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"Seismic Analysis of RC Building on Different Soil Types Considering Soil Interaction"

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ABSTRACT - Civil engineering deals with constructing different types of structures with ensuring safety, durability and serviceability. Now days "earthquake "is phenomena that affects the structures with their safety and serviceability. The amount of damage that earthquake can done to structures is depend on Type of building, Type of soil, Technology used for earthquake resistance, and last but not the least Location of building. Effects of earthquake is largely depend on type of soil in which foundation of building is done because earthquake changes the motion of ground that results the failure foundation. So it is important to study the behavior of different soil at the time of construction of structures. Also earthquake can resisted by various technologies used in building. Present study focusses on the behavior of reinforced concrete frames considering soil structure interaction by performing linear static and dynamic analysis. In this paper a reinforced concrete frame having G+10 storey was considered. The investigation on the behavior of RC frame is carried out by using dynamic analysis i.e., Response Spectrum method. The modeling of RC frame is carried out by using finite element-based computer program i.e., STAAD.Pro. The investigation is carryout by considering different soil profile beneath the structure such as Clay, Silt, Sand, Basalt Rock, Mudstone and Gneiss rock. Further investigation is carried out by considering Clay soil profile with different footing type. By considering all these parameter total 18 models for Static and Dynamic Conditions were created, all models were analyzed for the Seismic zone II. The Response of each RC frame with respect to others will be checked for Axial force, Shear Force, Twisting moment, Bending Moment, Lateral displacement, and Base Shear. The behaviour of each RC frame with respect to others is describes with the help of graphs.

Key Words: RC frame, Soil Structure Interaction, Response Spectrum Method, Soil Profiles, Density, Modulus of Elasticity, Modulus of Rigidity, Poisson's Ratio, Different Footing Type.

I. INTRODUCTION

Earthquake is moving phenomenon of soil or we can say that vibrations which disturb the earth surface due to waves inside the surface of earth is termed as earthquake. Earthquake can damage the structures which are not constructed according the earthquake consideration. A large number of building designed in India according to static and permanent loads but earthquake is an occasional loads. Present time in India approximately more than 60% area is under earthquake prone zone. So it is important to design the structures according to seismic forces. Earthquake damages the substructure and superstructures. Substructures is the lower part of buildings i.e.; foundation of buildings and superstructures is the part of buildings that rests above the ground level. It is important to understand the behavior of substructures due to seismic loads (soil-foundation interaction) and behavior of superstructures due to seismic loads (beam, column, slab, beam-column joint etc.). In conventional analysis of any civil engineering structure the super structure is usually analyzed by treating it as independent from foundation and soil medium on the assumption that no interaction takes place. This usually means that by providing fixity at the support structural analyst simplifies soil behaviour, while geotechnical engineer neglects structural behavior by considering only the foundation while designing.

When a structure is built on soil some of

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the elements of the structure are in direct contact with the soil. When the loads are applied on the structure, internal forces are developed in both the structure and as well as in soil. This results in deformations of both the components (structure and soil) which need to be compatible at the interface as they cannot be independent of each other. Because of this mutual dependence, which is termed as interaction, the stress resultants in structure and, stresses and strains in soil are significantly altered during loading. Therefore, it becomes imperative to consider the structure-foundation and soil as components of a single system for analysis and design of the structure and its foundation. The analysis that treats structure foundation-soil as a single system is called as **Soil Structure Interaction (SSI) analysis.**

The subject Soil Structure Interaction (SSI) suggests different philosophy in analysis and design procedure which is unconventional in civil engineering practice. The term soil structure interaction has been largely used for mechanics of interaction between soil and the structure or its part buried in it. From the very name it is evident that soil structure interaction is an interdisciplinary field involving geotechnical and structural engineers which is not used by both the group of engineers as it needs expertise of both the fields. In addition to this, dynamic analysis of soil structure interaction makes the problem still complex. Besides vibrations, wave propagation in the unbounded soil may also need to be addressed.

FactorsAffectingSoilStructureInteraction

The major factors which are responsible in influencing thebehavior of framed structure foundation- soil interactionare

- Typesofsoilavailablesurroundingandbelowthefoundationatvariousdepths.
- Stiffnessbetweenfootingandsoil,andalsobetweensuper-structureandfooting.
- Size,shapeandtypesoffooting/foundation.
- Stress-stainrelationshipandsoilnonlinearityoffoundationsoil.
- Typeofloading:

a) Static
b) Dynamic

- Watertabledepthfromsurface.

Parameters For SSI And Structural

SSI Parameters –
1) Local soil condition
2) Peak ground Acceleration
3) Shear wave velocity
4) Frequency content of motion

Structural Parameters –
1) Natural time period
2) Base shear
3) Roof displacement
4) Column moment
5) Beam moment

OBJECTIVES

1) To study the structural behaviour of G+10 Storey building by varying soil Types.
2) To include effects of non-linear stress strain characteristics of soil in interaction phenomenon.
3) To analyse seismic and non-seismic behaviour of the Building.
4) To determine the SSI effect on various dynamic properties of R.C. frame such as Beam End Forces, Beam End Displacement, Base Shear, Frequency, etc.
5) Effect of various soil and structural parameters are also studied to identify their effect on seismic
6) To study the effect of factors in structural analysis for linear and nonlinear soils.

System Modelling And Methodology

Project involves analysis of G+10 storey buildingconsidering variation in soil properties and its interaction byusing a very popular designing software STAAD Pro. Thedesign involves load calculations manually and analysing thewhole structure by STAAD Pro. The minimum requirementspertaining to the structural safety of G+10 storey building isbeing covered by way of laying downminimum design loadswhich must be assumed for dead loads, imposed loads, andother external loads, thestructure would be required to bear. Strict conformity to loading standards recommended in Indian Standards, it is hoped, will not only ensure the structural safety of the buildings which arebeing designed.

DESIGN PARAMETRES

Table-1: Detailsofstructureconfiguration

Sr. No	Parameters	Description
1	Building	OMRF
2	Size of Building	15m x 15m
3	Building Stories	G +10
4	Floor to Floor Height	3.15 meter
5	Unit Wt. of Concrete	23 KN/m³
6	Size of Beam	300mm x 450mm

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7	Size of Column	600mm x 600mm
8	Slab Thickness	200mm
9	Wall Thickness	230mm

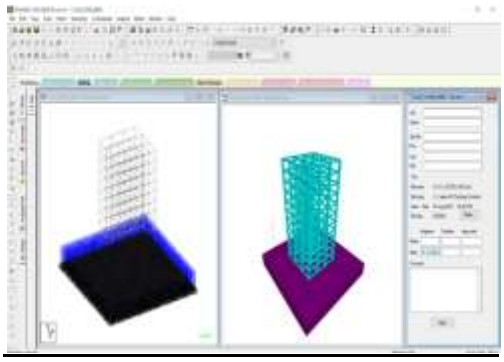

Figure 1: Isometric View of Completed G+10 Storey Structure.

SPECIFICATIONOFSOIL

Table2-:Detailsofsoilconfiguration

Soil Type	Porosity %	Modulus of Elasticity [MPa]	Poisson's Ratio
Sand	**0.25-0.50**	**5-18**	**0.15-0.4**
Silt	**0.35-0.50**	**7-21**	**0.3-0.35**
Clay	**0.40-0.70**	**2-250**	**0.1-0.5**
Basalt Rock	**0.05-0.50**	**40-80**	**0.10-0.20**
Mudstone	**0.05-0.50**	**5-70**	**0.15**
Gniess	**0.05-0.30**	**30-80**	**0.24**

Table 3.Design Seismic Parameters

Sr. No	Design Parameter	Value
1	Seismic Zone	II
2	Zone Factor	0.1
3	Response Reduction Factor	3
4	Importance Factor	1.5
5	Soil Type	II

Table 4. Material Properties

Sr. No	Design Parameter	Value
1	Unit weight of concrete	23.56 kN/m^3
2	Unit weight of infill walls	20 kN/m^3
3	Characteristic strength of concrete	20 N/mm^2
4	Characteristic strength of steel	500 N/mm^2
5	Damping ratio	5 %

Loads Considered

The types of loads considered during the design were:
1.Self-weight of the beams and columns.
2.Weight of slab.
3.Infill weight.
4.Live load of 4 kN/m^2
5.Floor Finished of 1 kN/m^2

DESCRIPTIONS OF DRAFTED MODELS

The type of building frames considered for the study is a regular building 15M X 15M in size with 10 number of storeys. length of bay in X-direction and Z-direction is 5 M, floor to floor height is 3.15 M

Type – I: Model with Clay.
Case – I: Model with Loose Clay (Density = 15.06 kN/m^3, E = 2 Mpa, u = 0.4)
Model 1**:** The type of building frame is analyzed for soft type soil.
Model 2:The type of building frame is analyzed for Loose Clay without earthquake load.
Model 3:The type of building frame is analyzed for Loose Clay with earthquake load.

Case – II: Model with Dense Clay (Density = 21.30 kN/m^3, E = 210 Mpa, u = 0.1)
Model 1: The type of building frame is analyzed for medium type soil.
Model 2: The type of building frame is analyzed for Dense Silt without earthquake load.
Model 3: The type of building frame is analyzed for Dense Silt with earthquake load.

Type – II: Model with Silt.
Case – I: Model with Loose Silt (Density = 12.79 kN/m^3, E = 5 Mpa, u = 0.35)
Model 1: The type of building frame is analyzed for soft type soil.

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Model 2: The type of building frame is analyzed for Loose Silt without earthquake load.
Model 3: The type of building frame is analyzed for Loose Silt with earthquake load.

Case – II: Model with Dense Silt (Density = 21.79 kN/m^3, E = 20 Mpa, u = 0.3)
Model 1:The type of building frame is analyzed for medium type soil.
Model 2: The type of building frame is analyzed for Dense Silt without earthquake load.
Model 3:The type of building frame is analyzed for Dense Silt with earthquake load.

Type – III: Model with sand.
Case – I: Model with loose sand (Density = 13.46 kN/m^3, E = 5 Mpa, u = 0.4)
Model 1: The type of building frame is analyzed for soft type soil.
Model 2:The type of building frame is analyzed for Loose Sand without earthquake load.
Model 3:The type of building frame is analyzed for Loose Sand with earthquake load.
Case – II: Model with Dense sand (Density = 21.79 kN/m^3, E = 81 Mpa, u = 0.15)
Model 1:The type of building frame is analyzed for medium type soil.
Model 2:The type of building frame is analyzed for Dense Sand without earthquake load.
Model 3:The type of building frame is analyzed for Dense Sand with earthquake load.

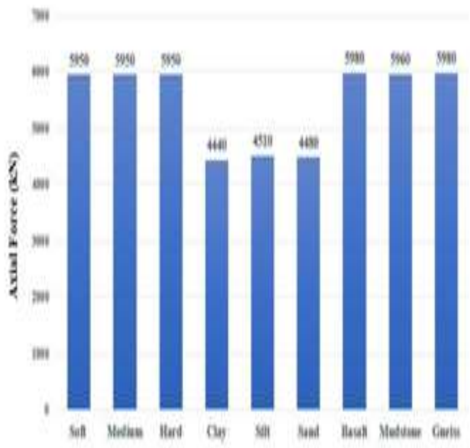
Type – IV: Model with Basalt (Igneous Rock).
Case – I: Model with Loose Basalt Rock (Density = 22.10 kN/m^3, E = 40 Mpa, u = 0.2)
Model 1:The type of building frame is analyzed for medium type soil.
Model 2: The type of building frame is analyzed for Loose Basalt Rock without earthquake load.
Model 3: The type of building frame is analyzed for Loose Basalt Rock with earthquake load.
Case – II: Model with Dense Basalt Rock (Density = 27.70 kN/m^3, E = 80 Mpa, u = 0.1)
Model 1: The type of building frame is analyzed for Hard type soil.
Model 2: The type of building frame is analyzed for Dense Basalt without earthquake load.
Model 3: The type of building frame is analyzed for Dense Basalt with earthquake load.

Type – V: Model with Mudstone (Sedimentary Rock).
Case – I: Model with Loose Mudstone (Density = 18.20 kN/m^3, E = 5 Mpa, u = 0.15)
Model 1:The type of building frame is analyzed for medium type soil.
Model 2:The type of building frame is analyzed for Loose Mudstone without earthquake load.
Model 3:The type of building frame is analyzed for Loose Mudstone with earthquake load.
Case – II: Model with Dense Mudstone (Density = 27.20 kN/m^3, E = 70 Mpa, u = 0.15)
Model 1:The type of building frame is analyzed for Hard type soil.
Model 2:The type of building frame is analyzed for Dense Mudstone without earthquake load.
Model 3:The type of building frame is analyzed for Dense Mustone with earthquake load.

Type – VI: Model with Metamorphic Rock.
Case – I: Model with Loose Metamorphic Rock (Density = 26.10 kN/m^3, E = 30 Mpa, u = 0.24).
Model 1:The type of building frame is analyzed for medium type soil.
Model 2:The type of building frame is analyzed for Loose Metamorphic Rock without earthquake load.
Model 3:The type of building frame is analyzed for Loose Metamorphic Rock with earthquake load.

Case – II: Model with Dense Metamorphic Rock (Density = 26.10 kN/m^3, E = 30 Mpa, u = 0.24).
Model 1:The type of building frame is analyzed for medium type soil.
Model 2:The type of building frame is analyzed for Loose Metamorphic Rock without earthquake load.
Model 3:The type of building frame is analyzed for Loose Metamorphic Rock with earthquake load.

II. RESULTS



Values of Axial Force

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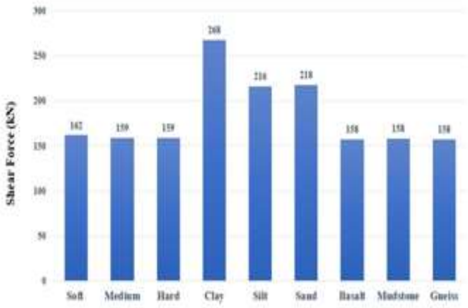
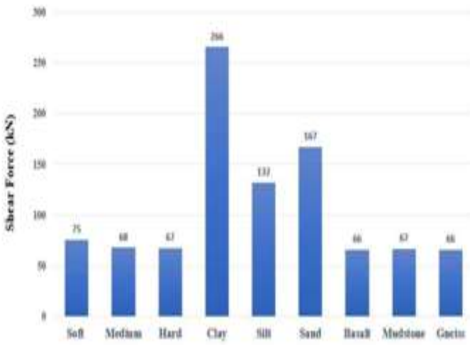
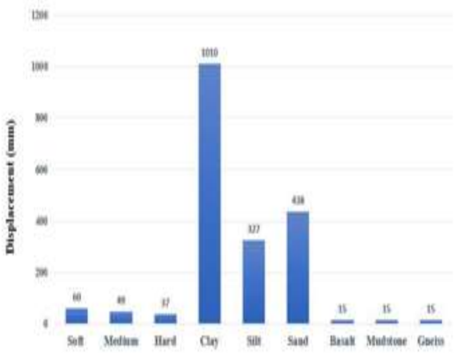


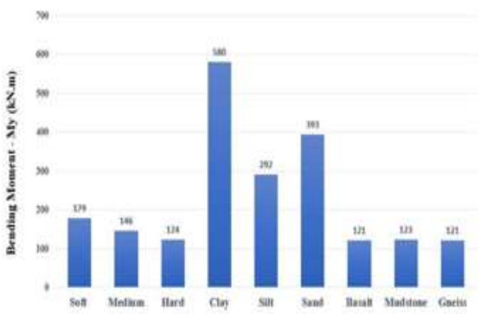
Values of Shear Forces (Fz)



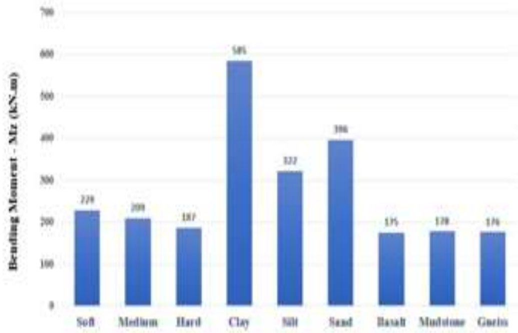
Values of Shear Force (Fy)



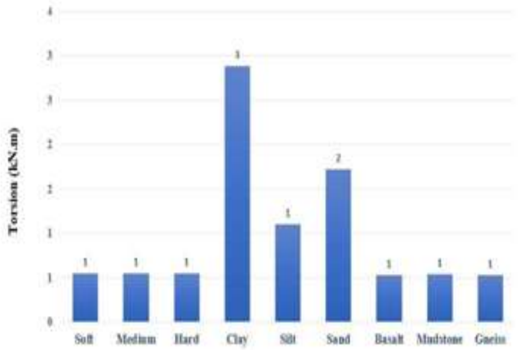
Values of Displacement (mm)



Values of Bending Moment (My)



Values Of Bending Moment (Mz)



Values of Twisting Moments

III. CONCLUSIONS

Present study focusses on seismic behavior of frames considering Soil Structure Interaction, from the above result and discussion, it can be concluded that many research studies and building codes have addressed this issue on Soil Structure Interaction. Seismic codes provide criteria to classify soil as soft, medium and hard. Most of the studies have focused on investigating the structure by considering the soil either soft, medium, and hard. It has been found that the seismic behavior is

1. Soil Profile as Clay

- Maximum axial force is observed in normal model whereas minimum in Loose Clay.
- Maximum shear force, twisting moment, buckling moment, bending moment and displacement isobserve in Loose Clay whereas minimum in normal (Fixed) model.

2. Soil Profile as Silt

- Maximum axial force is obtained for normal model while minimum axial force is obtained formodel with Loose Silt.
- Maximum shear force, twisting moment, buckling moment, bending moment and displacement is obtained for model with Loose Slit while minimum values were obtained for

normal model.

3. Soil Profile as Sand

- Maximum axial force is obtained for normal model while minimum axial force is obtained for model with Loose Sand
- Maximum shear force, twisting moment, buckling moment, bending moment and displacement isobtained for model with Loose Sand while minimum values wereobtained

4.Model with Soil Profile as Basalt (Igneous Rock).

- Maximum axial force is obtained for model with basalt rock while minimum axial force is obtained for Normal model with hard soil.
- Maximum shear force, twisting moment, buckling moment, and bending moment is obtained for Normal model with hard soil while minimum values were obtained for model with dense basalt rock.

5.Model with Soil Profile as Mudstone (Sedimentary Rock).

- Maximum axial force is obtained for model with dense Mudstone while minimum axial force is obtained for Normal model with hard soil.
- Maximum shear force, twisting moment, buckling moment, bending moment and displacement is obtained for Normal model with hard soil while minimum values were obtained for model with dense Mudstone.

6. Model with Soil Profile as Gneiss (Metamorphic Rock).

- Maximum axial force is obtained for model with dense Gneiss Rock while minimum axial force is obtained for Normal model with hard soil.
- Maximum shear force, twisting moment, buckling moment, bending moment, Displacement is obtained for Normal model with hard soil while minimum values were obtained for model with dense Gneiss Rock.
-

IV. SCOPE OF WORK

The main objective of this work was to compute the influences of different configurations of Soil Strata on the behaviour of building frames subjected to lateral forces. Hence, further investigations can be directed to update the design rules and recommendations for considering the effects of SSI. The study may be conducted in the following areas:

- The numerical and experimental studies can be extended to investigate the effect of parameters such as layered soils, relative stiffness of raft and soil, relative stiffness of pile and soil, and pile-head fixity and end- bearing-type mechanisms. This further investigation can give a broader range of results on soil-pile-structure interaction studies.
- The experimental study can be performed on a variety of building frames such as low-rise, mid-rise, and high-rise resting on sandy soil with various pile-group configurations. Hence, the effects of soil-pile- structure on seismic behaviour of these different types of superstructures can be quantified.
- Numerical and experimental dynamic analysis can be performed considering various ground motion parameters. Theeffects of ground motion characteristics on the response of soil-pile- structure systems can be studied adequately.
- Analysis further can be done by time history and pushover analysis and compare the accuracy of results.
- The soil is considered as single media but layered soil types exist below is not single, so differentlinear equilibrium effects can also be considered.

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