RESPONSE OF UNDERGROUND TUNNEL DUE TO UNIFORM AND MULTISUPPORT EXCITATION

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

CERTIFICATE

This is to confirm that the work which is being exhibited in the thesis title "**RESPONSE OF UNDERGROUND TUNNEL DUE TO UNIFORM AND MULTISUPPORT EXCITATION**" in partial satisfaction of the necessities for the honor of the level of Master of technology with specialization in "**Structural Engineering**" and submitted to the Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is a real record of work completed by **Abhishek Kumar (162657)** amid a period from July 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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Date: ----May 2018 Abhishek Kumar

M.Tech- Structural Engineering

ABSTRACT

In today's world, various structures are used for different purposes in many areas such as transportation, metro stations and water transportation. The serviceability of the structures is crucial in many cases following an earthquake, i.e., earthquake ought not force such harm prompting the loss of serviceability of the structure. The seismic outline philosophy used for these structures contrasts from numerous points of view from the over the ground structures. The most ordinarily used approach in powerful investigation of underground structures is to disregard the inertial powers of the substructures since these powers are moderately inconsequential in spite of the instance of surface structures. In seismic outline of these underground structures, distinctive methodologies are used like free-field deformation approach and soil-structure communication/interaction approach.

The effect of uniform excitation and multisupport excitation of earthquake on underground tunnel has to be analyzed. When subjected to uniform and multisupport excitation, the underground tunnel may be subjected to higher forces, displacement and stresses than they were designed to wear. It is assumed that the underground tunnels are safe from earthquakes without adequate analysis. There are few cases of damage to underground tunnels during earthquakes. Several difficulties may arise during the dynamic analysis of underground tunnels as the whole system as a whole is non-linear in nature. Like bridges this system is also a type of extended structure and soil conditions may change with the distance covered. A ground motion with phase difference or spatially correlated ground motion may be used to excite the system.

Underground tunnel will be modeled as circular and will be modeled in ABAQUS. In this software, we will do modeling and create different steps and perform the response spectrum method, modal analysis and time history analysis and applying different types of earthquake response to our structure and check the deformation, frequency stress at each and every nodes. After exciting the structure using uniform and multisupport excitation, the response of the system will be studied and then it will be compared i.e. between uniform and multisupport excitation of underground tunnel and this analysis will be analyzed.

Keyword:- Steel, Underground tunnel, Seismic analysis (Modal analysis, Response spectrum, Time history, El Centro, Kobe, Northridge Earthquake response inputs).

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CHAPTER 1

INTRODUCTION

BACKGROUND

It is analyzed that earthquake ground motion can vary significantly over distances for same order of magnitude. Some engineering structures are extended over very high distances like bridges, tunnels etc. It is typically known as SVEGM i.e. Spatial Varying Earthquake Ground motion. Seismic analysis is measured at different locations within the dimensions of an engineered structure like bridge and tunnel is typically different.

Factor:-

There are three factors on which spatial earthquake ground motion with same magnitude depends.

1. Depends on different arrival times of seismic waves at different stations.
2. Loss of coherency of motion (i.e. due to reflection and refraction of waves in heterogeneous medium).
3. Depends on local soil conditions.

These are the main three causes in which seismic response of the structure is depends i.e. the loss of coherency of motion, the time slack between the entry of the wave at focuses situated at various separations from the source point, and depends upon the soil types i.e. soil properties differences at different different sites or places. Due to these causes/factors, variation in ground motion occurs. Seismic analysis of underground tunnel is important as they may be used in areas of high seismicity. In general, our structure i.e. tunnel is going to fail when it is concentrated on high seismic scale (fails in according to displacement).Generally tunnels are made where is no way to construct roads, bridges. When we construct the structure, there are several loads resting on its surface of contact and also SVEGM effects also applies on it. The underground tunnel may not be able to wear this load and hence can collapse or damage. There are few shots that our structure is sheltered from Spatial Varying Earthquake ground Motion. The spatial variety of seismic ground movements importantly affects the reaction of life savers, for example, spans, pipelines, underground passages, correspondence transmission frameworks and so forth. Because of these structures reach out finished long separations parallel to the ground, their backings experience diverse movements amid a seismic tremor. It has been as of late perceived that the Uniform and multisupport of seismic ground movements can greatly affect the reaction of broadened structures. From this, we can easily calculate the response of the structure under seismic excitation and these results are identical same when earthquake in real life strikes on the surface.

The aftereffects of recurrence and relocation are past dissects announced in the writing demonstrate that the impact of the spatial variety of seismic ground movements on the reaction of extensions and towers can't be dismissed.

We are doing this study because there is no such work has been done on underground tunnel and this work is very helpful for future. The analysis and design is based on software (ABAQUS)

In which material properties and loadings and boundary conditions are given according to our assumptions. These supposition might be unlikely for the shifting ground movement For illustrations: - Northridge seismic tremor (1994), Landers Earthquake (1992). If there should arise an occurrence of multi-traverse frameworks of essentially bolstered spans, both the fluctuating vibration properties of adjoining ranges and the non-uniform spatial ground excitation at the extension backings can initiate differential developments of neighboring decks and prompts Pounding between connect decks if the underlying hole between the decks isn't sufficient to stay away from such a crash. In the current real quakes, for example, El Centro (1940), Northridge(1994) and Kobe (1995), the entire structure is fall because of high scope of tremor and low soil bearing limit. No attempts have been made to design a structure under seismic response which can lower and minimize the effect of damage. It is necessary to develop a unique technique to investigate the effect of uniform and multiple support excitations on the structure. The effect of earthquake on underground tunnel which can gave us accurate readings of displacement and stresses analyzed.

1.1 SVEGM:

SVEGM is a spatial varying earthquake ground motion. For measuring the seismic response of structure by means of equipment i.e. Earthquake Accelogram.When earthquake response is given to the structure, the part where response of earthquake is high is the top most part of the tunnel. From that, the stress value is maximum at its top surface. The stress and strain responses are calculated by random vibration analysis i.e. a part of finite element method. A 3-D model of underground tunnel is made in according to represent finite element model. There are few researchers who did the work on underground tunnel to check the deformation patterns of structure when earthquake strikes on the structure.

Assumptions:

. Excitations are same at all support points.

. Excitations are coherent at all location of structure.

1.1.1 Causes of Spatial Varying earthquake ground Motion:

. Wave passage effect

. Incoherence effect

. Local site effect

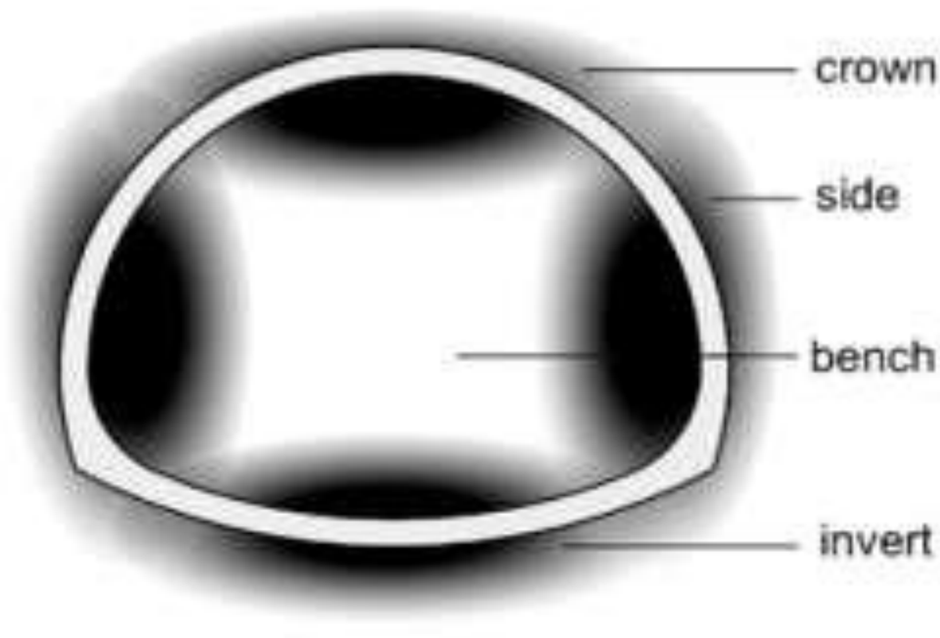
1.2 Underground tunnel:

When there is no way to built road and bridges (over an obstacles like mountain, water), a superstructure is built which can provide a passage through it known as tunnel.

Reasons to build a tunnel

- When the path simultaneousness a snag, for example, a mountain to stay away from by passing the deterrent.
- Built once in a while to defeat a water deterrent as a restoration for building a scaffold above it.
- Sometimes worked for framework like power links, water, correspondence and sewerage to evade harm and partition over the ground.

Parts of tunnel



CHAPTER 2

LITERATURE REVIEW

Zeghal M and Ahmed Ghaffar A (1992) [1]

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 is analyzed. In this paper, system identification techniques are used. They applied series of seismic response and check the non-linear behavior of dam. To evaluate the system behavior of dam, a pattern recognition step is added. They added the material property of dam from plastic theory. At the end when whole steps are completed, they conclude that pattern recognition step gave us the evidence of structure's nonlinearity and gave us the information that model response is pretty good in upstream and downstream as compared to longitude and vertical directions. [1]

Chen M and Harichandran S (2001) [2]

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 analyzed. From ths paper, they made a inhomogeneous dam model and apply seismic effect. From that they observe that the stress generated on the dam is maximum at its base and increased with increase in response of earthquake. In this paper, they made five coherency models (change in height and length) and compare their results. [2]

Zerva A and Zervas V (2002) [3]

In thus paper "**spatial variation of seismic ground motion**" is analyzed. To evaluate the response, a dense instrument arrays are used. Also, effect and estimation of coherency is evaluated. They made different models to describe the coherence and amplitudes that are made on structure when earthquake strikes on it. In this paper, they evaluate the difference in amplitude and phase of earthquake response at various locations and at extended years. They use SMART 1 array and also dense instrument array to initiate the phase and visibility effect. [3]

Chen, Zhiyi, Haitao Yu, and Yong Yuan (2014) [4]

In this paper" **Full 3D seismic analysis of a long-distance water conveyance tunnel**" in Shanghai is analyzed. In this, a model of tunnel is made in abaqus having small mesh size, giving soil properties and loading properties. For calculation, high performance supercomputer is used for numerical analysis, LS-DYNA is used. They investigate properly about the effect of seismic response on tunnel cross section i.e. stress, displacement, strain etc. Basically they restudied about the structure's deformation behavior i.e. affected by seismic response. . Also, they studied fitting flexible joints method which proved to be more adequate. In these type of structure, stiffness plays major role. So, when we made structure to stands against earthquake, is has low stiffness (Major point). And due to liquefaction of hydraulic fills, deformation took place in the structure (crakes and displacement). [4]

Mirko Corigliano , Laura Scandella Carlo G. Lai , Roberto Paolucci (2011) [5]

In this paper" **Seismic analysis of deep tunnels in near fault conditions"** a case study in Southern Italy is analyzed. This paper helps us to provide information about the earthquake response of underground tunnel in high range of seismic region. This paper basically a case study that compare the various approaches given by different researchers. From this, they conclude that the stress at the lining of the railway exhibits the maximum stress when earthquake strikes on it. So, when we construct a structure in seismic region, we have to check geological conditions of that site and soil-structure interaction along the transverse direction of underground tunnel. [5]

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

In this paper "**Analysis of dynamic response of an earth dam during 1999 chi-chi earthquake in Taiwan**" a numerical analysis is performed. In this paper, they evaluate dynamic responses (by use of p-z (pastor and zienkiewicz) model). Basically they compares the two methods of dynamic response calculation i.e. p-z model and Mohr-coulomb model. From that they calculate that the horizontal displacement is high at upstream shell and vertical settlement is high at top of the dam, when earthquake strikes on the dam. And with the help of p-z model, gave us the accurate results as compared to others. Also, displacement and settlement occurs due to pore water in the upstream. [6]

Yufeng Gaoa, Yongxin Wua, Dayong Li , Hanlong Liu , Ning Zhanga (2012) [7]

In this paper" **An improved approximation for the spectral representation method in the simulation of spatially varying ground motions**" is analyzed. In this paper, they use SRM(spectral representation method) which is used in the stimulation to calculate the responses from earthquake ground motion. In SRM, they used lagged coherency matrix. From this, the deformation of earthquake on the structure is not same at all points. This method is used for the combination with the interpolation approximation approach to check the coherence effect i.e. affected by earthquake.· [7]

Youssef M.A. Hashash,, Jeffrey J. Hook, Berger Schmidt,John I-Chiang Yao (2001) [8]

In this paper "**Seismic design and analysis of underground structures**" is discussed. This paper basically discussed about the type of tunnel, material property and where tunnels are mostly used (i.e. urban areas). They design tunnel having large diameter (greater than 6 meters) and portal structures. They doesn't discussed about pipelines, sewer lines. The larger diameter of tunnels means having cross section is smaller than the tunnel length.

Categories:

1. Exhausted or mined passages
2. cut-and-cover burrows
3. Inundated tube burrows

Utilizations: metro structures, parkway passages, and extensive water and sewage transportation channels. [8]

Youssef M.A. Hashash , Duhee Park , John I.-Chiang Yao (2005) [9]

In this paper "**Ovaling deformations of circular tunnels under seismic loading, an update on seismic design and analysis of underground structures**" is analyzed. In this paper, a cicular tunnel of diameter 6 meters is used. They evaluate the displacement and forces that are evolved on the tunnel when earthquake is strikes on it. When they compares the results of both procedure, they found that results are actually same that they found in both cases. But analytical method does not gave the exact result of the thrust on the tunnel lining i.e. gave us the limitation about other method. [9]

K.C. Lin , H.H. Hung , Judy P. Yang , Y.B. Yang (2016) [10]

In this paper "**Seismic analysis of underground tunnels by the 2.5 D finite/infinite element approach**" is analyzed. They use recorded free-field which is based on finite element approach. The near and far fields are displayed by limited and boundless components. They contrast the 1d and 2.5D. In 1D, the powers at every hub and relocation at close field is figured at every recurrence of tremor. They accept that the dirt passage framework is uniform along the passage hub, the2.5 D approach can represent the wave transmission along the passage pivot, which diminishes to the 2D case for limitless transmission speed. From Chi-Chi quake in 1990, the estimation of flat and vertical parts are received when numerical examination is performed. A definitive anxieties and appropriation examples of the passage segment under the P-and SV-waves are considered by the 2.5D and 2D approaches, i.e. demonstrate valuable to the plan of underground passages. [10]

Hassan Sedarat , Alexander Kozak , Youssef M.A. Hashash ,Anoosh Shamsabadi , Alex Krimotat (2009) [11]

In this paper "**Contact interface in seismic analysis of circular tunnels**" is analyzed. This paper includes the information about shear strain which is evaluate due to vertically propagating horizontal shear waves. At the point when strain is assess on the structure, it comes about ovaling and rounding disfigurement up roundabout and rectangular passages. However, this paper portrays the numerical limited component investigation of soil-roundabout passage fixing association with contact conditions that enable both constrained slippage and partition to forestall advancement of conceivably unreasonable typical elastic and extraneous powers at the interface of passage (in case of circular tunnel). [11]

Peng Li, Er-Xiang Song (2015) [12]

In this paper "**Three dimensional numerical analysis for the longitudinal seismic response of tunnels under an asynchronous wave input**" is analyzed. In this paper, 1-dimensional time space approach is applies to compute the free field movement and furthermore on the base of numerical investigation. Fundamentally the investigation of this paper may encourage the further refined nonlinear numerical examination and also a disentangled examination of the longitudinal seismic reaction of tunnels. [12]

J.Mirjapur, M.Sahmardani, S.Tariverdilo (2017) [13]

In this paper "Seismic **response of submerged floating tunnel under support excitation**" is analyzed. In this paper, the fluid forces in view of seismic stacking on SFT are learned with two procedures 2D and 3D fluid field models, and the seismic model is reproduced the same as cross spooky thickness of ground expanding speed. At that point, it is introduced that within the sight of circulated solidness, the state of methods of passage does not have standard system as frequencies increment, as it were; the state of modes is replaced. [13]

Duhee Park, Myung Sagong, Dong Yeop kwak, Chang Gyun Jeong (2009) [14]

In this paper"**Simulation of tunnel response under spatially varying ground motion"** is analyzed. In this paper, a three dimensional limited component investigation are performed to fortify the passage reaction. This examinations use the longitudinal evacuating profile prepared from the spatially factor ground development expulsion time history which are made at ten division detachments with a partition between time of 100m. The processed evacuation profiles are constrained reliably at the parallel limits of the ground profile encompassing the passages and 3-D pseudo static limited component investigations are performed. This investigation prompts high pivotal worry the longitudinal way. [14]

A.A.Stamos, D.E.Beskos (1996) [15]

In this paper "3-**D seismic response analysis of long lined tunnels in half space**" is analyzed. In this paper an uncommon BEM in the recurrence area has been developed for the seismic examination of unendingly since a long time ago lined passages of uniform cross-segment covered into a uniform half-space and subjected to plane symphonious influxes of a self-assertive heading of proliferation. Inelastic spectra, as opposed to flexible spectra with comparable damping and period. This three-dimensional issue is adequately regarded by this extraordinary technique as a two-dimensional one with clear computational increases. The utilization of quadratic limit components and progressed coordinate particular incorporation strategies expands the exactness of the technique, which has been affirmed by examinations with other mmaerical strategies based on some numerical investigations including a roundabout tube shaped lined passage subjected to 17 and SV symphonious waves. [15]

Peter Faijfar, M.EERI (2000) [16]

In this paper "**nonlinear analysis method for performance-based seismic design**" is analyzed. From this paper, a moderately straightforward nonlinear technique for the seismic investigation of structures (the N2 strategy) is exhibited. It joins the weakling investigation of a multi-degree-of-freedom (MDOF) show with the reaction range examination of an equal single-degree-of-freedom (SDOF) framework. This component speaks to the real contrast as for the limit range technique. In addition, request amounts can be acquired without cycle. By and large, the consequences of the N2 strategy are sensibly exact, given that the structure sways prevalently in the main mode. Some extra restrictions apply. In the paper, the strategy is portrayed and talked about, and it essential determinations are given. The likenesses and contrasts between the proposed technique and the FEMA 273 and ATC 40 nonlinear static investigation strategies are examined. [16]

Nicholas A. Alexander (2008) [17]

In this paper "**multi-support excitation of single span bridges, using real seismic ground motion recorded at the SMART-1 array**" is analyzed. In this paper the utilizing of some exponential sort best-fit for the total coherency between two disparate spatial areas, genuine multi-station information from SMART-1 is utilized to produce a more point by point photo of the spatial heterogeneity exhibit. A novel amendment conspire is utilized to reprocess the SMART-1 information. This paper thinks about the blunders, in seismically prompted powers, that can be accumulated if indistinguishable help excitation (ISE) examination is utilized as a part of place of a multi-bolster excitation (MSE) investigation. The impact of basic mode coupling is researched. The conditions under which an ISE investigation isn't moderate are accounted for**.** [17]

ZHOU, G., BAO, Y., LI, X., & PENG, X. (2009) [18]

In this paper "**Review on dynamic analyses of structures under multi-support excitation"** is examined. In this paper, This paper gives a general review and summary on dynamic analyses of structures under multi-support excitation according to recent researches. Firstly, the spatial variations of ground motions and the effect of critical traveling waves are presented. Secondly, the review and the remark on methods used in analyses are given. Thirdly, the importance for

Correcting ground motion records is discussed. Then, the seismic response characteristics of the structures under the multi-support excitations are summarized. [18]

Soyluk K. (2004) [19]

In this paper **"Comparison of random vibration methods for multi-support seismic excitation analysis of long-span bridges**" is examined. In this paper, the spatial inconstancy impacts of ground movements on the dynamic conduct of long-traverse spans are researched by an irregular vibration based ghostly investigation approach and two reaction range techniques. The spatial fluctuation of ground movements between the help focuses is considered with the coherency work, which emerges from three sources: ambiguity, wave-section and site-reaction impacts. Irregular vibration examinations are performed on two deck-type curve spans and a link stayed connect display. Power unearthly thickness capacity and reaction range esteems utilized as a part of arbitrary vibration examinations are resolved relying upon the accounts of September 20, 1999, ChiChi, Taiwan seismic tremor. The outcomes emphatically suggest that the separated background noise movement model can be acknowledged as a fairly advantageous model to speak to genuine tremor ground movements. It can be likewise watched that the basic reactions for every irregular vibration examination depend to a great extent on the force and recurrence substance of energy otherworldly thickness capacities. [19]

Lee M. C. & Penzien J. (1983) [20]

In this paper "**Stochastic analysis of structures and piping systems subjected to stationary multiple support excitations**" is analyzed. In this paper, A stochastic technique has been produced for seismic examination of structures and funneling frameworks subjected to different help excitations. Stationary background noise stationary sifted repetitive sound excitations are utilized. A PC program has been created to complete the stochastic seismic investigation. Results for a sensible atomic power plant structure and funneling framework with and without modular cross-correlations and bolster excitation cross-correlations are looked at. From these outcomes, it is presumed that disregarding cross-correlations can prompt huge mistakes. The stochastic strategy revealed is appeared to be more exact than the reaction range technique and more sparing than the time-history technique; along these lines, it is prescribed for seismic investigation of atomic power plants. [20]

Allam S. M., Datta T. K. (2000) [21]

In this paper "**Analysis of cable-stayed bridges under multi-component random ground motion by response spectrum method**" is analyzed. In this paper, A reaction range strategy is exhibited for the seismic examination of link stayed spans subjected to in part associated stationary irregular ground movement. The strategy depends on the connection between the power otherworldly thickness work and the reaction range of the info ground movement, and the essentials of the arbitrary vibration hypothesis. . In either the time or the recurrence space, mean and extraordinary estimations of auxiliary and funneling framework reaction can be found, including the impacts of cross-correlations of modular reaction and cross-correlations of numerous help excitations. The examination properly considers the fractional connection of ground movements between the backings, the quasistatic segment of the reaction and the modular relationship between's various methods of vibration. A link stayed connect is broke down under an arrangement of critical parametric varieties keeping in mind the end goal to confirm the reactions acquired by the reaction range technique by contrasting them and those got by the phantom examination approach of irregular vibration hypothesis. [21]

Luco J. E. & Wong H. L. (1986) [22]

In this paper "**Response of a rigid foundation to a spatially random ground motion**" ia analyzed In this paper, A technique to get the dynamic reaction of a broadened unbending establishment bolstered on a flexible half-space when subjected to a spatially changing ground movement including both arbitrary and deterministic impacts is exhibited. . Also, effect and estimation of coherency is evaluated. They made different models to describes the coherence and amplitudes that are made on structure when earthquake strikes on it The technique depends on a vital portrayal of the reaction of the establishment as far as the free-field ground movement. Numerical outcomes for an unbending square establishment and for a ground movement portrayed by a specific spatial soundness work are depicted. The outcomes got demonstrate that the spatial irregularity of the ground movement produces impacts like the deterministic impacts of wave section including diminishment of the translational parts of the reaction at high frequencies and making of shaking and torsional reaction segments. The likelihood of characterizing a successful clear level speed which produces impacts proportional to those from a given spatial arbitrariness is investigated. [22]

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 underground tunnel subjected to uniform and multisupport excitation.

3.2 Scope of the study:

Importance of the study:

- Leads to better design
- Low risk factor
- Public safety
- Low maintenance cost

CHAPTER 4

MODELING

4.1 Modeling

4.1.1 3D modeling of underground tunnel using abaqus

- Diameter of tunnel = 6 meters
- Length of tunnel = 200 meters

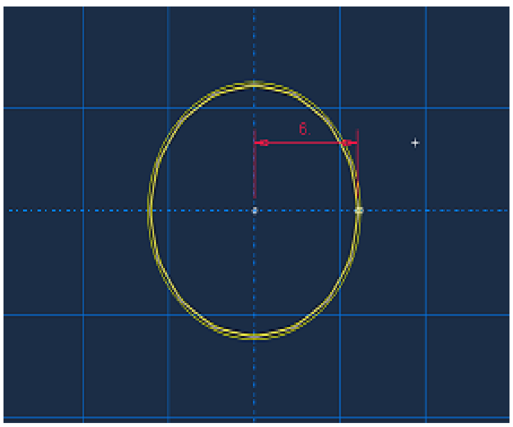


Fig 4.1.1.1 Diameter of tunnel

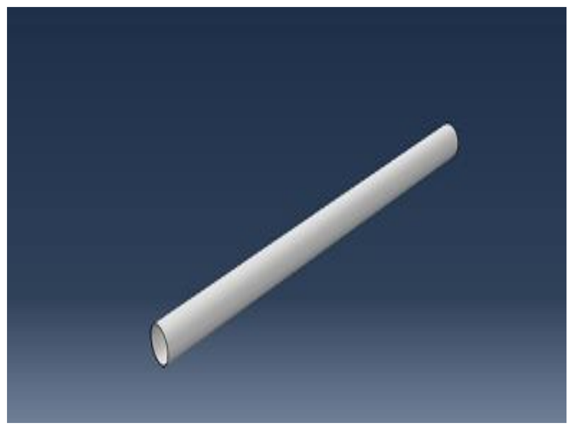


Fig 4.1.1.2 Model generate

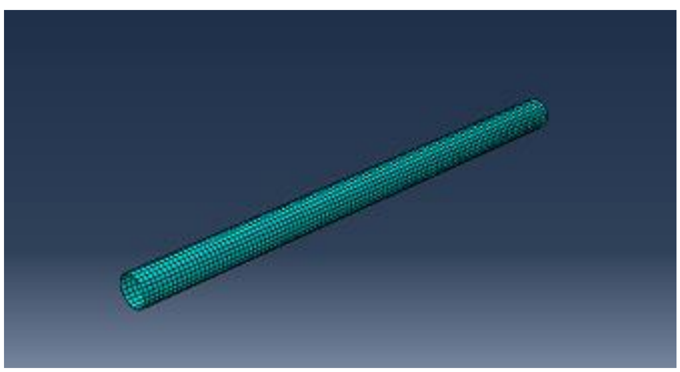


Fig 4.1.1.3 Meshing

4.1.2 a.) <u>Modal analysis</u>

A method used to decide a structure's vibration attributes.

- Natural frequencies
- Mode shapes
- Mode cooperation factors i.e. how much a given mode takes an interest in a provided guidance.
- Most central of all the dynamic investigation writes.

Procedure:-

Six steps in a modal analysis:

- First of all we have to build the model.
- Assign materials properties.
- Create step (procedure type – linear perturbation)
- Apply boundary conditions.
- Create meshing and job.
- Results

- **Build the Model:-**

Fig. 4.1.2.1 Modeling of tunnel

- **Assign materials properties.:-**

1. Mass density of steel = 7850 Kg/cubic meters
2. Young's modulus = 210 GPa
3. Poison's ratio = 0.3

- **Create step (procedure type – linear perturbation):-**

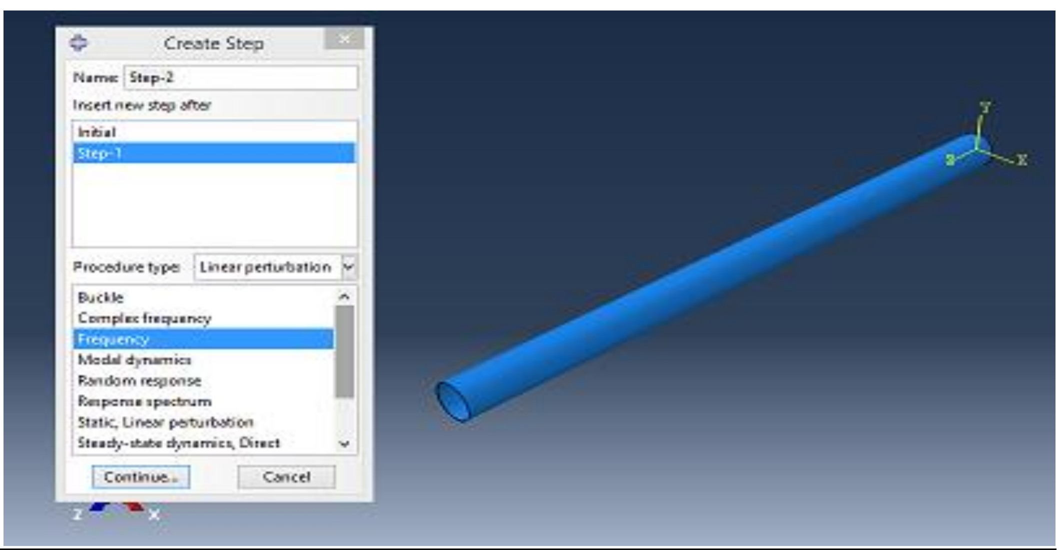


Fig. 4.1.2.2 Create step

- **Create Interaction:- (Elastic foundation = 200 MPa for dense soil)**

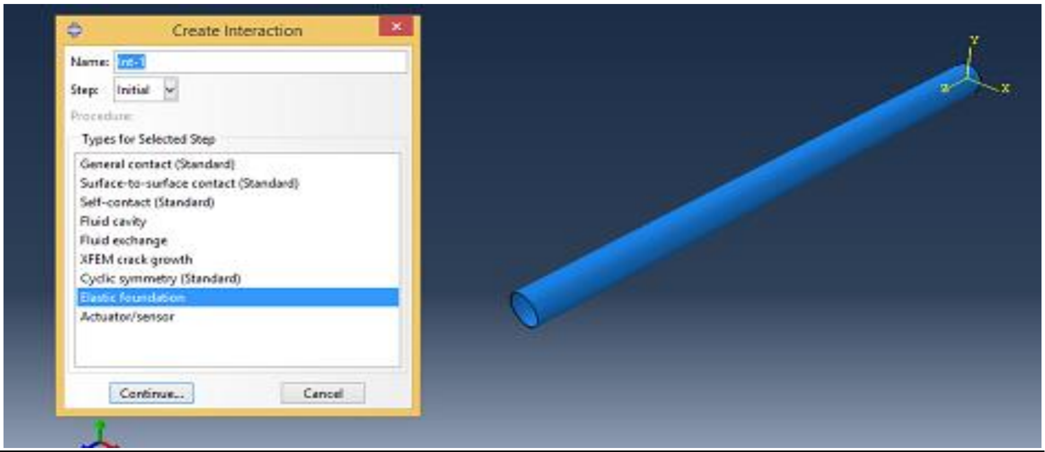


Fig 4.1.2.3 Create interaction

- **Create meshing:-**

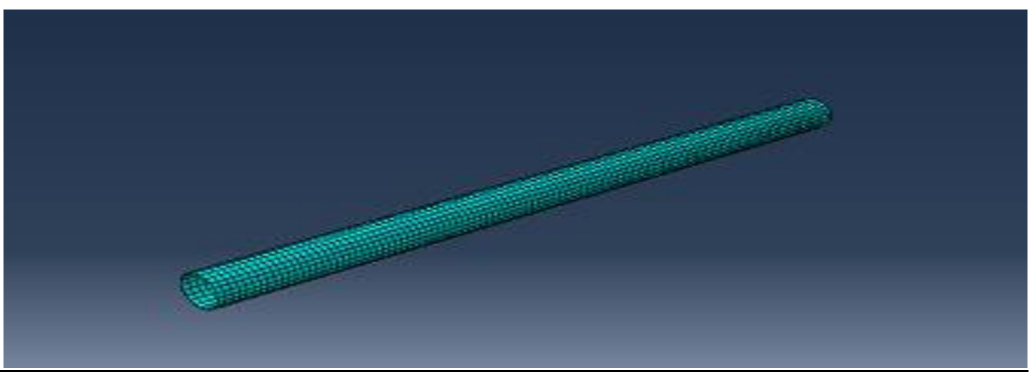


Fig 4.1.2.4 Meshing

- **Job Submission and Results.**

4.1.2 b.) Response Spectrum Analysis

Response spectrum or Reaction ranges a strategy which measures the commitment from every characteristic method of vibration to demonstrate the imaginable most extreme quake reaction of a flexible structure. Reaction range examination gives shrewdness into dynamic conduct by estimating ghostly quickening, speed or relocation as a component of basic period for a given time history and the plane of damping on the structure..

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:-

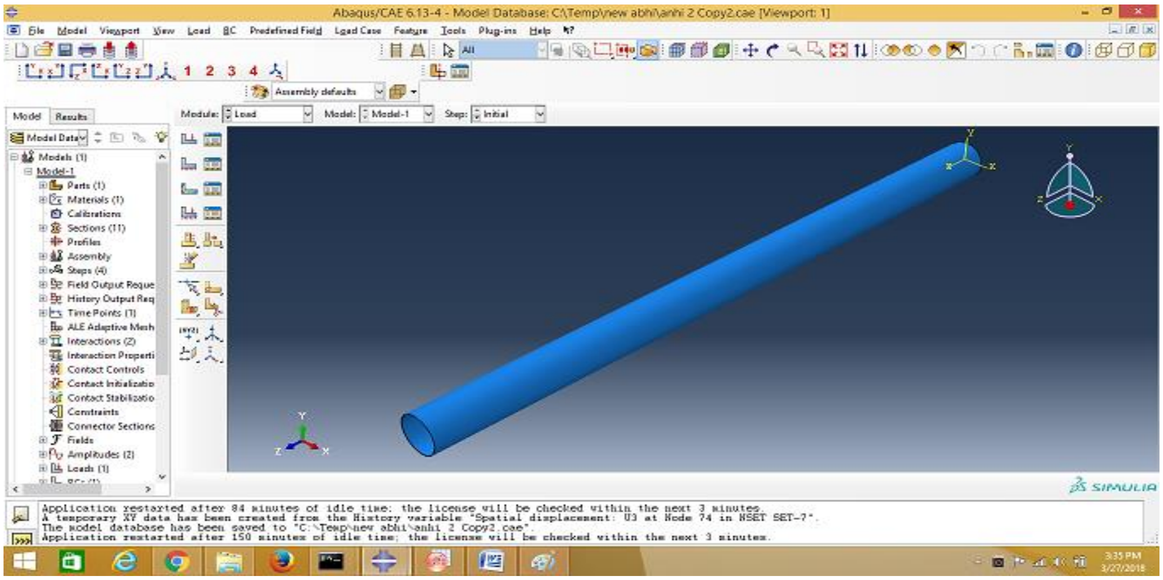


Fig 4.1.2.5 Load module

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

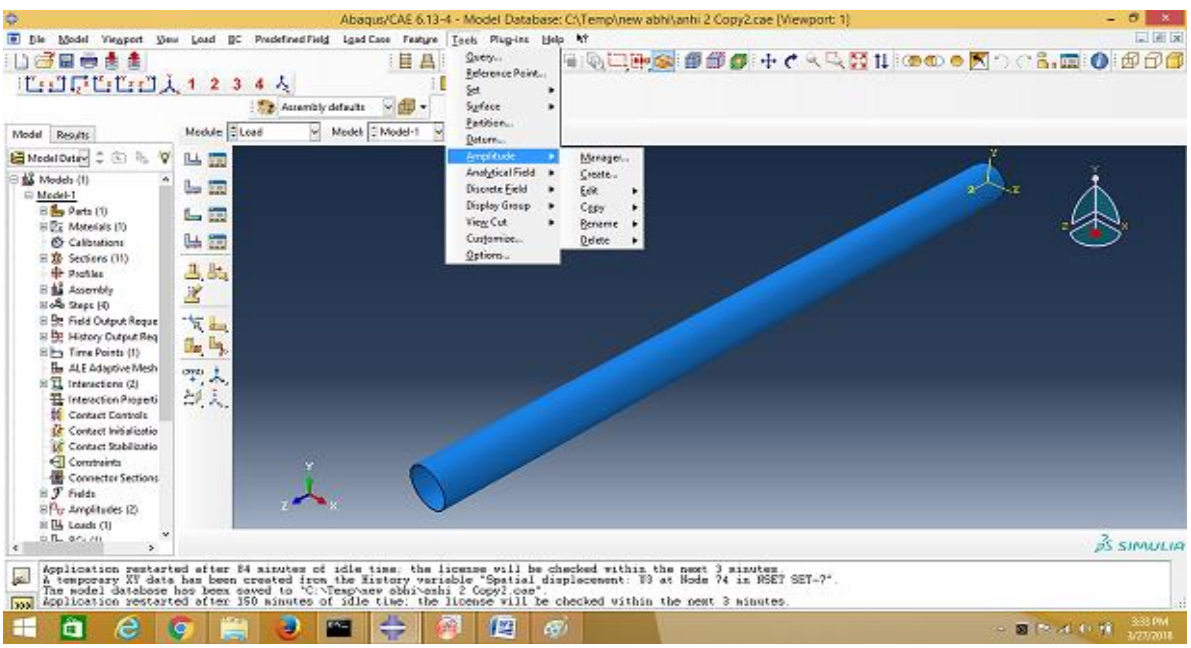


Fig 4.1.2.6 selection of amplitude from tool box

3. Create amplitude and select spectrum and continue:-

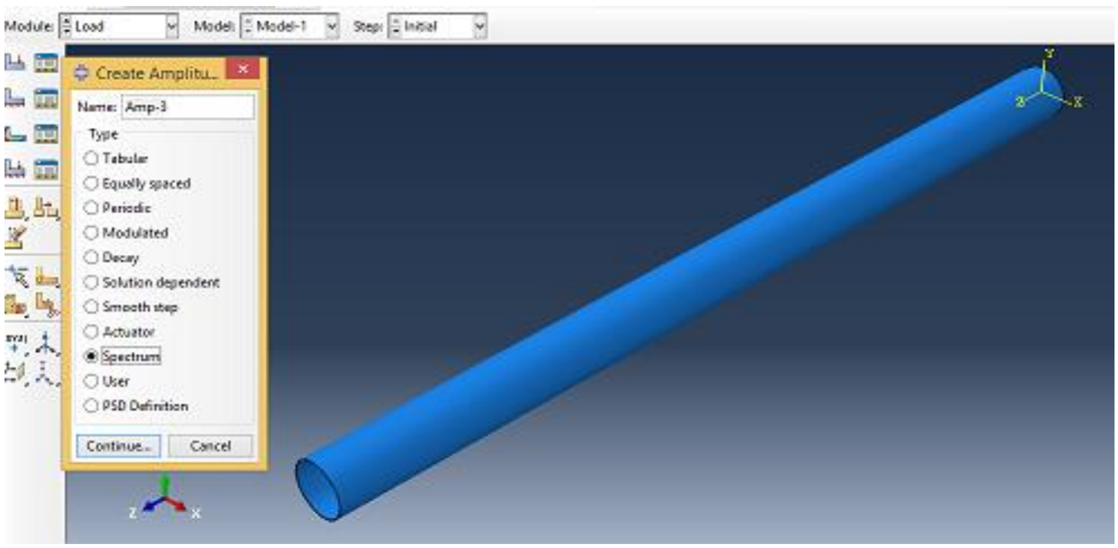


Fig 4.1.2.7 Create amplitude and select spectrum

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

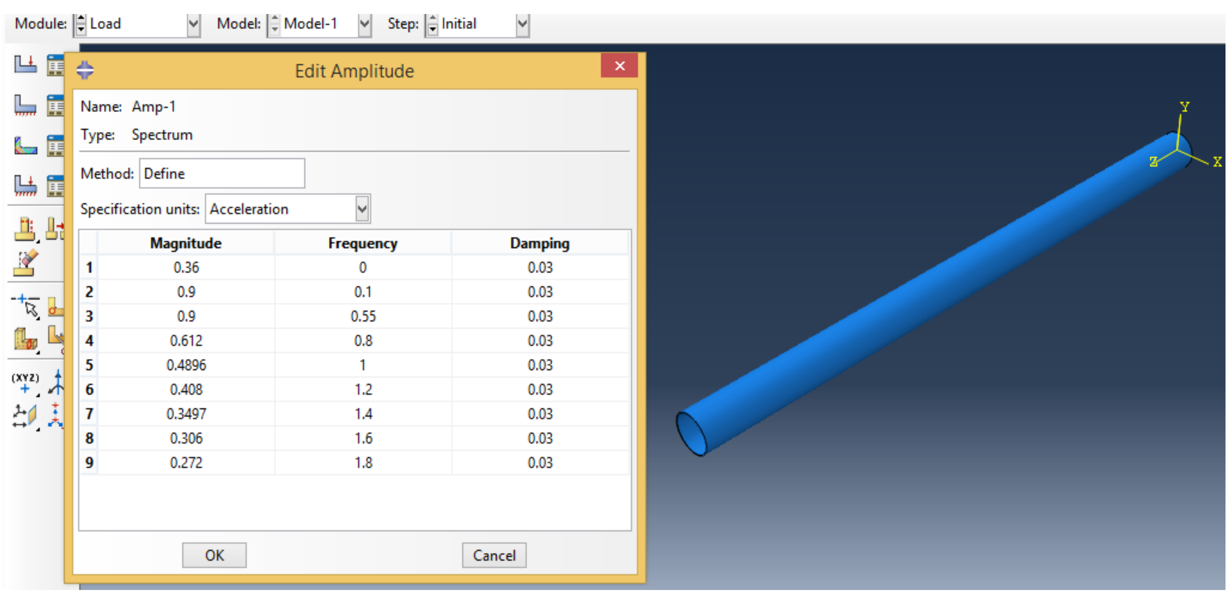


Fig 4.1.2.8Selection of acceleration from specification unit

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

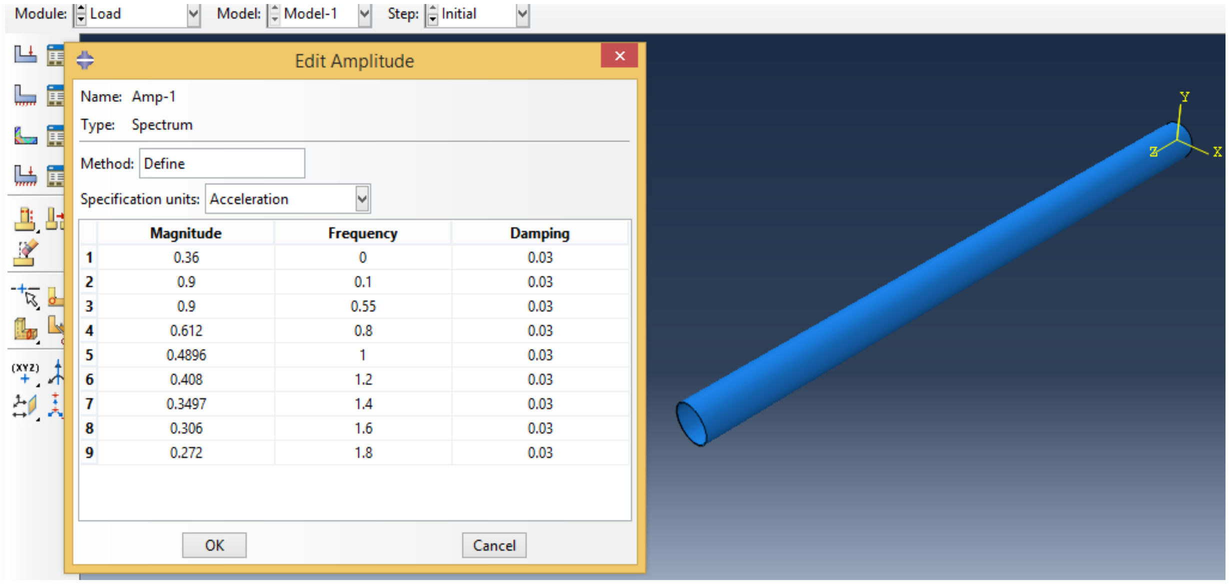


Fig 4.1.2.9 data enter of amplitude and damping

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

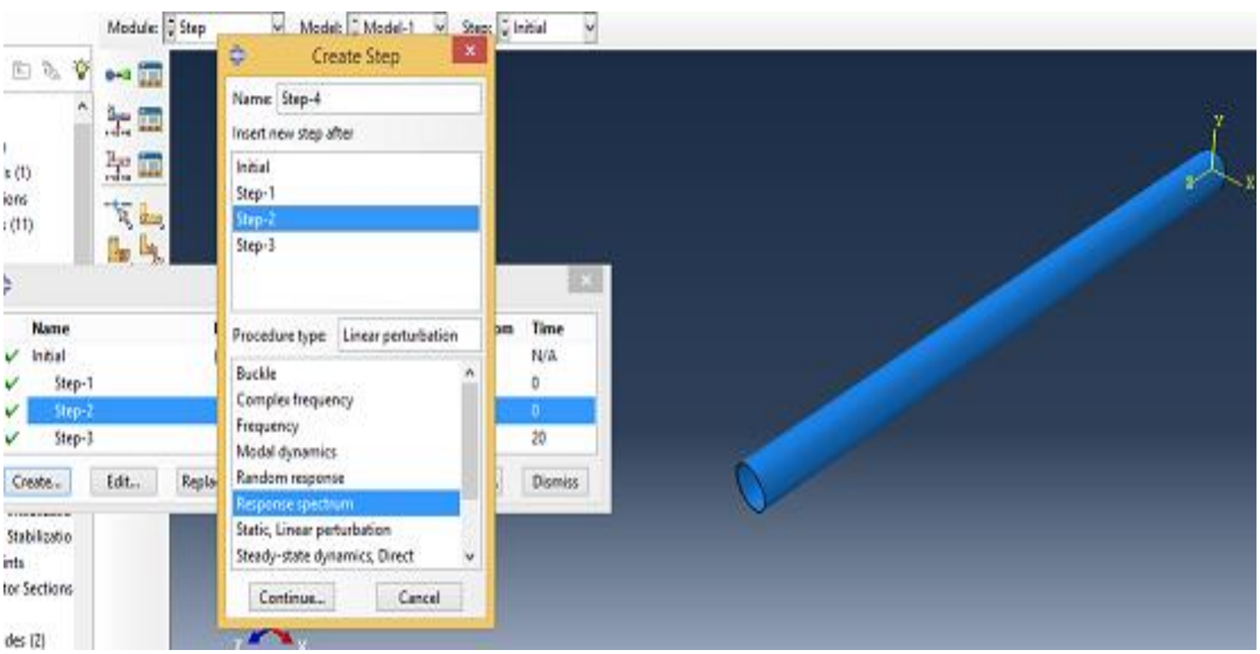


Fig 4.1.2.10 step generation and select spectrum

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

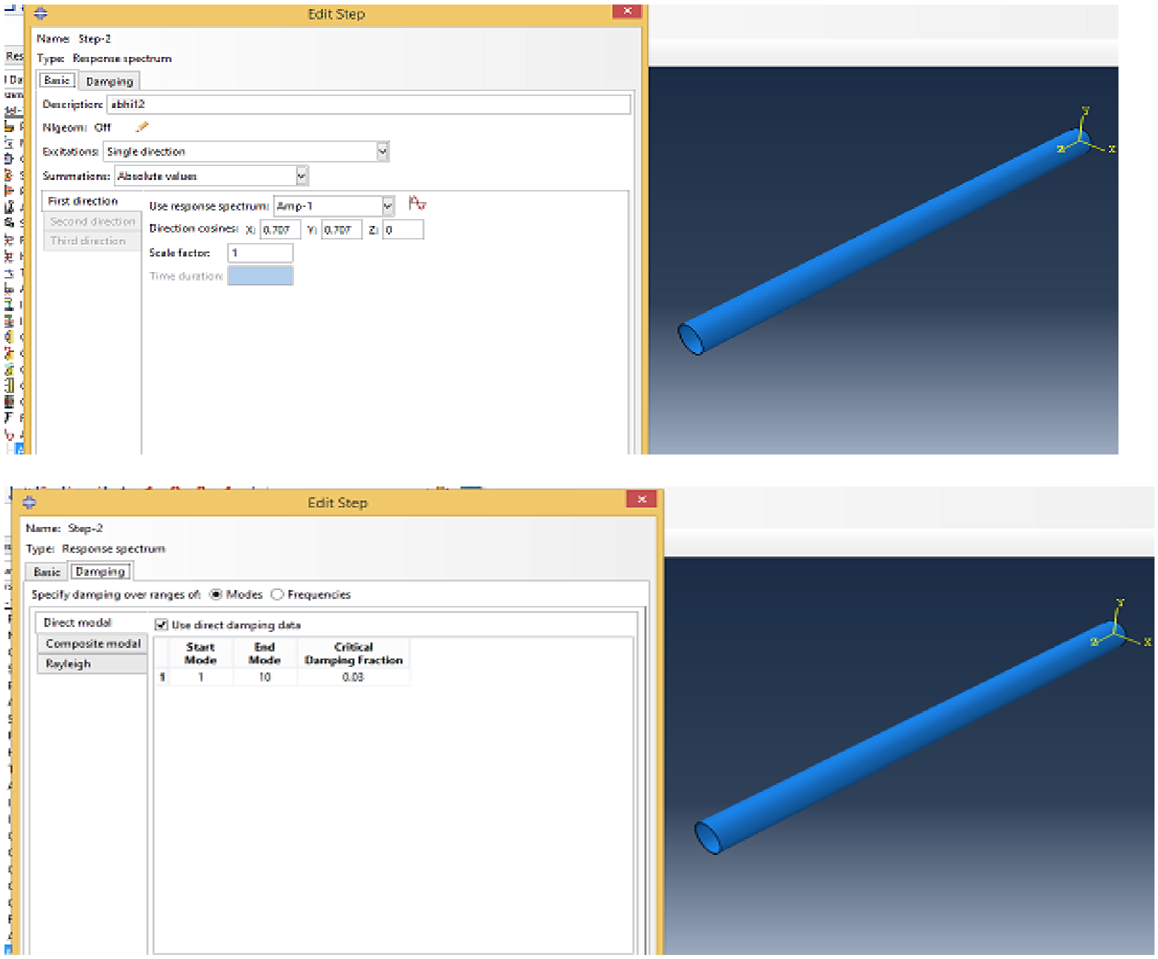


Fig 4.1.2.11 add directional cosine, damping and mode points

8. **Submit the job and result analysis:-**

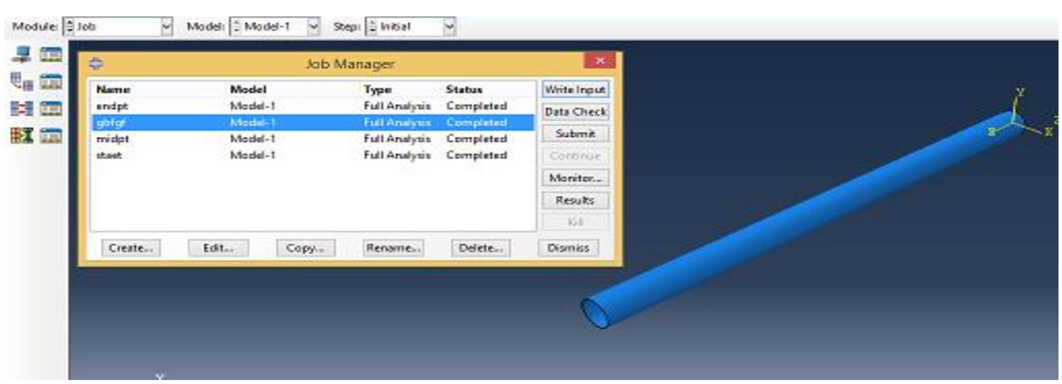


Fig 4.1.2.12 job submission and analyze result

4.1.2 c.) Time History Analysis

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

Difference between Response Spectrum and Time History analysis is:-

A full time history will give the reaction of a structure over the long haul amid and after the utilization of a heap. Though, Response-range examination (RSA) is a factual investigation strategy which measures the commitment from every common method of vibration to demonstrate the feasible most extreme seismic reaction of a basically versatile structure. Reaction range investigation gives understanding into dynamic conduct by estimating phantom increasing speed, speed, or dislodging as an element of auxiliary period for a given time history and level of damping.

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:-**

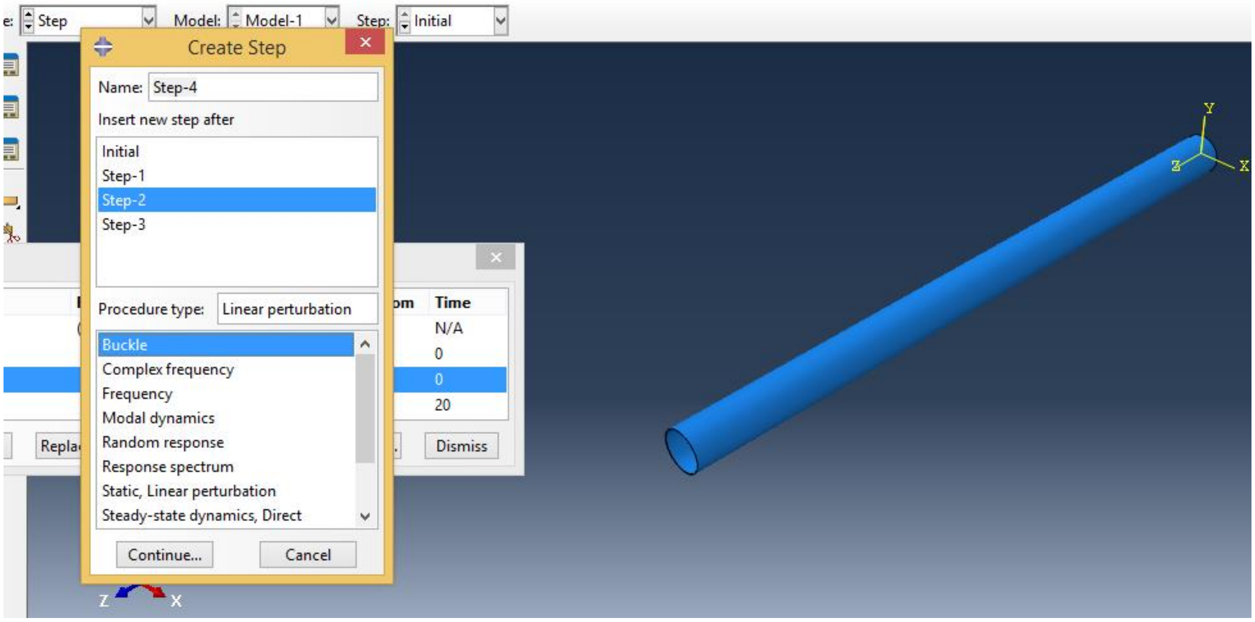


Fig 4.1.2.13 Step generation (linear perturbation)

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

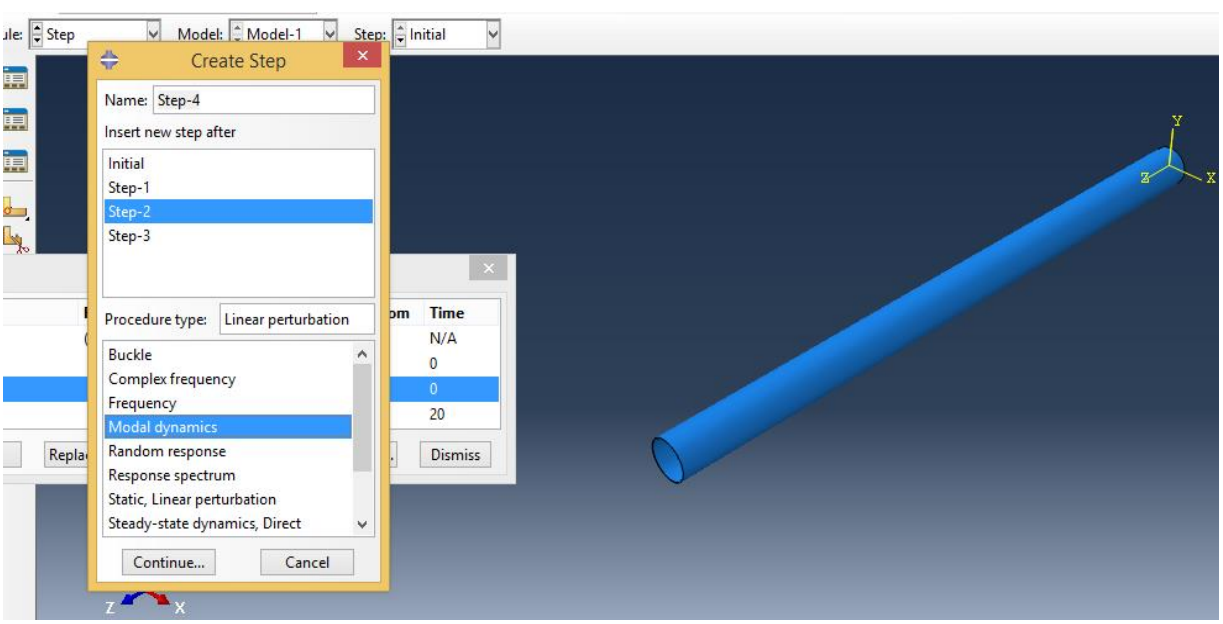
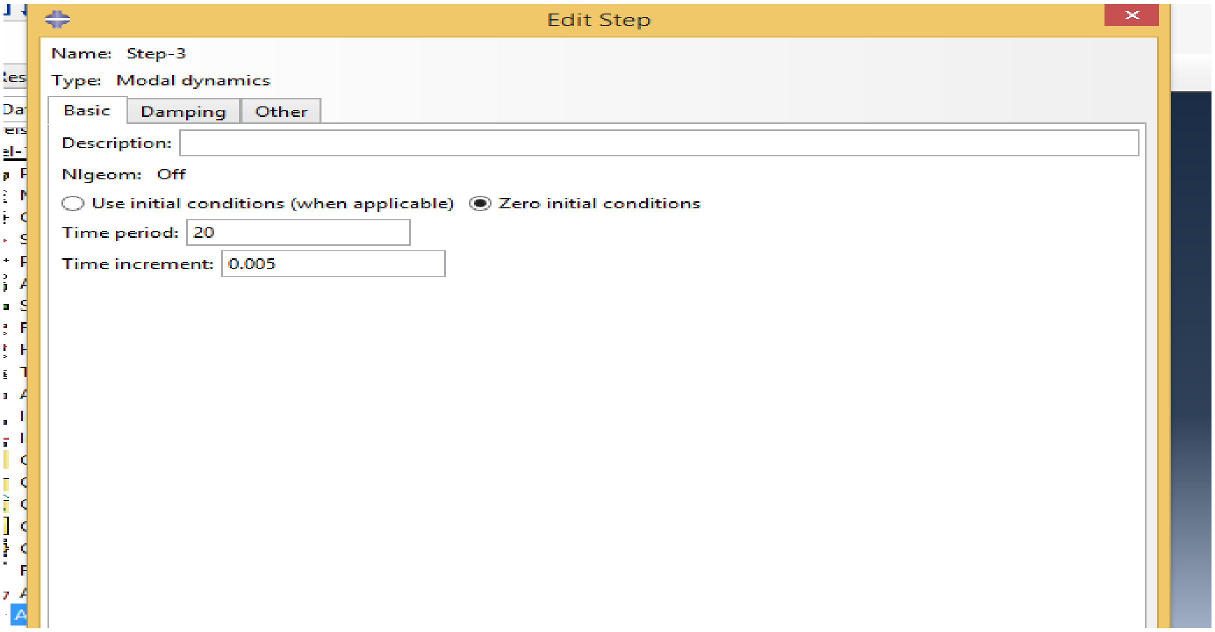


Fig 4.1.2.14 selection of modal analysis

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:-**



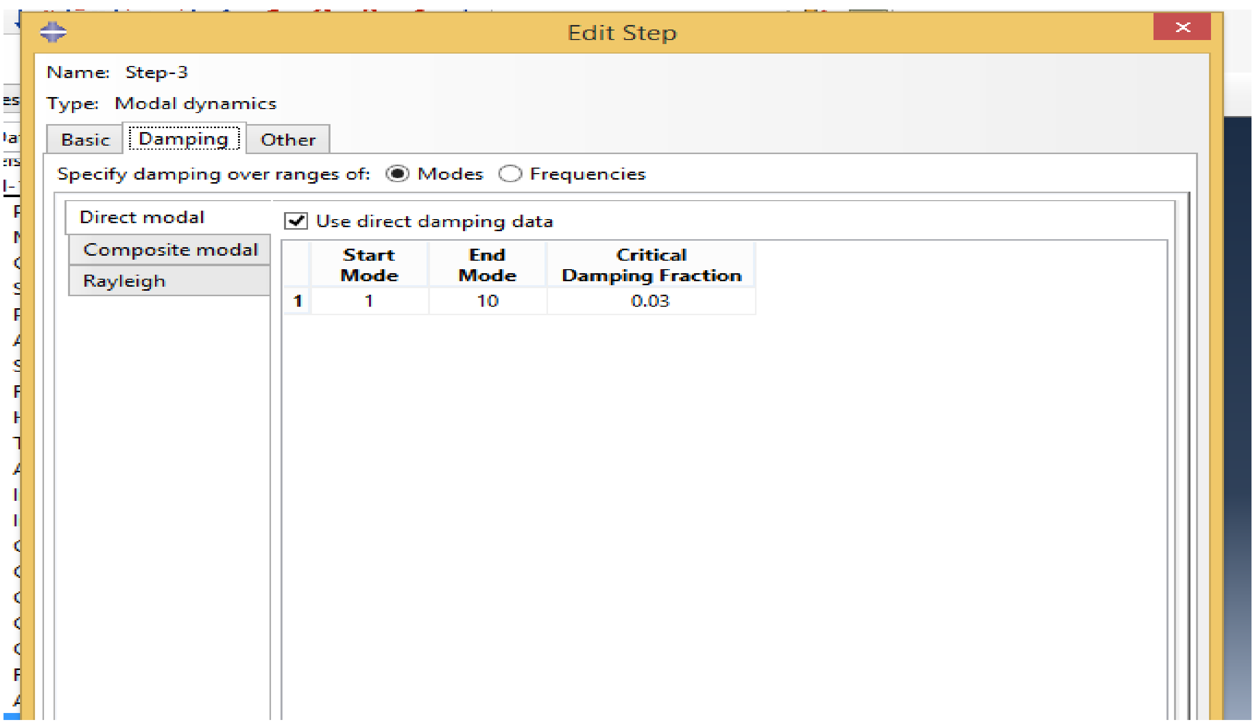


Fig 4.1.2.15 data enters time period, damping, mode pts, increment

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

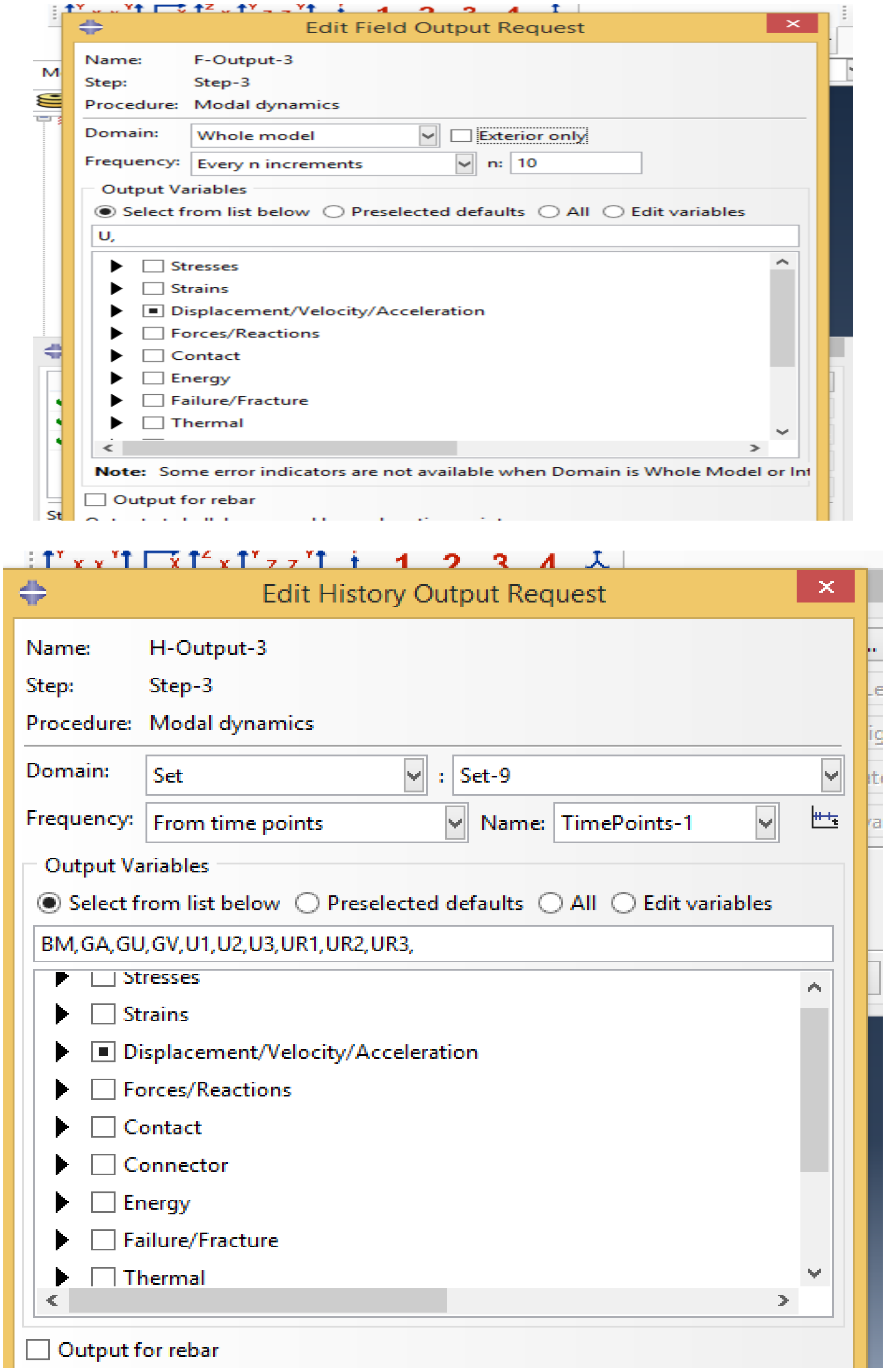


Fig 4.1.2.16 Create field output and output history field

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:-**

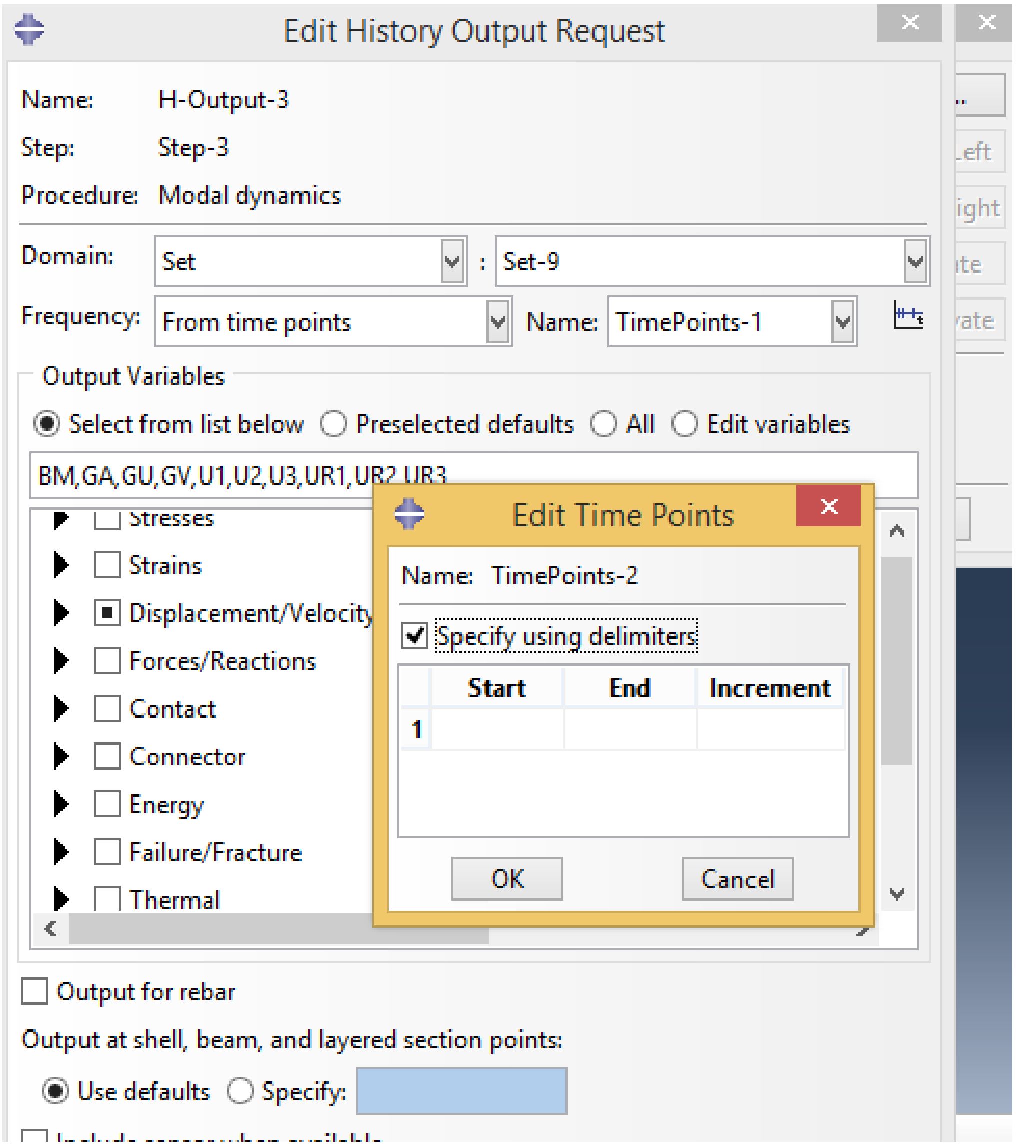


Fig 4.1.2.17 Create step and enter time interval

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

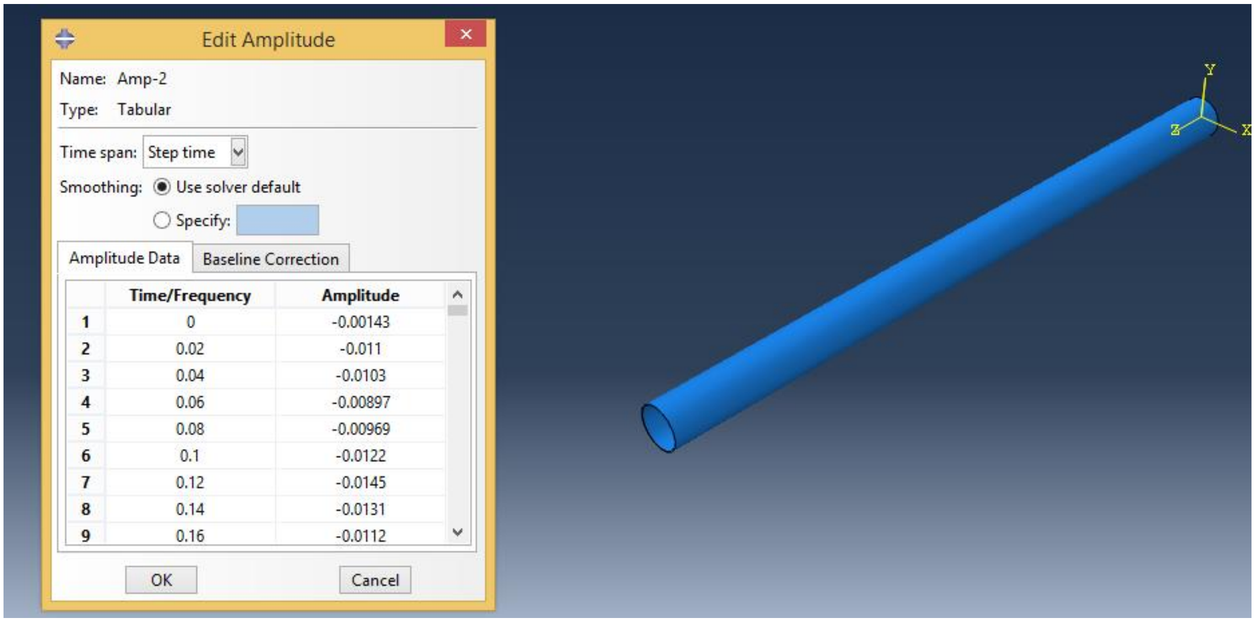


Fig 4.1.2.18 Create amplitude data

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

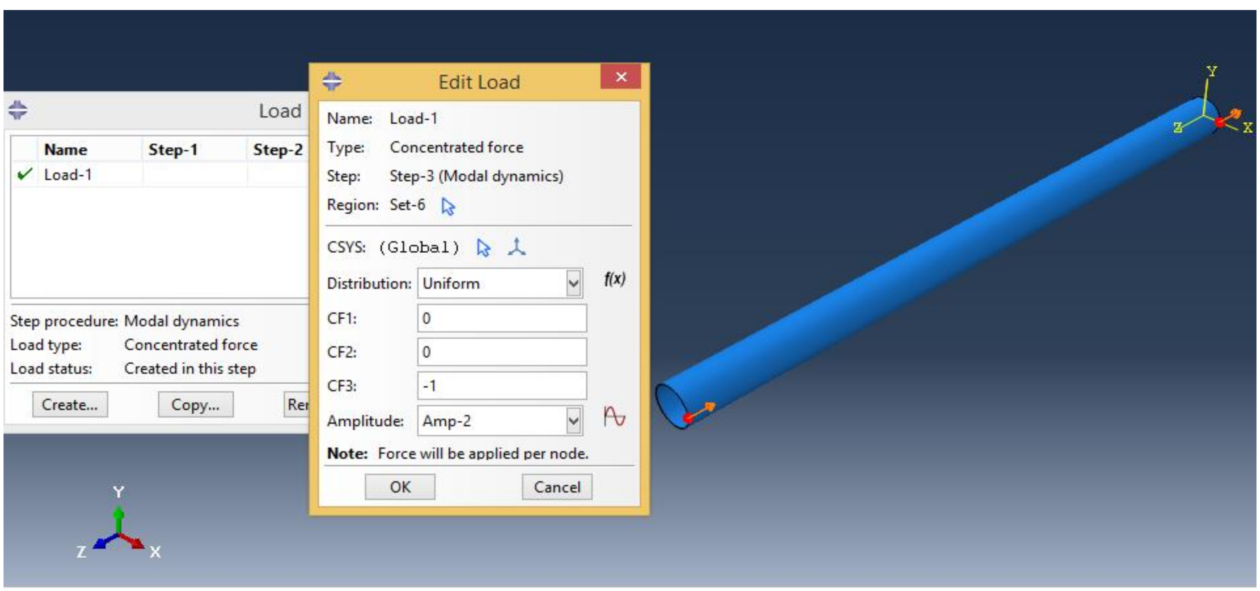


Fig 4.1.2.19 Apply load and boundary conditions

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

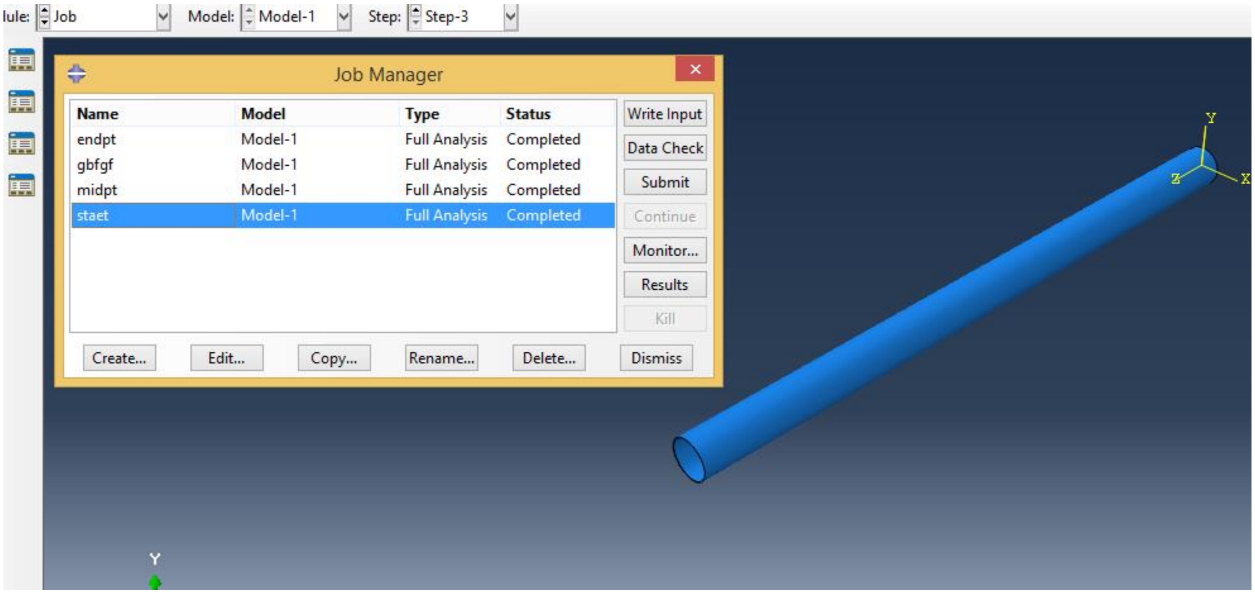


Fig 4.1.2.20 job submission and result analysis

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

CHAPTER 5
RESULT

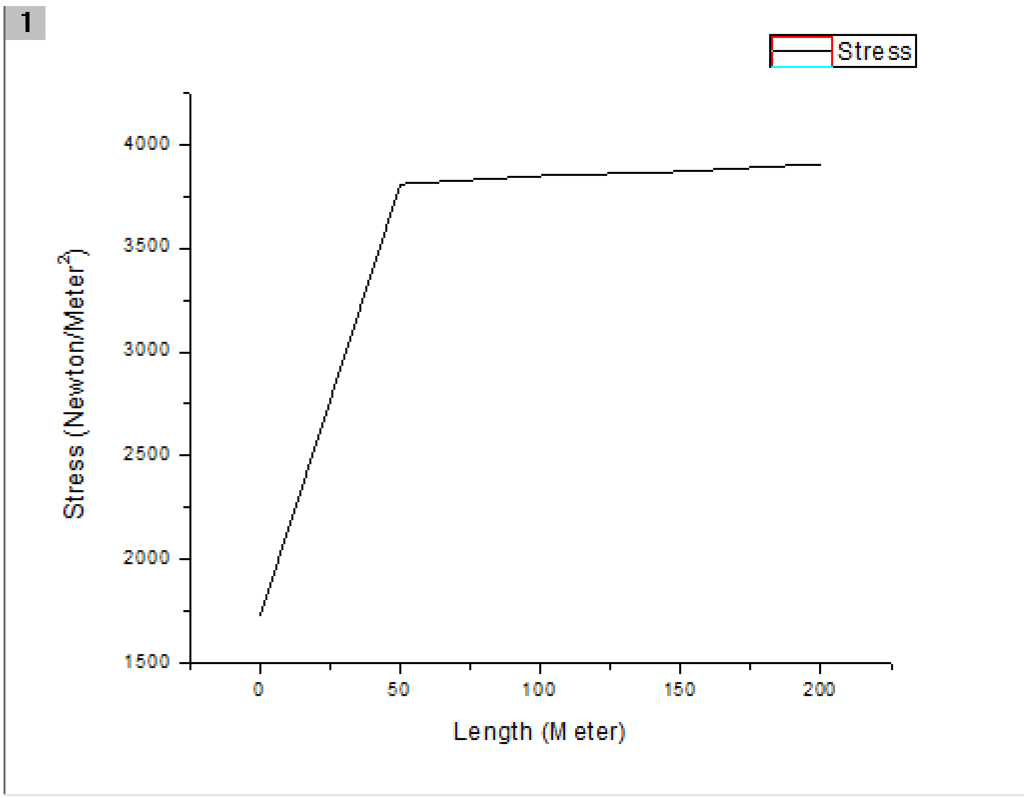
5.1 Modal Analysis:-

Table 5.1.1

Sr. No.	Frequency(Hz)
1.	2.9349
2.	10.602
3.	13.675
4.	14.139
5.	21.460
6.	26.363
7.	32.103
8.	39.228
9.	39.423
10.	48.534

5.2 Response Spectrum Analysis :-

1. **Along the length**

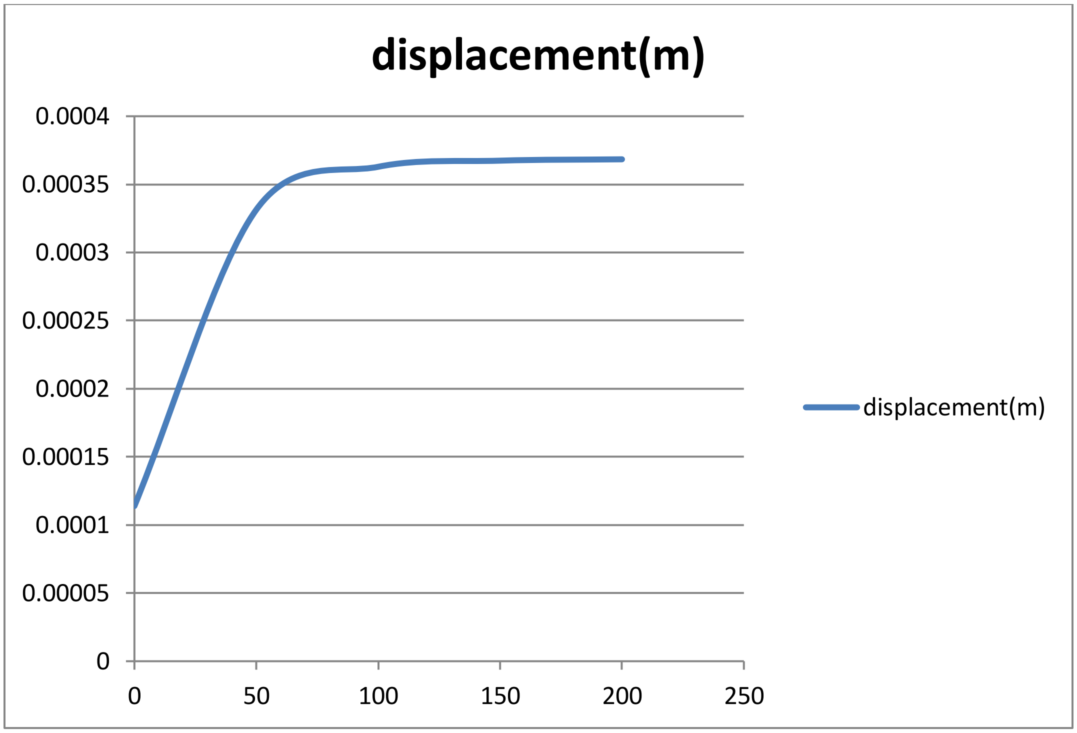


Graph 5.2.1 (stress v/s distance)

This graph shows that , the stress is increased with increase in length when earthquake is striking from left to right.

Table 5.2.1(Length and stress)

Sr.No.	Length(m)	Stress(N/m^2)
1.	0	$1.73*10^3$
2.	50	$3.81*10^3$
3.	100	$3.85*10^3$
4.	150	$3.87*10^3$
5.	200	$3.9074*10^3$



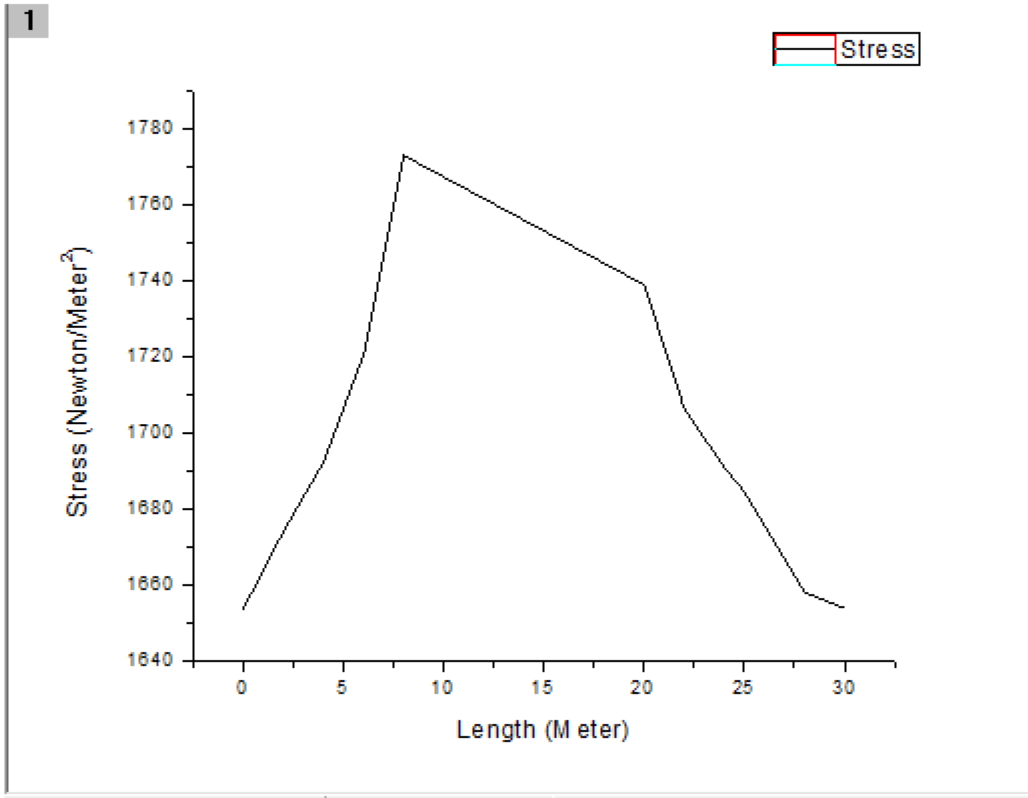
Graph 5.2.2(Displacement v/s Distance)

As we know that, stress is directly proportional to displacement. So, when stress is increased that means displacement is also increased with length. This graph exactly satisfies the relation between stress and displacement.

Table 5.2.2(Length and displacement)

Sr.No.	Length(m)	Displacement(m)
1.	0	**0.0001139**
2.	50	**0.0003314**
3.	100	**0.0003629**
4.	150	**0.0003674**
5.	200	**0.0003684**

2. **Along Cross Section:-**

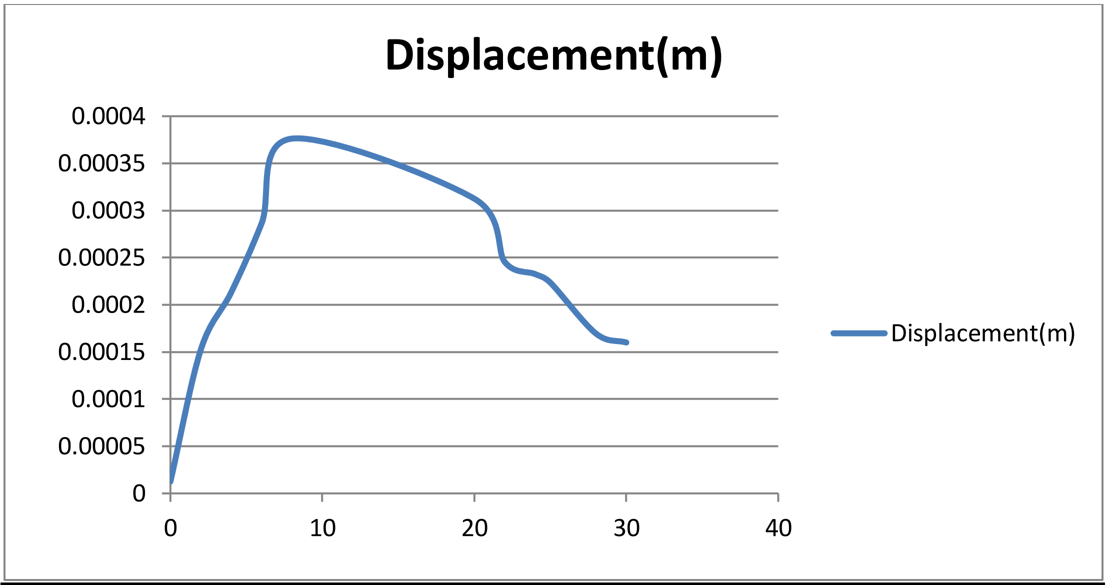


Graph 5.2.3 (Stress v/s distance)

This graph shows that , the stress is increased with increase in length when earthquake is striking from left to right.

Table 5.2.3(Length and stress)

Sr.No.	Length(m)	Stress(N/m$^{2)}$
1.	0	$1.65388*10^3$
2.	2	$1.67421*10^3$
3.	4	$1.69246*10^3$
4.	6	$1.72053*10^3$
5.	8	$1.773*10^3$
6.	20	$1.73892*10^3$
7.	22	$1.70644*10^3$
8.	24	$1.69106*10^3$
9.	25	$1.68457*10^3$
10.	28	$1.65812*10^3$
11.	30	$1.65388*10^3$



Graph 5.2.4 (Displacement v/s Distance)

As we know that, stress is directly proportional to displacement. So, when stress is increased that means displacement is also increased with length

Table 5.2.4(Length and displacement)

Sr.No.	Length(m)	Displacement(m)
1.	0	0.00001256
2.	2	0.0001524
3.	4	0.0002132
4.	6	0.000286247
5.	8	0.00037625
6.	20	0.000312525
7.	22	0.00024547
8.	24	0.00023256
9.	25	0.00022354
10.	28	0.000169525
11.	30	0.000160015

5.3 Time History Analysis :-

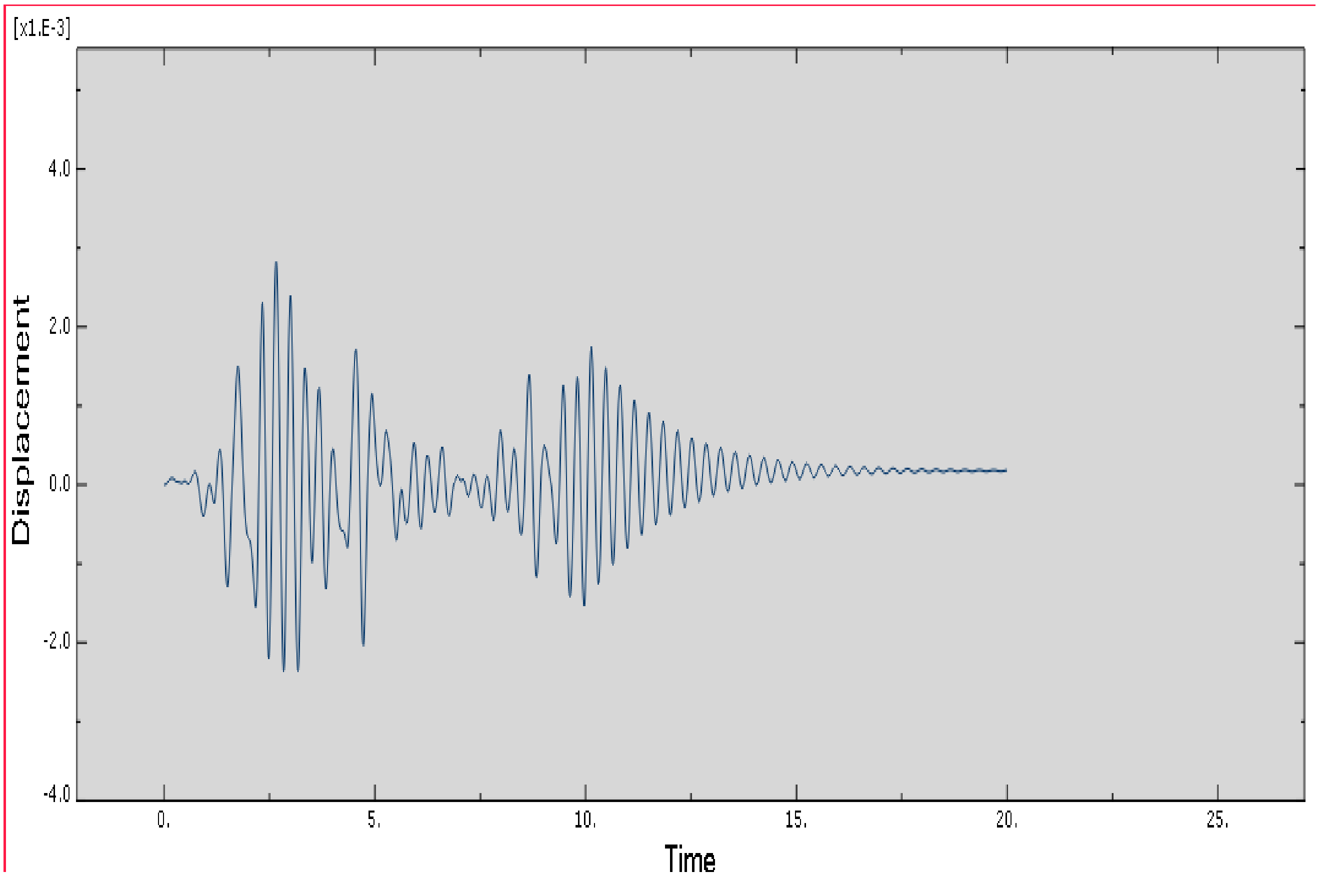
1. <u>El Centro input</u>

a.) At staring point(node 74):-

<u>Table 5.3.1</u>

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$5.32*10^{-8}$	0.005
3	$2.76*10^{-7}$	0.01
4	$7.37*10^{-7}$	0.015
5	$1.48*10^{-6}$	0.02
6	$2.51*10^{-6}$	0.025
7	$3.80*10^{-6}$	0.03
8	$5.32*10^{-6}$	0.035
9	$7.106*10^{-6}$	0.04
10	$9.20*10^{-6}$	0.045
11	$1.16*10^{-5}$	0.05
12	$1.43*10^{-5}$	0.055
13	$1.72*10^{-5}$	0.06
14	$2.01*10^{-5}$	0.065
15	$2.32*10^{-5}$	0.07
16	$2.62*10^{-5}$	0.075
17	$2.94*10^{-5}$	0.08
18	$3.26*10^{-5}$	0.085
19	$3.59*10^{-5}$	0.09
20	$3.93*10^{-5}$	0.095
21	$4.28*10^{-5}$	0.1
22	$4.62*10^{-5}$	0.105
23	$4.95*10^{-5}$	0.11
24	$5.28*10^{-5}$	0.115
25	$5.62*10^{-5}$	0.12
26	$5.96*10^{-5}$	0.125
27	$6.29*10^{-5}$	0.13
28	$6.62*10^{-5}$	0.135
29	$6.93*10^{-5}$	0.14
30	$7.22*10^{-5}$	0.145
31	$7.48*10^{-5}$	0.15
32	$7.72*10^{-5}$	0.155
33	$7.93*10^{-5}$	0.16

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



Graph 5.3.1 (Displacement v/s Time)

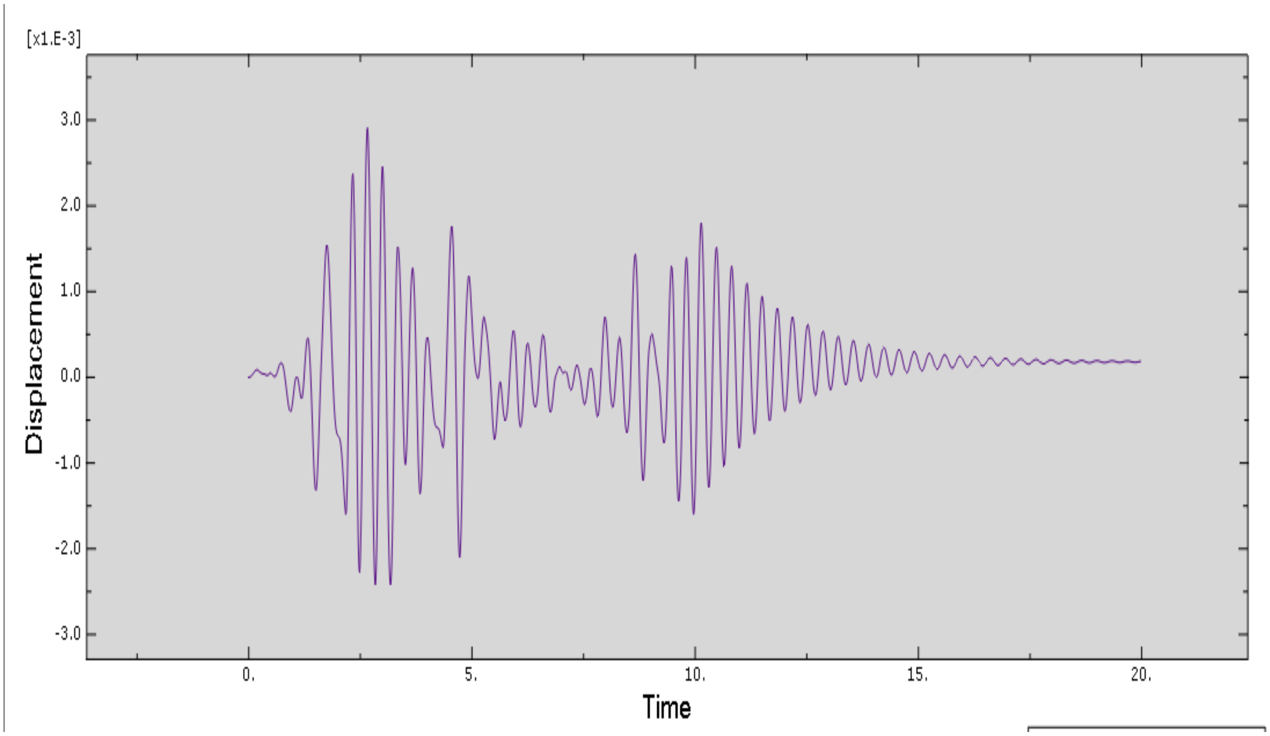
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

b.) At mid point(node 821):-

Table 5.3.2

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$2.32*10^{-8}$	0.005
3	$1.36*10^{-7}$	0.01
4	$4.21*10^{-7}$	0.015
5	$9.80*10^{-7}$	0.02
6	$1.91*10^{-6}$	0.025
7	$3.24*10^{-6}$	0.03
8	$4.95*10^{-6}$	0.035
9	$6.99*10^{-6}$	0.04
10	$9.28*10^{-6}$	0.045
11	$1.17*10^{-5}$	0.05
12	$1.44*10^{-5}$	0.055
13	$1.72*10^{-5}$	0.06
14	$2.02*10^{-5}$	0.065
15	$2.33*10^{-5}$	0.07
16	$2.66*10^{-5}$	0.075
17	$2.99*10^{-5}$	0.08
18	$3.33*10^{-5}$	0.085
19	$3.66*10^{-5}$	0.09
20	$4.00*10^{-5}$	0.095
21	$4.34*10^{-5}$	0.1
22	$4.68*10^{-5}$	0.105
23	$5.03*10^{-5}$	0.11
24	$5.39*10^{-5}$	0.115
25	$5.74*10^{-5}$	0.12
26	$6.08*10^{-5}$	0.125
27	$6.42*10^{-5}$	0.13
28	$6.75*10^{-5}$	0.135
29	$7.06*10^{-5}$	0.14
30	$7.36*10^{-5}$	0.145
31	$7.64*10^{-5}$	0.15
32	$7.90*10^{-5}$	0.155

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



Graph 5.3.2 (Displacement v/s Time)

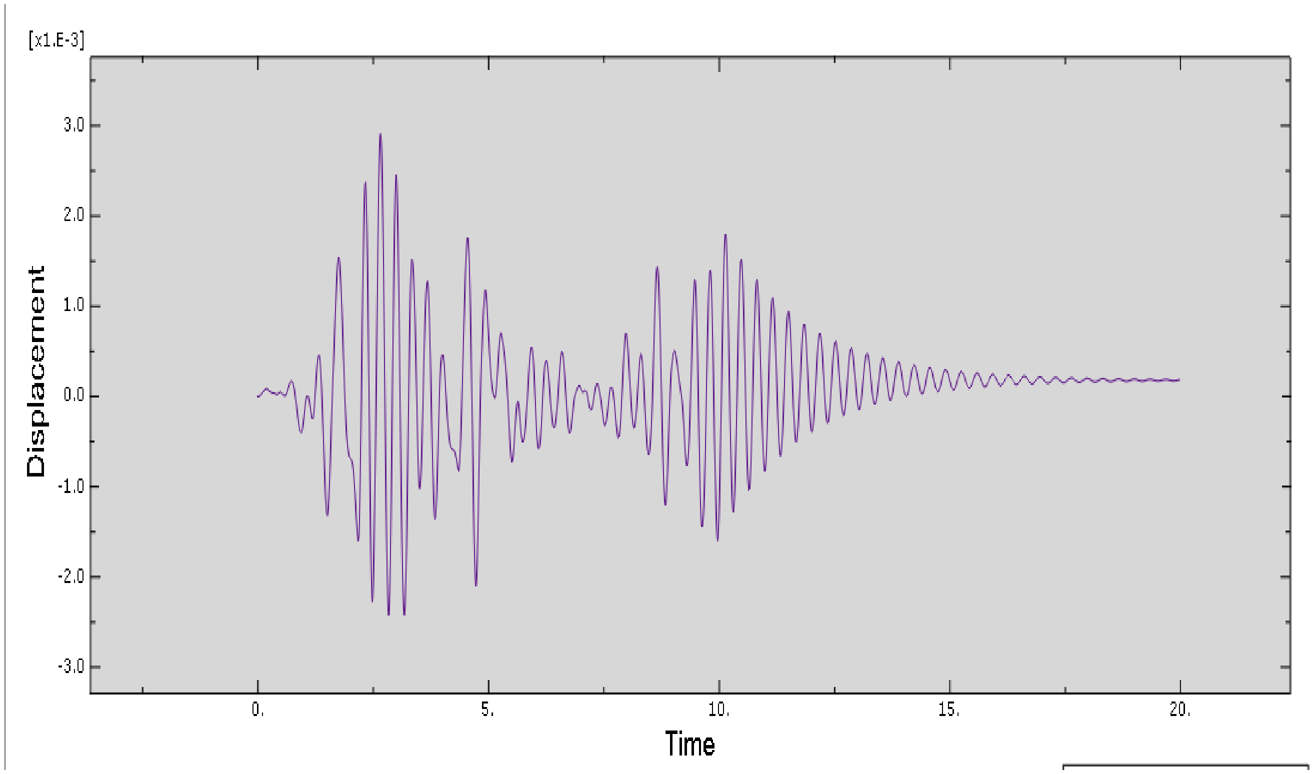
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

c.)At end point (node 3816):-

Table 5.3.3

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$5.23*10^{-8}$	0.005
3	$2.70*10^{-7}$	0.01
4	$7.18*10^{-7}$	0.015
5	$1.43*10^{-6}$	0.02
6	$2.42*10^{-6}$	0.025
7	$3.64*10^{-6}$	0.03
8	$5.06*10^{-6}$	0.035
9	$6.71*10^{-6}$	0.04
10	$8.65*10^{-6}$	0.045
11	$1.09*10^{-5}$	0.05
12	$1.33*10^{-5}$	0.055
13	$1.60*10^{-5}$	0.06
14	$1.87*10^{-5}$	0.065
15	$2.14*10^{-5}$	0.07
16	$2.42*10^{-5}$	0.075
17	$2.71*10^{-5}$	0.08
18	$3.01*10^{-5}$	0.085
19	$3.32*10^{-5}$	0.09
20	$3.64*10^{-5}$	0.095
21	$3.96*10^{-5}$	0.1
22	$4.27*10^{-5}$	0.105
23	$4.59*10^{-5}$	0.11
24	$4.90*10^{-5}$	0.115
25	$5.20*10^{-5}$	0.12
26	$5.52*10^{-5}$	0.125
27	$5.82*10^{-5}$	0.13
28	$6.12*10^{-5}$	0.135
29	$6.41*10^{-5}$	0.14
30	$6.67*10^{-5}$	0.145
31	$6.91*10^{-5}$	0.15
32	$7.13*10^{-5}$	0.155

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



Graph 5.3.3 (Displacement v/s Time)

From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

2. Kobe input

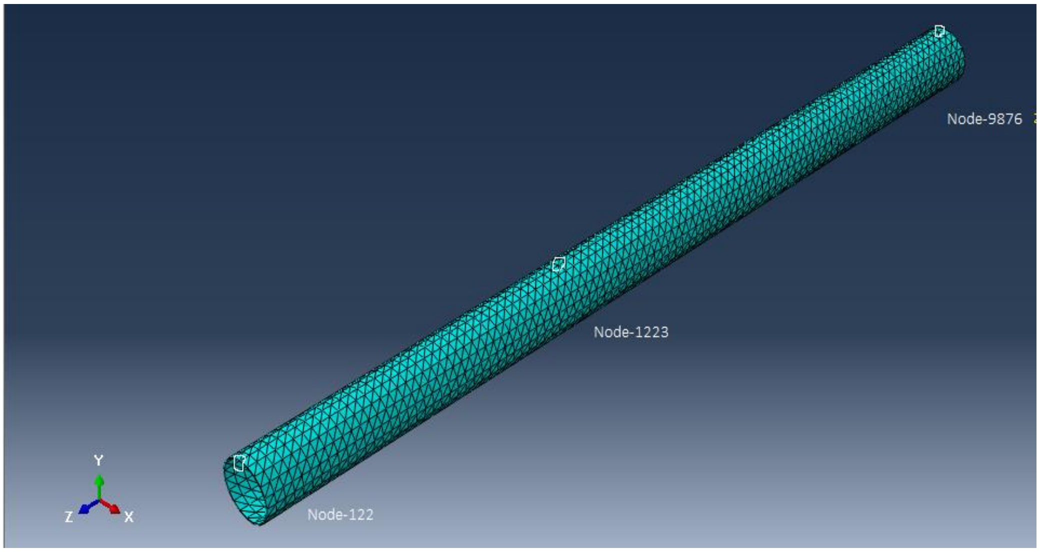


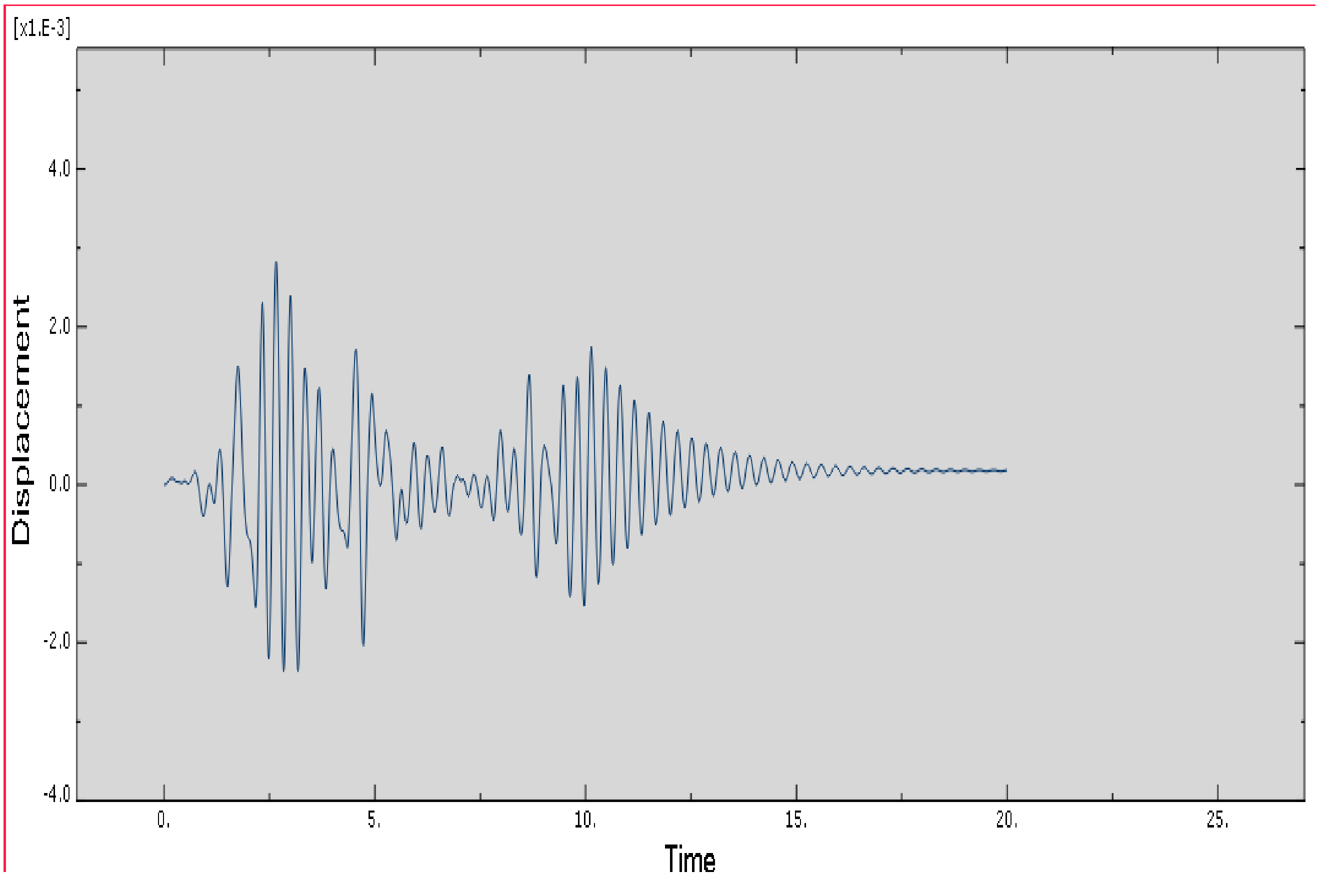
Fig 5.3.1 Selection of node points

a.)At staring point(node 122):-

Table 5.3.4

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$5.32*10^{-8}$	0.005
3	$2.76*10^{-6}$	0.01
4	$7.37*10^{-6}$	0.015
5	$1.48*10^{-6}$	0.02
6	$2.51*10^{-6}$	0.025
7	$3.80*10^{-6}$	0.03
8	$5.32*10^{-6}$	0.035
9	$7.10*10^{-6}$	0.04
10	$9.20*10^{-6}$	0.045
11	$1.16*10^{-5}$	0.05
12	$1.43*10^{-5}$	0.055
13	$1.72*10^{-5}$	0.06
14	$2.01*10^{-5}$	0.065
15	$2.32*10^{-5}$	0.07
16	$2.62*10^{-5}$	0.075
17	$2.94*10^{-5}$	0.08
18	$3.26*10^{-5}$	0.085
19	$3.59*10^{-5}$	0.09
20	$3.93*10^{-5}$	0.095
21	$4.28*10^{-5}$	0.1

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



Graph 5.3.4 (Displacement v/s Time)

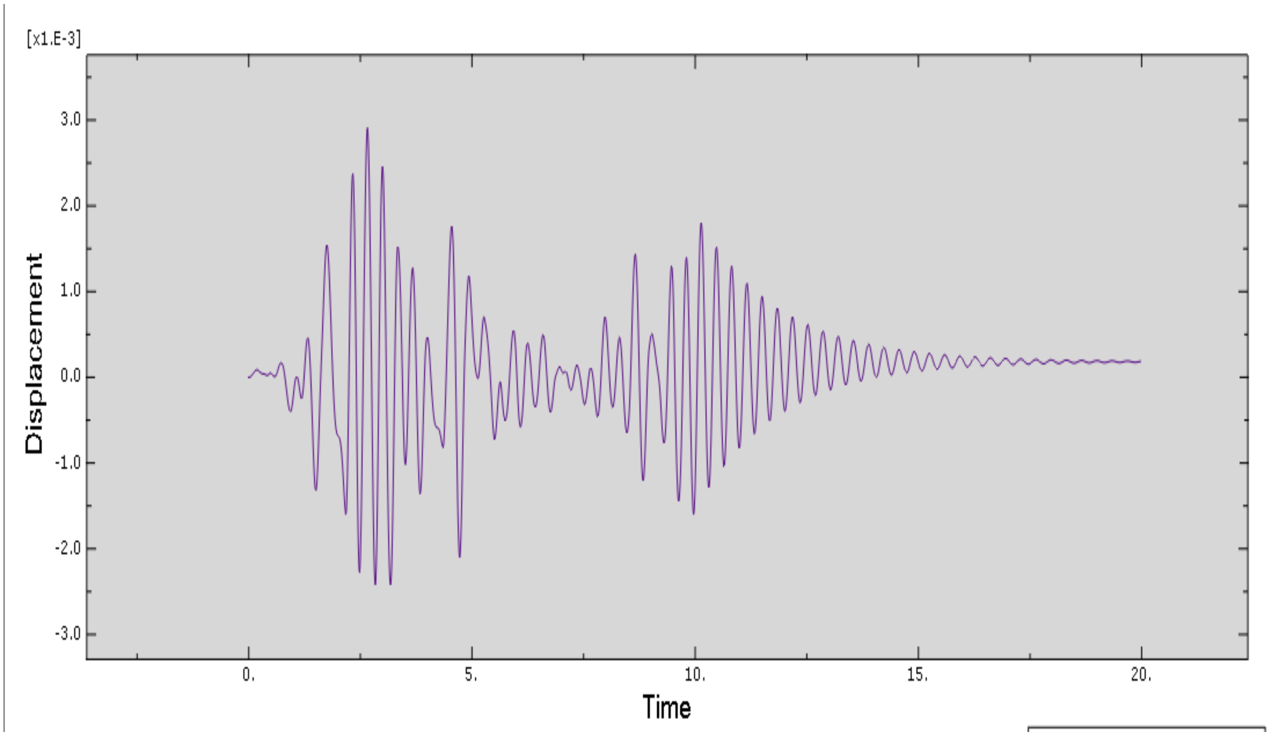
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

b.)At mid point(node 1223):-

Table 5.3.5

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$2.32*10^{-8}$	0.005
3	$1.36*10^{-7}$	0.01
4	$4.21*10^{-7}$	0.015
5	$9.80*10^{-7}$	0.02
6	$1.91*10^{-6}$	0.025
7	$3.24*10^{-6}$	0.03
8	$4.95*10^{-6}$	0.035
9	$6.99*10^{-6}$	0.04
10	$9.28*10^{-6}$	0.045
11	$1.17*10^{-5}$	0.05
12	$1.44*10^{-5}$	0.055
13	$1.72*10^{-5}$	0.06
14	$2.02*10^{-5}$	0.065
15	$2.33*10^{-5}$	0.07
16	$2.66*10^{-5}$	0.075
17	$2.99*10^{-5}$	0.08
18	$3.33*10^{-5}$	0.085
19	$3.66*10^{-5}$	0.09
20	$4.00*10^{-5}$	0.095
21	$4.34*10^{-5}$	0.1
22	$4.68*10^{-5}$	0.105
23	$5.03*10^{-5}$	0.11
24	$5.39*10^{-5}$	0.115
25	$5.74*10^{-5}$	0.12
26	$6.08*10^{-5}$	0.125
27	$6.42*10^{-5}$	0.13
28	$6.75*10^{-5}$	0.135
29	$7.06*10^{-5}$	0.14
30	$7.36*10^{-5}$	0.145
31	$7.64*10^{-5}$	0.15
32	$7.90*10^{-5}$	0.155

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



Graph 5.3.5 (Displacement v/s Time)

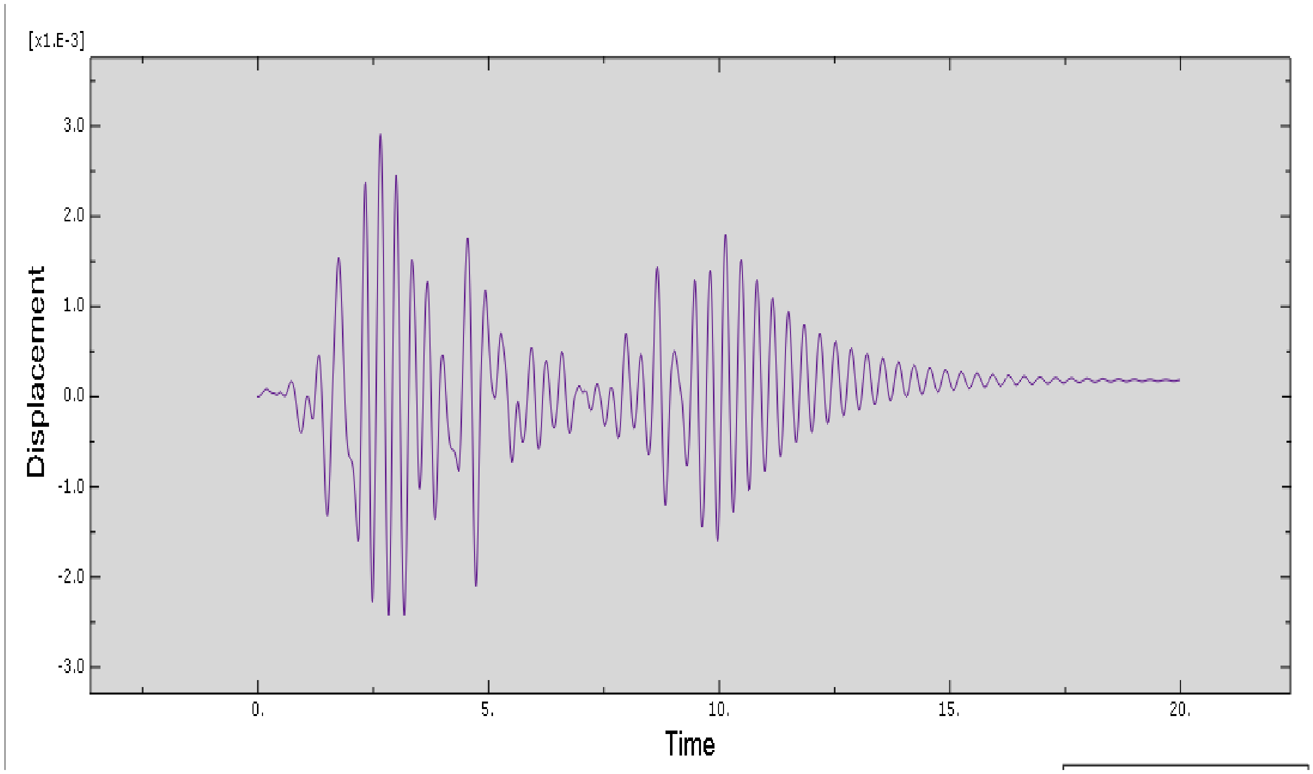
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

c.)At end point (node 9876):-

Table 5.3.6

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$5.23*10^{-8}$	0.005
3	$2.70*10^{-7}$	0.01
4	$7.18*10^{-7}$	0.015
5	$1.43*10^{-6}$	0.02
6	$2.42*10^{-6}$	0.025
7	$3.64*10^{-6}$	0.03
8	$5.06*10^{-6}$	0.035
9	$6.71*10^{-6}$	0.04
10	$8.65*10^{-6}$	0.045
11	$1.09*10^{-5}$	0.05
12	$1.33*10^{-5}$	0.055
13	$1.60*10^{-5}$	0.06
14	$1.87*10^{-5}$	0.065
15	$2.14*10^{-5}$	0.07
16	$2.42*10^{-5}$	0.075
17	$2.71*10^{-5}$	0.08
18	$3.01*10^{-5}$	0.085
19	$3.32*10^{-5}$	0.09
20	$3.64*10^{-5}$	0.095
21	$3.96*10^{-5}$	0.1
22	$4.27*10^{-5}$	0.105
23	$4.59*10^{-5}$	0.11
24	$4.90*10^{-5}$	0.115
25	$5.20*10^{-5}$	0.12
26	$5.52*10^{-5}$	0.125
27	$5.82*10^{-5}$	0.13
28	$6.12*10^{-5}$	0.135
29	$6.41*10^{-5}$	0.14
30	$6.67*10^{-5}$	0.145
31	$6.91*10^{-5}$	0.15
32	$7.13*10^{-5}$	0.155

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



Graph 5.3.6 (Displacement v/s Time)

From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

3. Northridge input

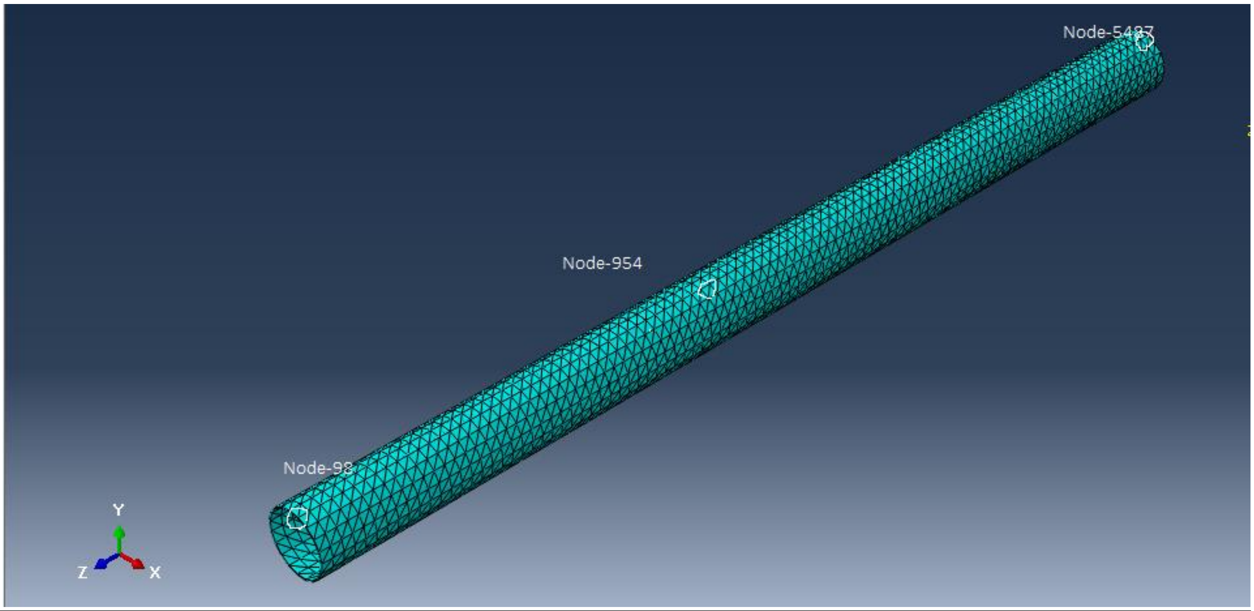


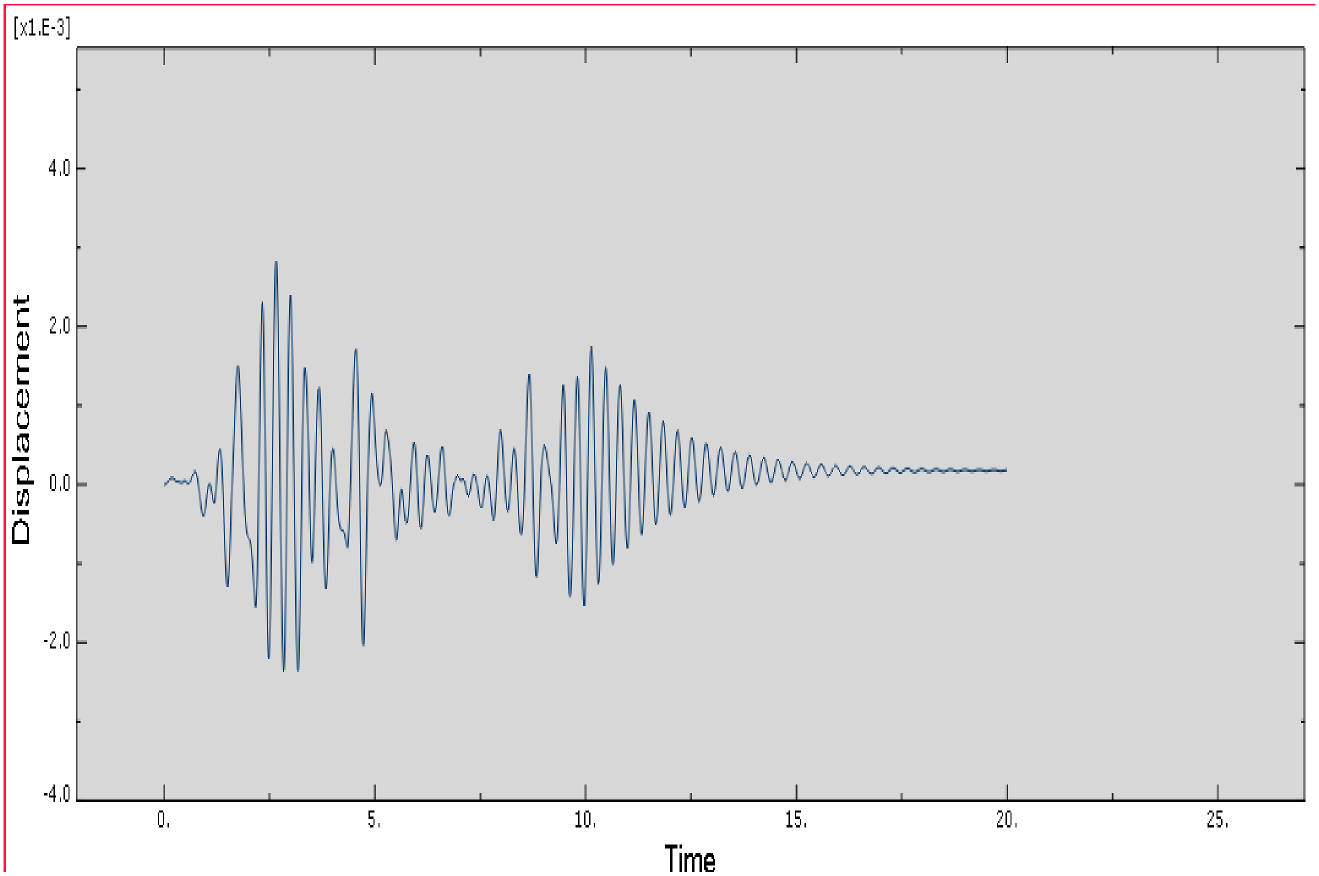
Fig 5.3.2 Selection of node points

a.)At staring point(node 98):-

Table 5.3.7

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$2.32*10^{-8}$	0.005
3	$1.36*10^{-5}$	0.01
4	$4.21*10^{-5}$	0.015
5	$9.80*10^{-5}$	0.02
6	$1.91*10^{-5}$	0.025
7	$3.24*10^{-5}$	0.03
8	$4.95*10^{-5}$	0.035
9	$6.99*10^{-5}$	0.04
10	$9.28*10^{-5}$	0.045
11	$1.17*10^{-5}$	0.05
12	$1.44*10^{-5}$	0.055
13	$1.72*10^{-5}$	0.06
14	$2.02*10^{-5}$	0.065
15	$2.33*10^{-5}$	0.07
16	$2.66*10^{-5}$	0.075
17	$2.94*10^{-5}$	0.08
18	$3.26*10^{-5}$	0.085
19	$3.59*10^{-5}$	0.09

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



Graph 5.3.7 (Displacement v/s Time)

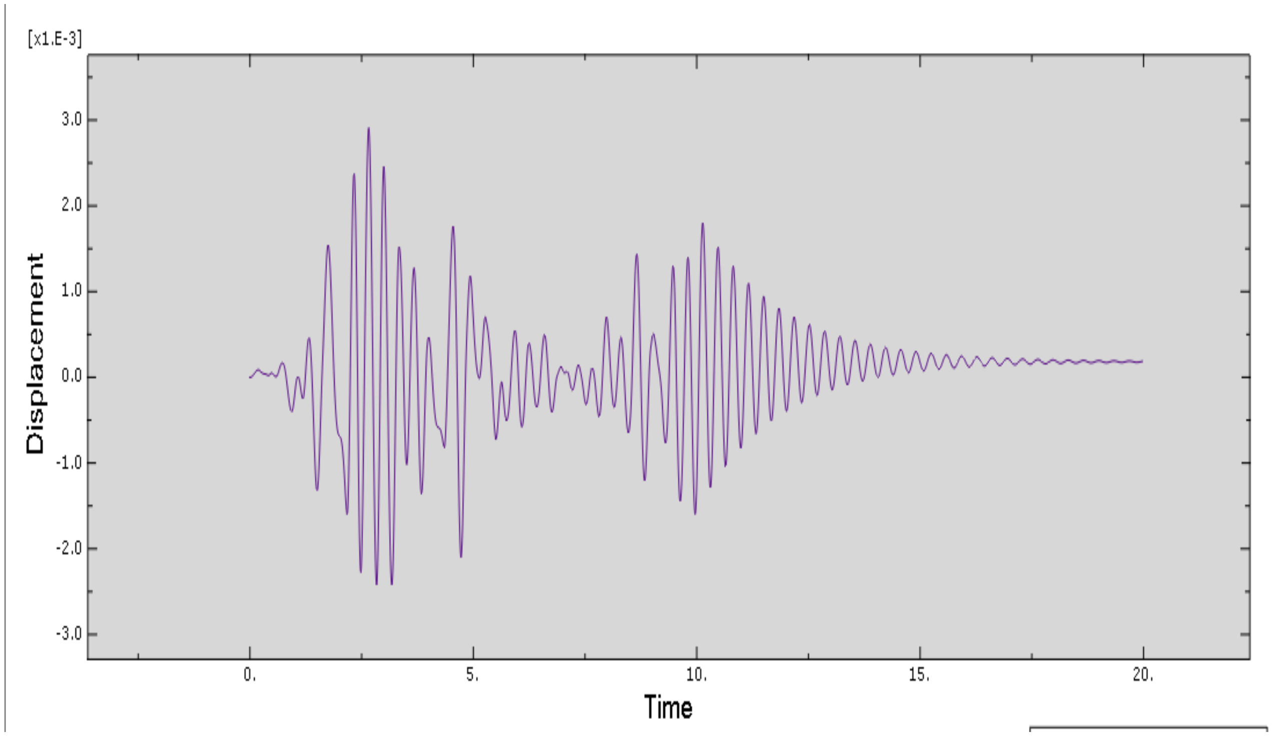
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

b.)At mid point(node 954):-

Table 5.3.8

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$2.99*10^{-5}$	0.08
3	$3.33*10^{-5}$	0.085
4	$3.66*10^{-5}$	0.09
5	$4.00*10^{-5}$	0.095
6	$4.34*10^{-5}$	0.1
7	$4.68*10^{-5}$	0.105
8	$5.03*10^{-5}$	0.11
9	$5.39*10^{-5}$	0.115
10	$5.74*10^{-5}$	0.12
11	$2.99*10^{-5}$	0.08
12	$3.33*10^{-5}$	0.085
13	$1.72*10^{-5}$	0.06
14	$2.02*10^{-5}$	0.065
15	$2.33*10^{-5}$	0.07
16	$2.66*10^{-5}$	0.075
17	$2.99*10^{-5}$	0.08
18	$3.33*10^{-5}$	0.085
19	$3.66*10^{-5}$	0.09
20	$4.00*10^{-5}$	0.095
21	$4.34*10^{-5}$	0.1
22	$4.68*10^{-5}$	0.105
23	$5.03*10^{-5}$	0.11
24	$5.39*10^{-5}$	0.115
25	$5.74*10^{-5}$	0.12
26	$6.08*10^{-5}$	0.125
27	$6.42*10^{-5}$	0.13
28	$6.75*10^{-5}$	0.135
29	$7.06*10^{-5}$	0.14
30	$7.36*10^{-5}$	0.145
31	$7.64*10^{-5}$	0.15
32	$7.90*10^{-5}$	0.155

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



Graph 5.3.8 (Displacement v/s Time)

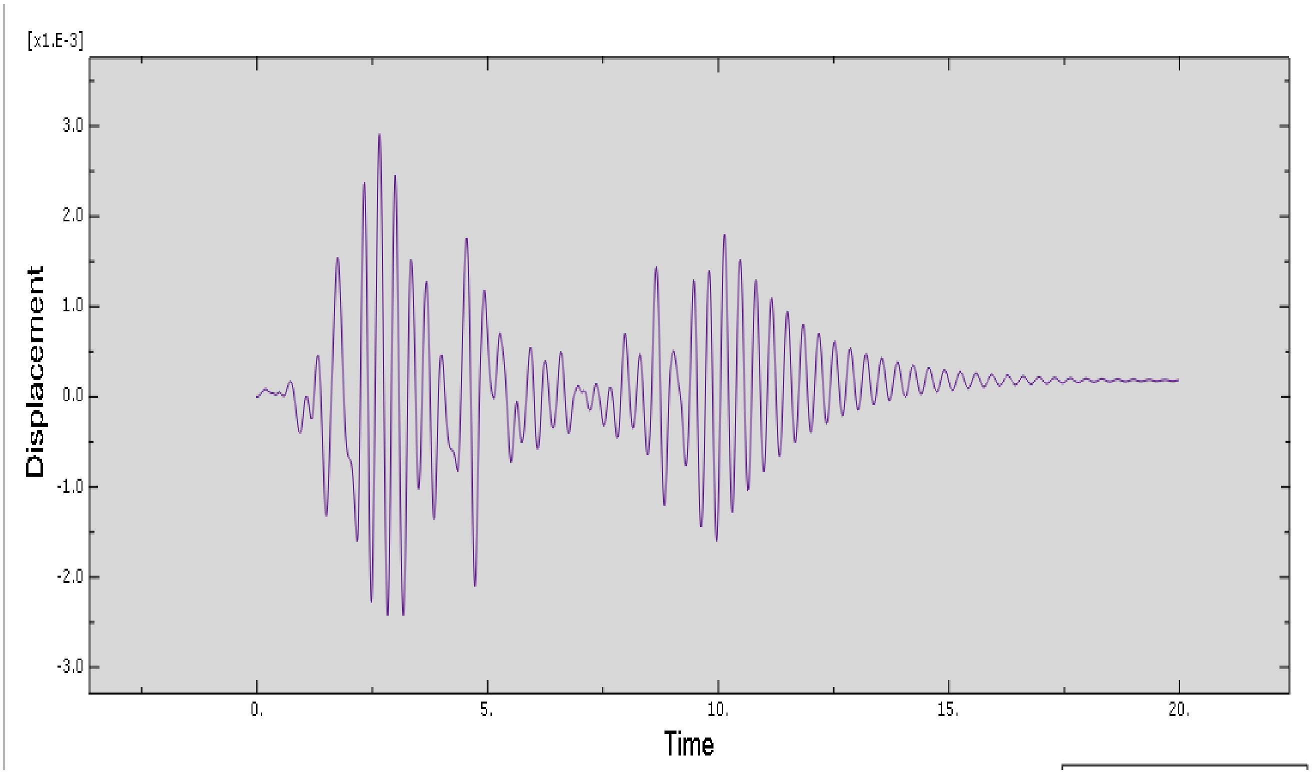
From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

c.)At end point (node 5497):-

Table 5.3.9

Sr.No.	Displacement (meters)	Time (seconds)
1	0	0
2	$5.23*10^{-8}$	0.005
3	$2.70*10^{-6}$	0.01
4	$7.18*10^{-6}$	0.015
5	$1.43*10^{-6}$	0.02
6	$2.42*10^{-6}$	0.025
7	$3.64*10^{-6}$	0.03
8	$5.06*10^{-6}$	0.035
9	$6.71*10^{-6}$	0.04
10	$8.65*10^{-6}$	0.045
11	$1.09*10^{-5}$	0.05
12	$1.33*10^{-5}$	0.055
13	$1.60*10^{-5}$	0.06
14	$1.87*10^{-5}$	0.065
15	$2.14*10^{-5}$	0.07
16	$2.42*10^{-5}$	0.075
17	$2.71*10^{-5}$	0.08
18	$3.01*10^{-5}$	0.085
19	$3.32*10^{-5}$	0.09
20	$3.64*10^{-5}$	0.095
21	$3.96*10^{-5}$	0.1
22	$4.27*10^{-5}$	0.105
23	$4.59*10^{-5}$	0.11
24	$4.90*10^{-5}$	0.115
25	$5.20*10^{-5}$	0.12
26	$5.52*10^{-5}$	0.125
27	$5.82*10^{-5}$	0.13
28	$6.12*10^{-5}$	0.135
29	$6.4*10^{-5}$	0.14
30	$6.67*10^{-5}$	0.145
31	$6.91*10^{-5}$	0.15
32	$7.13*10^{-5}$	0.155

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



Graph 5.3.9 (Displacement v/s Time)

From this graph, this is directly shows that when earthquake is strikes on the structure, the output we get from the structure is same as that of input. From this, the peak displacement of structure is 3mm.

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

Ground movement causes tremor. Structures are powerless against ground movement. It harms the structures. So as to avoid potential risk for the harm of structures because of the ground movement, it is critical to know the attributes of the ground movement. The attributes of ground movement are top ground speeding up (acceleration), crest ground speed (velocity), top ground uprooting (peak ground displacement), period, and recurrence content (frequency) and so on.

Here, structure is studied under uniform-frequency content ground motions A single ground motion of uniform-frequency content is introduced to the corresponding structure. Linear time history analysis is performed in **ABAQUS**. Seismic inputs are given once at a single time. By this, we check the response of our structure under different inputs like Kobe, Northridge and El Centro type earthquake.

The outputs of the structure are given in terms of structure displacement, Stress along with time and length,. The responses of each ground motion for each type of building is studied and compared.

6.2 CONCLUSION

Underground tunnel was great archived and subjected to different types of harm amid due to different types of earthquake inputs. An area of the passages is displayed and reaction amid the seismic shaking is mimicked through itemized dynamic examinations. The conclusions came to are the accompanying:

1. According to paper, minimum frequency for a structure lies between 2.5 – 4.7 Hz. And according to our analysis, frequency is 2.934Hz.
2. Displacement of structure behaves same as we given same type of amplitude.
3. Maximum displacement of structure is 3mm i.e. low risk factor and public safety.
4. Structure experience minimum displacement due to uniform-frequency content ground motion in z-direction.
5. In literature review, no such research took place to incorporate the earthquake amplitude applied uniform and multisupport excitation.

Suggestion for Future Study:

The present study depends on a few presumptions and approximations which can be enhanced through further research. These points, which include site information gathering and extensive 3D demonstrating, are the accompanying:

1. The passage liners are expected to react straightly versatile in this examination. Nonlinear or elastoplastic conduct of such components can be used in the investigations.

2. Impact of the ground water on seismic reaction of the passage can be actualized in the investigations.

3. Impact of seismic tremor can be limiting by increment the measurement of passage and gives underpins at least space interims can be inspected.

4. The impacts of the blaming and the directivity impacts over the ground movement at the site of the passages can be inspected in detail.

CHAPTER 7

ORGANIZATION OF THESIS

This part contains the work that is done in all chapters. That is,

In first chapter, we discuss about the spatial varying earth ground motion , its causes and introduction about the tunnel.

In second chapter, it contains the data about the conclusion of papers that we are studied.

In third chapter, we finally decide the objective and scope of our thesis.

In fourth chapter, we perform modeling in Abaqus and contains procedure of modal analysis, response spectrum method and time history analysis.

Chapter fifth includes the results of modal analysis, response spectrum analysis and time history analysis.

Chapter sixth includes the summary and conclusion of thesis.

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