Soil Structure Interaction of Tall Buildings

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ABSTRACT
The conventional design procedure involves the assumption of the fixity at the base of the foundation and therefore, neglects of the flexibility of the foundation and the compressibility of the sub-soil. For the realistic solution, it is essential that the superstructure- foundation- soil interaction be considered as one compatible unit. Finite element method is one such amongst them.in view of the afore-mentioned observations, the interaction analyses have been reported to quantify the effect of soil-structure interaction on the response of the building frame resting on raft foundation recently. Along similar lines and based on the scope outlined in those studies, an attempt has been made here to carry out the interactive analysis of the building frame having forty and eighty storey resting on typical raft foundation. For this purpose a study is carried out on raft foundation resting in cohesive soil, subjected to lateral load. For the purpose of the analysis, simplified idealizations are made in the theory of finite elements. The slab of the frame is idealized as three dimensional four-noded shell elements. Beams and columns of the superstructure frame are idealized as three dimensional two-noded beam elements. Raft of the sub-structure is idealized as three dimensional four-noded shell elements. In the independent analysis response of the structure is considered in terms of bending moments, shear force, deflection developed in structure. The effect of soil- structure interaction is observed to be significant for the behavior of structure considered in the present study for all the cases considered. The building is analyzed for various load cases, mainly gravity loads (due to dead load and live load) and lateral loads). Analysis is carried out by using standard package ETABS. The comparison of these models for different parameters like Storey Displacement, Column Bending moments and Time period are presented

Keywords
Lateral displacement, Shear force, Storey drift, Storey shear, Shear wall, Time period

1. INTRODUCTION
Spectacular failure of structures has been observed in every major seismic event. Gujarat earthquake of 26 January 2001 have demonstrated that the strength alone would not be sufficient for the safety of structures during the earthquake. In conventional design, buildings are generally considered to be fixed at their bases. In reality, flexibility of the supporting soil medium allows some movement of the foundation. However, if the structure is very massive and stiff, such as high-rise buildings, and the foundation is relatively soft, the motion at the base of the structure may be significantlydifferent than the free-field surface motion. A foundation is interface between superstructure with underlying soil or rock. In seismic environment, the loads imposed on a foundation from a structure under seismic excitation can greatly exceed the static vertical loads or even produce uplift; in addition, there will be horizontal forces and possibly moments at the foundation level. Structural engineering and geotechnical engineering are frequently isolated from one another as if they were two independent disciplines. In reality, however, a structure and the soil on which it is founded are one system, and their interplay must be considered in order to achieve reasonably accurate soil settlement prediction In cities like Mumbai which are located on seashore, most of area consist of reclaimed soil, because of constraint on space & land high rise building are essential. Also recent trend of construction is that numbers of buildings are constructed on island where founding base of building created by artificial created inland. As a result of this soft layers of soil the earthquake ground motion get modified & high rise building have relatively longer predominant time period. Due to this soil structure interaction, response of structure get significantly modified and detailed studies needs to be done while design such a buildings

2. BUILDING DESCRIPTION
A building is assumed for analysis that consists of a G+40 storey R.C.C. Residential building. The plan of the building is regular in nature. The building is located in Seismic Zone III and is assume on soil with bearing capacity of 80 T/m2 and 250 T/m2. The building is 120.0 in height, length is 50m and 55m in width. The important features of this building are shown in Table 1.

Table 1: Salient features of the building

Type of Structure	Multi-storey frame structure.
Design Philosophy	Limit state method conforming to IS: 456 - 2000
Number of stories	(G + 40)
Total height of buildings above Natural Ground level	120 m
Floor Heights	All Typical Floors = 3.00m
Walls	200 mm thick including plaster
Materials	M 30 , M40, M50, M60, M70 and Fe 500
Seismic analysis	Dynamic method
Seismic zone	III
Response Reduction factor	5
Importance Factor	1
Basic Wind Speed	44m\s
Category Wind	3
Class	1
Spring properties	Bearing capacity / Allowable settlement

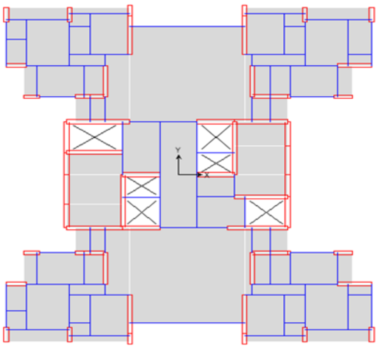

Fig 1: Plan

3. MODEL & ANALYSIS

Building is modeled using standard package ETAB. Beams are modeled as two noded beam elements with six DOF at each node. Shear wall are modeled using shell element. Equivalent static analysis or linear static analysis is performed on models. Based on analysis result parameters such as story displacement, column forces, the time period is compared with respect to mode shape are compared for each model. Following the model have been considered

Case I: Forty storey building having fixed support at base.

Case II : Forty storey building having raft foundation resting on soil having bearing capacity of 250 T/m2.

Case III: Forty storey building having raft foundation resting on soil having bearing capacity of 80T/m2

Fig 2: Etabs 3D view of model with (i) Fixed support (ii) Support on raft

4. RESULTS & DISCUSSION

4.1 Column / Shear wall forces

Table 1 – Column Forces

		P (Kn)			M3 (Kn-m)		
Pier	Story	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
W1	40	373	374	373	240	246	252
	30	5251	5207	5147	3498	3489	3466
	20	10167	10076	9951	6441	6382	6307
	10	16236	15831	15441	10499	10196	9924
	1	22819	20304	18364	14993	15884	15166
W2	40	712	702	692	1491	1452	1417
	30	6169	6068	5974	1722	1710	1695
	20	11650	11432	11238	1547	1555	1552
	10	17349	16841	16505	1776	2271	2163
	1	3243	25520	26666	4984	12308	13771
W3	40	723	732	743	159	187	219
	30	7963	8081	8226	398	424	449
	20	15268	15533	15857	386	401	426
	10	22555	23064	23674	1070	1072	1096
	1	29227	30136	31197	3599	4100	9830
W4	40	255	257	259	128	138	150
	30	2753	2780	2816	84	89	96
	20	5285	5336	5413	102	108	118
	10	7813	7886	8028	128	135	150
	1	10016	10098	10349	196	381	237
W5	40	136	137	139	100	96	92
	30	1750	1756	1759	66	65	49
	20	3358	3364	3359	66	65	64
	10	4999	4963	4897	88	91	90
	1	6469	6346	6128	142	387	491

From the analysis result of all the three cases it is observed that the column forces at lower storey increases drastically for buildings under SSI as compared to the fixed support.. The variation in forces is in the range of 10-125 percent .Columns in the internal part of the frame is less effected as compared to the columns in the outer edges. Bending moment / forces in the column increased at lower levels by performing SSI analysis as compared to that of fixed condition

4.2 STOREY DISPLACEMENT

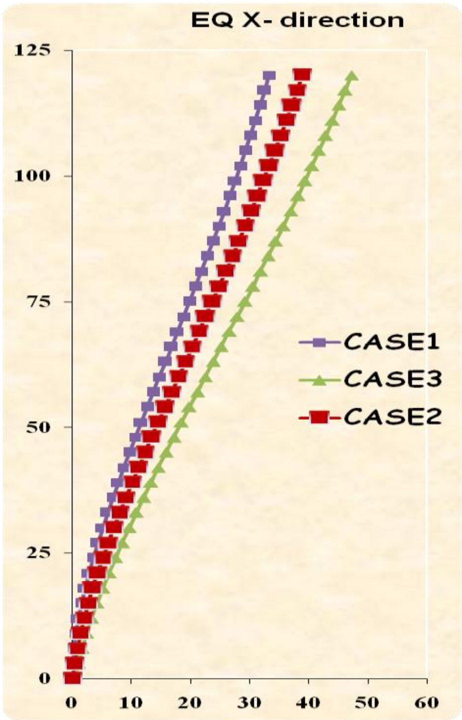

Fig 3: Displacement in EQx

The storey deformation in X and Y direction graphical representation is shown in Fig. 3 and 4 respectively.

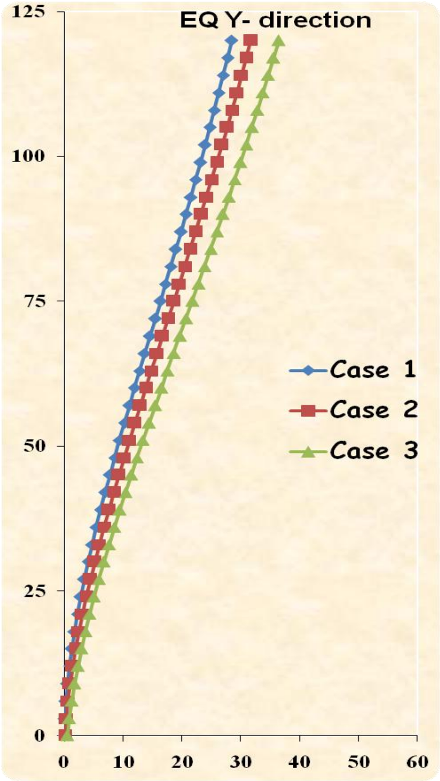

Fig 4: Displacement in EQy

From the storey displacement in X and Y direction for different cases, it is seen that the model 3 shows the higher displacement. However, in respect of other models, the storey drift is found to increase with number of stories. Deflection of the building increases while analyzing the tall buildings with SSI method

4.3 TIME PERIOD & MODE SHAPE

The mode shape with respect to time period for different models is shown in Table 5. Along similar lines, the mode shape with respect to fundamental time period is shown in Fig.6

Table 2 – Table of time period & frequency

Mode	Case 1	Case 2	Case 3
1	2.69	2.92	3.24
2	2.44	2.59	2.79
3	2.01	2.08	2.14
4	0.72	0.75	0.77
5	0.65	0.67	0.70
6	0.61	0.62	0.64
7	0.34	0.36	0.38
8	0.30	0.34	0.36
9	0.21	0.31	0.33
10	0.16	0.22	0.24
11	0.14	0.22	0.24
12	0.07	0.19	0.22

Frequency (Hz)

Mode	Case 1	Case 2	Case 3
1	0.37	0.34	0.31
2	0.41	0.39	0.36
3	0.50	0.48	0.47

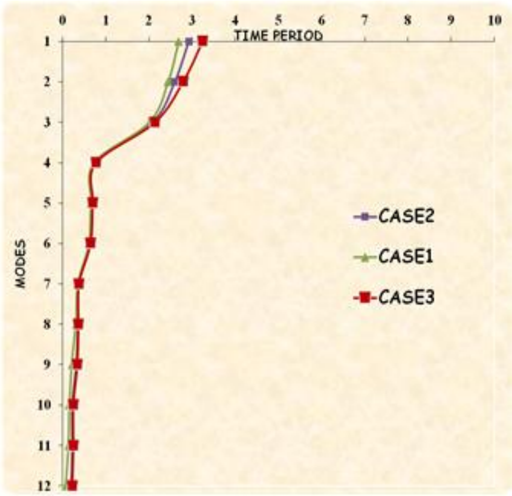

Fig 6: Mode shape with respect to time period.

From Fig. 6, the fundamental time period is found to be more in Mode shape 1 from model 3. The trend of time period is less in other models considered in the present investigation) we see considerable difference in the response of the building. Time period of the buildings has increased from fixed base to actual Raft spring model.

5. CONCLUSION

The behaviors of multistoried building with fixed support & without fixed but resting on the raft with consideration of soil interaction have been studied in present paper. In this we get the results from analysis of model for case1 (case 1) its shows the less lateral displacement, mode shape with respect to time. From the nonlinear Etabs models, it is concluded that the soil interaction effect is very remarkable. Deflection of the building increases while analyzing the tall buildings with SSI method. In addition to building height, stiffness of the structural members in building the soil parameters played a main role in controlling the deflection of the building. Softer the soil more was the deflection. Time period & frequency is shooting up for the cases considering SSI. Softer the soil more was the time period. Also the time period variation was higher for taller buildings, hence higher the storey more will be the effect due to soil .Comparing the time period of building (case 1 with case 2 and case 3) we see considerable difference in the response of the building. Time period of the buildings has increased from fixed base to actual Raft spring model. This results in under estimation the actual force in structure in case 1, this may also affect the stability of the building. Bending moment / forces in the column increased at lower levels by performing SSI analysis as compared to that of fixed condition.

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