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Finite Element Analysis of Reinforced Concrete Building Frame with Consideration of Soil Structure Interaction

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Abstract — *Present Analysis investigates the effect of soil structure interaction on the structural behavior of a G+6 Storey building during an earthquake. The analysis is done by using (Simulia Abaqus/CAE 6.14) software. The Analysis is carried out for 1x1 bays with G+6 storey's R.C. Frame building with Isolated Footing - Fixed Support Condition (without Soil) & with three different types of soils - soft, Medium, Hard. The interactive analyses are carried out for 3 different values of Modulus of Elasticity and Poisson's Ratio. Comparison of Translation & Rotation (U) and Equivalent Stress (S) of the frame is done for Fixed Support (without Soil) and with three different types of soils - soft, Medium, Hard.*

Keywords— *Building Analysis, Soil structure interaction, Soil Condition, Abaqus/CAE 6.14, Equivalent Stress(S), Translation & Rotation (U).*

I. INTRODUCTION

The analysis of a Reinforced concrete building frame, columns at the foundation level are considered as fixed. But in Actual condition it is not the case. While considering soil in the analysis of Reinforced concrete building frame 100% fixity may not be ensured. Because of the settlement and rotation of foundation, response of the superstructure gets altered. This effect is called as "Soil Structure Interaction". Under consideration of Vertical Load and Seismic effect interaction has been modelled and analyzed with soil (flexible base) and without soil (fixed base) in the finite element package of Abaqus/CAE 6.14 incorporating geometric non-linearity. The study in this paper is extended by comparison between fixed base model and flexible base model. Neglecting Soil Structure Interaction effect for relatively light structure founded on hard soil is reasonable. But, for relatively heavy (stiff) structure founded on either soft or medium soil, neglecting Soil Structure Interaction has a great impact on structural response and design.

II. LITERATURE REVIEW

A simplified response spectrum superposition method has been generalized for the dynamic analysis of the multistoried building-soil response to earthquake ground motions via Fourier-transformed frequency domain. Gupta, V. K. et al.[1] An approach is formulated for the linear analysis of three-dimensional dynamic soil–structure interaction of asymmetric buildings in the time domain .Shakib, H. et al.[2] Focused on the response spectrum analysis of the soil-structure model considering fixed base and flexible base of modeling the structure. Nirav et al.[3] In-filled frame have higher lateral stiffness lateral load resistance than the bare frame. It was also observed that behavior of masonry in-filled RC frame was excellent in terms of strength and stiffness. Gaikwad, M. V. et al.[4] Results illustrate that both sandy soils amplify seismic waves on the soil-structure interface because of the soil-structure interaction effect. Matinmanesh, H. et al.[6] . Concluded that the interaction of building foundation-soil field and super-structure has remarkable effect on the structure. Nimisha A.S. et al.[7] Present Analysis investigates the effect of soil structure interaction on the structural behavior of a G+6 storey building during an earthquake in case of flexible and fixed base.

III. OBJECTIVE OF THE RESEARCH WORK

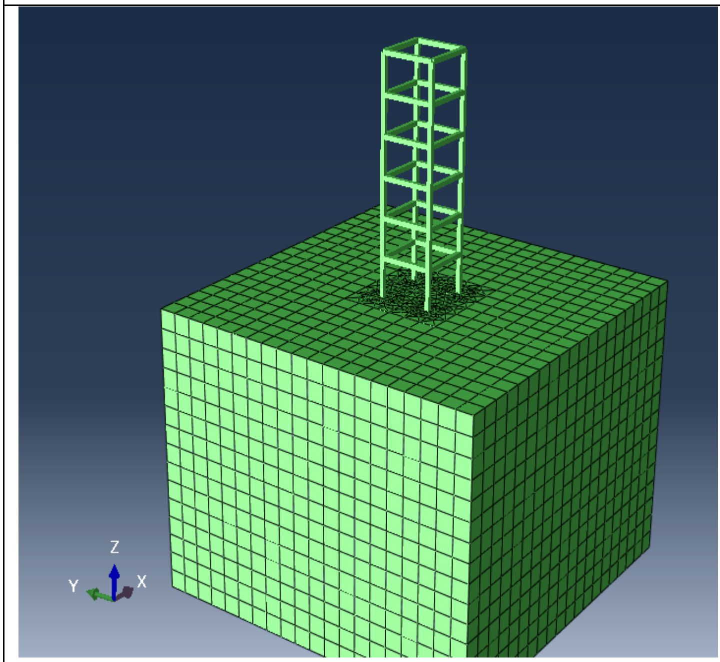
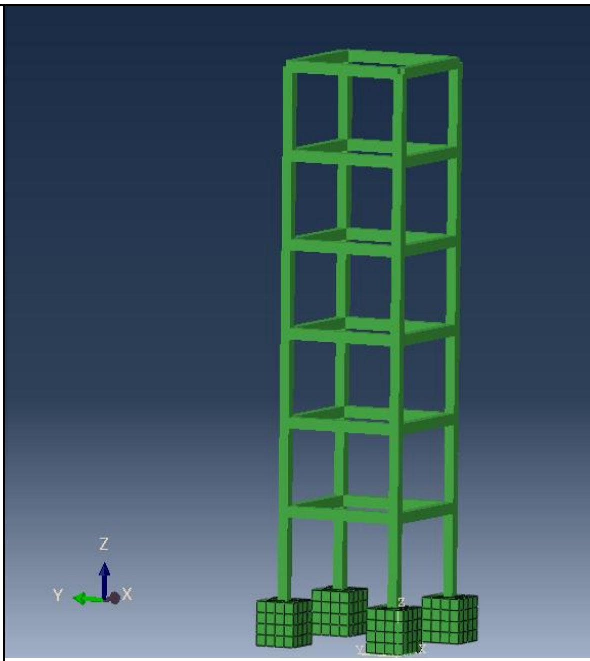
- Comparison of Translation & Rotation (U) and Equivalent Stress (S) of the frame is done for Fixed Support (without Soil) and with three different types of soils - soft, Medium, Hard.

IV. METHODOLOGY

Three different types of soil (Soft, Medium & Hard) upon which the structural frames are considered to be resting in case of flexible base model and fixed base model (without soil) are analyzed for G+6 Storey Building. Total 4 structures are analyzed as presented in table 1.

Table 1.Types of Building Considered For Analysis

<table>
<tr><th>BUILDING</th><th colspan="4">MODELS</th></tr>
<tr><td rowspan="4">G + 6</td><td colspan="2">FIXED BASE MODEL</td><td colspan="2">FLEXIBLE BASE MODEL</td></tr>
<tr><td rowspan="3">SUPPORT CONDITION</td><td rowspan="3">FIXED</td><td rowspan="3">SOIL TYPE</td><td>SOFT</td></tr>
<tr><td>MEDIUM</td></tr>
<tr><td>HARD</td></tr>
</table>

<table>
<tr><th colspan="2">Table 2. G-6 Building Considered for Analysis</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Flexible base building model</td><td>Fixed base building model</td></tr>
</table>

V. DISCRIPTION OF BUILDING

5.1 Geometry of the building

In the present analysis a 1x1 bays with G+ 6 storeys R.C. Frame building is considered to investigate SSI effects on tall buildings. The plan dimension of the building is 6.0 m x 6.0 m and the height of the building is 24 m from the ground level for G+6 storey building .

Table 3.Discription of Building

Component	Description	Data
Frame	No. of Storey	G + 6
	No. of bays in X and Y direction	1 x 1 bays
	Storey height	4 m
	Bay width in X and Y direction	6m x 6m
	Size of beam	500mm x 500mm
	Size of column	500mm x 500mm

5.2 Geometry of the Soil

The Soil plan area was fixed such that horizontal dimension should be at least five times the horizontal dimension of building and depth of soil should be at least three times depth of foundation. Therefore, Soil volume modelled is 40x40x30m.The overall geometry of the building configurations, fixed base and flexible base are shown in Table 2.

VI. MODELING OF SUPER AND SUB – STRUCTURE

The elements of the superstructure (beam, column) and that of substructure (isolated footing and soil) are modelled using simplified modeling approach. The soil is modelled as the discrete independent linear springs. Mesh convergence study was done for building and used 500 mm element size and for soil a coarser mesh of 2m was used in the analysis.

6.1 Modeling in Abaqus/CAE 6.14

Pre-processing:-
It comprises all the steps to create the model with Abaqus/CAE 6.14. The following principle steps are taken sequentially:-

1. Creating a part/defining the model geometry.
2. Defining material and section properties.
3. Creating Section Profile.
4. Assigning created section to parts.
5. Assembly of parts.
6. Configuring the analysis.
7. Assigning interaction properties.
8. Applying boundary condition and applied loads.
9. Designing the mesh.
10. Creating, running and monitoring a job.

Post-processing:-
The Visualization module provides graphical display of finite element models and results. It obtains model of finite element models and results. It obtains model and result information from output database; it is controlled what information is written to the output database by modifying output requests in the Step module. In assembly module instances are created for individual parts already created and such instances can be increased in numbers also can be positioned as required. Also some instances can be joined to each other.

Instances are created for Column, Beam, Frame and foundation. Instances numbers are created by using part option. Angle of Instances are changed by Rotate Instances option and position is shifted by using Translate Instances. Every part is positioned as required for structure. After proper positioning all instances are joined using Merge/Cut Instances. After Merge/cut Instances Abaqus/CAE 6.14 Creates Final Building.

6.2 Material models used

For assessing the complete behavior of structure and soil, material properties and element selection is required. Structure and soil were modeled as linear and isotropic. Properties considered for analysis are Modulus of Elasticity (E), Poisson's ratio (μ) and Density (ρ). Properties of concrete and soil are given in Table 4.

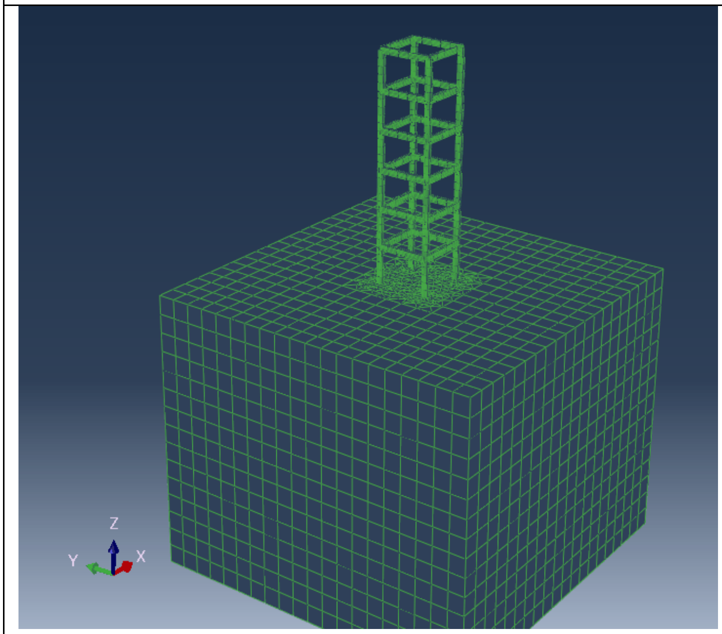
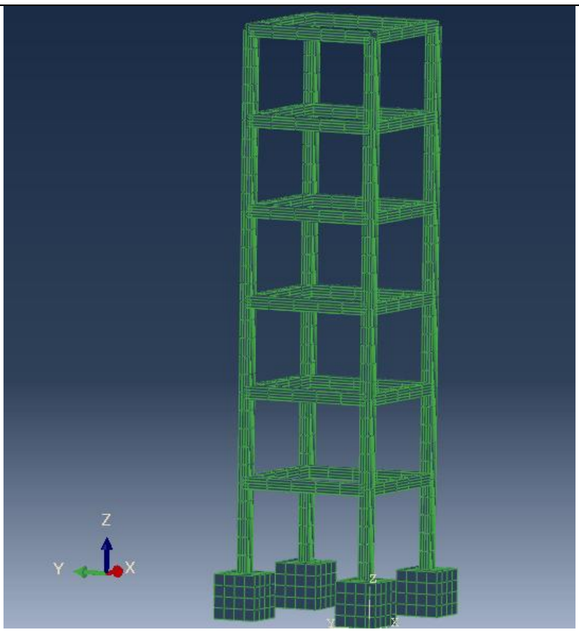
Table 4.Material properties of Concrete and Soil

Properties	Structure	Soil		
Material	Concrete	Soft Soil	Medium Soil	Hard Soil
Modulus of Elasticity, E (Pa)	3.0×10^{10}	10×10^7	35×10^7	80×10^7
Possion's Ratio (μ)	0.2	0.25	0.34	0.45
Density (ρ) (kg/m^3)	2500	1900	2200	2400

6.3 Boundary conditions and loading

Soil is modeled as rectangular solid around the foundation due to scope limit. In actual case soil can be extended infinitely in any direction, we modelled it as finite sized solid and applied boundary conditions. Bottom layer is considered as hard strata, so it restrains the movement in any direction, hence a fixed boundary condition is provided at the bottom of soil solid element. That is, if soil lateral side is perpendicular to x axis, displacement in y axis & z axis is free to move. Thus soil is restrained in the corresponding direction and allows free movement in other directions.

Table 5. Meshed Models

	
Flexible base building model	Fixed base building model

Dead load and Live Load are given as per IS 875 (Part-1) and (Part II) 1987 respectively .Seismic Amplitudes are considered in the analysis.

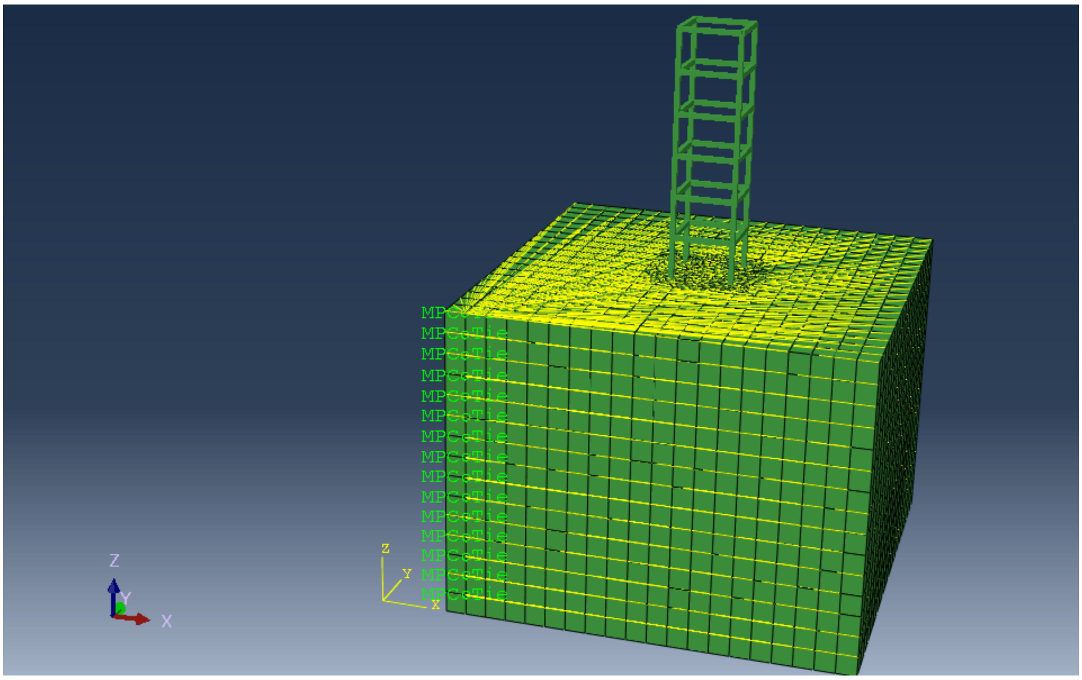


Fig 1.Multi Point Constraints considered in flexible base model

Fig 1. Shows Multi-point constraints are considered in case of flexible base model to connect different nodes and degrees of freedom together in the analysis.

VII. RESULTS AND DISCUSSIONS

In this section Comparison of Translation & Rotation (U) and Equivalent Stress (S) of the frame is done for Fixed Support (without Soil) and with three different types of soils - soft, Medium, Hard.

7.1 Comparison of Translation & Rotation (U) of G+6 Building

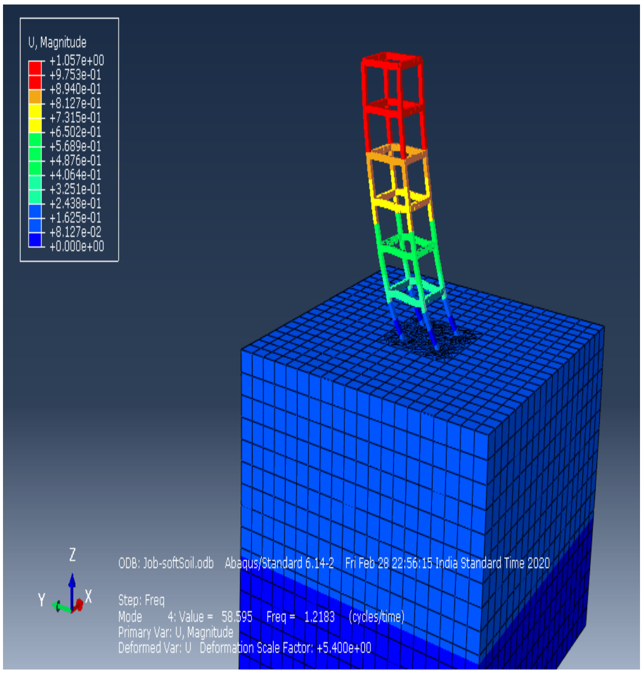


Fig. 2(a) Translation & Rotation (U) of building with flexible Base (soft soil)

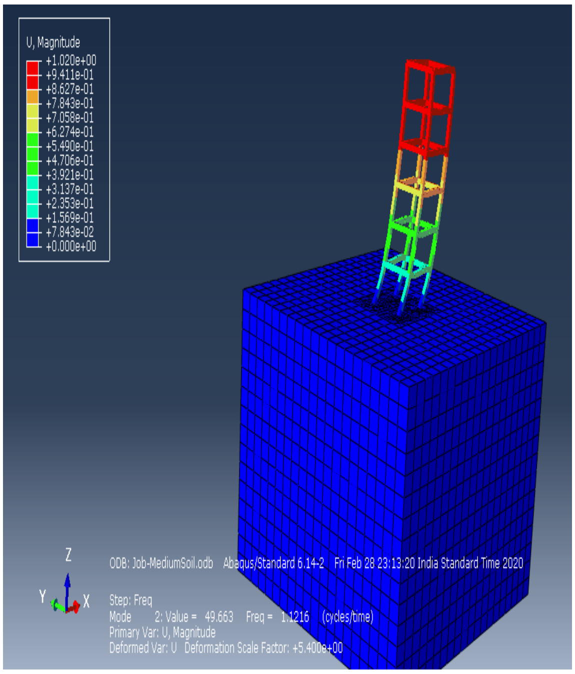


Fig. 2(b) Translation & Rotation (U) of building with flexible Base (Medium soil)

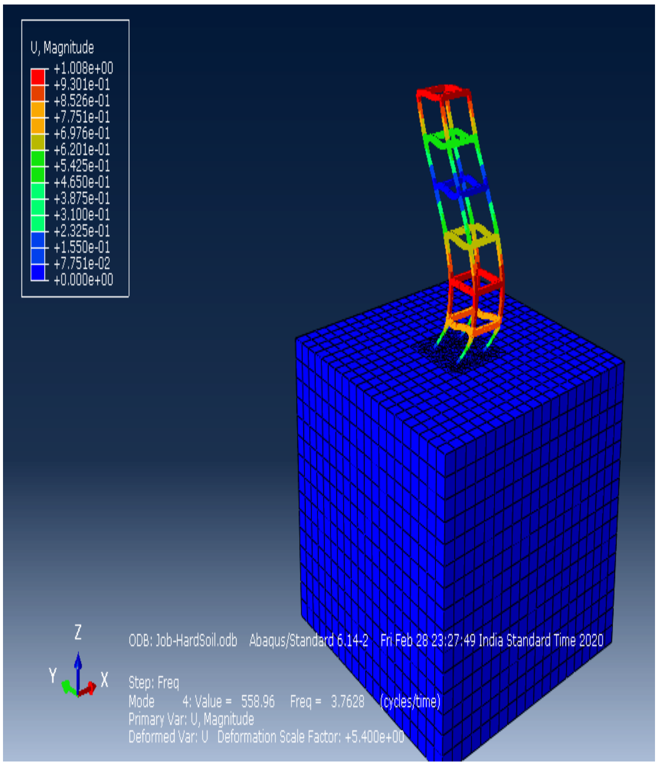


Fig. 2(c) Translation & Rotation (U) of building with flexible Base (Hard soil)

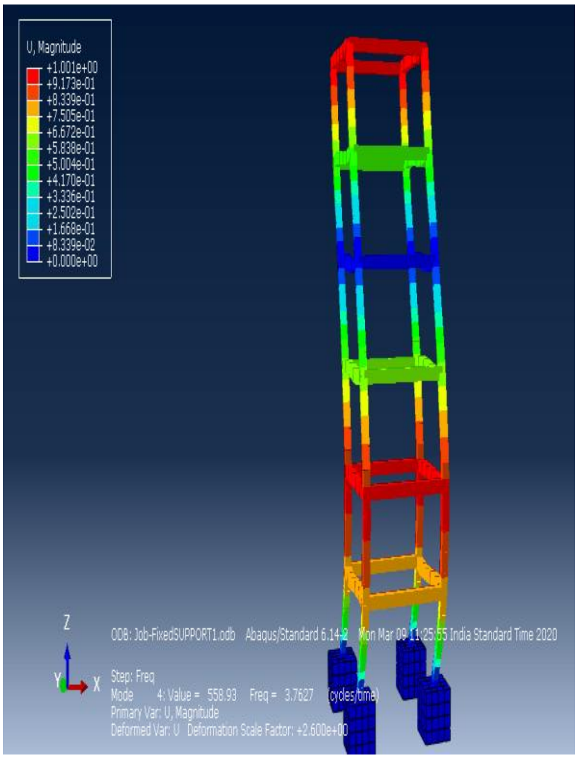


Fig. 2(d) Translation & Rotation (U) of building with fixed Base

Above figure 2(a), 2(b), 2(c) and 2(d) shows the Translation & Rotation (U) in Flexible and Fixed base buildings models. In case of flexible base (1.057 m - Soft Soil) translation and rotation (U) is more than fixed base (1.001 m).

7.2 Comparison of Equivalent Stress (S) of G+6 Building

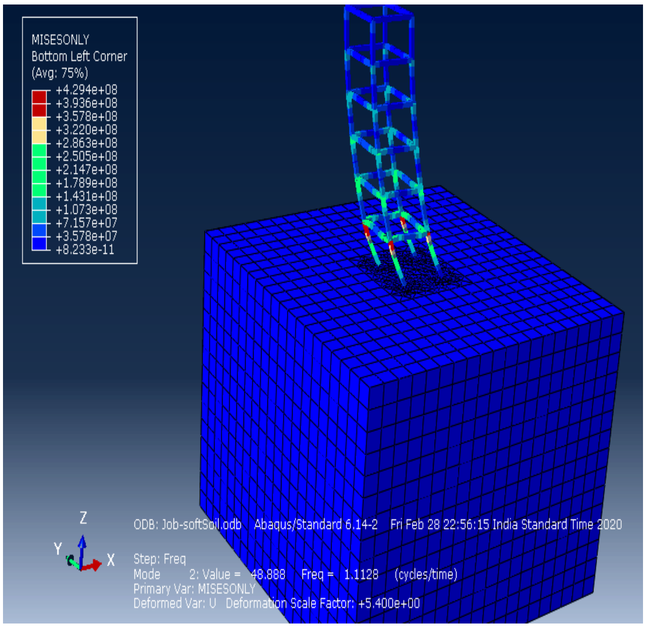


Fig. 3(a) Equivalent Stress in building with flexible Base (soft soil)

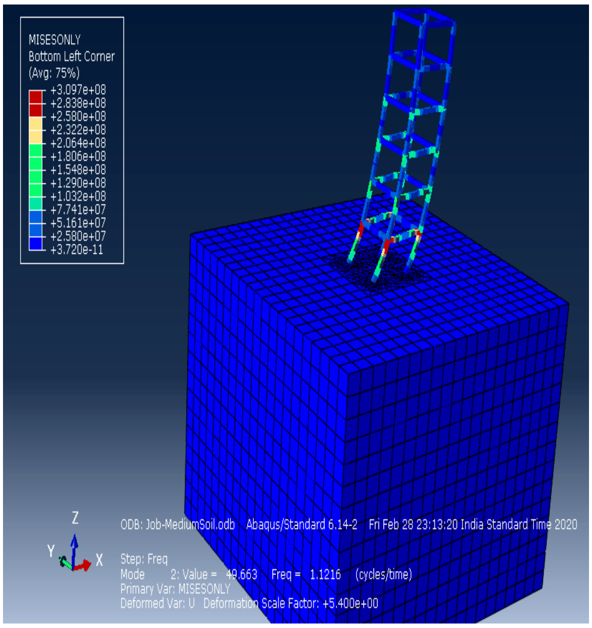


Fig. 3(b) Equivalent Stress in building with flexible Base (Medium soil)

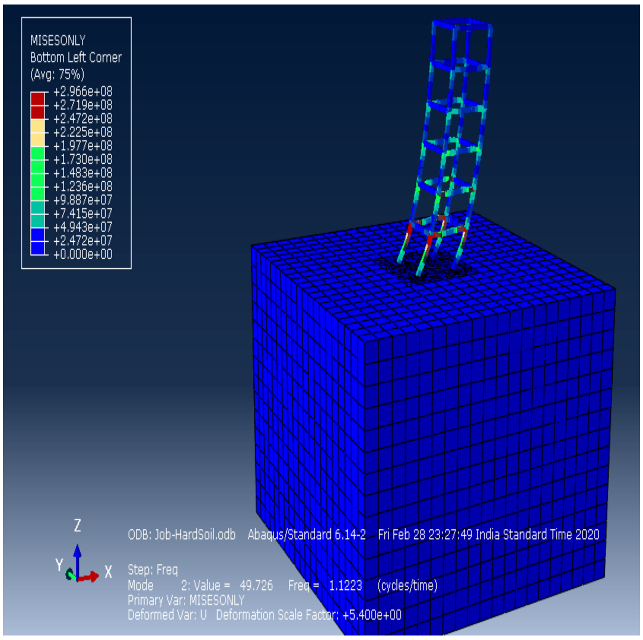


Fig. 3(c) Equivalent Stress in building with flexible Base (Hard soil)

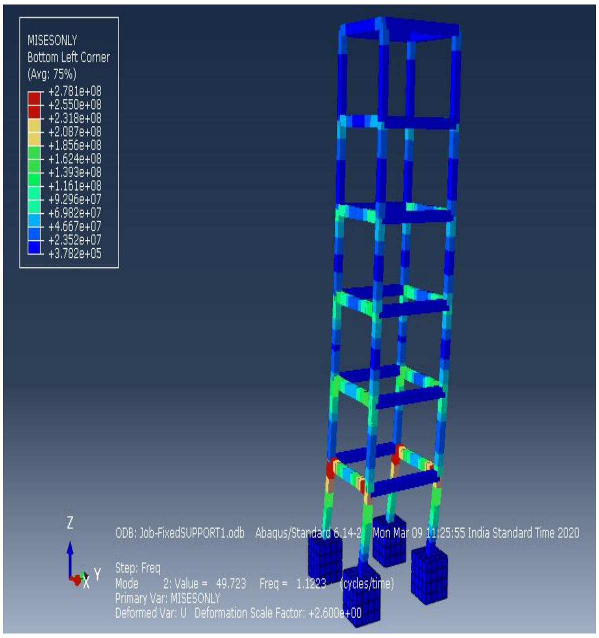


Fig. 3(d) Equivalent Stress in building with fixed Base

Above figure shows the equivalent stress in building, considering both the cases flexible and fixed base. From which we can conclude that there is a wide difference in stress distribution, when we consider actual soil condition along with building while analyzing. Equivalent Stress developed in flexible base model (4.294e+08 Pa – Soft soil) is more than fixed base model (2.781e+08 Pa).

VIII. CONCLUSION

Following observations were made during the analysis of G+6 Storey Building in case of Flexible and Fixed Base Building Models.

1. In case of Flexible base (with soil) Translation and Rotation value was more as compared with Fixed base (without soil),which Signify that in actual case differential settlement occurs in soil.
2. Equivalent Stress was higher in case of Flexible base (Soft soil) as compared with Fixed base (without soil).

3. This Study indicates that for safe design of building, it should be modelled along with soil in which it is resting considering all properties of soil (Young's Modulus, Possion's ratio, Density e.t.c) for the analysis and design purpose.
4. Multi storey building resting on soft, medium Soil. Soil Structure Interaction has to be considered in the analysis, because flexibility of foundation and compressibility of soil mass can alter response of super-structure.

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