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Analysis of Soil Structure Interaction in Seismic Zone for Composite Structure

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ABSTRACT: The influence of the soil structure interaction in the dynamic behaviour of the structure is reflected in an increase in the vibration period as well as increase in the system damping in comparison with the fixed-base model, which does not consider the supporting soil. Conventional fixed-base analysis ignoring the effect of soil-flexibility carried out for the seismic design of buildings may result in unsafe design. In seismic analysis provision of bracing system is one of the important option for the structure to have sufficient strength with adequate stiffness to resist lateral forces.. In present study, two RC building frames, G+10 and G+10 with six different combinations of steel bracing system at alternate locations incorporating the effect of soil flexibility is considered in order to investigate the effectiveness of bracing system to control SSI. The seismic analysis is carried out using equivalent static method as per IS1893-2002 The study is carried out using Elastic continuum approach(ECM) The influence of SSI on various seismic parameters and the flexural parameters are presented.

KEYWORDS: Soil Structure Interaction, Composite Structures, Bracing

I. INTRODUCTION

The popularity of steel-concrete composite construction in cities can be owed to its advantage over the conventional reinforced concrete construction. Reinforced concretes frames are used in low rise buildings because loading is nominal. But in medium and high rise buildings, the conventional reinforced concrete construction cannot be adopted as there is increased dead load along with span restrictions, less stiffness and framework which is quite vulnerable to hazards. In construction industry in India use of steel is very less as compared to other developing nations like China, Brazil etc. Seeing the development in India, there is a dire need to explore more in the field of construction and devise new improved techniques to use Steel as a construction material wherever it is economical to use it. Steel concrete composite frames use more steel and prove to be an economic approach to solving the problems faced in medium to high rise building structures.

1.1. Soil Structure Interaction

Soil-structure interaction is the powerful tool to design analyses and monitor frame structures. Analysis is to be performed to find out behaviour of structures in the design stage and it provides instrumentation data from completed structures. Behaviour of the soil-structure interaction has a significant influence on the magnitudes of the loads acting against structure.

1.2. Effect of The Earthquake On The Soil Structure

In all the case of earthquake excitation, it has been assumed that the earthquake motions are introduced as specified quantities at the structural support points. In effect, these important displacements are assumed to depend only on the earthquake generation and wave mechanism and are not influenced by the response of the structure. In actual fact, the structure and the soil on which it is founded from the combined dynamic response mechanism and there may be significant feedback from the structure into the soil layer. Hence, the extent to which the structural response may have the characteristics of the earthquake motions observed at the foundation level depend upon the relative mass and the stiffness properties of the soil as well as the structure. Thus the physical properties of the foundation medium form an

important factor in the intensity of the earthquake response of structure supported on it. Because of the reason the soil layer will influence on the structural response to the earthquake.

1.3. Effect Of Earthquake On Soil Structure Interaction

The forces that a structure subjected to earthquake motion is called up to resist result directly from the distortion included by the magnitude of the ground on which it rests. The response of the structure resulting from such a base of motion is influenced by properties as well as characteristics of the exciting motion. The ground on which the building rests is displaced the base of the building moves with it. However the inertia of the building mass resists this motion and causes the building to suffer the distortion. This distortion wave travels along the height of the structure in much the same manner as stress wave in a bar with free end. The continued shaking of the base causes the building to undergo a complex series of oscillations. As both wind and earthquake force are dynamic in character, a basic difference exists in the manner in which they are included in a structure whereas wind force are loads applied and hence proportional to exposed surface of the structure, earthquake force are essentially inertial forces. The latter of result from the distortion produced by both earthquake motion and internal resistance of the structure their magnitude is then function of the mass of structure rather than its exposed surface. Also in contrast to the structural response to the essentially static gravity levelling or even to wind loads, which can often validly treated as static loads the dynamic characteristics of the response of the earthquake excitation can seldom be ignored. Thus, whereas in designing for the static loads one would feel greater assurance about the safety structure made up of member of heavy section in the cause of a earthquake loading the stiffer and the heavier structure does not necessarily represent the safer design.

- The values of the structural parameters affecting the dynamic properties of the soil or supporting medium. In so far as earthquake motion is concerned the quantity, most commonly used in analysis is the time wise variation of the ground acceleration in the immediate vicinity of the structure.

1.4. Soil Structure Interaction System

It is generally recognized that soil-structure interaction will effect structural vibrations induced by environmental loads such as earthquakes, winds or sea waves. Different soil conditions and different foundation properties will leave different effects on structural response. When dealing with earthquake excitation, there are two factors contributing to these effects are;

1. The inability of a relatively rigid foundation to confirm to non-uniform, specially varying ground motion, i.e. so called averaging reduction of motion by the foundation. This reflects the kinetic part of the soil foundation interaction.
2. The action and reaction but being the soil and the foundations causing soil deformation and foundation motion.

1.5. Characteristics of SSI

1. Characterization of the soil-structure interaction is followed by two significant effects
 1. Flexibility of soil foundation immediately enhances the fundamental period of a fixed base structure.
 2. Due to energy dissipation ability of soil through the radiation material type of damping, there is a change in the effective damping of a fixed base structure.

1.6. Composite Structures: When a steel component, like an I-section beam, is attached to a concrete component such that there is a transfer of forces and moments between them, such as a bridge or a floor slab, then a composite member is formed. In such a composite T-beam, as shown in Figure 1.2, the comparatively high strength of the concrete in compression complements the high strength of the steel in tension. Here it is very important to note that both the materials are used to fullest of their capabilities and give an efficient and economical construction which is an advantage.

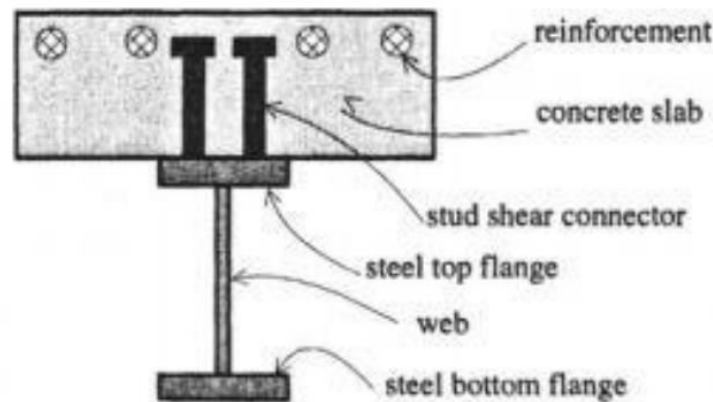


Figure 1. Cross Section of a typical composite member

1.7. Composite Steel-Concrete beam:

A concrete beam is formed when a concrete slab which is casted in-situ conditions is placed over an I-section or steel beam. Under the influence of loading both these elements tend to behave in an independent way and there is a relative slippage between them. If there is a proper connection such that there is no relative slip between them, then an I-section steel beam with a concrete slab will behave like a monolithic beam.

II. REVIEW OF LITERATURE

Chinmayi H.K and Jayalekshmi B.R. et al. (2013)[19] focused on SSI analysis of a symmetric 16story 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.

Amar R Chougule and S S Dyavanal et al. (2013)[20] studied the effect of soil structure interaction on multi Storeyed buildings with various foundation systems. Also studied the response of multi Storeyed buildings subjected to seismic forces with rigid and flexible foundations subjected to seismic forces were analysed under different soil conditions like hard, medium and soft.

Jenifer Priyanka, N.Anand and S.Justin, et al. (2012)[21] studied the effect of lateral force on tall buildings with different type of irregularities. An attempt made in this study to understand the behaviour of tall buildings subjected to lateral forces for different soil conditions. Ten Storeyed building with various spacing of columns such as 2.5m, 4m and 5m of buildings with different irregularities like Vertically irregular, Mass irregular and Stiffness irregular, were analysed using the software STAADPro . The top storey lateral deflection due to seismic load of these buildings was compared with regular building configuration for different soil conditions. It was found that building with soft soil gives more deflection as compared to medium and hard soil for all types of building. Building with stiffness irregularity gives more deflection as compared to other type of buildings with different irregularity.

Bahador Bagheri, Ehsan SalimiFiroozabad and Mohammadreza Yahyae et al. (2012)[22]As the world move to the accomplishment of Performance Based Engineering philosophies in seismic design of Civil Engineering structures, new seismic design provisions require Structural Engineers to perform both static and dynamic analysis for the design of structures. While Linear Equivalent Static Analysis is performed for regular buildings up to 90m height in zone I and II, Dynamic Analysis should be performed for regular and irregular buildings in zone IV and V.

Tavakoli.H.R, Naej.M and Salari.A, et al. (2011) [23]studied to investigate the effect of near fault and far fault earthquake motions on the response of reinforced concrete structures considering soil structure interaction. In detail, a series of linear time history analysis was carried out for three example buildings. The effects of soil-structure interaction were evaluated for a 3-story building, a 7-story building and a 15-story building.

Koushik Bhattacharya et.al (2006)[24], 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 conduct the investigation for formulating direct design guidelines, calculated the design spectrum based on code specified for the elastic domain.

Ravikumar C M et.al (2012)[25], Addressed many buildings have irregular configurations in both plan and elevation. This in a future earthquake subjected to devastating such type of buildings. 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 set back

III. METHODOLOGY

1. Soil Idealization.

The structure is assumed to support by firm non liquefiable soil produced by the inertia of structure. The modeling of the supporting soil can be done using FEM blocks of soil or by spring and dashpot support. From the analysis output of literature the modeling of soil in this research is done providing spring and dash- pot support.

To incorporate the effect of soil-structure interaction in the analysis impedance functions associated with rigid massless foundations was utilized. The present study considers translations of foundations in two mutually perpendicular principal horizontal directions and vertical direction as well as rotations of the same about these three directions. For buildings with raft foundation, the link support have been attached below the column to simulate the effect of soil flexibility taking three translation, two along horizontal and one vertical axes together with three rotation about these three mutually perpendicular axes.

The study primarily attempts to see the effect of soil-structure interaction on buildings resting on different types of non-cohesive soil, viz., soft, stiff, dense and rock. To obtain the values of the stiff- ness of the springs for these varieties of soil, values of shear modulus (G) of soil have been estimated using the shear wave velocity.

Seismic analysis of structure for the effect of soil-structure interaction is carried out based on the design spectrum provided in IS: 1893-2002. The seismic analysis of these buildings are obtained due to the design spectrum corresponding to 5% of critical damping [13]. The medium category type of soil is taken in consideration

Description	Shear wave velocity V_s (m/sec)	Poission's ratio	Mass density (ρ) KN/m^3
Rock	1500	0.3	22
Dense Soil	600	0.3	20
Stiff Soil	300	0.35	18
Soft Soil	100	0.4	16

Table 1: Detail of soil parameter considered

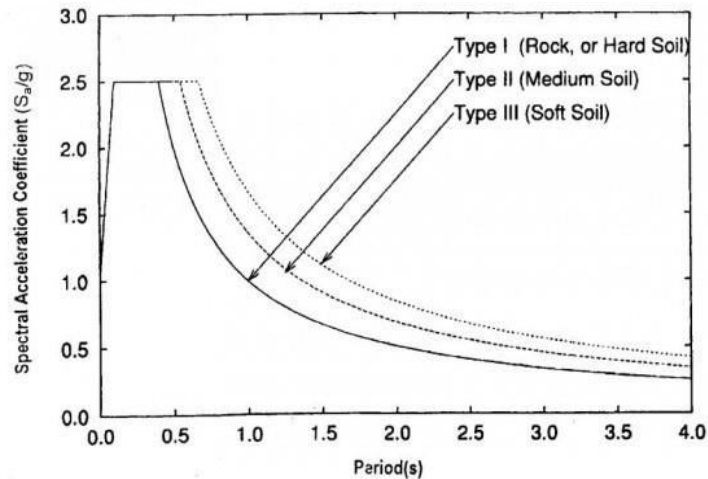


Figure 3.1. Design Response Spectrum From IS: 1893-2002

Both static method and Response Spectrum method of seismic analysis are performed by applying seismic zone factor value 0.36 for very severe seismic intensity, reduction factor 5 for both special RC moment resisting frame & ductile shear wall with SMRF with importance factor 1. The linear time history analysis is performed for all the models.

IV. SCOPE

The connection with engineering practice however appears to be somehow lost, which forms a problem for practicing engineers dealing with design of structures in seismically active areas. This study focuses on the effect of soil structure interaction on seismic response of reinforced concrete building structure. The present study is concentrated at a R.C.C. building models, those typically meets the conditions regarding raft foundation in different types of soil.

V. CONCLUSION

The present study makes an effort to evaluate the effect of soil structure interaction on the seismic behavior of bare frame buildings and building with frame-shear wall of varying height over varying soil property. The scope of the work is to highlight rather than fully resolve the role of SSI. After the observation of the change in lateral natural period, seismic base shear, storey displacement and storey drift the following conclusion were drawn.

- [1] The variation in fundamental period, seismic base shear & storey displacement of the building increases with the reduction in stiffness of soil.
- [2] The variation of storey drift is more in case of shear frame building on fixed soil support than the soft soil support corresponding to same type of frame building on same type of soil profile. The stiff structure are more affected by the soil structure interaction.
- [3] These increase in fundamental period of structure in soft soil deposit leads to resonance of the building for long period ground motion.
- [4] The stiff structure on hard rock support is more affected by short period wave and the flexible Structure on soft soil deposit are affected by long period wave.

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