`

STOCHASTIC RESPONSE OF A CURVED DAM DUE TO SPATIAL VARYING EARTHQUAKE GROUND MOTION

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY
IN

CIVIL ENGINEERING

With specialization in

STRUCTURAL ENGINEERING

Under the supervision of

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May-2018

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"STOCHASTIC RESPONSE OF A CURVED DAM DUE TO SPATIAL VARYING EARTHQUAKE GROUND MOTION"** in partial fulfillment of the requirements for the award of the degree of Master of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Sahil Thakur** during a period from August 2017 to May 2018 under the supervision of **Mr. Bibhas Paul** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: ----- May 2018

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I extend my heartily gratitude to my Project Guide **Mr. Bibhas Paul** for his constant guidance and support in pursuit of this Project. He has been a true motivation throughout and helped me in exploring various horizons of this project. Without his guidance, this project wouldn't have been possible. I would also like to thank my colleagues for their co-operation in framing the project.

Date: ---- May 2018 Sahil Thakur

M.tech- Structural Engineering 2nd year

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ABSTRACT

The effect of the spatial varying earthquake ground motion on a dam is that it increases the maximum shear stress. The effect is computed using a SVEGM model that accounts for both incoherency and propagation of seismic wave. A 3d inhomogeneous finite element model is used to represent a dam. Random vibration analysis is used to compute the stress strain responses. The assumption taken is that the excitations at all the supports are identical. The response arising from SVEGM compared to the response from identical excitation at al supports and delayed excitations due to wave passage. The modeling of the dam is done in Abaqus. For identifying the failure mechanism of the dam cone penetration test is performed. The cracks generated in the dam are due to the liquefaction of hydraulic fill. To accomplish the stated objective analysis should be done. The results obtained from analysis will be use to rectify a finite element model in Abaqus software. The results from the one dimensional analysis, two dimensional analysis and excite structure subjected to the SVEGM will be compared to get relevant results and conclusion.

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CHAPTER 1

INTRODUCTION

Most existing dams in seismic regions were designed using methods that are now considered simplistic and inaccurate. From the last 20 years, the earthquake safety of the dams has been calculated and some of them have been modified to raise their earthquake resistance.

1.1 Spatial varying earthquake ground motion:

Earthquake magnitude measured at different locations within the dimensions of an engineered structure are typically different; this is spatial varying earthquake ground motion. Due to the effect of spatial varying earthquake ground motion stress response near the base of the dam of stiff material can be increased. That is, the SVEGM increases the maximum shear stress in the stream bed. Due to the effect of SVEGM the pore pressure also increases in the upstream. The stress-strain responses are computed by finite element based random vibration analysis. A 3d inhomogeneous finite element based model is used to represent a dam. For the analysis of dam different coherency model are used which is given by different researchers. The dam response arising from SVEGM is compared to the response from identical excitation at all supports and delayed excitations due to wave passage.

Assumptions are:

- At all support points excitations are same.
- Excitations at all locations are assumed to be fully coherent.

1.1.1 Causes of SVEGM:

- Wave passage effect
- Incoherence effect
- Local site effect

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1.1.2 Effect of SVEGM:

. Due to the spatial varying earthquake ground motion the stresses in the stream bed of dam increases.

. Large horizontal displacement at upstream shell and large vertical displacement at the top of the dam.

. This leads to increase the pore pressure at the upstream shell.

. Due to the SVEGM cracking generates in the dam.

1.2 Spatial Coherence:

Spatial coherence is a concept of wave disturbance describing the correlation between periodic transmitted energy from one point to another , it can also be said that it is a mutual interdependence or connection of variable wave quantities of two different points in a given instant of time.

1.3 Arch dam:

An arch dam is just a curved beam, the ends of which are restrained and the way in which the loads are resisted is termed a arch action.

An arch may be defined as a solid wall, curved in plan, standing across the entire width of the river valley, in a single span. This dam body is usually made of cement concrete, although rubble and stone masonry has been used in the past.

This wall will structurally behave ; partly as a cantilever retaining wall standing up from its base, and partly, the load will be transferred to the ends of the arch span by horizontal arch.

The arch load will, thus be transferred to the side wall of the canyon, which must be strong.

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CHAPTER 2

LITERATURE REVIEW

Chen M and Harichandran S (2001) [1]

In this paper " Response of earth dam subjected to spatial varying earthquake ground motion" , the response of ' Santa felicia' earth dam in southern california is analysed. Model used to show a dam is inhomogeneous finite element model. The analysis indicates that due to SVEGM stress response near the base of the dam increased. In this paper five coherency models used for analysis. The conclusion obtained is that the SVEGM increases the maximum shear stress in stream bed. So it is necessary to check the sensitivity of the measured response to various coherency models. [1]

Zeghal M and Ahmed Ghaffar A (1992) [2]

In this paper "Analysis of behavior of earth dam using strong motion earthquake records" , series of earthquakes strike a long valley earth dam in California. The analysis is based on ideas of system identification techniques. For this seismic records were utilized for identifying the salient features of the dam nonlinear behavior. Pattern recognition step is added to determine the class of system behaviour. The dam material modeling is done by plastic theory. The conclusion obtained is that the pattern recognition step shows evidence for the nonlinearity of dam. The analysis showed that the model response in the upstream-downstream direction has a better quality of fitness to the recorded response than the longitudinal and vertical direction. [2]

Zerva A and Zervas V [3]

This paper address the topic of "spatial variation of seismic ground motion". This variation is evaluated from the data recorded at dense instrument arrays. In this paper estimation of coherency is presented. Some coherency models are described for this analysis. This paper investigates the difference in amplitudes and phase of seismic motion recorded over extended years. This variation finds the difference in the seismic time histories at various locations on the ground surface. By the use of SMART-1 array and dense instrument array the modeling of spatial variability and coherency is initiated. [3]

Bardet J and Davis C (1996) [4]

In this paper "performance of San Fernando dam during Northridge earthquake" is analysed. Series of earthquakes strikes the dam. Due to these earthquake dam is subjected to strong ground motions. Cone penetration test and slope stability analysis is used for the analysis of this dam. The effect of earthquake on this dam was estimated by using Newmark sliding block method.

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The conclusion obtained from this analysis is that the movement and cracks are generated in dam due to liquefaction of their hydraulic fill. [4]

Chopra A (2012) [5]

In this paper "Earthquake analysis of arch dam" some factors considered that influence the 3-d analysis of arch dam. The factors are, the semiunbounded size of the reservoir and foundation-rock domains, dam-water interaction, water absorption at the reservoir boundary, water compressibility, dam-foundation rock interaction, and spatial variations in ground motion. By the analysis of the dam it was demonstrated that stress may be underestimated or overestimated when water compressibility is neglected, by some factor of 2 to 3 stress may be estimated by neglecting rock foundation damping and mass, the spatial variation in ground motion induced stresses in the dam. [5]

Tsai P, Yifeng Z and Yeong chi (2011) [6]

In this paper "Analysis of dynamic response of an earth dam during 1999 chi-chi earthquake in Taiwan" a numerical analysis was performed. The p-z model (pastor and zienkiewicz) was adopted here to study the dynamic responses. The comparison was achieved between two model, p-z and mohr coulomb model by analysis of dam.Through the analysis it was demonstrated that large horizontal displacement at upstream shell and large vertical settlement at the top of dam after earthquake. This was due to the generation of pore water in the upstream. [6]

Vanmarcke E, Zavoni E, A.Fenton G (1993) [7]

In this paper " Conditional simulation of spatially correlated earthquake ground motion" methodology is presented for simulating properly correlated earthquake ground motion. The input consist of spectral density function and frequency dependent spatial correlation function. The advantage of mrthod is that it reproduce the space-time correlation structure of ground motion. For the simulation of non-homogeneous earthquake ground motion the methodology can easily be extended by spectral density function. [7]

Anil K. Chopra P. Chakrabarti (1981) [8]

In this paper "Earthquake analysis of Concrete gravity dam including dam water foundation rock Interaction"the procedure to calculate the response of concrete dams including the rock foundation and the dynamic effect of the impounded water, to the transverse (horizontal) and vertical components of earthquake ground motion is presented. The problem is reduced to one in two dimensions, considering the transverse vibration of a monolith of the dam.The system is analysed under the assumption of linear act for the rock foundation, water. [8]

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Kemal Hacıefendioğlu , Alemdar Bayraktar b, Yasemin Bilici (2009) [9]

In this paper "the ice-cover effect on sudden earthquake response of concrete dams subjected to multisupport earthquake action are studied including foundation, reservoir, ice, dam interaction. Foundation, ice, reservoir, dam interaction system is formed using the displacement based fluid and solid isoparametric quadrilateral finite elements by using a program called ANSYS. The surface movement is characterized by filtered white noise and joined to every support point of the 2-D finite element model of the foundation reservoir arrangement. The west-east part of Erzincan earthquake which held on 1992, 13 march is taken in to consideration for the pretending dynamic investigation of Sariyar concrete dam. Results are achieved for foundation, dam, reservoir and foundation, ice, reservoir, dam arrangements. Parametric investigations are computed in order to analyse effects of the abnormalities of the density, thickness, elastic modulus, length of the ice-cover on the earthquake dynamic reaction of the dam. It is seen that the abnormalities of the values of the elastic modulus, length, thickness of ice-cover, effects the stresses of the system appreciably. This paper use two different methods for the modeling of the dam. These methods are displacement based. These method are applicable to every node point of the modeled dam. These variations in dimensions results in changing the stress of the coupled system. [9]

Tan H, Chopra A(1996) [10]

In this paper dynamic "dam-foundation rock interaction effects in earthquake response of arch dam", the dynamic response is presented for properties dam, rock foundation, enclosed water and material of reservoir boundary. On the basis these response results, the effect of the rock foundation, dam interaction having no water in the reservoir are investigated. In standard analyses the dam-foundation rock interaction significance is neglected. It is concluded that there is increase in dam-foundation interaction. There is increase in the displacement and stress response of the dam due to water enclosed behind the dam. The displacement and the stress increase on the solid foundation which leads to decrease in the earthquake response on the solid foundation of the dam. This fall is due to the absorption on the reservoir boundary. [10]

Valliappan S, Yazdchi M, Khalili N(1999) [11]

This paper "seismic analysis of arch dam" uses the concept of continuum dynamic mechanism to present the non-linear seismic behavior of arch dam. Finite element technique and appropriate non-linear material are used for this analysis. In the material which exhibit strain rate dependent behavior is used to represent a damaged model. This is done because of elastic strain softening property f the concrete. Mesh dependent hardening technique is used for the evaluation of the damage. During the earthquake motion stiffness recovery is allowed by this model. [11]

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Maeso O, Dominguez J(1993) [12]

In this paper “earthquake analysis of arch dam” the earthquake analysis is presented by a three dimensional boundary element technique. It is supposed that the dam and the foundation rock are viscoelastic domain. Due to vertical propagation of p and s-wave there recorded a linear response of arch dam which is represented only for empty reservoir conditions. In it the effect of travelling wave and dam-rock foundation interaction is presented. There is reduction in the resonant frequency of the dam. This is due to the travelling wave effect and dam-rock foundation interaction. For the cross stream and upstream excitation the reduction is very significant of the response function of the first peak. It is concluded that there is reduction in frequency of the dam. [12]

J.Dowling M, F.Hall J(1989) [13]

In this paper “non linear seismic analysis of arch dam” arch dam analysis is presented by finite element procedure. In it the horizontal cracking planes, vertical contraction joints with gradual closing and opening are considered. In it some of the nonlinearities like sliding and compressive are not included. The dm response is greatly increased by the full reservoir. The response drops back to a reasonable level, when the ground motion scale is reduced to 0.44 with full reservoir, but the separation of the contraction joints remains. The results shows that for moderate to severe ground motion many non linear phenomena are present with different degrees of importance. Opening of the dam foundation interface joints and upper position of the vertical contraction is one of the most important. [13]

Lokke A, K.Chopra A (2015) [14]

`In this paper “response spectrum analysis of concrete gravity dams including dam-water-foundation interaction” response spectrum analysis is performed. It gives us the peak response of the displacement, velocity, acceleration. This paper compares the results of response spectrum analysis with the time history analysis. This includes dam-rock foundation-water interaction. In this paper ground motions are considered. From these analyses it is concluded that the dam response estimated by RSA is similar to that of time history analysis. From this it is observed that RSA procedure is adequate for the opening phase of the design of the dam. This RSA procedure is very much satisfactory for calculating the stresses. [14]

H.Mejia L(2017) [15]

In this paper “response of fena dam to the 1993 guam earthquake” response or the performance of the dam is estimated the strong ground motion or the earthquake with higher magnitude. The performance of the dam during the guam earthquake is very much satisfactory, this is due to the clayey nature of the foundation and the foundation material having the low susceptibility to liquefaction. The dam performance is estimated by the current method of analysis. Seed-lee-idriss approach is used to estimate the induced strains. The observed performance is unvarying with the nonlinear analyses of the deformation. [15]

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Yang R, Tsai C.S, Lee G.C(1996) [16]

In this paper “procedure for time-domain seismic analysis of concrete dams” time-domain earthquake analysis of solid dam is exhibited. This method utilizes substructure strategy, the limited component technique, and a usual transmitting limit stated by the authors. This diffusing yield exact hydrodynamic following up on dams, with less measured cost. The method can be received for both straight and non linear time-domain analysis of dam reservoir. Modal investigation can be fused in direct analysis to additionally trim the measured effort. A few numerical cases under different ground motion inputs are likewise introduced to exhibit the exactness and effectiveness of the advised strategy. [16]

Gao Y, Gu Q, Qui Z, Wang J(2016) [17]

In this paper “seismic response sensitivity analysis of coupled dam-reservoir-foundation systems” the RSA methodology in view of the immediate separation strategy is increased accordingly and spred to foundation reservoir dam systems. The DDM based reaction sensitivity to material are determined for different components and material models recreating the material nonlinearity, the dynamic solid-liquid interaction, dam-foundation connection, and the truncation limits of the water, fundamentally expanding the limit of the DDM-based response spectrum analysis strategy. The newly created calculations are actualized in a broadly useful nonlinear finite element analysis program, approved through a practical dam-reservoir-foundation system. It is shown that DDM based calculation is correct and adequate in computing the response sensitivity. [17]

Yu Lin C, L.Tassoulas J(1987) [18]

In this paper “three-dimensional dynamic analysis of dam-water-sediment systems” a reliable transmitting limit is produced for the therapy of boundless water-sediment area in the 3-D analysis of dams. The limit can be coupled straightforwardly with the dam, water and sediment finite elements. Functions that confirm the effectiveness of the improvement and outline the utilization of the limit are studied. The hydrodynamic impacts on unbending dams with vertical upstream faces of rectangular or trapezoidal shape were required for upstream-downstream, cross-stream and vertical ground motions. The outcome were found to be in great concurrence with accessible solutions. A restricted parametric study demonstrated that the pressure wave velocity of the silt has a important effect on the hydrodynamic force. [18]

Hao H(1994) [19]

This paper “ground motion spatial variation effects on circular arch responses” studies the effect of spatial variation earthquake ground motion on reaction of in-plane roundabout concentrated arches. The reaction of arches subjected to both connected even and vertical numerous movements are computed. The reactions of arches disposed to the combined horizontal and vertical excitation are additionally talked about. It is found that the more-corresponded various even movements excites the curve antisymmetric modes increasingly and the symmetric modes

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less, while the more-connected vertical movements excites the symmetric modes increasingly and the antisymmetric modes less. [19]

Maeso O, J.Aznarez J, Dominguez J(2002) [20]

In this paper "effects of space distribution of excitation on seismic response of arch dams" the impact of the ground movement spatial displacement and the canyon geometry on the dynamic reaction of the curve dams during earthquake is studied. The earthquake response of the dam subject to time harmonic longitudinal, shear and Rayleigh waves impinging the dam site from various headings is figured out. The foundation-rock is displayed as a orderly viscoelastic limitless domain where the happening voyaging wave field is characterized by its analytical definition, which may incorporate any spatial variation. The achieved results shows the significance of three-dimensional impacts which are ordinarily unconcerned. One might say as a general outcome that in inclusion to other development, for e.g, water compressibility, bottom sediments and rock foundation flexibility and the spatial variation of the activity along the dam-foundation rock alliance impact the dam reaction. [20]

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CHAPTER 3
OBJECTIVE AND SCOPE OF STUDY

3.1 Objective of study:

The main objective of the proposed study is to check the response of arch dam subjected to spatial varying earthquake ground motion

3.2 Scope of the study:

Importance of the study:

.Analysis leads to better design

.Better seismic performance of the dam

.Low risk factor

.Public safety

.Low maintenance cost

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CHAPTER 4

MODELING

4.1.1 3D modeling using abaqus

Height of Dam = 94.5m , Base Width = 68.25m

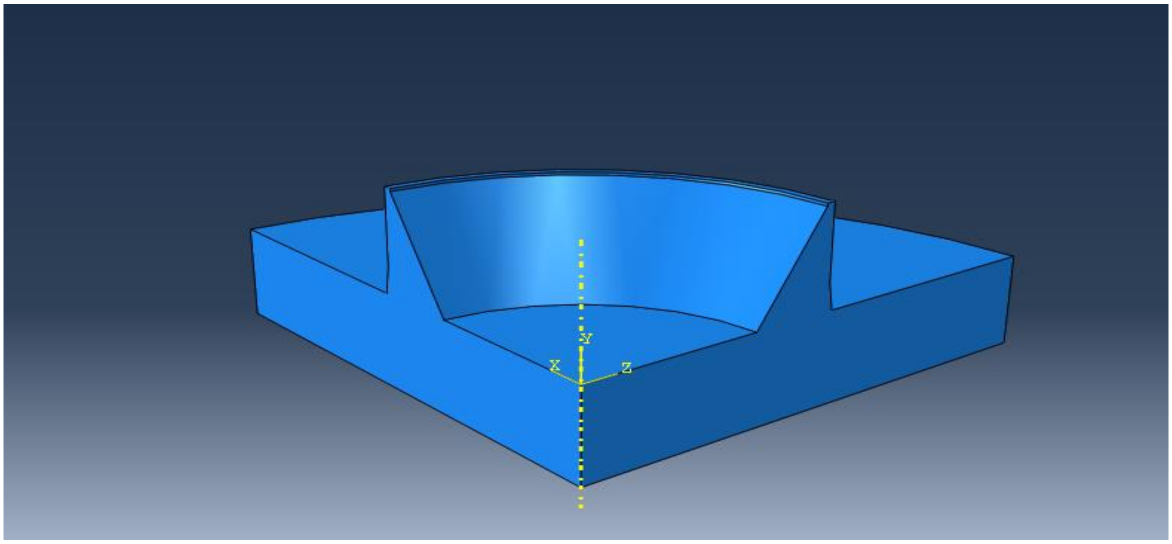

Fig 4.1.1.1 Modeling of dam

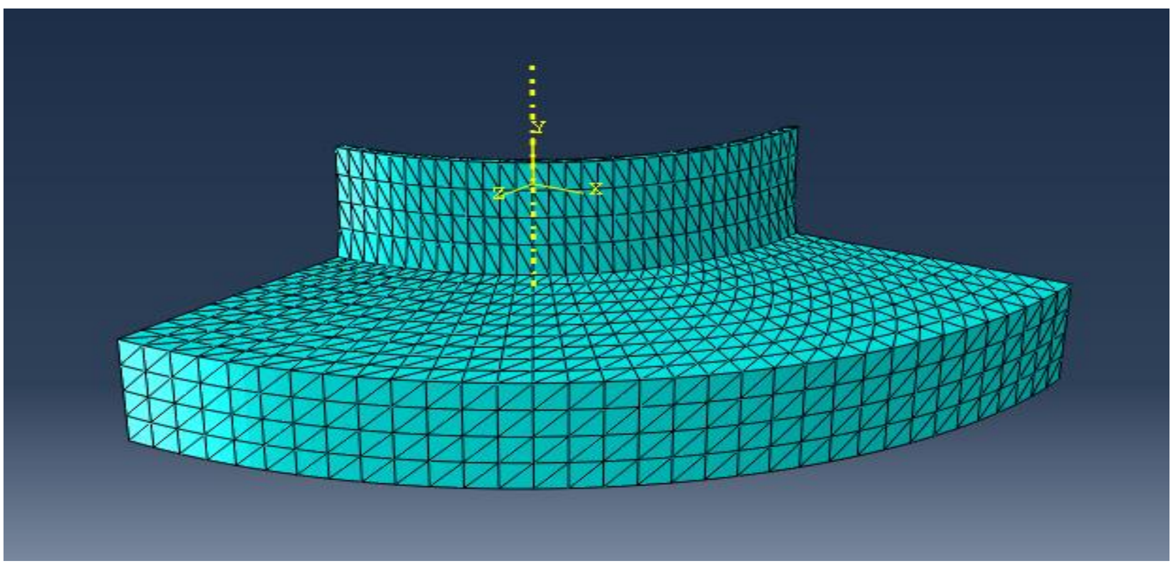

Fig 4.1.1.2 Meshing

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a.) Modal analysis

Vibration distinctive of structures can be decided by this technique.

- Give us natural frequency.
- Mode shapes.
- Gives us the idea that how much a mode participate in a given direction.
- Most crucial of all the dynamic study types.

Procedure:-

Steps of analysis:

- Frame the model.
- Selection of analysis type.
- Application of boundary conditions.
- Analyse results.

- **Build the model:-**

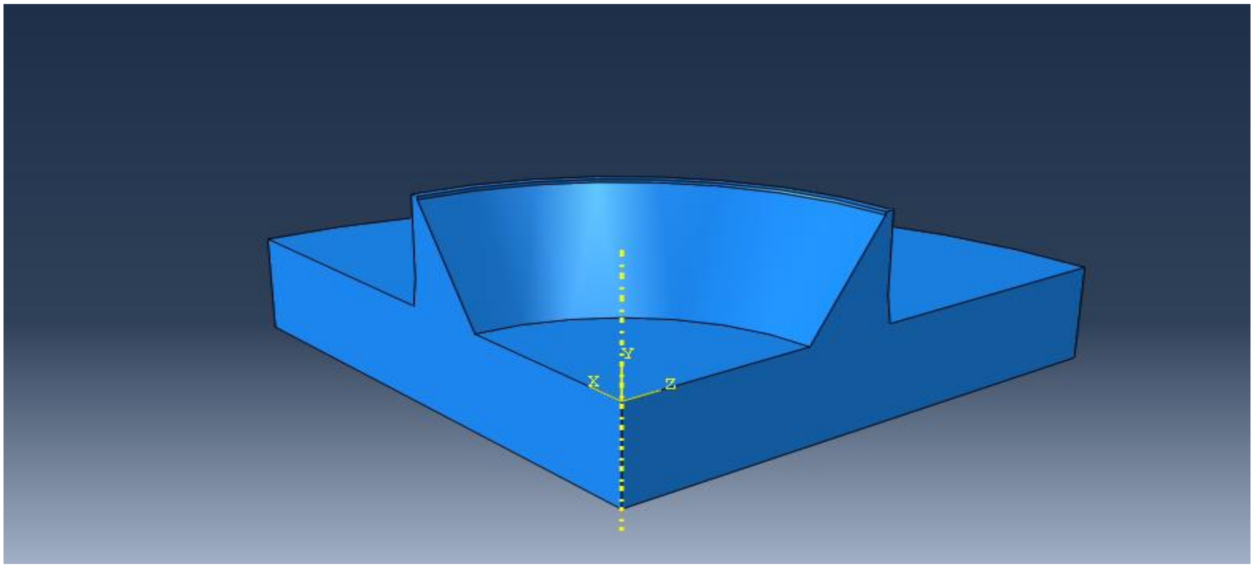

Fig 4.1.1.3 Geometry of model

Material Properties:-

Mass density of concrete = 2400kg/m^3

Young’s Modulus = 38.73 GPa

Poison’s Ratio = .2

- **Choose analysis type and options:-**

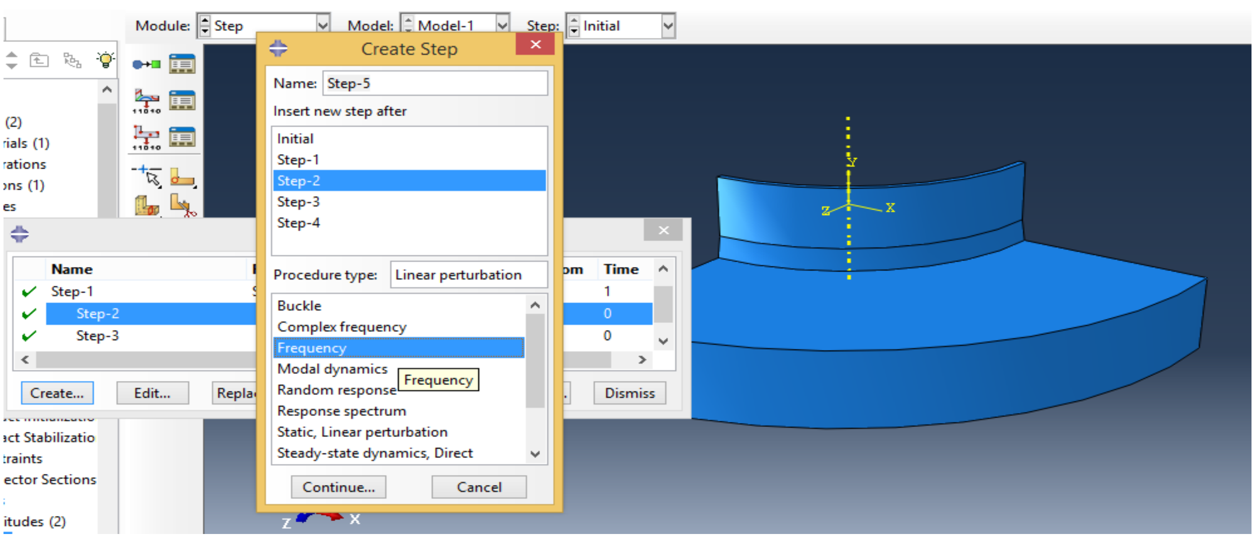

Fig 4.1.1.4

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Apply boundary conditions and solve:-

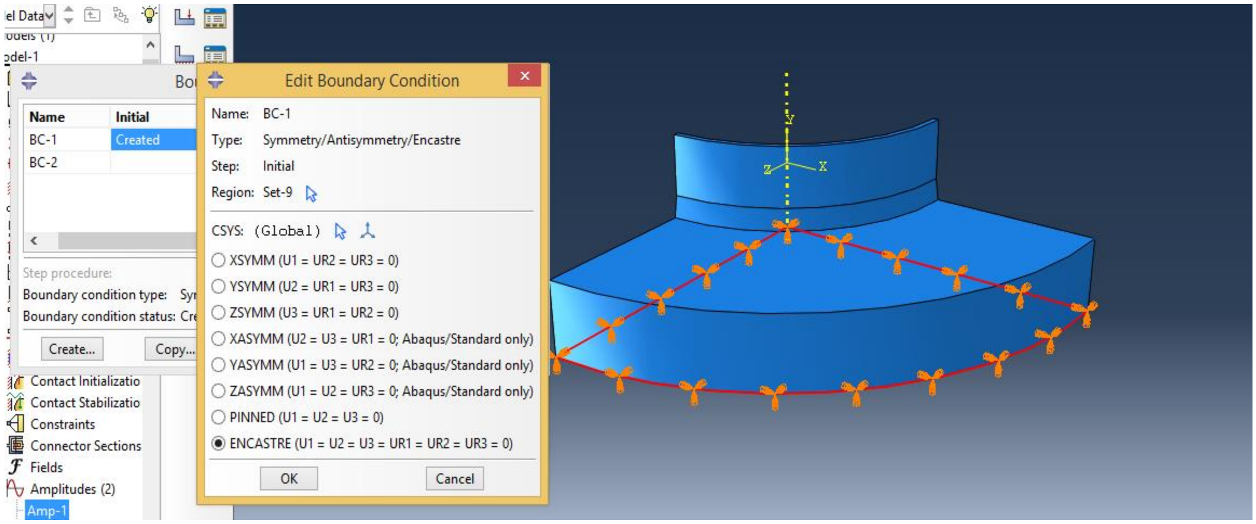

Fig 4.1.1.5

- **Review results**

Sr. No.	Frequency(/sec)
1.	3.9558
2.	4.2426
3.	4.8510
4.	5.1588
5.	6.5255
6.	6.6784
7.	6.9137
8.	7.3423
9.	7.4275
10.	7.7272

Table 4.1.2.1

`

a.) Response Spectrum analysis

It is a approach which calculate input from every natural mode of vibration to demonstrate the feasible most extreme earthquake response of a elastic structure. Response spectrum analysis gives understanding into dynamic conduct by estimating acceleration, velocity, displacement as a function of auxiliary period for a given time history and level of damping.

Procedure:-

1. Click on load module.
2. Then click on Tools menu and select Amplitude.
3. Create amplitude and select spectrum and continue.
4. A new window is open and select acceleration from specification units.
5. Enter the values of amplitude, frequency and damping.
6. After that, create step and select response spectrum.
7. From where, add directional cosine values and direct modal damping.
8. Submit the job and result analysis.

1. Click on load module:-

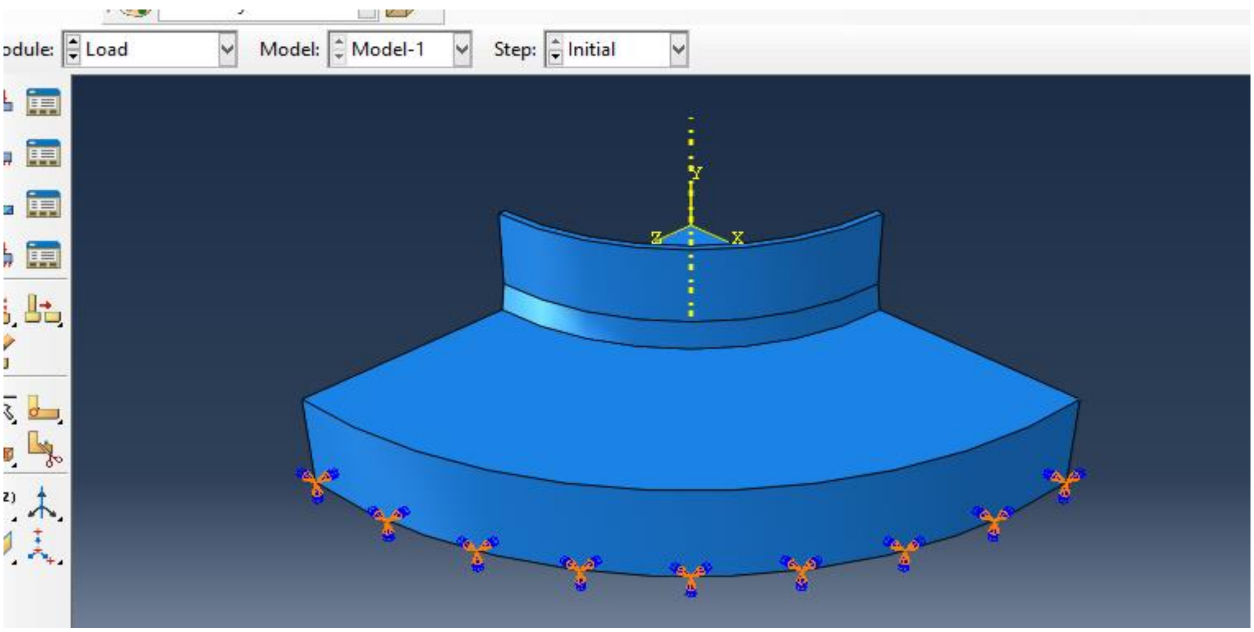

Fig 4.1.1.6

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2. **Then click on Tools menu and select Amplitude:-**

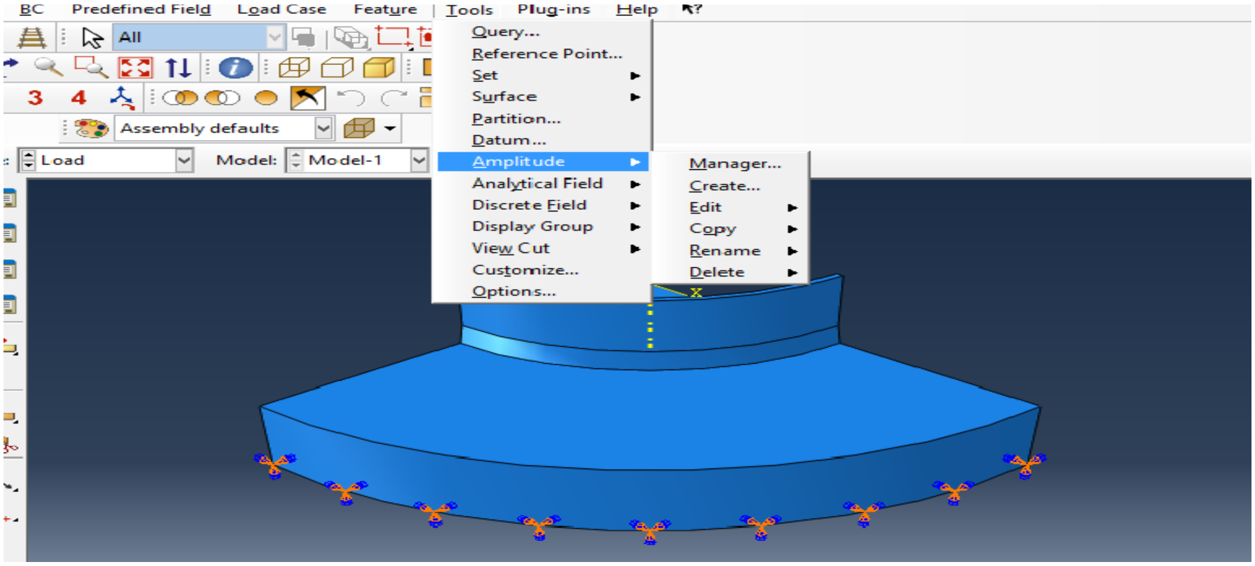


Fig 4.1.1.7

3. **Create amplitude and select spectrum and continue:-**

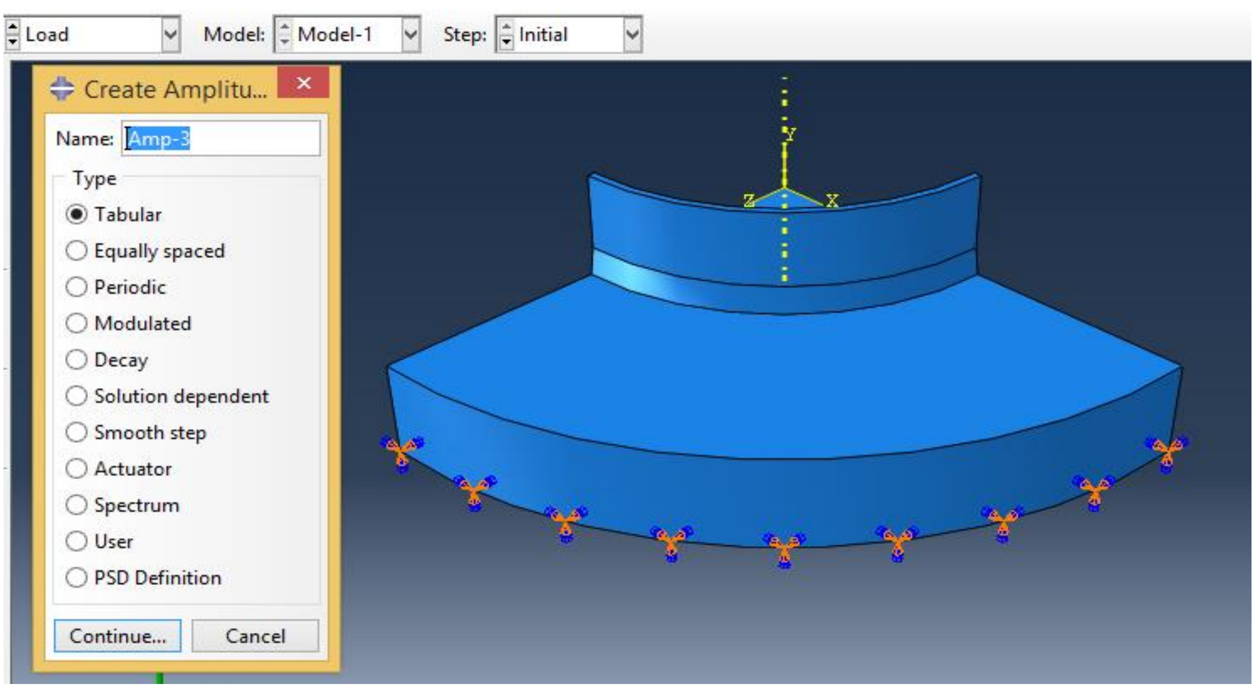


Fig 4.1.1.8

4. A new window is open and select acceleration from specification units:-

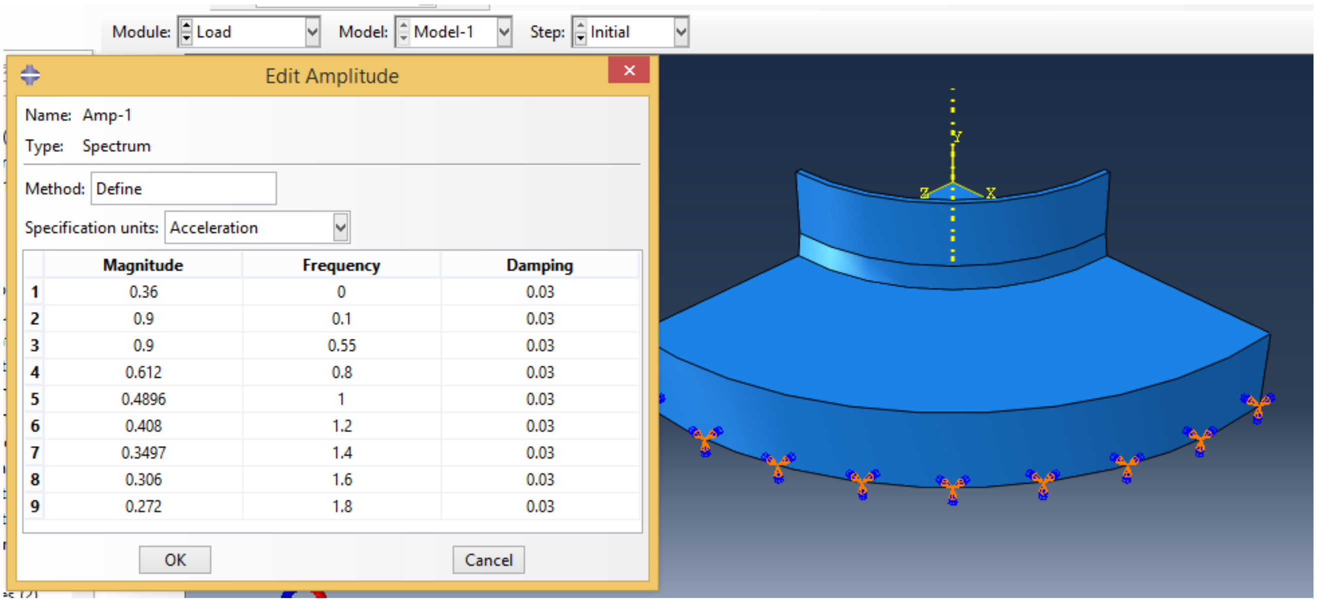


Fig 4.1.1.9

5. Enter the values of amplitude, frequency and damping:-

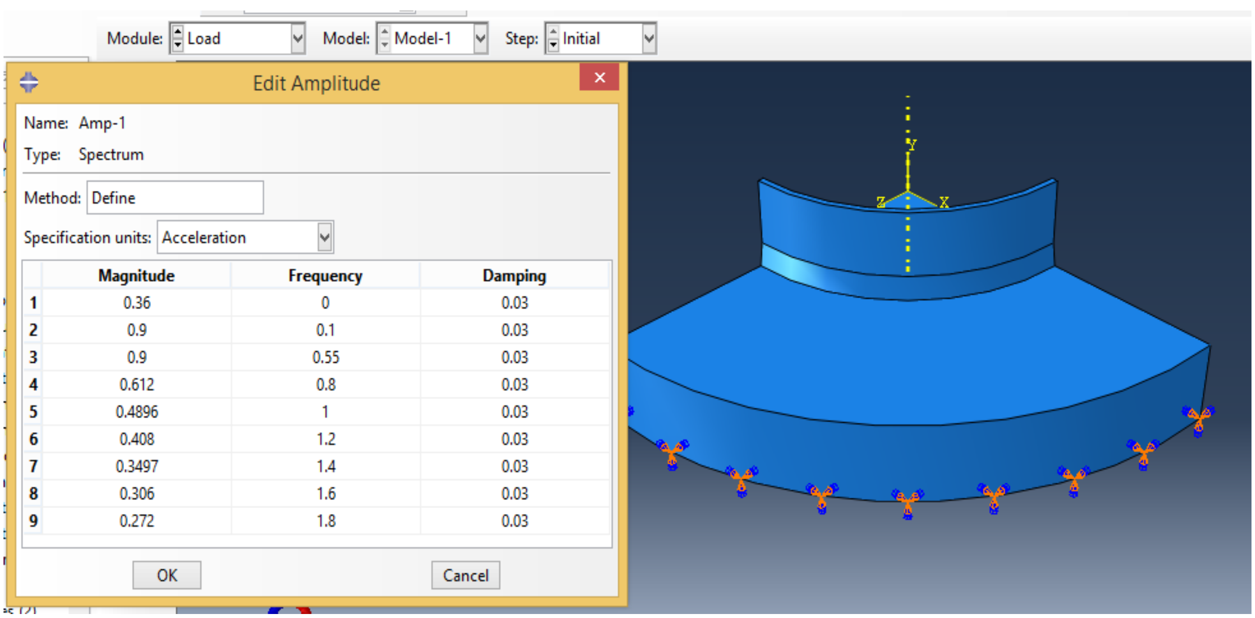


Fig 4.1.1.10

6. After that, create step and select response spectrum:-

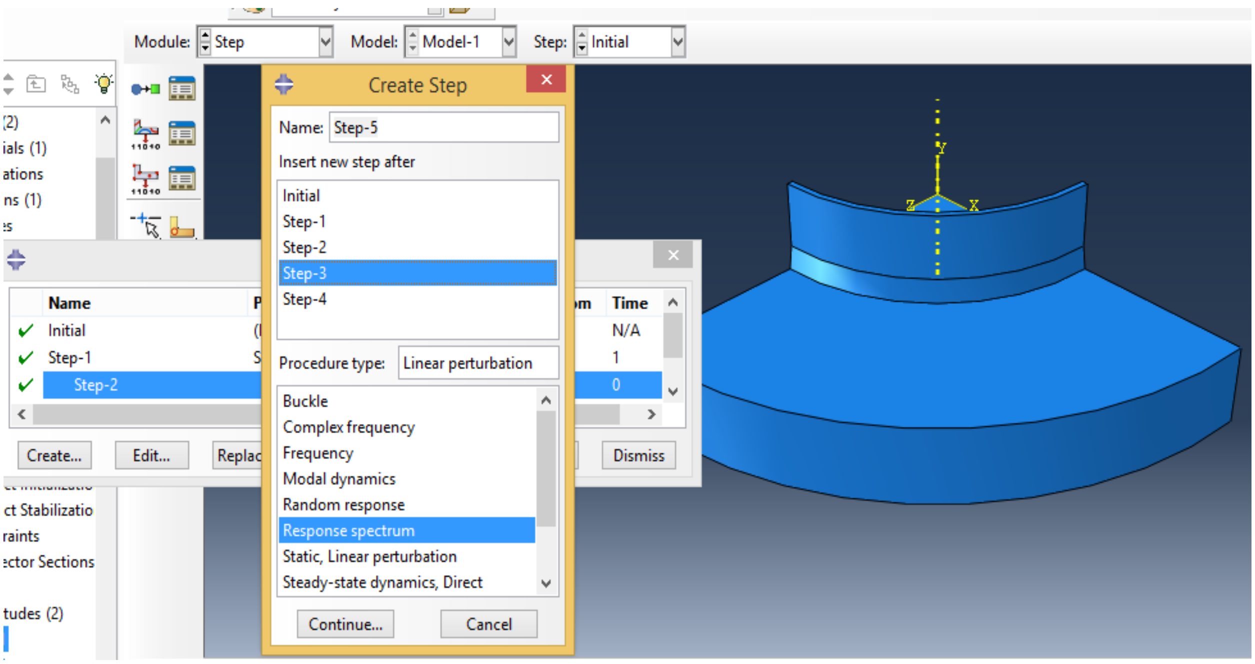
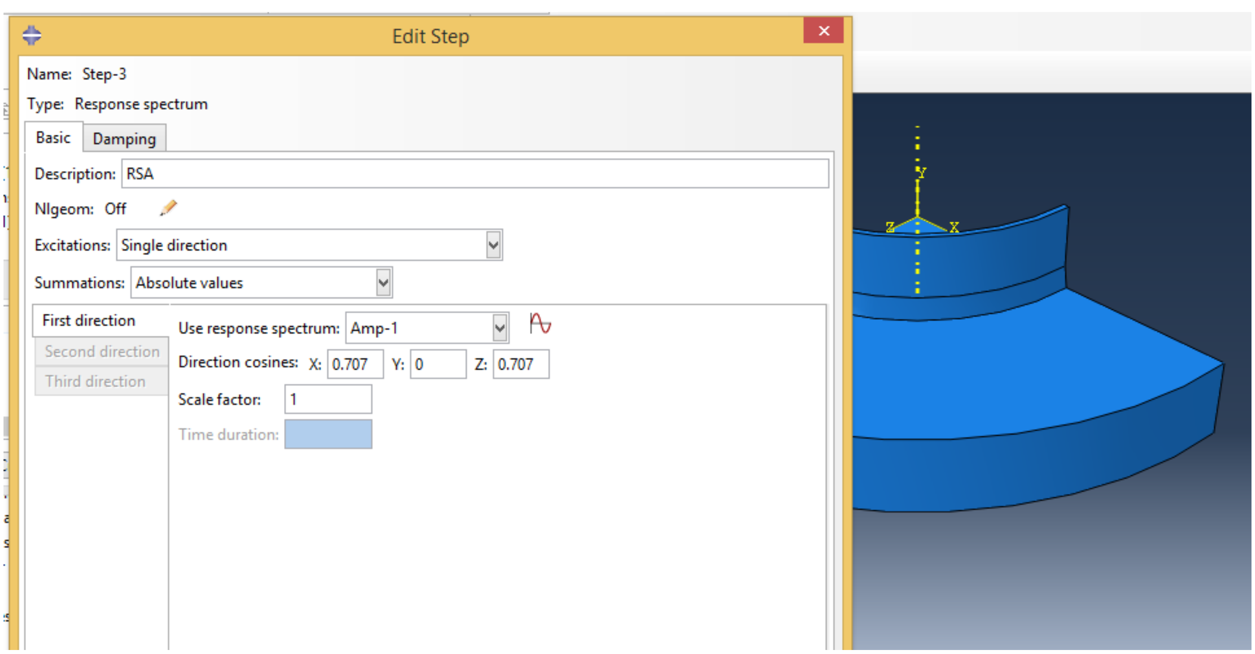


Fig 4.1.1.11

7. From where, add directional cosine values and direct modal damping:-



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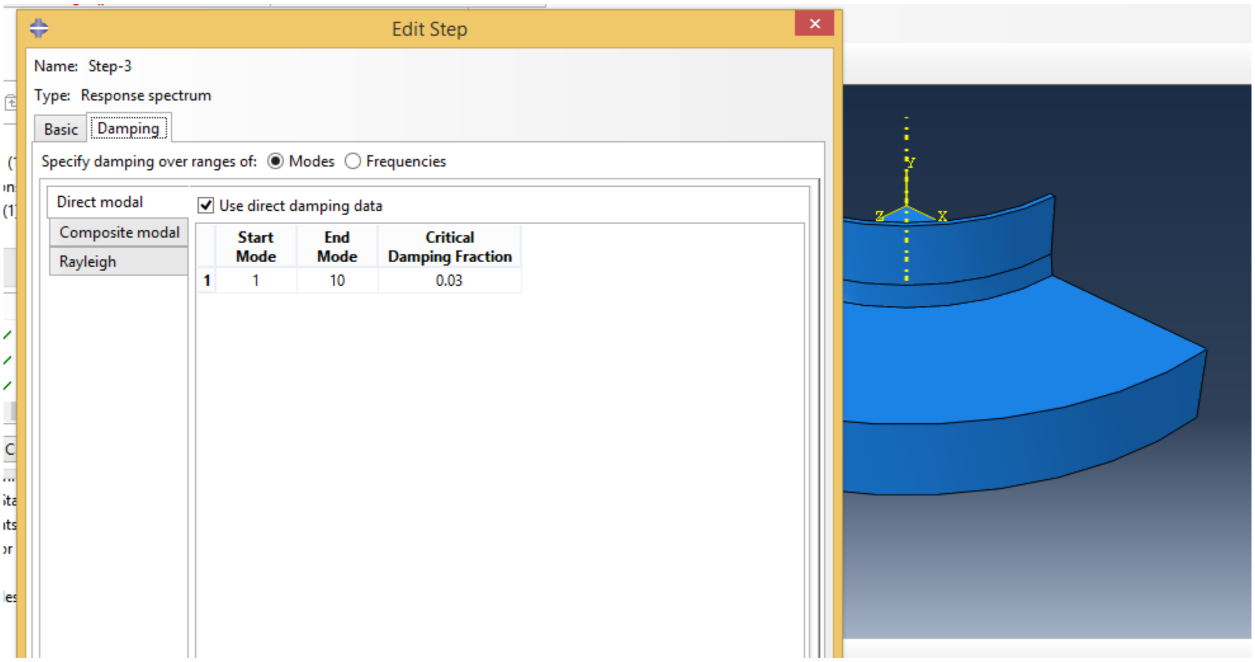

Fig 4.1.1.12

8. Submit the job and result analysis:-

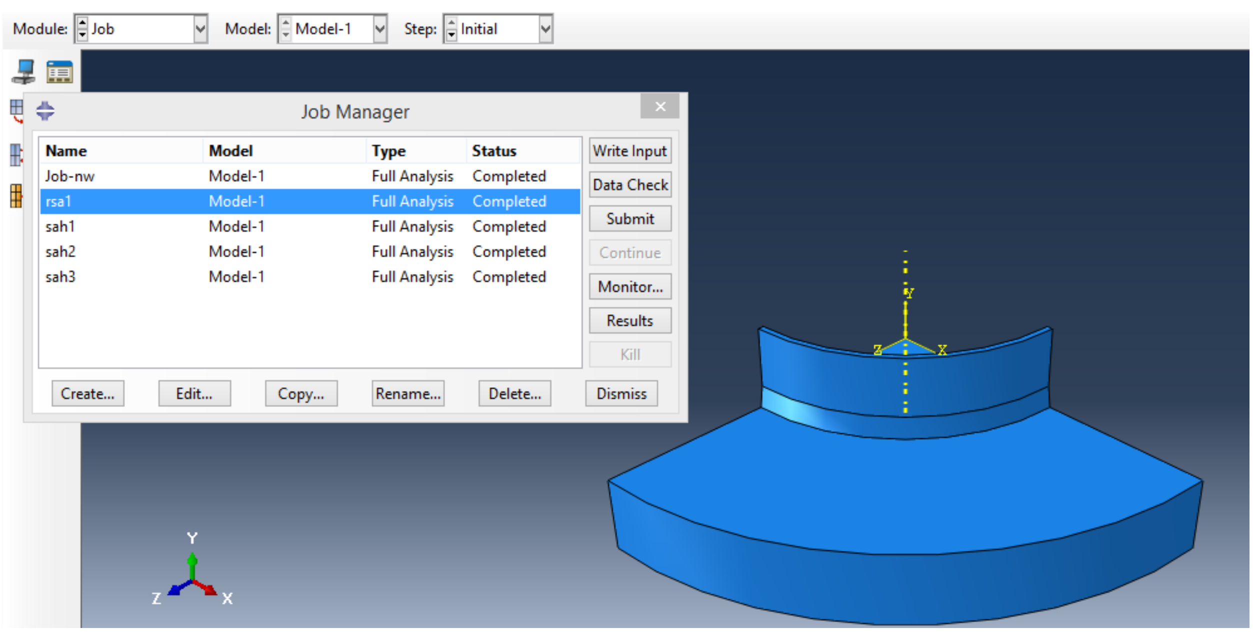

Fig 4.1.1.13

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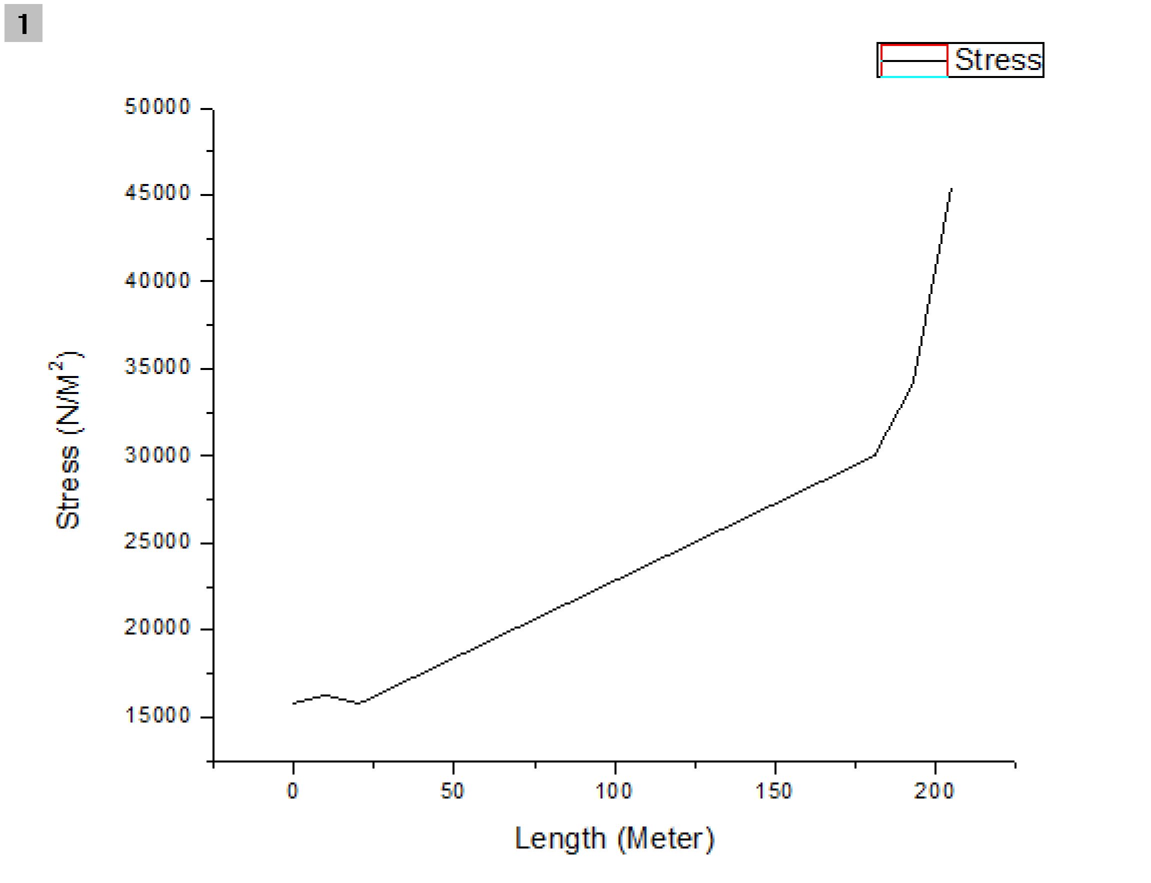
Result of Response Spectrum:-

1. **Along the length**

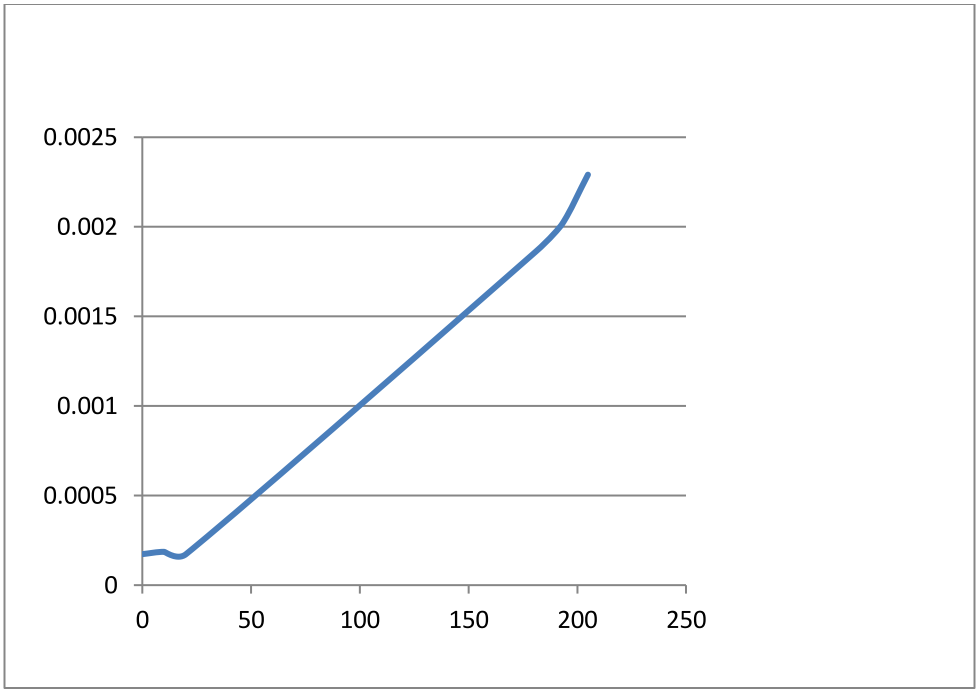


Graph 4.1.2.1 (Stress v/s Length)

Sr.No.	Length(m)	Stress(N/m^2)
1.	0	15797
2.	10.0433	16254.8
3.	20.0867	15758.7
4.	180.868	30014.6
5.	192.888	34148.6
6.	204.909	45429.4

Table 4.1.2.2

`



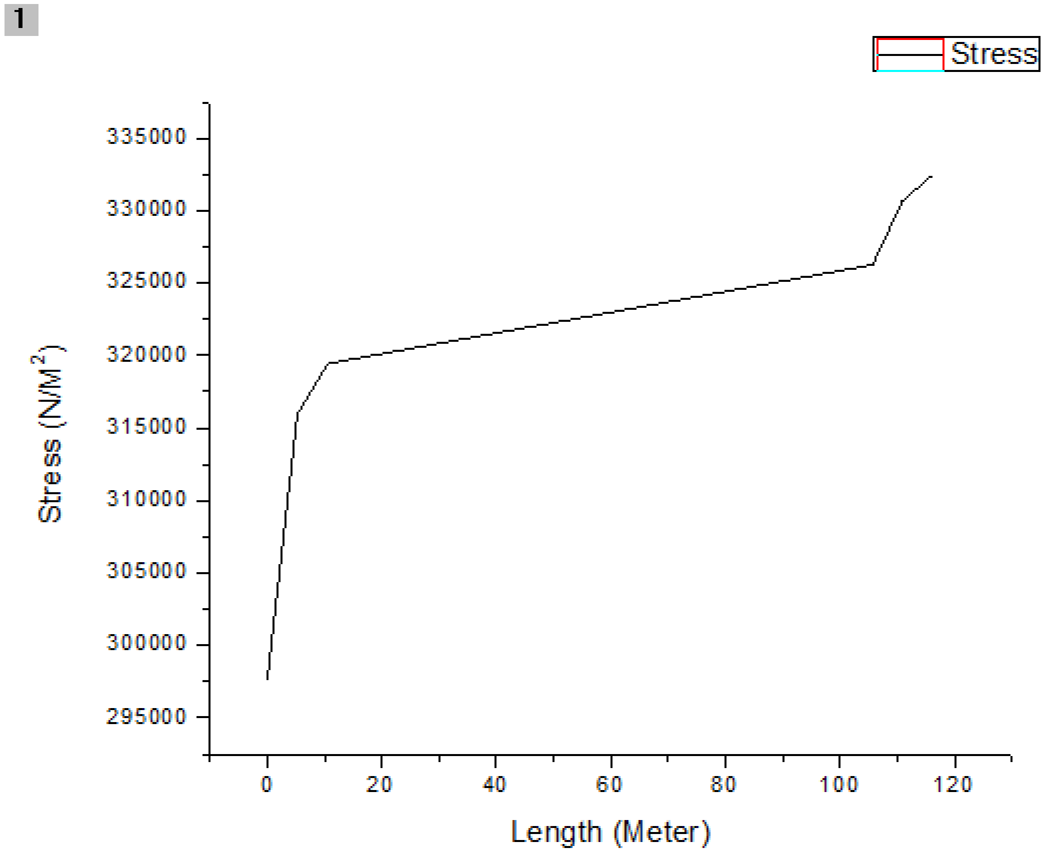
Graph 4.1.2.2 (Displacement v/s Length)

Sr.No.	Length(m)	Displacement(m)
1.	0	0.000173
2.	10.0433	0.000186
3.	20.0867	0.000173
4.	180.868	0.001861
5.	192.888	0.002013
6.	204.909	0.002291

Table 4.1.2.3

`

2. Along Height:-



Graph 4.1.2.3 (Stress v/s Length)

Sr.No.	Length(m)	Stress(N/m^2)
1.	0	297583
2.	5.28345	315940
3.	10.5669	319436
4.	105.72	326266
5.	110.915	330686
6.	116.109	332434

Table 4.1.2.4

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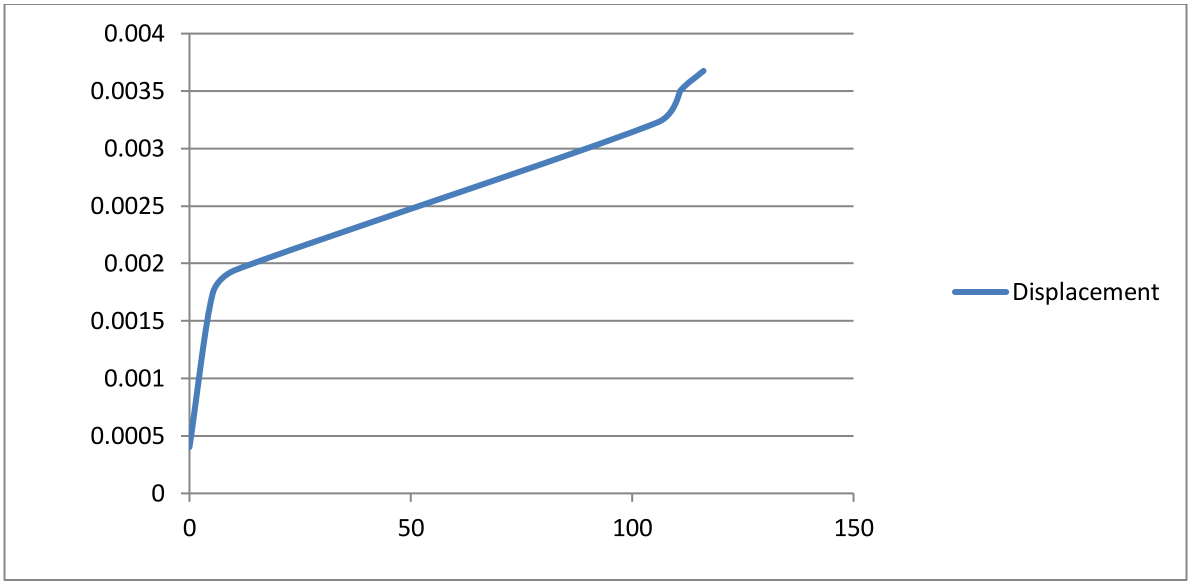

Graph 4.1.2.4 (Displacement v/s Length)

Sr.No.	Length(m)	Displacement(m)
1.	0	**0.00040344**
2.	5.28345	0.00174495
3.	10.5669	0.0019465
4.	105.72	0.00322742
5.	110.915	0.00350447
6.	116.109	0.00367556

Table 4.1.2.5

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b.) Time History analysis

In time history analysis, the structural response is computed at a number of subsequent time instants.

- **Procedure:-**

1. Firstly, we create a step and then choose linear perturbation.
2. From where, we select Modal Dynamics.
3. After that, a new dial up box opened, and we enters the values of time periods, increment, starting and end point of mode shape and damping.
4. After completing this step, we create a new field output for same step and output history field for same step.
5. In output history field, we select the step(not for whole model) i.e. for a single node and then create the time interval as given in the modal dynamics.
6. Then, we create a amplitude table having some time and amplitude data.
7. Then, we apply load and boundary conditions.
8. At last, submit the job and analyze the result.
9. And perform analysis for different points of the model.

`

1. **Firstly, we create a step and then choose linear perturbation:-**

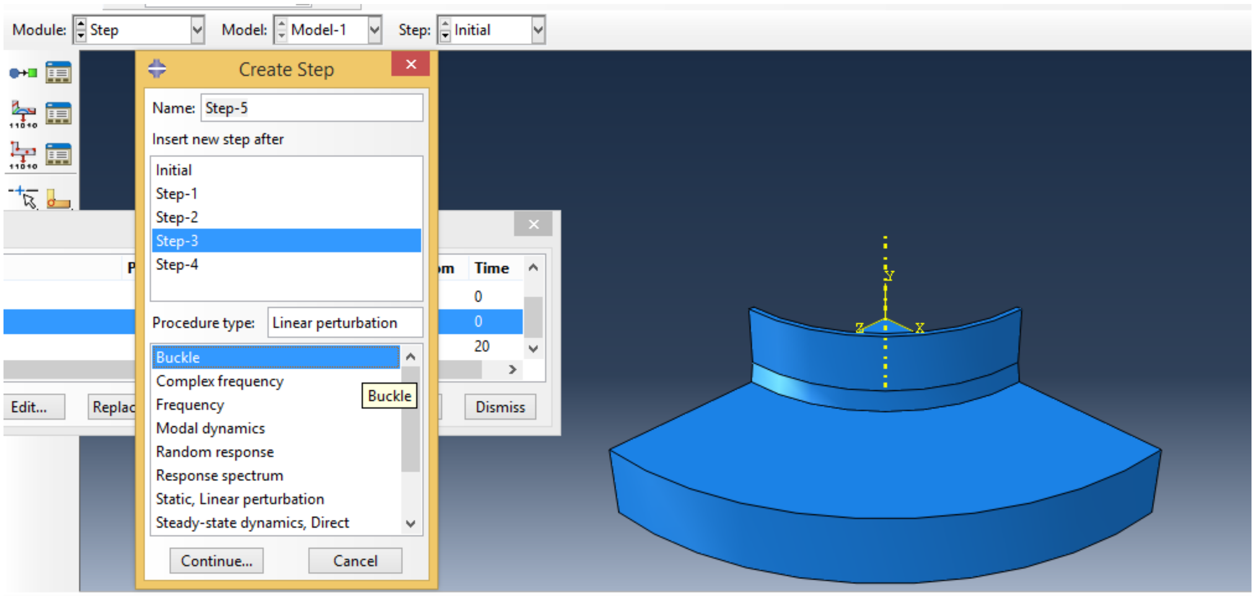


Fig 4.1.1.14

2. **From where, we select Modal Dynamics:-**

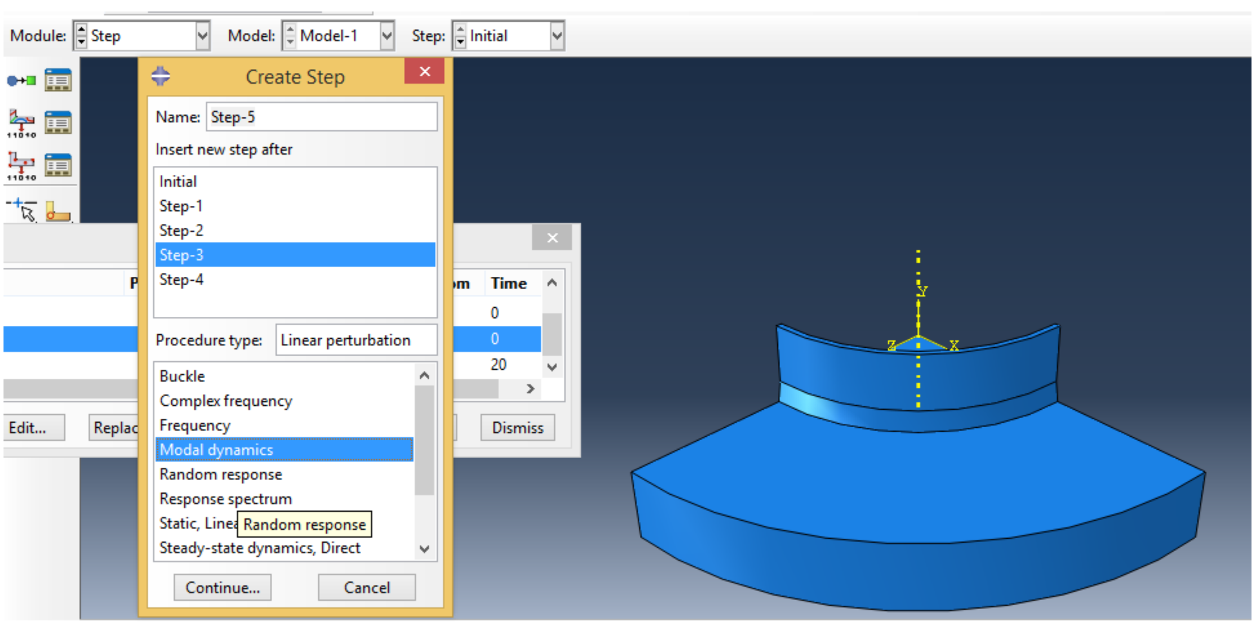
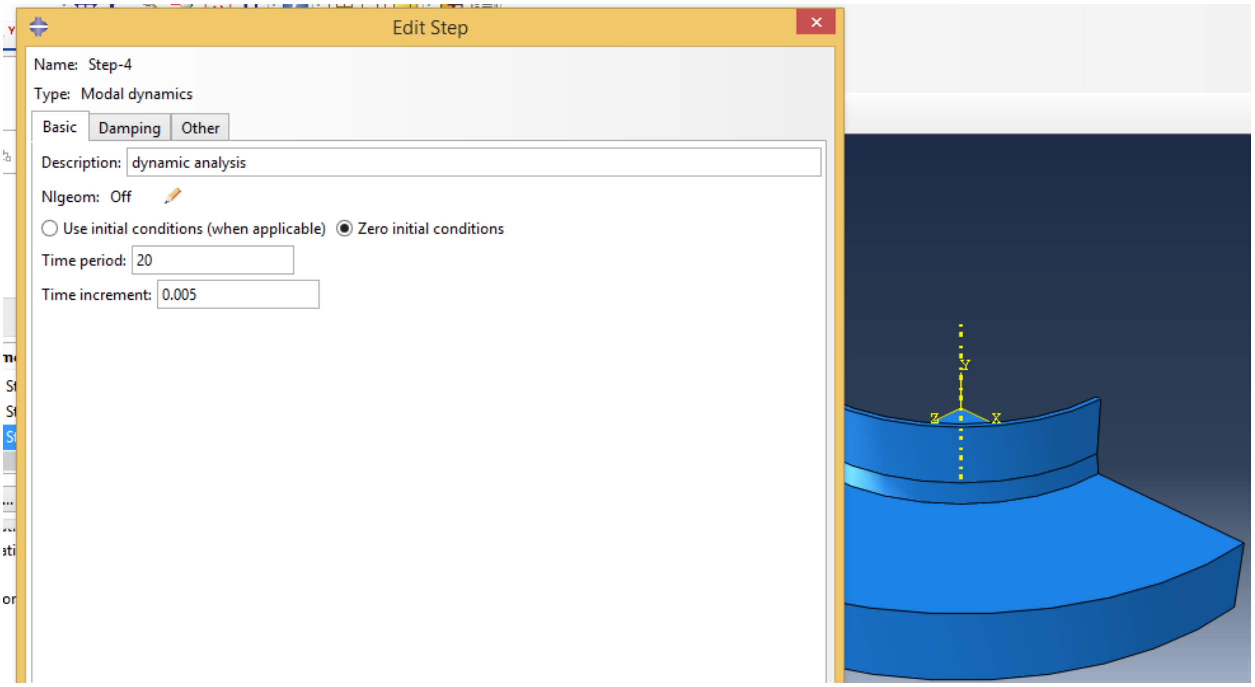


Fig 4.1.1.15

`

3. **After that, a new dial up box opened, and we enters the values of time periods, increment, starting and end point of mode shape and damping:-**



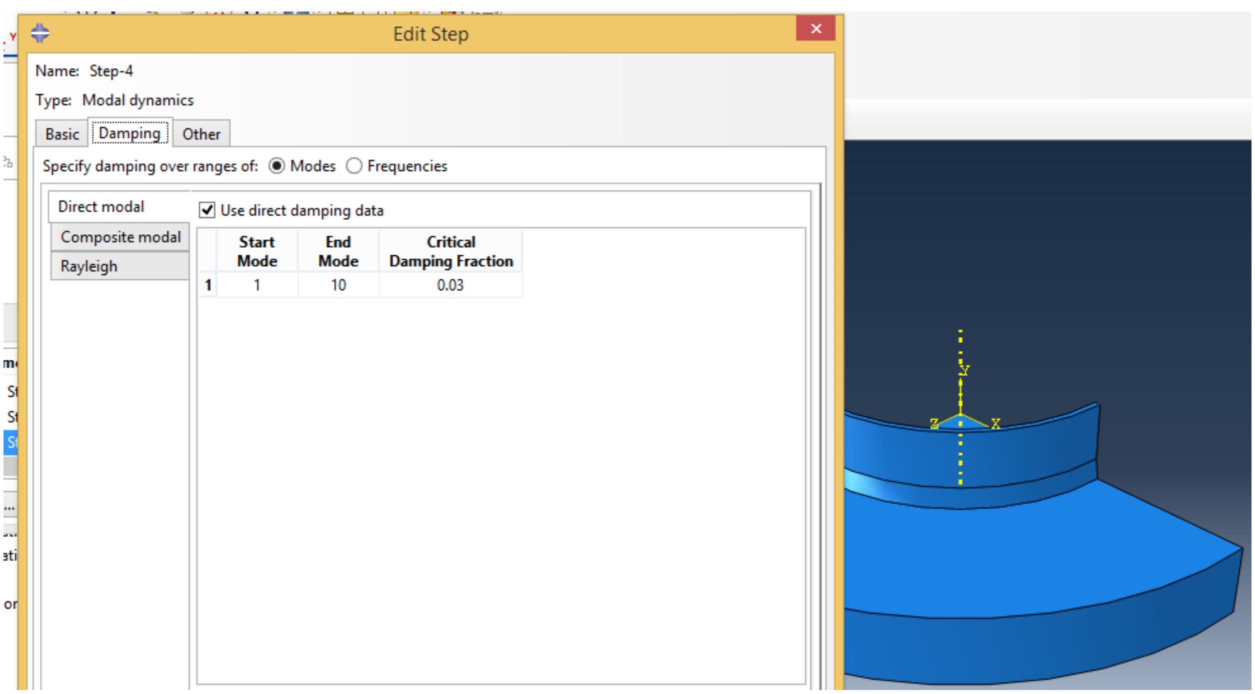


Fig 4.1.1.16

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4. **After completing this step, we create a new field output for same step and output history field for same step:-**

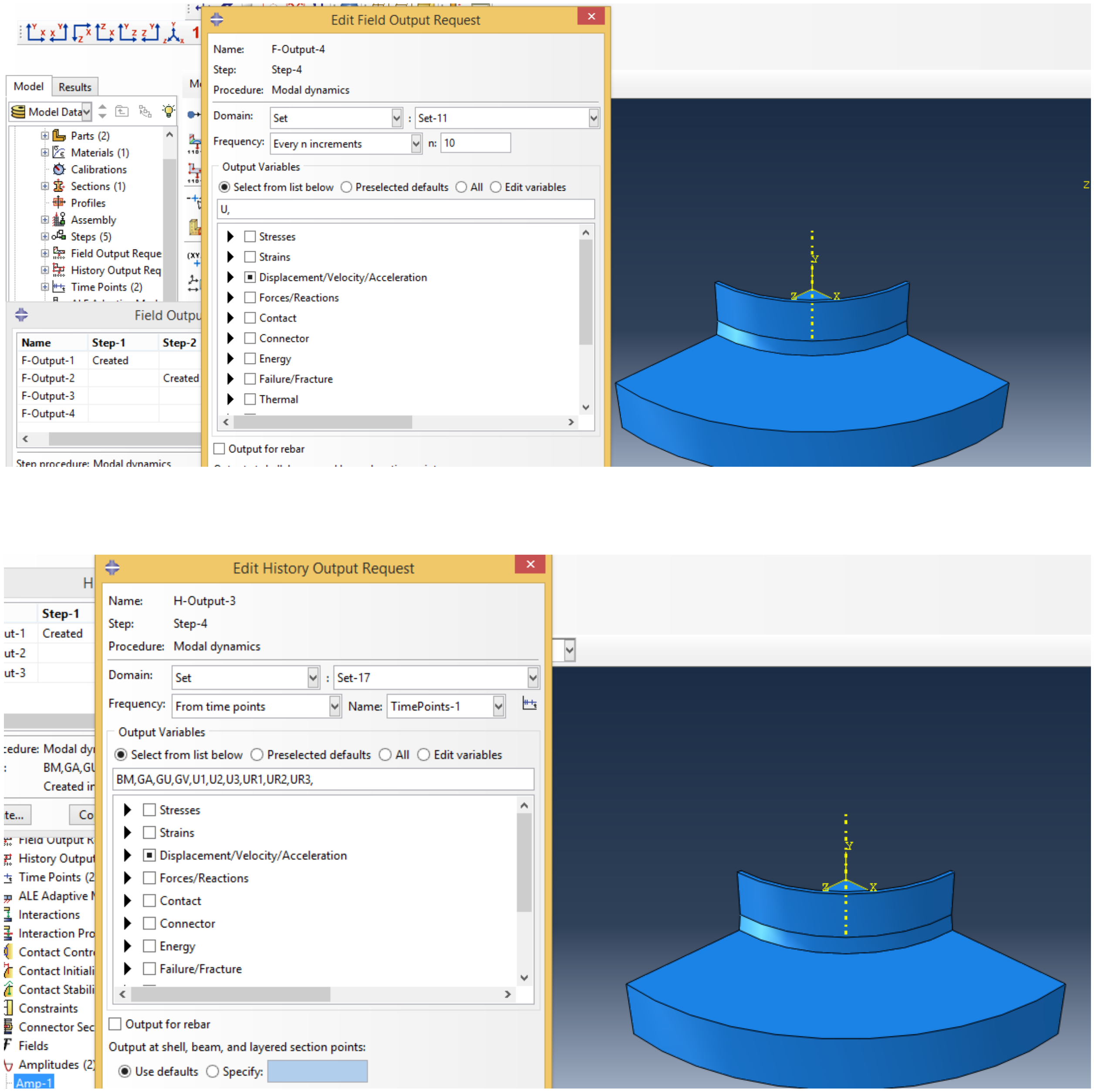


Fig 4.1.1.17

5. **In output history field, we select the step(not for whole model) i.e. for a single node and then create the time interval as given in the modal dynamics:-**

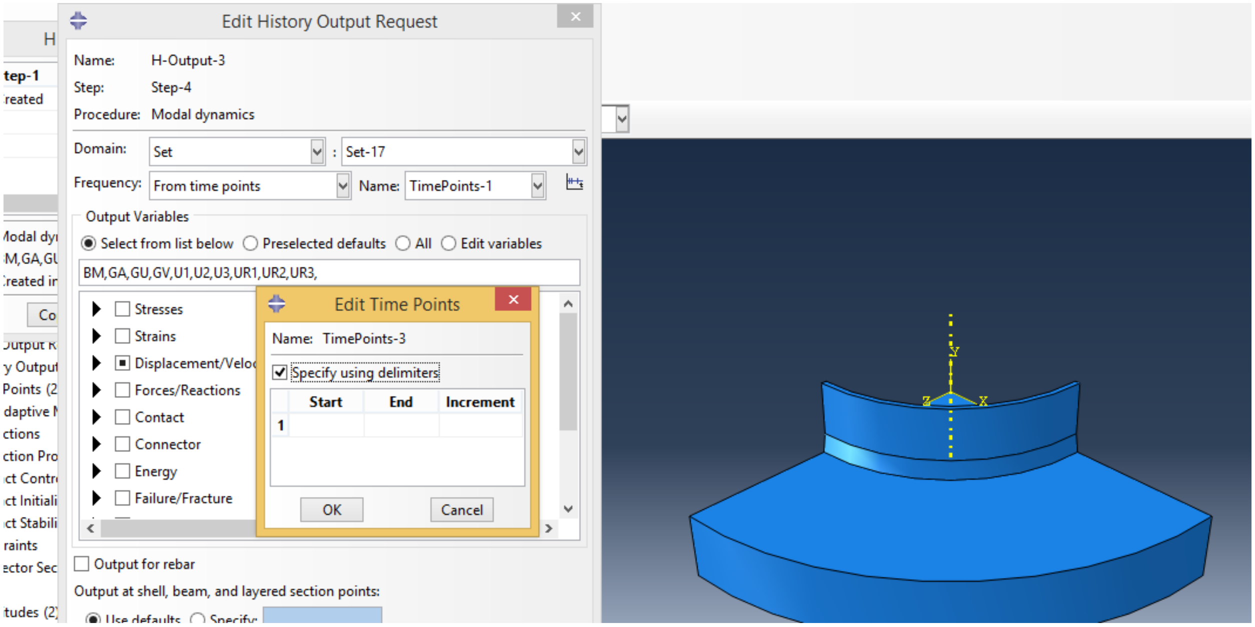


Fig 4.1.1.18

6. **Then, we create a amplitude table having some time and amplitude data:-**

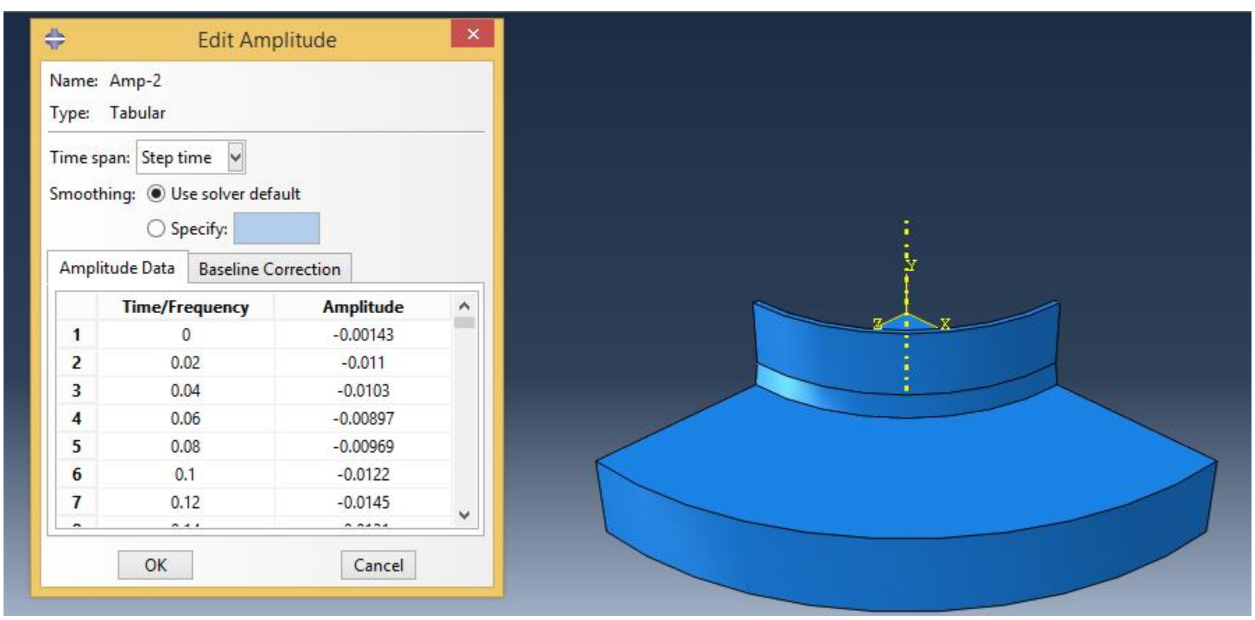
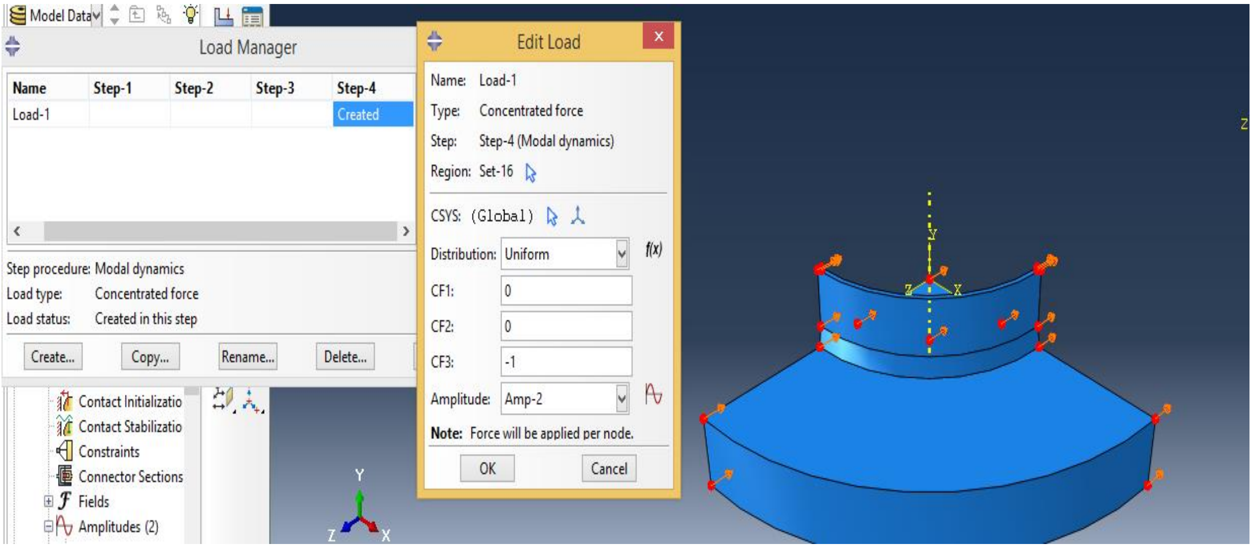


Fig 4.1.1.19

`

7. Then, we apply load and boundary conditions:-



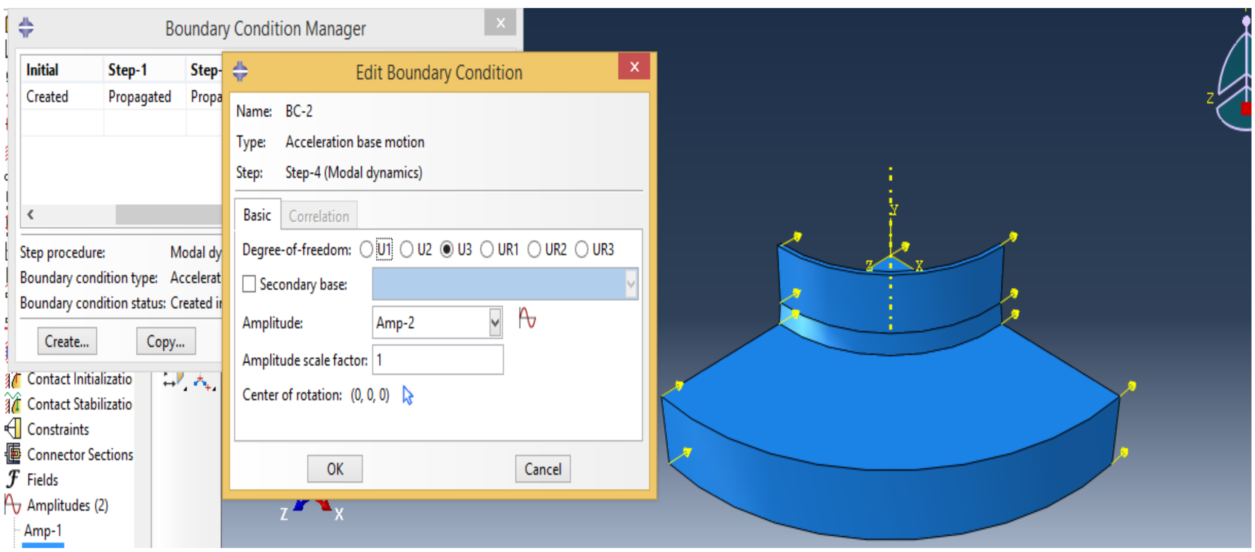


Fig 4.1.1.20

`

8. At last, submit the job and analyze the result:-

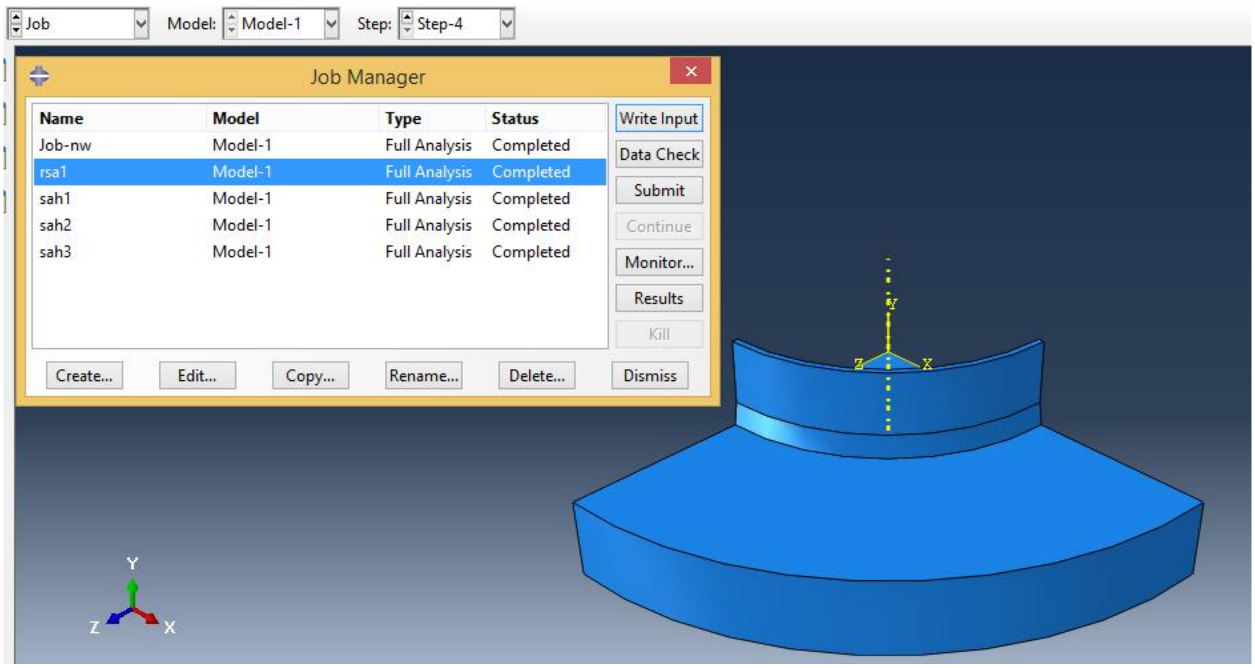


Fig 4.1.1.21

`

9. **And perform analysis for different points of the model**

Elcentro input:-

a.) At mid Point (Node 97):-

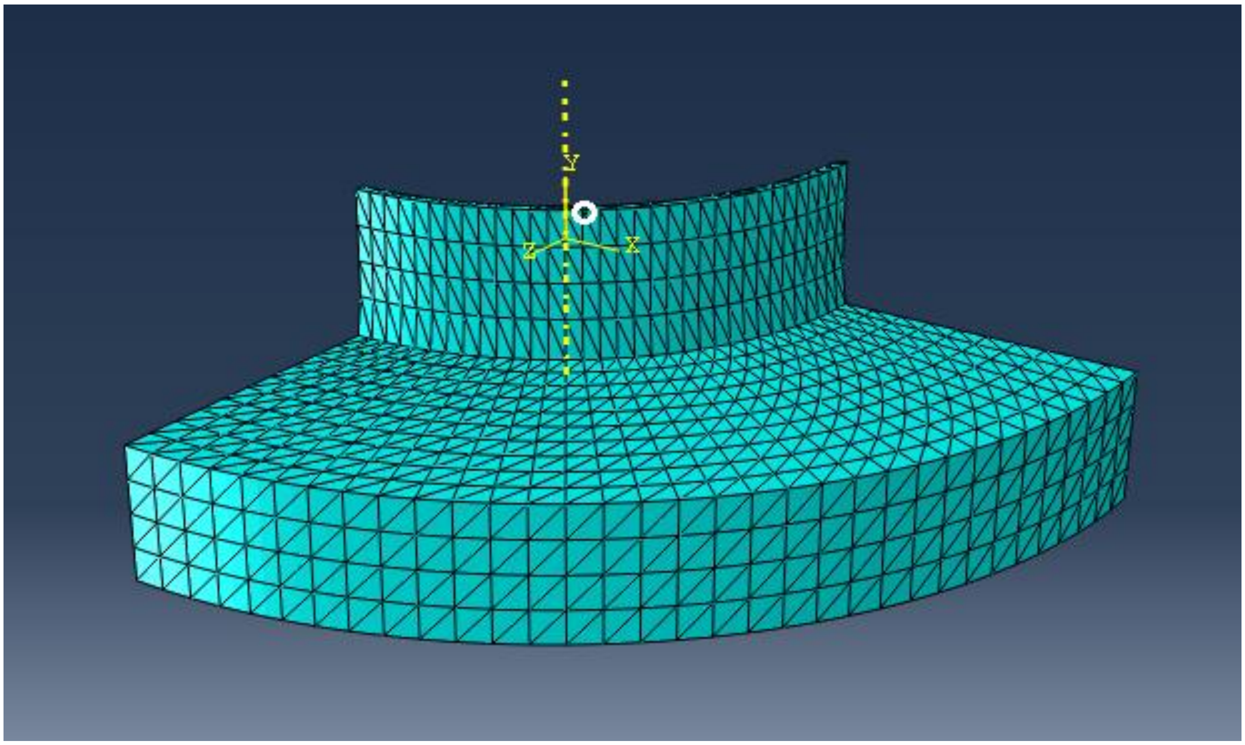


Fig 4.1.1.22

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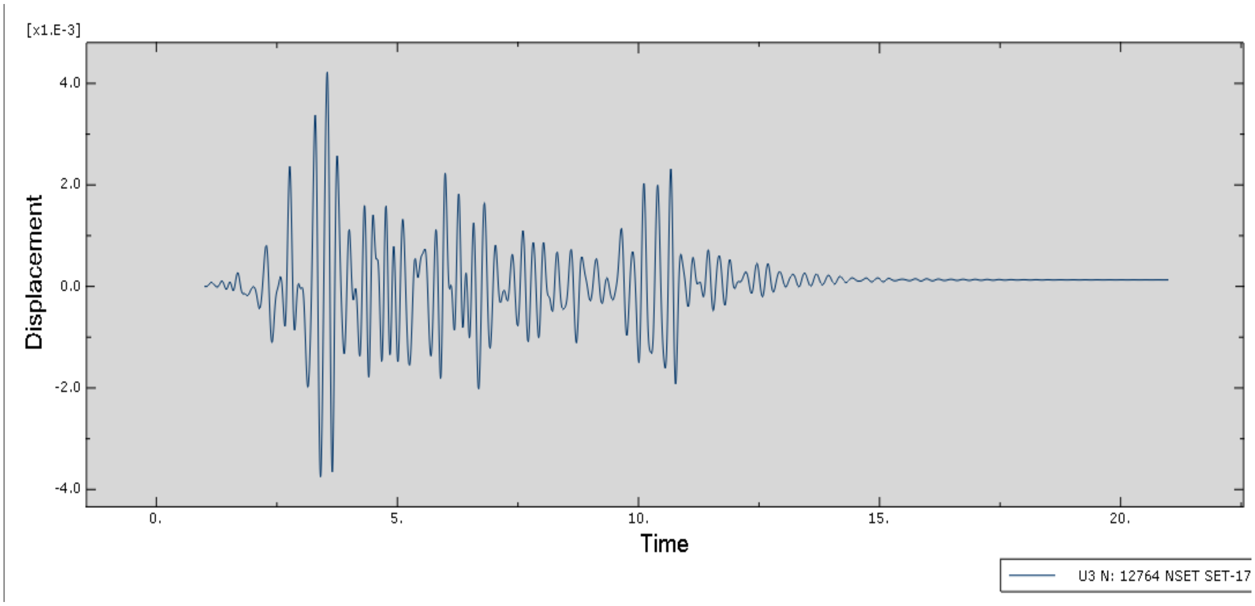
Sr.No.	Displacement (meters)	Time (seconds)
1	1	0
2	1.005	2.43E-08
3	1.01	1.32E-07
4	1.015	3.79E-07
5	1.02	8.23E-07
6	1.025	1.51E-06
7	1.03	2.47E-06
8	1.035	3.71E-06
9	1.04	5.24E-06
10	1.045	7.07E-06
11	1.05	9.21E-06
12	1.055	1.16E-05
13	1.06	1.44E-05
14	1.065	1.74E-05
15	1.07	2.07E-05
16	1.075	2.42E-05
17	1.08	2.78E-05
18	1.085	3.16E-05
19	1.09	3.55E-05
20	1.095	3.94E-05
21	1.1	4.32E-05
22	1.105	4.69E-05
23	1.11	5.03E-05
24	1.115	5.35E-05
25	1.12	5.62E-05
26	1.125	5.86E-05
27	1.13	6.04E-05
28	1.135	6.17E-05
29	1.14	6.23E-05
30	1.145	6.23E-05
31	1.15	6.17E-05
32	1.155	6.04E-05
33	1.16	5.84E-05

Table 4.1.2.6

`

In this graph, Displacement is in meters and time is in seconds.



Graph 4.1.2.5 (Displacement v/s Time)

`

b.) At Base (Node 12764):-

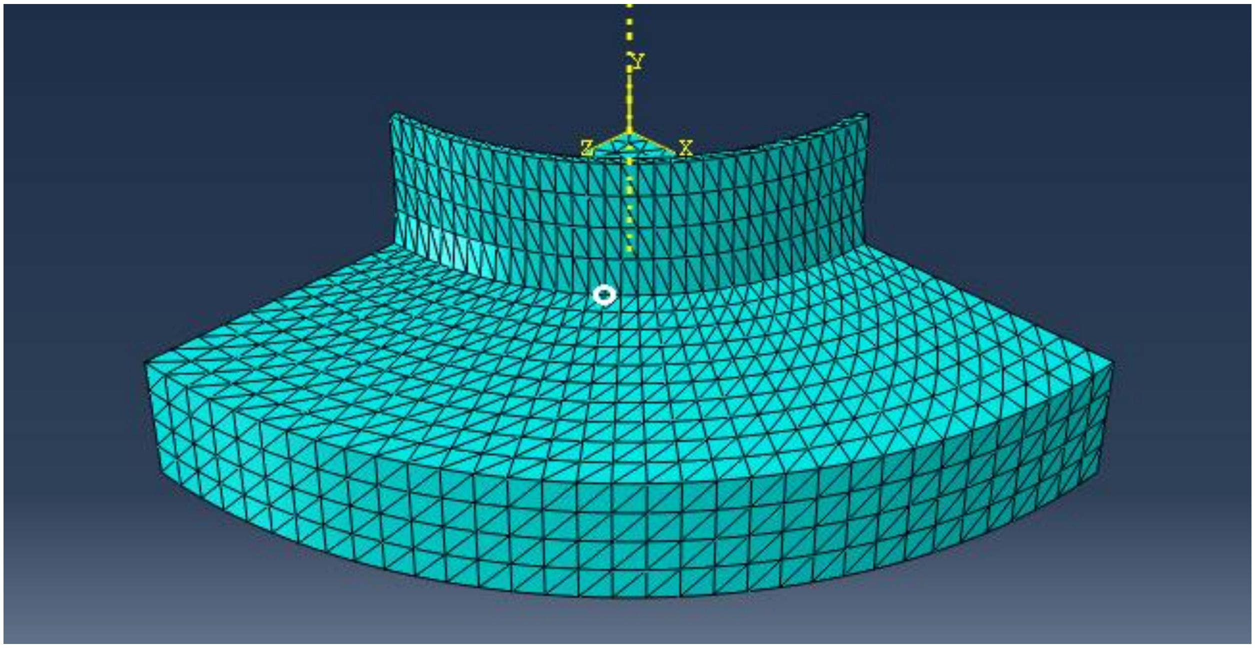


Fig 4.1.1.23

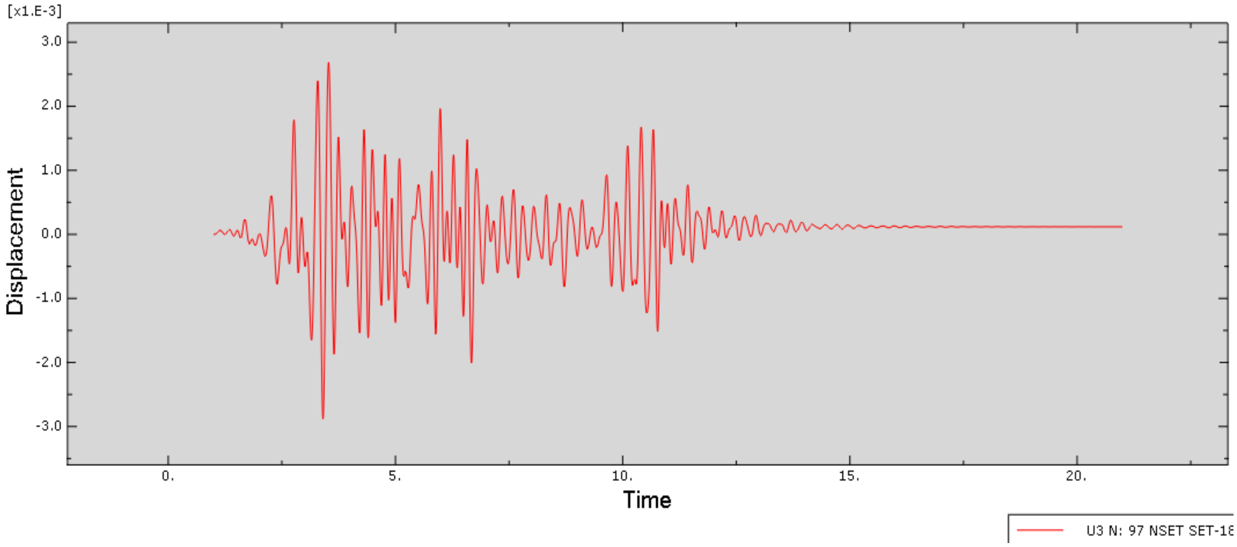
`

Sr.No.	Displacement (meters)	Time (seconds)
1	1	0
2	1.005	-3.10E-09
3	1.01	-1.35E-08
4	1.015	-2.49E-08
5	1.02	-1.72E-08
6	1.025	4.87E-08
7	1.03	2.35E-07
8	1.035	6.19E-07
9	1.04	1.29E-06
10	1.045	2.32E-06
11	1.05	3.82E-06
12	1.055	5.84E-06
13	1.06	8.43E-06
14	1.065	1.16E-05
15	1.07	1.55E-05
16	1.075	1.99E-05
17	1.08	2.48E-05
18	1.085	3.02E-05
19	1.09	3.59E-05
20	1.095	4.17E-05
21	1.1	4.76E-05
22	1.105	5.34E-05
23	1.11	5.89E-05
24	1.115	6.40E-05
25	1.12	6.84E-05
26	1.125	7.22E-05
27	1.13	7.51E-05
28	1.135	7.71E-05
29	1.14	7.82E-05
30	1.145	7.83E-05
31	1.15	7.75E-05
32	1.155	7.58E-05
33	1.16	8.52E-05

Table 4.1.2.7

`

In this graph, Displacement is in meters and time is in seconds.



Graph 4.1.2.6 (Displacement v/s Time)

`

Kobe input:-

a.) At node 19876:-

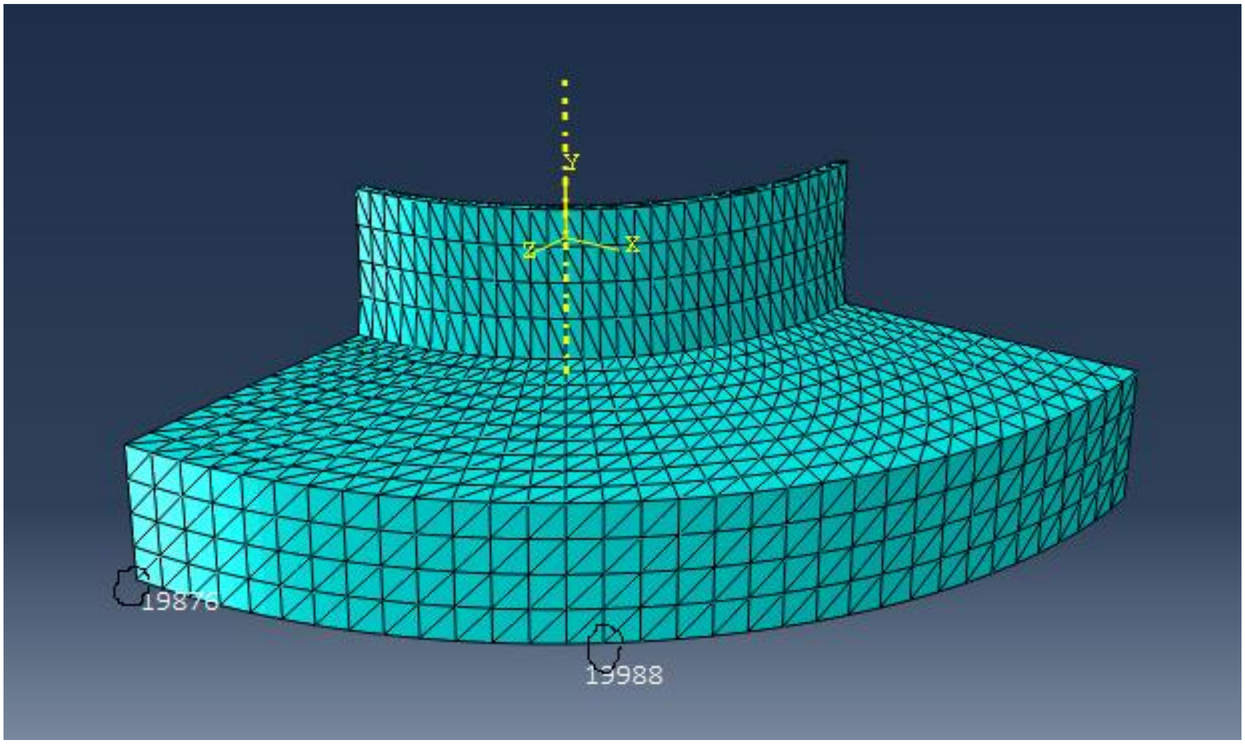


Fig 4.1.1.24

`

Sr.No.	Displacement (meters)	Time (seconds)
1	1	0
2	1.005	-3.10E-09
3	1.01	-1.35E-08
4	1.015	-2.49E-08
5	1.02	-1.72E-08
6	1.025	4.87E-08
7	1.085	3.02E-05
8	1.09	3.59E-05
9	1.095	4.17E-05
10	1.1	4.76E-05
11	1.105	5.34E-05
12	1.11	5.89E-05
13	1.115	6.40E-05
14	1.12	6.84E-05
15	1.125	7.22E-05
16	1.13	7.51E-05
17	1.135	7.71E-05
18	1.14	7.82E-05
19	1.145	7.83E-05
20	1.15	7.75E-05
21	1.155	7.58E-05
22	1.16	8.52E-05

Table 4.1.2.8

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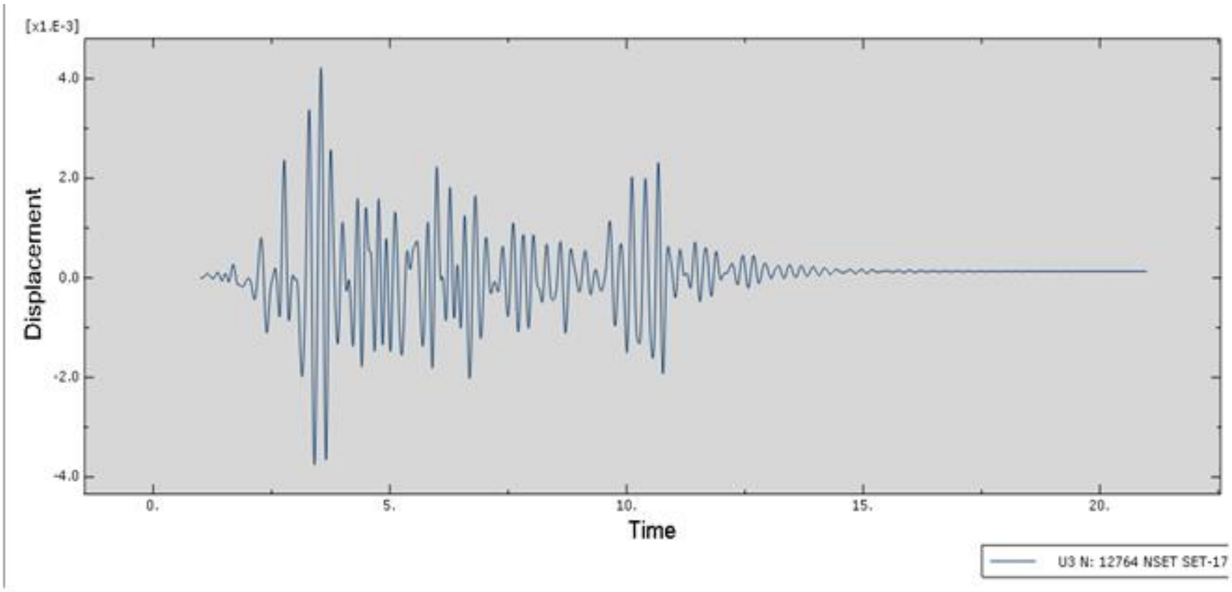

Graph 4.1.2.7 (Displacement v/s Time)

`

b.) At node 1998:-

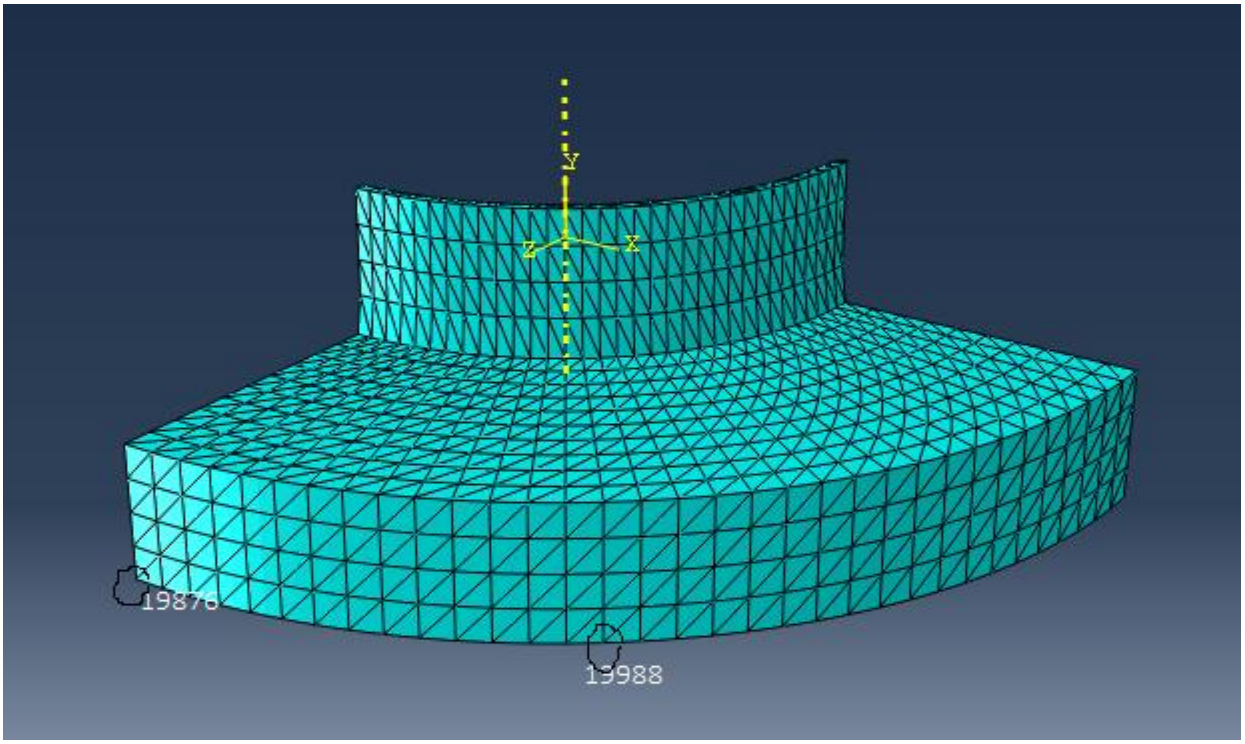

Fig 4.1.1.25

`

Sr.No.	Displacement (meters)	Time (seconds)
1	1.06	1.44E-05
2	1.065	1.74E-05
3	1.07	2.07E-05
4	1.075	2.42E-05
5	1.08	2.78E-05
6	1.085	3.16E-05
7	1.09	3.55E-05
8	1.095	3.94E-05
9	1.1	4.32E-05
10	1.105	4.69E-05
11	1.11	5.03E-05
12	1.115	5.35E-05
13	1.12	5.62E-05
14	1.125	5.86E-05
15	1.13	6.04E-05
16	1.135	6.17E-05
17	1.005	2.43E-08
18	1.01	1.32E-07
19	1.015	3.79E-07
20	1.02	8.23E-07
21	1.025	1.51E-06
22	1.03	2.47E-06
23	1.035	3.71E-06
24	1.04	5.24E-06

Table 4.1.2.9

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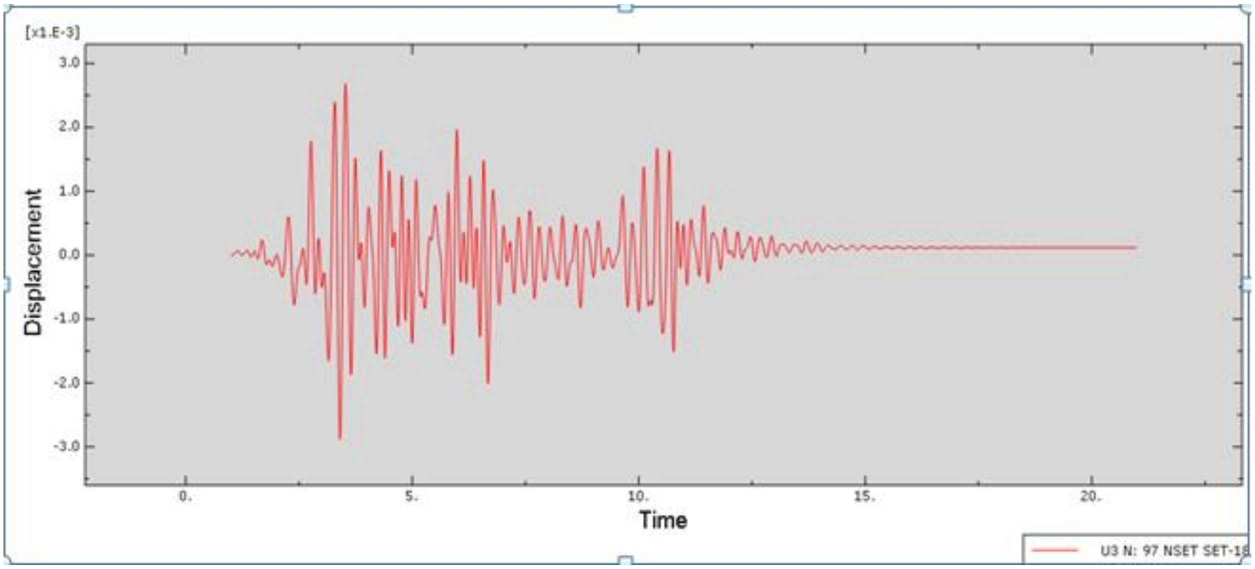

Graph 4.1.2.8 (Displacement v/s Time)

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Northridge input:-

AT node 13604:-

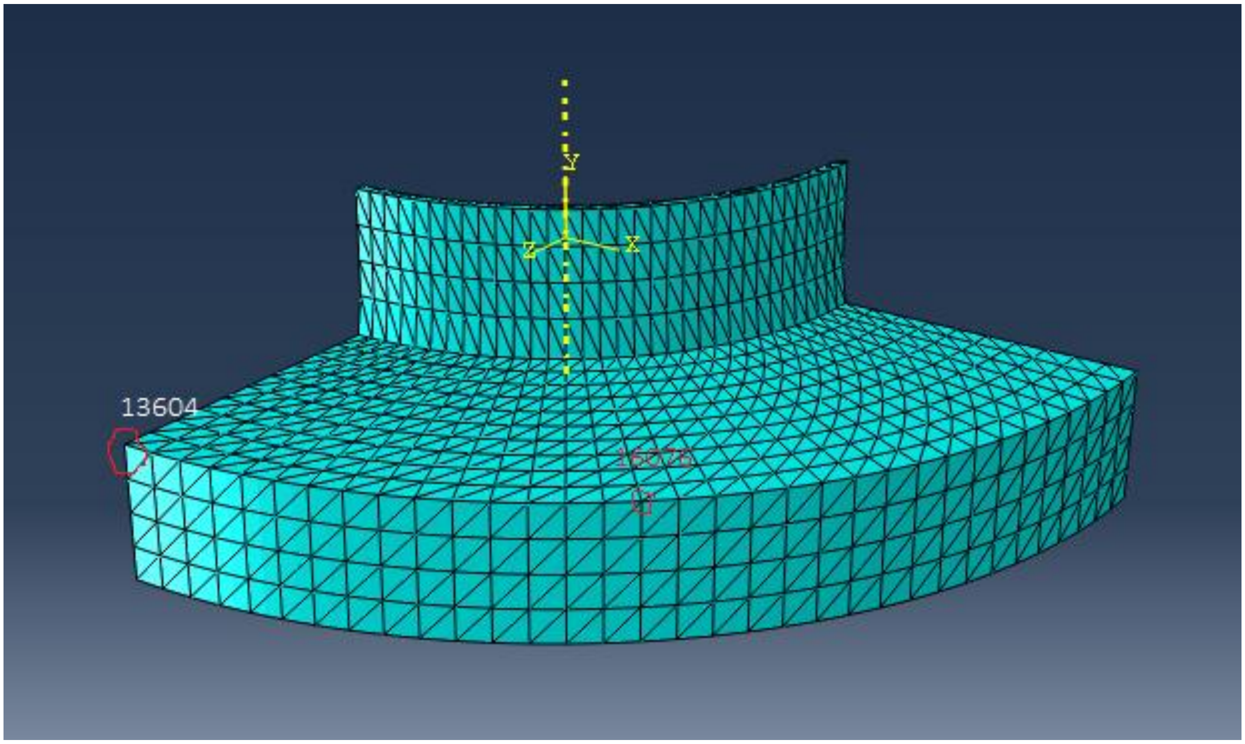

Fig 4.1.1.26

`

Sr.No.	Displacement (meters)	Time (seconds)
1	1	0
2	1.005	-3.10E-09
3	1.01	-1.35E-08
4	1.015	-2.49E-08
5	1.02	-1.72E-08
6	1.025	4.87E-08
7	1.085	3.02E-05
8	1.09	3.59E-05
9	1.095	4.17E-05
10	1.1	4.76E-05
11	1.105	5.34E-05
12	1.11	5.89E-05
13	1.115	6.40E-05
14	1.12	6.84E-05
15	1.125	7.22E-05
16	1.13	7.51E-05
17	1.135	7.71E-05
18	1.14	7.82E-05
19	1.145	7.83E-05
20	1.15	7.75E-05
21	1.155	7.58E-05
22	1.16	8.52E-05

Table 4.1.2.10

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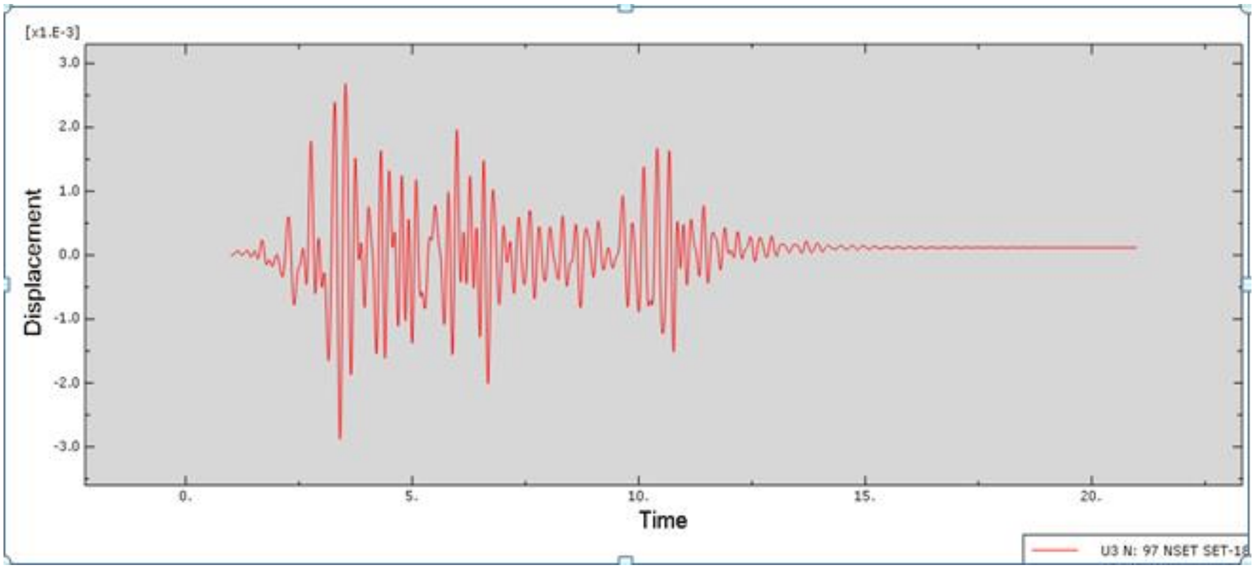

Graph 4.1.2.9 (Displacement v/s Time)

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At node 16076:-

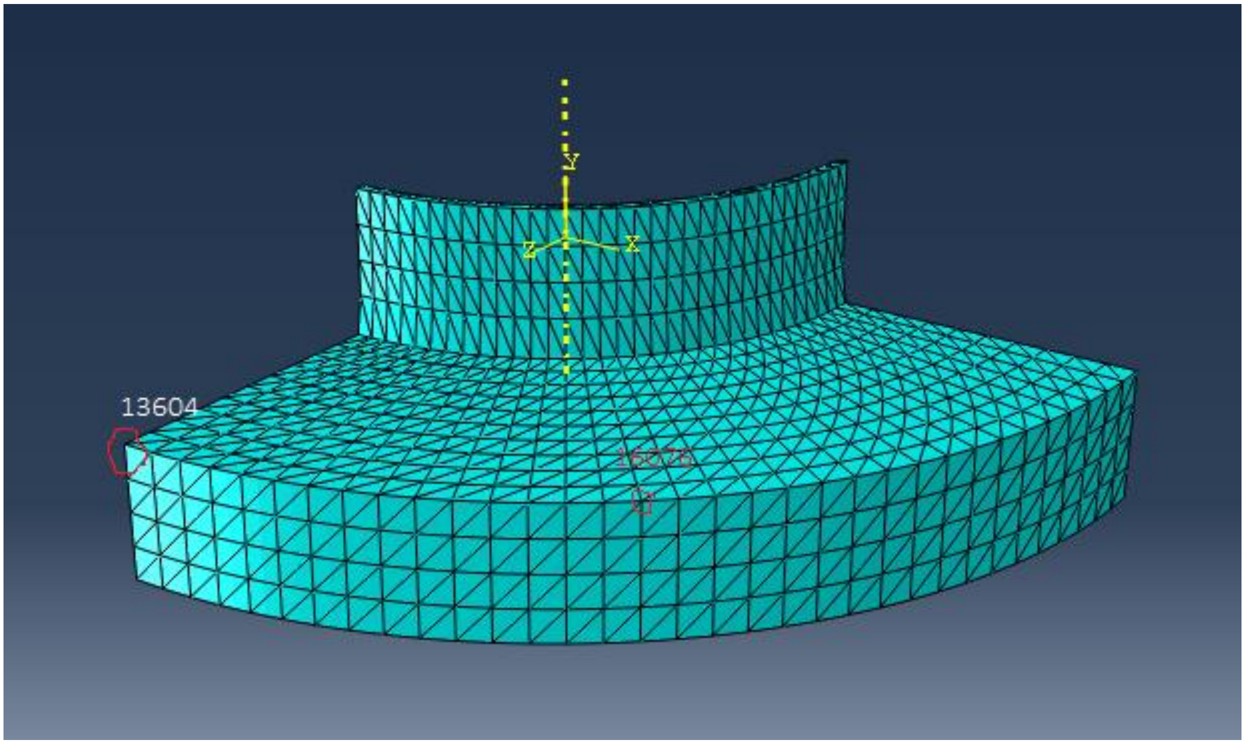

Fig 4.1.1.27

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Sr.No.	Displacement (meters)	Time (seconds)
1	1.06	1.44E-05
2	1.065	1.74E-05
3	1.07	2.07E-05
4	1.075	2.42E-05
5	1.08	2.78E-05
6	1.085	3.16E-05
7	1.09	3.55E-05
8	1.095	3.94E-05
9	1.1	4.32E-05
10	1.105	4.69E-05
11	1.11	5.03E-05
12	1.115	5.35E-05
13	1.12	5.62E-05
14	1.125	5.86E-05
15	1.13	6.04E-05
16	1.135	6.17E-05
17	1.005	2.43E-08
18	1.01	1.32E-07
19	1.015	3.79E-07
20	1.02	8.23E-07
21	1.025	1.51E-06
22	1.03	2.47E-06
23	1.035	3.71E-06
24	1.04	5.24E-06

Table 4.1.2.11

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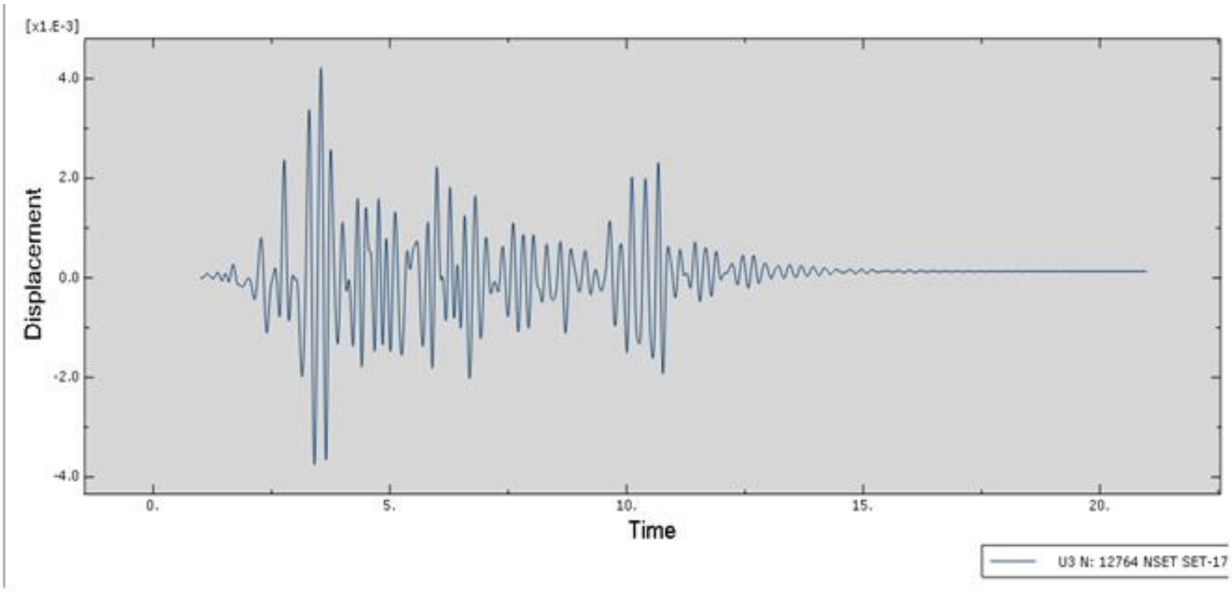

Graph 4.1.2.10 (Displacement v/s Time)

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CHAPTER 5

CONCLUSION

1. Incorporate the amplitude of earthquake in uniform and different points of structure (which does not briefly explained in the literature review).
2. According to paper the frequency should range between 2.5 to 4.7 Hz. According to my results the frequency is 3.9 which satisfies the above statement
3. Maximum displacement is 4.1mm i.e. increase in public safety and low risk factor.
4. This study will help in minimizing the stress generated in dam due to spatial varying earthquake ground motion which results in cracking of dam.
5. Distance and the natural period are the two factors on which magnitude of correlation depends.

Recommendation for future study:-

In future we will include the regional earthquake information to exhibits local information and will do the 3-D tomography to get the total crustal structure. This leads to better understanding of the seismic effect. Further to comprehend the idea of geometry in 3-D it is critical to utilize high determination design acknowledgement apparatus connector to the 3-D seismic design. This analysis helps to know the maximum deflection or displacement on the particular location on the structure during the earthquake.

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