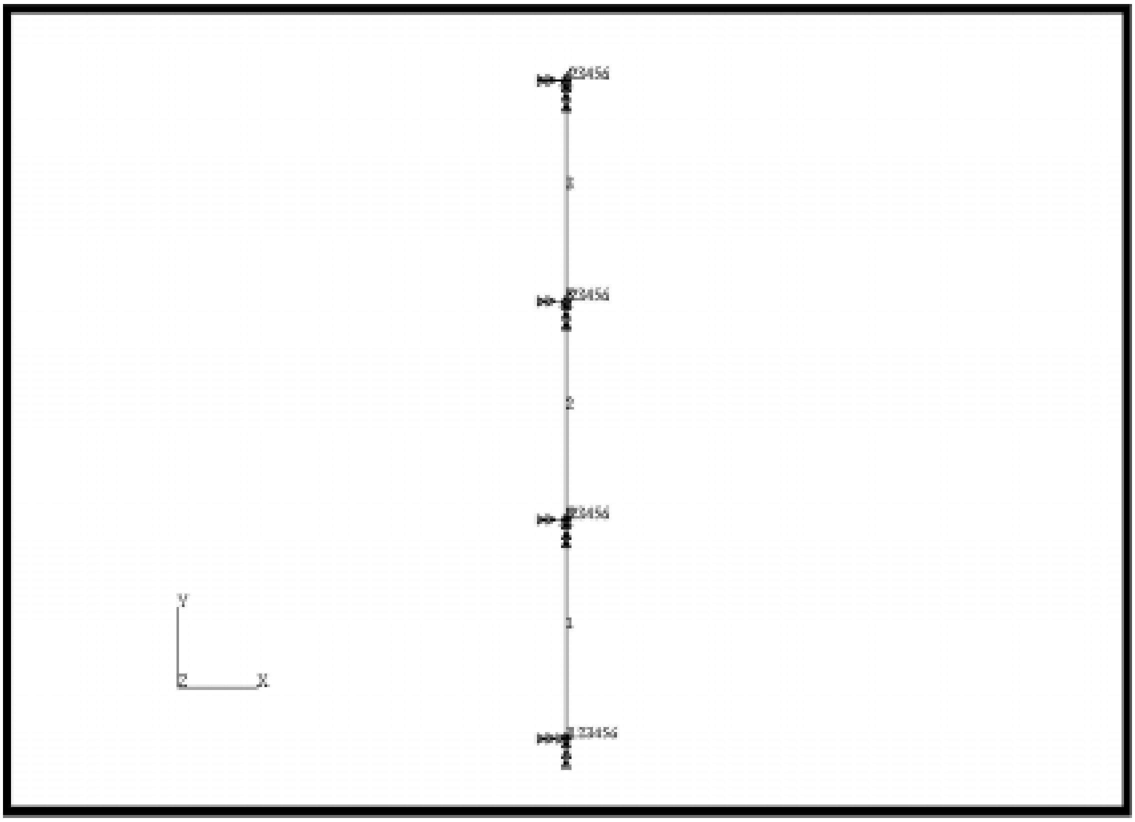
Select Nodes: **Node 2:4**

Add

OK

Apply

Your screen should look like this:



6. Create a linear elastic isotropic material with an elastic modulus of 30E6 and a poisson's ratio of .30.

◆ **Materials**

Action: **Create**

Object: **Isotropic**

Method: **Manual Input**

Material Name: **steel**

Input Properties...

Elastic Modulus: **30.0E6**

Poisson's Ratio: **0.30**

Apply

Cancel

7. Next define 3 0-D point masses and apply these to the point elements. The mass values are 1000, 1500, 2000lbs from top to bottom. To make sure you are applying the element properties to the FEM click on the corresponding box in the select menu.

Point Element

◆ **Properties**

Action: **Create**

Dimension: **0D**

Type: **Mass**

Property Set Name: **mass1**

Input Properties...

Mass Magnitude: **1000**

OK

Select Members: **Elm 6**

Add

Apply

Repeat the above steps for the table below:

Prop Name	Mass	Element
mass1	1000	Elem 6
mass2	1500	Elem 5
mass3	2000	Elem 4

8. Create 3 1-D beam in space using cubic interpolation with a general section. Use the above element properties to define the cross section for each of the elements.

◆ **Properties**

Action: **Create**

Dimension: **1D**

Type: **Beam In Space**

Property Set Name: **beam1**

Options: **General Section**

Cubic Interpolation

Input Properties...

Material Name: **steel**

X-Sectional Area; **8.0**

Area Moment I11: **288.**

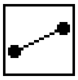
Area Moment I22: **28.8**

Torsional Constant: **28.8**

Definition of XY Plane: **< 0, 0, 1 >**

OK

Be sure to use the following entity select icon:

 **Beam Element**

Select Members: **Elm 3**

Add

Apply

Repeat the same procedure for **beam2** and **beam3.**

Property Set Name : **beam2**

Input Properties...

Material Name: **steel**

X-Sectional Area: **16.0**

Area Moment 11:	**576.**
Area Moment 22:	**57.6**
Torsional Constant:	**57.6**
Definition of XY Plane:	**< 0, 0, 1 >**
OK	
Select Members:	**Elm 2**
Add	
Apply	
Property Set Name:	**beam3**
Input Properties...	
Material Name:	**steel**
X-Sectional Area:	**24.0**
Area Moment 11:	**864.**
Area Moment 22:	**86.4**
Torsional Constant:	**86.4**
Definition of XY Plane:	**< 0, 0, 1 >**
OK	
Select Members:	**Elm 1**
Add	
Apply	

9. Create a Natural Frequency step requesting 3 modes.

◆ **Analysis**

Action:	**Analyze**
Object:	**Entire Model**
Method:	**Full Run**
Step Creation...	
Job Step Name:	**modes**

Solution Type:	**Natural Frequency**
Solution Parameters...	
Number of Modes:	**3**
OK	
Apply	
Cancel	

10. Create a Response Spectrum step with the corresponding parameters.

◆ **Analysis**

Action:	**Analyze**
Object:	**Entire Model**
Method:	**Full Run**
Step Creation...	
Job Step Name:	**response**
Solution Type:	**Response Spectrum**
Solutions Parameters...	
Excitation Components:	**Algebraic**
Response Values Sum:	**SRSS**
Spectrum Type:	**Velocity**
Modal Damping:	**None**
Define Response Spectra...	
1ST Multiplying Factor:	**1.0**
Define Spectrum...	
Frequency:	**0.731**
Magnitude:	**20.88**
OK	
2ND Multiplying Factor:	**0.0**
Define Spectrum...	
Frequency:	**1.563**

Magnitude: **16.92**

OK

3RD Multiplying Factor: **0.0**

Define Spectrum...

Frequency: **2.320**

Magnitude: **14.40**

OK

On the *Response Spectra* form click:

OK

Once more on the *Solution Parameters* form:

OK

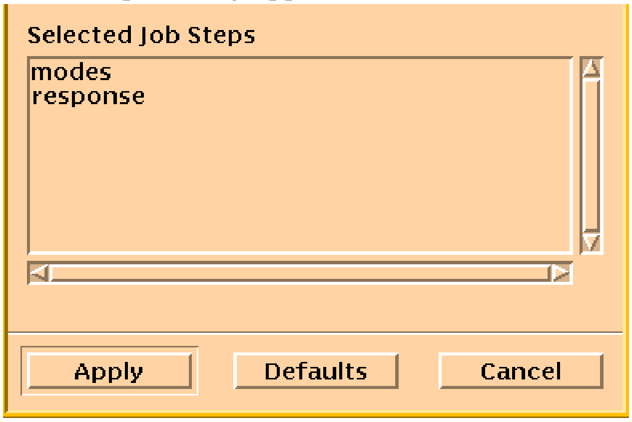
Apply

Cancel

11. Select the two steps in order (Natural Frequency then Response Spectrum) and submit the job for analysis.

Step Selection...

Select the steps so they appear in this order under **Selected Job Steps:**



Apply

Apply

12. Read in the results.

◆ **Analysis**

Action:	**Read Results**
Object:	**Result Entities**
Method:	**Translate**
Select Results File...	**seismic.fil**

Ok

Apply

13. The frequencies of the first three modes can be read from the **Results** form in the *Select Results Case* databox. To find the displacement at each floor create a marker on the viewport.

◆ **Results**

Action:	**Create**
Object:	**Marker**
Method:	**Vector**
Select Results Case:	**Default, Step2, Inc=1**
Select Vector Results:	**Deformation, Displacement**

Apply

Results Summary:

The frequencies can be compared to the analytical results given in Reference (Dynamics of Structures, Clough, Ray W., and Penzien, Joseph, McGraw Hill, 1975). Below is the solution for step 1 for the first three modes.

Table 1: Modal Frequencies

Mode	Analytic Solution	P3/AFEA	% Diff
1	**0.731**		
2	**1.563**		
3	**2.320**		

Below are the displacements for the structure due to the response spectrum analysis.

Displacement	Analytic Solution	P3/AFEA	% Diff
Ux at 1rst story	**2.040**		
Ux at 2nd story	**4.212**		
Ux at 3rd story	**6.552**		

After obtaining the answers, close the database and quit PATRAN.

This concludes this exercise.

Mode	Analytic Solution	P3/AFEA	% Diff
1	**0.731**	**.731**	**0.0**
2	**1.563**	**1.563**	**0.0**
3	**2.320**	**2.320**	**0.0**
Displacement	Analytic Solution	P3/AFEA	% Diff
Ux at 1rst story	**2.040**	**2.110**	**3.43**
Ux at 2nd story	**4.212**	**4.255**	**1.02**
Ux at 3rd story	**6.552**	**6.554**	**.03**