International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 4, Issue 1, pp: (203-210), Month: April 2016 - September 2016, Available at: www.researchpublish.com

Seismic Behavior of RC Framed Residential Building Considering Soil Structure Interaction

D.VANEELA[1], A.H.L.SWAROOP[2], SK.YAJDANI[3]

[1]P.G Student (Structural Engineering) Gudlavalleru Engineering College Ap India
[2]Sr.Gr.Asst Professor, Department of Civil Engineering, Gudlavalleru Engineering College, Ap India
[3]Associate Professor, Department of Civil Engineering, Andhra University Vizag, Ap India.

***Abstract*: Many cities exist in seismically hazardous region. As relocation is neither desirable nor practical, these metropolises present the modern engineers with the challenge of creating safe and robustic structures which are capable of withstanding inevitable seismic events. Thus the engineer must evaluate seismic performance in dense, urban environments. In the analysis and design of multi-storey building it is generally assumed that underlying soil is perfectly rigid or bounded to the structure. This postulation leads to gross error in evaluation of overall response under dynamic loads. As a result the accuracy in assessing structural safely during earthquake cannot be accounted accurately. So investigation of energy transfer mechanism from soils to buildings during earthquake is vital for the design of earthquake resistant structures and for retrofitting existing structures. Hence the soil - structure interaction analysis of framed structures is the main focus of this study. The effects of soil-structure interaction are analyzed for typical multi- storey building resting on different soils. The analysis is carried out using a finite element method software package ANSYS under normal loads and seismic loads. Various load combinations are considered as per IS-1893 (part-1):2002 and the mass is assumed to be lumped at various discrete locations. The obtained results are compared with and without soil-structure interaction.**

***Keywords:* Soil-Structure Interaction, ANSYS, Framed Structure.**

1. INTRODUCTION

Seismic Analysis of building plays an important role in the present scenario. The conventional structural analysis of a frame is carried out assuming foundation resting on unyielding supports i.e. by considering end of the columns fixed and neglect the effect of soil deformations. In veracity, any civil engineering structure rests on deformable soils, resulting in redistribution of forces and moments because of soil-structure interaction. Thus, conventional analysis is idealistic and may be unsafe. The interaction effect is more prominent in case of multi-storied buildings due to intense loads and may become further aggravated when such buildings are subjected to seismic loads. Post-earthquake study of the structures reveals an idea about behavior of structure to seismic forces and their damage.

In the present study, Soil- Structure interaction has been carried out for a G+5 RC framed building subjected to normal as well as seismic loads using ANSYS (finite element software). The analysis is carried out considering an RC frame resting on three different types of soils. Various combinations of dead, live and seismic loads are considered as per IS-1893 (Part-1): 2002. The model is easily extendable to any configuration considered for analysis. The results of conventional i.e. non interaction analysis and linear interaction analysis i.e. considering Soil-Structure interaction are compared for RC frame resting on deformable soil to investigate the effect of total displacements and rotations at discrete locations.

Soil-Structure Interaction(SSI): Most of the civil engineering structures entail some type of structural element with direct contact with ground. When the exterior forces, such as earthquakes, act on these systems, neither the ground displacements nor the structural displacements, are independent of each other. The process in which the response of the soil influence the movement of the structure and the movement of the structure influences the response of the soil which is termed as soil-structure interaction (SSI). Ordinary structural design methods neglect the SSI effects. Neglecting SSI is sensible for light structures in relatively stiff soil such as short buildings and simple rigid retaining walls. The effect of SSI becomes predominant for heavy structures resting on relatively soft soils for example high-rise buildings, elevated-highways on soft soil and nuclear power plants.

II. LITERATURE REVIEW

- Aarlin K Mathew, Sat Kumar Tomer& Lovely K M had considered the Effect of Soil-Structure Interaction in Seismic Analysis of Framed Structures using Ansys. The main aim of their investigation is to prove that the interaction of a building, its foundation and the underlying soil has considerable influence on the behavior of each of the components and on the overall behavior of the system. A six storied frame structure resting on isolated footing & supported by deformable soil is taken for the analysis. Clay, silt, gravel soils are taken in layers. They had observed an increase in bending moments and axial forces in the footings due to differential settlements when SSI has been considered.

- Miss. Anjali B and Dr. Raji M had carried out their research on Seismic Analysis and Soil Structure Interaction of Multistoried Building with Different Types of Footing. Soil is considered in layers i.e. sand, clay and stiff clay. Acceleration record of Kobe earthquake is taken for analysis. The soil is modeled using FEM method. The final observation was that deformation is higher for raft, least for under reamed piles and medium for pile.

- Gaikwad M., Ghogare R., Vageesha S. Mathada studied The Finite Element Analysis of Frame with Soil Structure Interaction. For the analysis the columns at foundation level are considered as fixed. But in reality it is not so. Because of the settlement and rotation of foundation, shear force and bending moments in superstructure get altered. So they had carried out their work on bare frame and in-filled frame resting on soft, medium and hard soils considering soil-structure interaction. Analysis of bare frame and in-filled frame considering soil structure interaction shows more displacement, less shear force, more bending moments than frame where soil structure interaction is not considered.

- A. Massumi1 and H.R. Tabatabaiefar A criterion for considering soil-structure interaction effects in seismic design of ductile rc-mrfs according to Iranian codes. Dynamic Soil-structure interaction is necessary for assessing structural safety in face of earthquake. For this reason four types of structures consisting 3, 5,7 &10 storey buildings resting on three different types of soils according to Iranian codes are considered. Soil is modeled by Finite Element method. The results led to a conclusion that soil-structure interaction is necessary for buildings greater than three stories on soil type whose V_s<175m/s and for building higher than seven stories on soil type 175< V_s<375m/s.

- Reddy S.R.K(2005):In accordance with this as far as possible construction of important structures should be avoided in thick soft clays. If necessary ground improvement techniques should be used. To increase the stiffness of staging system against earthquake forces, number of bracings shall be increased along the height and they should be connected well with columns.

III. PROBLEM FOR INVESTIGATION

As the location of new capital Andhra Pradesh is already established any many high rise structures are expected in the new city in future. This area falls under seismic zone III, and covered by different types of geomorphic units like black cotton soil, silty sand, gravel under some places different types of rocky soils and the interaction of multi-storied structures with these soils plays vital role in response of the structure during an earthquake. So the building under analysis is considered to be situated in seismic zone III of India.

A G+5 RC framed building with raft foundation resting on a homogeneous soil has been considered in this study. The building consists of 3 bays in X-direction and 5 bays in Z-direction. For resisting lateral forces a system consisting of ordinary moment resisting frames (OMRF) is considered. Plinth beams are provided. These types of buildings are very common in urban areas. The frame and soil are analyzed as a single structural unit for the interaction analysis is carried out with frame resting on various soils. The complete details of the problem under investigation are shown in Figure 1 and Figure 2. For the present analysis, super-structure, sub-structure, and soil are considered to behave in linear elastic manner.

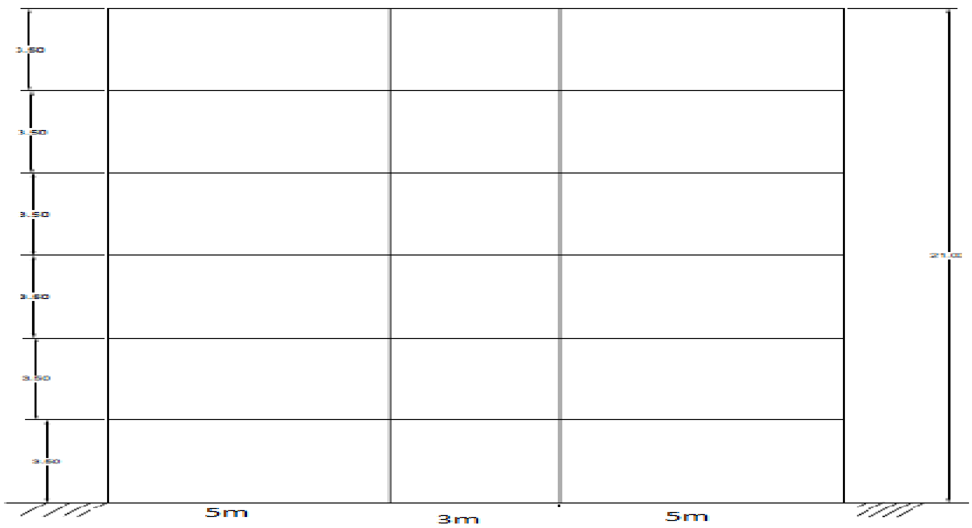

Fig.1: Elevation of the building

Each floor is of 3.5m height which accounts to a total of 21m. The plinth beam is assumed to be located at a depth of 1.5m below the ground level. Width of each bay in Z-direction is 4m.

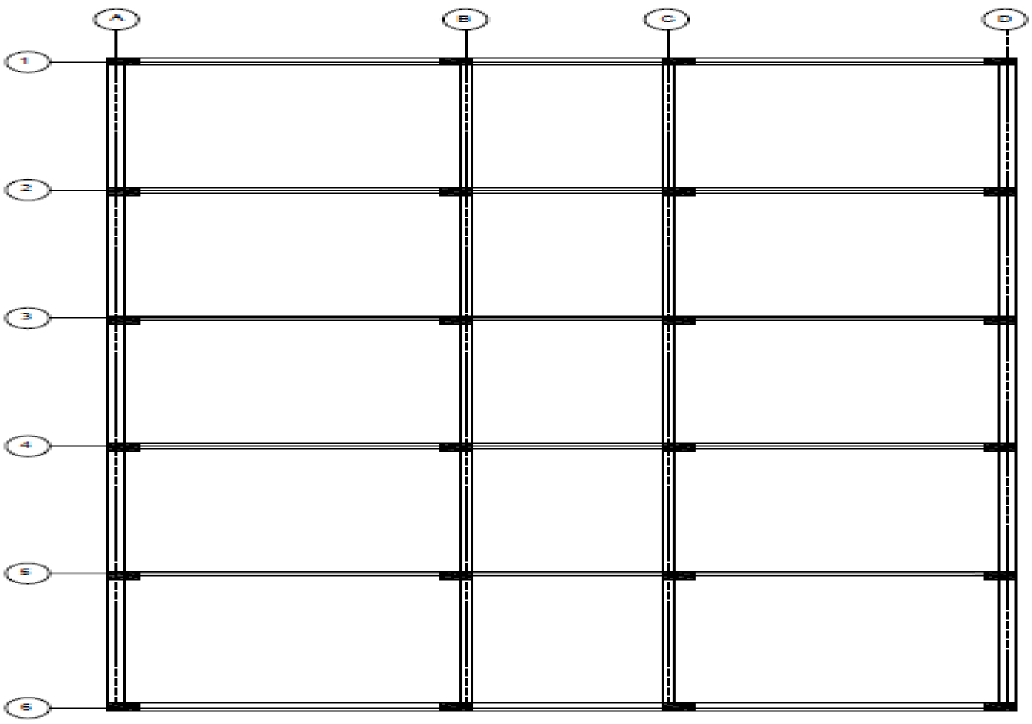

Fig.2: Plan and Beam column

TABLE.1: Material Properties of Concrete

Property	Value
Grade of Concrete for all Structural Elements	M25
Modulus of Elasticity of Concrete(N/mm^2)	Ec=5000√fck =$25X10^6$ KN/m^2
Poisson's Ratio	0.15
Density of Concrete	$24KN/m^3$

TABLE.2: Material Properties of Soil

Soil Type	Modulus of Sub grade Reaction
Stiff Clay	635 KN/m^3
Silty Sand	17435 KN/m^3
Hard Rock	151053.5 KN/m^3

TABLE.3: Geometric Parameters

Parameters	Value
Number of Stories	G+5
Height of each Storey	3.50m
Slab Thickens	0.12m
Size of beam	0.23X0.50m
Size of column	0.23X0.60m
Height of Plinth Beam	1.50m
Infill Wall Thickness Exterior wall Interior Wall	 0.23m 0.115m

IV. MODELLING OF STRUCTURE

The structure has been modeled using ANSYS.

Ansys is finite element software. It is the best tool for analyzing structural aspect very efficiently. The primary unknowns calculated in structural analysis are displacements. Other quantities such as stress, strains and reaction forces are then derived from nodal displacements. For generating a structure in Ansys we require creation of model geometry, selection of appropriate element type, defining real constant set i.e. in terms of cross-sectional area and material properties. In the next step we need to assign them to the various elements. The next is the pre-processing module. In this stage we have to discretize the element in to finite elements. The accuracy depends on the fineness of the meshing. The results mainly depend on the quality of mesh.

V. METHODOLGY

Specimen Geometry

- BEAM4 has been selected for Column and Beam. BEAM4 is a uniaxial element with torsion, compression, tension and bending capabilities. The element is allowed to have six degrees of freedom at each node i.e. displacements in the x, y, and z directions and rotations about x, y, and z axes.

- SHELL63 element has been chosen for Slabs and Footings. SHELL63 has both membrane and bending capabilities. Both in-plane and normal loads are permitted. The element is allowed to have six degrees of freedom at each node i.e. translations in the nodal x, y, and z directions rotations about the nodal x, y, and z-axes.

- For footings an additional property of modulus of sub-grade reaction is assigned.

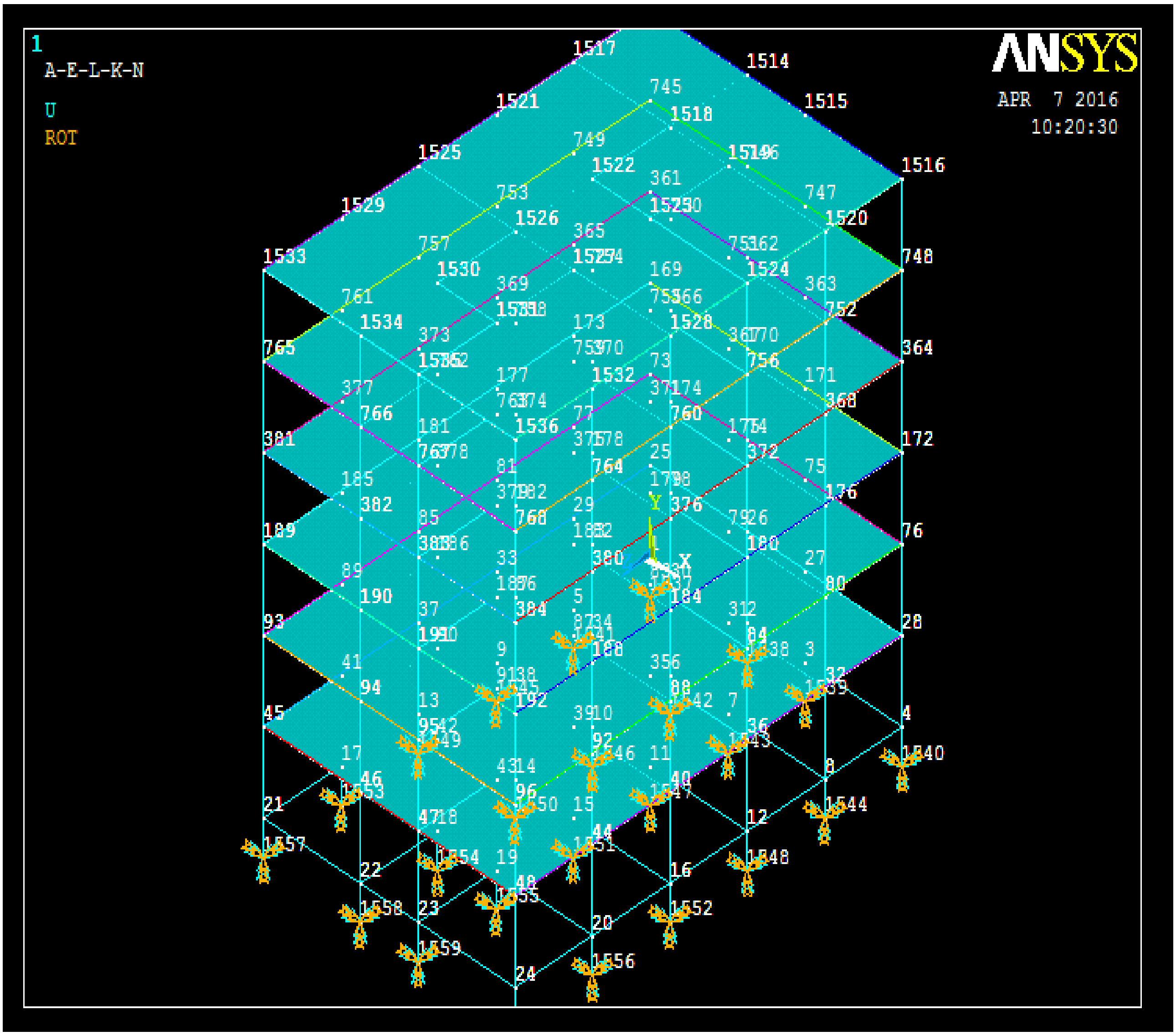

Fig.3: Modeling in Ansys

Boundary Conditions:

For fixed base condition the columns at plinth level are assumed to be fixed in all directions.

For flexible base condition the mat foundation is assumed to be constrained in Uz and Ux directions only.

VI. LOADING

The structure is considered as a residential building. The live loads are considered as per IS 875 (Part 2):1987. Live loads of 3kN/m^2 on floors and 1.5 kN/m^2 on roof are allowed. The brick masonry wall on outer periphery of the building and parapet wall on roof are also considered. These are in addition to the self-weight of the structure. For lateral load calculations, equivalent static lateral force method is used as per IS 1893 (Part 1): 2002. The parameters used for lateral load calculations are given in Table4.

Seismic Load Calculations:

Calculation of masses to various floor levels:

The earthquake loads are considered for dead load plus the percentage of imposed load as specified in Table-8 of IS 1893 (Part 1): 2002.In accordance with the code 50% of live load on floors and 25% of live load on roof is considered. The lumped mass of each floor is worked out by adding mass of slab, mass of reduced live load on slabs, mass of beams in longitudinal as well as transverse directions at that floor, mass of column for half column height above and below floor, mass of wall for half height above and below beams, mass of parapet wall on outer periphery beams on roof.

Seismic weight of floor = lumped masses of floors x g

g = gravitational acceleration

W= Seismic weight of building (sum of seismic weights of all floors)

Determination of fundamental natural period of frame:

The fundamental natural period of vibration (Ta) of the space frame-shear wall structure is estimated as per the empirical expression given in the clause 7.6.1 of IS 1893 (Part 1): 2002

$Ta = 0.075\ h^{0.75}$

Where h = height of building, in m.

TABLE.4: Seismic Load Parameters

Parameter	Value
Earthquake Zone	III
Zone Factor 'Z'	0.16
Importance Factor	1
Response Reduction Factor 'R'	5
Approximate fundamental time period	0.52
Average response acceleration coefficient(S_a/g)	2.5

Determination of design base shear:

The design base shear is calculated as per clause 7.5.3 of IS 1893 (Part 1): 2002

The design seismic base shear is given by,

$V_b = A_h W$

A_h = Design horizontal acceleration spectrum coefficient, as per clause 6.4.2 of IS 1893 (Part 1): 2002.

W = Seismic weight of the building

$$A_h = \frac{Z\,I\,S_a}{2\,R\,g}$$

Z = Zone factor [Table 2 of IS 1893 (Part 1): 2002].

I = Importance factor [Table 6 of IS 1893 (Part 1): 2002].

R =Response reduction factor, depending on the perceived seismic damage performance of the building [Table 7 of IS 1893 (Part 1): 2002].

Sa/g = Average response acceleration coefficient for soil for 5% damping [Figure-2 of IS 1893 (Part 1): 2002] for the natural period as worked out above.

Determination of vertical distribution of base shear to different floor levels

The design seismic base shear, V_b is distributed to different floor levels along the height of the building as per the clause 7.7.1 of IS 1893 (Part 1): 2002

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

Where

Q_i = Design lateral force at floor 'i'

W_i = Seismic weight of floor 'i'

h_i= Height of floor i measured from base, and

n = Number of storey's in the building is the number of levels at which masses are located.

VII. DISTRIBUTION OF DESIGN LATERAL FORCE

The Lateral Force Obtained at each floor is distributed to various nodes. The external nodes are assumed to carry half the value of design lateral force and internal nodes will carry full value.

TABLE.5: Obtained values of Lateral Forces

Storey	5	4	3	2	1	G
Design Lateral Force(**KN**)	241.39	233.84	149.36	82.98	37.72	9.05

VIII. RESULTS

Design lateral force is applied to various nodes and static analysis is carried out for a similar structure considering fixed base and flexible base analysis considering different soil conditions. The results are compared to analyze the change in displacement and rotations.

TABLE.6: Maximum Displacements obtained along three directions

Displacement Along (mm)	WITHOUT SSI	CONSIDERING SSI		
		Stiff clay	Medium Sand	Hard Rock
X Direction	3.81	5.69	4.13	4.00
Y Direction	0.22	1.14	0.46	0.40
Z Direction	2.25	3.82	2.85	2.50

TABLE.7: Maximum Rotations obtained along three directions

Rotation Along (Rad/sec)	WITHOUT SSI	CONSIDERING SSI		
		Stiff clay	Medium Sand	Hard Rock
X Direction	0.000129	0.000192	0.000148	0.000144
Y Direction	0.000164	0.00018	0.000181	0.000183
Z Direction	0.000162	0.00030	0.000237	0.00027

IX. CONCLUSION

- The displacements and rotations vary considerably for different soil types because of stiffness of soils.
- The displacements and rotations are decreasing from soft soils to hard rock
- Finally as far as possible the constructions of important structures in thick soft clays should be avoided.
- On analyzing the structure for soil-structure interaction the results have proved that soil-structure interaction plays a major role in the response of the structure.
- If necessary ground improvement techniques may be employed and the analysis should be done considering soil-structure interaction.

REFERENCES

[1] Effect Of Soil-structure Interaction In Seismic Analysis Of Framed Structures Using Ansys By 1Aarlin K Mathew,2 Sat Kumar Tomer,3lovely K M

[2] Seismic Analysis And Soil Structure Interaction Of Multistoried Building With Different Types Of Footing Miss. Anjali B &Dr. Raji.

[3] Finite Element Analysis Of Frame With Soil Structure Interaction By Gaikwad M.V1 , Ghogare R.B2 , Vageesha S. Mathada3

[4] A Criterion For Considering Soil-structure Interaction Effects In Seismic Design Of Ductile Rc-mrfs According To Iranian Codes By Massumi 1 And H.R. Tabatabaiefar 2
[5] Soil Structure Interaction In The Analysis And Seismic Design Of Reinforced Concrete Frame Buildings Julio A. García 1
[6] SSI Analysis Of Framed Structure Supported On Pile Foundations - With And Without Interface Elements Dr. Sushma Pulikanti*1, Prof. Pradeep Kumar Ramancharla.
[7] Bureau Of Indian Standards Is 1893 (Part I): 2002. Criteria For Earthquake Resistant Design Of Structures. Part I General Provisions And Buildings, 2002.
[8] Raju P.S.N,Reddy S.R.K,Raju K.R.K,Reddy (2004):Influence of soil-structure interaction on response of structures against earthquake forces. STTP on disaster resistant design and construction of structures
[9] IS 13920 (1993)"Ductile detailing of reinforces concrete structures subjected to earthquake forces"