

## 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)*

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### I. 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<sub>[5]</sub>. 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<sub>[6]</sub>. 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.

## **II. Objective**

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.

## **III. Literature Review**

1. **Meghna Modi**, 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. The space frame is supported by raft foundation on Winkler's spring bed. Winkler's spring base is applied in STAAD.Pro by assigning nodal springs having value equal to soil stiffness at the base of discretized plate. The space frame is subjected to various combinations of gravity and earthquake loads. The space frame is analyzed keeping its base fixed and spring (soil) based on and plate mat based on the result of analysis, it is designed as per IS: 456 (2000) and IS: 1893 (2002). Based on Winkler's hypothesis, the soil beneath the footing is modeled as bed of linear springs having stiffness equal to the modulus of subgrade reaction of the soil. The

interactive analyses are carried out for 3 different values of modulus of subgrade reaction. A comparison of the maximum nodal displacements of the frame and the time period of the whole structure is done. Shear, story displacement, story drift and time period.

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. The soil system below a raft footing is replaced by providing a true soil model (continuum model). In continuum model, soil is considered as homogeneous, isotropic, elastic of half space for which dynamic shear modulus and Poisson's ratio are the inputs. Influence of number of parameters such as number of storey's, soil types and height ratio for seismic zone-V is considered in present study.

3. **Dr. S.S. Patil**, 2016 In conventional method of design of raft foundation, base flexibility due to soil mass is ignored. The purpose of this study is, to understand the effect of soil flexibility on the performance of the building frames resting on raft foundation. The Soil Structure Interaction (SSI) study is carried out on symmetrical building space frame of 4bay in both x and y direction, for 10 storey to 25 storey building frame with raft foundation under fixed base and flexible base condition. In this analysis three types of soil i.e. Hard, Medium hard and Soft Soil are used for soil structure interaction (SSI) study. 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. The effect of SSI on various dynamic properties i.e. natural time period and base shear are discussed. The comparison is made between the non-interaction (non-SSI) and soil structure interaction (SSI) analyses with fixed base and flexible base conditions.

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. Building-foundation-soil interactions are complex phenomena requiring advanced mathematical and numerical modeling. The soil-structure interaction plays an important role particularly when subjected to seismic excitation, due to the potentially disastrous consequences of a seismic event. In the present work effectiveness of modeling in software for determination of seismic behavior of the medium rise building over raft considering soil flexibility interaction is studied. Modal analysis of building system is carried out in software.

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. Contact pressure values obtained on the basis of non-linear analysis are much higher than those from linear analysis.

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. Effect of SSI is marginal for single story, single-bay frame irrespective of its span & hence, irrespective of ratio stiffness of beams & columns. The study clearly shows that building frames with isolated footing may have large increase in column axial loads and settlements with increase in the number of stories and number of bays.

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. Winkler hypothesis, despite its obvious limitations yields reasonable performance & it is easy to exercise. Non-linear modelling desired for clayey soil because of stress settlement relationship. To get more realistic modelling & soil should be taken visco-elastic model with time dependent process.

9. **JagadishponrajNadar.**, 2015 For this purpose a study is carried out on raft foundation resting in cohesive soil, subjected to lateral load. For the purpose of the analysis, simplified idealizations are made in the theory of finite elements. The slab of the frame is idealized as three dimensional four-noded shell elements. Beams and columns of the superstructure frame are idealized as three dimensional two-noded beam elements. Raft of the sub-structure is idealized as three dimensional four-noded shell elements. In the independent analysis response of the structure is considered in terms of bending moments, shear force, deflection developed in structure. The effect of soil- structure interaction is observed to be significant for the behavior of structure considered in the present study for all the cases considered. The building is analyzed for various load cases, mainly gravity loads (due to dead load and live load) and lateral loads). Analysis is carried out by using standard package ETABS. The comparison of these models for different parameters like Storey Displacement, Column Bending moments and Time period are presented.

10. **Dange Swati.**, 2016 Response of a structure subjected to gravity and lateral loads depends on the boundary conditions assigned at the base of structure in numerical modeling. Stiffness of the spring depends on geotechnical parameters as well as on the dimensions of the foundation. 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. Stiffness of springs for spring base structure is calculated as per ATC-40 guidelines. In this paper static linear analysis is done which contains gravity load analysis and equivalent load analysis.

11. **Basavanagowda G. M.**, 2017 In the last few decades, 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. Impact of variety of the parameters on different soil conditions like variation in soil profile and number of soil layers, influence of slab and infill are considered for which the buildings are modelled by alternate approaches, namely, (1) bare frame with fixed supports, (2) frames including slab and infill with support accounting for soil-flexibility. The results indicate that the roof displacement varies significantly for different soil layer combinations if included the soil structure interaction compared to that of fixed base analysis. Thus considering the effect of SSI is essential.

12. **JanardhanShanmugam** 2015 The effect of soil-structure interaction on a four storeyed, two bay frame resting on pile and embedded in the cohesive soil is examined in this paper. For the purpose of the analysis, simplified idealizations made in the theory of finite elements are used. The slab provided for all storeys are idealized as three dimensional four noded shell elements. Beams and columns of the superstructure frame are idealized as three dimensional two noded beam elements. Pile of the sub-structure is idealized as three dimensional two noded beam elements. 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. **PreetiCodoori** 2017 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. In this paper, numerical analysis of a single pile subjected to the 1940 El Centro earthquake (Mw 6.9) ground motion was carried out to understand the soil-pile interaction for different soil conditions, namely, C-soil, Ø-soil, and C-Ø soil. The axi-symmetric numerical model was developed by using Finite Element Program "OpenSeesPL", to understand the soil pile interaction for the dynamic earthquake loading condition. Response profiles, displacements response time history at the base and at the crest, and stress contours are studied to understand the behavior of short and long piles in various soil conditions.

14. **Dheekshith K** The type of footing used in the study is isolated footing. Building is investigated under subsequent dissimilar situations. (a) Single storey on three soil layers having gravel well graded soil at the topmost, then gravel silty at intermediate and sand silty at the bottommost, (b) single storey on three soil layers having Gravel poor graded soil at the uppermost then sand poor at the intermediate and sand silty at the bottommost, (c) (G+5) storey on three soil layers having Gravel well graded soil at the top, then Gravel silty at middle and sand silty at the bottom, (d) (G+5) storey on three soil layers having Gravel poor graded soil at top then sand poor graded at middle and sand silty at the bottom, (e) (G+3) storey on three layers of soil with Gravel well graded at the upper, gravel clay at the central and sand silty at the bottom, (f) (G+3) storey on three layers of soil having Gravel poor graded soil at the top, gravel clay at the middle and sand silty at the bottom. 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 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. For integrating the SSI effect, four types of soils based on shear wave velocity are considered. Responses in terms of variation in natural period, base shear and deflection obtained from the analysis of the SSI model are compared with that obtained from conventional method assuming rigidity at the base of the structure. The results show that the SSI effects are significant in altering the seismic response.

16. **Siddharth Shah**, (2007) studied post failure analysis of massive structures and have seen that the soil-structure interaction (SSI) is a crucial phenomena influencing seismic response of massive structures. He observed the effect of depth of foundation on seismic response of structures. The result yielded that SSI effects must be considered for soft soil conditions irrespective of the depth of foundation. The effects of SSI are site specific and cannot be generalized. However the fundamental time period is increasing due to SSI effects. The depth of foundation has also great role in seismic response of structures, the medium depth foundation is proven critical compare to other cases[23].

17. **Koushik Bhattacharya** et.al (2006), Studied the effect of soil structure interaction which was ignored in the design of a low rise building resting on shallow foundation, ignoring such effects it may create an unsafe seismic design. Later the effect of soil structure interaction is considered for low rise building to conducted the investigation for formulating direct design guidelines, calculated the design spectrum based on code specified for the elastic domain. Dynamic characteristic of the building with various numbers of storeys, bays, etc.. are computed to seismic vulnerability of low rise building with isolated footing and Mat foundation. The study attempts to identify the influence of various parameter effects to regulating the SSI of base shear and torsional to lateral period ratio for low rise building.

18. **Ravikumar C M** et.al (2012), In case, it identifies the necessary performance of the new and existing structure to withstand against disaster. This paper studied the two kinds of irregularities in the structure, namely plan irregularity with diaphragm and geometric discontinuity and vertical irregularity with sloping ground and setback. This irregularity is framed as per IS 1893 (part 1), class 7.1 code. The considered in identifying the most vulnerable buildings, in both linear and nonlinear seismic demands to identify the performed various analytical approaches. It is also tested by different lateral loads for various irregular buildings with the performance of pushover analysis. Finally, the result shows that the building capacity may be significant, but the seismic demand differs with respect to the configuration.

19. **Dutta S C** et.al (2010), Proposed study is considering SSI in soil pile structure system for investigating the seismic response. In general, Pile foundation and structure under seismic loads of base shear is designed and estimating for the fixed base condition.. The flexibility variations are considered to the response is consistent for ground motion. A changes in the shear force transmitted columns of soil is observed as compared to the results in SSI effect to fixed base condition. Summarily the study indicated the total shear carrying capacity is underestimated for soil and the column is over estimated for shear for considered in fixed condition. The design shear force of a pile is closely transmitted for total shear. Hence, the fixed base assumption condition design of column over safe and design of pile unsafe. Finally, this study indicated the considering SSI in design.

20. **Prerna Nautiyal**, (2013) observed that the buildings with floating column is a typical feature in the modern multi-storey construction in urban India. Such features are highly undesirable in a building built in seismically active areas .He investigated the effect of a floating column under earthquake excitation for various soil conditions and as there is no provision or magnification factor specified in I.S. Code, hence the determination of such factors for safe and economical design of a building having floating column.

21. **B.R. Jayalekshmi**, (2013) studied conventional analysis of structures which are generally carried out by assuming the base of structures to be fixed. However, the soil below foundation alters the earthquake loading and varies the lateral forces acting on structure. Multistorey reinforced concrete framed buildings of different heights with and without shear wall supported on raft foundation incorporating the effect of soil flexibility are considered to investigate the differences in spectral acceleration coefficient , base shear, and storey shear obtained following the seismic provisions of Indian standard code and European code. Study shows that the

value of base shear obtained for symmetric plan building is lowest in buildings with shear wall at all the four corners

### 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.
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- [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.
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- [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 K2016** 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..