Seismic Response of RC Shear Wall Frames Considering Soil Structure Interaction

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Abstract- *The significance of including soil-structure interaction effect in the analysis and design of RC frame buildings is increasingly recognized but still not entered to the grass root level owing to various complexities involved. The shear walls are often provided in such buildings to increase the lateral stability to resist seismic lateral loads. In the present work, the linear soil-structure analysis of a G+11 storey RC shear wall building frame resting on raft footing and supported by deformable soil is presented. The soil stiffness is computed as per FEMA 356 guidelines. The finite element modeling and analysis is carried out using ETABS software under gravity loads as well as under seismic loads. The non-interaction analysis of space frame-shear wall suggests that the presence of shear wall significantly reduces time period and displacement of the building but the interaction effect causes restoration of the time period and displacement to a great extent.*

Keywords- soil structure interaction, shear wall, bare frame, base shear, time period.

I. INTRODUCTION

The technique in which the reaction of the soil impacts the movement of the structure and the movement of the structure influences the reaction of the soil is named as soil- structure interaction (SSI). Earthquake has a super potential to purpose a wide-spread damages in thickly populated elements which causes heavy loss of human life and excessive economic losses. This is because of lack of understanding of the engineers which leads to wrong design of systems. The structural engineer who designs earthquake-resistant systems desires to recognize as to how precisely the soils reply at some stage in an earthquake. The essential part inside the knowledge of failure of the structure is seismic soil-structure interaction, however is pretty difficult to examine. Soil Structure Interaction implements a major role in the behavior of foundations, for structural components like beams, piles, mat foundations and box cells and it is essential to consider the deformational characteristics of soil and foundation flexural properties. When soil-structure interaction is taken into account, it is seen that the values or the real design outcomes are noticeable and may be unique without figuring out the soil-structure interaction proposal.

II. LITERATURE REVIEW

Mohammed Hashim Basheer et.al (2016), "Dynamic Behavior of a High Rise Reinforced Cement Concrete- RCC Structure for Different Orientation of Shear Wall with and without Soil-Structure Interaction**"** This paper includes structure with different positioning of shear wall with and without SSI using fixed base conditions have been studied. The study indicates that soil flexibility increases with decrease in stiffness. For the following boundary conditions the building is analyzed. They are fixed base and flexible base. Author concluded that Storey stiffness of flexible base decreased almost 2 to 4 times when compared to models with fixed base.[1]

B R Jayalekshmi and H K Chinmayi (2016), "Effect of soil stiffness on seismic response of reinforced concrete buildings with shear walls"This paper includes, combined shape-foundation-soil system was analyzed via finite detail software LS DYNA based on direct method of SSI assuming linear elastic conduct of soil and structure. Parametric studies have been performed to determine the impact of SSI through considering exclusive stiffness for supporting soil medium. It is concluded that better seismic performance will be available if shear walls are located at the center. [2]

Mahadev Prasad N et.al (2015), "Seismic Response of RC Bare Frame and Shear wall Frame with and without considering Soil Structure Interaction in Buildings"This paper presents, analysis of G+5 storey resting on raft footing.SAP2000 tool is considered for the study. The positioning of the shear wall at different possible location is made so that maximum benefit can be achieved. Author concluded that large difference was found in outer frame when compared to inner frame with respect to bending moment. [3]

B. R. **Jayalekshmi andH K Chinmayi** (2013) "Soil-structure interaction analysis of RC frame shears wall buildings over raft foundations under seismic loading"This paper contains building, with multiple storey which are RC framed. Analysis is made for building with and without shear wall. It is found that the value of base shear is minimum with shear wall in the building. [5]

III. PROBLEM FORMULATION

In this present study two buildings were considered one is shear wall and other is a bare frame. It is assumed to be located in severe zone on type I soil as per IS 1893 (part 1): 2002.

The following methodology is used to achieve the defined objectives.

1. A 11 storey RCC framed building with raft footing resting on homogeneous soil mass has been considered in this study. [3]
2. The building consists of 3 bays in X-direction and 2 bays in Y-direction.
3. For resisting lateral forces a double system consisting of special moment resisting frames (SMRF) and reinforced concrete shear walls are considered.
4. The shear walls are provided at the corners of the building.
5. The modeling and analysis is done by using E-tabs software.

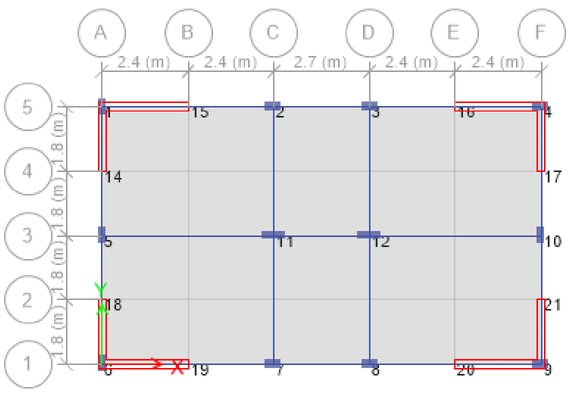

Figure- 1 Plan of Frame with Shear Wall

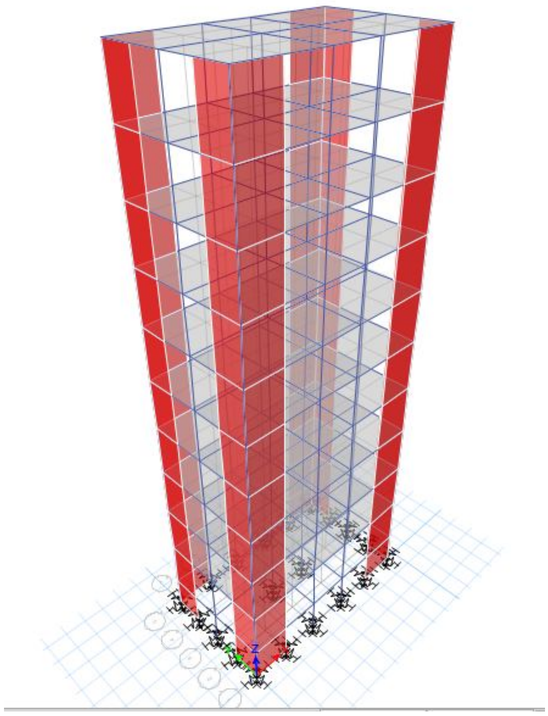

Figure-2 Sectional Elevation

Table-1 Geometric parameters of space frame-shear wall- soil system.

PARAMETER	VALUE
Number of storeys	11
Number of bays in X-direction	3
Number of bays in Y-direction	2
Bay width in X-direction	4.8m, 2.7m, 4.8m
Bay width in Y-direction	3.6m each
Storey height	3.1m
Slab thickness	150mm
Beam size	230mm x 450mm
Column sizes: 1. Exterior 2. Interior	 230mm x 450mm 230mm x 650mm
Shear wall thickness	230mm
Depth of foundation below G.L.	2.1m
Raft foundation thickness	0.6m
Semi-infinite extent of soil mass	15m from all the sides of the building and depth is 30m below footing (5m intervals)

Table-2 Material Properties of Concrete.

PROPERTY	VALUE
Grade of concrete for all structural elements	M30
Modulus of elasticity of concrete (N/mm^2)	$E_c = 5000\sqrt{fck}$
Poisson's ratio of concrete	0.2
Density of concrete	25000 N/m^3

The building is considered to be a residential building. The live loads are considered as per IS 875 (Part 2):1987. The brick masonry wall on the beams of the building and parapet wall on roof periphery are also considered. The details of various loads considered are given in Table.2. These are in addition to the self-weight of the structure.

Table-3 Dead load and Live load on structure.

DESCRIPTION	VALUE
Dead load of floor finish	1.5kN/m^2
Dead load of finishing and water proofing on roof	1.5kN/m^2
Live load on floors	2 kN/m^2
Live load on roof	1 kN/m^2
Brick walls (on all beams)	14.26 kN/m
Parapet wall on roof periphery	4.6kN/m

For seismic load calculations, equivalent static lateral force method is used as per IS 1893 (Part 1): 2002.

Table-4 Parameters for Lateral Seismic Load calculations on the structure.

PARAMETER	VALUE
Earthquake zone	V
Zone factor 'Z' (Table 2 of IS 1893 (Part 1): 2002)	0.36
Importance factor 'I' (Table 6 of IS 1893 (Part 1): 2002)	1.0
Response reduction factor 'R' (Table-7 of IS 1893 (Part 1): (2002) (Ordinary shear wall with SMRF)	5
Approximate fundamental natural period of vibration (Ta) $Ta = 0.075h^{0.75} = 0.075(33.1)^{0.75} = 1.034$ (as per clause 7.6.1 of IS 1893 (Part 1): 2002	1.034 sec
Soil type	I (Hard soil)

IV. RESULTS

1. *FUNDAMENTAL NATURAL PERIOD*

Table-5: Percentage Variation in Natural Period of Building

NATURAL PERIOD OF BUILDING						
BUILDING TYPE	SOIL TYPE	TIME PERIOD (SEC)		% Variation in natural period		
		WITHOUT SSI	WITH SSI	Due to soil	Due to shear wall	Due to soil and shear wall
BARE FRAME	Hard soil	1.364	1.281	-6.085	–	–
	Dense soil		1.348	-1.17		
	Soft soil		1.382	1.31		
SHEAR WALL	Hard soil	0.843	0.708	-16.01	-48.09	-44.73
	Dense soil		0.821	-2.609	-39.80	-39.09
	Soft soil		0.856	1.54	-37.24	-38.06

2. *BASE SHEAR*

Table-6 Percentage Variation in Base Shear of Building

Percentage variation in base shear of building				
BUILDING TYPE	SOIL TYPE	% variation in base shear		
		WITHOUT SSI (KN)	WITH SSI (KN)	Due to soil and shear wall
BARE FRAME	Hard soil	816.191	816.191	–
	Medium soil		1110.02	
	Soft soil		1363.039	
SHEAR WALL	Hard soil	1031.712	712.5202	12.70
	Medium soil		969.0275	12.70
	Soft soil		1189.909	12.70

3. *STOREY DISPLACEMENT*

Table-7: Storey Displacement in X-X direction for shear wall

STOREY	SHEAR WALL X-X DIRECTION			
	WITHOUT SSI (mm)	HARD SOIL (mm)	MEDIUM SOIL (mm)	SOFT SOIL (mm)
STOREY 11	51.494	25.713	34.869	43.099
STOREY 10	46.865	23.468	31.82	39.341
STOREY 9	41.882	21.046	28.531	35.288
STOREY 8	36.486	18.687	24.96	30.887
STOREY 7	30.728	15.6	21.137	26.176
STOREY 6	24.746	12.662	17.148	21.26
STOREY 5	18.741	9.698	13.125	16.299
STOREY 4	12.973	6.831	9.235	11.497
STOREY 3	7.763	4.211	5.683	7.105
STOREY 2	3.509	2.024	2.722	3.432
STOREY 1	0.575	0.393	0.523	0.871
BASE	0	0	0	0

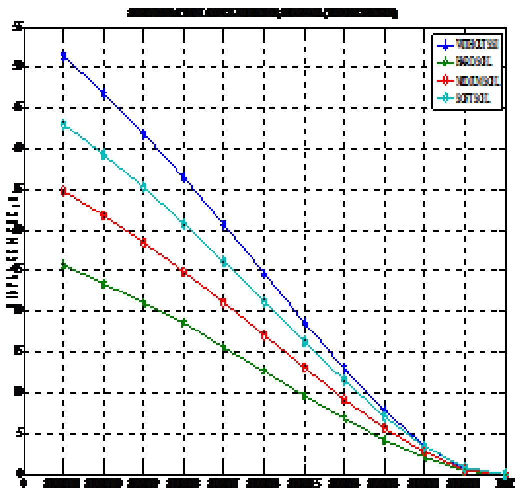

Figure no.3: Graphical representation of storey displacement for shear wall (X-X) direction with and without SSI.

Table no. 8: Storey Displacement in Y-Y direction for shear wall

STOREY	SHEAR WALL Y-Y DIRECTION			
	WITHOUT SSI (mm)	HARD SOIL (mm)	MEDIUM SOIL (mm)	SOFT SOIL (mm)
STOREY 11	62.201	31.277	42.394	52.447
STOREY 10	57.485	28.955	39.247	48.555
STOREY 9	52.162	26.336	35.247	44.165
STOREY 8	46.121	23.359	31.656	39.179
STOREY 7	39.426	20.055	27.173	33.647
STOREY 6	32.253	16.508	22.36	27.707
STOREY 5	24.851	12.837	17.378	21.56
STOREY 4	17.543	9.194	12.437	15.459
STOREY 3	10.736	5.772	7.796	9.723
STOREY 2	4.97	2.82	3.799	4.77
STOREY 1	0.829	0.686	0.916	1.17
BASE	0	0	0	0

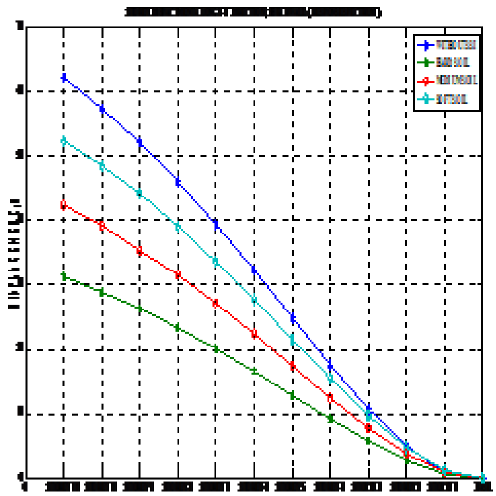

Figure no.4: Graphical representation of storey displacement for shear wall (Y-Y) direction with and without SSI

4. STOREY DRIFT

Table-9: Storey Drift in X-X direction
For shear wall with and without SSI

STOREY	SHEAR WALL X-X DIRECTION			
	WITHOUT SSI (mm)	HARD SOIL (mm)	MEDIUM SOIL (mm)	SOFT SOIL (mm)
STOREY 11	0.0014	0.000724	0.000982	0.001211
STOREY 10	0.001607	0.000781	0.001059	0.001306
STOREY 9	0.00174	0.000848	0.001151	0.001418
STOREY 8	0.00185	0.000908	0.001232	0.001518
STOREY 7	0.00193	0.000908	0.001285	0.001583
STOREY 6	0.001937	0.000948	0.001295	0.001598
STOREY 5	0.001861	0.000956	0.001252	0.001546
STOREY 4	0.001681	0.000925	0.001142	0.001412
STOREY 3	0.001372	0.000845	0.000961	0.001185
STOREY 2	0.000923	0.000706	0.000676	0.000839
STOREY 1	0.000398	0.000259	0.000319	0.000405
BASE	0	0	0	0

Table -10: Storey Drift in Y-Y direction for shear wall with and without SSI.

STOREY	SHEAR WALL Y-Y DIRECTION			
	WITHOUT SSI (mm)	HARD SOIL (mm)	MEDIUM SOIL (mm)	SOFT SOIL (mm)
STOREY 11	0.001521	0.000749	0.001013	0.001252
STOREY 10	0.001717	0.000845	0.001144	0.001413
STOREY 9	0.001949	0.00096	0.0013	0.001605
STOREY 8	0.00216	0.001066	0.001443	0.001788
STOREY 7	0.002314	0.001144	0.00155	0.001913
STOREY 6	0.002388	0.001184	0.001604	0.001979
STOREY 5	0.002358	0.001175	0.00159	0.001964
STOREY 4	0.002196	0.001104	0.001492	0.001845
STOREY 3	0.00186	0.000873	0.001283	0.00159
STOREY 2	0.001295	0.000714	0.000916	0.001143
STOREY 1	0.000776	0.000477	0.00043	0.000548
BASE	0	0	0	0

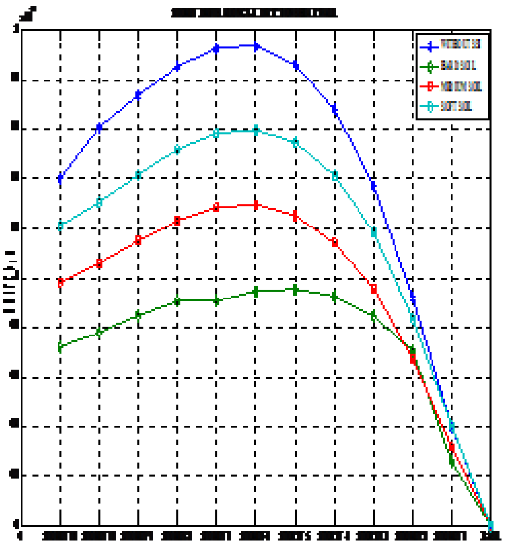

Figure no. 5: Graphical representation of storey drift for shear wall (X-X) direction with and without SSI.

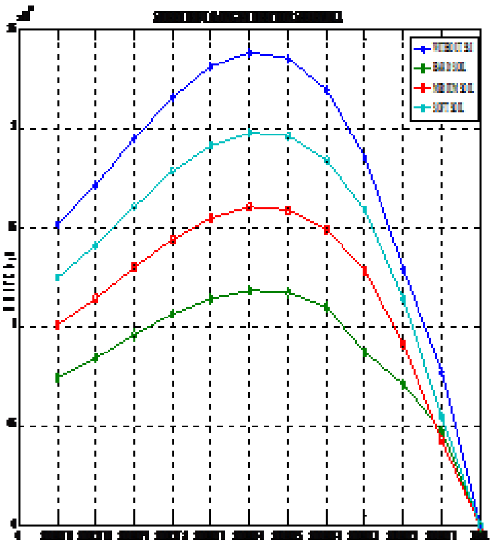

Figure no. 6: Graphical representation of storey drift for shear wall (Y-Y) direction with and without SSI.

V. CONCLUSION

From 11 storeys building considering different parameters the following observations were made.

i. The base shear values by manual calculation and ETABS software are compared and are validated.
ii. In consideration of SSI there is rise in time period of the structure when compared to without SSI.

iii. The values of base shear obtained for building models with shear walls are more when compared with bare frame.
iv. The storey displacement is more in top storey in bare frame with SSI in soft soil when compared to bare frame with SSI in medium and hard soil.
v. Storey drifts is found higher in the middle floors of the structures with and without soil structure interaction.
vi. The effect of SSI should be considered in the buildings which are located in the earthquake prone areas.
vii. Shear walls are quite stiff in their own plane and flexible in perpendicular plane. Therefore, it can transfer the lateral force in its own plane by developing moment and shear resistance. Shear walls increase the stiffness of the building so that the horizontal deflection due to the earthquake forces is minimized.
viii. The seismic behavior of high rise buildings, heavy structures resting on relatively soft soil is greatly influenced by the soil structure interaction and hence SSI should be taken into consideration.
ix. Considering the effect of SSI enable the structure to perform better during seismic activity.

REFERENCES

[1] M. H. B. et.al, "Dynamic Behaviour of a High Rise Reinforced Cement Concrete- RCC Structure for Different Orientation of Shear Wall with and without Soil-Structure Interaction," *IJESC,* vol. 6, no. 4, pp. 4492-4499, april 2016.
[2] B. R. J. a. H. K. Chinmayi, "Effect of soil stiffness on seismic response of reinforced concrete buildings with shear walls," *Hindawi* , pp. 1-18, 2016.
[3] M. H. N. D. N. a. M. S. Y. B. Mahadev Prasad N, "Seismic Response of RC Bare Frame and Shear Wall Frames With and Without Considering Soil Structure Interaction in Buildings," *ijraset,* vol. 03, no. 11, pp. 45-56, june-2015.
[4] S. H. a. R. J. Fernandes, "Soil Structure Interaction on RC Framed irregular Building with Shear Walls," *International Research Journal of Engineering and Technology* , vol. 02, no. 04, pp. 1739-1745, july-2015.
[5] B. R. J. a. H. K. Chinmayi, "Soil-structure interaction analysis of RC frame shear wall buildings over raft foundations under seismic loading," *International Journal of Scientific & Engineering Research* , vol. 04, no. 05, pp. 99-102, may 2013.
[6] M. H. Vivek garg, "A review on interaction behaviour of structure-foundation-soil system," *IJERA,* vol. 2, no. 6, pp. 639-644, 2012.
[7] K. M. H. S.A, " Effect of Shear Wall in the Seismic Analysis of Building Frames Considering Soil- Structure Interaction," vol. 05, pp. 3372-3379, oct-2015.
[8] P. V. et.al, "Soil-Structure Interaction Effects on RC framed Shear wall Buildings - A Review," vol. 02, no. 02, pp. 102-106, April-2016.
[9] "IS 1893 (part I): 2002 -Criteria for Earthquake Resistant Design of Structures.".
[10] V. H. Kanhiya Abhay Zanwar, "Study on Soil Structure Interaction," *IJSRD,* vol. 04, no. 05, 2016.