



International Journal for Innovative Engineering and Management Research

A Peer Reviewed Open Access International Journal

www.ijiemr.org

COPY RIGHT



ELSEVIER
SSRN

2020 IJEMR. Personal use of this material is permitted. Permission from IJEMR must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works. No Reprint should be done to this paper, all copy right is authenticated to Paper Authors

IJEMR Transactions, online available on 27th Aug 2020. Link

[:http://www.ijiemr.org/downloads.php?vol=Volume-09&issue=ISSUE-08](http://www.ijiemr.org/downloads.php?vol=Volume-09&issue=ISSUE-08)

Title: **IMPACT ON SUB STRUCTURE MAT FOUNDATION IN MULTI STORED FRAME USING FEM METHODS**

Volume 09, Issue 08, Pages: 71-82

Paper Authors

D.JESUDAS, DR. CH.BHAVANNARAYANA



USE THIS BARCODE TO ACCESS YOUR ONLINE PAPER

To Secure Your Paper As Per **UGC Guidelines** We Are Providing A Electronic Bar Code

IMPACT ON SUB STRUCTURE MAT FOUNDATION IN MULTI STORED FRAME USING FEM METHODS

D.JESUDAS*, DR. CH.BHAVANNARAYANA **

*PG Scholar , Kakinada Institute of Engineering and Technology - II, Korangi, Kakinada

** Professor &HOD, Kakinada Institute of Engineering and Technology - II, Korangi, Kakinada

ABSTRACT: This paper addresses the behavior of multi storey structure considering soil structure interaction i.e. interaction between substructure of the building and soil. For this purpose a sample of 5 storey RC frames is analyzed in conventional method with incremental static analysis for various load combinations and determines the parameters displacement, shear force and bending moment. Then a same 5 storey RC frame is analyzed in numerical analysis using Finite Element Method (FEM) with raft foundation by assigning the soil properties to substructure and determine the parameters displacement, shear force and bending moment. According to the analysis results the parameters displacements, shear force and bending moment varies from conventional analysis to numerical analysis. Displacements of the structure increases, shear forces of the structure decreases and bending moment of the structure decreases at some points and increases at some points from conventional method of analysis to numerical method of analysis.

Keywords: Soil Structure interaction, Displacement, Shear Force, Bending Moment.

1. INTRODUCTION

1.1 General: Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil such as low rise buildings and simple rigid retaining walls. The effect of SSI, however, becomes prominent for heavy structures resting on relatively soft soils for example nuclear power plants, high-rise buildings and elevated-highways on soft soil. Investigations of soil structure interaction have shown that the dynamic response of a structure supported on flexible soil may differ significantly from response of the same structure when supported on rigid base. One of the important reasons for this

difference is that part of the vibrational energy of flexible mounted structure is dissipated by radiation of stress waves in the supporting medium and by hysteretic action in the medium itself. Analytical methods to calculate the dynamic soil-structure interaction effects are well established. When there is more than one structure in the medium, because of interference of the structural responses through the soil, the soil structure responses through the soil, soil structure problem evolves to a cross interaction problem between multiple structures. All those discussions have laid a solid theoretical and practical foundation for the subsequent research on Soil Structure

Interaction (SSI). However, most of those studies are based on the elastic half space theory, which make analyzing the structure with shallow foundation attached to a homogeneous and thick soil layer simple and practical for engineers. Due to the difficulty of the solution for the analysis method and the excessive simplification of the model for soil and structures, it was far from the real solution for problems of SSI. When superstructures, foundations, and topographic and geological conditions become complicated, producing a mathematical solution can be difficult.

1.2 Methods used to solve SSI problems:

1.2.1 Numerical Methods: The numerical method greatly developed because of the rapid progress of computers. This method of calculations is considered one of the most effective tools for the study of SSI. Thus, some seismologists have used it, and a great deal of publications based on it having spring up from 1980 up to present.

1.2.2 Finite Element Method: Finite element method, an efficient common computing method widely used in civil engineering, discretizes a continuum into a series of elements with limited sizes to compute for the mechanics of the continuum. FEM can simulate the mechanics of the soil and structures better than other methods, deal with complicated geometry and applied loaded, and determine non linear phenomena. To date, there are many general purpose programs developed by commercial corporations for research in the study of SSI, and has produced some notable achievements in the field of SSI

1.2.3 Experiment: Experiment is an important mean for scientist and engineers to improve human knowledge about the nature law.

1.2.4 Prototype Observation: Studies of recorded responses of instrumental structures constitute an integral part of earthquake hazard-reduction programs, leading to improved designing or analyzing procedures are done by modelling a prototype structure and those are results are compared with conventional design methods so as to ensure the safety of structure.

1.3 Effect of soil structure interaction on structural response:

It has conventionally been considered that soil-structure interaction has a beneficial effect on the seismic response of a structure. Many design codes have suggested that the effect of SSI can reasonably be neglected for the seismic analysis of structures. This myth about SSI apparently stems from the false perception that SSI reduces the overall seismic response of a structure, and hence, leads to improved safety margins. Most of the design codes use oversimplified design spectra, which attain constant acceleration up to a certain period, and thereafter decreases monotonically with period. Considering soil-structure interaction makes a structure more flexible and thus, increasing the natural period of the structure compared to the corresponding rigidly supported structure. Moreover, considering the SSI effect increases the effective damping ratio of the system. The smooth idealization of design spectrum suggests smaller seismic response with the increased natural periods and effective damping ratio due to SSI. With

this assumption, it was traditionally been considered that SSI can conveniently be neglected for conservative design. In addition, neglecting SSI tremendously reduces the complication in the analysis of the structures which has tempted designers to neglect the effect of SSI in the analysis. This conservative simplification is valid for certain class of structures and soil conditions, such as light structures in relatively stiff soil. Unfortunately, the assumption does not always hold true. In fact, the SSI can have a detrimental effect on the structural response, and neglecting SSI in the analysis may lead to unsafe design for both the superstructure and the foundation. In this paper a 5 storey reinforced concrete frame is analyzed and designed as per IS 456:2000 in conventional method with different load combinations and determine the parameters displacements, shear force and bending moment by keeping the base as fixed. From the reactions obtained in conventional methods for the RC frame, raft foundation is designed. Similarly a same 5 storey reinforced concrete frame is analyzed in Numerical method based on finite element method with raft foundation at the base by assigning soil properties to the substructure and determine the parameters displacements, shear forces, bending moment.

Comparison of parameters displacements, shear forces and bending moments for both models is done i.e. with soil structure interaction and without soil structure interaction.

2.LITERATURE REVIEW

M.V Gaikwad analyzed a frame with soil structure interaction using FEM. It states the behavior of bare frame having soil beneath. The results shows bare frame with soil structure interaction shows more displacements than the analysis of structure without soil structure interaction. Also analysis of bare frame with soil structure interaction shows less shear force and bending moment as compared with analysis of bare frame without soil structure interaction.

Rama Rao et al analysed a structure to study the effect of soil-structure interaction on horizontal and vertical displacements at the supports for various heights providing sub grade modulus of soil as a defining soil medium by springs for some defined wind loads. From the results it states that the displacement increases with the increase in the value of sub grade modulus reaction and the displacement increases with the increase in the storey level of the building.

3. CONVENTIONAL METHOD OF ANALYSIS

3.1 Introduction: A symmetrical 5 storey building is modeled using STAAD Pro software package with 4 no of bays in X direction and 4 no of bays in Z direction. The span of the columns is 3m in X direction and 3m in Z direction. The plinth area of the building is 12m x 12m. The total height of the 5 storey building is considered as 15m. The height of each storey is taken as 3m respectively.

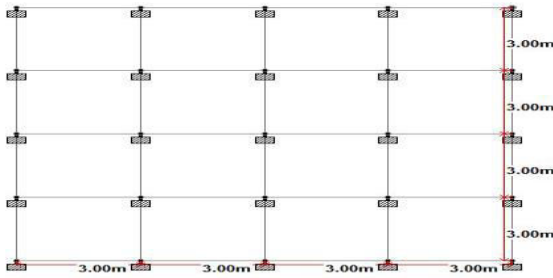


Fig. 1: Plan view of the structure

3.2 Model data of the Structure:

Structural Properties	
Structure	OMRF
No of Storeys	5
Storey Height	3.00 m
Type of building used	Residential
Foundation Type	Raft Foundation
Seismic Zone	III
Material Properties	
Grade of concrete used	M 30
Grade of steel used	415 MPA
Young's Modulus of Concrete	27.38×10^6 KN/m ²
Density of Reinforcement Concrete	25 KN/m ³
Modulus of Elasticity of brick masonry	3.50×10^6 KN/m ³
Density of brick masonry	19.2 KN/m ³
Member Properties	

Thickness of Slab	0.125 m
Beam size	0.45 x 0.23 m
Column size	0.45 x 0.45 m
Thickness of outer wall	0.230 m
Thickness of inner wall	0.115 m
Seismic Parameters	
City	Vishakapatna
Zone	III
Response Reduction Factor	3
Structure type	RC Framed building
Damping Ratio	5%
Soil Properties	
Type of soil	Loose Sand
Soil Bearing Capacity	215 KN/m ²
Codes	
RCC Design	IS 456:2000
Seismic Design	IS 1893 Part 4

3.3 Calculations of loads:

3.3.1 Dead loads and Live loads of the building: The dead load of the building includes the self weight, wall load (outer walls and inner walls), floor load and parapet wall load are calculated as for codes

3.3.2 Wind load:

From IS 875 (Part III)

$$\text{Design Wind Pressure } (P_z) = 0.6 V_z^2$$

Where P_z = design wind pressure in N/ms at height z , and

V_z = design wind velocity in m/s at height z .

Design Wind Speed (V_z) = $V_b \times k_1 \times k_2 \times k_3$

Where V_b = basic wind speed

[$V_b = 55\text{m/s}$, $V_b = 50\text{m/s}$, $V_b = 47\text{m/s}$ and $V_b = 39\text{m/s}$]

k_1 = probability factor (Table 1 clause 5.3.1)

k_2 = height and structure size factor (Table 2 clause 5.3.2)

k_3 = topography factor (Table 2 clause 5.3.3)

For 5 storey building

$V_z = 55 \times 1 \times 1.1 \times 1 = 60.5 \text{ m/s}$; $P_z = 0.6$
 $V_z^2 = 2.196 \text{ KN/m}^2$

$V_z = 50 \times 1 \times 1.1 \times 1 = 55.0 \text{ m/s}$; $P_z = 0.6$
 $V_z^2 = 1.815 \text{ KN/m}^2$

$V_z = 47 \times 1 \times 1.1 \times 1 = 51.7 \text{ m/s}$; $P_z = 0.6$
 $V_z^2 = 1.603 \text{ KN/m}^2$

$V_z = 39 \times 1 \times 1.1 \times 1 = 42.9 \text{ m/s}$; $P_z = 0.6$
 $V_z^2 = 1.104 \text{ KN/m}^2$

3.3.3 Earthquake load parameters:

For Zone III

Structure type = RC framed building

Response reduction factor (RF) = 3

Importance Factor (I) = 1

Zone Factor = 0.16

Damping ratio (DM) = 5%

3.4 Base Shear Calculation:

Zone factor for zone III = 0.16

Importance factor = 1.5

Response factor = 3

Intensity of dead load = 16.8 KN/m^3

Imposed load:

Floor load = slab thickness x density of concrete

$$= 0.125 \times 25$$

$$= 3.125 \text{ KN/m}^3$$

Live load = 2 KN/m^3

Dust load = 0.5 KN/m^3

Imposed load = Floor load + live load + Dust Load

$$= 3.125 + 2 + 0.5$$

$$= 5.625 \text{ KN/m}^3$$

Total floor area = $12\text{m} \times 12\text{m} = 144 \text{ m}^2$

Load on one floor = $144 (16.8 + 0.25 \times 5.625) = 2621.7 \text{ KN}$

Load on roof = $144 \times 16.8 = 2419.2 \text{ KN}$

Total load on structure (W) = $5 \times 2621.7 + 2419.2 = 15527.7 \text{ KN}$

Base shear (V_b) = $A_h W$

$$A_h = (ZIS/2RG) = (0.16 \times 1.5 \times 2.5) / (2 \times 3) = 0.1$$

Base shear (V_b) = $0.1 \times 15527.7 = 1552.7 \text{ KN}$

Vertical distribution of base shear:

$$Q_5 = (W_1 h_1^2 / \sum W_i h_i^2)$$

4. NUMERICAL ANALYSIS USING FINITE ELEMENT METHOD

Various software based on finite element methods which are widely used in construction industry are:

1. ABACUS
2. ANSYS
3. SAP 2000
4. SAFE
5. ETABS

In this paper numerical analysis using ANSYS software package is done.

4.1 ANSYS:

ANSYS is a general purpose finite element modeling package for numerically solving a wide variety of mechanical problems. These problems include: static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

In general, a finite element solution may be broken into the following three stages. This

is a general guideline that can be used for setting up any finite element analysis.

1. Pre-processing: The major steps in pre-processing are given below:

- Define key points /lines/areas/volumes
- Define element type and material/geometric properties
- Mesh lines/areas/volumes as required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axi-symmetric, 3D).

2. Solution: assigning loads, constraints and solving; here we specify the loads (point or pressure), constraints (translational and rotational) and finally solve the resulting set of equations.

3. Post processing: Further processing and viewing of the results, in this stage one may wish to see:

1. Lists of nodal displacements
2. Element forces and moments
3. Deflection plots
4. Stress contour diagrams

A similar symmetrical 5 storey building is taken with 4 no of bays in X direction and 4 no of bays in Z direction. The span of the columns is 3m in X direction and 3m in Z direction. The plinth area of the building is 12m x 12m. The total height of the 5 storey building is considered as 15m. The height of each storey is taken as 3m respectively.

Raft foundation is designed for this 5 storey building from the axial loads obtained from conventional method of analysis for worst cases.

4.2 Structural Design of Raft Foundation:

This foundation will be done for a 5 storey building. The raft will be economical consideration.

The raft foundation is a kind of combined footing that may cover the entire area under the structure supporting several columns in one rigid body. In this project, the soil profile shows that the bearing stress is around 215 KN/m². The raft foundation is usually used with this kind of soil. The columns have high axial loads. In this big spread footing condition, the raft foundation could be much practical and economical.

In this project, the raft will be design as flat plate, which has uniform thickness and without any beams or pedestals.

4.3 Objective:

This report shows the structural design of the raft foundation. All analysis and design are based on Indian code. Raft foundation can be design using several methods. In this project the method used in the design called “The Conventional Rigid Method” and all design steps will be shown below.

All design parameters are shown in table below

Parameters	Value
Yield strength of steel	415 MPA
Strength of concrete	30 MPA
Young modules of elasticity	2000000
Soil unit weight	17.5 KN/m ³
Allowable bearing stress	215 KN/m ³

4.4 Raft Modeling and Analysis:

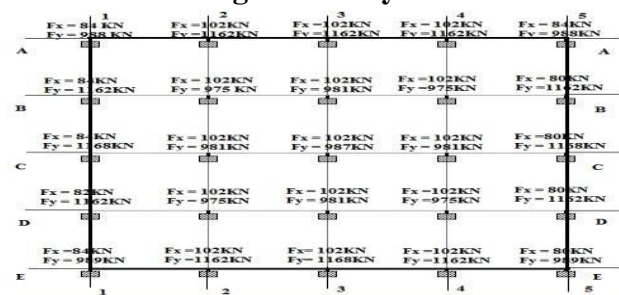


Fig.2: Raft layout

Modeling in ANSYS:

A symmetrical 5 storey building with raft foundation is taken with 4 no of bays in X direction and 4 no of bays in Z direction. The span of the columns is 3m in X direction and 3m in Z direction. The plinth area of the building is 12m x 12m. The total height of the 5 storey building is considered as 15m. The height of each storey is taken as 3m respectively.

4.5.Elements used in Modelling of structure:

BEAM4 Element: BEAM4 is a uniaxial element with tension, compression, torsion, and bending capabilities. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analyses. See BEAM4 in the Theory Reference for the Mechanical APDL and Mechanical Applications for more details about this element. A tapered unsymmetrical elastic beam is described in BEAM44 and a 3-D plastic beam in BEAM24. In this structure beams and columns are taken as beam elements. The

geometry, node locations, and coordinate systems for this element are shown in figure below.

BEAM4 Real constants:

SHELL63 Element: SHELL63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection (finite rotation) analyses. See SHELL63 in the Theory Reference for the Mechanical APDL and Mechanical Applications for more details about this element. Similar elements are SHELL181 (plastic capability) and SHELL281 (mid side node capability). The ETCHG command converts SHELL57 and SHELL157 elements to SHELL63.

In this structure slabs and raft foundation are taken as shell elements. The geometry, node locations, and coordinate systems for this element are shown in figure below.

SHELL63 Real constants:

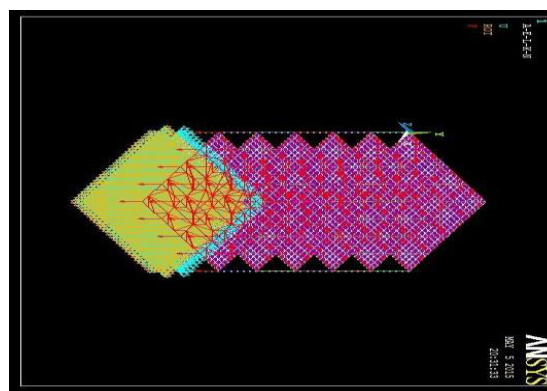
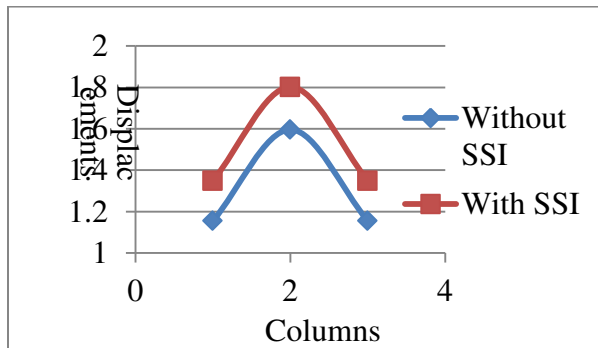


Fig. 3: Loads acting on the Structure

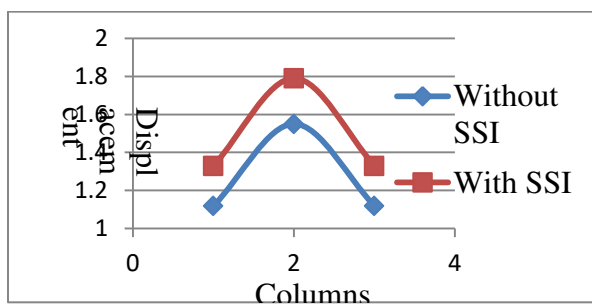
5. RESULTS AND DISCUSSIONS

Maximum Displacements:

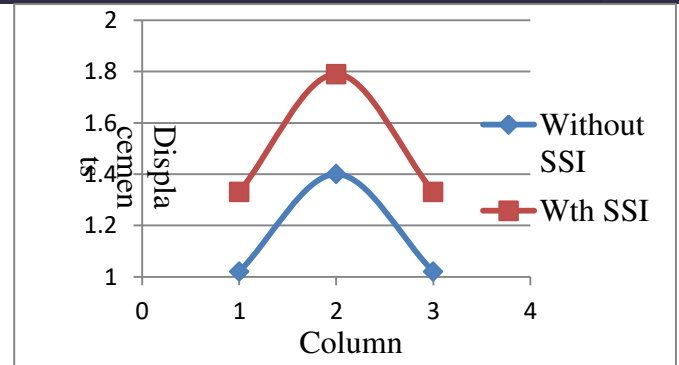
The maximum displacements of 5 storeyed building for the cases of dead load, live load multiplied with safety factor with soil structure interaction and without soil structure interaction for each storey is presented in table below. The results are taken only for extreme loading conditions and static loading condition i.e. only dead loads and live loads are considered.



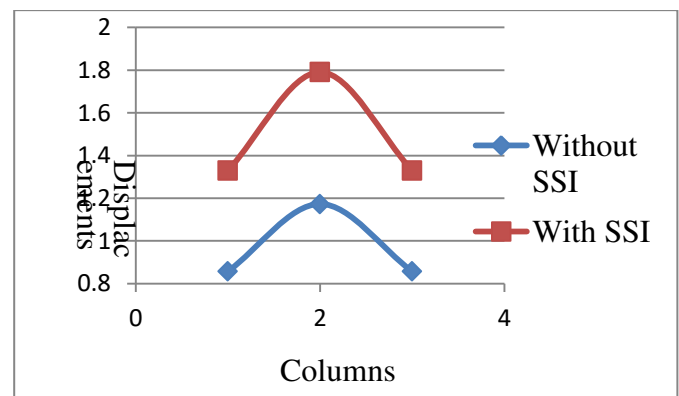
Graph 1 Maximum displacements in 5th storey with and without soil structure interaction



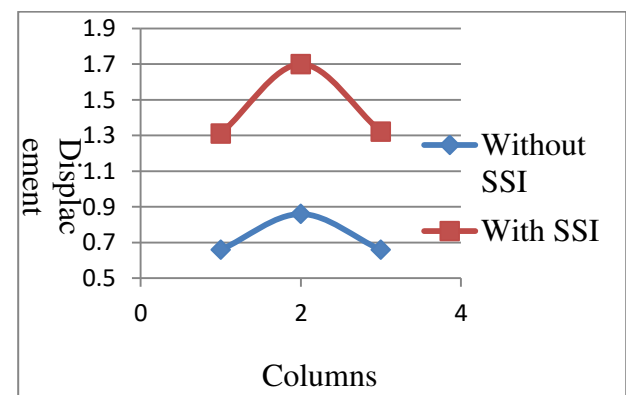
Graph 2 Maximum displacements in 4th storey with and without soil structure interaction



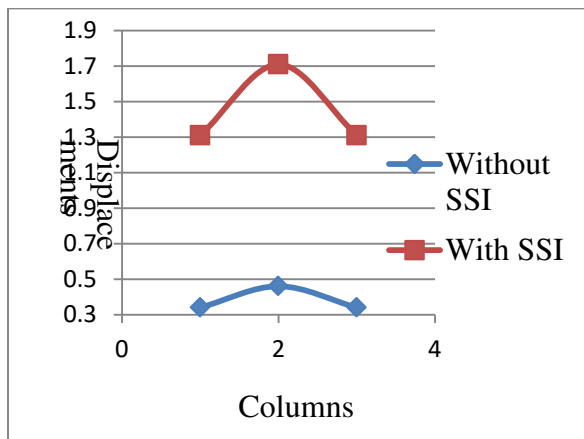
Graph 3 Maximum displacements in 3rd storey with and without soil structure interaction



Graph 4 Maximum displacements in 2nd storey with and without soil structure interaction



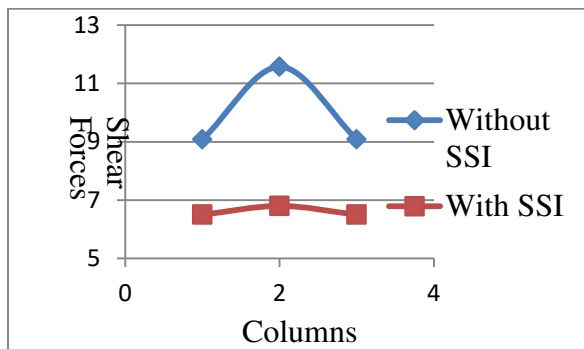
Graph 5: Maximum displacements in 1st storey with and without soil structure interaction



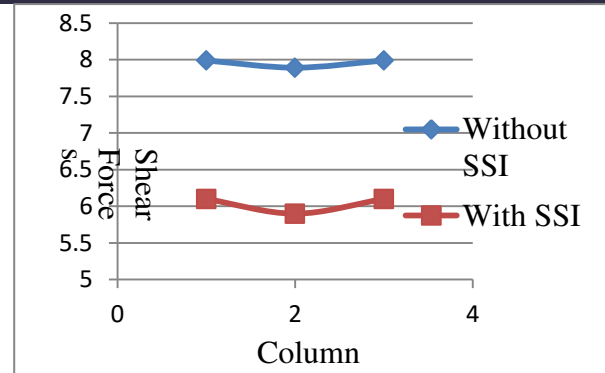
Graph 6 : Maximum displacements in G.L with and without soil structure interaction

Maximum Shear Forces:

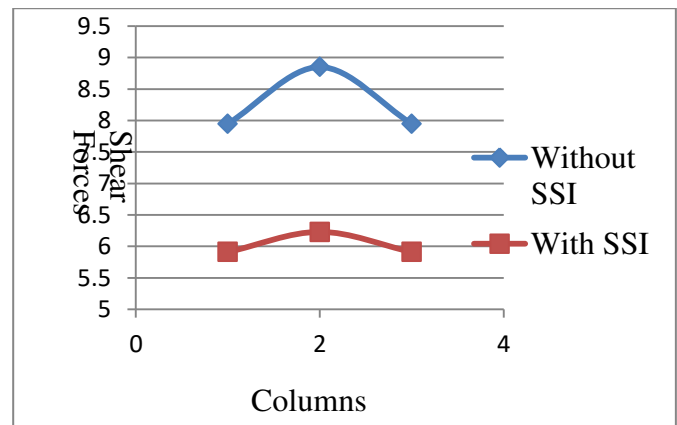
The maximum shear forces of 5 storeyed building for the cases of dead load, live load multiplied with safety factor with soil structure interaction and without soil structure interaction for each storey is presented in table below. The results are taken only for extreme loading conditions and static loading condition i.e. only dead loads and live loads are considered.



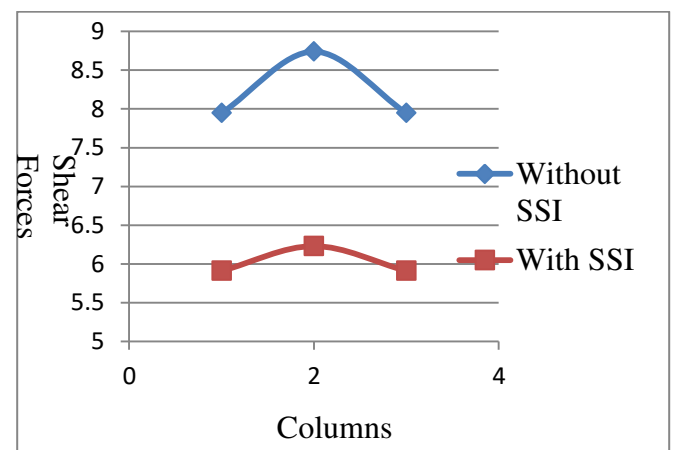
Graph 7 Maximum SF in 5th storey with and without soil structure interaction



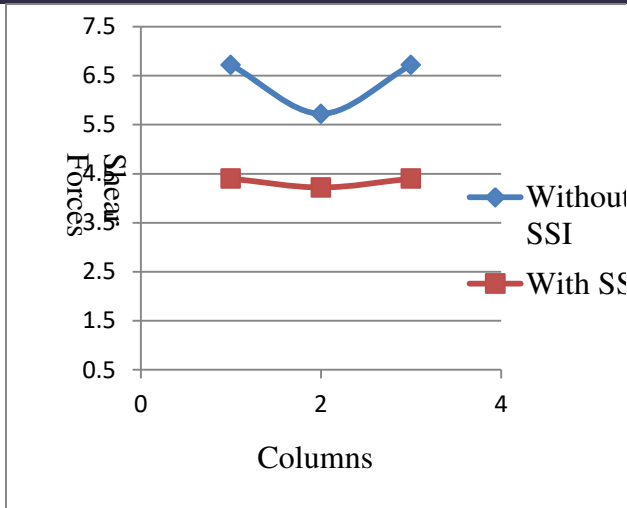
Graph 8: Maximum SF in 4th storey with and without soil structure interaction



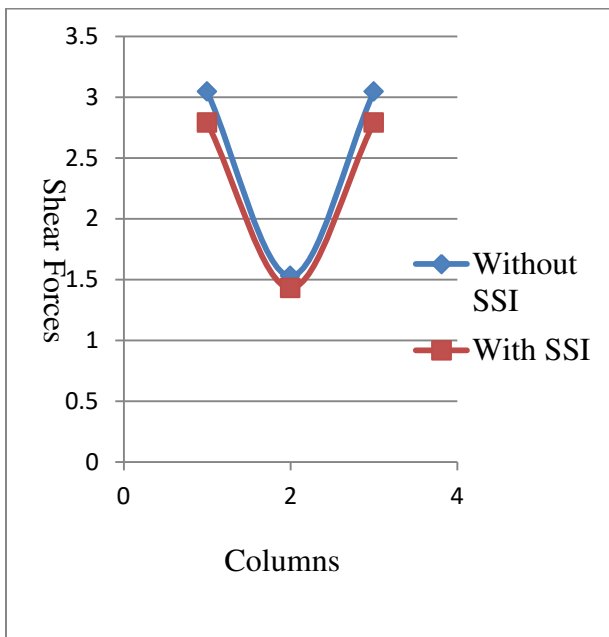
Graph 9: Maximum SF in 3rd storey with and without soil structure interaction



Graph 10: Maximum SF in 2nd storey with and without soil structure interaction



Graph 11: Maximum SF in 1st storey with and without soil structure interaction

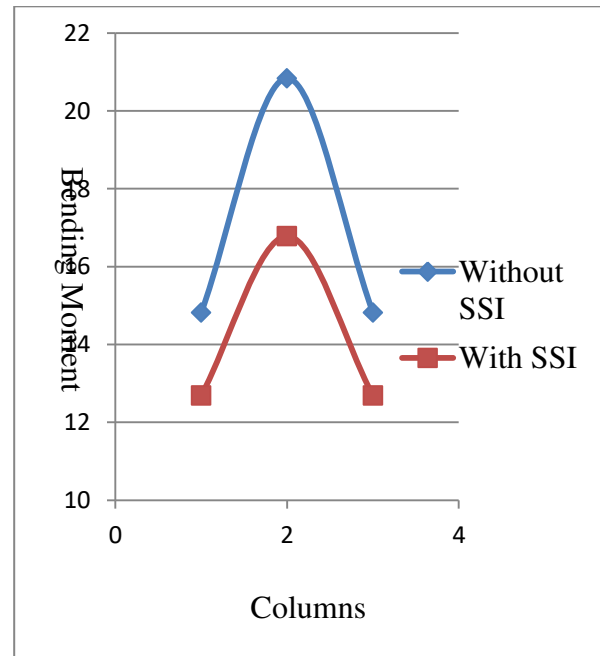


Graph 12: Maximum SF in G.L with and without soil structure interaction

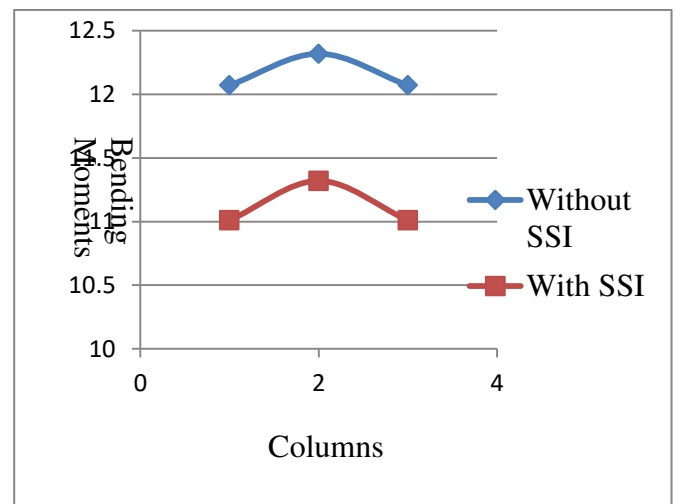
Maximum Bending Moments:

The maximum Bending Moment of 5 storeyed building for the cases of dead load, live load multiplied with safety factor with soil structure interaction and without soil structure interaction for each storey is

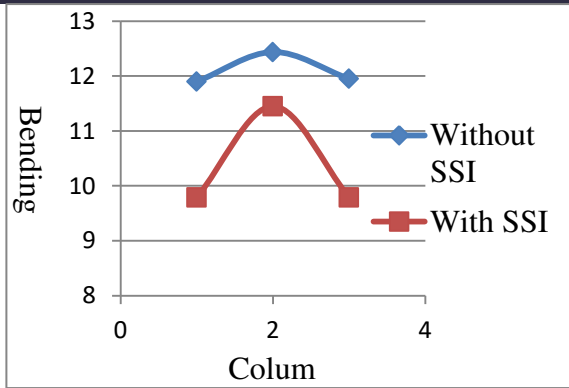
presented in table below. The results are taken only for extreme loading conditions and static loading condition i.e. only dead loads and live loads are considered.



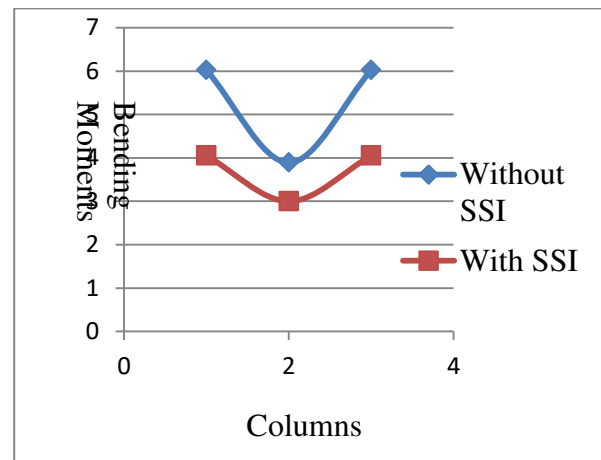
Graph 13: Maximum BM in 5th storey with and without soil structure interaction



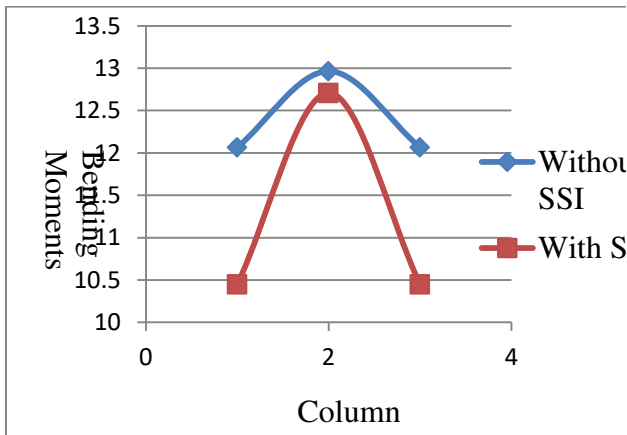
Graph 14: Maximum BM in 4th storey with and without soil structure interaction



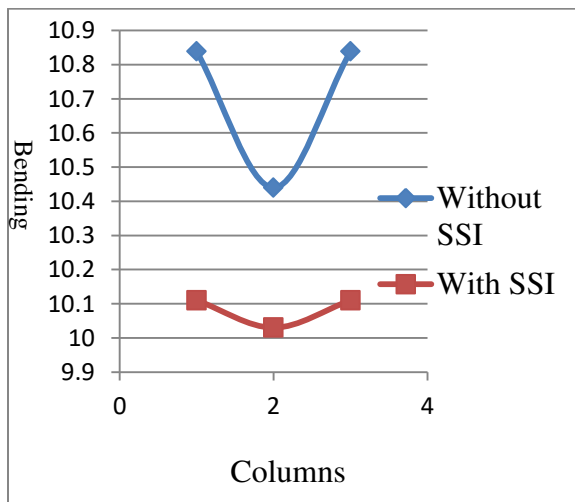
Graph 15: Maximum BM in 3rd storey with and without soil structure interaction



Graph 18: Maximum BM in G.L with and without soil structure interaction



Graph 16: Maximum BM in 2nd storey with and without soil structure interaction



Graph 17: Maximum BM in 1st storey with and without soil structure interaction

CONCLUSION

The displacements, shear forces and bending moments are estimated from conventional design method and numerical analysis method using finite element method in columns i.e. without soil structure interaction and with soil structure interaction. The displacements, Shear forces and bending moments are compared with soil structure interaction and without soil structure interaction. The value of sub grade modulus reaction K_s have been assumed 12000 KN/m³.

The following conclusions have been drawn from above results:

1. Analysis of structure with soil structure interaction shows more displacement than the analysis of structure without soil structure interaction.
2. Analysis of structure with soil structure interaction shows less shear forces as compared with analysis of structure without soil structure interaction.

3. Analysis of structure with soil structure interaction shows more or less Bending moments as compared with analysis of structure without soil structure interaction.
4. Analysis of structure with soil structure interaction shows avg of 38% increase in displacements compared with analysis of structure without soil structure interaction.
5. Analysis of structure with soil structure interaction shows avg of 29.6% decrease in shear forces compared with analysis of structure without soil structure interaction.

REFERENCES

1. Dr. C. Ravi Kumar Reddy and T.D Gunneswara Rao 2011: Experimental study of a modeled building frame supported by pile groups embedded in cohesionless soil.
2. K. Natarajan and B. Vidivelli 2009 : Effect of column spacing on the behaviour of frame raft and soil systems.
3. Haytham Adnan Sadeq, Mohammed saleem Taha 2009: Structural design of raft foundation with soil structure interaction.
4. H.S Chore , V.A Sawant and R.K Ingle 2012: Non-linear analysis of pile groups subjected to lateral loads.
5. Sushma Pulikanti and Pradeep kumar Ramancharla 2013: SSI Analysis of framed structures supported on pile foundations
6. Vivek Garg and M.S Hora 2012: A review on interaction behavior of structure foundation soil system.
7. R. R. Chaudhari, Dr K. N. Kadam 2013: Effect Of Piled Raft Design On High-Rise Building Considering Soil Structure Interaction.
8. Gaikwad M.V, Ghogare R.B, Vagesha S. Mathada 2015: Finite element analysis of frame with soil structure interaction.
9. Lou Menglin, Wang Huaifeng, Chen Xi Zhai Yongmei 2011: Structure soil Structure interaction: literature review.
10. Dr. M. Reza Emami Azadi, Ali Akbar Soltani 2010: Effect of soil structure interaction on dynamic response of Delijan cement storage silo under earthquake loading.
11. D. Daniel Thangaraj and L Ilampathi 2012: Numerical analysis of soil raft foundation and space frame system.
12. Eduardo Kausel 2010: Early history of soil structure interaction.
13. ”.