



# A STUDY ON THE BEHAVIOUR OF A MULTI STORIED BUILDING WITH SOIL STRUCTURE INTERACTION

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## ABSTRACT

The soil structure interaction (SSI) is gaining a lot of importance in structural engineering with the development of huge constructions on soft soils like huge concrete and stuff dams, tall buildings, long span bridges, wide tunnels and underground structures which require a very careful attention. In every structure, the super structure and the foundation executed on soil, represent an entire structural system. It will not be analysed without considering the both. The analysis of a framed structure while not modelling its foundation system and its rigidity could mislead the axial forces, moments due to bending and due to settlement. It is, thus necessary to hold out the analysis considering the type of soil, foundation and above the sub structure i.e. (super structure), that taken as a single unit. In this paper the effect of soil interaction on design parameters in a multi storied building such as, Shear force, Bending moment and settlements have been studied and compared with a conventional case of considered building resting on unyielding supports and the effect of SSI is quantified using finite element analysis.

**Keywords:** soil structure interaction (SSI), super structure, settlements, foundation, axial force, moments, bending, finite element analysis.

## INTRODUCTION

Generally any engineering structure commonly involves some form of structural part with direct contact with ground. Once the forces due to gravity like Dead loads and live loads which acts on the structural system may mislead the shear forces and bending moments of that structure and also when the structure is interacted with the soil the forces which are acting from the super structure will be able to transfer some part of the load to the sub structure also. The phenomenon in which the behaviour of the soil influences the motion of the structure and therefore the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI).

In the conventional structural engineering practices we usually neglect the soil structure interaction (SSI) effect. It is not much important to consider the SSI effect for light weight structures executed on stiff soil like low rise buildings. But the consideration of soil structure interaction plays a very prominent role in execution of heavy structures like huge concrete and stuff dams, tall buildings, long span bridges, wide tunnels and underground structures on soft soils. In economy point of view a structure which is constructed by analysing the structure with SSI before execution saves a huge amount of cost. And the structures which are executed without considering SSI while analysing may lead to increase in cost of construction

## LITERATURE REVIEW

The soil structure interaction effects on soil settlements and structural forces are studied by Mosleh A. Al-Shamrani and Faisal A. Al-Mashary [1]. They have given a very simple procedure for the analysis of soil structure interaction of structural frames of Reinforced Concrete which are resting on various kinds of soil they have calculated the effect of interaction on the notified

settlements and the loads on footings of two - dimensional framed structures of many bays.

A study on soil, foundation and the super structure interaction for plane two bay frames was carried out by Hany Farouk and Mohamed Farouk [2]. They have examined the effect of super structure's rigidity on the varying differential settlements and the contact stress for two bay plane frames .they have achieved this by making the effect of super structure members and the rigidity of footings on the average of maximum settlements and the contact stress beneath the footings.

Vivek Garg and M. S Hora [3] carried out a study on interaction behaviour of structure foundation soil system they have made an attempt to publish available alternate solutions proposed by various scientists to evaluate the phenomenal behaviour of soil structure interaction from time to time. They have concluded that the prevailing forces in super structure, foundation and soil mass are changing rapidly due to interaction of soil structure. They have mentioned that to get a very appropriate accuracy in estimating the design force quantities it is compulsory to consider soil structure interaction effect.

Dr. D. Daniel Thangaraj and Dr. K. Ilamparuthi have carried out a parametric study on soil-raft-frame interaction [4]. They concentrated mainly on identifying the parameters which affects the interaction and these parameters are classified into relative stiffness factors  $k_{rs}$  and  $k_{sb}$ . They have noticed that there is a reduction in differential settlements due to interaction with soil. They have also identified that in case of beam there is a more variation in support moments in comparative to span moments. The axial forces in peripheral columns increase and to that extent the inner column axial loads are reduced. Vivek Garg and M. S Hora has carried out a study on Interaction effect of space frame strap footing soil system on forces in super structure [5]. They mainly concentrated



the study on conventional method of building frame analysis assumes that columns are resting on unyielding supports. In reality, the supporting soil strata deforms unevenly under the action of loads, which causes redistribution of forces in the frame members and stresses in the supporting soil media. Their analyses have been carried out to evaluate the axial force and Moment in columns, bending moments and shear force in floor, plinth and strap beams. The comparison is made between the non-interaction and interaction analyses.

Ankur Acharya, Mrs. Rashmi Sakalle, Mrs. Nita Rajvaidya have carried out a study on the linear soil structure interaction on the columns of an unsymmetrical plane frame for different types of soil [6]. Their study says that the foundation of a multi-storey building resting on a Settable soil mass undergoes differential settlement which Change the forces in the beams and columns significantly. And it is necessary to consider building frame, foundation and soil as single integral compatible structural unit for real analysis of the system. Finite element method is a powerful tool for numerical analysis of any soil-structure interaction problem.

H.M. Rajashekhar Swamy, Krishnamoorthy, D.L. Prabakhara, and S.S. Bhavikatti have studied the relevance of interface elements in soil structure interaction analysis of three dimensional and multi scale structures on raft foundation [7]. Their study states that Horizontal stresses and horizontal displacements are much affected by the Nature of bonding between the foundation and the soil. And also the in soil-structure interaction analysis of a structure by adopting finite element method, usage of link/interface elements between two elements of different materials is assumed as a standard procedure. In this study two extreme cases of compatibility of horizontal displacements between raft foundation and soil elements are considered to obtain pressure settlement relations of raft foundation by developing three Dimensional mathematical model and performing numerical experiments. And finally their study says that variation of horizontal displacements and horizontal stresses are there due to interaction.

## METHODOLOGY

In this paper the plan of a multi storied building is firstly executed in conventional analysis (i.e.) without considering the soil structure interaction effect in STAAD .Pro V8i software. In that conventional analysis the supports are taken as fixed which neglects the settlements.

## PLAN FOR G+5 RESIDENTIAL BUILDING

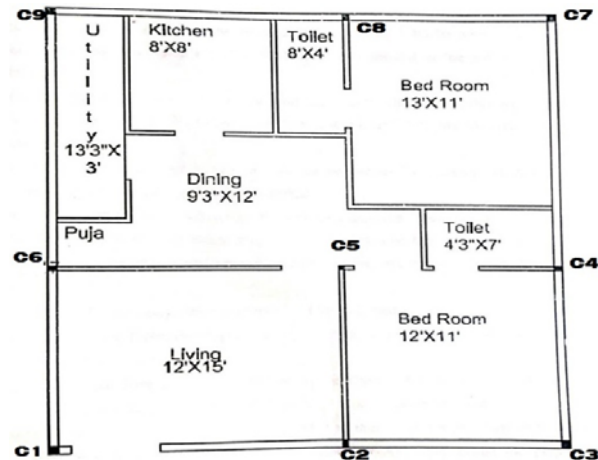


Figure-1.

While doing analysis in the conventional method i.e. without SSI, the parameters which are considered that are taken as:

- Beam -0.3m x0.3m
- Column-0.3m x0.45 m
- Self weight
- Floor load -4kN/m<sup>2</sup>
- Wall load-13.8 kN/m
- Live load-2 kN/m<sup>2</sup>
- Parapet wall load-6.9kN/m
- Load combinations of gravity loads
- Characteristic strength of concrete-20000 kN/ m<sup>2</sup>
- Yield strength of steel – 415000 kN/ m<sup>2</sup>

Finally the structure without SSI is analysed and the analysed structure is as follows:

After analysis the Shear force and bending moment of beams in x & z directions are considered and the support reactions of each column is also considered.

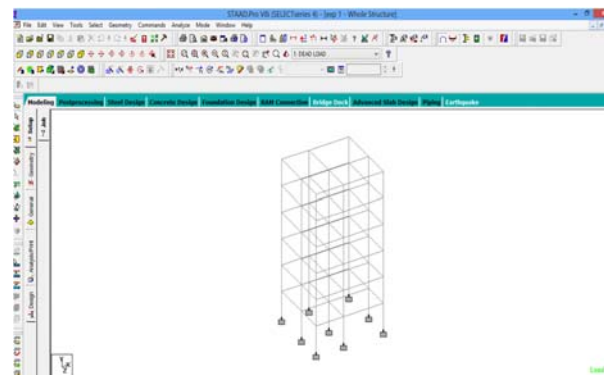


Figure-2.

## SOIL STRUCTURE INTERACTION ANALYSIS

Now considering the soil structure interaction, the multi storied building is analysed by designing the footings based on the support reactions which are obtained



from non SSI analysis. The parameters which are considered in SSI are as follows:

- Size of beams 300mm x 300mm
- Size of columns 300mm x 450mm
- Thickness of slab 150mm
- Size of corner footing 2500mm x 2500mm
- Size of edge footing 3000mm x 3000mm
- Size of center footing 3500mm x 3500mm

The type of the soil on which the footings are resting is taken as medium sandy clay having Elastic modulus of soil as 20MPa and Poisson's ratio as 0.25.

After elevating the structure the loads that are taken in non SSI analysis and the loads which are taken in SSI are same and the loads are assigned. The analyzed structure in soil structure interaction analysis is as follows.

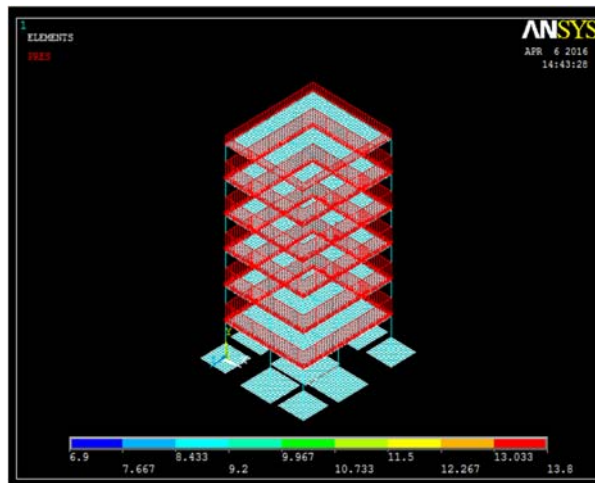


Figure-3.

After this SSI and non SSI analysis the shear forces, bending moment, and settlements of the structure at each floor level are compared.

## RESULTS AND DISCUSSIONS

The comparative results of the shear forces, bending moment, and settlements of the structure at each floor level are as follows:

The settlements which are observed in Soil Structure Interaction are as follows

Table-1. Settlements in footings.

Footings	Settlements
First footing	8.811 mm
Second footing	8.352 mm
Third footing	7.288 mm
Fourth footing	9.220 mm
Fifth footing	9.883 mm
Sixth footing	10.93 mm
Seventh footing	9.514 mm
Eighth footing	10.714 mm
Ninth footing	11.302 mm

According to IS 1904-1986, it gives the details about permissible Settlement in reinforced concrete structures and multi-storeyed Buildings. And the maximum settlement of 50 mm for an isolated footing is permissible.

Hence, from Table-1 the settlements are in permissible limit.

The settlements that are observed in conventional method are zero because of fixed supports.

## FOOTINGS

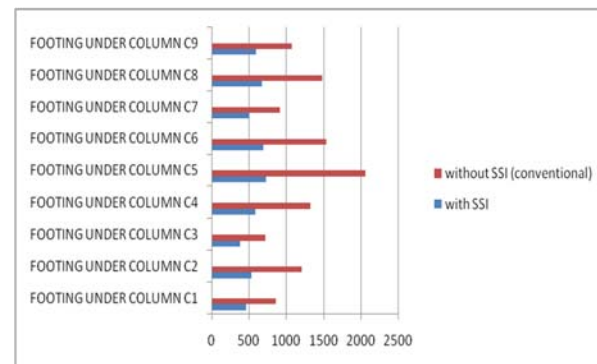
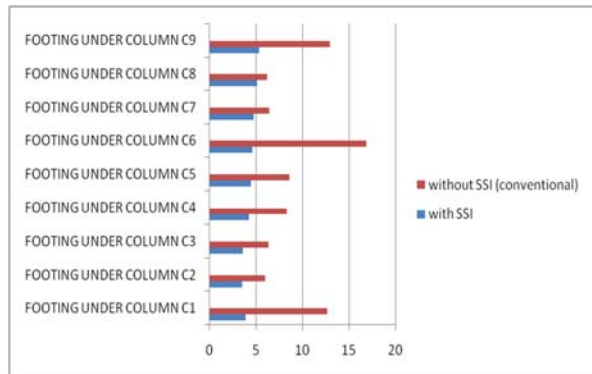


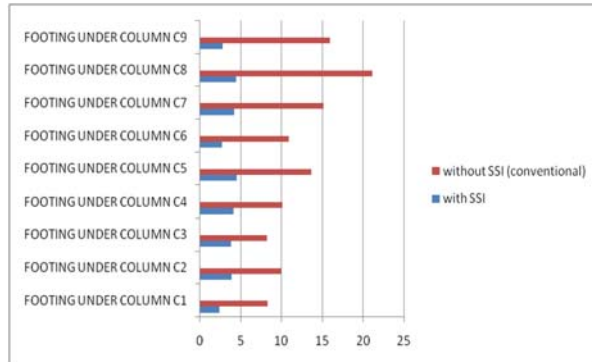
Figure-4. Axial force (kN) on footings.

From Figure-4, it is observed that the values of axial forces on footings are high when soil interaction is not considered in the analysis and the axial load acting is reduced to a range of 45 to 65% due to SSI.



**Figure-5.** Bending moment (kNm) in X- Direction.

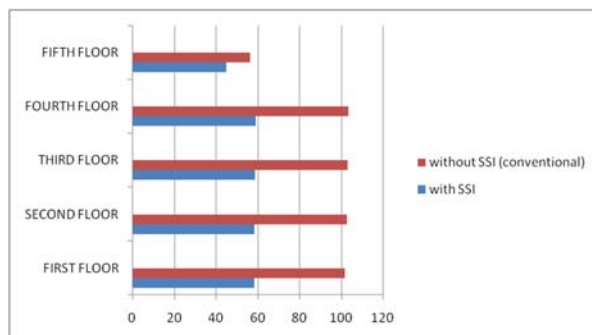
From Figure-5, it is observed that the values of bending moments in footings of X-direction are high when soil interaction is not considered in the analysis and the bending moment reduces to a range of 40-73% due to SSI.



**Figure-6.** Bending moment (kNm) in Z- Direction.

From Figure-6, it is observed that the values of bending moments in footings of Z-direction are high when soil interaction is not considered in the analysis and the bending moment reduces to a range of 54 to 83% due to SSI.

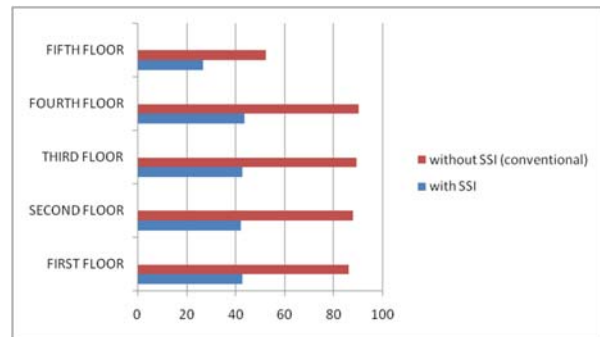
#### BEAM RESULTS IN Z-DIRECTION



**Figure-7.** Shear force (kN).

From Figure-7, it is observed that the values of shear force in beams of Z-direction are high when soil

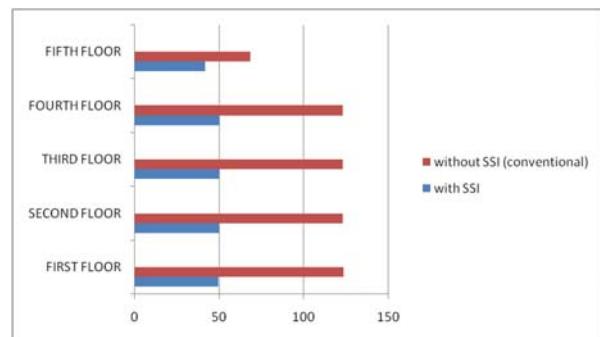
interaction is not considered in the analysis and the shear forces are reduced up to 44% due to SSI.



**Figure-8.** Bending moment (kNm).

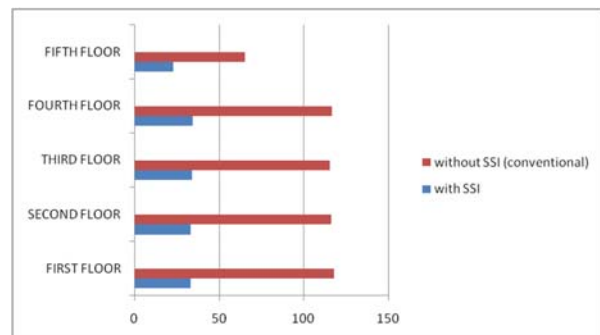
From Figure-8, it is observed that the values of bending moment in beams of Z-Direction are high when soil interaction is not considered in the analysis and the bending moments are reduced up to 53% due to SSI.

#### BEAM RESULTS IN X-DIRECTION



**Figure-9.** Shear force (kN).

From Figure-9, it is observed that the values of shear force in beams of X-direction are high when soil interaction is not considered in the analysis and the shear forces are reduced up to 60% due to SSI.



**Figure-10.** Bending moment (kNm).

From Figure-8, it is observed that the values of bending moment in beams of X-Direction are high when



soil interaction is not considered in the analysis and the bending moments are reduced up to 72% due to SSI.

### COLUMN RESULTS

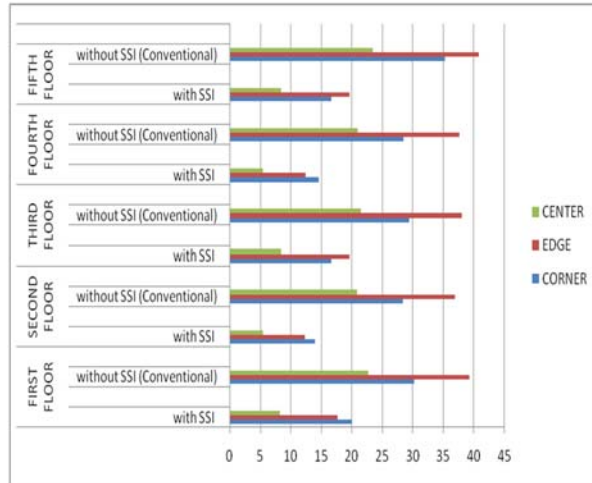


Figure-11. Shear force (kN).

From Figure-11, it is observed that the values of shear forces on columns are high when soil interaction is not considered in the analysis and due to SSI, the shear forces in the corner columns are reduced to a range of 33 - 54%, in edge columns the shear forces are reduced to a range of 54-67% And also in centre column the shear forces are reduced to a range of 63-75%.

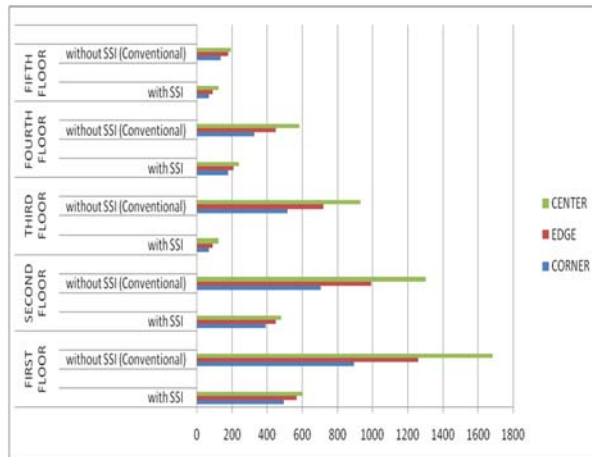


Figure-12. Axial force (kN).

From Figure-12, it is observed that the values of axial forces in columns are high when soil interaction is not considered in the analysis and due to SSI, the axial forces in the corner columns are reduced to a range of 44 - 64%, in edge columns the axial forces are reduced to a range of 49-55% And also in centre column the axial forces are reduced to a range of 56-65%.

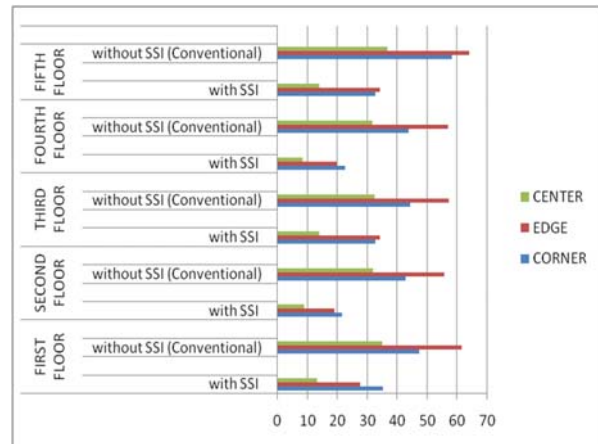


Figure-13. Bending moment (kNm).

From Figure-13, it is observed that the values of bending moments in columns are high when soil interaction is not considered in the analysis and due to SSI, the bending moments in the corner columns are reduced up to a range of 50%, in edge columns the bending moments are reduced to a range of 46-66% And also in centre column the bending moments are reduced to a range of 62-73%.

### CONCLUSIONS

Based on the soil structure interaction and non soil structure interaction analysis of a multi storied building the conclusions are as follows:

In Footings, the Axial Loads are reduced up to 65% and Bending moments are reduced up to 80% due to SSI.

In Beams, the shear Forces are reduced up to 60%, the Bending Moments are reduced up to 73% due to SSI.

In Columns, the shear Forces are reduced up to 75%, the Axial Forces are reduced up to 85% and the Bending moments are reduced up to 73% due to SSI.

### REFERENCES

- [1] Mosleh A. Al-Shamrani and Faisal A. Al-Mashary. Soil-Structure Interaction Effects on Soil Settlements and Structural Forces, ASCE.
- [2] Hany Farouk, Mohamed Farouk. Soil. Foundation and Superstructure Interaction for plane Two-Bay Frames, ASCE. International Journal of Geomechanics. [http://dx.doi.org/10.1061/\(ASCE\)GM.1943-5622.0000453](http://dx.doi.org/10.1061/(ASCE)GM.1943-5622.0000453).
- [3] Vivek Garg and M.S. Hora. 2012. A Review on Interaction Behaviour of Structure- Foundation-Soil System. International Journal of Engineering Research and Applications. 2(6): 639-644.





- [4] Dr. D Daniel Thangaraj and Dr.K. Ilamparuthi. 2012. Parametric Study on Soil - Raft - Frame Interaction Advances in Architecture and Civil Engineering. 1: 378-383
- [5] VivekGarg and M.S. Hora. 2012. Interaction Effect of Space Frame-Strap Footing-Soil System on Forces in Super structure. ARPN Journal of Engineering and Applied Sciences. 7(11): 1402-1415.
- [6] Ankur Acharya, Mrs. Rashmi Sakalle, Mrs. Nita Rajvaidya. 202. Linear Soil-Structure-Interaction Effect on the Columns of an Unsymmetrical Plane Frame for Different Types of Soil, IJLTEMAS. IV(XI): 48-54.
- [7] H.M. Rajashekhar Swamy, Krishnamoorthy, D.L. Prabakhara and S.S. Bhavikatti. 2011. Relevance of Interface Elements in Soil Structure Interaction Analysis of Three Dimensional and Multiscale Structures on Raft Foundation, EJCE. 16: 199-218.
- [8] IS 875 (Part-1) 1987: Code of Practice for Design Loads for Buildings and Structures, part-1: Dead Loads.
- [9] IS 875 (Part-2) 1987: Code of Practice for Design Loads for Buildings and Structures, part -2: Imposed Loads.
- [10] IS: 1904 - 1986 Code of Practice for Design and Construction of Foundations in Soils: General Requirements.