Influence of Soil Structure Interaction on Seismic Response of Multistorey Building Located in Kutch Area

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Abstract— Soil plays an important role in static as well as dynamic response of structure. Hence evaluation of the site specific effect of soil stiffness on structure becomes important to understand behavior of structure. Flexibility of soil increases natural period of structure which in turn changes the seismic response of structure. G+14 story building is analyzed considering soil base. Soil data of 3 location in Kutch region are collected upto 35 m depth. Three synthetic time history are prepared at that location using time frequency approach and nonlinear time history analysis had been carried out. Effect of soil structure interaction on natural period, base shear, roof displacement, maximum bending moment and torsion moment in column are compared with fixed base analysis. Midas Gen is used for the analysis tool.
Key words: Multistorey Building, Influence

I. INTRODUCTION

Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil such as low rise building. The effects of SSI however becomes prominent for heavy structures resting on relatively soil having Vs,30 <200 m/s.

Damage sustained in past earthquakes such as 1995 Kobe earthquake have also highlighted that the seismic behavior of structure is highly influenced not only by response of the superstructure, but also by the response of the foundation and the ground as well. A seismic soil structure interaction analysis evaluates the collective response of structure, the foundation and geologic media underlying and surrounding the foundation.

There are basic two types of effects due to SSI: 1. Difference between foundation input motion and free field ground motion 2. Stiffness and damping of foundation. The smooth idealization of design spectrum suggests smaller seismic response with the increased natural period and effective damping ratio due to SSI. With this assumption, it was traditionally been considered that SSI can be neglected for conservative design.

II. GENERAL DATA

- Location: Kutch (Seismic Zone V)
- Type of structure: RC framed structure
- Storey height: 3 m
- Size of column: 400mm x 700mm
- Size of beam: 300mm x 600mm
- Thickness of shear wall: 230mm
- Plan dimension: 20m x 20m
- Grade of material: M40 and Fe415

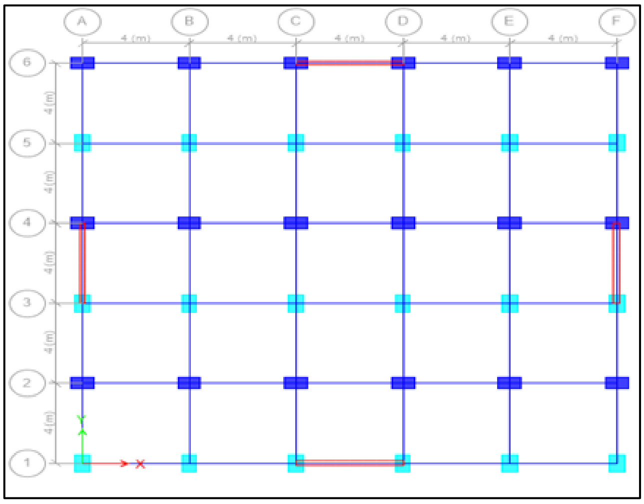

Fig. 1: Plan of Building

There are two foundation system is used for G+14 storey building i.e. raft footing and piled raft foundation. The depth of foundation is kept 2m below ground level.

Sr. No.	Type of foundation	Details of foundation	Grade of concrete
1	Raft foundation	1600 mm Thick raft	M30
2	Piled raft foundation	Raft : 1000mm Thick Piles : 500mm Dia, 36 No of pile having 14m length	M30

Table 1: Details of Substructure System

III. SOIL PROPERTY

The soil property had been taken from actual bore log report at three different location of Kutch region i.e. Greater ran of kutch near Hajipur, Kandla and Hajipur. Various soil property such as modulus of elasticity and poisons ratio are taken from its co-relation with SPT value.

Depth	Type of Soil	E_s (N/mm^2)	μ
1.2 m	Brownish clay	45	0.30
7.6 m	Hard clay	65	0.37
15.0 m	Very stiff clay	89	0.35
23.2 m	Stiff clay and gravel	105	0.38
30.0 m	Clay, sand and gravel	135	0.39
35.0 m	Gravelly soil	150	0.41

Table 2: Soil Property at Hajipur

Depth	Type of Soil	E_s (N/mm^2)	μ
3.2 m	Soft clay and silts	15	0.4
9.6 m	Stiff brownish clay	50	0.3
19.2 m	Very stiff clay	72	0.26
27.0 m	Dense sand	81	0.20
35.0 m	Shale type rock	5000	0.13

Table 3: Soil Property at Kandla

Depth	Type of Soil	E_s (N/mm^2)	μ
0.8 m	Organic Silty clay	5	0.38
5.6 m	Loess	22	0.37
15.4 m	Loam	27	0.32
23.7 m	Very stiff clay	75	0.26
29.2 m	Very hard clay	135	0.25
35.0 m	Gravelly soil	150	0.25

Table 4: Soil Property at Bhachau

IV. MODELLING AND ANALYSIS

The 15 storey building had been modeled and analyzed in Midas Gen. In fixed base analysis, the base of column in considered to be fixed neglecting the effects of flexibility of soil media below foundation.

In substructure method of SSI (flexible base), the layered soil had been modeled as equivalent static spring having six degree of freedom (3 DOF in translation direction, 2 DOF in rocking and 1 DOF in torsion). The stiffness of spring had been determined as per ASCE 41-06 code. The stiffness of spring account for dimension of footing, depth of foundation, modulus of elasticity and poisons ratio of soil. In Midas Gen, Elastic Link command had been used to model layered soil as massless spring element.

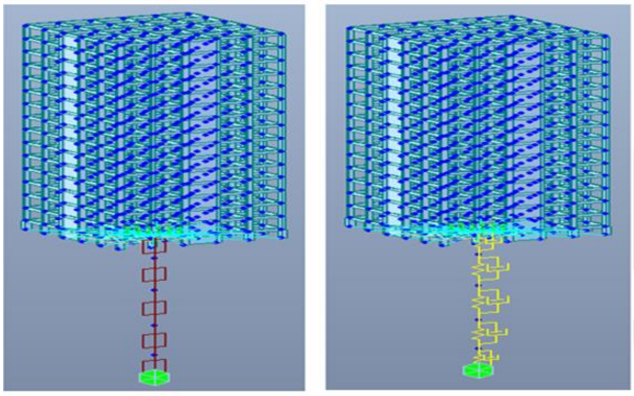

Fig. 2: Substructure Method of SSI in Midas Gen

In the second method of soil structure interaction, the layered soil had been modeled as a series of dynamic spring having 6 degree of freedom along with damping. The dynamic stiffness of spring had been determined as per guideline of NIST. The radiation damping ratio had been calculated as per guideline of NIST after adding hysteretic damping to radiation damping which is obtained from NIST guideline.

Nonlinear analysis had been carried out using direct integration method with modal damping of 5%. The synthetic time history (Mw 7.6) of 19thJune 2012 Kutch EQ (Mw 5.1) had been prepared with help of Indian Seismological Research Centre using time frequency approach.

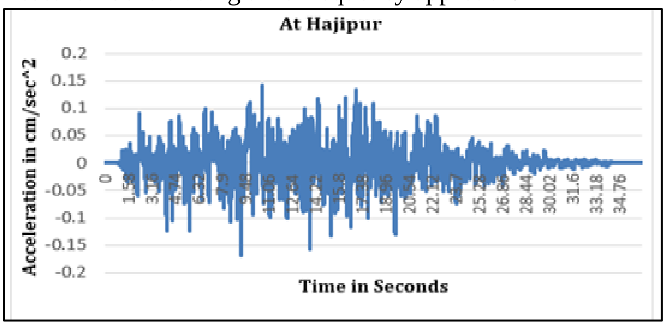

Fig. 3: Synthetic Time History at Hajipur

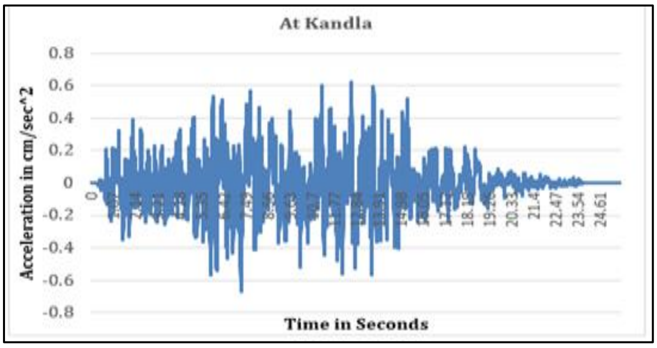

Fig. 4: Synthetic Time History at Kandla

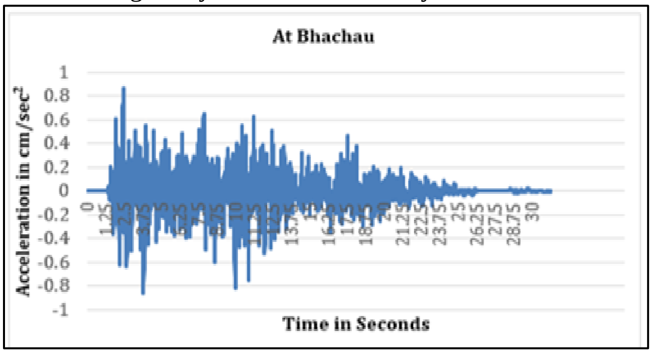

Fig. 5: Synthetic Time History at Bhachau

V. RESULTS

The natural period of 15 storey building with raft footing has been increased by 9.06% at Hajipur, 19.00% at Kandla and 18.09% at Bhachau in case of flexible base as compared to fixed case while in case of piled raft footing, natural period had been increased by 5.13% at Hajipur, 8.40% at Kandla and 8.95% at Bhachau.

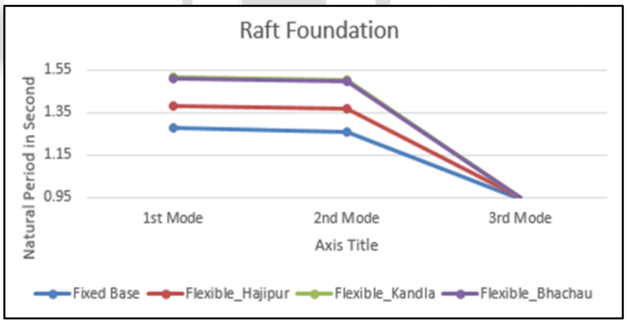

Fig. 6:

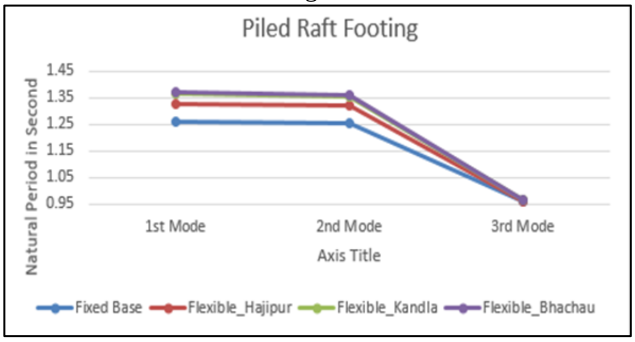

Fig. 7:

The base shear had been reduced by 9.91% at Hajipur, 37.60% at Kandla and 40.00% at Kandla in raft foundation in substructure method of SSI as compared to fixed base condition while in case of piled raft footing, base shear had been reduced by 14.50% at Hajipur, 38.01% at Kandla and 38.59% at Bhachau.

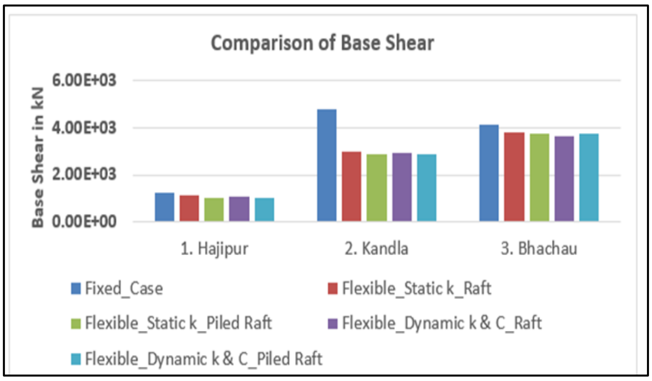

Fig. 8:

The roof displacement had been increased in case of substructure method when compared to fixed base analysis. The increase of roof displacement is highest for raft footing when compared to pile raft footing because of additional stiffness provided by piles to the superstructure. Also increase of roof displacement is least for Hajipur location because of hard soil and smaller PGA.

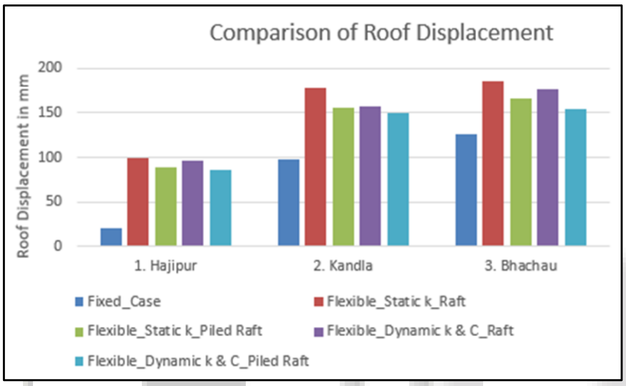

Fig. 9:

The torsion moment in exterior column at ground level had been decreased by 5.63% at Hajipur, 3.03% at Kandla and 2.17% at Bhachau in raft foundation with static stiffness of spring while in case of dynamic spring with damping, the decrease of torsion moment is 3.90% at Hajipur, 2.97% at Kandla and 2.09% at Bhachau when compared to fixed condition.

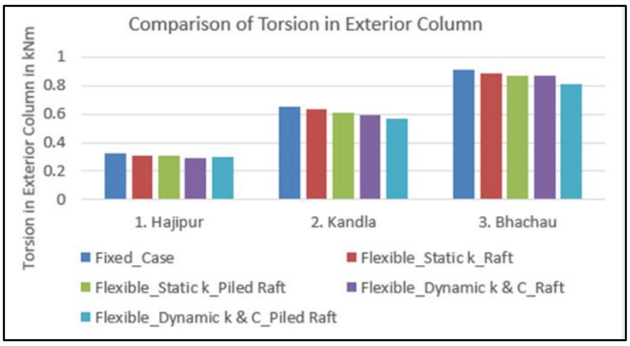

Fig. 10:

The moment in exterior column had been decreased by 9.10% at Hajipur, 2.01% at Kandla and 1.97% at Bhachau in raft foundation in static spring of flexible base method of SSI when compared with fixed base condition while in case piled raft footing with dynamic stiffness along with damping, moment had been decreased by 18.68% at Hajipur, 15.79% at Kandla and 14.56% at Bhachau.

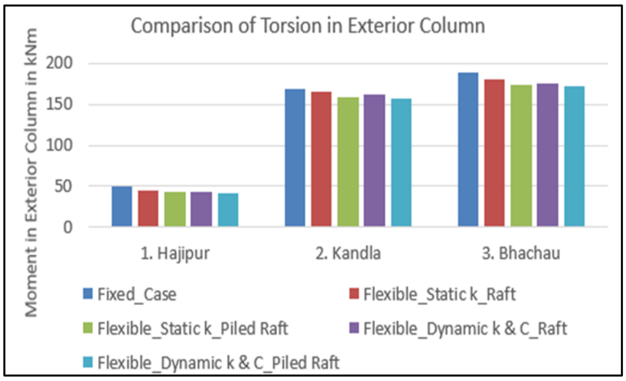

Fig. 11:

VI. CONCLUSION

The natural period of structure is increased at all location when flexibility of soil considered in analysis. However increase of natural period depend upon stiffness of soil and type of foundation. The effect of irregularity on natural period is very less.

Base shear is highest at Kandla location while it is least for Hajipur hence magnitude of reduction in base shear depend on PGA observed at site as well as shear wave velocity through soil media.

The inclusion of SSI effects in analysis always accompanied by increase of roof displacement. The increase of roof displacement is highest for Hajipur while it is least at Bhachau.

The inclusion of damping of soil media in analysis and design reduce base shear and moment in column while it has very less effects on roof displacement.

SSI effects must be considered for multistoried building resting on soft media as it changes seismic response parameter considerably.

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