SOIL STRUCTURE INTERACTION EFFECTS ON G+5 STOREY FRAMED STRUCTURE SUBJECTED TO SEISMIC ACTIVITY

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Under the supervision

of

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STUDENT'S DECLARATION

I hereby declare that the work presented in the M.Tech Thesis entitled **"Soil structure interaction effects on G+5 storey framed structure subjected to seismic activity**"submitted for partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering, with specialization in Structural Engineering at **Jaypee University of Information Technology, Waknaghat,** is an authentic record of my work carried out under the supervision of **Dr. Saurav, Assistant Professor.** This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my M.Tech Thesis.

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CERTIFICATE

This is to certify that the work which is being presented in the thesis titled "**Soil structure interaction effects on G+5 storey framed structure subjected to seismic activity**" in partial fulfillment of the requirements for the award of the degree of Master of Technology in Civil Engineering with specialization in "Structural Engineering" and submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Digvijay Singh Thakur(212655)** during a period from July 2022 to May 2023 under the supervision of **Dr. Saurav, Assistant Professor**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

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ABSTRACT

In the era of rapid urbanization ,various heavy structures like buildings , bridges are being built. Specially when it comes to himalayan regions which are prone to earthquakes, landslides study of these structures becomes important. Most of the study focuses on designing part of these structures but very few talk about their soil-structure interaction (SSI). There are cases where building got tilted by ground failure caused by soil deformation. Therefore considering SSI becomes crucial.

The aim of this research paper is to investigate the effects of SSI on G+5 storey framed structure building situated in Himachal Pradesh lying in Zone IV of the himalayan region which is being subjected to EL centro earthquake record. An comparative study is conducted to evaluate the effect of different types of soil on their values of poissons ratio ranging between 0.3-0.35 on the maximum displacement of the building. A 3D finite element analysis is conducted for framed structure and results for the structures built on different types of soils are compared on basis of their peak displacements.

Keywords: SSI, FEM, El centro, Poisson's ratio, Framed structure

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RC	Reinforced concrete
SSI	Soil Structure Interaction
NPP	Nuclear Power Plant
BH	Bore hole
SPT	Standard penetration test
CDP	Concrete damage plasticity

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CHAPTER 1
INTRODUCTION

1.1 General

Dynamic response of multistorey structures along with considering its SSI effects is a challenging task for design and earthquake engineers. Methods for analysis are quite few which includes direct approach and substructure approach. These methods require a special softwares tools like Abaqus for direct modelling and opensees for substructure approach which is a programing software. The property of soil is a significant parameter that affects seismic behavior of structures. As per hypothesis fixed base concept is assumed for analysis . In fixed base structure we assume that our structure is resting on hard soil. This hypothesis holds only true when our structure is resting on hard soil. But site conditions of all structures are not same , most of the structures that are build on soft soils zones gets influenced by the soils flexibility due to kinematic and inertial interactions[1]

1.2 What is SSI

A seismicc soil structure interaction accesses how the structure as a whole, the superstructure, the foundation and the soil beneath and around the foundation all react collectively to a given free field ground motion. Free field motion are described as those which are unaltered by structural vibration or scaterring of waves near the foundation. In theoretical case SSI effects for a structure resting on rigid soil becomes almost negligible. In reality all soils are not rigid & the ability of supporting soil to deform induces deformation in the structure as shown below in fig1.1. That’s why considering SSI effects becomes important.

In assessment of seismic vulnerability the earth below the building is typically neglected. Although its cruciality in construction of buildings is unclear whether to take it in seismic analysis or not. In earlier studies SSI was always considered as favourable [2] because of the increment in flexibility of soil caused by decrement of internal forces and drifts. Conservative results were obtained when we consider fixed based buildings for seismic analysis.

(a)

(b)

(c)

Fig 1.1(a)(b)(c) – Building got tilted by ground failure due to soil deformation (Taiwan earthquake,2018)[3]

1.3 Soils in SSI

The forces generated during earthquake motion in form of overturning moments and transfer shear won't lead to distortion at the base of hard soil such as rock while stiffness of the structure remains constant. In this case motion of the structure depends only on the properties of the structure. When soft soil is used as base it gets deformed and this base deformation changes the stiffness of the structure during an seismic activity and this phenomenon is termed as Soil Structure Interaction[4].

Fig 1.2 explains effects of SSI where m is mass, H is height, K_s is foundation stiffness, K_y is lateral stiffness and (Kθ)is rotational stiffness , üg is ground acceleration. Due to acceleration base has deformed by an angle θ and structural deformation can be seen.[5]

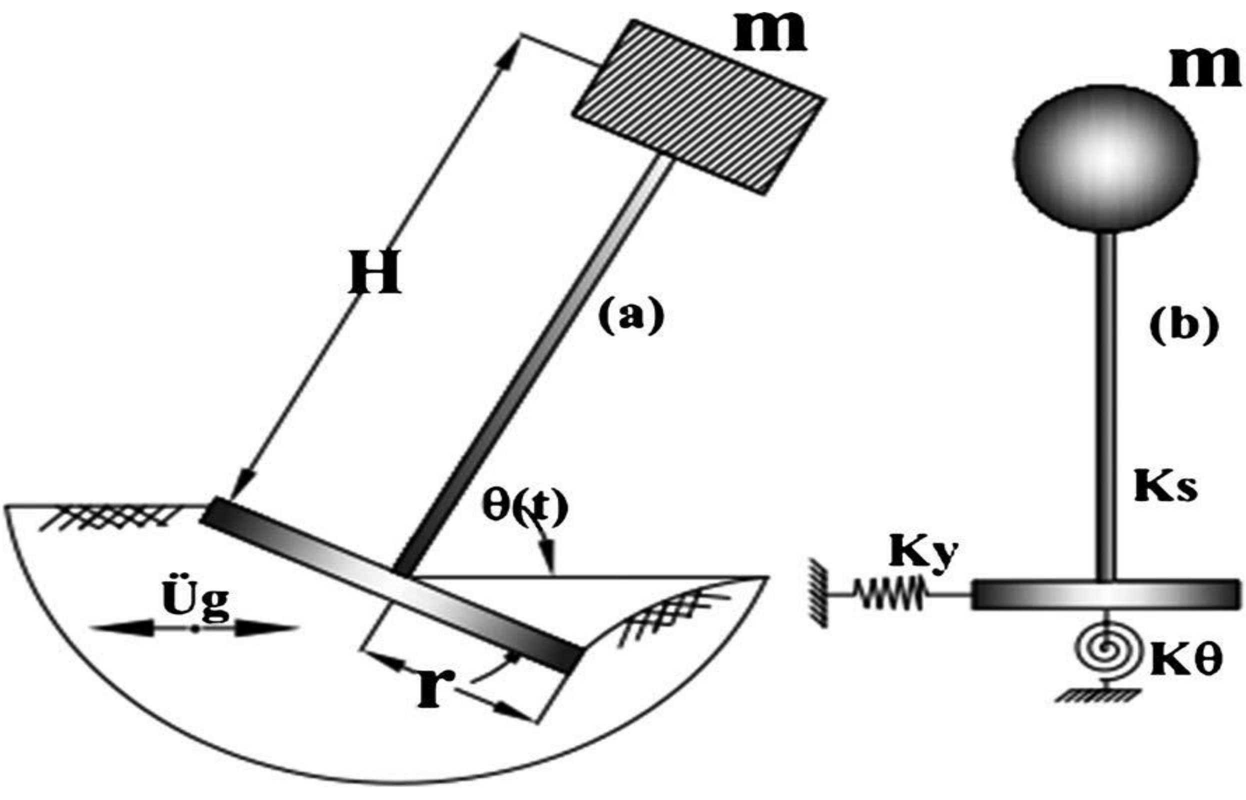

Fig 1.2. SSI model [5] – (a) shows structure supported on soft soils (b) SSI idealised model

For the same building when different types of soil are used different seismic responses are observed[6]. Soil numerical parameters such as poisons ratio, modulus of elasticity, damping ratio influences seismic behavior of soils[7]. Shear waves velocity (Vs) have also a significant impact on SSI. If the shear wave velocity of soil profile is less than 600m/s SSI have a significant impact on dynamic response of the structures[8].

If Vs <300m/s then the soil is considered to be soft.
If Vs >800m/s then the soil is considered to be hard.
If Vs >1100m/s then the soil is considered to be rigid.

By knowing the value of density of soils(p) and shear wave velocity(Vs), the shear modulus(G_S)of soils can be calculated by the equation 1

$$\text{Vs} = \sqrt{\frac{G_s}{p}} \qquad (1)$$

The modulus of elasticity (E_s) of soils can be calculated by using equation (2)

$$G_S = E_S/2(1+\text{v}) \qquad (2)$$

Where v is poisons ratio of the soils.

1.4. SSI and Structural Response-

SSI has beneficial & detrimental effects on the structural response as per conventional theories in the past due to an increase in damping, flexibility& natural period of the structure. Results shows that there is decrease in base shear and at the same time displacement for the building structures increases. Decrease in base shear is good but when displacement increase it induces secondary moments P- Δ effects due to interstorey drifts. This P- Δ effect results in excessive deflection of building and could lead to failure and instability of the whole structure. There are studies that claim that fixed base models can cause an underestimating of seismic responses in specific scenarios[9-11].SSI resulted in benefiiting the seismic demand as a economic advantage. Catastrophic failure is seen when P- Δ effects are neglected [12].

1.5 Methods of Analysis –

a) Direct Method –

In this method whole model including soil, foundation & structure as a whole are analyzed in a single step as shown in fig 1.3.This is easiest and complex method of analysis. It requires basic properties of soil and structures. Input motions and boundary conditions are also needed here. Uses numerical methods to calculate structural response. This method can be performed on FEM softwares like ABAQUS , SAP2000.

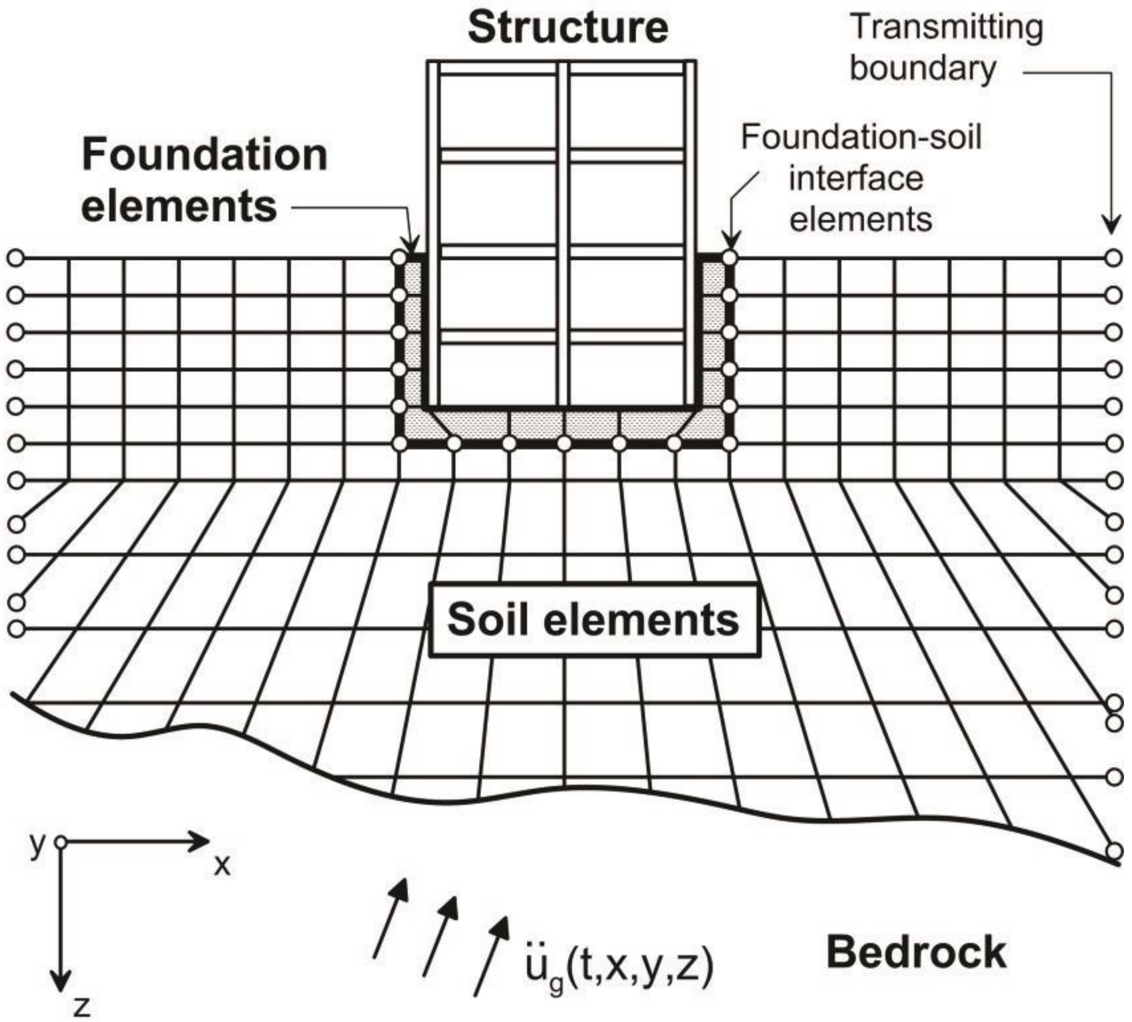

Fig 1.3 – Direct method

b) Sub structure approach –

This method involves representations of whole model in form of Springs/dashpots. This approach relies upon the superposition concept, in which each component of the system is independently modelled and linked to the entire system via its interface with other components. As a result, the substructure technique is restricted to linear systems only. Fig 1.4 shows how model is analysed in substructure approach.

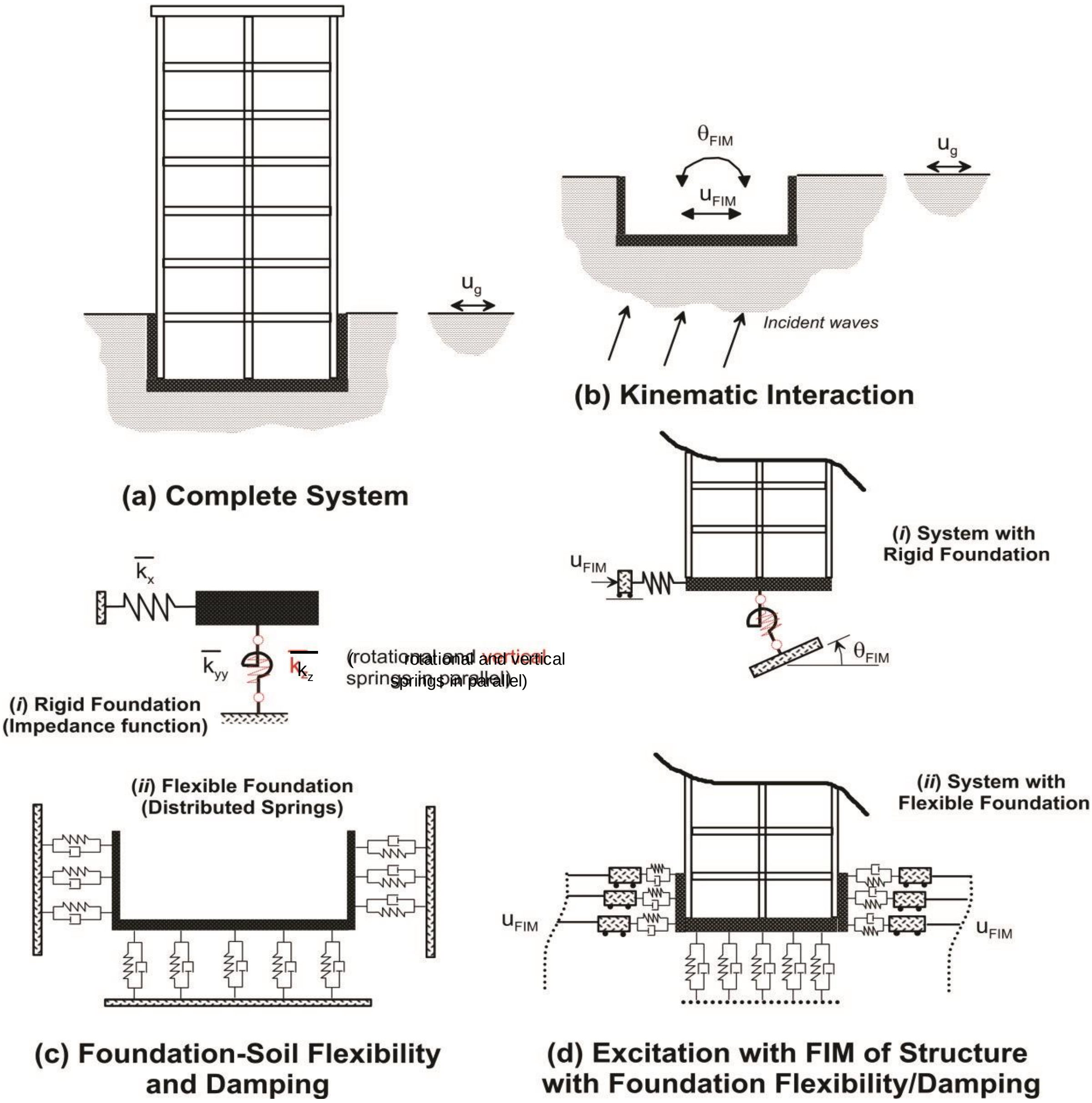

Fig 1.4 – Substructure approach

1.6 Research Structure –

Chapter 1 discussess about general introduction about SSI explaining about what is SSI. Important parameters of soil like poisson’s ratrio, modulus of elaticity,shear waves velocity, shear modulus all impacting SSI .SSI and structural response is also included in inroduction. Method of analysis used in SSI is also explained.

Chapter 2 discusses about literature survey, review of all the papers in depth and finding out research gaps to frame aim and objectives of the research.

Chapter 3 discusses about the methodoloy used in the research work which includes the present study and steps followed in research work.

Chapter 4 discusses the Numerical modelling & Analysis used in abaqus , including data collection involving all the necessary details of G+5 storey framed structure including plan of its floor and foundation. Beam and columns cross section used in framing the model. The soil investigation report telling about soil profile data and density of soils used in modelling. Reinforcement detailing of beam and columns and footings used in modelling. After numerical modelling analysis in Abaqus is performed including fem analysis and time history analysis of whole structure on different types of soil.

Chapter 5 discusses about results and discussion in brief.

Chapter 6 discusses about the conclusions can be made from the study.

After discussing about all the chapters references are mentioned which is used research work.

CHAPTER 2
LITERATURE REVIEW

2.1 General -

In this chapter addresses with the evaluation of the literature with regards to the effects of SSI. This chapter discusses how the studies conducted by investigators on SSI effects influences base shear , inter-storey drift, displacement of RC buildings and frames under various earthquake records and using various approaches to solve the models of SSI. The main aim of the literature survey is to find the research gaps and understanding various approaches of SSI. What are the new advancements are there in the field of SSI and towards framing the research objectives.

2.2 Literature Survey-

M.V Requena et al.[13] has studied earthquake hazard assessments of RC structures subjected to SSI effects. A methodology was given to understand SSI effects on real-world investigation of an RC structure at Lisbon.. Results for soil is obtained by two geotechnical investigation and clayey type of soil is founded. Superstructure modelling is done by two ways ie Direct modelling of soil and beam on non linear winkler method .It contains evidence to support that the building is being impacted by SSI effect.

Analysis by BNWM-

To get reliable results modelling of footing is important strongest point on capacities curves and initial stiffness gets affected. Models' actual modal behaviours were not captured by BNWM method because mass of footing and soil was unable to considered in this method. As a result from the software's limitations due to q-z springs omission. When foundation is not typically modelled it leads to milder reaction from the model by WMN. To define for non linear materials different stiffness coefficient of foundation is taken into account. Better results has been obtained by WMS and WBS models of foundation. Solid configuration has more similar values to WMS model. Less computation and modelling time is taken by this WMS model. The behavoiur of the building is effected by the most important parameters like ultimate capacities of the soil (p_{ult}, t_{ult} and q_{ult}).

Higher shear forces in the capacity and smaller displacement are lead by higher values of p_{ult} and $t_{ult.}$ These results are of a mide rise RC building built on a shallow foundation on clay soil.

.For the case *p-y* springs the stiffness of the footings is crucial. In important horiziontal analyses the slipping from foundation onto ground. For t-z and p-y spring, lateral passive pressure is considered to be the most important factor.

Results by direct 3d model –

Rigid soil behaviours is caused by linear soil modelling with coarser meshing. Hence grounds flexibility is not captured by these models giving nonreliable results. Due to shortage of properties considered in those analyses compared to the BNWM, shaking capability has never been as extensive models because of : Solid modelling for footings , due to deep and hard soil layers are present and complete behaviour for soil was taken into account. Higher values of V_s determine that results are of a rigid soil. It has been stated that higher seismic damage and higher periods are lead by increasing soil flexibility based on results of the RC building. Overestimation of strength capacities is observed by neglecting SSI effects. When SSI effects are taken there is a reduction by 15% on th maximum strength. Maximum strength is varied by 10 % in BNWM approach as per variation in parameters of soil . Maximum strength variation is 10% as per soil parametrs variability in BNWM method.

When footings are modelled the BNWM predict same behavior of structure as direct modelling does. When analyses was performed in under drained condition and if softer soils were used the prediction fails.

Ravi kant et al. [14] studied soil-structure interaction effect on reinforced concrete multi-storey building subjected to seismic activity. Direct modelling method is adopted for analysis. Finite element analyses was conducted with the help of finite element software i.e Abaqus to examine the effects 20,25 and 30 number of stories, and raft foundation sizes under seismic loading of EL Centro record of time history on the seismic performance. Iner-storey drift, time period, base shear , displacements were inverstigated for the fixed base and varied mat sizes considering their SSI effects. Results concluded that there is a increment in displacements , base shear , interstorey drift, and time period. When the size of the raft foundation is 2B the effects of fixed base is similar to that of hard soil. When the size of raft foundation is 1.1B there is great differences can be seen in values of base shear , interstorey drift, time period and displacements and softer soil is used here for 30 number of stories when compared with a fixed base. When the size of raft foundation is 2B there is very less difference in the values of time period ,base shear , interstorey drift and displacements and the type of soil used is hard for 20 storey structure when is compared with fixed base.

Halmat Ahmed Awla et al.[15] has perfomed a parametric study on four story steel structure in which important parameters of soil influencing SSI was studied on different types of soil including Stiff , verydense , soft , and rock soils. Poisons ratios of soil was interpolated between 0.11-0.41. A total 16 poisson ratio value was taken into study. Based on density of soil shear modulus for soils is calculated. Based on shear modulus, Elastic modulus is also calculated for 16 cases of soils based on their poissons ratios. The results were computed in form of top displacements and base shear .

Based on research it can can be concluded that actual poisson ratios values are needed for stiffer and softer soils, while poisson ratio value can be assumed for hard and very dense soils.

For the very dense and rock soils poissons ratio effect is minimum on dynamic response of the structure which is 2.4% whereas the effect of poisson ratio is 19.7% and 28.4% on the soft and stiffer soils.

Max top story displacements were 0.6% ,2.4%, 11% and 27 % for rock, very dense , stiff and soft soils while the difference in base shear ratios is 0.5%, 2.1%, 19.7% and 28.4%.

SSI has significant impact on dynamic response of the structures if the shear wave velocity of soil profile is less than 600m/s.

Khaled E. El-Hoseiny et al. [16] investigated mutltisorey building sesismic response subjected to SSI. 3D finite element analysis was performed on moment resisting frame resing on differentclass of soils B,C,D as per ECP code having different shear modulus and shear wave velocities.

The structural models total 3 in number of five , eight and ten storey models have been analysed in ABAQUS under flexible and fixed base conditions. These models were ananlysed under two ground motion records name EL CENTRO 1940 and KOBE 1995. When shear modulus and shear waves velocities are decreased there is decrement in base shear forces also. Economical and safe design of multi-storey buildings is achieved in the seismic analysis of moment resisting frame.

Hailu Getachew Kabtamu et al. [17] studied RC framed structure on founded on soft soil and is compared with same structure resting on fixed base. 7 and 12 story RC framed 2d structure is choosen for analysis. For the structure founded on soft soil having Vs <150 m/s as per China code taken in study and their analysis is done by winkler method and direct method. The linear time history analysis frames experience intense ground motions linked to soft soil spectral response of Ethiopian ES8-2015 along Chinese GB50011-2010. The results of the dynamic analysis demonstrate that for stories twelve and seven, mass participation of flexible base and spring meets 90% in two or three modes, as compared to direct method eleven and thirty modes. The second order (P- Δ) effects along inter story drift are also variable with frame heights in flexible base models. Models of the spring exhibits increased (P- Δ) effects and story drift near the softer soil bottom. Model, obtained by direct method on the other hand, shows value in the opposite direction of the spring model; it provides greater P- Δ effect along with storey drift in the upper storey when compared to fixe base. Final conclusion was that base shear reduction is not beneficial regularly. Due to an increase in interstory drift and a decrease in flexible bases story shear, where the gravity loading is steady, the P- Δ effect is more pronounced at the bottom stories.

Umal Chandekar et al. [18] studied that because of its flexibility, the supporting soil has been investigated in relation to how the building would behave. All of these distortions are ignored by the fixed support. This study looked at how a structure with a flexible basis responded. If not considered, the behavior difference between permanent and flexible support structures could result in inaccurately determining the structural safety. Multistory structures with isolated foundation resting on medium along with stiff soil are taken for study. Seismic forces are taken into study via response spectrum analysis. SAP2000 is for building analysis. Based on IS 1893(II), and FEMA-356 all the soil variables needed to define soil classification have been determined collectively. Equivalent springs have been used to simulate the soil for each of the six degrees of freedom. This method should be utilised effectively with known soil parameters to take the effects of SSI into account because it is easier when compared to the direct method. Various soil circumstances, the total number of stories, and the type of footing have all had an impact upon the structure's structural behavior It was found that shifting from fixed to flexible support increased the building's laterally deflection and time period. Shear of the base and shape of the modes was little bit changed.

Salah Khalfallah et al. [19] had done numerical modelling to understand the impacts of soil characteristics, seismic impact, and interactions between the frame structure and the soil foundation in this work. Continuum modelling of frame ,soil and interface is done by finite element method. In the present study, a numerical programme based on the technique of direct analysis was constructed to analyse the interaction between the soil along with structure under seismic loads. To develop contact between footing and soil an thin layer element is taken. Results are obtained in form of interface effect in SSI ,Deflection of superstructure under time history record, diaplacements at top floors of framed structure. Calculation of shear stesss at the at the contact surface between foundation and soil. Results showed that hard soils had lower displacements as compared to softer soils for the framed structure and the response of framed is in proportion with the mechanical properties of soil.

2.3 Research gaps –

- Especially on hard soils effects of SSI is known but less study is done for stiff as well as softer soils.
- Poissons ratio value can be assumed for hard soil , but very accurate value of poissons ratio is needed for softer and stiffer soils.

2.4 Research objectives –

- A comparative study is conducted to evaluate the SSI effects on G+5 storey framed structure building resting on different types of soil including softer and stiffer soils based on their poisson ratios values i.e 0.31,0.33,0.35.
- Peak displacements of framed structures resting on different types of soils are also compared.

CHAPTER 3

METHODOLOGY

3.1 Present Study –

Present study is about a real G+5 storey RC framed structure building in Himachal Pradesh which is resting on silty soil medium. Soil characterization is done by carrying out 3 geotechnical investigations. With the help of site engineer and report of geotechnical investigations denity of soil is known. M25 grade of concrete is used in beam , columns and footings. The plan of building including its foundation plan is show in chapter 4 along with reinforcement detailing of beam and columns. All necessary information about framed structure and soil is shown in chapter 4 under data collection title. This framed structure is modelled in Abaqus by providing all the necessary inputs in numerical modelling by direct method of analysis under ELcentro 1940 time history record.

3.2 Procedure to be followed –

1
- Data collection of soil and G+5 storey framed structure

2
- Numerical modelling of soil and G+5 story framed structure by direct method in Abaqus.

3
- Analysis of G+5 framed structure including its convergence study and full time history analysis of whole model resting on different types of soil.

4
- Results and discussion

5
- Conclusion

CHAPTER 4

NUMERICAL MODELLING AND ANALYSIS

4.1 General –

This chapter discusses about the data which is needed in framing the G+5 storey framed structure. Numerical modelling is carried in Abaqus a FEM software. FEM analysis is also carried in this chapter. The procedure is described below.

4.2 Data Collection –

4.2.1 Plan of G+5 storey framed structure –

The figure below 4.1 shows the plan of G+5 storey framed structure which is used in modelling by Abaqus where beams B1 and B2 are shown with their dimensions i.e

B1 -3550 mm , B2 -3250mm, Plan area =8450 X 8300 mm2

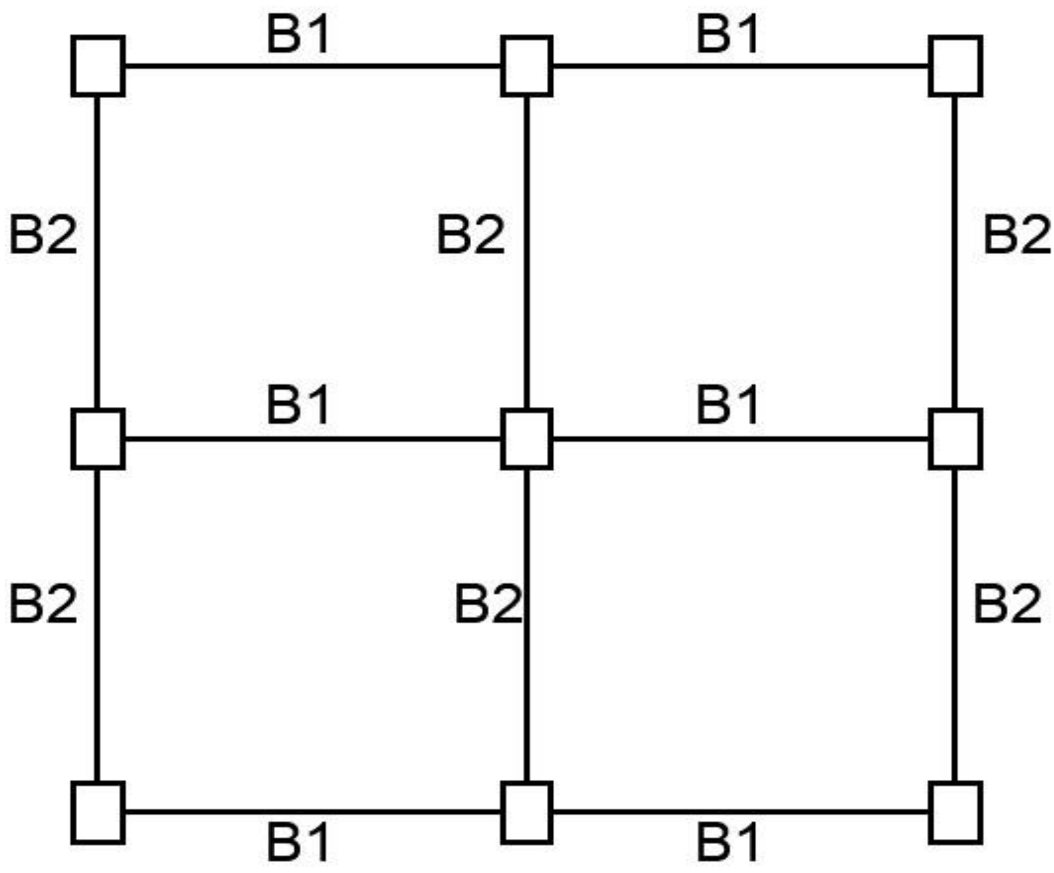

Fig 4.1- Plan of framed structure

4.2.2 Foundation plan of G+5 Structure –

Isolated square footings are used as substructure in G+5 storey framed structure with specification which can be easily shown in fig 4.2

Length = 3200 mm , Breadth =3200 mm , Depth = 675mm , and clear cover =40mm

plan is shown in figure below

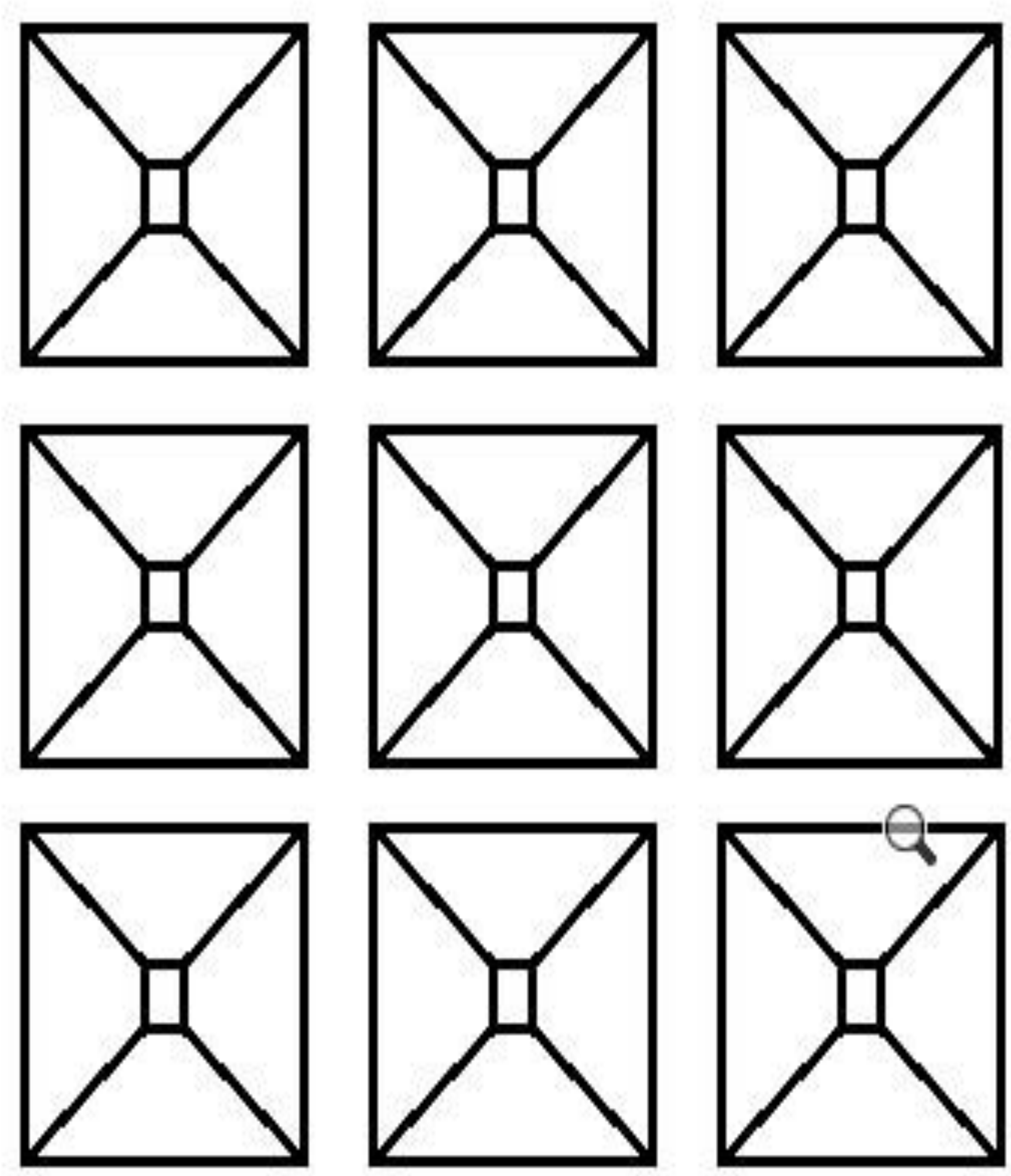

Fig 4.2 – Foundation plan

4.2.3 Soil Profile data -

The soil profile data is computed from 3 geotechnical tests. **S**pt test of 3 bore holes was conducted and soil profile data is evaluated as shown in fig 4.3 from bore hole1.

From Bore hole 1-

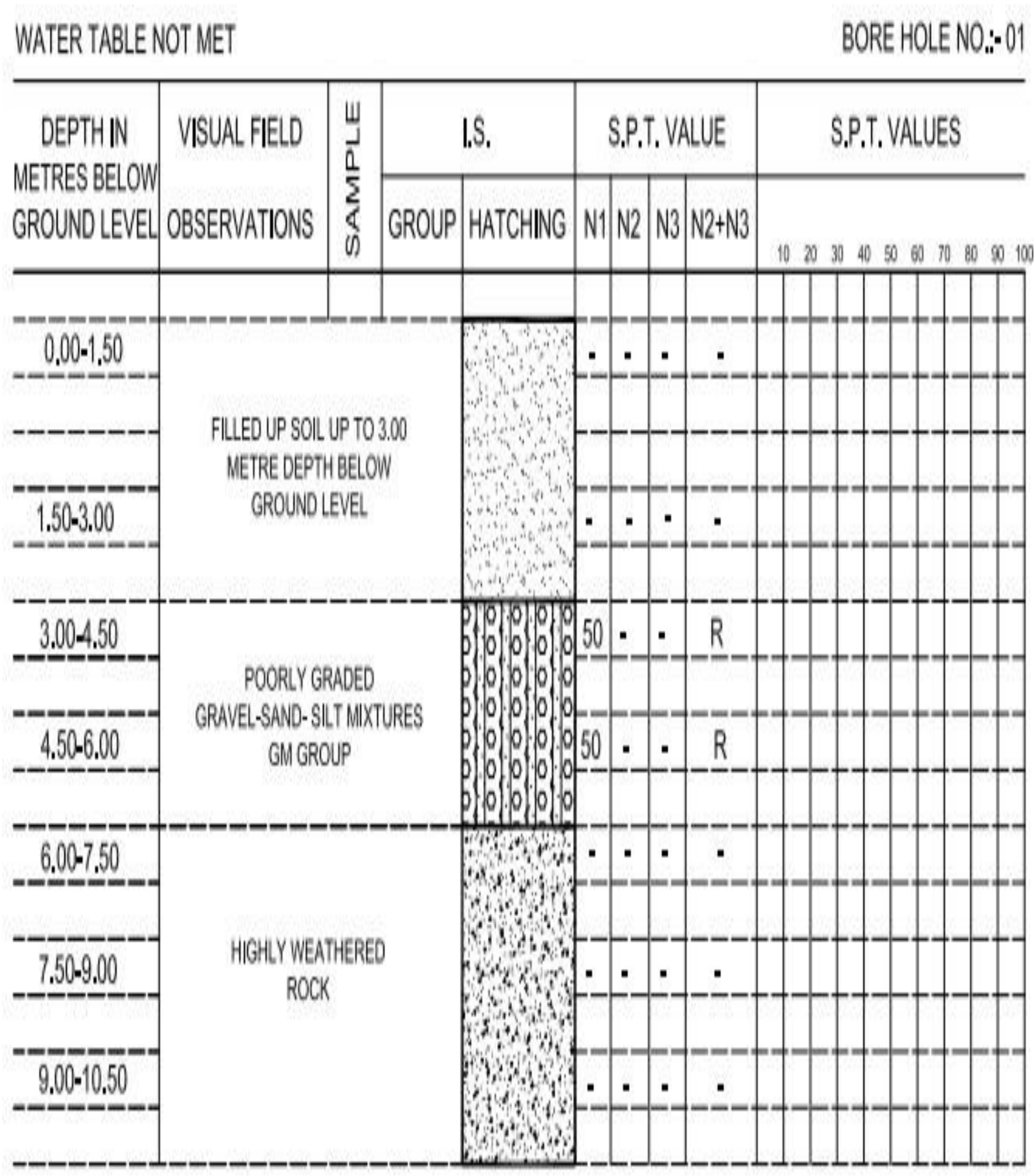

Fig 4.3- Soil profile from bore hole 1

Soil profile data from bore hole 2 is shown in fig 4.4

WATER TABLE NOT MET — BORE HOLE NO.:- 02

DEPTH IN METRES BELOW GROUND LEVEL	VISUAL FIELD OBSERVATIONS	SAMPLE	I.S. GROUP	I.S. HATCHING	S.P.T. VALUE N1	N2	N3	N2+N3	S.P.T. VALUES (10 20 30 40 50 60 70 80 90 100)
0.00-1.50	POORLY GRADED GRAVEL		GM		50	.	.	R	
1.50-3.00	HIGHLY WEATHERED ROCK				.	.	.	.	
3.00-4.50					.	.	.	.	
4.50-6.00					.	.	.	.	
6.00-7.50					.	.	.	.	
7.50-9.00					.	.	.	.	
9.00-10.50					.	.	.	.	

Fig 4.4- Soil profile data from bore hole 2

Soil profile data from bore hole 3 is shown in fig 4.5

WATER TABLE NOT MET | BORE HOLE NO.:- 03

DEPTH IN METRES BELOW GROUND LEVEL	VISUAL FIELD OBSERVATIONS	SAMPLE	I.S. GROUP	I.S. HATCHING	S.P.T. VALUE N1	N2	N3	N2+N3	S.P.T. VALUES (10 20 30 40 50 60 70 80 90 100)
0.00-1.50	FILLED UP SOIL UP TO 3.00 METRE DEPTH BELOW GROUND LEVEL				·	·	·	·	
1.50-3.00					·	·	·	·	
3.00-4.50	POORLY GRADED GRAVEL-SAND- SILT MIXTURES GM GROUP				50	·	·	R	
4.50-6.00					50	·	·	R	
6.00-7.50	HIGHLY WEATHERED ROCK				·	·	·	·	
7.50-9.00					·	·	·	·	
9.00-10.50					·	·	·	·	

Fig 4.5- Soil profile data from bore hole 3

4.2.4 Ductile deailing of beam and column -

Fig 4.6 shows the ductile detailing of beams which is designed as per IS 1893:2002. Clear cover in case of beams is 25mm and for columns it is 40mm.

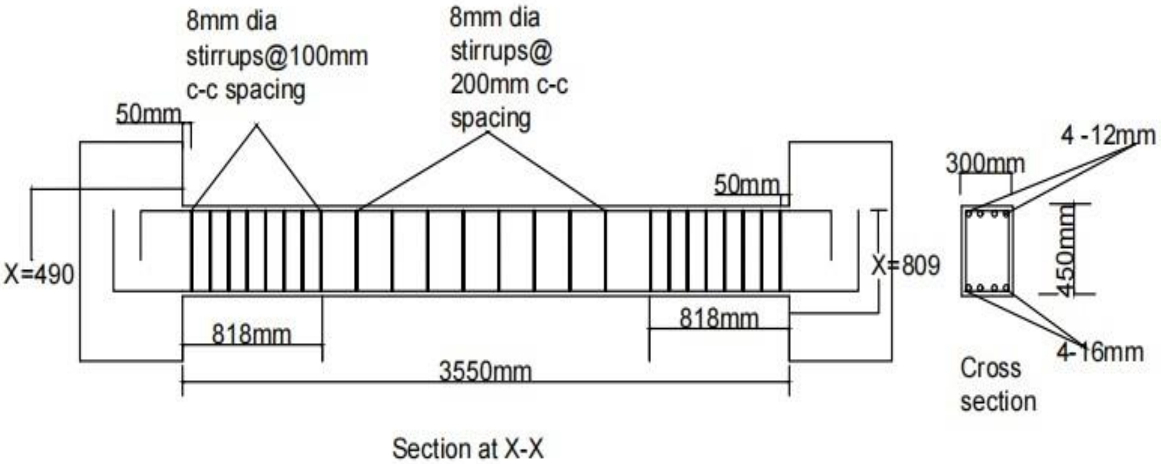

Fig 4.6- Ductile detailing of beam B1

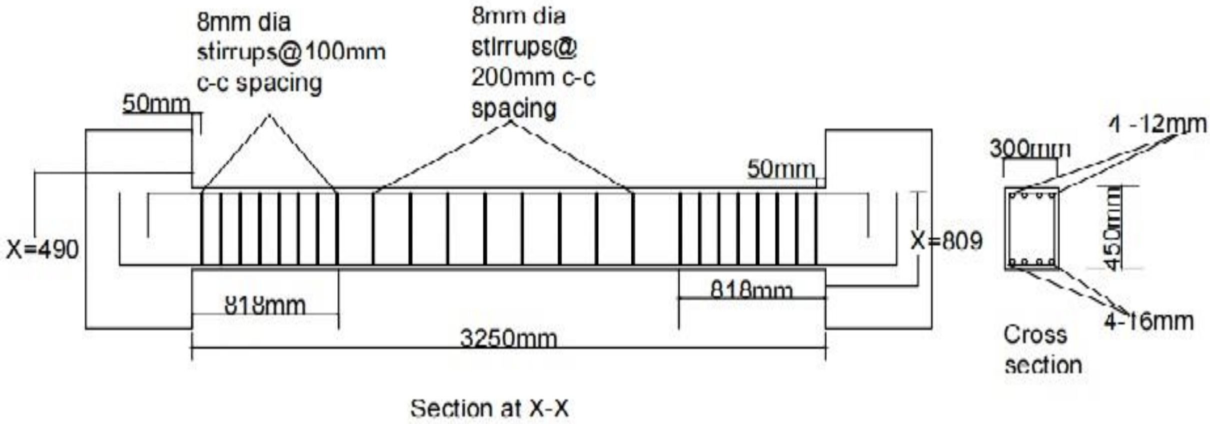

Fig 4.7 - Ductile detailing of beam B2

Fig 4.8 showing ductile detailing of columns.

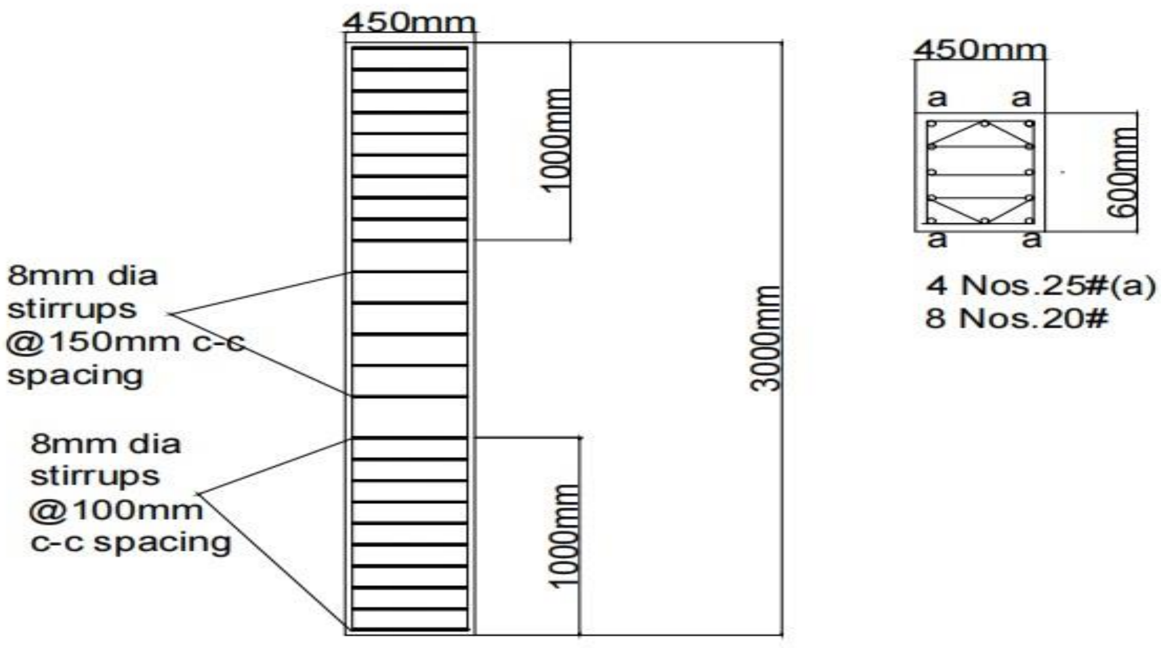

Fig 4.8 – Column detailing

4.2.5 Footing detail-

Fig 4.9 shows the reinforcement detailing of footing used in analysis with a clear cover of 50 mm

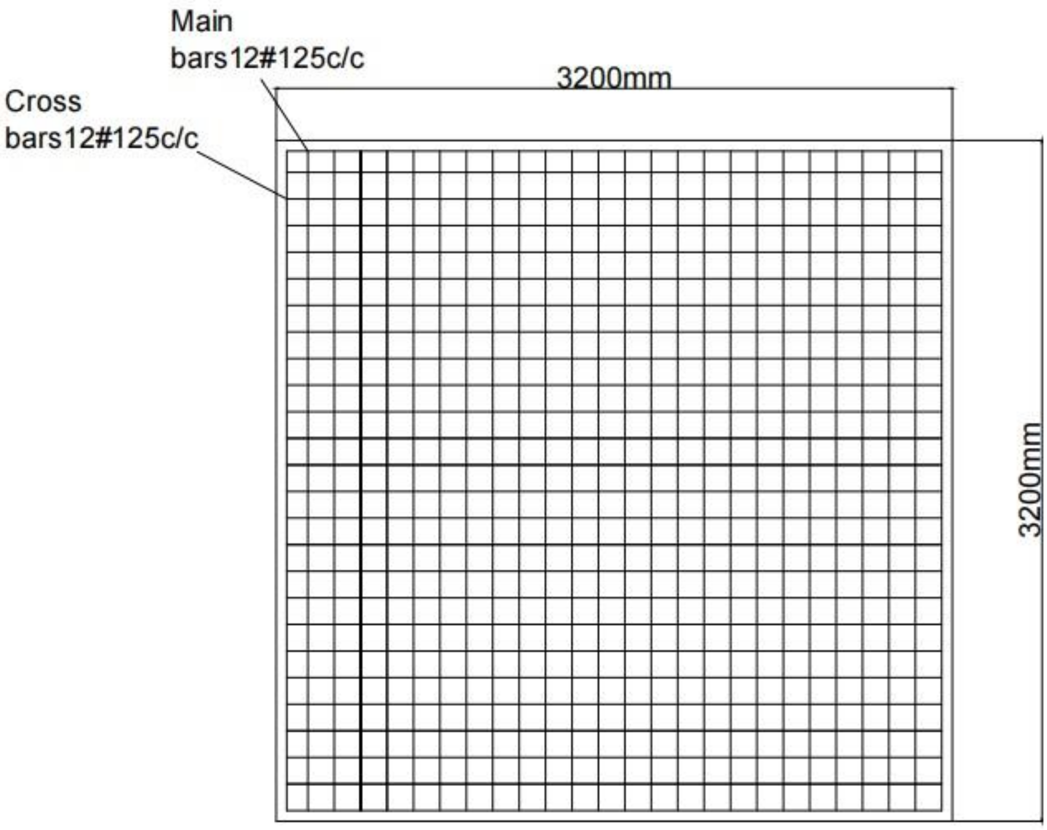

Fig 4.9 – Footing reinforcement

4.3 Soil parameters used in modelling-

The following values of poisson ratio is used in modelling the soil in Abaqus from JE bowles book.

Table 4.1 –Values for poisson ratio

Type of soil	Poisson ratio
Silt	0.3 – 0.35
Sand, Gravelly sand	0.1 -1.0
Commonly used	0.3-0.4
Rock	0.1-0.4

Based on density of soil provided by site engineer, shear modulus can be computed from equation 1. i.e G=140.69 Mpa for stiff soil and G=55.7 Mpa for soft soil

Density of soil = 1930 kg/m^3

Table 4.2- Shear waves velocity(Vs) in m/s of various soil profiles

Rock	1130
Very Dense	560
Stiff	270
Soft	170

The value of modulus of elasticity is calculated from poissons ratio and shear modulus from equation 2

Table 4.3 – Modulus of Elasticity and poissons ratio

Poisson ratio	0.31	0.33	0.35
Stiff soil	368.6	374.23	379.86
Soft soil	145.93	148.16	150.39

4.4 Numerical Modelling –

In numerical modelling the steps used in Abaqus for modelling the structure are explained step by step. In general Abaqus is a fem software . The steps in modelling includes parts, property ,aseembly , step ,interaction , load , Mesh , job and after jobs results can be seen. Fig 4.10 shows the basic interface of Abaqus.

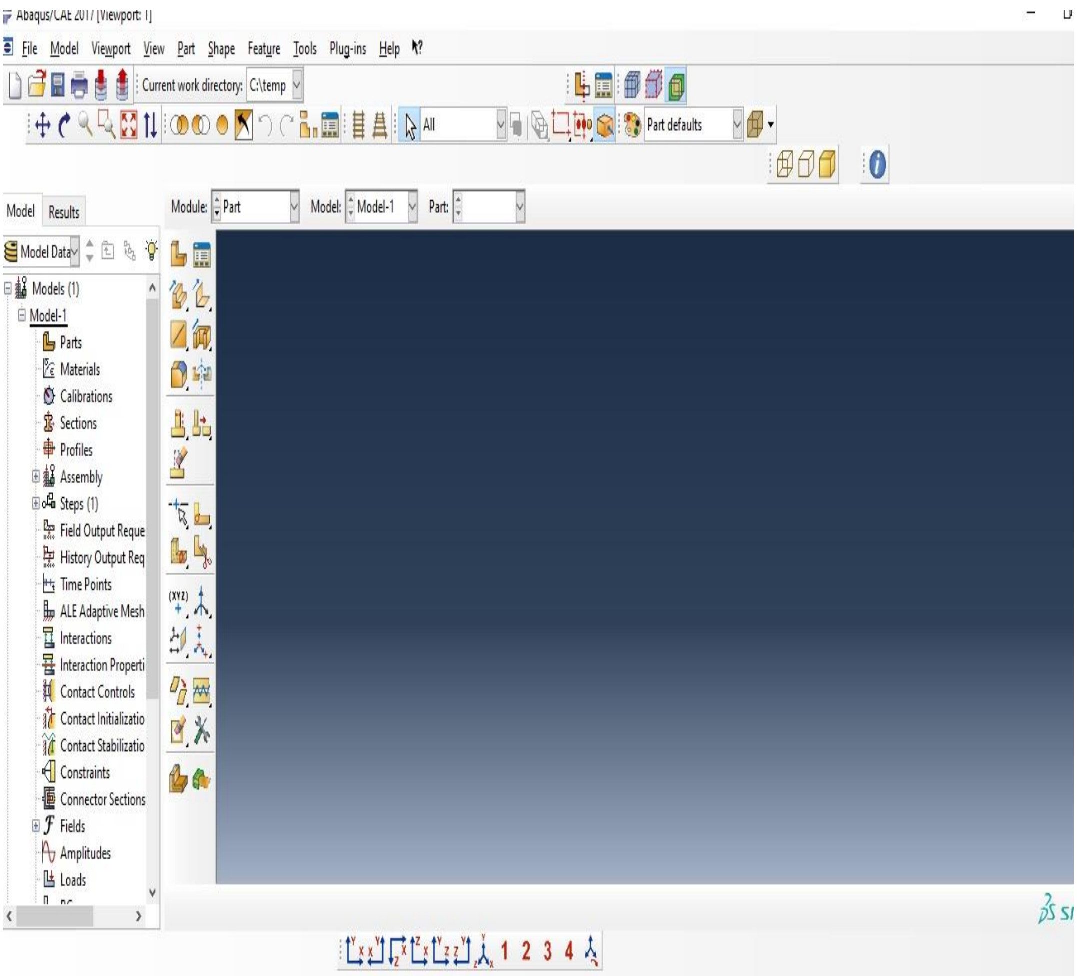

Fig 4.10 – Basic interface of Abaqus

4.4.1 Building and soil modelling –

Beam modelling

Modelling of beam is done first and can be done by steps shown in figure below –

Click on create part enter name and then it will ask for dimension of beam.

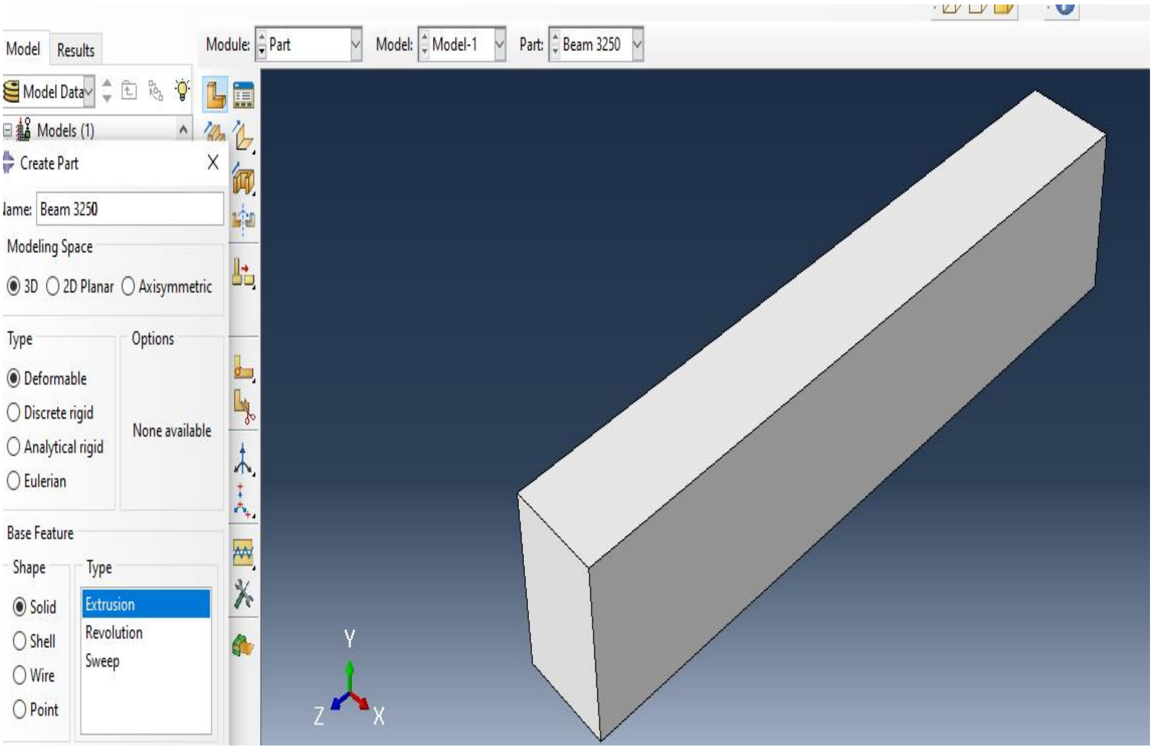

Fig 4.11- Beam 3250mm

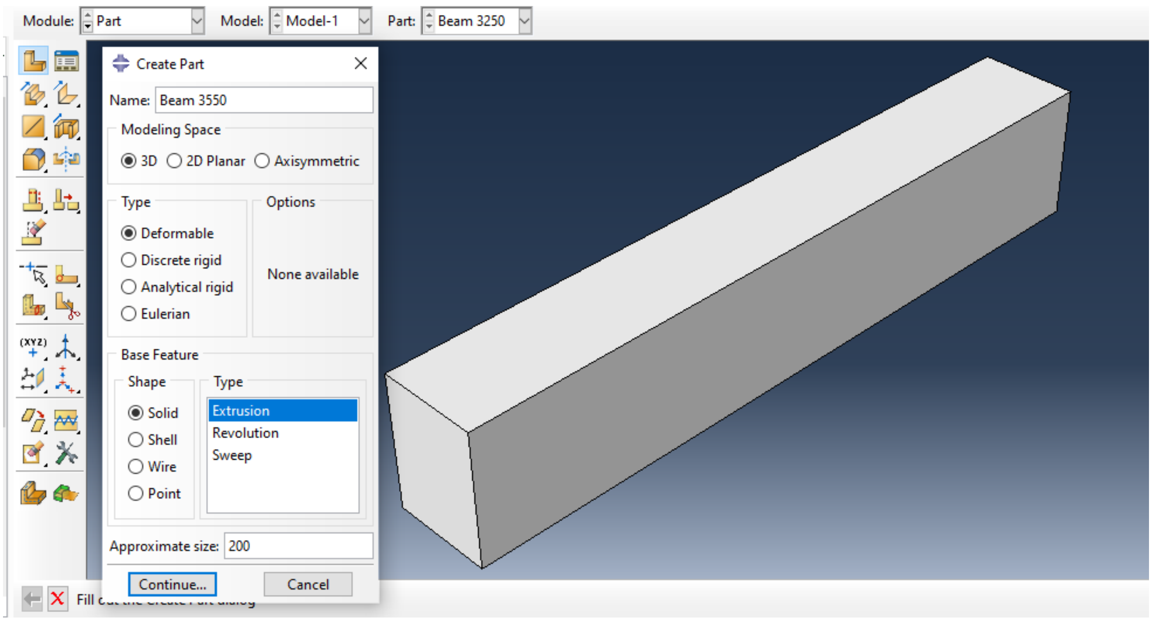

Fig 4.12 – Beam 3550 mm

Column- Columns are also created in a same way as beams as shown in fig 4.13

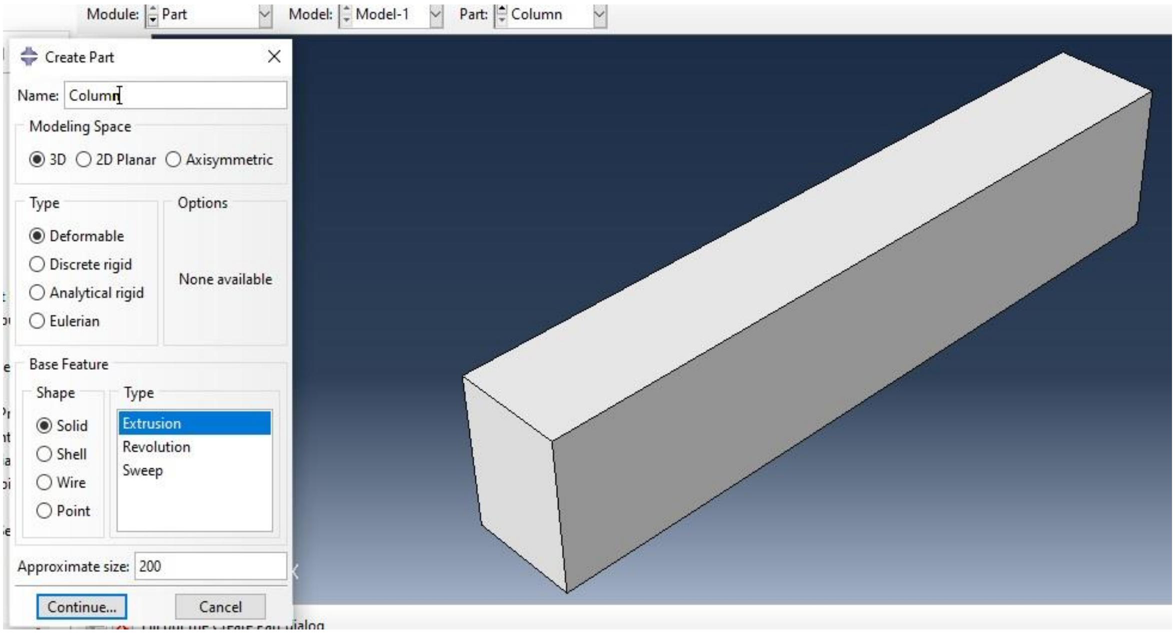

Fig 4.13 –Column

Footings –

Isolated footing are used in modelling of foundation as per fig below

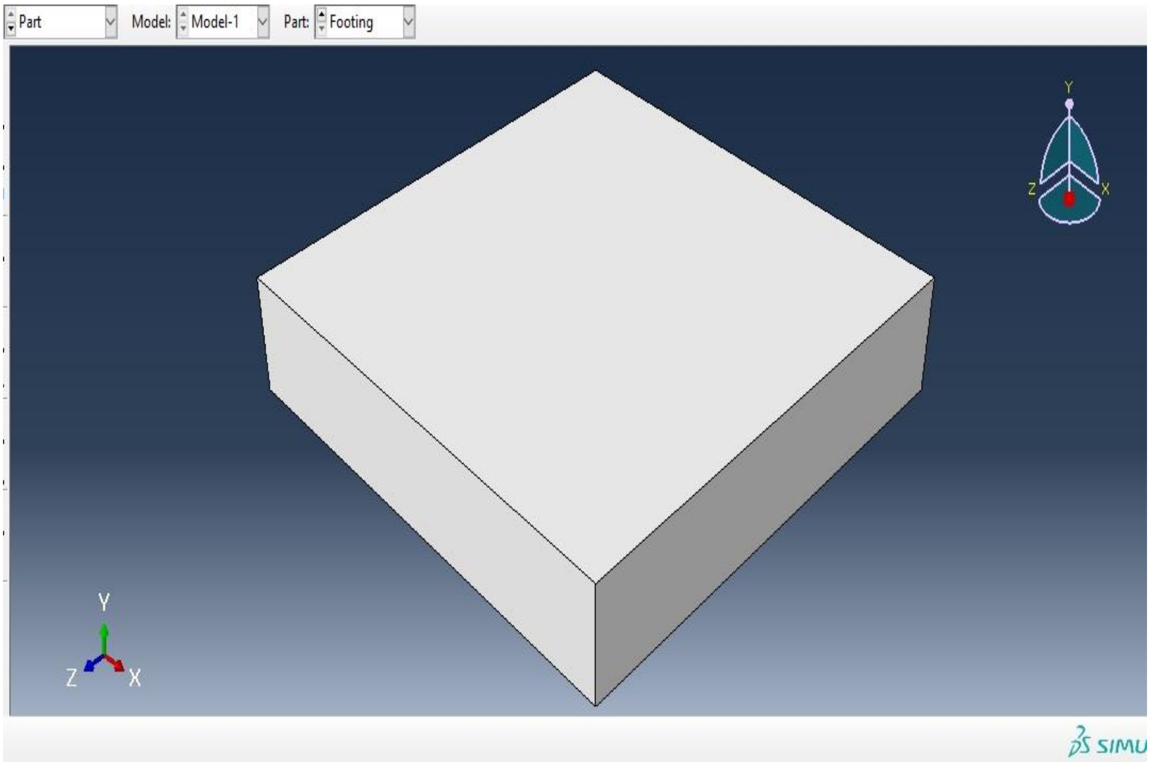

Fig 4.14 -Footing model

Soil modelling –

The soil is modelled as soil box with size 30x30x15m as shown in fig below

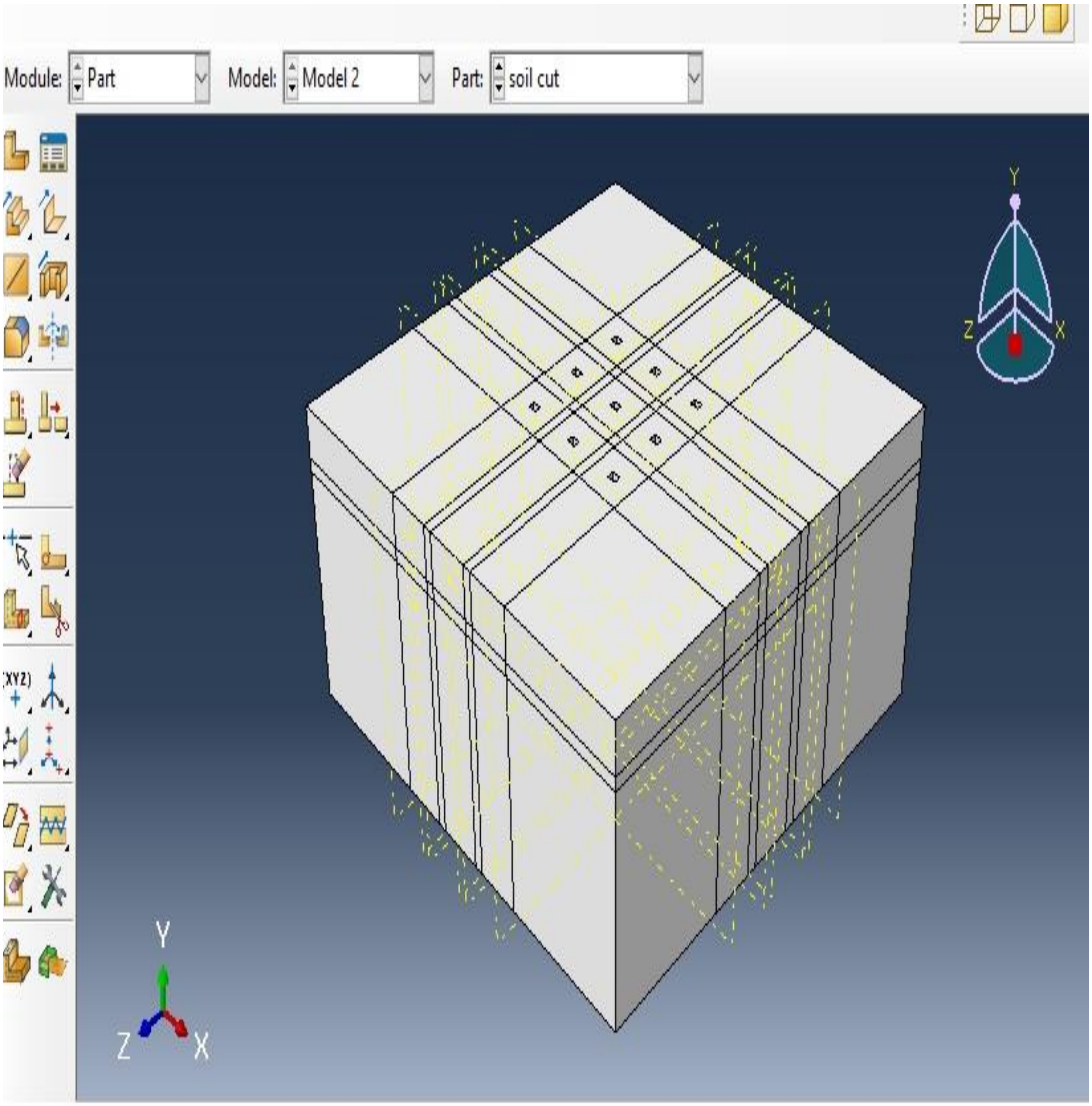

Fig 4.15 – Soil modelling

3D Model –

This is direct modelling in abaqus in which G+5 storey is modelled and each storey is having height of 3m. Soil box having dimension of 30mX30mX15m. Depth is foundation is also 3m.

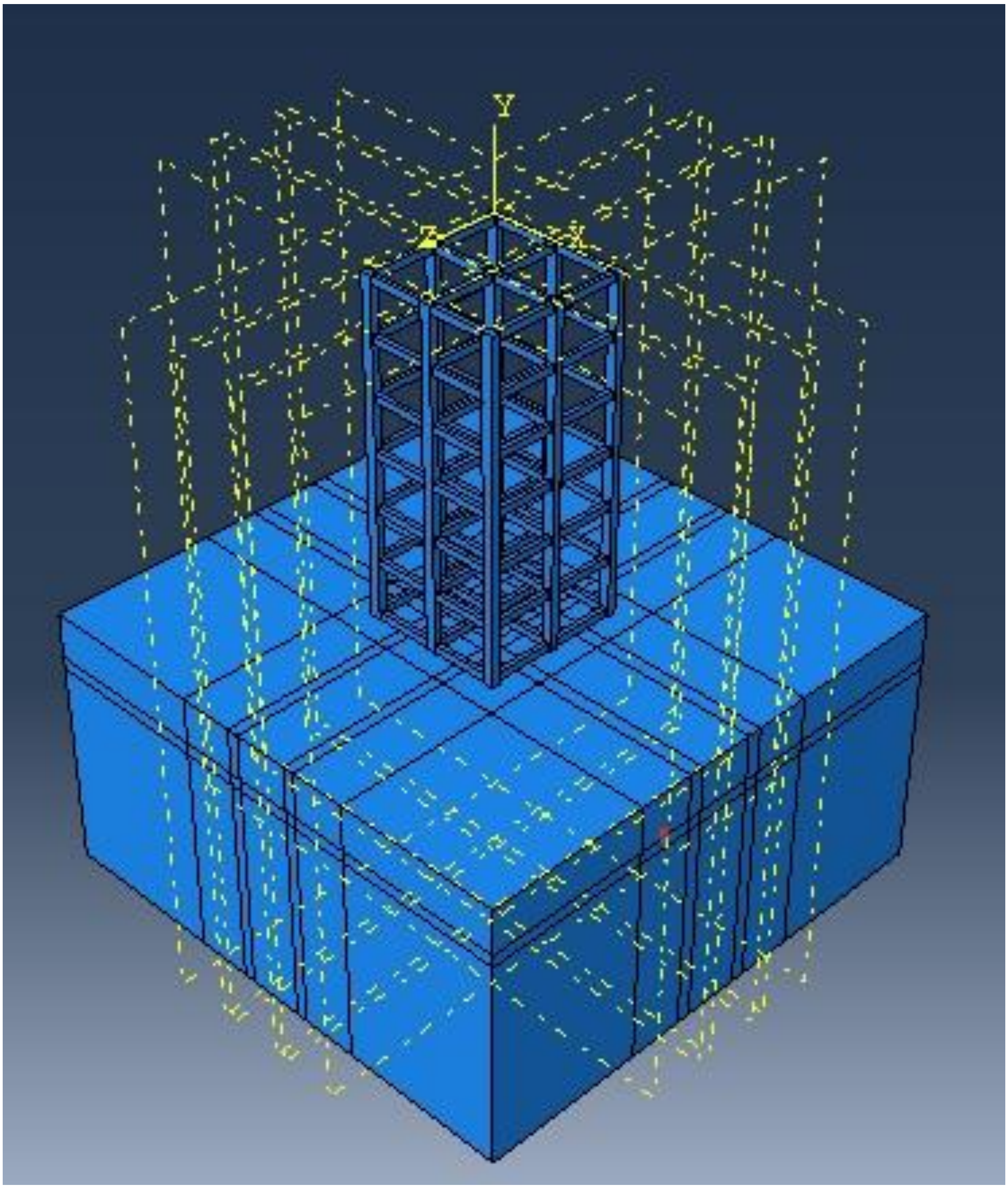

Fig 4.16 – 3D modelling of soil

4.4.2 Reinforcement in building–

The reinforcement in building is provided as per the data can be shown in fig 4.17

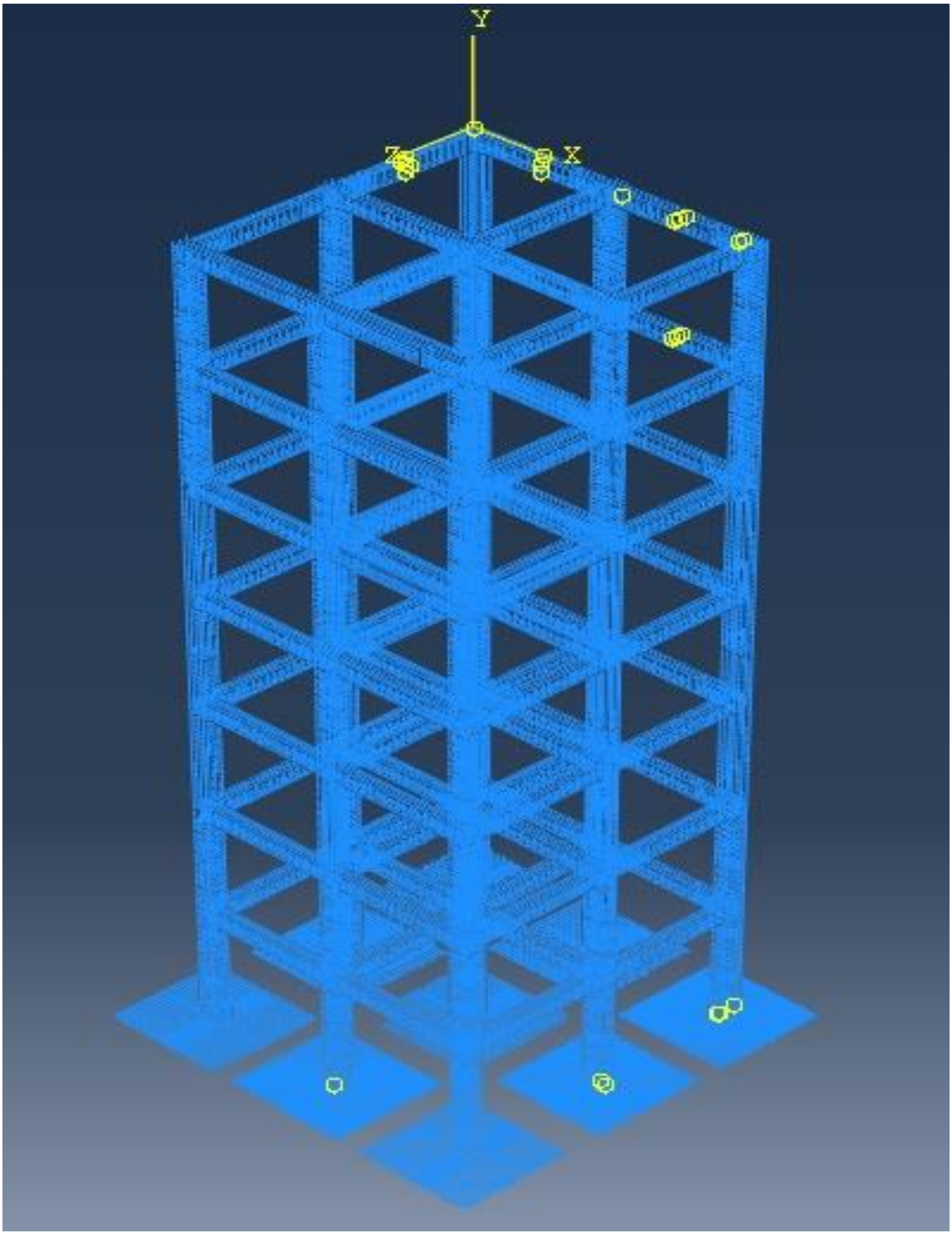

Fig 4.17 – Building reinforcements

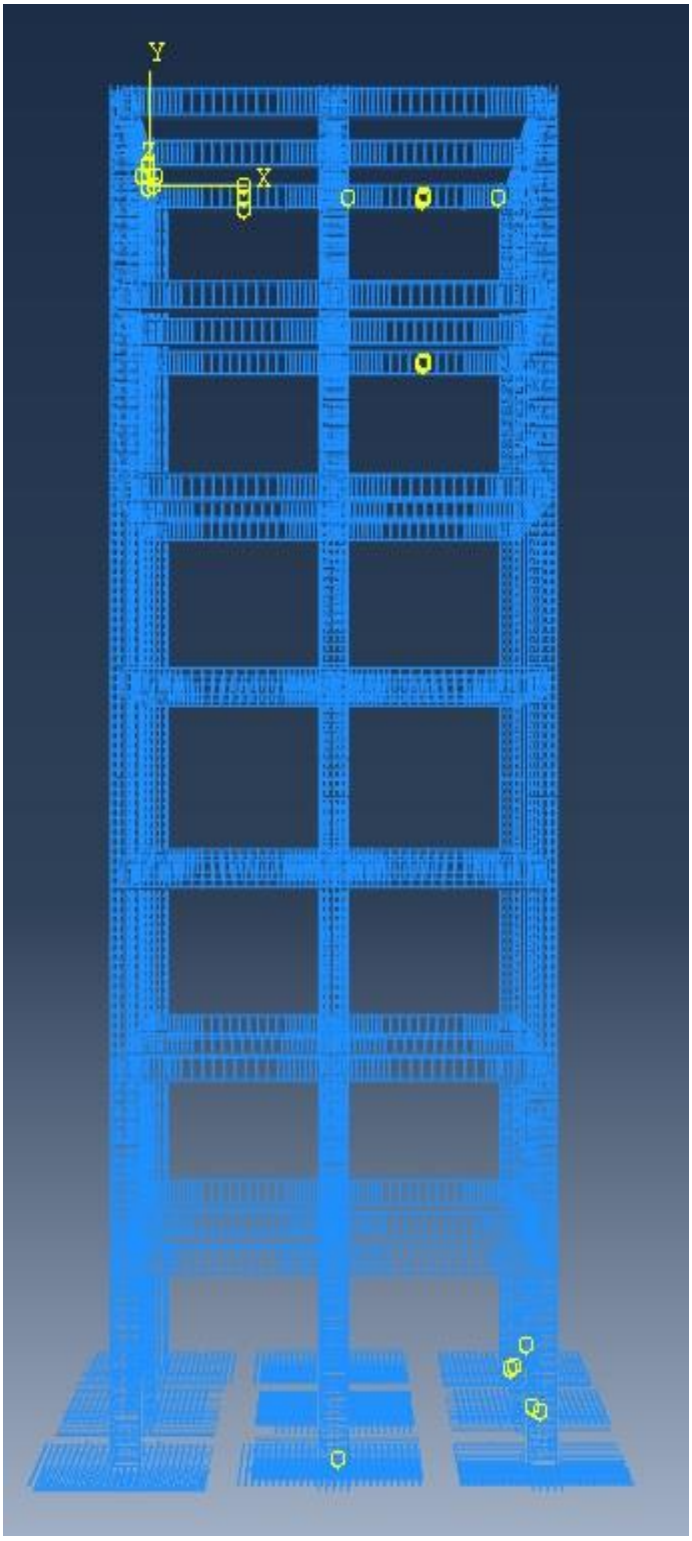

Fig 4.18 – Side view of reinforcements

4.5 Material Parameters used in modelling –

4.5.1 Soil parameters -

Soil identified at site is silty soil GM . In this study modulus of elasticity was calculated as per table 4.2

In modelling of soils three poissons ratio values were taken i.e 0.31,0.33,0.35 for stiff and soft soils. Corresponding values of modulus of elasticity were taken for each type of soil amd total 6 cases were formulated as per table 4.3 shown below –

Table 4.3 – Cases used in soil modelling

Cases	Type of soil	Poissons ratio (v)	Modulus of Elasticity (Mpa)
Case 1	Stiff	0.31	368.6
Case 2	Soft	0.31	145.93
Case 3	Stiff	0.33	374.23
Case 4	Soft	0.33	148.16
Case 5	Stiff	0.35	379.86
Case 6	Soft	0.35	150.39

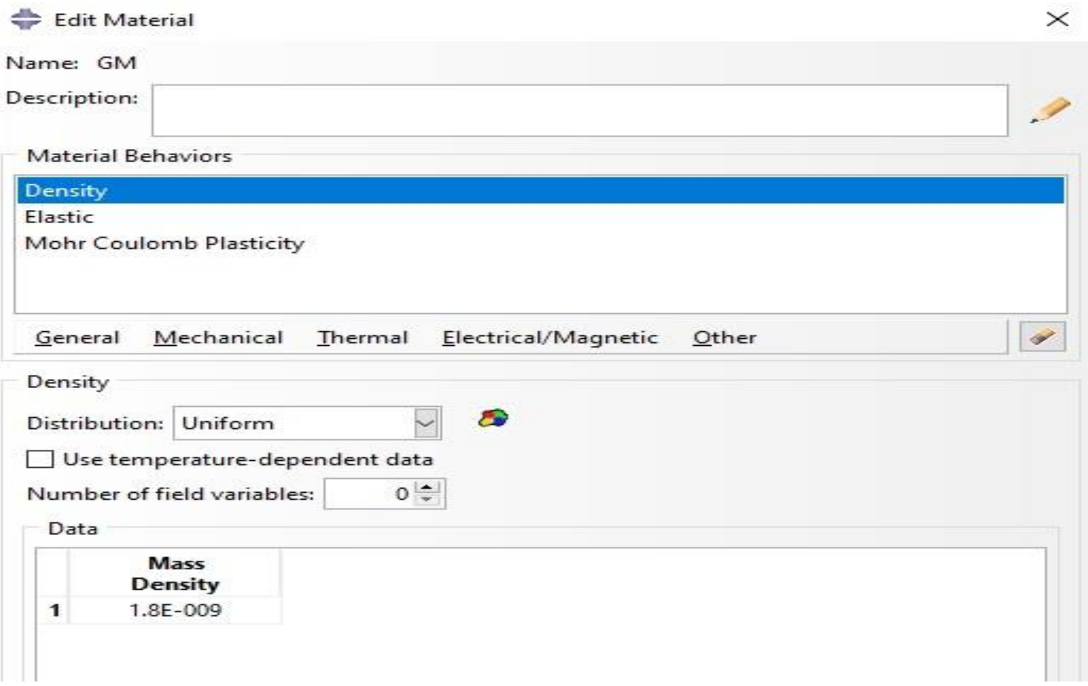

Fig 4.19 – Density of soil used in modelling

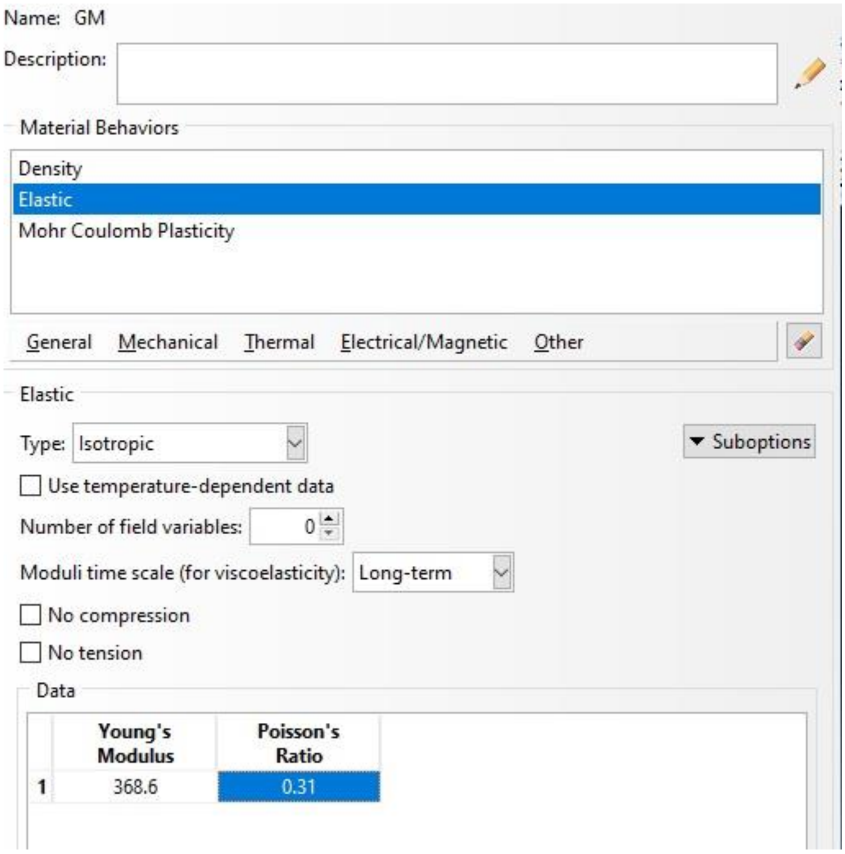

Fig 4.20 – Case 1

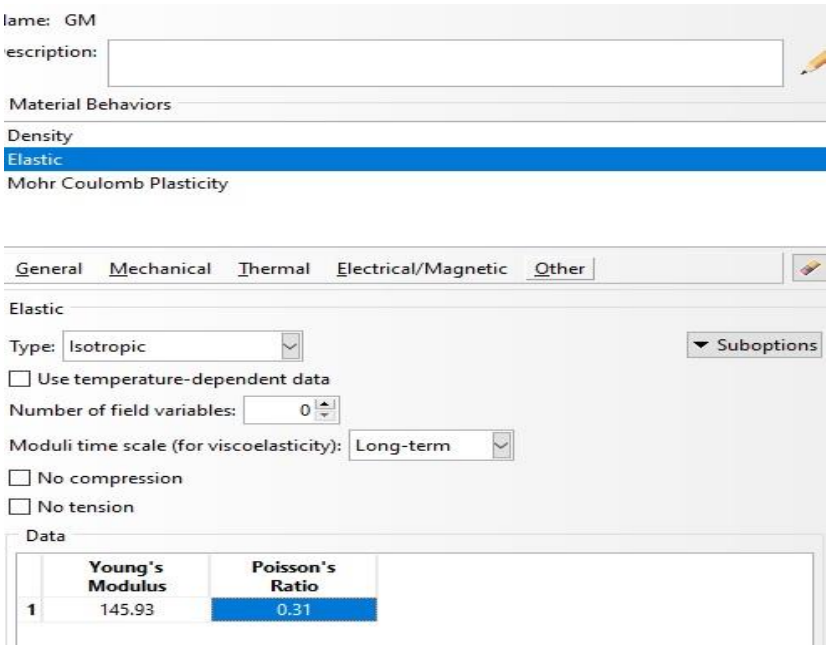

Fig 4.21 – Case 2

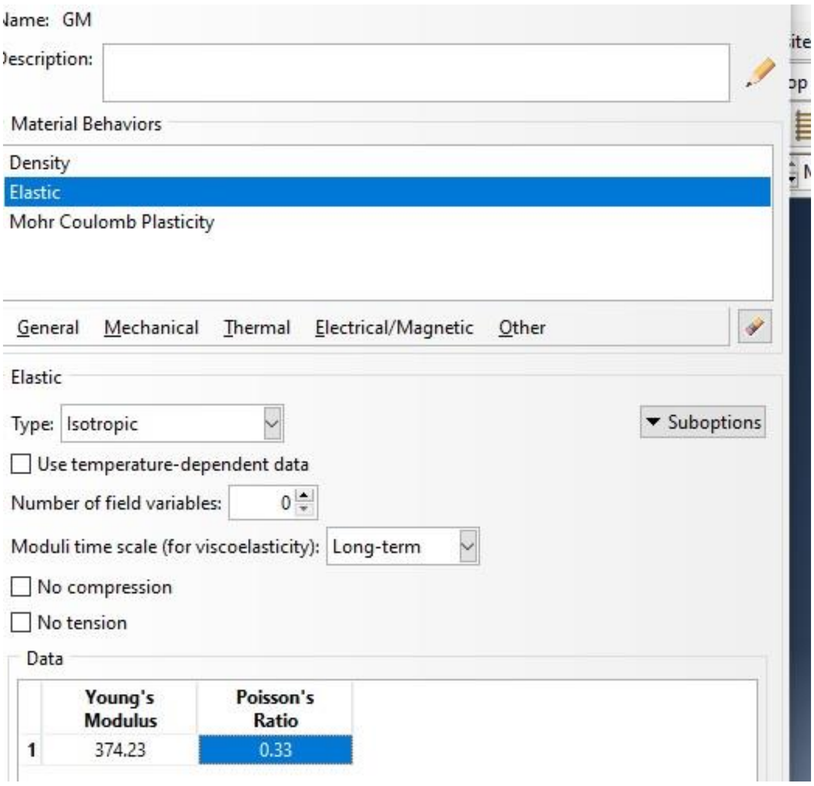

Fig 4.22 – Case 3

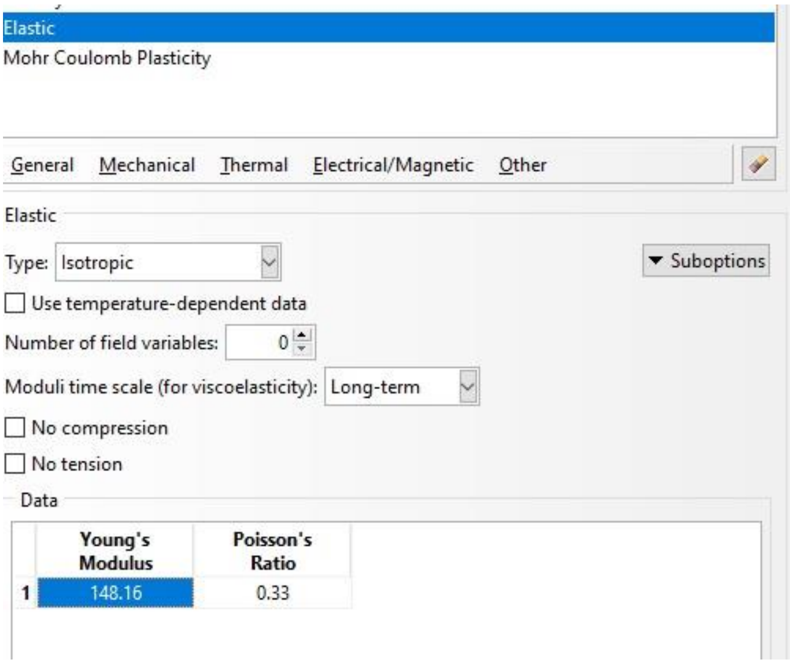

Fig 4.23 – Case 4

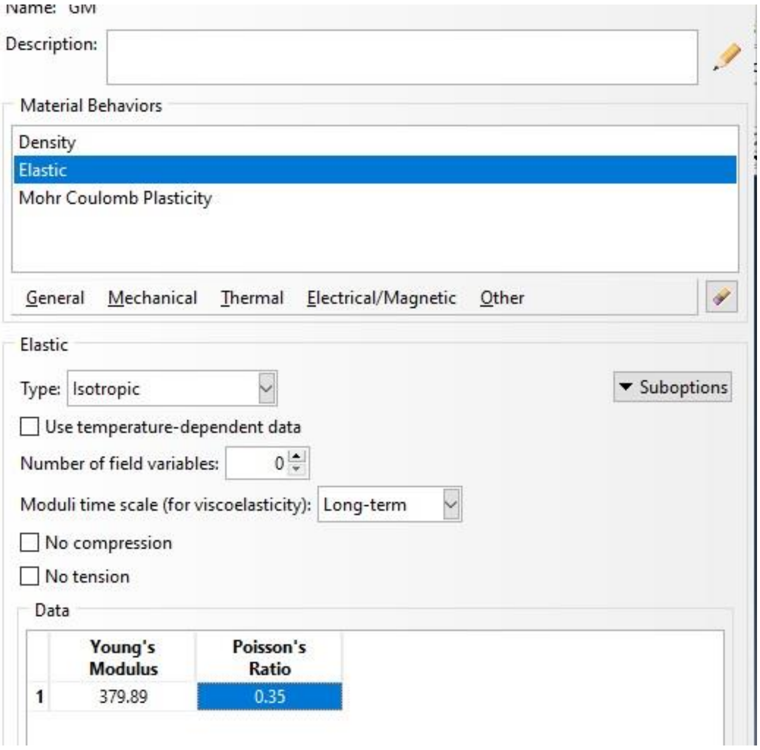

Fig 4.24 – Case 5

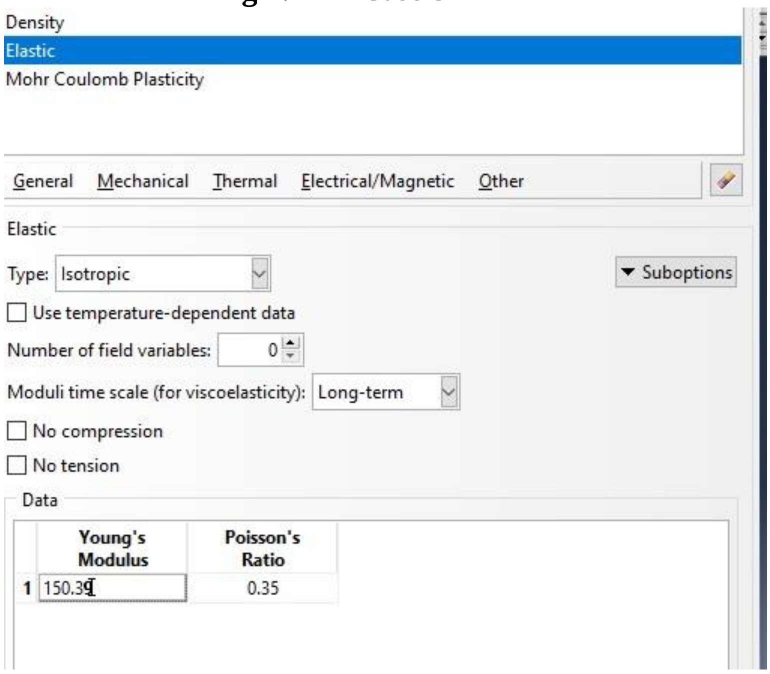

Fig 4.25 – Case 6

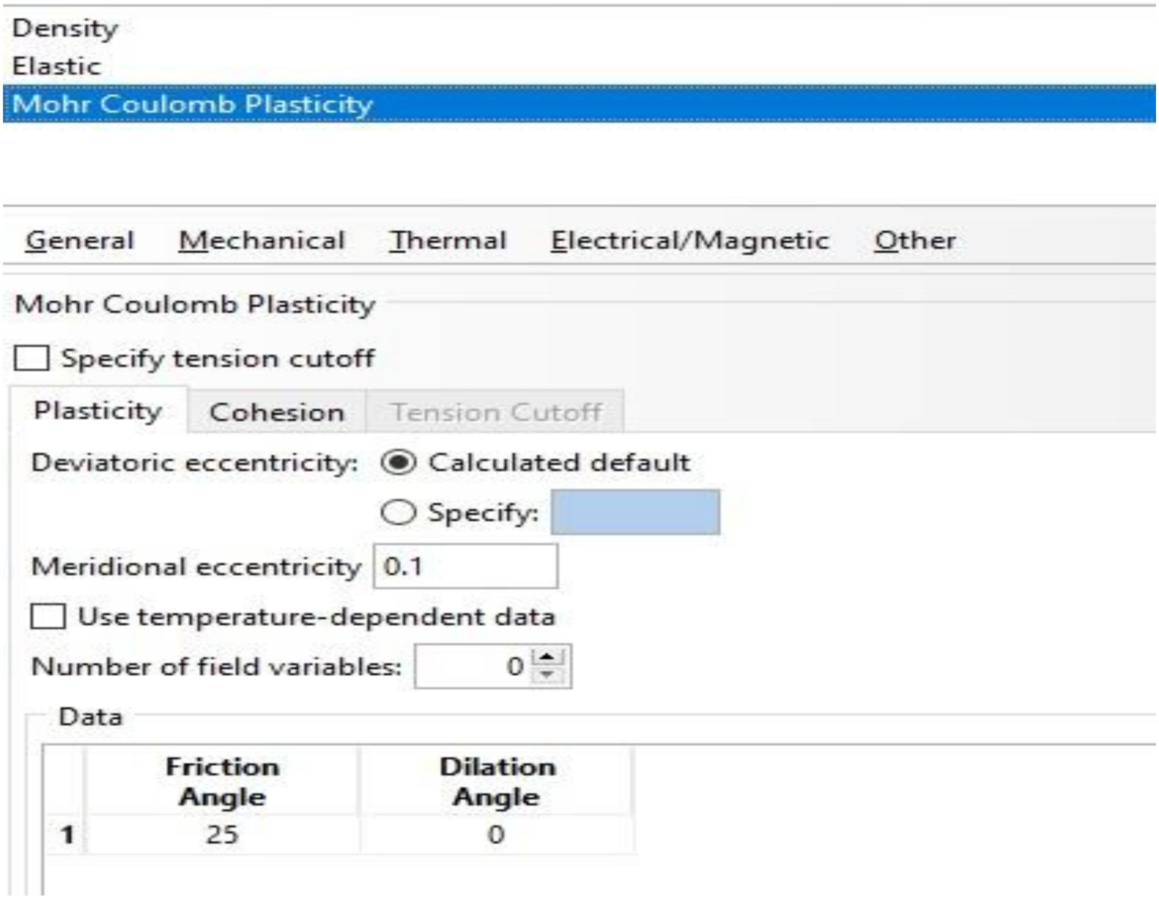

Fig 4.26 – Mohr Coulomb Plasticity

4.5.2 Concrete parameters –

M25 concrete is used in modelling

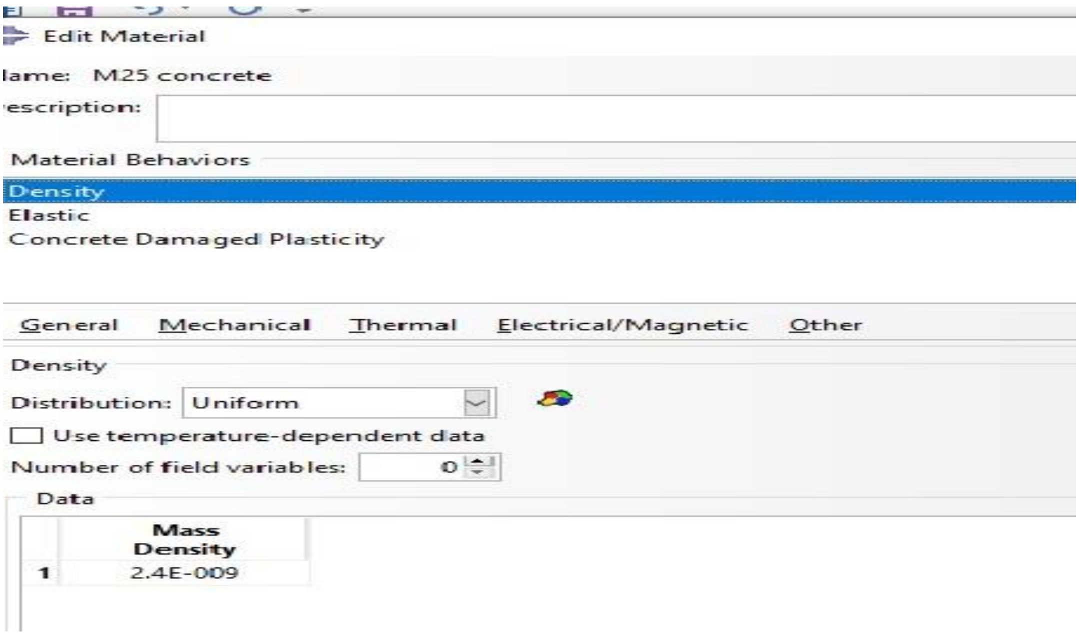

Fig 4.27 – Mass Density

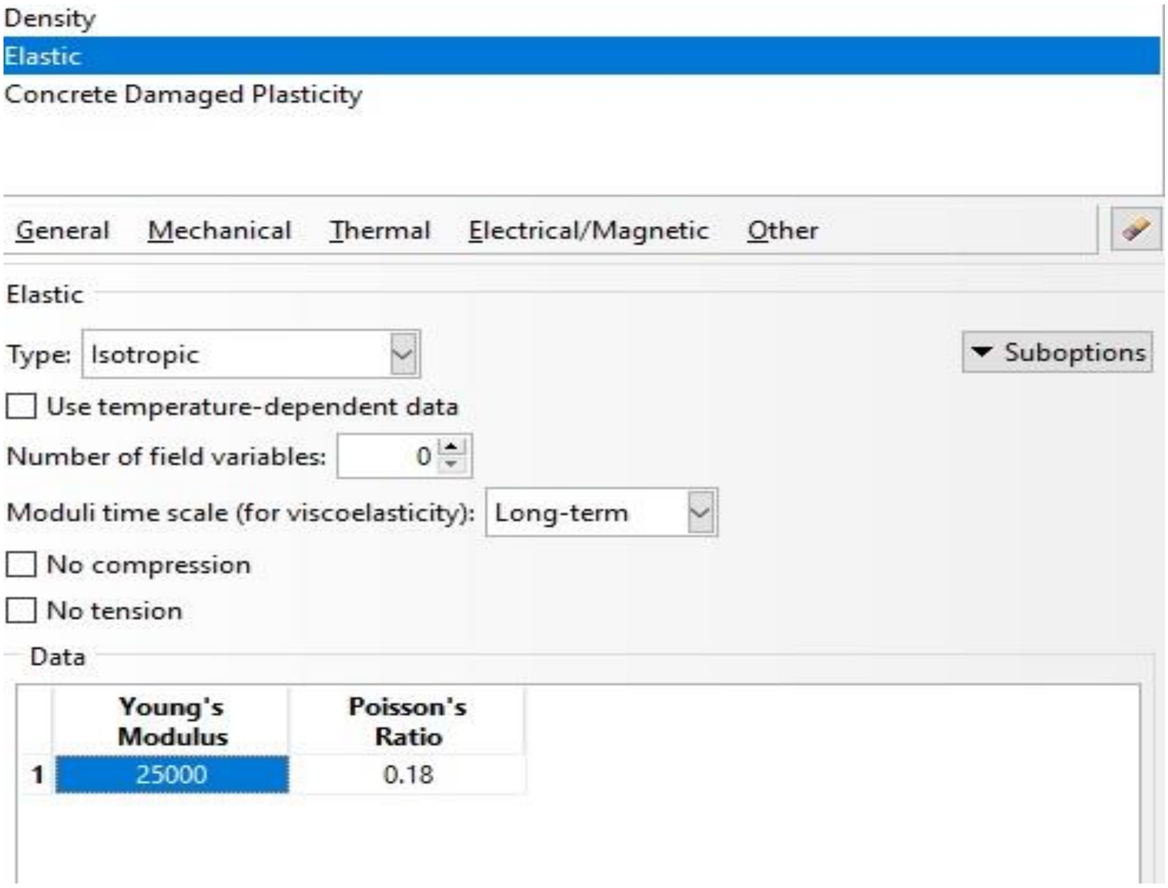

Fig 4.28 – Modulus of elasticity of M25 concrete

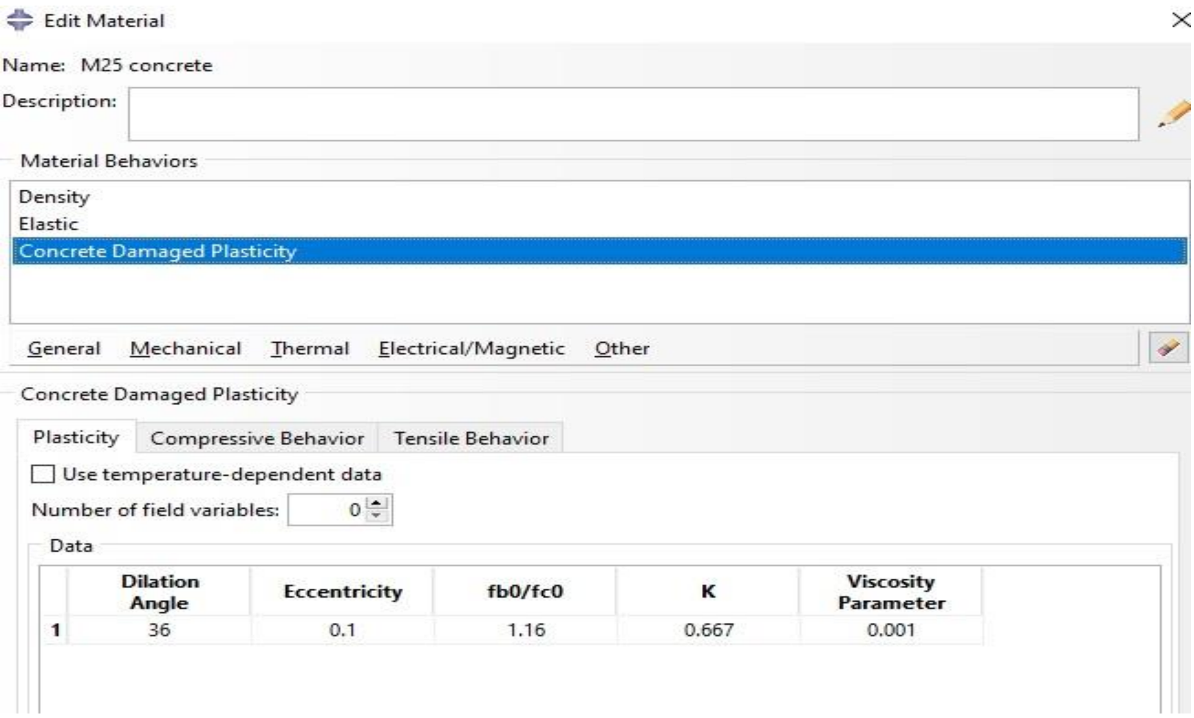

Fig 4.29 – CDP parameter

4.5.3 Steel parameters –

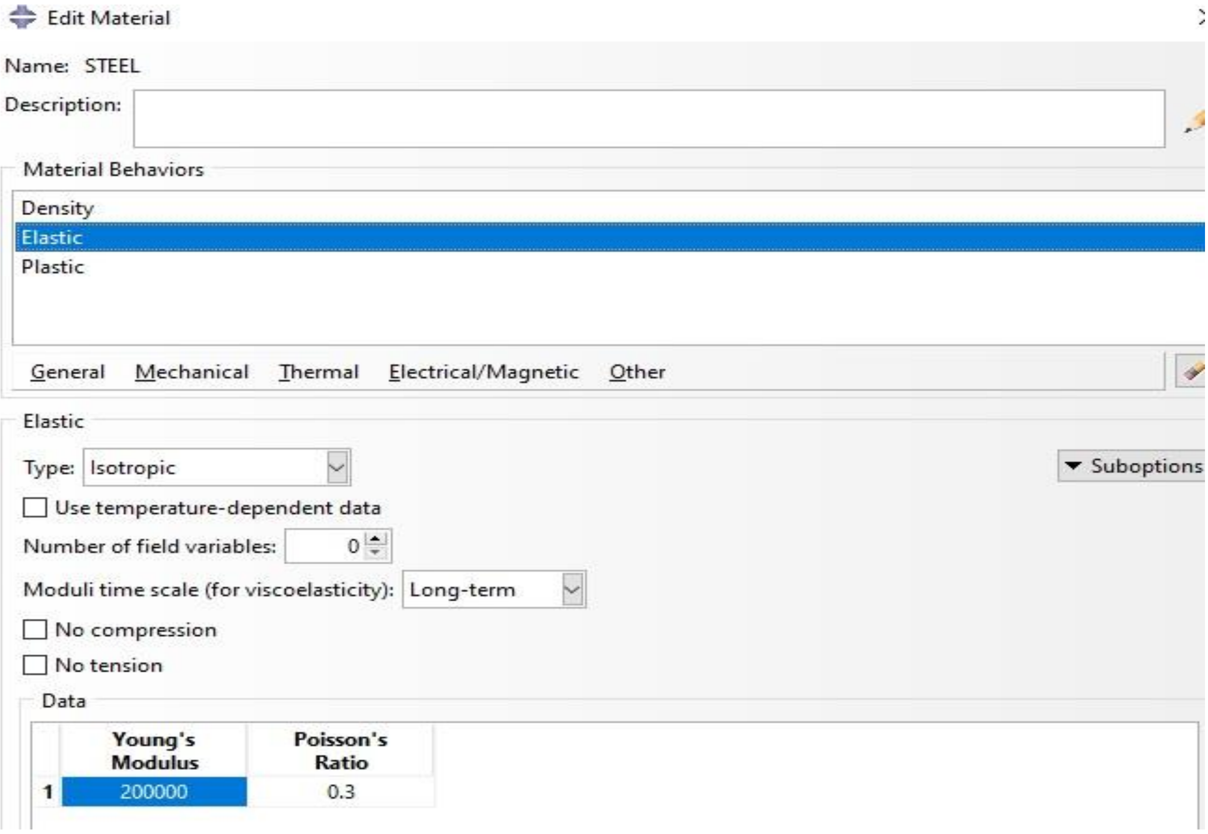

Fig 4.30 – Elasticity of steel

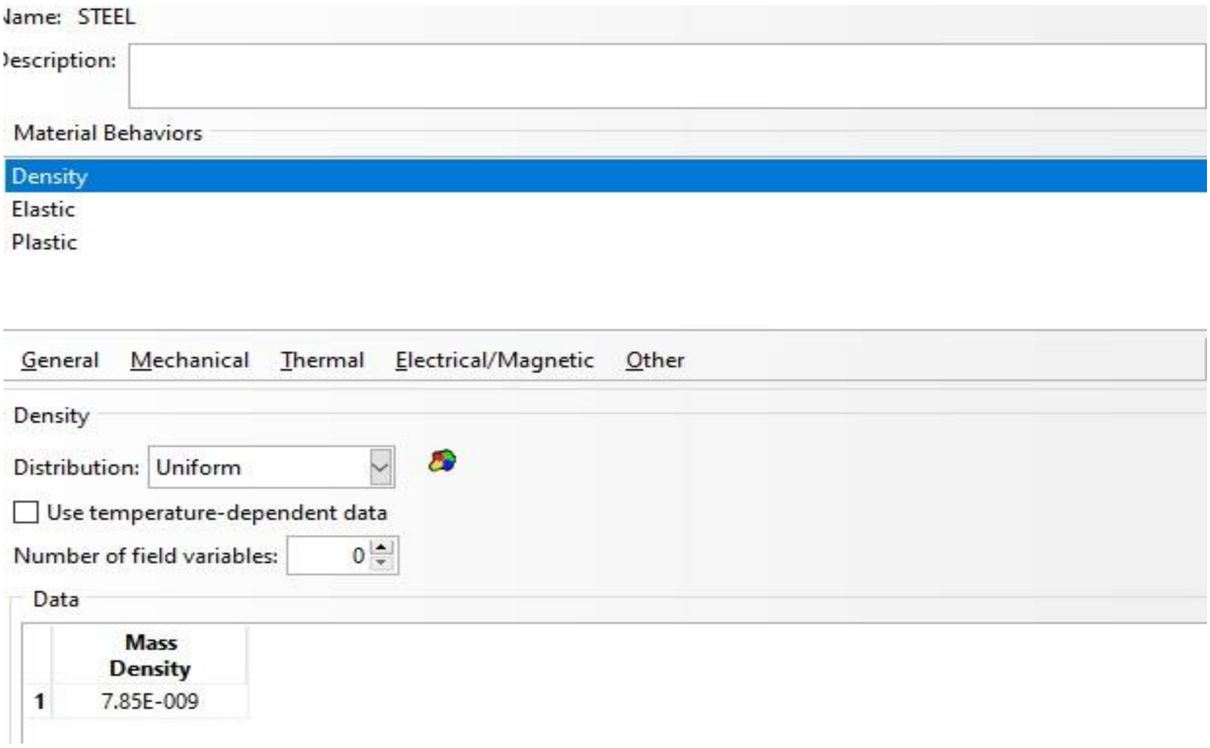

Fig 4.31 – Density of steel

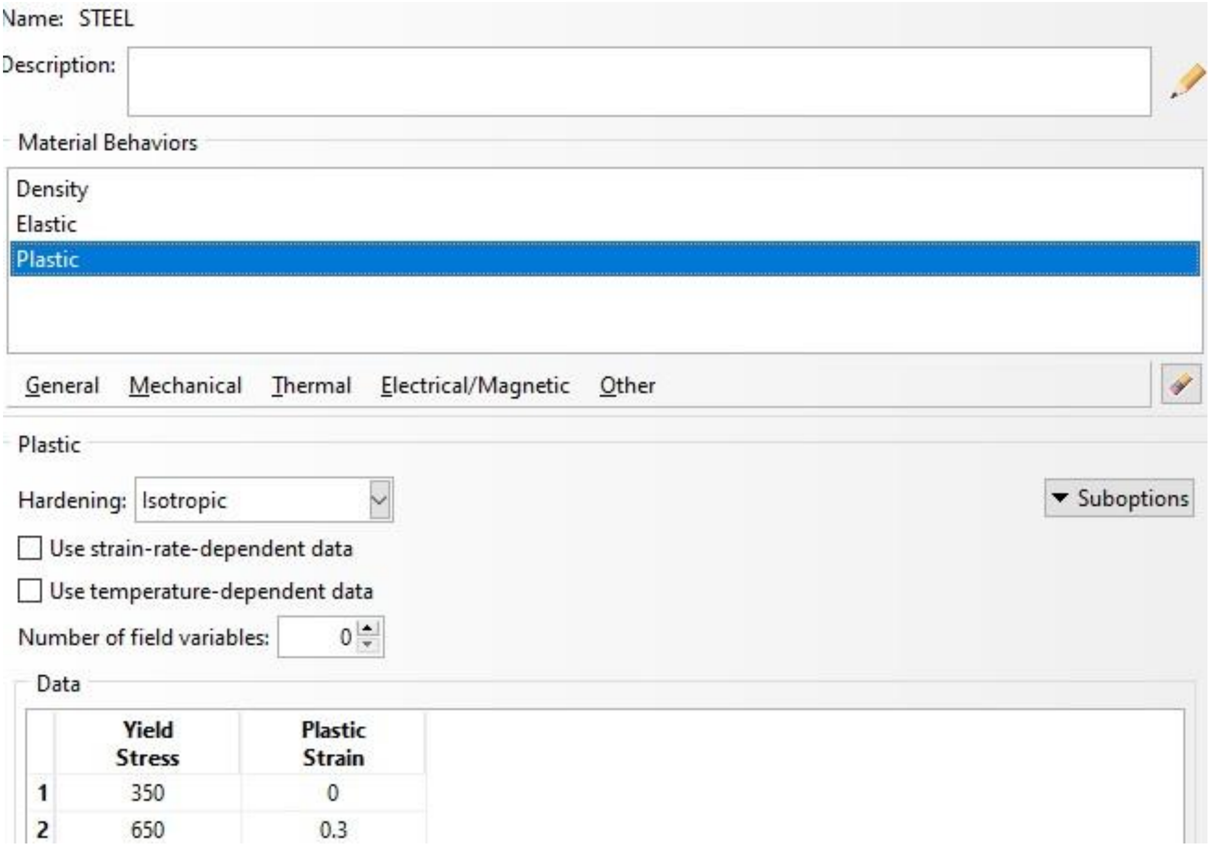

Fig 4.32 – Plasticity of steel

4.6 Assignment of material to section –

This fig below shows how material is assigned to sections.

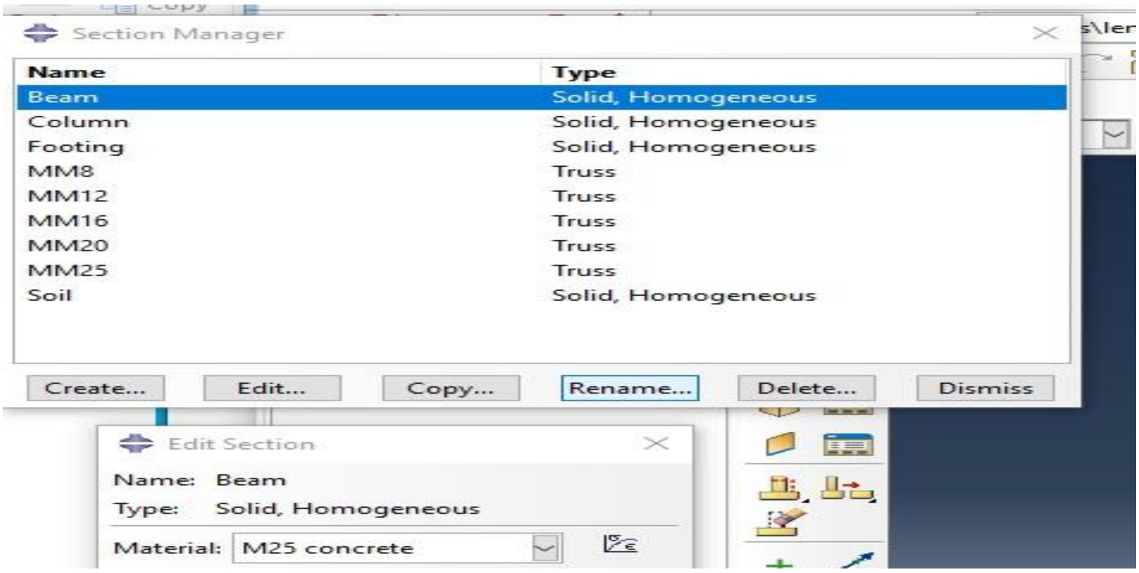

Fig 4.33 – beams section assignment

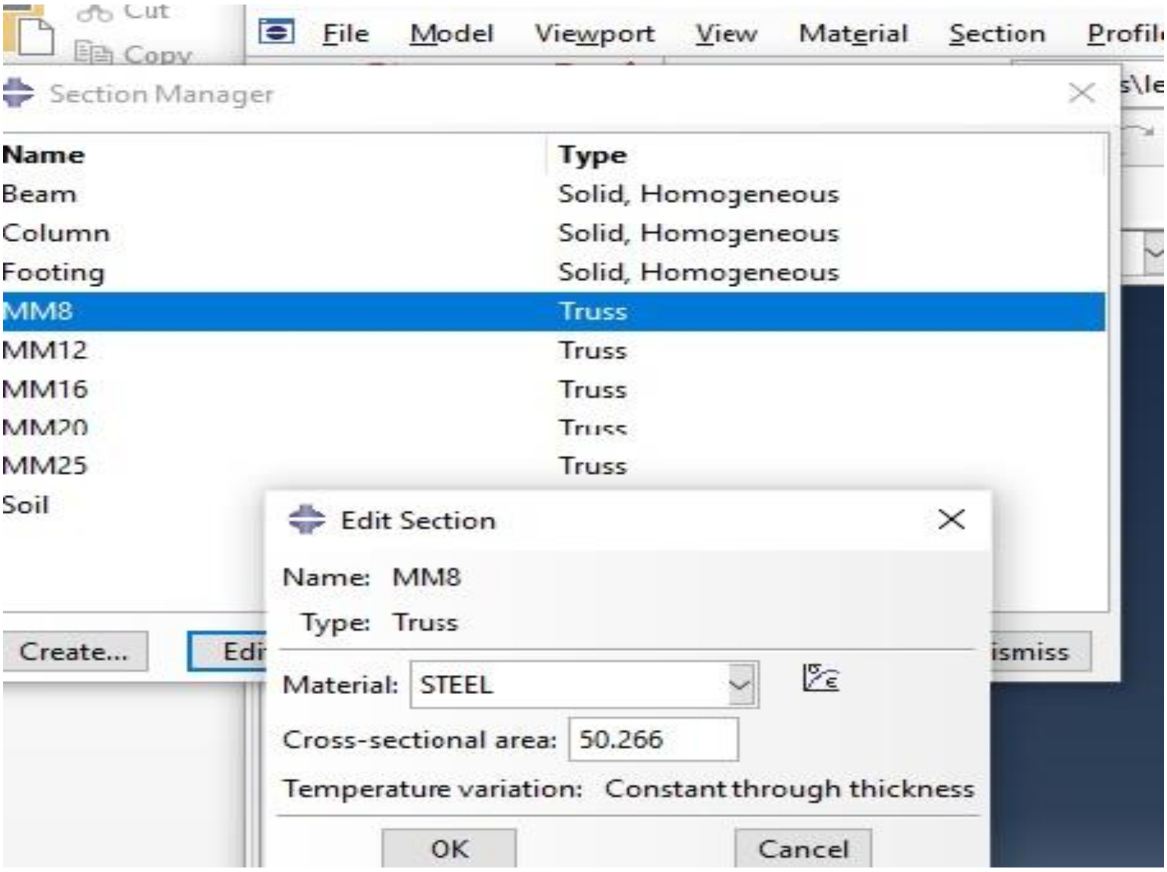

Fig 4.34 – 8mm dia bars

Similarly for 12mm ,16mm,20mm 25mm same procedure is followed.

4.7 Step Module –

In step manager steps are created as shows in fig below

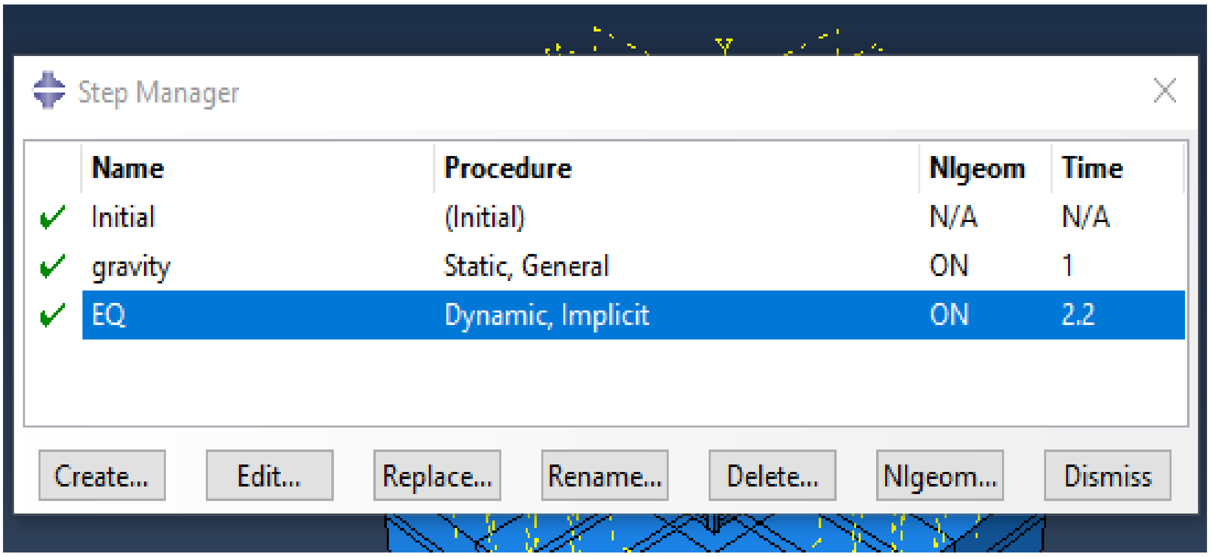

Fig 4.35 – Steps

4.8 Loads and boundary conditions –

Gravity load is created in this fig below -

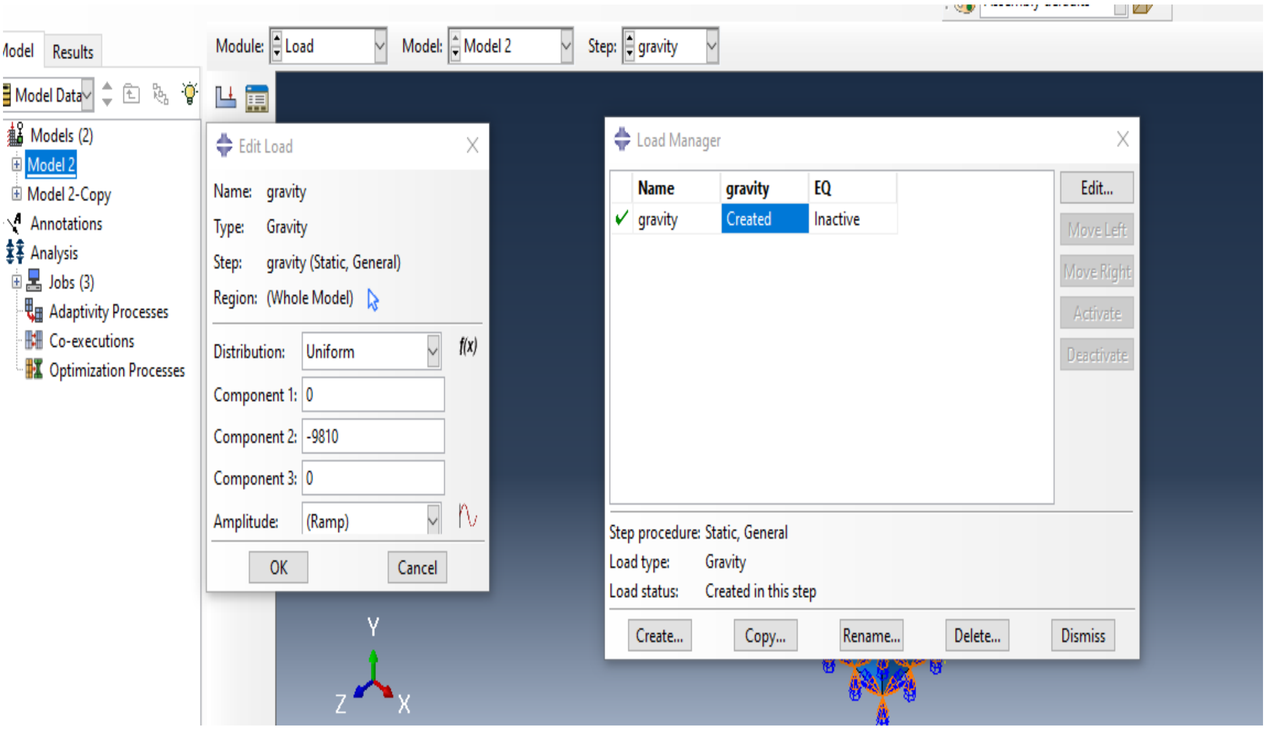

Fig 4.36 – gravity load

Boundary conditions – Boundary conditions can be shown in fig below

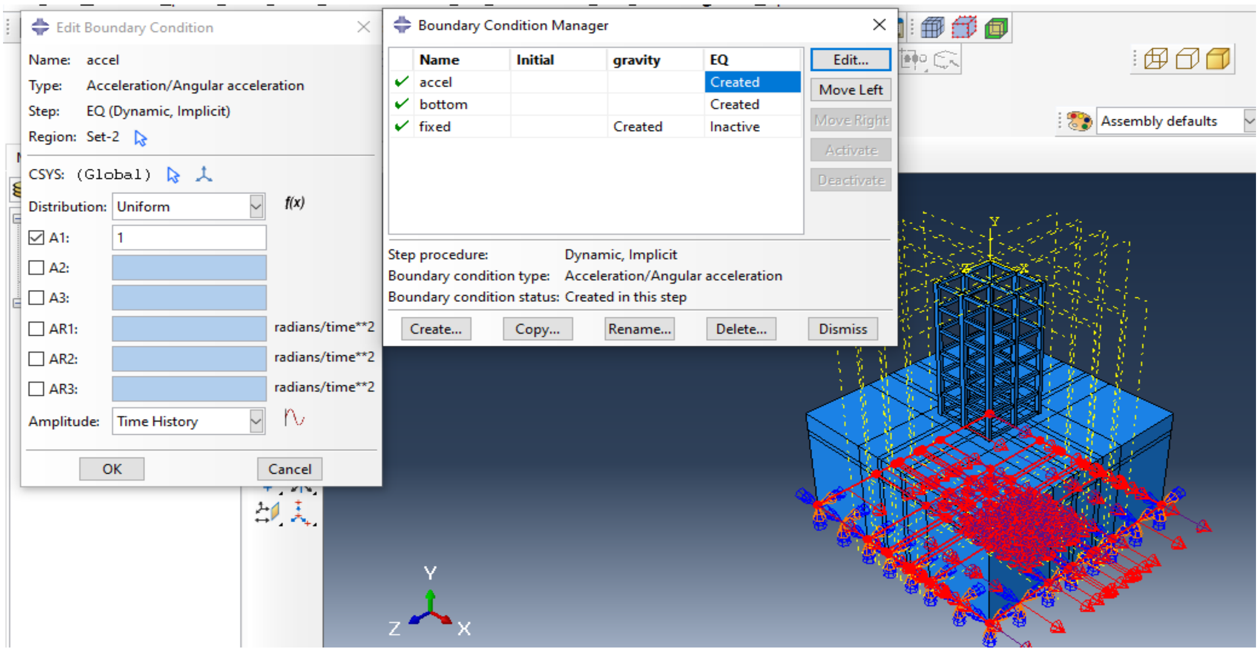

Fig 4.37 – Boundary condition 1

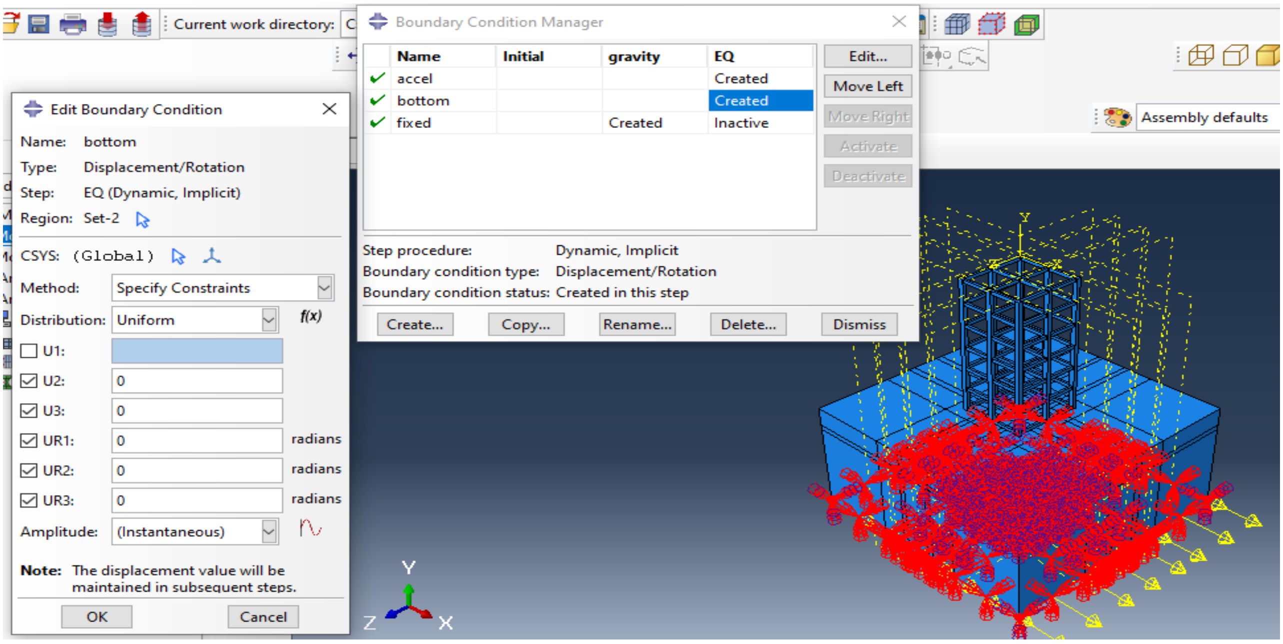

Fig 4.38 – Boundary condition 2

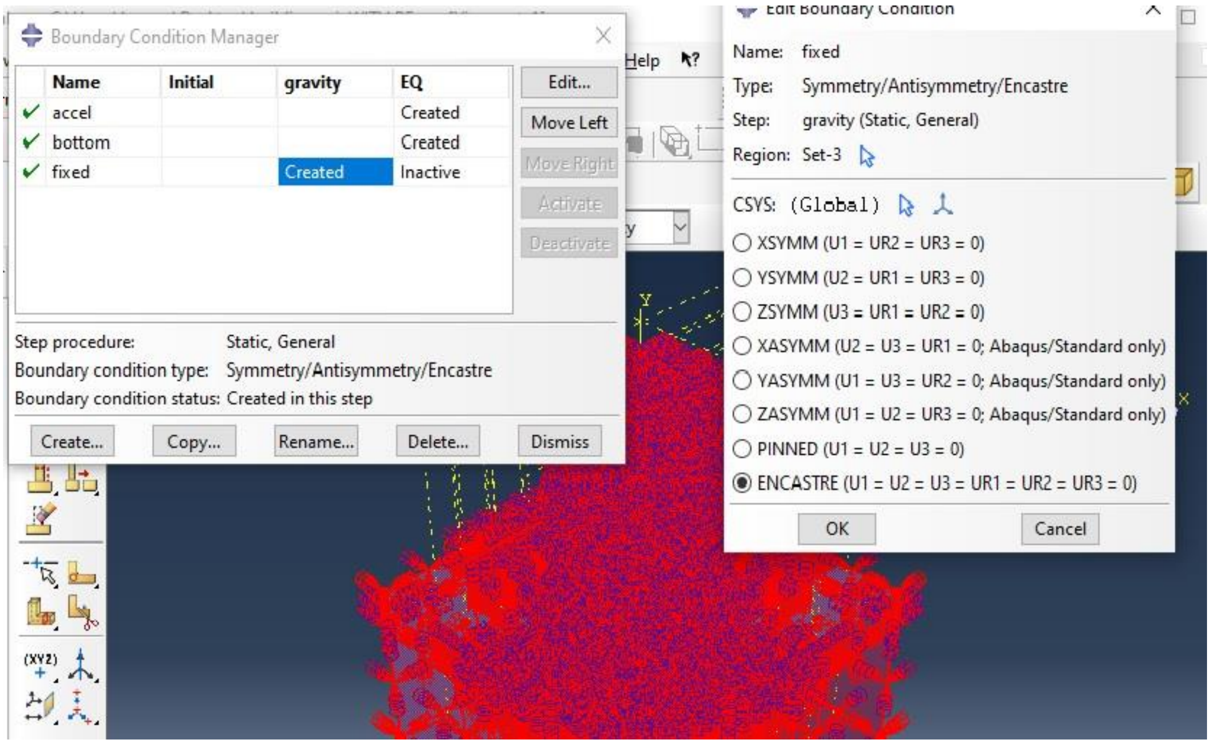

Fig 4.39 – Boundary condition 3

4.9 Time History Used in analysis –

EL cenro eq data is used in analysis.

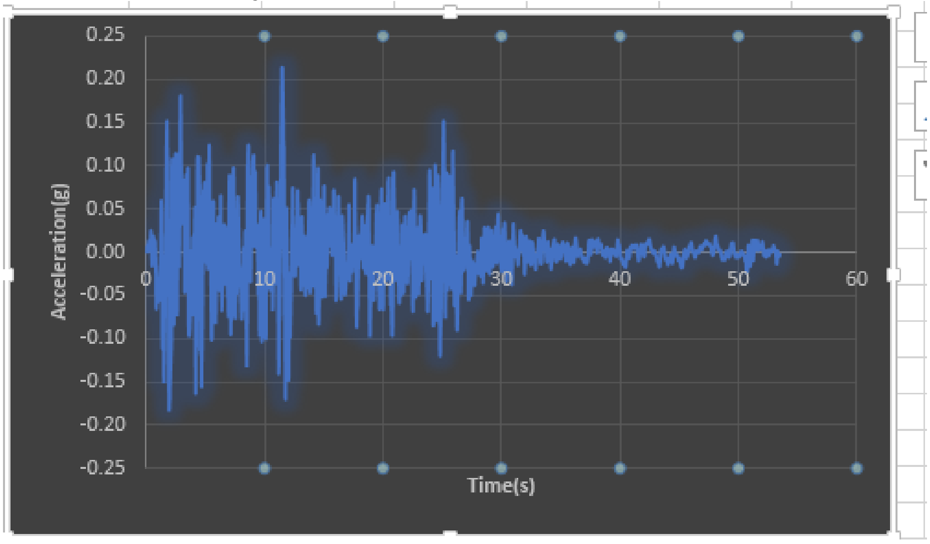

Fig 4.40 – EL Centro (1940)

4.10 Contact elements used in study-

Spring elements is used as a contact element between footing and soil. The stiffness Kh is calculated as per equation[13] below.

Kh(x,y)− towardslongside = GL/2-v[2+2.5$(B/L)^{0.85}$]

Where G = Concrete shear modulus

v = 0.18 , E =25000N/mm2 , G=E/2(1+v) ,

G =10593N/mm2

Kh = 82453621.5 which is used in spring stiffness.

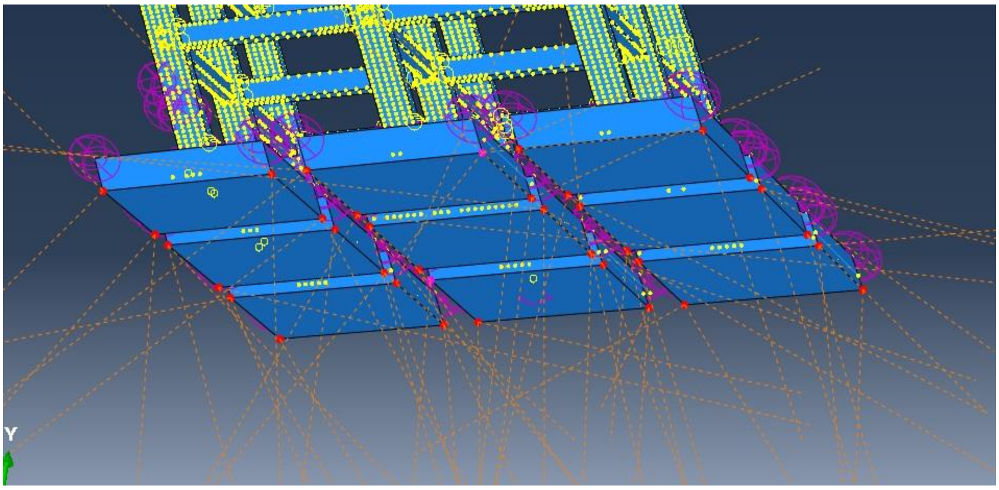

Fig 4.41 – Contact Elements

4.11 Convergence Study –

In convergence study different element sizes of C3d8r element is taken in different models as shown in table below-

Table 4.4 – Cases used in convergence study

Structure elements	Model 1	Model 2	Model 3	Model 4	Model 5
Beam (mm)	500	600	700	1000	900
Column (mm)	500	600	700	1000	900
Footing (mm)	500	600	700	1000	900
Soil (mm)	1000	1100	1200	1500	1400

Covergence study is done without considering reinforcement in the models. The main aim of this study to get accurate element size in tolerance limits. This study is carried out using gravity and Eq loads. Different nodes of the building is choosen for study to get the results in form of displacements and time period is 1.220 sec.

4.12 Nodes considered the study –

The nodes which are shown in fig below are considered in the convergence study analysis as well as full analysis of whole model.

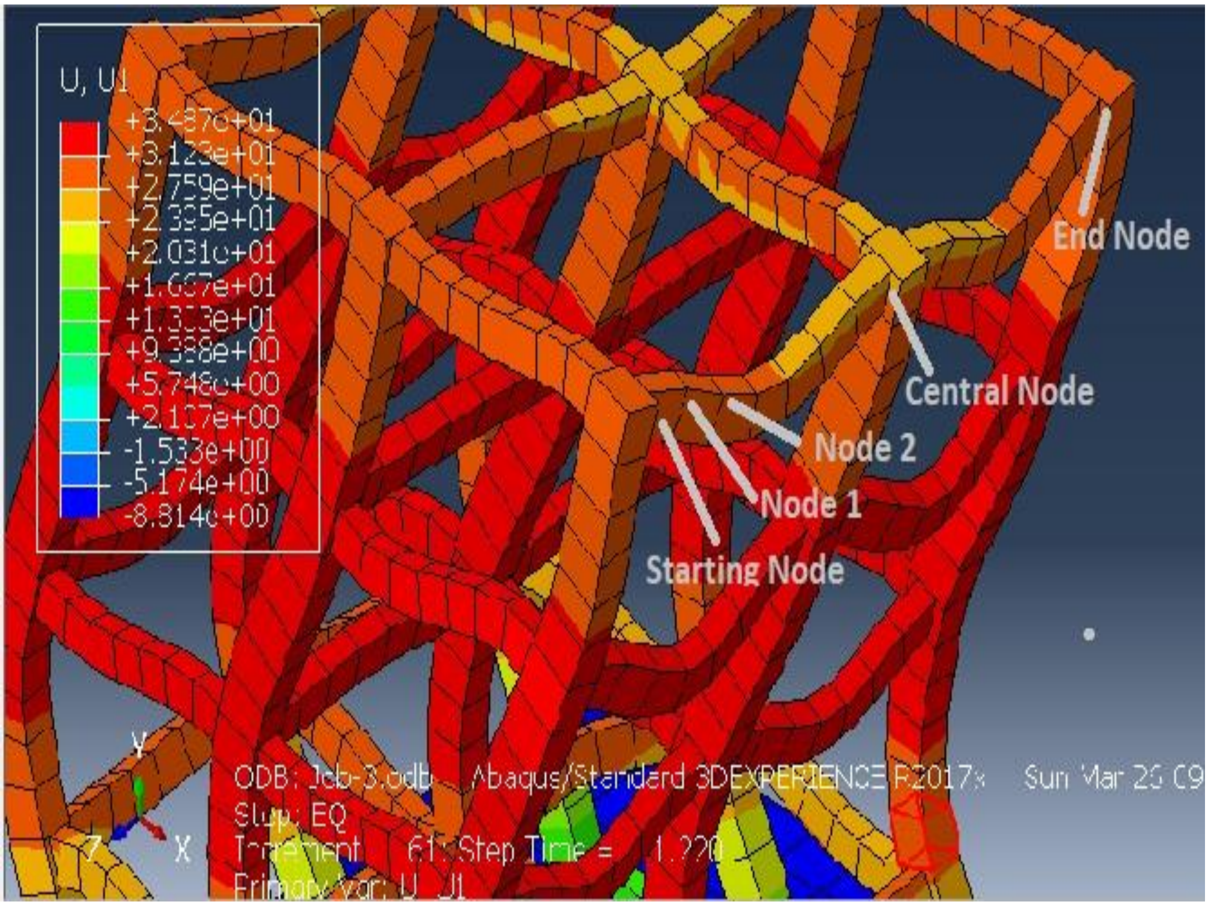

Fig 4.42 – Nodes considered in the study.

CHAPTER 5

RESULTS & DISCUSSION

5.1 Results from the convergence study –

- From the convergence study results few conclusion can be made-
  For the column , beam and footing meshing size for the elements should be taken as 700mm for further modelling.
- For the soil mesh meshing size for the elements should be taken as 1400mm.

Table 5.1- Results from convergence study

Nodes	Displacement (mm)	Model 1	Model 2	Model 3	Model 4	Model 5
Starting node	U1	53.515	53.894	53.963	54.145	53.863
	Tolerance		0.379	0.069	0.182	1.718
Node 1	U1	54.171	54.652	53.919	54.959	
	Tolerance		0.481	0.733	1.04	
Soil node	U1	20.710	1.490	20.714	20.752	20.773
	Tolerance		19.220	19.224	0.38	0.021

Tolerance Limit Taken = 0.1

5.2 Results from Abaqus modelling –

In Abaqus modelling total 6 cases are considered for soft and stiff soils based on poissons ratio values i.e 0.31 , 0.33 ,0.35. The value of modulus of elasticity is calculated for both the soils based on their poisson ratio values. Models for each case is analysed in Abaqus . The results are formulated in form of ,maximum of maximum displacements occurring at first nodes of every floor of the G+5 storey framed structure. The graphs are plotted below to show peak displacements in every cases at 1.620sec.

The figure below shows the peak displacements of case 1 and case 2

Case 1 –

Poissons ratio =0.31

Stiff soil modulus of elasticity =368.6 Mpa

Case 2 –

Poissons ratio = 0.31

Soft soil modulus of elasticity = 145.93 Mpa

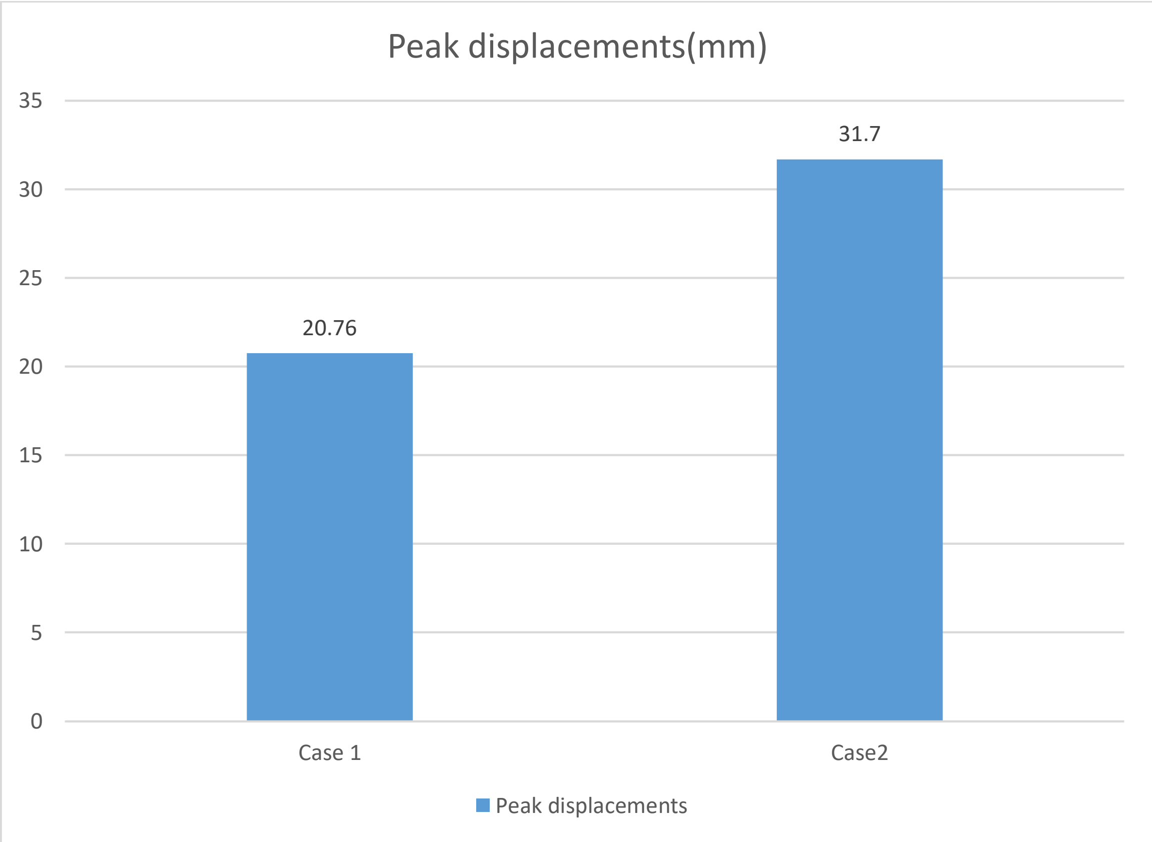

Fig 5.1- Case 1 and Case 2

From case 1 and case 2 it is seen that when poissons ratio is kept same for both stiff and soft soils , there is minor increment in peak displacement in case of soft soil by 10.94mm when compared with stiff soils.

Therefore poissons ratio value of 0.31 have more impact on peak displacements of the frame structure resting on soft soil as compared to stiff soil.

Case 3 –

Poissons ratio =0.33

Stiff soil modulus of elasticity =374.23mpa

Case 4 –

Poissons ratio = 0.33

Soft soil modulus of elasticity = 148.16mpa

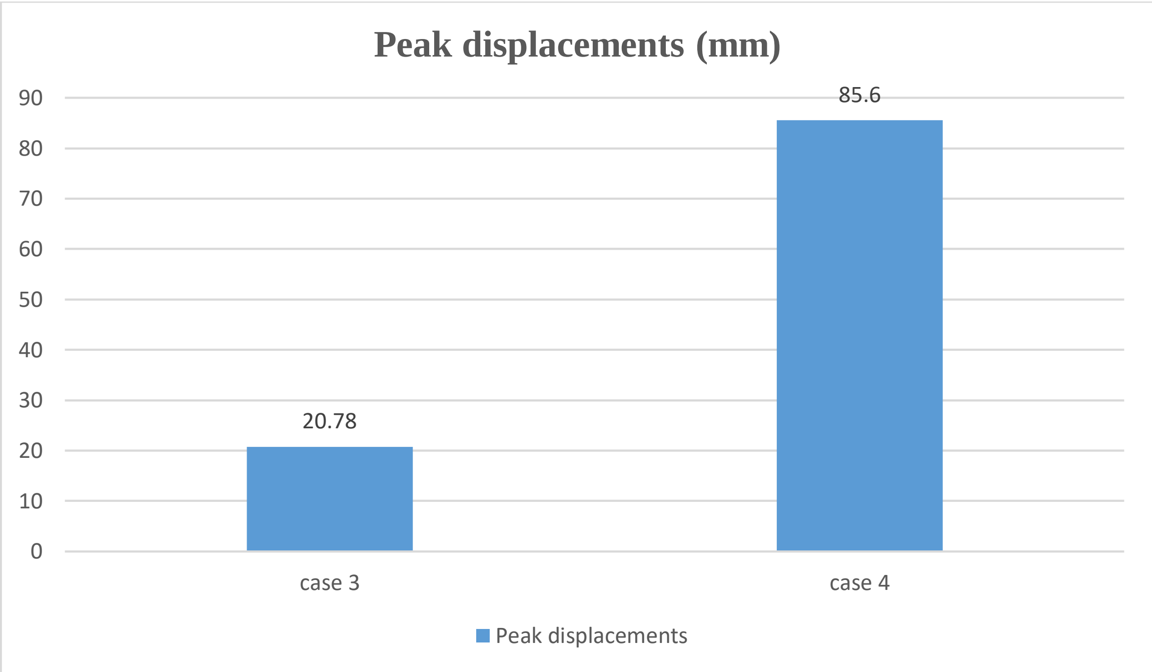

Fig 5.2- Case 3 and Case 4

In case 3 and case 4 it is seen that when poissons ratio value is 0.33 there is increment in peak displacements and there is much variation in values of peak displacements by 64.82mm in case of softs soils. It is also seen that poissons ratio value of 0.33 have a great impact on peak displacement of the structure in case of soft soils.

Case 5 –

Poissons ratio =0.35

Stiff soil modulus of elasticity =379.86mpa

Case 6 –

Poissons ratio = 0.35

Soft soil modulus of elasticity = 150.39mpa

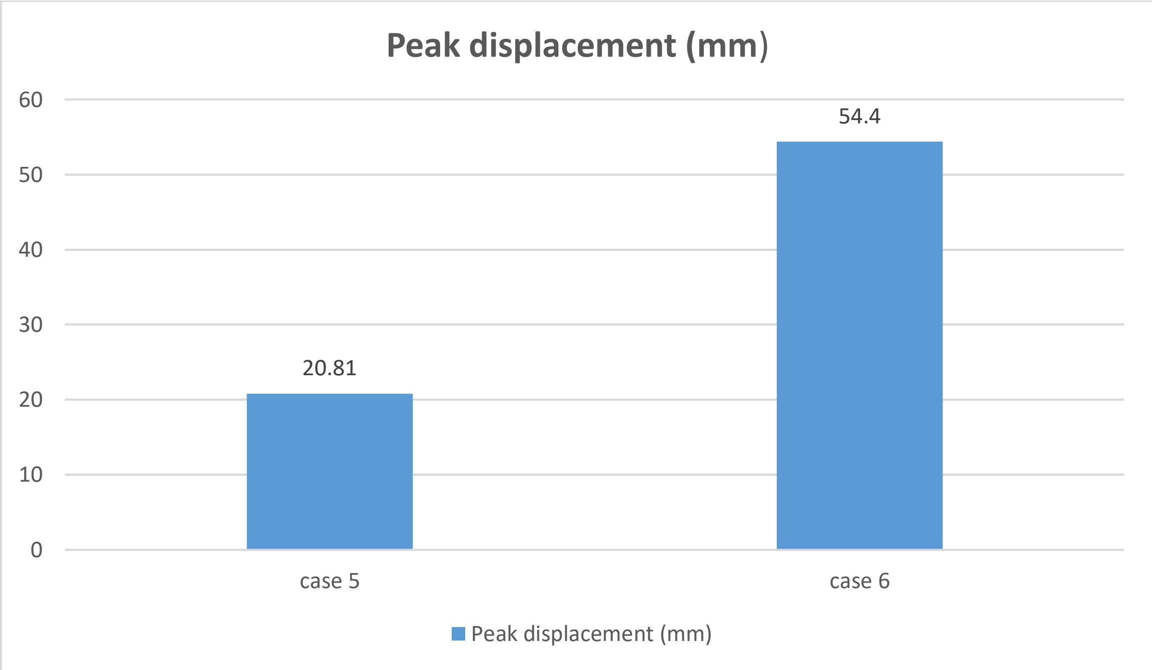

Fig 5.3- Case 5 and Case 6

From case 5 and case 6 it is shown from figure above that when value of poissons ratio is 0.35 there is increment in peak displacement for soft soil as compared to stiff soil. The value of peak displacement is increased by 33.59mm in case of soft soils. It is also seen that poissons ratio value of 0.35 have a great impact on peak displacement of the structure in case of soft soils.

CHAPTER 6

CONCLUSION

6 Conclusion –

From this study it can be concluded that –

- As per the previous studies SSI effects are not much prominent in case of rocks, therefore stiff and soft soils are considered in study.
- Poissons ratio value of 0.31 have small impact on peak displacements when compared between stiff and soft soils.
- Poissons ratio value of 0.33 have more impact on peak displacement on soft soil as compared to stiff soils. Therefore SSI effects are more prominent in case of soft soils than stiff soil when poisson ratio value is increased from 0.31 to 0.33.
- When poisson ratio value is 0.35 it does not have much SSI effects as compared to poisson ratio value of 0.33.
- From the study it is also seen that when the values of modulus of elasticity for soft soil increased from 145.95 mpa to 148.16 mpa SSI effects on framed structures become more prominent.

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