Soil Interaction Analysis of A Tall Structure Under Dynamic Loading Using Analysis Tool

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Abstract- *The foundation, the surrounding and underlying soil, and the building itself form interconnected systems that collectively determine a structure's response to seismic activity. Evaluating the interplay between soil and structure is crucial in understanding their combined reaction to specific ground movements. In literature, the terms "soil-structure interaction" (SSI) and "soil-foundation-structure interaction" (SFSI) are often used interchangeably to describe this phenomenon. Despite the potential impact of SSI, structural engineers sometimes overlook its influence, assuming it has no detrimental effects on the structure. However, this assumption may not always hold true. Recognizing the foundation's critical role in the structure, this project adopts the term "SSI." For analytical purposes, we consider a B+S+24 R.C.C. building to compare the influence of SSI.*

Soil Structure Interaction (SSI) is the phenomenon of the motion of the soil affecting the response of the structure and the response of the structure affects the motion of the soil. Modelling of structures is done using various analysis software like SAP, ETABS etc.

Keywords- Earthquakes, fixed support, Soil Structure Interaction (SSI), SAP 2000 and Response Spectrum Analysis.

I. INTRODUCTION

Since the hazards occurring all over the world due to seismic pressure is increasing and causing damage to the infrastructure and people, thus for designing structures prone to resist such tremors are necessary. As we all know seismic hazards generally occurs due to movement in tectonic plates beneath the earth therefore foundations and soil pressure below the structure should be analyze for safe distribution of vertical pressure of the building. Soil interaction is one of the most important aspect which is been considered by engineers and architects from several years after the examination of impacts on structure due to earthquake all around the globe.
Soil structure interaction is analyzed by interacting the combine effect of base of the structure and soil beneath.The layers of structure stated on deformable soil redistributes forces and moment because of soil interaction, in such case symmetric examination is not effective and might is inappropriate.

The interaction impact is increasingly usymmetrically if there should be an occurrence of multi-storeyed buildings because of overwhelming loads and may turn out to be additionally distorted when such buildings are exposed to seismic hazards.

In general, Soil Structure Interaction (SSI) is widely accepted being a simple and highly impactful technique having several advantages which should be considered in every structure design. SSI courses of action of seismic pressure are optional and empower architects to analyze the structure. Base shearVb of the structures is considering soil-structure interaction (SSI) as a beneficial effect. The crucial idea behind the plans is that the soil structure system can be displaced with a proportionate fixed-base model with a progressively drawn-out period and normally a greater dampihikng extent. A huge part of the structure codes utilizes effect of different soil types, which is necessary for analysis of structure at different soil regions and studying effect of structure on different type of soil. Since soil properties also have effect on the structure stability due to its swelling and shrinking conditions. In explanatory manner it can be said that structure stability depends on soil type (properties) and have been considered in I.S. 1893-I:2016.

This research work presents an explanatory comparison of a high rise symmetrical structure of G+10 storey considering seismic zone IV with three different soil conditions i.e. soft soil, medium soil and Hard strata, In this study we are interacting structure and soil using analysis tool SAP2000.

Objectives

The primary objectives of this study is as follows:

1. To check the stability of tall structure analyzing soil structure interaction.

2. To perform comparative analysis of three different type of soil.
3. To Analyze the interaction of soil and column where column support end is provided 2 m beneath the soil.
4. To justify the utilization of soil interaction in seismic design of the structure.

II. LITERATURE REVIEW

As in this study we are analyzing a soil structure interaction to determine its effect over the seismic design of the structure, In this chapter we are reviewing the survey of authors did researches related to interaction of soil and structure.

Hamid Asadi et.al (2024) This paper deals with the nonlinear soil structure interaction (SSI) impact seismic response of the vertical irregular reinforced concrete building. This paper modelled RC frames of 5 and 10 stories considering parameters of soil type and vertical safety factor of the foundation. Nonlinear winker model is used for modelling shallow foundations resting on semi-infinite sandy soil. The models are subjected to 15 earthquake ground motions for considering nonlinear time history analysis. Results compared are storied drift and story response of foundation is observed. The study considered both regular and irregular stories and results are more predominant in the soft story. The first mode of natural response is also studied, and the irregularity ratio is also studied in this paper.

Sayali Rajendra Kadam et.al (2024) The study highlights the significant influence of Soil-Structure Interaction (SSI) on structural performance, particularly for buildings constructed on soft soil. For hard soil conditions, SSI has minimal impact on axial forces, bending moments, and shear forces. However, in soft soils, bending moments in columns increase by 100–130% in seismic zones IV and V, while shear forces and bending moments in stilt beams rise by 20–30% and 30–45%, respectively. This demonstrates the crucial need to consider SSI in seismic design for soft soil foundations. Additionally, storey drift is greatest in middle storeys, showing a parabolic variation, and increases by 30–60% under soft soil conditions. Higher stories exhibit significant lateral displacement changes due to the flexible base effect introduced by SSI. Although the seismic weight and base shear remain nearly constant between fixed-base and SSI models, the natural time period is slightly reduced in SSI cases. Overall, structures on soft soils experience considerably higher seismic responses compared to those on hard soils. Therefore, incorporating SSI in the design of high-rise structures built on soft soil is strongly recommended to enhance seismic safety and performance.

III. METHODOLOGY

Following steps are required in a sequence for proper completion:

Step-1Select Geometrical data and modelling of structure using SAP2000.

An RCC Structure is rigid to get together of Beams, Columns, Slabs, and establishment between associated with one another as a solitary unit. For the most part, the uniform load in these structures is from slab to rebar, from beams to the column section to the foundation which thus exchanges the whole load to the soil. In this investigation, we are analyzing G+10 structure considering three different type of soil cases by expecting distinctive frameworks for load opposing structure demonstrated utilizing Csi-SAP2000. The arrangement and 3-D perspective of the unpredictable building are appeared in the figure beneath.

Step-2: Creating sectional properties of structure.

Step-3: Creating Soil Property

Soil properties such as poisons ration and unit weight is considered from references paper.

Step-4: Creating Soil Mass below the structure:

SAP2000 give us a development alternative to give material properties in a particular way to dole out in structure. In SAP2000 we are allowed to dole out any sort of material as it gives a practical altering device to make the material. For this study we are considering soil solid of 50m x 50m x 50m.

Step-5: Interacting Structure and Soil solid:

Step-6 Assigning hinged support at the soil soilid and structure.

In this step we are assigning hinged support at the bottom of the structure which is 2 m below the soil mass.In SAP2000 we are allowed to assign out any sort of support condition either fixed, pinned or roller for which we have to tap on end points of the structure.

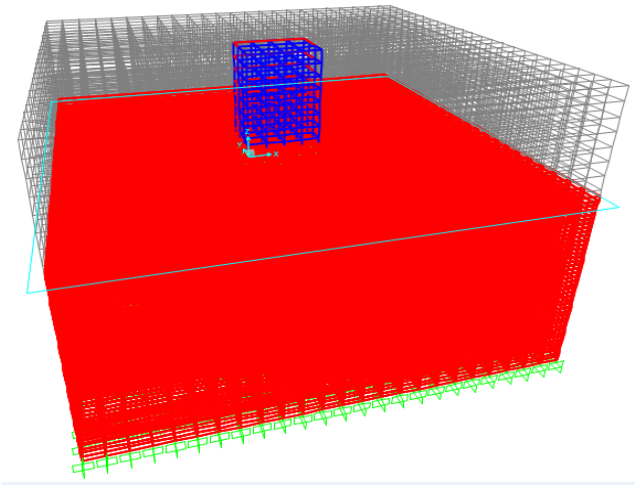


Figure 1 Assigning Support Conditions

Step-7: Assigning Load Conditions:

Step-8: Lateral Effect of load

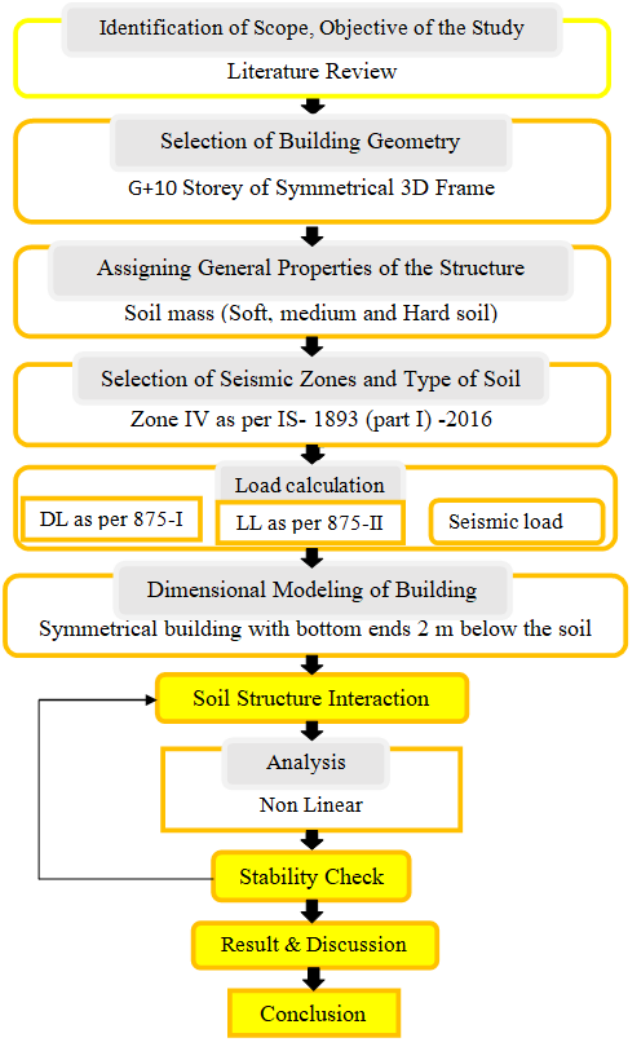
Seismic pressure is generating in both X and Y direction, causing unstability to the structure which causes unsymmetrical distribution of load to the soil.

Step-9: Analysis of soil structure

Non linear analysis is performed using SAP2000 software, for this analysis soil mass is meshed in elements to determine the minute variation in different elements of the soil.

Step-11: Comparative Analysis

Flow chart of the study:



FLOW CHART DIAGRAM

Figure 3Steps for Analysis

Description	Value
HEIGHT OF BUILDING	33 m (G+10)
Length	26 m
width	26 m
column	0.5 x 0.5 m
Beam size (main)	0.3 x 0.25 m
Soil Type	As per I.S. 1893-I:2016
Soil Mass	50 x 50 x 50 meter
Support type	Fixed support

Seismic Interaction

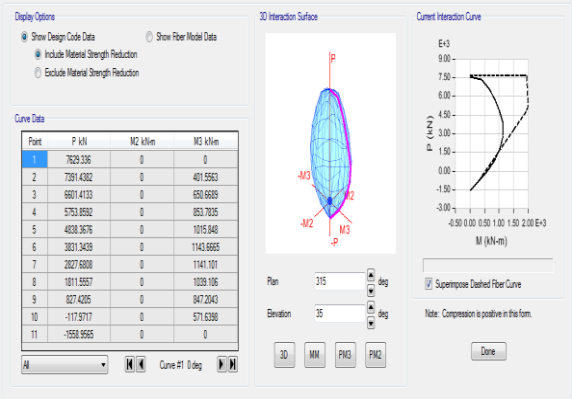


Figure Interaction of soil surface

Mode Shapes

Natural Period (Sec.)	Mode shapes		
Soil Type	Soft	Medium	Hard
7th Storey	0.953	0.89	0.856
6th Storey	0.821	0.785	0.731
5th Storey	0.434	-0.93	0.987
4th Storey	0.217	-1.5717	0.989
3rd Storey	-0.0425	-2.4817	1.0545
2nd Storey	-0.302	-3.3917	1.12
1st Storey	-0.5615	-4.3017	1.1855
Base	-0.821	-5.2117	1.251

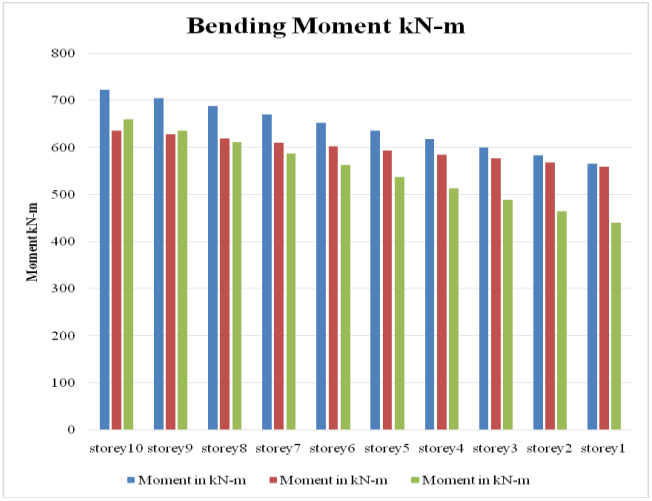


Figure Bending Moment

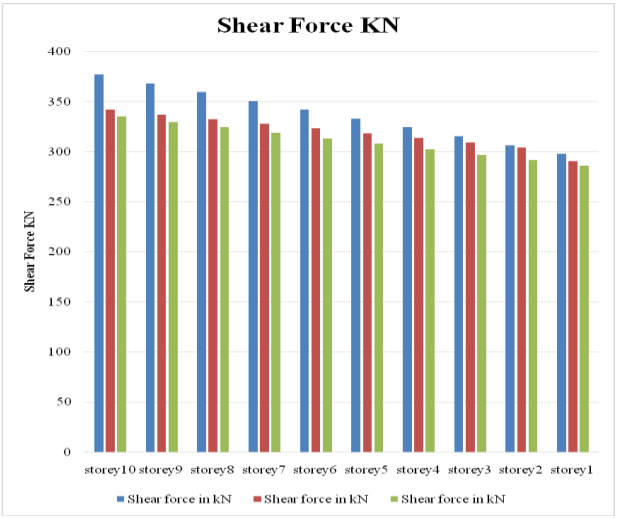


Figure Shear force

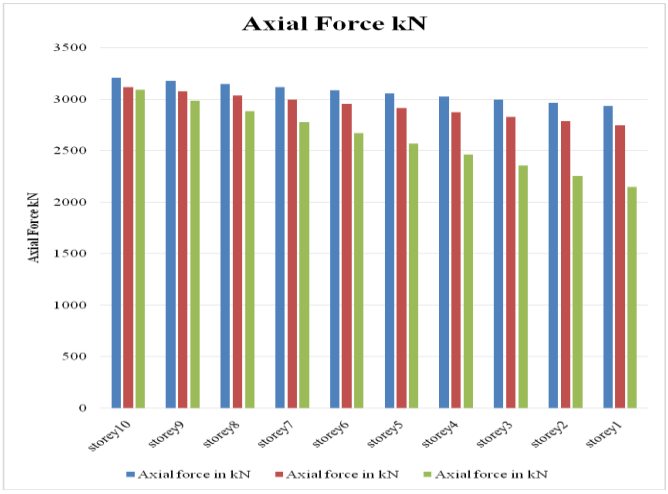


Figure Axial Force

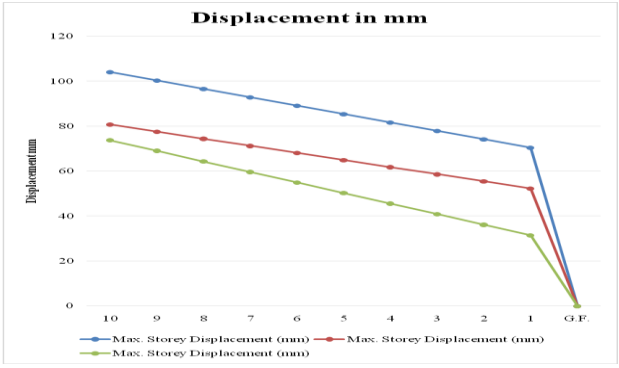


Figure Storey displacement mm

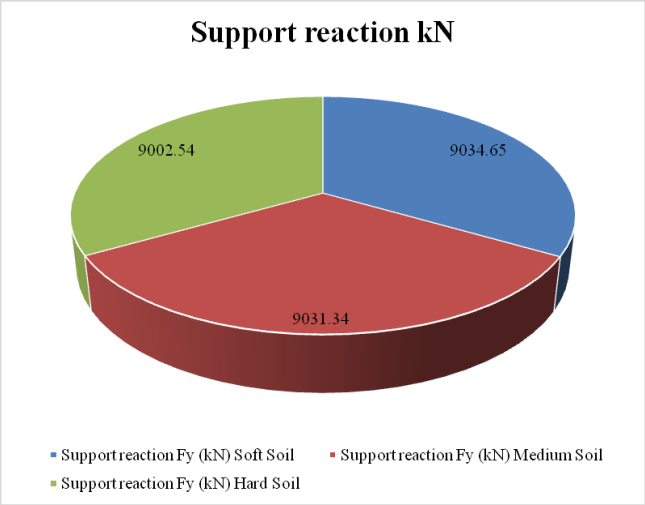


Figure Support reaction

IV. CONCLUSION

This study explores the SSI effect on the overall risk of ahigh rise building structure with respect to two failure modes: strength in terms of plate and joint forces, moment, Displacement and Support reaction at the base of the structure:

1 It is observed in the above analysis that hard strata soil is 11.20 % more stable in resisting Shear forces.
2 It is observed that effect of lateral forces is more in soft soil as compared to medium soil and hard soil, variation of 8.79% is observed.
3 It is observed that soil mass is meshed finitely in SAP2000 which provide accurate and linear results.
4 It can be concluded that there is variation in the cases i.e. structure under soft soil, medium soil and hard soil, as forces and moment are varying by 11% and 9 % respectively.
5 The consideration of SSI shows a complete conflicting effect on the seismic fragility and risk depending on the two different soil failure modes. This has a positive effect regarding the strength failure mode, but this brings a negative effect regarding the displacement failure mode.
6 It is observed that effect of structure is upto 18 m depth in soft soil whereas in medium soil it is resisted upto 17.58m whereas hard soil is most suitable and distribution effect onlyupto 12 m depth

Summary

Here it can be concluded that the soil properties effect the overall stability of the structure and it is justify that for designing lateral forces soil type have major role in analysis.

Future Scope

i) In the present study building models are analyzed using non linear analysis. Although Time history and P-delta analysis can be Introduce in future, it is kept outside the scope of the present study due to time limitation.
ii) The effect of soil-structure interaction with two different type of soil is considered for analysis whereas is future mix proportion of two different soils in layers can be consider.
iii) Building models considered in this study are of linear height. For high-rise buildings shift-in-period can be an additional parameter what is not accounted in the present study.

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