Soil Interaction Effect OnRc Building With Different Types Of Foundations

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Abstract: The process in which the response of the soil influences the motion of the structure and response of the structure influences the motion of the soil is known as Soil- Structure Interaction (SSI).The social economic damages caused by an earth quake depend to a great extent on the features of the strong ground motions, these motions reflect primarily from factors such as source characteristics, propagation wave path and local site conditions. In the normal design practice all will consider building frame as a fixed base but in actual case the flexible nature of soil allows the foundation for movement. Due to this the stiffness of the building frame get decreases thus increase in the natural time period of the structure and thus the overall response gets changed. Hence the present thesis work deals with the response of the building frame with Isolated and raft foundation under soil flexibility due to seismic behavior.

Keywords: Soil- Structure Interaction (SSI).Maximum Considered Earthquake (MCE)

1.INTRODUCTION

Earthquake is known to be one of the most destructive phenomenon experienced on earth. It is caused due to a sudden release of energy in the earth's crust which results in seismic waves. When the seismic waves reach the foundation level of the structure, it experiences horizontal and vertical motion at ground surface level. Due to this, earthquake is responsible for the damage to various man-made structures like buildings, bridges, roads, dams, etc. It also causes landslides, liquefaction, slope-instability and overall loss of life and property.

Most of the time earthquakes are caused by the slippage along a fault in the earth's crust. When the fault ruptures in the earth's crust, the seismic waves will travel away from the source known as focus, in all direction to the ground surface. As they travel through different geological materials, the waves are reflected and refracted. Throughout the whole journey from the bedrock to the ground surface, the waves may experience amplification [1].Seismic wave amplification may cause large acceleration to be transferred to the structures, especially when the resulting seismic wave frequencies match with the structure resonant frequencies. This phenomenon may result in catastrophic damages and losses. Thus, with respect to the possible risk of earthquake hazard, it is essential to estimate the peak ground acceleration at the ground surface in order to produce appropriate response spectra for the purpose of structural design and structural safety evaluation. An earthquake is a ground vibration due to the rapid release of energy [2].The vibration produced causing the ground to be in motion where such ground motion generates complicated transient vibrations in structures. The response of a structure under earthquake loading is directly associated with the response of soil to ground shaking. Thus, the extent and degree of damage during an earthquake is mainly influenced by the response of soil to ground vibrations. Therefore, it is vital to evaluate the response of soil due to ground vibration.Though the structures are supported on soil, most of the designers do not consider the soil structure interaction and its subsequent effect on structure during an earthquake. Different soil properties can affect seismic waves as they pass through a soil layer. When a structure is subjected to an earthquake excitation, it interacts the foundation and soil, and thus changes the motion of the ground. It means that the movement of the whole ground structure system is influenced by type of soil as well as by the type of structure [3].Tall buildings are supposed to be of engineered construction in sense that they might have been analyzed and designed to meet the provision of relevant codes of practice and building bye-laws. IS 1893: 2002 "Criteria for Earthquake Resistant Design of Structures" gives response spectrum for different types of soil such as hard, medium and soft soil?The complete protection against earthquakes of all sizes is not economically feasible for structures. The seismic design should be such that it prevents loss of life and minimize the damage to the property. The concept of earthquake resistant design is that the building should be designed to resist the forces which arises due to Design Basis Earthquake, with only minor damages and the forces, which arises due to Maximum Considered Earthquake with some accepted structural damages but no collapse .The method of analysis commonly used by structural engineers assumes the structure to be attached rigidly to the ground, but as the foundation of the structure rests on the soil, it is apparent that the response depends on the properties of the structure as well as the soil. Hence the method of analysis based on soil-structure interaction gives more realistic and reasonable results.The importance of the nature of sub-soil for the seismic response of structures has been demonstrated in many earthquakes like Mexico (1957), Caracas (1967), Turkey (1970), and Bhuj (2001).The dynamic response of a structure resting on soft soils in particular, may differ substantially in amplitude and frequency content from the response of an identical structure supported on a very stiff soil or rock[5].However, data on many failure examples of rigid structures resting on flexible soils and intensive analytical studies in recent years have made considerable advances in the field of soil-structure interaction and analytical techniques are now available. This interaction phenomenon is principally affected by the mechanism of energy exchanged between soil and the structure.A seismic soil-structure interaction analysis evaluates the collective response of the structure, the foundation, and the geologic media underlying and surrounding the foundation, to a specified free-field ground motion. The term free-field refers to motions that are not affected by structural vibrations or the scattering of waves at, and around, the foundation. SSI effects are absent for the theoretical condition of a rigid foundation supported on rigid soil [6]. Accordingly, SSI accounts for the difference between the actual response of the structure and the response of the theoretical, rigid base condition. Soil-structure interaction (SSI) analysis evaluates the collective response of three linked systems: the structure, the foundation, and the soil underlying and surrounding the foundation. Problems associated with practical application of SSI for building structures are rooted in a poor understanding of fundamental SSI principles. Implementation in practice is hindered by a literature that is difficult to understand, and codes and standards that contain limited guidance. It provides a synthesis of the body of SSI literature, distilled into a concise narrative, and harmonized under a consistent set of variables and units. Techniques are described by which SSI phenomena can be simulated in engineering practice, and specific recommendations for modeling seismic soil-structure interaction effects on building structures are provided.

As waves from an earthquake reach a structure, they produce motions in the structure. These motions depend on the structure's vibrational characteristics and the layout of structure. For the structure to react to the motion, it needs to overcome its own inertia force, which results in an interaction between the structure and the soil. The extent to which the structural response changes the characteristics of earthquake motions observed at the foundation level depends on the relative mass and stiffness properties of the soil and the structure. Thus the physical property of the foundation medium is an important factor in the earthquake response of structures supported on it. Problems associated with the practical application of SSI for building structures are rooted in a poor understanding of fundamental SSI principles. Soil-structure interaction topics are generally not taught in graduate earthquake engineering courses, so most engineers attempting SSI in practice must learn the subject on their own. Unfortunately, practice is hindered by a literature that is often difficult to understand, and codes and standards that contain limited guidance. Most articles rely heavily on the use of wave equations in several dimensions and complex arithmetic to formulate solutions and express results. Moreover, nomenclature is often inconsistent, and practical examples of SSI applications are sparse. This gives rise to the present situation in which soil-structure interaction is seldom applied, and when it is, modeling protocols vary widely and are not always well conceived.

2. OBJICTIVE

The main aim of this project is to generate fundamental research information on the seismic performance of building structural systems having soft, medium, hard soil media.

- The structure should withstand the moderate earthquakes, which may be expected to occur during the service life of structure with damage within acceptable limits.
- Create computer models of building with fixed base and soil interaction.
- To study the seismic performance of the regular building for different types of soils.
- To study the seismic performance of the regular building for fixed base and soil interaction.
- To analyze the displacement of the structure along different direction by using response spectrum method.
- Various static checks are applied on the results.
- Study the effect of important parameters such as base shear and lateral displacement.
- Use the research to find axial force and moments in columns and shear and moments in beams.

3.METHODOLOGY

In the current study, to depict the influence of soil structure interaction on the seismic response of a structure due to earthquake loading, a 21 storied (G+20) building supported on individual foundation and raft foundation resting on stratified soil was selected. The building sections were modelled and analyzed for different configurations i.e., with fixed support and with SSI using finite element method ETAB 2016 subjected to seismic zone IV. The deformations under seismic loading in the structure and by incorporating the effect of soil-structure interaction and fixed base condition were extracted, compared and discussed.

4. DEFINING THE MATERIAL PROPERTIES, STRUCTURAL COMPONENTS AND MODELING THE STRUCTURE:

Beam, column and slab specifications are as follows:

Column 700mm x 700mm
Beam 700mm x 350mm
Slab thickness 150mm
Brick wall thickness 230mm

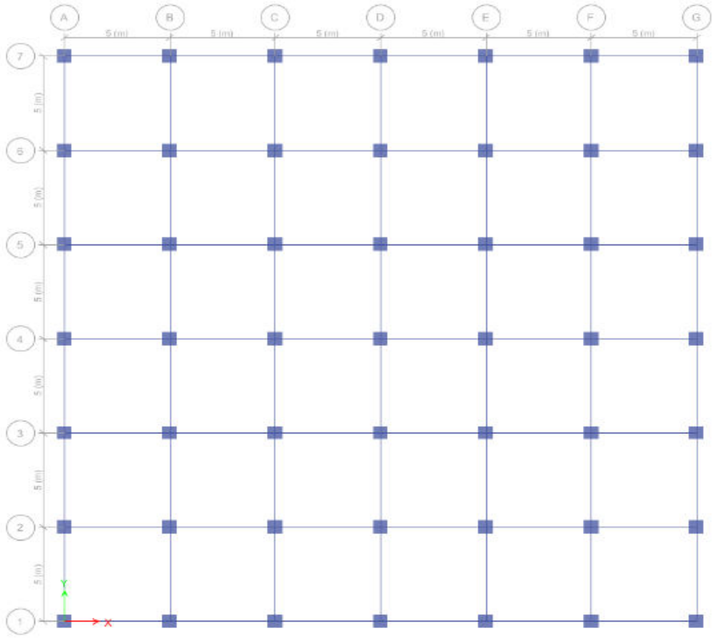

Fig. 4.1 Typical Plan of G+20 RCC building

Span of each beam is 5 m in X-direction and Y-direction both.
The required material properties like mass, weight density, modulus of elasticity, shear modulus and design values of the material used can be modified as per requirements or default values can be accepted. M40 concrete grade &Fe 500 steel grade are use.
Beams and column members have been defined as 'frame elements' with the appropriate dimensions and reinforcement.
Soil structure interaction has been considered and the columns have been restrained in all six degrees of freedom at the base.
Slabs are defined as area elements having the properties of shell elements with the required thickness. Slabs have been modeled as rigid diaphragms.

4.1ASSIGNING LOADS

After having modeled the structural components, all possible load cases are assigned. These are as follows:

4.2 GRAVITY LOADS

Gravity loads on the structure include the self weight of beams, columns, slabs, walls and other permanent members. The self weight of beams and columns (frame members) and slabs (area sections) is automatically considered by the program itself. The wall loads have been calculated and assigned as uniformly distributed loads on the beams.
Wall load = unit weight of brickwork x thickness of wall x height of wall.
Unit weight of brickwork = 20KN/m3
Thickness of wall = 0.23m
Wall load on all other levels = 20 x 0.23 x 3 = 13.8KN/m udl (wall height = 3m)

4.3SEISMIC DESIGN PARAMETERS:-

Forthe presentstudyfollowingvalues forseismicanalysisare assumed. The values are assumed on thebasisof referencestepsgiveninIS1893-2016and 3920- 1993 andIS456:2000.

1. Zonefactor forzoneIV–0.24 (Table 2, P.16)
2. Importancefactor forofficebuilding=1.5(Table 6,P.18)
3. Special Reinforced Concrete Moment resistingFrame (SMRF) = 5

SMRFisamoment resistingframe detailed to provide ductile behaviorand complywith therequirements of 13920-1993

4. Typeof soil = Hard, Medium, Soft
5. Dampingpercent = 5 %(0.05)
6. Brick infill panel buildingtype.
7. Live loads have been assigned as uniform area loads on the slab elements as per IS 1893 (Part 1) 2016

Live load on roof 1.5 KN/m^2
Live load on all other floors 4 KN/m^2
As per Table 10, **Percentage of Imposed load to be considered in Seismic weight calculation**, IS 1893 (Part 1) 2016, since the live load class is above 3 KN/m2 , 50% of the imposed load has been considered.

4.4 DEFINING LOAD COMBINATIONS:
According to IS 1893 (Part 1) 2016 for the limit state design of reinforced and prestressed concrete structures, the following load combinations have been defined.
The basic load combinations given by the code as per clause 6.3.4.1 are as follows

1. 1.2(DL+LL±(EQX±0.3EQY±0.3EQZ))
2. 1.2(DL+LL±(EQY±0.3EQX±0.3EQZ))
3. 1.5(DL±(EQX±0.3EQY±0.3EQZ))
4. 1.5(DL±(EQY±0.3EQX±0.3EQZ)
5. 0.9DL±1.5(EQX±0.3EQY±0.3EQZ)
6. 0.9DL±1.5(EQY±0.3EQX±0.3EQZ)

4.5 ANALYSIS OF THE STRUCTURE

Namely three types of analysis procedures have been carried out for determining the various structural parameters of the model. Here we are mainly concerned with the behavior of the structure under the effect of ground motion and dynamic excitations such as earthquakes and the displacement of the structure in the elastic range. The analyses carried out by Response Spectrum method.
Here we are primarily concerned with observing the deformations, forces and moments induced in the structure due to dead, live loads and earthquake loads. The load case 'Dead' takes care of the self weight of the frame members and the area sections. The wall loads have been defined under a separate load case 'Wall' and the live loads under
the case 'Live'. Analysis is carried out for all three cases for obtaining the above mentioned parameters.
Modal analysis is carried out for obtaining the natural frequencies, modal mass participation ratios and other modal parameters of the structure. Response Spectrum analysis of the nine models will doing in the zone IV where
Z = 0.24 considering zone factor IV
I = 1.5 considering commercial building.
R = 5.0 considering special RC moment resistant frame (SMRF)
S a /g = By software

4.6MODELGENERATED FOR PROBLEMSTATEMENT:-

Fromthe valuesmentionedinthe problemdefinitionthree modelsare generatedtostudy thebehaviorofearthquakeresistantstructure.Figure4.1shows plan ofthe structuregenerated in ETABS 2016. Followingarethe modelsgenerated.

1) Model1–Simplestructureas RC frame with fixed base.Figure4.2illustratesthis model.Inthismodelalltheparametersareconsideredfordesigning the structure asearthquakeproof as perIS1893:2016.
2) Model2 – It is modification over first model with soil structure interaction. Figure4.3illustratesthis model.Inthismodel isolated footing of 3.5mx3.5mx0.8m for all three types of soils is used. Damping ratio is 0.05 while doing soil structure interaction analysis. Shear modulus strength reduction factor is 0.6, 0.4, 0.2 for hard, medium and soft soil respectively. Alltheparametersareconsideredfordesigning the structure asearthquakeproof as perIS1893:2016.
3) Model3 – It is modification over first model with soil structure interaction. Figure4.4illustratesthis model.Inthismodel raft foundation of 32mx32mx0.5m for all three types of soils is used. Damping ratio is 0.05 while doing soil structure interaction analysis. joint spring are considered in this model. Spring constant k is calculated for area spring by considering permissible bearing capacity 110 kN/m², 180 kN/m², 250 kN/m² for soft soil, medium soil and hard soil respectively cause 1cm settlement. All the parameters are considered for designing the structure as earthquake proof as per IS1893:2016.
   Calculation of joint spring
   Assume 0.5m x 0.5m mesh area and bearing capacity cause settlement(Δ) 1cm
   Load P = Bearing Capacity × Area of Mesh(m2)
   Spring Constant, K = Load(p) / Allowable settlement(Δ)

Table 4.1 Joint Spring Constant (K)

Model	Soil Type	SBC	Load	Subgrade Modulus
G+20		(kN/m2)	kN	(kN/m3)
	Soft	110	27.5	2750
	Medium	180	45	4500
	Hard	250	62.5	6250

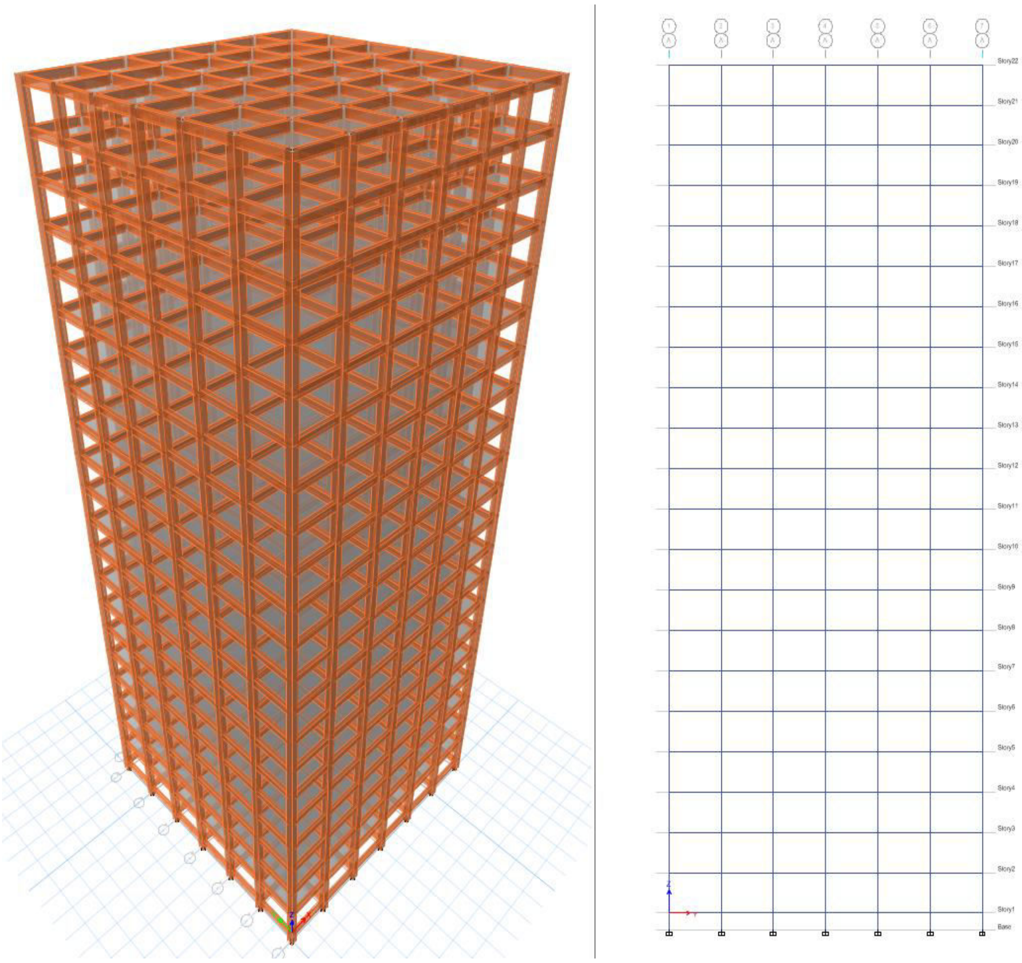

Figure4.2: Model1–Simplestructureas RC frame with fixed base.

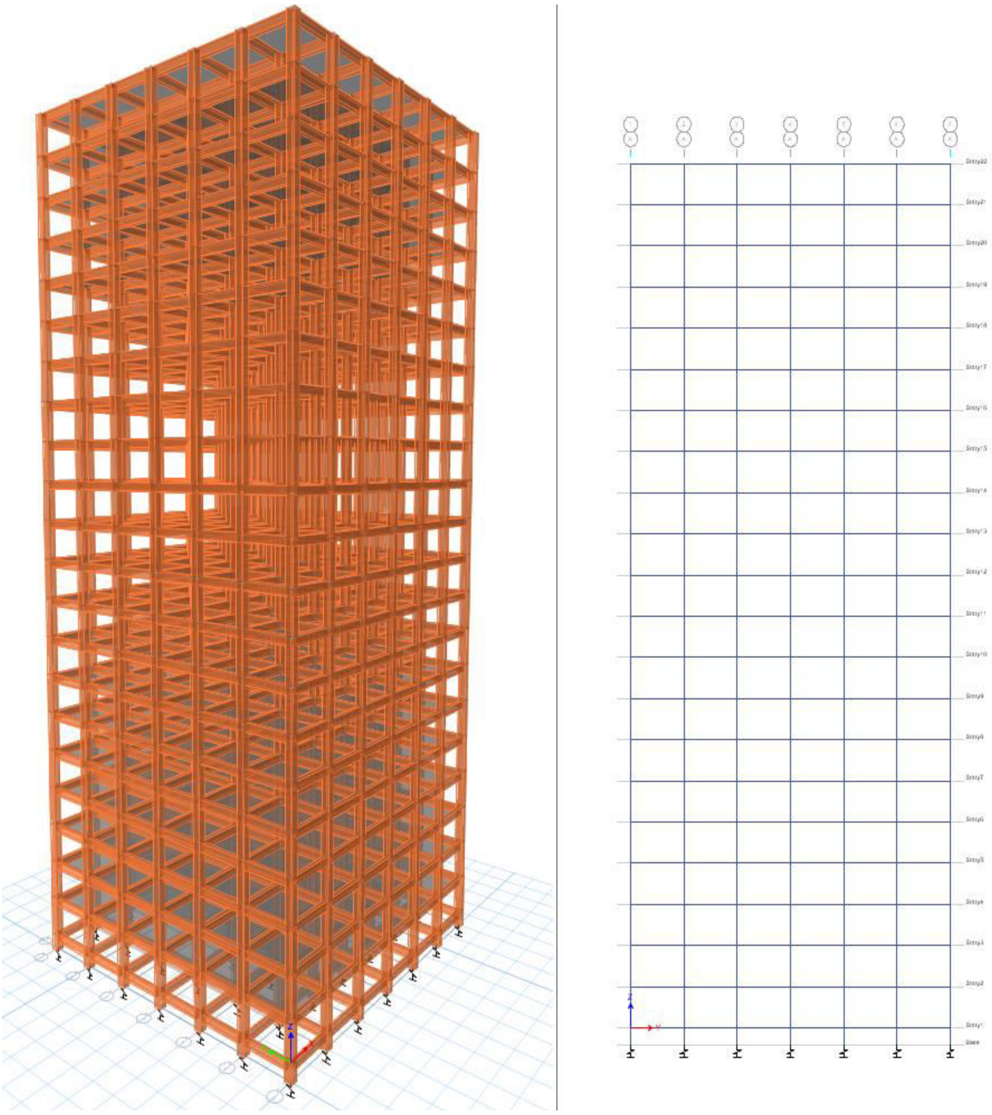

Figure4.3:Model2 –RC frame with isolated footing and soil structure interaction

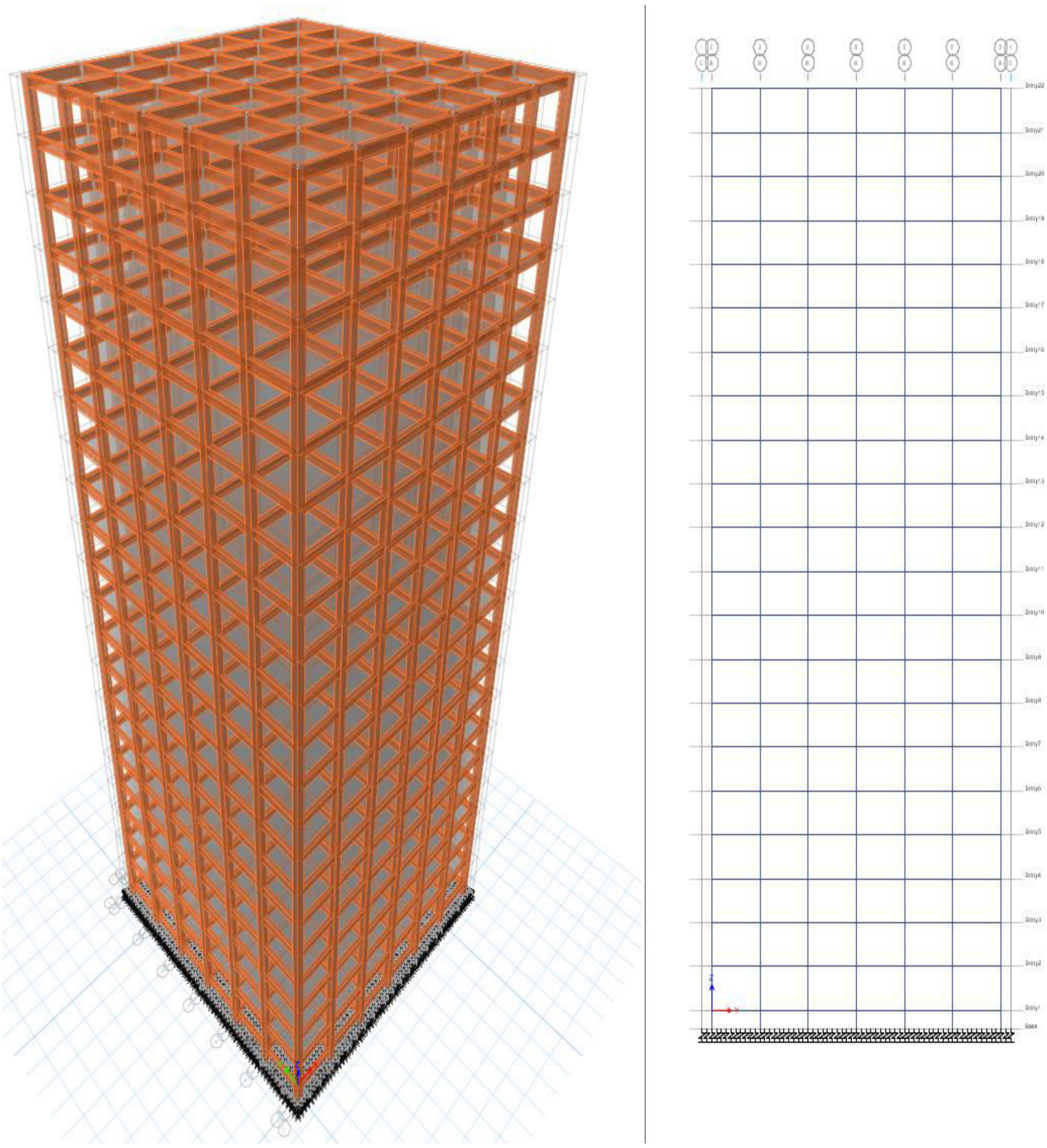

Figure4.4:Model 3 –RC frame with raft foundation and soil structure interaction

REFERENCES

1. **MeghnaModi, 2016**In practice, conventional method of analyzing the structure is by applying its base as FIXED/HINGED. In conventional structural design, SSI effects are not considered. In the present paper, an attempt has been made to carry out a parametric study for analysis of 3 bays x 3 bays space frames will be analyzed.
2. **Kuladeepu M N, 2015** In the present study the dynamic behavior of building frames over raft footing under seismic forces uniting soil structure interaction is considered. The analysis is carried out using FEM software SAP2000 *Ver14. For the interaction analysis of space frame, foundation and soil are considered as parts of a single compatible unit and soil is idealized using the soil models for analysis.
3. **Dr. S.S. Patil, 2016**In conventional method of design of raft foundation, base flexibility due to soil mass is ignored. The analysis carried out using Equivalent Static Method (ESM) in accordance with IS1893-2002. The soil flexibility is incorporated in the analysis by using Winkler approach (Spring Model). SAP-2000 software. is used to model fixed base and flexible base.
4. **Venkatesh M. B., 2017** Civil engineering structures such as building must have sufficient safety margin under dynamic loading like earthquake. The dynamic performance of a RCC building can be determined accurately that requires appropriate modeling considering foundation-soil, building-foundation and soil interactions.
5. **M.N. Viladkar (1990)** conducted SSI in plane frames using coupled Finite-Elements. In this case study, a beam bending element, which accounts for transverse shear deformation and axial-flexural interaction has been used for frame members and a combined footing which is treated on a part of the frame. A hyperbolic stress-strain model is used for the treatment of soil non-linearity.
6. **VivekGarg (2012**) conducted Interaction effect of space frame-strap footing -soil system on forces in superstructure. In this present work, RCC space frame footing-strap beam-soil system carried out to investigate in interaction behaviour of 3 storeys and 3 bay. Frame foundation soil is considered as linear elastic.
7. **SaugataDasgupta (1999)** determined the Effect of soil-structure interaction on building frames on isolated footings. In this study, the effect of these parameters on soil structure interaction is studied through the variation of axial force in column & change in differential settlement supported on isolated footing.
8. **Sekhar Chandra dutta (2002)** conducted A critical review on idealization & modelling for interaction among soil-foundation-structure system. This paper is review on different models of SSI, it draws conclusion that SSI should be considered in both static and dynamic loading. This paper helps to arrive at a suitable method of analysis by properly weighing the strength and limitation of the same against the particular characteristics and need the problem at hand.
9. **JagadishponrajNadar., 2015** The conventional design procedure involves the assumption of the fixity at the base of the foundation and therefore, neglects of the flexibility of the foundation and the compressibility of the sub-soil.interaction is observed to be significant for the behavior of structure considered in the present study for all the cases considered.
10. **Dange Swati., 2016**In the present paper an attempt is made to understand the difference between the values of shear force values and bending moment values in fixed base support and spring base support by using SAP2000 software.
11. , it has been perceived that Soil Structure Interaction (SSI) changed the reaction attributes of a structural system due to huge and firm nature of structure and frequently, soil softness. In the current study, to depict the influence of soil structure interaction on the seismic response of a structure due to earthquake loading, a 5 storied (G+4) simple square building supported on pile foundation resting on stratified soil was selected. The building sections were modelled and analysed for different configurations (i.e., with and without slab and infill) using finite element method SAP2000.
12. **JanardhanShanmugam 2015** The finite element based software program ANSYS is used for the purpose of analysis. The effect of different pile diameters on the response of superstructure is evaluated. The responses of the superstructure considered include storey displacements at respective storeys.
13. **PreetiCodoori2017** Study of Soil-Pile interaction is an important consideration in evaluating the seismic performance of pile-group supported structures, particularly in soft clay or liquefiable soils. Additionally, dynamic deformations can also get induced within the structure due to the underneath soft soils.
14. **Dheekshith K**2016 In the current circumstances, an attempt is made to investigate the soil structure interaction when the erection is built on numerous under lying soil types. The structure, foundation and soils are modeled using 20 node solid 95 element in ANSYS software. The type of footing used in the

study is isolated footing. Building is investigated under subsequent dissimilar situations. In this study, static nonlinear modal analysis is done under earthquake loading. The displacement or settlements in soil, Von Mises Stress developed is studied and compared.

15. **Chinmayi H.K 2013** During earthquake the behavior of any structure is influenced not only by the response of the superstructure, but also by the response of the soil beneath. Structural failures in past have shown the significance of soil-structure interaction (SSI) effects. The present study focuses on SSI analysis of a symmetric 16 story RC frame shear wall building over raft foundation subjected to seismic loading. The transient analysis of structure-soil-foundation system is carried out using LS-DYNA software. Earthquake motion in time domain corresponding to zone III of IS 1893:2002 design spectrum is used to excite the finite element model of soil-structure system..