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Dynamic Analysis of Military Bunker using Soil Structure Interaction

S. P. Bhat [1]
[1]M.E Civil-Structure Student,
Department of Civil Engineering,
JSPM's Rajarshi Shahu College of Engineering
Tathawade, Pune-411033, India

R. A. Dubal[2]
[2]Associate Professor,
Department of Civil Engineering,
JSPM's Rajarshi Shahu College of Engineering
Tathawade, Pune-411033, India

***Abstract*— A bunker is a military fortification that is designed Military with the aim of protecting people or valuable goods from bombs or any types of attacks. Bunkers were extensively used during the First World War, Second World War, and the Cold War. They acted as command centres, stores for weapons, and distribution points. The project deals with the analysis and design of a bunker constructed on three different soil types. Though each and every bunker have mostly similar components and machines but the analysis and design of civil structures in a plant are always done with different ideas and optimized techniques. Hence this paper is based on some new and different considerations in analysis and design aspects and optimization. In this paper study of dynamic analysis as well as study of different soil structure interaction models is done. The structure results are found by means of 'ANSYS'. Optimum analysis results in optimum design. As earthquake ground shaking affects all structures below ground in case of a Military bunker and since some of them must sustain or withstand the strongest earthquake ground motion, they have to be designed and checked for different types of design earthquakes. The Military structure is analysed for all the three soil types mentioned above and values for parameters like Total Deformation, Normal Elastic Strain, Shear Stress and Equivalent Stress are compared and the most suitable soil type is finalized.**

***Keywords*— ANSYS, DYNAMIC ANALYSIS, SOIL STRUCTURE INTERACTION**

I. INTRODUCTION

Modal analysis is a commonly used tool in design in an effort to reduce or avoid vibration in machine designs. A dynamic loading on a machine will introduce vibrations. The excessive vibrations will cause noise, lead to fatigue damage of the components. Vibrations in a vehicle will make passengers uncomfortable and lead to tiredness. Every structure has its own natural frequencies. When the excitation of a vibration on a machine coincide with a natural frequency of the system, the structure resonance with the excitation force which lead to excessive sometimes violent vibrations, which may lead to damage of the structure. Modal analysis is used to identify natural frequencies and their vibration modes. Engineers are often required to design the system which do not have natural frequencies near the frequency of a excitation loads. Using an iterative process with modal analysis, the relevant component structure can be varied to shift the natural frequency higher or lower. With Natural Frequency Analysis, mode shapes associated with the natural frequencies can be used to decide the suitable location of support and evaluate the significance of a particular vibration mode. Modal analysis is also a pre-requisite of harmonic response analysis and some further shock / vibration analysis, such as shock spectrum analysis and power density spectrum analysis (PSD) for random vibration.

A. Objectives of the Present Study

1. To calculate various parameters like Total Deformation ,Normal Elastic Strain, Shear stress and Equivalent Stress .
2. To Examine the behaviour of a Military Bunker structure in different soil conditions during seismic excitation.
3. To compare all the parameters and finalize the most suitable soil.

B. Soil Structure Interaction

The scales of socio–economic damages caused by an earthquake depend to a great extent on the characteristics of the strong ground motion. It has been well known that earthquake ground motions results primarily from the three factors. Also, the Soil- Structure Interaction (SSI) problem has become an important feature of Structural Engineering with the advent of massive constructions on soft soils such as nuclear power plants, concrete and earth dams. Buildings, bridges, tunnels and Military structures may also require particular attention to be given to the problems of SSI. If a lightweight flexible structure is built on a very stiff rock foundation, a valid assumption is that the input motion at the base of the structure is the same as the free-field earthquake motion.

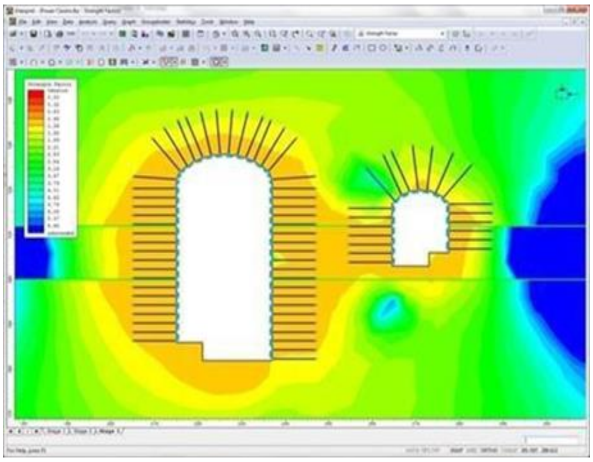

Figure.1 Soil Structure Interaction

C. Necessity of dynamic analysis

In design of Bunker, Soil plays an important role as it is constructed underground. The different parts of bunkers like its access tunnel, bunker cavern are analysed in Ansys workbench. Different soil strata affects the foundation conditions and Bunker should be designed according to these

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conditions. Different parameters like Equivalent stress, shear stress, deformation are calculated in this study which helps in understanding the concept of Dynamic analysis.

D. DYNAMIC EQUILIBRIUM EQUATION

When the structural configuration is complex or, significant dynamic interaction between interconnected members cannot be avoided, a coupled analysis approach can be used. The coupled analysis approach can include as few as two degrees of freedom to represent a structural system or it can involve the use of many degrees of freedom in a single, comprehensive dynamic analysis of the entire superstructure. Responses of MDOF systems are determined from the solution of the following dynamic equilibrium equation. This equation is the matrix form of the equilibrium equation for a SDOF system.

$$K\,x(t) + Cx'(t) + Mx''(t) = r\,(t)$$

Where, K is the stiffness matrix, C is the proportional damping matrix, M is the diagonal mass matrix, and x,x',x" are the relative displacements, velocities, and acceleration with respect to the ground, and r is the applied load.

E. Description of Structure

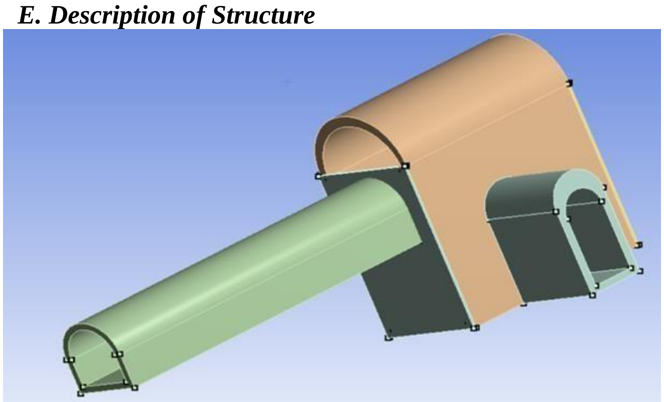


Figure 2 Military Bunker

II. PROBLEM STATEMENT

A Military bunker project is carried out in a fractured soil mass. It consists of a series of Military structures. Three main parts of the bunker are analysed in this study: the bunker cavern, transformer cavern and access tunnel. The domain of rock mass with dimensions 130 m * 114 m * 110 m is considered. Three joint sets are identified based on the analysis of the collected data from field survey, and the detailed information is shown in Table 3.1. Three types of surrounding soils are considered in this paper, clayey, silty and sandy soil conditions. The effect of earthquake waves on each of the soil types and the ultimate effect on the bunker structure is analysed with the help of ANSYS.

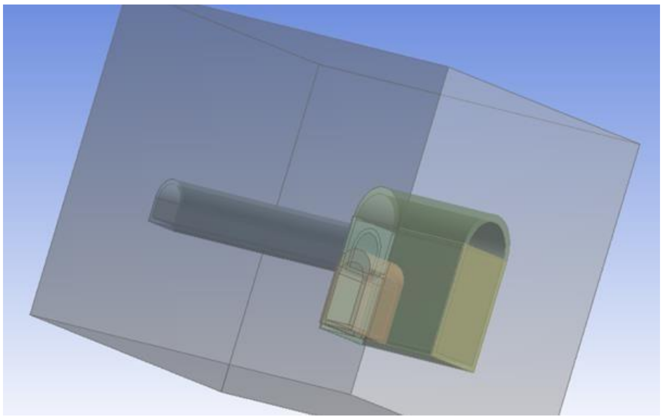


Figure 3 Structure Embedded in Soil mass

Sr.No.	Material	Property	Value
1	Structural steel	Yield stress *fsy* (MPa)	265
		Ultimate strength *fsu* (MPa)	410
		Young's modulus *Es* (MPa)	205 103
		Poisson's ratio µ	0.3
		Ultimate tensile strain *et*	0.25
2	Reinforcing bar	Yield stress *fsy* (MPa)	250
		Ultimate strength *fsu* (MPa)	350
		Young's modulus Es (MPa)	200 103
		Poisson's ratio µ	0.3
		Ultimate tensile strain et	0.25
3	Concrete	Compressive strength *fsc* (MPa)	42.5
		Tensile strength *fsy* (MPa)	3.553
		Young's modulus Ec (MPa)	32920
		Poisson's ratio µ	0.15
		Ultimate compressive strain es	0.045
4	Stud shear connector	Spacing (mm)	110
		Number of rows	2
		Numbers of connectors	68
		Yield stress *fsy* (MPa)	435
		Ultimate strength *fsu* (MPa)	565
		Young's modulus *Es* (MPa)	200 103
		Poisson's ratio µ	0.15
		Ultimate strain *e*	0.045

Table 1 Material Properties

	Width	Side Wall Height (m)	Arch Height (m)	Length (m)
Bunker Cavern	20	24	5	47
Transformer cavern	10	10	3	14
Access Tunnel	6	4	3	43

Table.2 Components of Bunker

III. MODELLING AND ANALYSIS

ANSYS 16, initially the geometry of the structure is to be defined.

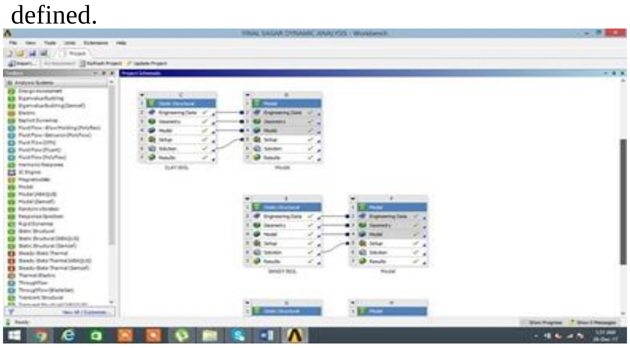


Figure 4 Ansys Start Window

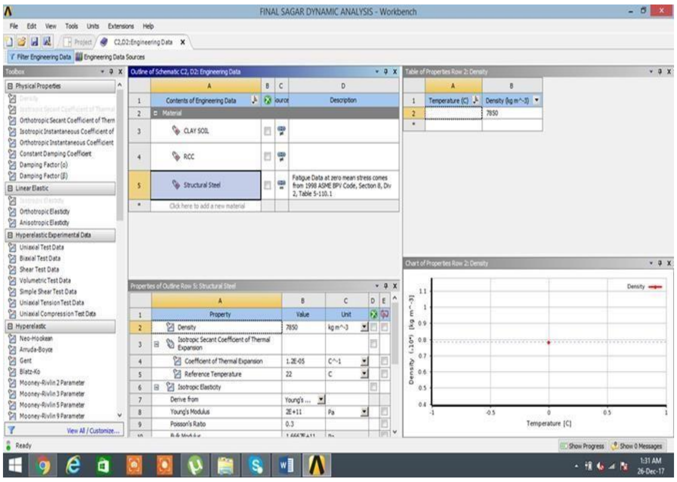


Figure 5 Inputting Structural Details

Imposed Uniformity Distributed Floor Loads (kN/ m2)	Percentage of Imposed Load
Up to and including 3.0	25
Above 3.0	50

Table 3 Percentage of Imposed Loads

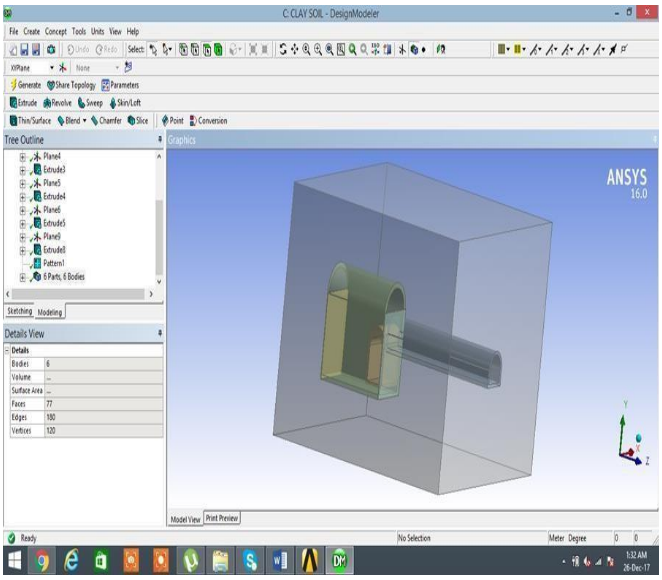


Figure 6 Model in Workbench Geometry

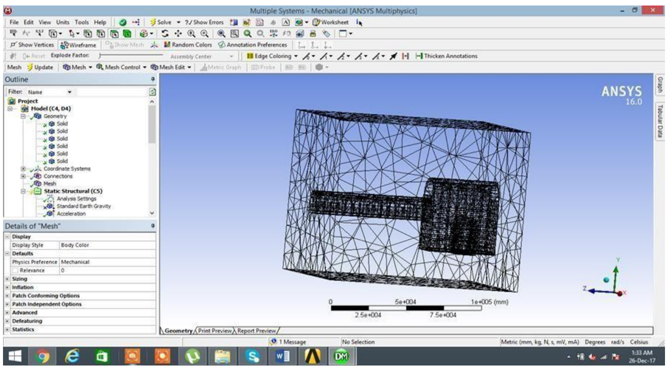


Figure 7 Meshing in Design Modular

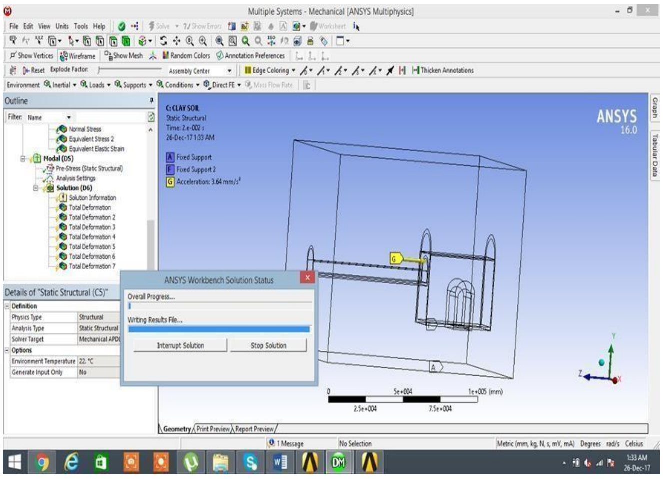


Figure 8 Ansys16 Solving Model for different parameters

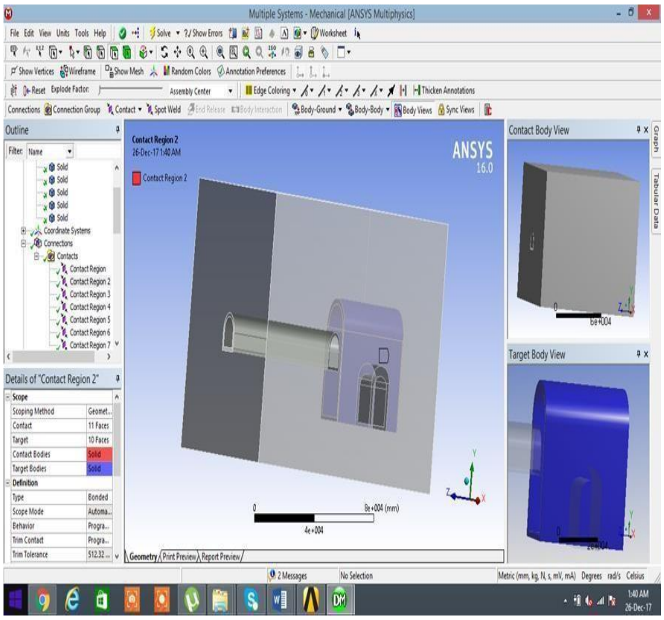


Figure 9 Connection of Soil With Strucсture

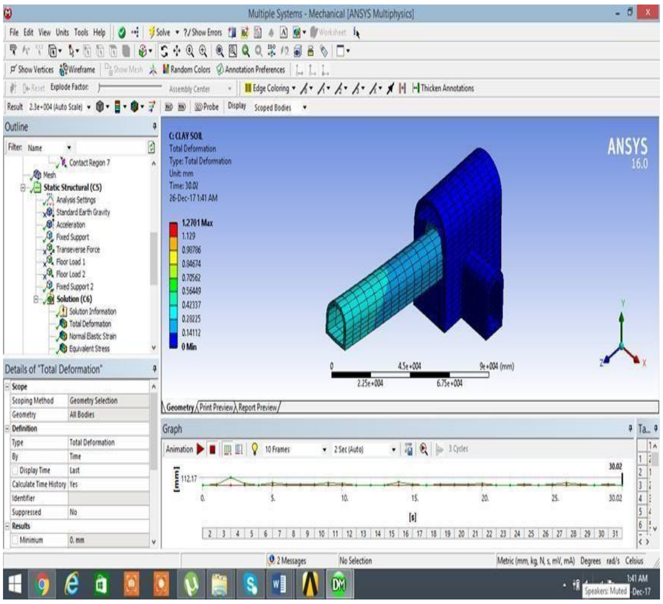


Figure 10 Structure with deformed parameters displayed in colour

Type of soil	Mass density P (Mg/m3)			
	Poorly graded soil		Well-graded soil	
	Range	Typical value	Range	Typical value
Loose sand	1.70–1.90	1.75	1.75–2.00	1.85
Dense sand	1.90–2.10	2.07	2.00–2.20	2.10
Soft clay	1.60–1.90	1.75	1.60–1.90	1.75
Stiff clay	1.90–2.25	2.00	1.90–2.25	2.07
Silty soils	1.60–2.00	1.75	1.60–2.00	1.75
Gravelly soils	1.90–2.25	2.07	2.00–2.30	2.15

Table 4 Typical Mass Density of basic Soil types.

Type of soil	U
Clay (saturated)	0.4 – 0.5
Clay (unsaturated)	0.1 – 0.3
Sandy clay	0.2 – 0.3
Silt	0.3 – 0.35

Table 5 Typical values of Poisson ratio for soils.

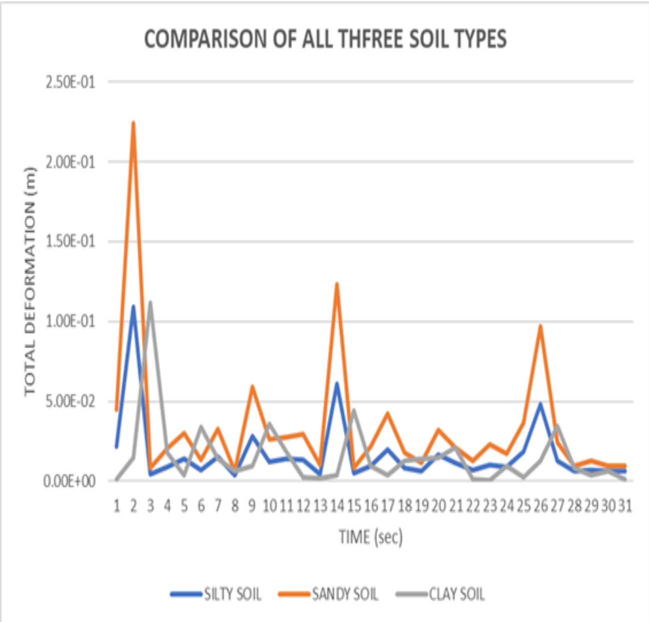
Soil depth (m)	Dense sand (s)	5 m of fill over normally consolidated clay*(S)
10	0.3–0.5	0.5–1.0
30	0.6–1.2	1.5–2.3
60	1.0–1.8	1.8–2.8
90	1.5–2.3	2.0–3.0
150	2.0–3.5	—

Table 6 Fundamental period values

IV. RESULTS AND DISCUSSION

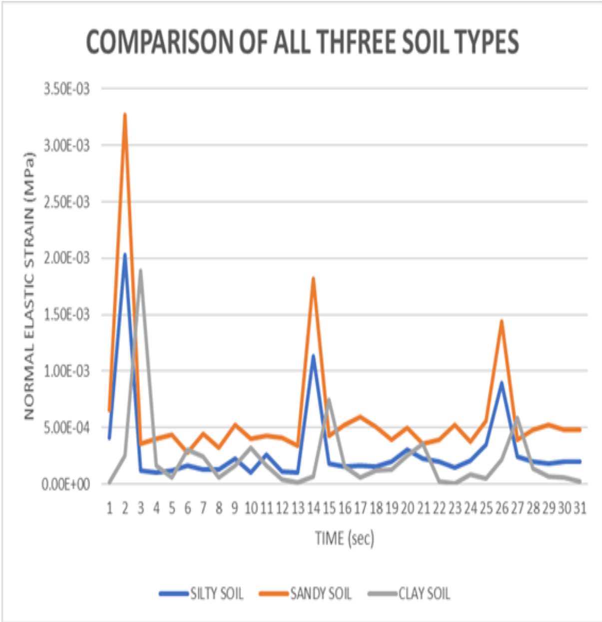
A. TOTAL DEFORMATON PARAMETER.

Graph no 1 total deformation obtained from Ansys



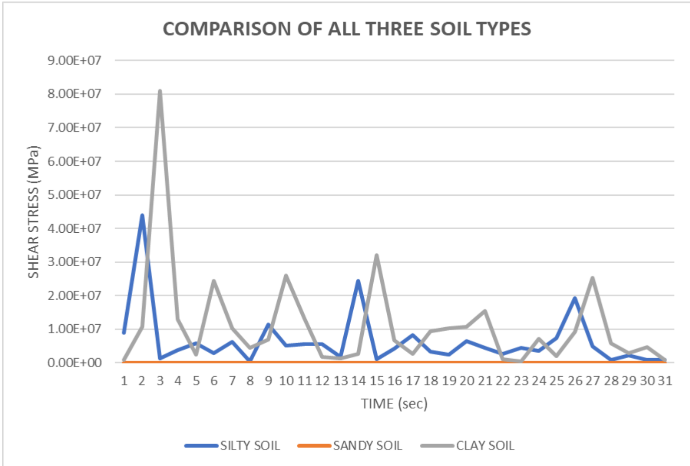
B. NORMAL ELASTIC STRAIN

Graph no 2 normal elastic strain obtained from Ansys



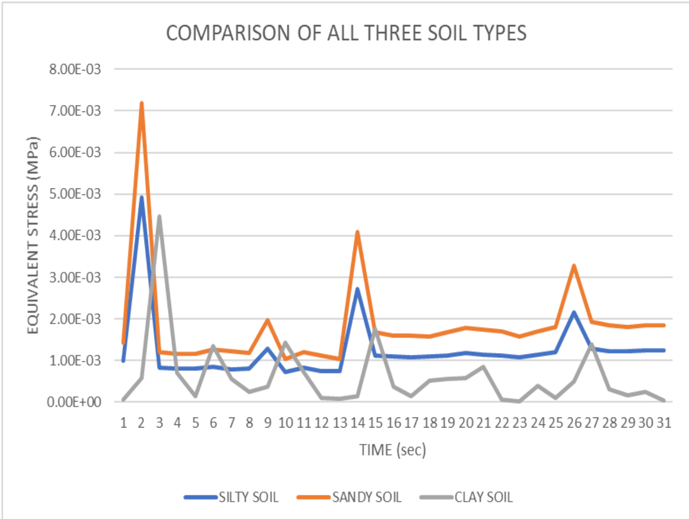
C. SHEAR STRESS

Graph no 3 Shear Stress obtained from Ansys



D. EQUIVALENT STRESS

Graph no 4 Equivalent Stress obtained from Ansys



E. DISCUSSION

1. The above graphs show us that the Total Deformation and Normal Elastic Strain is maximum in Sandy soil.

2. The above graphs show us that the Total Deformation is minimum in clayey soil.

3. Graph Shows that the maximum deformation is 2.25E-01 in sandy soil.

4. The difference between sandy soil and silty soil is 40%.

5. As long as Total Deformation is concerned clayey soil will be best suited for the construction for a Military bunker.

6. Shear Stress is minimum in sandy soil so as far as shear is concerned sandy soil is best suited.

IV CONCLUSIONS

In this study soil structure interaction of Military bunker is studied using FEA tool ANSYS 16. After applying El-Centro data it is observed that the total deformation, normal stress, shear stress and equivalent (von misses) stress are less in clayey soil as compared to Silty soil and Sandy soil.

1. The difference observed between the values of different parameters goes on decreasing as we further analysed.
2. However, no abrupt change is observed in the natural frequency and time of structure.
3. For clayey soils the value of Poisson ratio lies between 0.4 and 0.5and for sandy soils it lies between 0.3 and 0.35 and for silty soils it lies between 0.2 and 0.4.
4. From the study we concluded that out of the three soils sandy soil gives maximum values for normal elastic strain and equivalent stress.
5. By the analysis results, the difference of equivalent stress and shear stress between clayey and silty soil is 20% and 43%and the difference of total deformation between sandy soil and silty soil is 40%.

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