Seismic Response of Structure on Different Types of Soil

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Abstract— Soil is one of the most important engineering materials. When a structure is placed on a foundation consisting of soil, the loads from the structure cause the soil to be stressed. The two most important requirements for the stability and safety of the structure are firstly, the deformation, especially the vertical deformation, called 'settlement' of the soil, should not be excessive and must be within tolerable or permissible limits. And secondly, the shear strength of the foundation soil should be adequate to withstand the stresses induced. This project aims to study the seismic response of structure on different types of soil. All the Civil Engineering structures, ultimately rest on the soil. They transfer their whole load to the soil, so we have to construct the foundations to retain these structures. In case of the hard soil having sufficient strength we can provide the shallow foundations. If we know the strength of the soil then we can decide which type of foundation is to be used. If the soil is weak in strength then we have to provide the deep foundations like pile foundation, well foundation etc. A RCC building of G+10, G+15, and G+20 storeys with floor height 3.2m constructed on hard, medium and soft soil subjected to earthquake loading in Zone II, III, IV and V has been considered for analysis. In this regard, STAAD Pro V8i software has been considered as a tool to perform. Effect of different types of soil on RCC structure is analysed. Displacements, axial forces and bending moments along X and Z direction are calculated for four different columns. Maximum base Shear along X and Z direction is also calculated.

Key words: Different Types of Soil, Seismic Response

I. INTRODUCTION

The response of a structure to earthquake shaking is affected by interactions between three linked systems: the structure, the foundation, and the soil underlying and surrounding the foundation. Soil-structure interaction analysis evaluates the collective response of these systems to a specified ground motion.

Buildings are susceptible to soil structure interaction effects due to the induced changes in the dynamic characteristics of soil during seismic excitation. The soil-structure interaction is a phenomenon that influences many aspects in the design of a structure : safety, serviceability and costs. During the last few decades, it has been well recognized that the soil on which a structure is constructed may interact dynamically with the structure during earthquakes, especially when the soil is relatively soft and the structure is stiff. This kind of dynamic soil-structure interaction can sometimes modify significantly the stresses and deflections of the whole structural system from the values that could have been developed if the structure were constructed on a rigid foundation. The analysis of high rise reinforced concrete structures is commonly made easy by assuming a fixed base and disregarding the effect of soil structure interaction. However, different soil conditions have an effect on the static and dynamic characteristics of high rise structures and manipulate their static and dynamic performance. To design these buildings for static and dynamic loadings, the basic natural periods, base bending moments, and base shear forces are required as the most significant parameters and must be evaluated appropriately. Hence, this research is based on the study of Seismic Response of Structure on different types of Soil to study the effect of different types of soil on structure during earthquake.

A. *Classification of Soil*

Hard Soil	Soils having Standard penetration value, N > 30
Medium Soil	Soils with Standard penetration value, N between 10 and 30
Soft Soil	Soils with Standard penetration value, N < 10

Table 1: Classification of Soil

(From IS : 1893 (Part 1) – 2002 - Indian Standard Criteria for Earthquake Design of Structures , page no. 15, Table 1 Percentage of Permissible Increase in Allowable Bearing Pressure or Resistance of Soils.)

B. *Objective of Study*

- To determine the various forces on the structure due to earthquake.
- To study the effect of hard soil on R.C.C. building in different zones (i.e. zone II, III, IV and V).
- To study the effect of medium soil on R.C.C. building in different zones (i.e. zone II, III, IV and V).
- To study the effect of soft soil on R.C.C. building in different zones (i.e. zone II, III, IV and V).
- To study the seismic response of structure on different types of soil.

C. *Methodology*

To fulfill the above objectives, the following methodology was adopted:

- Selection of geometry of R.C.C. building.
- To model G + 10, G + 15, etc… storey R.C.C. building on hard soil.
- To model G + 10, G + 15, etc… storey R.C.C. building on medium soil.
- To model G + 10, G + 15, etc… storey R.C.C. building on soft soil.
- To analyse the above models of building in different zones (i.e. zone II, III, IV and V).
- To compare the analytical data.

II. LITERATURE REVIEW

A. *Liaqat Ali Qureshi, Nasir-u-din and Tahir Sultan & M. Ilyas Sh. (2012) (1)*

In this research, behaviour of the high-rise buildings and their vulnerability under combined non-seismic loads (gravity loads) and seismic loads (Earthquake loads) have been checked for different types of soils named SA, SB, SC, SD and SE, graded from hard rock (SA) to very soft soil (SE). A typical model of 20-storeyed building was selected. The software ETAB was used for analysis and design of frames. Structure with 200 ft. height and higher must be designed on the basis of dynamic analysis (Response spectrum analysis) instead of static analysis to get a safer and economical structure.

B. Abel Ordonez. (2012) [2]

This paper presents the study of ground motion during an earthquake, considering not only the acceleration but also the displacements generated by the earthquake. Two case studies are presented based on experience acquired in the past years in the mining industry and alternative, different structure failure mechanisms are proposed with a recommendation to review and complement the current seismic design concepts. From the results, it is found that, the inertial model cannot be applied to structure behaviour in soft soil.

C. Erfan Alavi and Mojtaba Alidoost. (2012) [3]

This study focuses on effects of Soil Structure Interaction on base-isolated buildings founded on the different soil types, to evaluate quantitatively as well as qualitatively the seismic responses of the combined system. In that regard, four base-isolated buildings with 2, 4, 7, and 10 stories are selected and designed preliminarily with ignorance of the soil interaction effects. The results indicate that on the very stiff soil, the Soil Structure Interaction has negligible effects on the responses for all the base-isolated models, however, on the softer soil, the soil interaction effects will become larger.

D. G. Saad, F. Saddik & S. Najjar. (2012) [4]

This paper studies the seismic behaviour of reinforced concrete buildings with multiple underground stories. This research mainly aims at understanding the effects of soil structure interactions, this study has the ultimate goal of finding appropriate recommendations concerning the inclusion of underground stories in the modelling and analysis of reinforced concrete shear wall buildings and optimizing their design. The base shear, inter-story shears and moments are evaluated in order to quantify the effects of soil structure interaction on the design process. The results show that the effect is more pronounced in buildings resting on softer soil.

E. Bijan Mohraz. (1976) [5]

This study examines the effects of geological conditions on the response spectra and the ground-motion parameters such as peak ground acceleration, velocity, and displacement. The findings in this study show that the current design spectra, which are based primarily on records from stations located on alluvium deposits, are conservative for other geological conditions. It is shown that for low- and intermediate-frequency regions, the spectral bounds for rock deposits are substantially lower than those for alluvium deposits.

III. CODAL PROVISION

During the seismic analysis of various models, following IS codes were used:

1) IS 1893 (Part 1): 2002 - Indian Standard Criteria for Earthquake Design of Structures.
2) IS: 875 (Part II) - 1987 - Indian Standard Code of Practice for design loads (other than earthquake) for buildings and structures.

IV. STRUCTURAL MODELING

A RCC building of G+10, G+15, and G+20 storeys with floor height 3.2m constructed on hard, medium and soft soil subjected to earthquake loading in Zone II, III, IV and V has been considered and modelled using STAAD.Pro V8i software.

A. Architectural Plan

Fig. 1: Typical Plan of Building

B. Geometry of Proposed Building, Materials and Method

- Type of building – Educational building
- Type of frame – Special RC moment resisting frame fixed at the base
- Seismic Zone – II, III, IV and V
- Importance Factor – 1.5
- Floor to floor height – 3.2 m
- Location – N.P.N., K.D.K. Campus, Nagpur
- Number of storeys – G + 10

1) Assumed Beam sizes –

- Main beams : 300mmX900mm
- Secondary beams : 300mmX600mm
- Assumed Column size – 300mmX900mm

2) Number of storeys – G + 15

- Assumed Beam sizes –
- Main beams: 300mmX900mm
- Secondary beams: 300mmX600mm
- Assumed Column size – 450mmX1200mm

3) Number of storeys – G + 20

- Assumed Beam sizes –
- Main beams: 300mmX900mm
- Secondary beams: 300mmX600mm
- Assumed Column size – 600mmX1200mm
- Thickness of Slab – 150mm
- Grade of concrete – M-25
- Grade of Steel – Fe500
- Type of Soil – Hard, Medium and Soft

- Response Spectrum Method – As per IS 1893 (Part 1) : 2002
- Damping of Structure – 5 percent

V. Analysis of Structure

A RCC building of G+10, G+15, and G+20 storeys with floor height 3.2m constructed on hard, medium and soft soil subjected to earthquake loading in Zone II, III, IV and V has been considered. In this regard, STAAD.Pro V8i software has been considered as a tool to perform. Effect of different types of soil on RCC structure is analysed. Displacements, axial forces and bending moments along X and Z direction are calculated for four different columns as shown in fig. 4.2.1 Maximum base Shear along X and Z direction is also calculated.

A. *STAAD Model*

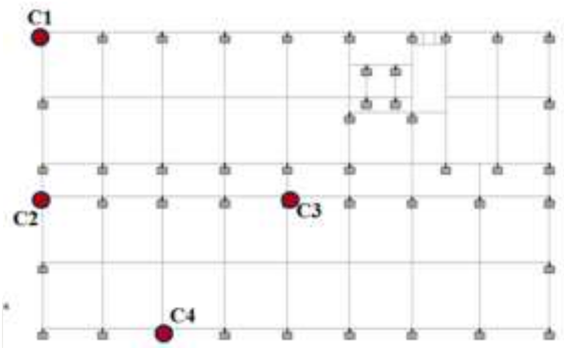


Fig. 2: STAAD Model of Building

Above Fig. shows the modelling of plan in STAAD.Pro software in which four columns C1, C2, C3 and C4 are indicated for the further study.

B. *Calculation of Time Period*

1) *Time Period,*

$T = 0.075\ h^{0.75}$ --- For RC Frame building - (From IS: 1893 (Part 1) – 2002 - Indian Standard Criteria for Earthquake Design of Structures, page no. 24, clause no. 7.6.1)

Where, h = height of building, in metre.

2) *G+10 Building : (h = 37.2 m.)*

T = 1.13 sec. (By IS Code)
T = 1.19 sec. (By STAAD)

3) *G+15 Building : (h = 53.2 m.)*

T = 1.48 sec. (By IS Code)
T = 1.53 sec. (By STAAD)

4) *G+20 Building : (h = 69.2 m.)*

T = 1.80 sec. (By IS Code)
T = 1.85 sec. (By STAAD)

The Time Period calculated by the formula given in IS Code and the Time Period obtained from STAAD output are nearly about same for G+10, G+15 and G+20 Buildings.

Analysis of Structure for G+10, G+15 and G+20 Buildings constructed on hard, medium and soft soil in Zone II, III, IV and V is done and Lateral displacement, Axial Force, Moment and Base shear are calculated.

VI. Result and Comparison

A RCC building of G+10, G+15, and G+20 storeys constructed on hard, medium and soft soil is analysed for four different columns in zone II, III, IV and V. Parameters like Lateral displacement, Axial force, Moment and Base shear is calculated. Graphical representation of data is discussed in this chapter.

A. *Lateral Displacement*

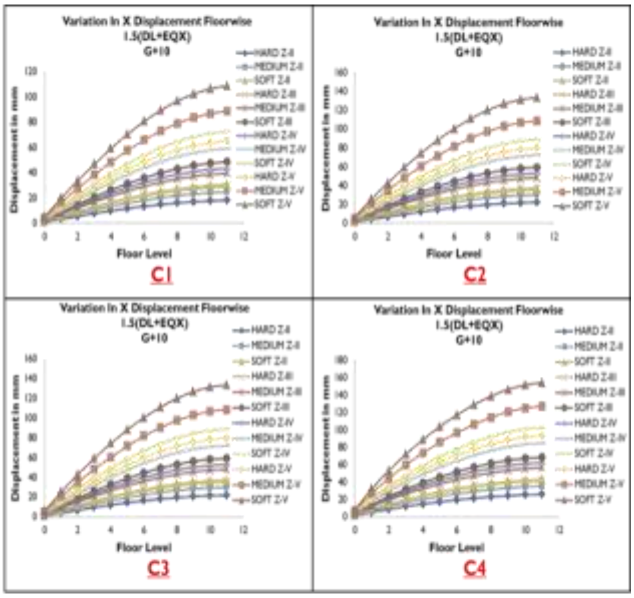
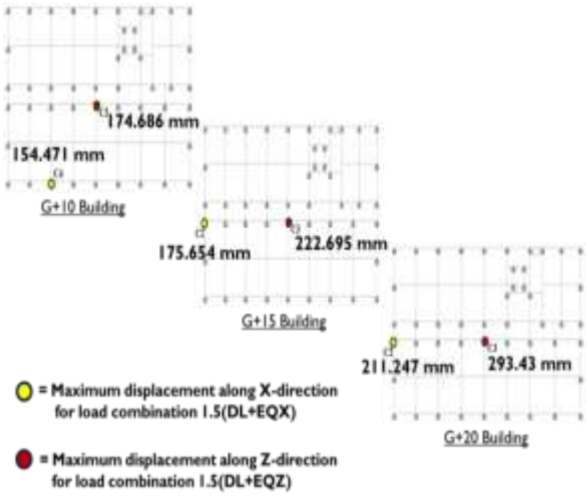


Fig. 3: Lateral displacement along X-direction for columns 1, 2, 3 and 4 (G+10 Building)

Similarly, graphs are plotted for Lateral displacement along X and Z-directions in all zones (G+10, 15 and 20 storey Buildings)

From graphs it is observed that,

- Lateral displacement along X and Z-directions is gradually increasing from hard soil to soft soil. This increase in displacement is directly associated with soil profile.
- The displacement goes on increasing with the zones.
- As number of floor increases, displacement increases.
- The nature of graph of displacement along X-direction for all columns is approximating same.
- The nature of graph of displacement along Z-direction for C1 is same as C2 and C3 is same as C4.



Above shows the position Columns having Maximum Lateral displacement along X and Z-directions for both the load combinations 1.5(DL+EQX) and 15(DL+EQZ) of G+10, 15 and 20 storey Buildings

B. Axial Force

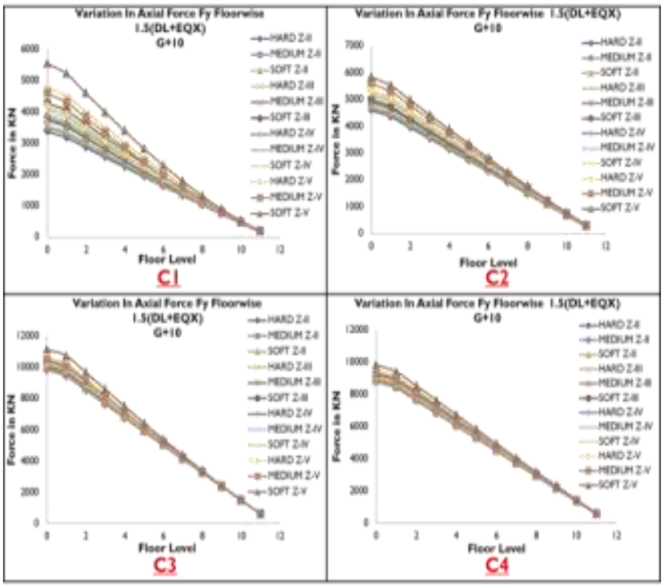
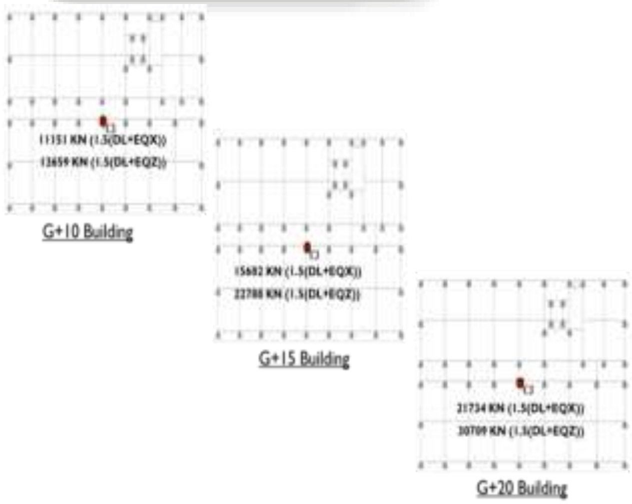


Fig. 4: Axial force for load combination 1.5(DL+EQX) for columns 1, 2, 3 and 4 (G+10 Building)

Similarly, graphs are plotted for Axial force for load combinations 1.5(DL+EQX) and 1.5(DL+EQZ) in all zones (G+10, 15 and 20 storey Buildings)

From graphs it is observed that,

- Axial force along X and Z-directions linearly increases from hard soil to soft soil.
- The axial force goes on increasing with the zones.
- For a particular column, Axial force decreases floor wise.
- Maximum Axial Force was found in column no. 3 (C3) for all G+10, G+15 and G+20 buildings.
- The trend of axial force pronouncing more in C3-C4 as compare to that of C1-C2 for both the load combinations.



Above Fig. shows the position of Columns having Maximum Axial Force for both the load combinations 1.5(DL+EQX) and 15(DL+EQZ) of G+10, 15 and 20 storey Buildings

C. Moment

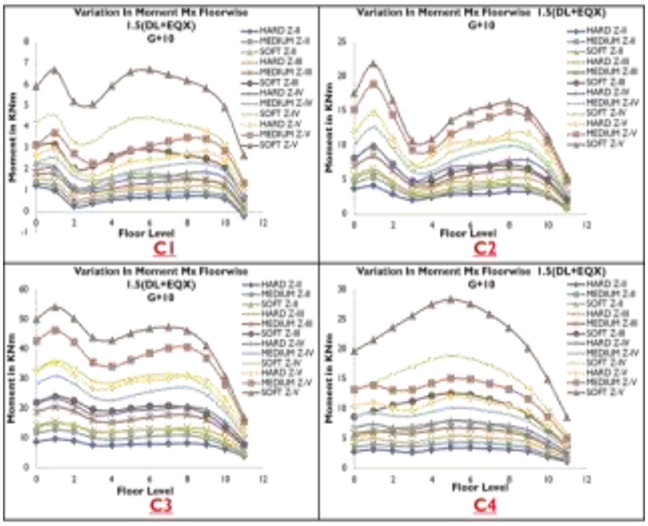


Fig. 5: Moment for load combination 1.5(DL+EQX) for columns 1, 2, 3 and 4 (G+10 Building)

Similarly, graphs are plotted for Moment for load combinations 1.5(DL+EQX) and 1.5(DL+EQZ) in all zones (G+10, 15 and 20 storey Buildings)

From graphs it is observed that,

- Moment along X and Z-directions varies drastically from hard soil to soft soil.
- The value of moment goes on increasing with the zones.

D. Base Shear

Similarly, from the values of Base shear along X and Z-directions in all zones for G+10, 15 and 20 Buildings constructed on hard, medium and soft soil, it is observed that,

- Base shear is gradually increasing from hard soil to soft soil, which directly affects the cost and also affects the forces of structural members.
- The values of Base Shear along X-direction are greater than the values of Base Shear along Z-direction.

VII. CONCLUSION

For three Buildings G+10, 15 and 20 constructed on three different soils hard, medium and soft, 36 models are prepared in Zone II, III, IV and V using STAAD.Pro V8i software and the following Conclusions are obtained :

- As number of floor increases, displacement increases linearly, axial force decreases linearly and moment changes drastically along X and Z direction from hard soil to soft soil .
- Base shear increases gradually from hard soil to soft soil as the number of storey increases which directly affects the cost and also affects the forces of structural members.
- The values of displacement, axial force and moment go on increasing with the zones.
- Therefore the structures on hard soil are more stable, economical and also provide more resistance against lateral forces than that of structure on soft soil.

- General nature of graph of moment is, as floor increases moment decreases when we consider earthquake forces only. But here Moments are changing randomly due to combination of dead load with earthquake load.
- The Maximum displacement along X-direction for load combination 1.5(DL+EQX) is being observed on exterior column.
- The Maximum displacement along Z-direction for load combination 1.5(DL+EQZ) is being observed on interior column.
- The Maximum Axial Force for both the load combinations 1.5(DL+EQX) and 1.5(DL+EQZ) is being observed on interior column.

VIII. FUTURE SCOPE

- Same study can be done considering wind load.
- Same study can be extended for composite structures.
- We can take the height of the building more than G+20.

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