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RESEARCH ARTICLE

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DYNAMIC SOIL STRUCTURE INTERACTION ON PILE FOUNDATIONS AND RETAINING STRUCTURES

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ABSTRACT

This paper addresses the behaviour 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. According to the analysis results the parameters displacements, shear force and bending moment varies from conventional analysis to numerical analysis.

Keywords: Soil Structure interaction, Conventional Method of Analysis, Displacement, Shear Force, Bending Moment.

1.1 Introduction

Most of the civil engineering structures involve some type of structural element with direct contact with ground. When the external forces, such as earthquakes, act on these systems, neither the structural displacements nor the ground displacements, are independent of each other. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as soil-structure interaction (SSI)

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 analysing 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 stimulate 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 analysed 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 analysed 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.

CONVENTIONAL METHOD OF ANALYSIS

3.1 Introduction

A symmetrical 5 storey building is modelled 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.

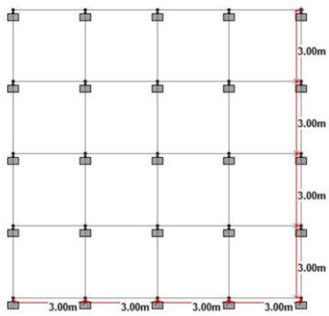

Fig 3.1 Plan view of the structure

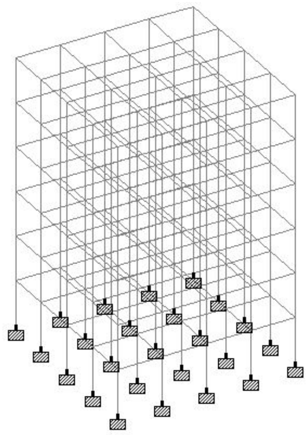

Fig 3.2 Isometric view of the structure

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	Vijayawada
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.

Type of Section	No	Length (m)	Breadth (m)	Height (m)	DensityKN/m^3	Load	Weight KN
Slab	1	12	12	0.125	25	1	450
Beam							
1) P Beams in X direction	5	12	0.45	0.23	25	1	155.25
2) P Beams in Y direction	5	12	0.45	0.23	25	1	155.25
Columns	150	0.45	0.45	2.55	25	1	1936.40
External wall	1	48	0.23	2.55	20	1	563.04
Internal wall	1	72	0.115	2.55	20	1	422.28

Parapet wall	1	48	0.23	1.2	20	1	264.96
Live Load	2	12	12	1	1	2	576
Floor Finishes	1.5	12	12	1	1	1	216
Total Load							15650.96

3.3.2 Wind load: From IS 875 (Part III)

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 = 55m/s, V_b = 50m/s, V_b = 47m/s and V_b =39m/s]

k_1= probability factor (Table 1 clause5.3.1)

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

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

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

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

$V_z = 39 \times 1 \times 1.1 \times 1 = 42.9$ m/s; $P_z = 0.6\ V_z^2 = 1.104$ 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 x 25

= 3.125 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 KN/m^3

Total floor area = 12m x 12m = 144 m^2

Load on one floor = 144 (16.8 + 0.25 x 5.625) = 2621.7 KN

Load on roof = 144 x 16.8 = 2419.2 KN

Total load on structure (W) = 5 x 2621.7 + 2419.2 = 15527.7 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 x 15527.7 = 1552.7 KN

Vertical distribution of base shear:

1st Floor:

$Q_1 = (W_1 h_1^2 / \Sigma\ W_i h_i^2)$

$= (2621.7 \times 6^2) / ((2419.2 \times 18^2)\ (2621.7 \times 15^2)\ (2621.7 \times 12^2)(2621.7 \times 9^2)\ (2621.7 \times 6^2)\ (2621.7 \times 3^2))$

$Q_1 = 0.045$

Ground Level:

$Q_{gl} = (W_{gl} h_1^2 / \Sigma\ W_i h_i^2)$

$= (2621.7 \times 3^2) / ((2419.2 \times 18^2)\ (2621.7 \times 15^2)\ (2621.7 \times 12^2)\ 2621.7 \times 9^2)\ (2621.7 \times 6^2)\ (2621.7 \times 3^2))$

$Q_{gl} = 0.011$

Table 3.1 : Design lateral loads at each floor

Level	W_i (KN)	h_i (m)	$(W_1 h_1^2/\Sigma W_i h_i^2)$	Lateral Force (KN)
5th Floor	1552.7	18	0.37	585
4th Floor	1552.7	15	0.28	434.7
3rd Floor	1552.7	12	0.18	281.6
2nd Floor	1552.7	9	0.10	155.2
1st Floor	1552.7	6	0.045	70.4
Ground Level	1552.7	3	0.011	17.07

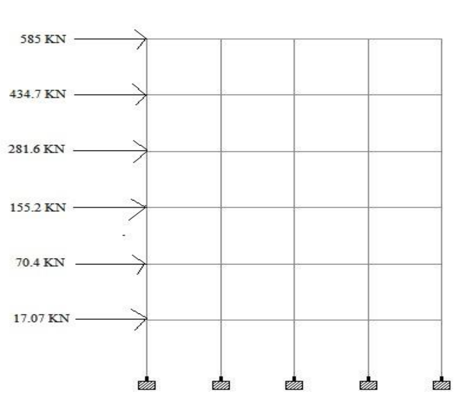

Fig 3.3 Equivalent static lateral load (sway to right) on frame in KN

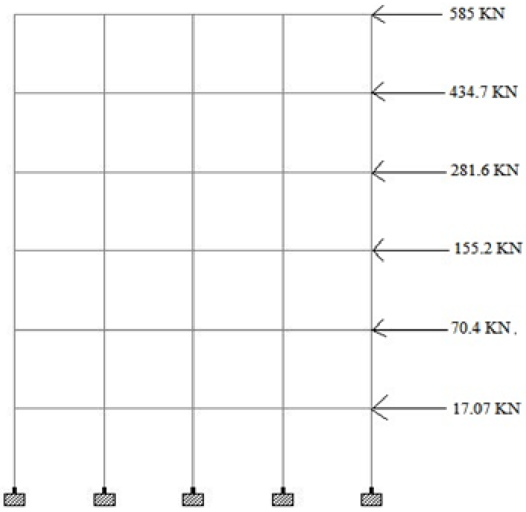

Fig 3.4 Equivalent static lateral load (sway to left) on frame in KN

3.5 Load Combinations:

The load combinations given in the analysis according to relevant IS codes of practice (IS 1893-2002 and IS 875 Part III-1987)

- 1.5(DL ± LL)
- 1.5(DL ± WL_x)
- 1.5(DL ± WL_z)
- 0.9 DL ± 1.5 WL_x
- 0.9 DL ± 1.5WL_z
- 1.2 (DL+LL± WL_x)
- 1.2 (DL+LL± WL_Z)
- 1.5(DL ± EL_x)
- 1.5(DL ± EL_z)
- 0.9 DL ± 1.5 EL_x
- 0.9 DL ± 1.5EL_z
- 1.2 (DL+LL± EL_x)
- 1.2 (DL+LL± EL_Z)

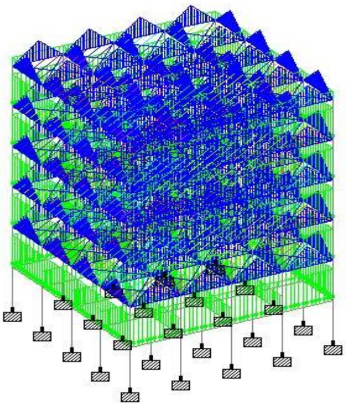

Fig 3.5 Dead Load Diagram

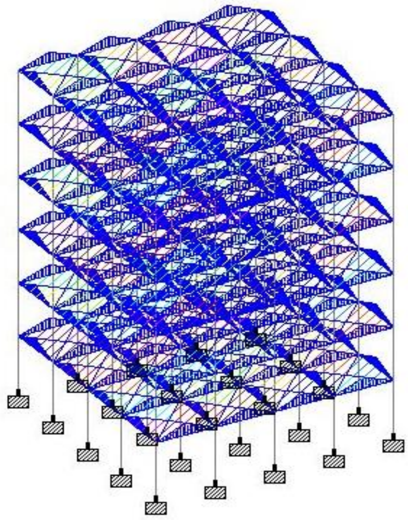

Fig 3.6 Live load Diagram

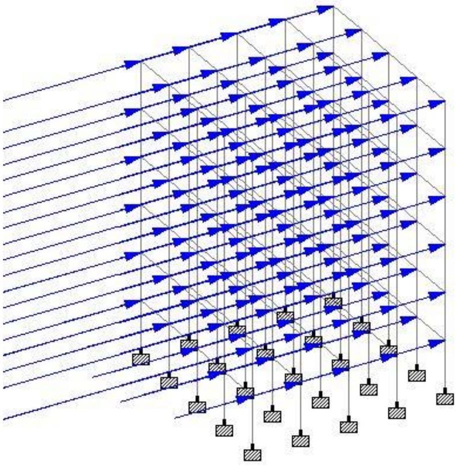

Fig 3.7 Earthquake Load in X Direction

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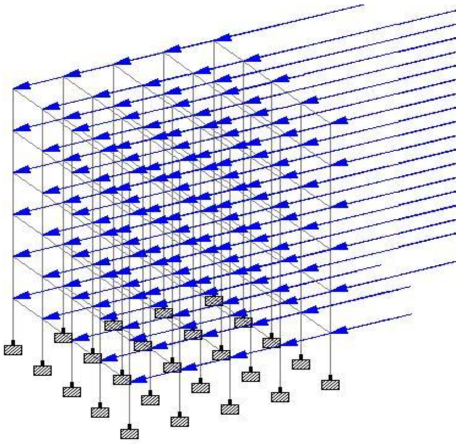


Fig 3.8 Earthquake Load in -X Direction

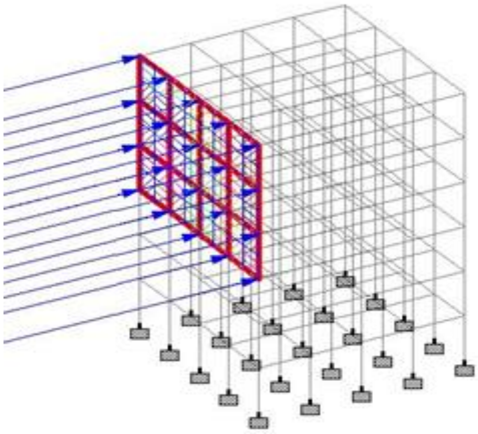


Fig 3.11 Wind Load in X Direction

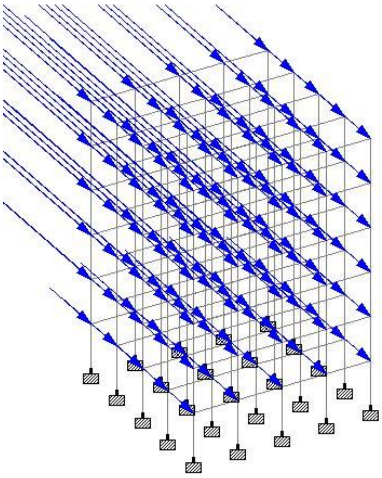


Fig 3.9 Earthquake Load in Z Direction

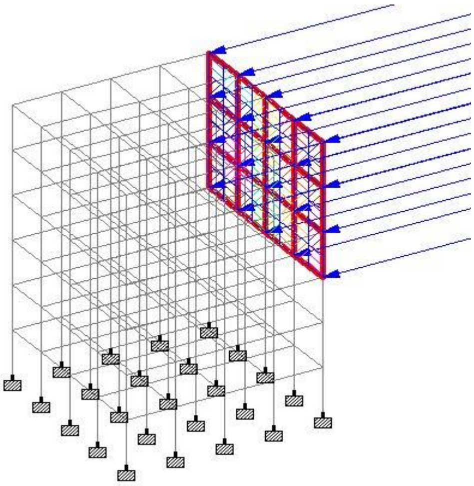


Fig 3.12 Wind Load in -X Direction

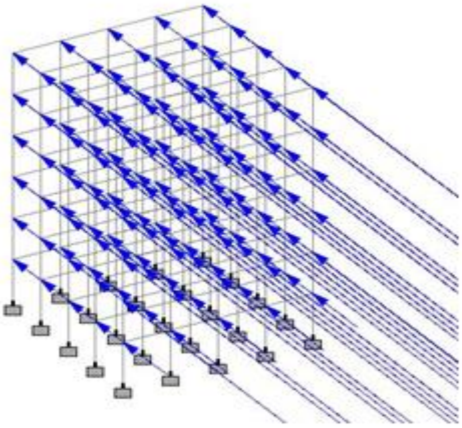


Fig 3.10 Earthquake Load in -Z Direction

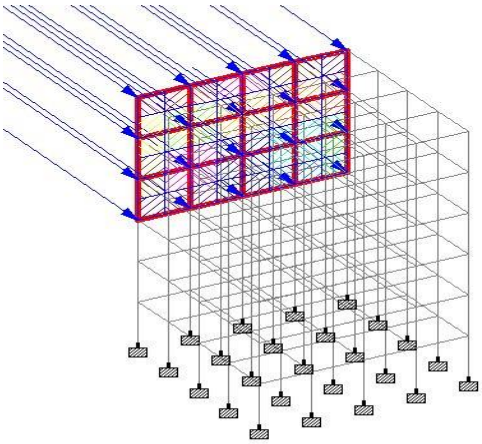


Fig 3.13 Wind Load in Z Direction

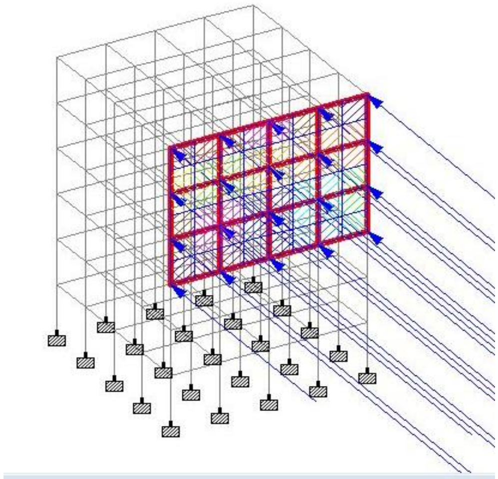


Fig 3.14 Wind Load in -Z Direction

3.6 Reaction at Ends

Node	Env	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
1	+ve	83.477	988.447	83.477	272.981	0.122	267.949
1	+ve	Load: 17	Load: 17	Load: 19	Load: 19	Load: 17	Load: 20
1	-ve	-78.516	-294.119	-78.516	-267.949	-0.122	-272.981
1	-ve	Load: 20	Load: 1	Load: 22	Load: 22	Load: 16	Load: 17
2	+ve	101.556	1.16E+3	82.122	272.163	0.117	290.373
2	+ve	Load: 17	Load: 19	Load: 19	Load: 19	Load: 22	Load: 20
2	-ve	-101.300	-296.031	-79.504	-269.396	-0.118	-290.733
2	-ve	Load: 20	Load: 3	Load: 22	Load: 22	Load: 19	Load: 17
3	+ve	101.345	1.17E+3	82.154	272.418	0.066	290.558
3	+ve	Load: 17	Load: 19	Load: 19	Load: 19	Load: 17	Load: 16
3	-ve	-101.345	-296.870	-79.583	-269.696	-0.066	-290.558
3	-ve	Load: 16	Load: 3	Load: 22	Load: 22	Load: 16	Load: 17
4	+ve	101.300	1.16E+3	82.122	272.163	0.118	290.733
4	+ve	Load: 21	Load: 19	Load: 19	Load: 19	Load: 19	Load: 16
4	-ve	-101.556	-296.031	-79.504	-269.396	-0.117	-290.373
4	-ve	Load: 16	Load: 3	Load: 22	Load: 22	Load: 22	Load: 21
5	+ve	78.516	988.447	83.477	272.981	0.122	272.981
5	+ve	Load: 21	Load: 16	Load: 19	Load: 19	Load: 19	Load: 16
5	-ve	-83.477	-294.119	-78.516	-267.949	-0.122	-267.949
5	-ve	Load: 16	Load: 2	Load: 22	Load: 22	Load: 18	Load: 21
36	+ve	82.122	1.16E+3	101.556	290.733	0.118	269.396
36	+ve	Load: 17	Load: 17	Load: 19	Load: 19	Load: 17	Load: 20
36	-ve	-79.504	-296.031	-101.300	-290.373	-0.117	-272.163
36	-ve	Load: 20	Load: 1	Load: 22	Load: 22	Load: 20	Load: 17
37	+ve	101.720	974.958	101.720	291.383	0.076	291.016
37	+ve	Load: 17	Load: 11	Load: 19	Load: 19	Load: 17	Load: 20
37	-ve	-101.458	-0.697	-101.458	-291.016	-0.076	-291.383
37	-ve	Load: 20	Load: 1	Load: 22	Load: 22	Load: 16	Load: 17
38	+ve	101.506	980.936	101.806	291.690	0.079	291.204
38	+ve	Load: 17	Load: 11	Load: 19	Load: 19	Load: 17	Load: 16
38	-ve	-101.506	-0.702	-101.544	-291.322	-0.079	-291.204
38	-ve	Load: 16	Load: 3	Load: 22	Load: 22	Load: 16	Load: 17
39	+ve	101.458	974.958	101.720	291.383	0.076	291.383
39	+ve	Load: 21	Load: 11	Load: 19	Load: 19	Load: 19	Load: 16
39	-ve	-101.720	-0.697	-101.458	-291.016	-0.076	-291.016
39	-ve	Load: 16	Load: 3	Load: 22	Load: 22	Load: 22	Load: 21

40	+ve	79.504	1.16E+3	101.556	290.733	0.117	272.163
40	+ve	Load: 21	Load: 16	Load: 19	Load: 19	Load: 21	Load: 16
40	-ve	-82.122	-296.031	-101.300	-290.373	-0.118	-269.396
40	-ve	Load: 16	Load: 2	Load: 22	Load: 22	Load: 16	Load: 21
71	+ve	82.154	1.17E+3	101.345	290.558	0.066	269.696
71	+ve	Load: 17	Load: 17	Load: 19	Load: 19	Load: 22	Load: 20
71	-ve	-79.583	-296.870	-101.345	-290.558	-0.066	-272.418
71	-ve	Load: 20	Load: 1	Load: 18	Load: 22	Load: 19	Load: 17
72	+ve	101.806	980.936	101.506	291.204	0.079	291.322
72	+ve	Load: 17	Load: 11	Load: 19	Load: 19	Load: 18	Load: 20
72	-ve	-101.544	-0.702	-101.506	-291.204	-0.079	-291.690
72	-ve	Load: 20	Load: 1	Load: 18	Load: 18	Load: 19	Load: 17

Node	Env	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
73	+ve	101.592	986.904	101.592	291.511	0.000	291.511
73	+ve	Load: 17	Load: 11	Load: 19	Load: 19	Load: 19	Load: 16
73	-ve	-101.592	-0.000	-101.592	-291.511	-0.000	-291.511
73	-ve	Load: 16	Load: 2	Load: 18	Load: 18	Load: 18	Load: 17
74	+ve	101.544	980.936	101.506	291.204	0.079	291.690
74	+ve	Load: 21	Load: 11	Load: 19	Load: 19	Load: 19	Load: 16
74	-ve	-101.806	-0.702	-101.506	-291.204	-0.079	-291.322
74	-ve	Load: 16	Load: 2	Load: 18	Load: 18	Load: 18	Load: 21
75	+ve	79.583	1.17E+3	101.345	290.558	0.066	272.418
75	+ve	Load: 21	Load: 16	Load: 19	Load: 19	Load: 19	Load: 16
75	-ve	-82.154	-296.870	-101.345	-290.558	-0.066	-269.696
75	-ve	Load: 16	Load: 2	Load: 18	Load: 18	Load: 18	Load: 21
106	+ve	82.122	1.16E+3	101.300	290.373	0.117	269.396
106	+ve	Load: 17	Load: 17	Load: 23	Load: 23	Load: 20	Load: 20
106	-ve	-79.504	-296.031	-101.556	-290.733	-0.118	-272.163
106	-ve	Load: 20	Load: 1	Load: 18	Load: 18	Load: 17	Load: 17
107	+ve	101.720	974.958	101.458	291.016	0.076	291.016
107	+ve	Load: 17	Load: 11	Load: 23	Load: 23	Load: 16	Load: 20
107	-ve	-101.458	-0.697	-101.720	-291.383	-0.076	-291.383
107	-ve	Load: 20	Load: 1	Load: 18	Load: 18	Load: 17	Load: 17
108	+ve	101.506	980.936	101.544	291.322	0.079	291.204
108	+ve	Load: 17	Load: 11	Load: 23	Load: 23	Load: 16	Load: 16
108	-ve	-101.506	-0.702	-101.806	-291.690	-0.079	-291.204
108	-ve	Load: 16	Load: 4	Load: 18	Load: 18	Load: 17	Load: 17

109	+ve	101.458	974.958	101.458	291.016	0.076	291.383
109	+ve	Load: 21	Load: 11	Load: 23	Load: 23	Load: 19	Load: 16
109	-ve	-101.720	-0.697	-101.720	-291.383	-0.076	-291.016
109	-ve	Load: 16	Load: 2	Load: 18	Load: 18	Load: 18	Load: 21
110	+ve	79.504	1.16E+3	101.300	290.373	0.118	272.163
110	+ve	Load: 21	Load: 16	Load: 23	Load: 23	Load: 16	Load: 16
110	-ve	-82.122	-296.031	-101.556	-290.733	-0.117	-269.396
110	-ve	Load: 16	Load: 2	Load: 18	Load: 18	Load: 21	Load: 21
141	+ve	83.477	988.447	78.516	267.949	0.122	267.949
141	+ve	Load: 17	Load: 18	Load: 23	Load: 23	Load: 16	Load: 20
141	-ve	-78.516	-294.119	-83.477	-272.981	-0.122	-272.981
141	-ve	Load: 20	Load: 4	Load: 18	Load: 18	Load: 17	Load: 17
142	+ve	101.556	1.16E+3	79.504	269.396	0.118	290.373
142	+ve	Load: 17	Load: 18	Load: 23	Load: 23	Load: 18	Load: 20
142	-ve	-101.300	-296.031	-82.122	-272.163	-0.117	-290.733
142	-ve	Load: 20	Load: 4	Load: 18	Load: 18	Load: 23	Load: 17
143	+ve	101.345	1.17E+3	79.583	269.696	0.066	290.558
143	+ve	Load: 17	Load: 18	Load: 23	Load: 23	Load: 16	Load: 16
143	-ve	-101.345	-296.870	-82.154	-272.418	-0.066	-290.558
143	-ve	Load: 16	Load: 4	Load: 18	Load: 18	Load: 17	Load: 17
144	+ve	101.300	1.16E+3	79.504	269.396	0.117	290.733
144	+ve	Load: 21	Load: 18	Load: 23	Load: 23	Load: 23	Load: 16
144	-ve	-101.556	-296.031	-82.122	-272.163	-0.118	-290.373
144	-ve	Load: 16	Load: 4	Load: 18	Load: 18	Load: 18	Load: 21

RESULTS AND DISCUSSIONS

5.1 Introduction

In this study the displacements, shear force and bending moment of the 5 storey building is compared with conventional design method and numerical method using finite element analysis i.e. without soil structure interaction and with soil structure interaction. All the above stated parameters are compared in columns in F_y direction for each storey, the columns taken for comparison are peripheral columns and centre columns. It is observed that displacement, shear forces and bending moments varies from conventional design methods to numerical method.

5.2 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.

Table 5.1 Maximum displacements in Structure

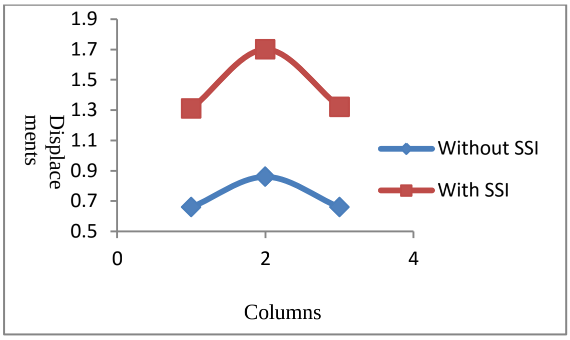
Maximum Displacements in 1st Storey in mm

Column Number	Displacement without SSI	Displacement with SSI
C 1	0.659	1.31
C 2	0.86	1.7
C 3	0.659	1.31

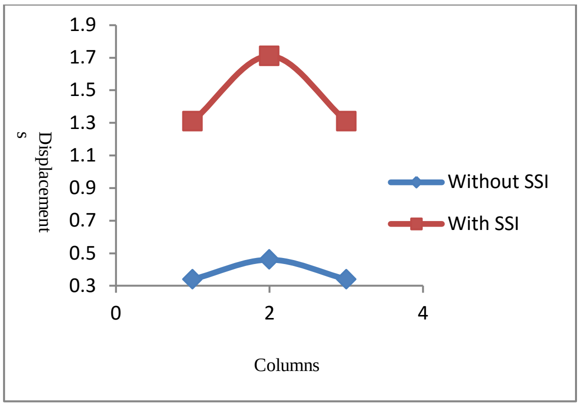
Column Number	Displacement without SSI	Displacement with SSI
C 1	0.659	1.31
C 2	0.860	1.7
C 3	0.659	1.31

Maximum Displacements in G.L in mm

Column Number	Displacement without SSI	Displacement with SSI
C 1	0.340	1.31
C 2	0.460	1.71
C 3	0.34	1.301



Graph 5.5 Maximum displacements in 1st storey with and without soil structure interaction



Graph 5.6 Maximum displacements in G.L with and without soil structure interaction

5.3 Maximum Shear Forces

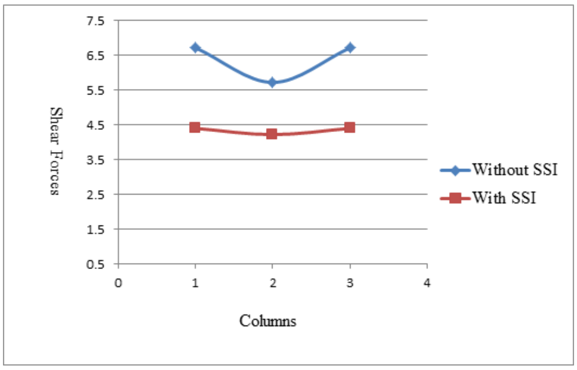
The maximum shear forces of 5 storeyed building for the cases of dead load, live load multiplied with safety factor with soil structure interaction and without soil structure interaction for each storey is presented in table below. The results are taken only for extreme loading conditions and static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

Maximum Shear Forces in 1st Storey in KN

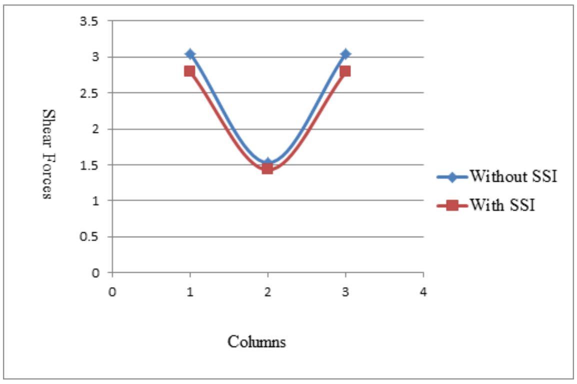
Column Number	SF without SSI	SF with SSI
C 1	6.720	4.431
C 2	5.724	4.22
C 3	6.720	4.431

Maximum Shear Forces in G.L in KN

Column Number	SF without SSI	SF with SSI
C 1	3.045	2.79
C 2	1.529	1.43
C 3	3.045	2.79



Graph 5.11 Maximum SF in 1st storey with and without soil structure interaction



Graph 5.12 Maximum SF in G.L with and without soil structure interaction

5.4 Maximum Bending Moments

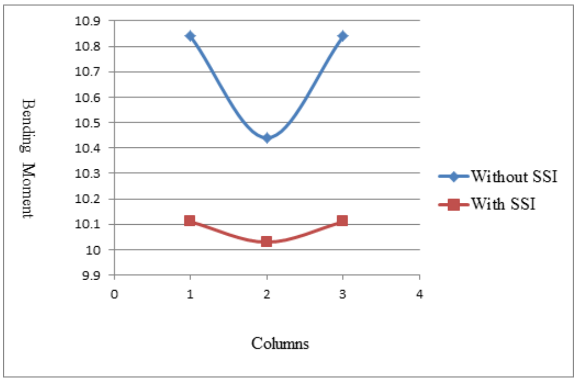
The maximum Bending Moment of 5 storeyed building for the cases of dead load, live load multiplied with safety factor with soil structure interaction and without soil structure interaction for each storey is presented in table below. The results are taken only for extreme loading conditions and static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

Maximum Bending Moments in 1st Storey in KN/m

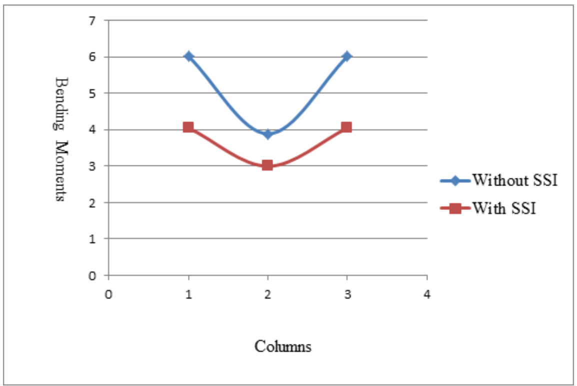
Column Number	BM without SSI	BM with SSI
C 1	10.839	10.11
C 2	10.440	10.03
C 3	10.839	10.11

Maximum Bending Moments in G.L in KN/m

Column Number	BM without SSI	BM with SSI
C 1	6.021	4.051
C 2	3.89	3.0
C 3	6.021	4.071



Graph 5.17 Maximum BM in 1st storey with and without soil structure interaction



Graph 5.18 Maximum BM in G.L 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/m^3.

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.
6. Design performed by conventional method is high safe as we are designing the structure for higher shear forces and higher bending moments.
7. Conventional method of design is somewhat uneconomical as the structure is design for higher shear forces and higher bending moments, so we can go for a structure designed by considering soil structure interaction.

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