INTERNATIONAL INSTITUTE OF INFORMATION TECHNOLOGY

HYDERABAD

STRUCTURAL DYNAMICS

1. Perform modal analysis, time history analysis, response spectrum analysis in SAP2000.
2. Prepare a Matlab code for tripartite Plot for any ground motion.
3. Eigen Analysis-MDOF-Generalised Code in MATLAB or Python or Excel or C.

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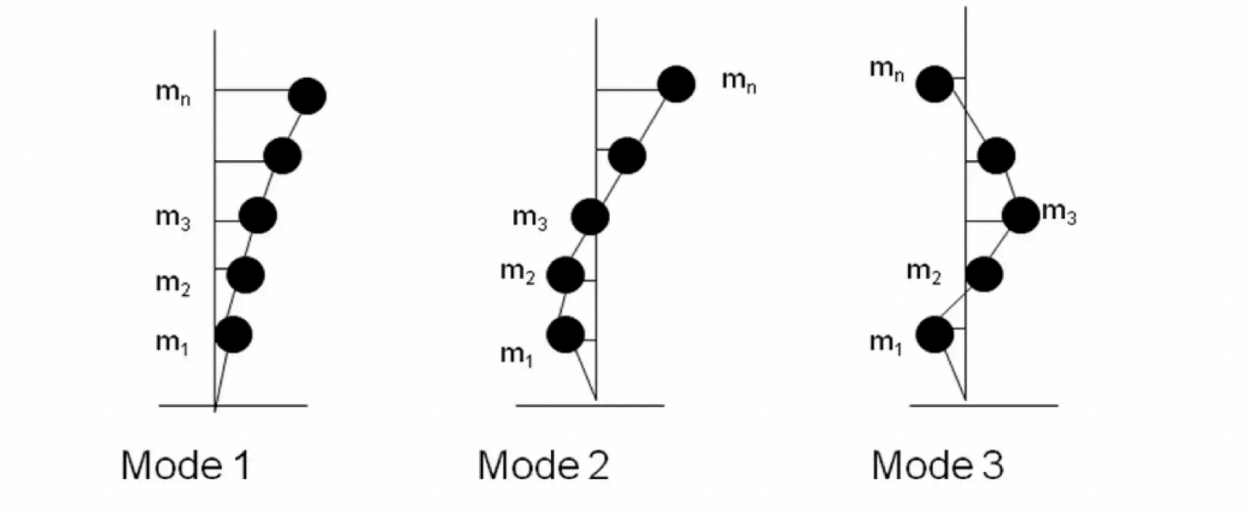
CHAPTER-1

Perform modal analysis, time history analysis, response spectrum analysis in SAP2000:

Modal Analysis:

- A modal analysis calculates the frequency modes or natural frequencies of a given system, but not necessarily its full time history response to a given input.
- The natural frequency of a system is dependent only on the stiffness of the structure and the mass which participates with the structure (including self-weight).
- It is not dependent on the load function. Modal analysis uses the overall mass and stiffness of a structure to find the various periods at which it will naturally resonate.
- These periods of vibration are very important to note in earthquake engineering, as it is imperative that a building's natural frequency does not match the frequency of expected earthquakes in the region in which the building is to be constructed.
- If a structure's natural frequency matches an earthquake's frequency, the structure may continue to resonate and experience structural damage.

MODAL AND RESPONSE SPECTRUM (IS 1893:2002) ANALYSIS 0F R.C FRAME BUILDING



Time-history analysis:

Time-history analysis provides for linear or nonlinear evaluation of dynamic structural response under loading which may vary according to the specified time function. Dynamic equilibrium equations, given by $K\,u(t) + C\,{}^{d}/_{dt}\,u(t) + M\,d^2/_{dt}\,u(t) = r(t)$, are solved using either modal or direct-integration methods. Initial conditions may be set by continuing the structural state from the end of the previous analysis.

Linear time history analysis calculates the solution to the dynamic equilibrium equation for the structural behaviour (displacement, member force etc.) at an arbitrary time using the dynamic properties of the structure and applied loading when a dynamic load is applied. The Modal superposition method and Direct method are used for linear time history analysis.Because of linear analysis characteristics, nonlinearity is not considered. When using a nonlinear material, the material is converted to an equivalent linear elastic material for analysis.

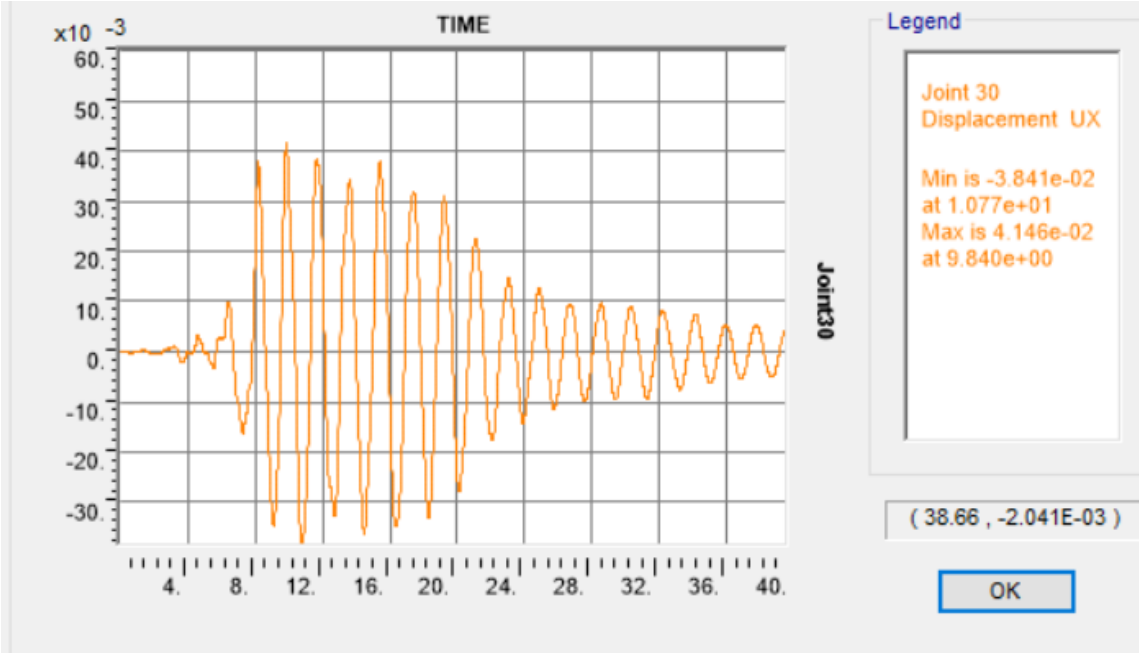
Mode superposition method:

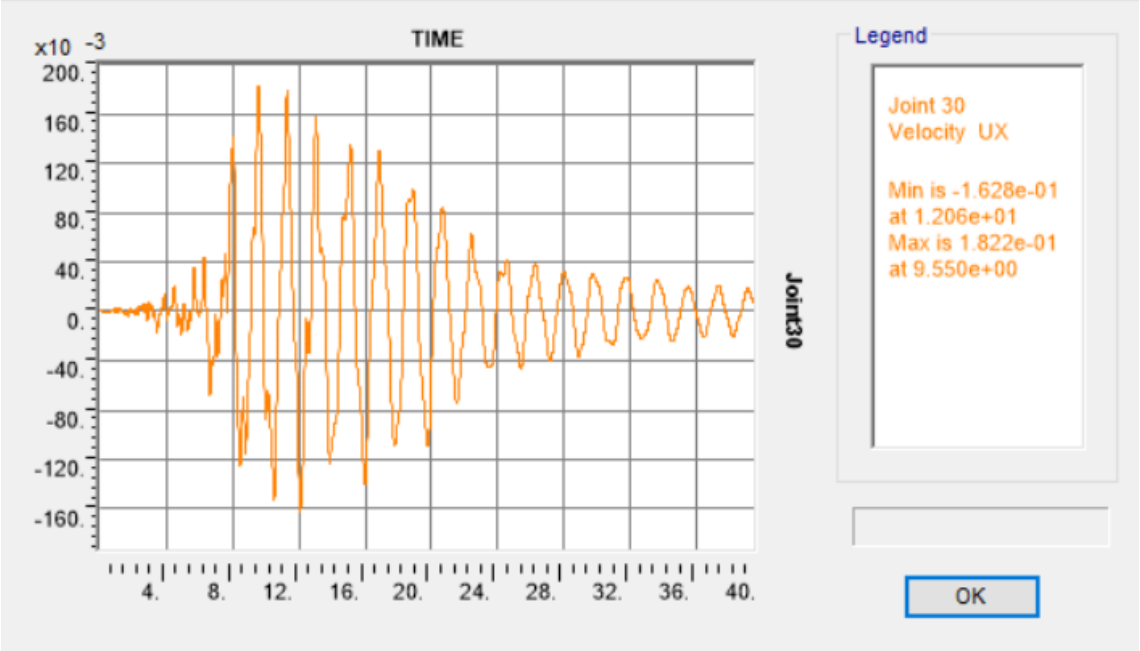
The mode superposition method assumes the structural displacement as a linear combination of orthogonal displacements. Using this, a more simplified time integral function can be used to calculate the dynamic response for a selected mode. The mode superposition method is used in many structural analysis programs and is an effective way to calculate the dynamic response for the linear dynamic analysis of large structures with little computational cost. However, the accuracy of the total response depends on the number of used natural modes and so, the number of modes used in the calculation need to be selected appropriately.

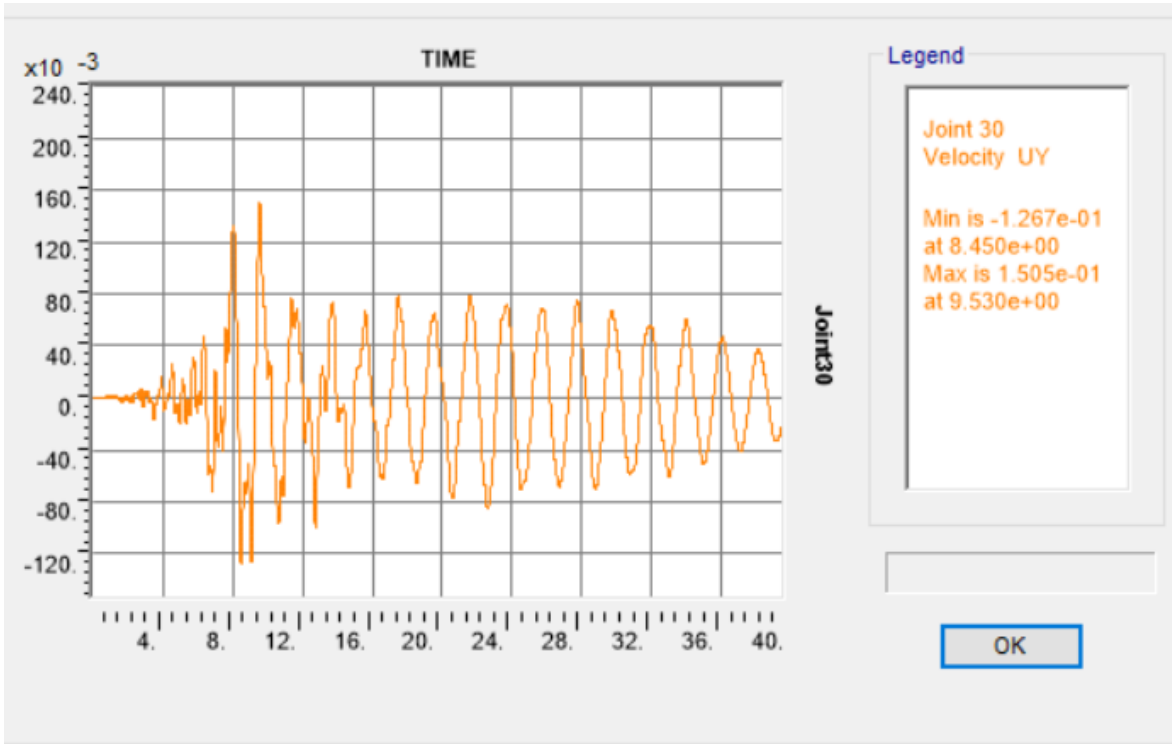
- Loading in Linear time history analysis
- Dynamic loads that change with time can be used in linear time history analysis.

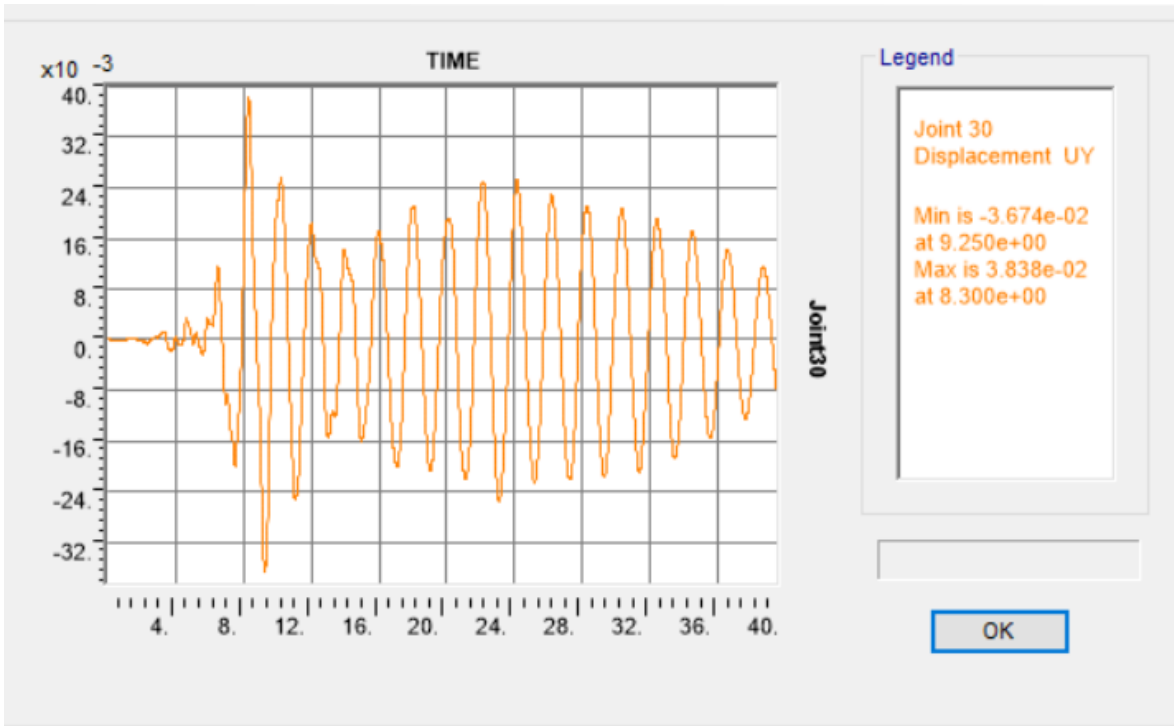
Input : North-ridge ground motion

Output : Displacement, reactions, velocity & acceleration wrt time in x-y directions of any node.






x10 -3
TIME
240.
200.
160.
120.
80.
40.
0.
-40.
-80.
-120.
4.
8.
12.
16.
20.
24.
28.
32.
36.
40.
Joint30
Legend
Joint 30
Velocity UY
Min is -1.267e-01
at 8.450e+00
Max is 1.505e-01
at 9.530e+00
OK


x10 -3
TIME
40.
32.
24.
16.
8.
0.
-8.
-16.
-24.
-32.
4.
8.
12.
16.
20.
24.
28.
32.
36.
40.
Joint30
Legend
Joint 30
Displacement UY
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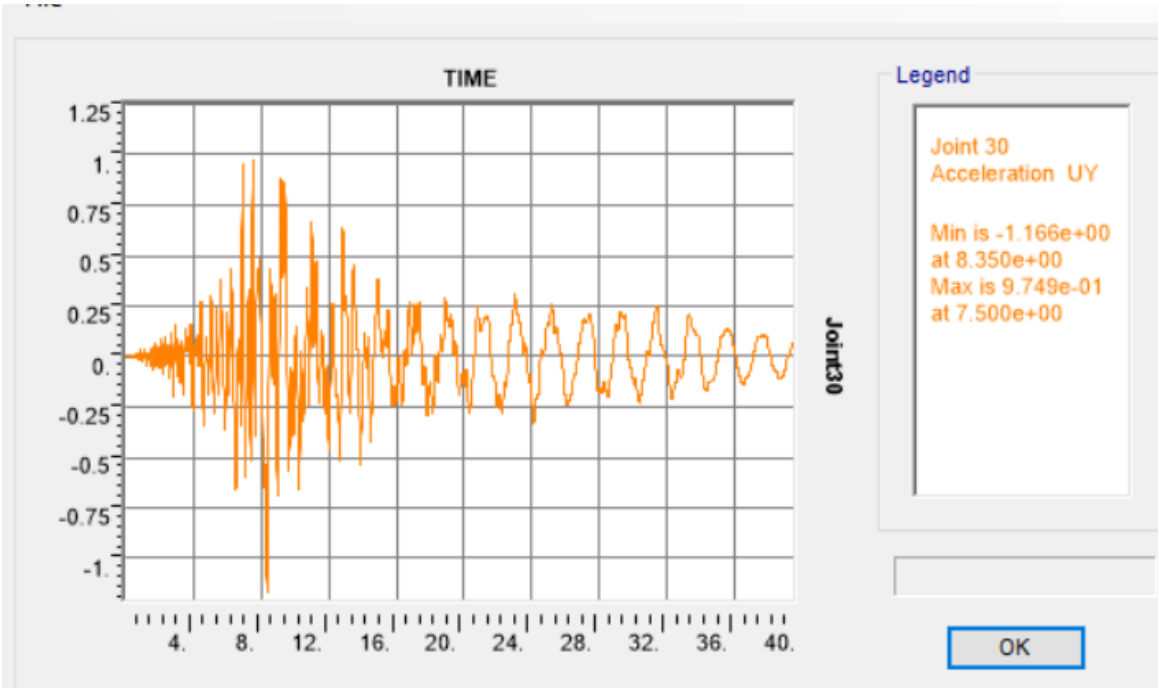
at 9.250e+00
Max is 3.838e-02
at 8.300e+00
OK


TIME
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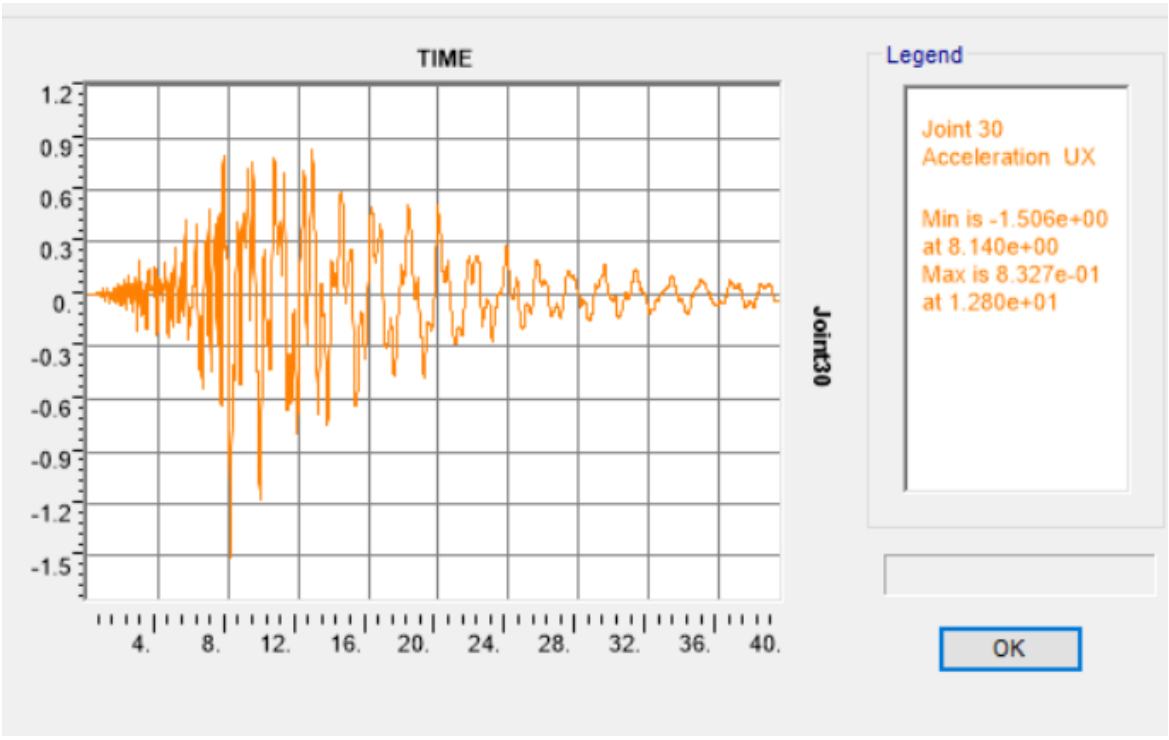
1.
0.75
0.5
0.25
0.
-0.25
-0.5
-0.75
-1.
4.
8.
12.
16.
20.
24.
28.
32.
36.
40.
Joint30
Legend
Joint 30
Acceleration UY
Min is -1.166e+00
at 8.350e+00
Max is 9.749e-01
at 7.500e+00
OK


TIME
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0.9
0.6
0.3
0.
-0.3
-0.6
-0.9
-1.2
-1.5
4.
8.
12.
16.
20.
24.
28.
32.
36.
40.
Joint30
Legend
Joint 30
Acceleration UX
Min is -1.506e+00
at 8.140e+00
Max is 8.327e-01
at 1.280e+01
OK

Conclusions:

The displacement, velocity and acceleration responses are calculated at different times using Newmark's Beta method and Central difference method and the results obtained are compared with each other by overlapping the graphs obtained.

The spectral displacement, velocity and acceleration are calculated and corresponding graphs are plotted for different time periods for both Central difference method and Newmark's Beta method and the results are compared by overlapping the graphs obtained.

The graphs for Central difference method and Newmark's beta method are almost overlapping and hence can be concluded that the results obtained by both methods are almost same.

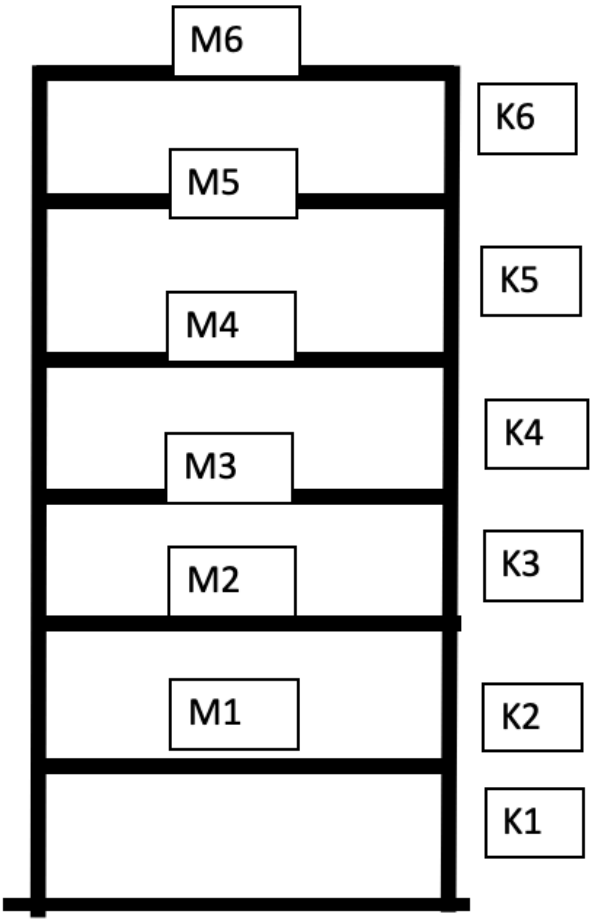
CHAPTER-2

Prepare a Matlab code for tripartite Plot for any ground motion:

RESPONSE SPECTRUM:

CHAPTER-3

Eigen Analysis-MDOF-Generalised Code in MATLAB or Python or Excel or C:



INTRODUCTION TO MATLAB

MATLAB is a proprietary multi-paradigm programming language and numeric computing environment developed by MathWorks.

MATLAB (an abbreviation of "MATrix LABoratory") is a programming platform designed specifically for engineers and scientists to analyse and design systems and products that transform our world. The heart of MATLAB is the MATLAB language, a matrix-based language allowing the most natural expression of computational mathematics.

MATLAB combines a desktop environment tuned for iterative analysis and design processes with a programming language that expresses matrix and array mathematics directly. It includes the Live Editor for creating scripts that combine code, output, and formatted text in an executable notebook.

Eigen analysis:

Eigen analysis is a mathematical operation on a square, symmetric matrix. A square matrix has the same number of rows as columns. Each eigenvalue has an eigenvector, and there are as many eigenvectors and eigenvalues as there are rows in the initial matrix. Eigenvalues are usually ranked from the greatest to the least.

Characterisation of the natural frequencies and mode shapes play a key role in the analysis and design of engineering dynamic systems.
The determination of natural frequency and mode shapes require the solution of an eigenvalue problem. Eigenvalue problems also arise in the context of the stability analysis of structures. This problem could either be a differential eigenvalue problem or a matrix eigenvalue problem, depending on whether a continuous model or a discrete model is used to describe the given vibrating system.

Steps involved in Eigen Analysis:

- **STEP-1 :** Construct Mass Matrix(M) and Stiffness Matrix(K)

$$M = [1000 \quad 1000 \quad 1000 \quad 1000 \quad 2000]$$

$$K = [40000 \quad 30000 \quad 40000 \quad 50000 \quad 10000]$$

- **STEP-2:** Let 'λ'(lambda) be a variable and let λ= ω^2 (omega). Now calculate the determinant of ([K]- λ[m])=0 to obtain a characteristic equation in terms of 'λ'. And find the roots for the variable.

$$\lambda = [1.839 \quad 10.696 \quad 45.949 \quad 91.550 \quad 144.96]$$

- **STEP-3**: Then we will calculate 'Φ' vectors for each 'λ'
  Φ = [φ1 φ2 · · · φN]

EIGEN VECTORS

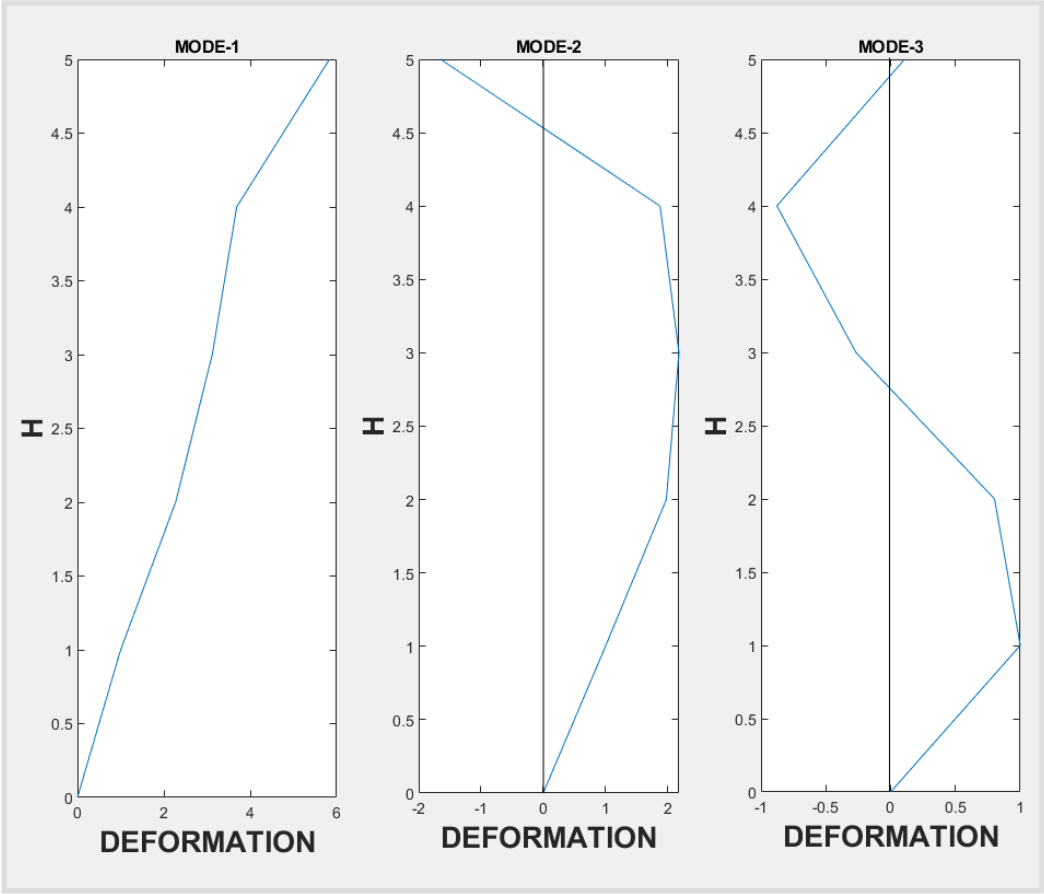
Φ1 = {1 ; 2.27 ; 3.12 ; 3.68 ; 5.83}

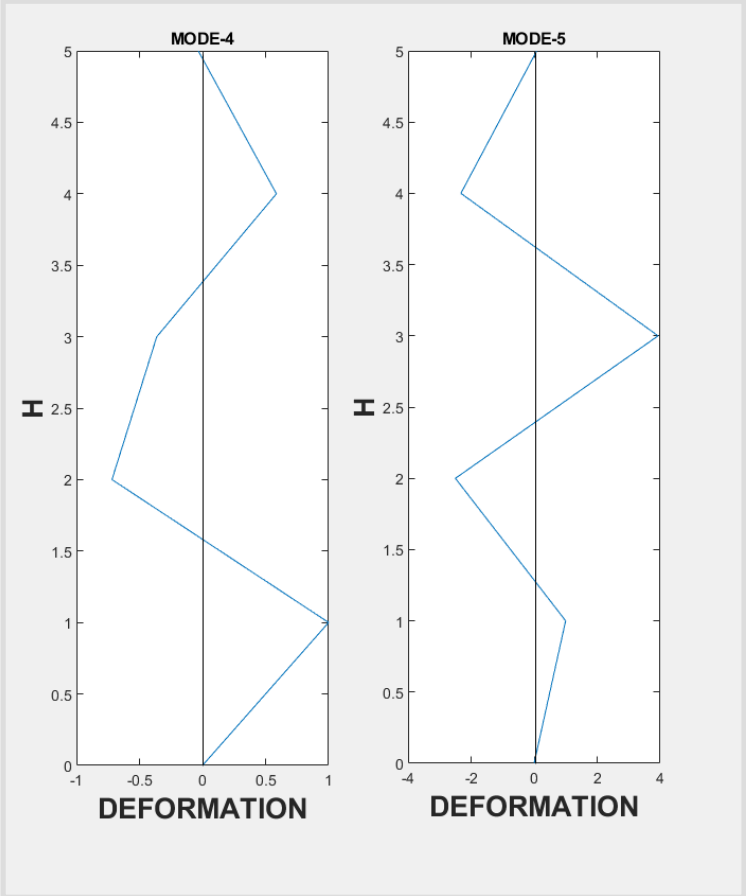
Φ2 = {1 ; 1.97 ; 2.18 ; 1.87 ; -1.64}

Φ2 = {1 ; 0.80 ; -0.26 ; -0.87 ; 0.10}

Φ2 = {1 ; -0.71 ; -0.36 ; 0.58 ; -0.03}

Φ2 = {1 ; -2.49 ; 3.93 ; -2.32 ; 0.08}


MODE-1
MODE-2
MODE-3
H
DEFORMATION
DEFORMATION
DEFORMATION


MODE-4
MODE-5
H
DEFORMATION
DEFORMATION

- **STEP-6**: Then we will calculate mode participation and mass participation factors.

MODE PARTICIPATION FACTOR

Pi = [0.223 0.201 0.347 0.219 0.009]

MASS PARTICIPATION FACTOR

Mi = [0.808 0.125 0.050 0.016 0.0004]

SHEAR	MODE-1	MODE-2	MODE-3	MODE-4	MODE-5
Q1	16.991	36.908	132.226	117.828	6.636
Q2	38.604	72.960	106.002	-84.642	-16.582
Q3	53.038	80.487	-35.435	-42.768	26.099
Q4	62.634	69.290	-116.020	69.040	-15.424
Q5	198.185	-121.629	28.332	-7.976	1.102

SHEAR	MODE-1	MODE-2	MODE-3	MODE-4	MODE-5
V1	369.453	138.017	115.105	51.481	1.831
V2	352.462	101.108	-17.121	-66.347	-4.805
V3	313.858	28.148	-123.124	18.295	11.7773
V4	260.820	-52.339	-87.688	61.063	-14.322
V5	198.185	-121.629	28.332	-7.976	1.102

CONCLUSION:

1) MATLAB, is a tool which is really efficient in solving the calculations of higher order matrices and equations.
2) Here, by using MATLAB as a tool to calculate the natural frequencies by various methods and then compare.
3) From results we can observe the exact natural frequency lies is in between the frequencies calculated from **upper and lower bound** (from approximation) methods.