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Assessment of Soil Structure Interaction Analysis of Asymmetrical RC Building

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***Abstract*—The influence of soil-structure interaction in the analysis and design of a 4Bay and 5Bay 5-storey building with isolated footing is investigated. Models simulating two different conditions: namely soil-structure interaction and fixed-base behavior, effect of infill on lateral load resistance are considered. The influence of the soil structure interaction in the dynamic behavior of the structure shows an increase in the vibration period in comparison with the fixed-base model, which does not consider the supporting soil. The influence of the soil-structure interaction in the seismic design of the structure is reflected in a decrease of the horizontal spectral acceleration values. The inclusion of the soil in the structural analysis provides results, base shear and displacement values, which are closer to the actual behavior of the structure than those provided by the analysis of a fixed-base structure.**

Keywords— Soil-structure interaction, dynamic behavior of soil, performance point, spectral accelerations, base shear

I. INTRODUCTION

The aim of this paper is to investigate the influence of soil-structure interaction in the analysis of an asymmetric public building consisting of 5-storey and structured as reinforced concrete frames using E-TABS 2013 software.
Special attention is paid to:

a. The influence of soil-structure interaction in the dynamic behavior of the structure
b. The implications of the soil-structure interaction in the seismic design of the structure. The building is located in North Karnataka, India.

II. IDEALIZATION OF THE SYSTEM

a. Structural Idealization

A five-storey public buildings located in zone 3 as per Indian code is considered. The building models having 4bay and 5bay of size 20 m wide and 20 m resting on isolated footing. The storey height of the building frame was chosen as 3.5m and depth of foundation is 1.5m for all cases dimensions of the column 400 x 500 mm, dimensions of beam 300 x 400 mm the thickness of slab is 120mm and thickness of wall is 230mm.

b. Idealized Soil Behavior model

The function of the foundation media is to resist the forces applied to it by the base of the building. During earthquake, a rigid base may be subjected to displacement in six degrees of freedom, and the resistance of soil may be expressed by the six corresponding resultant force components. Hence the structural behavior of the elastic half space is presented completely by a set of force displacement relationships defined for these degrees of freedom. Appropriate static spring constants can be evaluated for the elastic half space by the method of continuum mechanics.

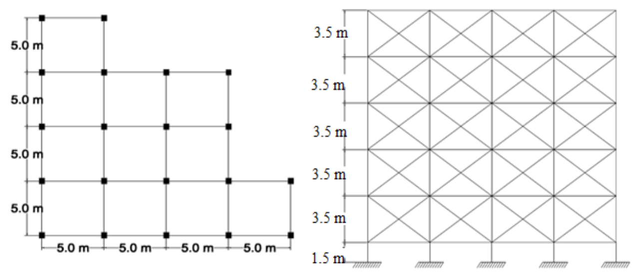


Fig 1.Plan and Elevation of 4 Bay Building

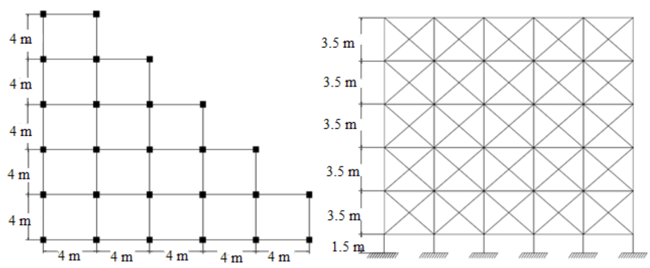


Fig 2.Plan and Elevation of 5 Bay Building

Table 1 Details of Soil Parameters Considered

Type of soil	N value considered	Mass density (ρ) KN/m^3	Shear modulus $G = 13333.33\ N^{0.8}$ KN/m^2	Poisson ratio (μ)
Hard	30	21	202598.22	0.5
Medium	6	18.5	55906.16	0.5
Very soft	1	13.5	13333.33	0.5

Table 2 Static Stiffness's of Equivalent Soil Spring for Rectangular Footing

Length L (m)	Breadth B (M)	Equivalent soil spring stiffness	Very soft soil	Medium soil	Hard soil	units
2.0	1.5	Kx	67692	283830	1028572	KN/m
2.0	1.5	Ky	70358	295011	1069092	KN/m
2.0	1.5	Kz	105126	440792	1597388	KN/m
2.0	1.5	Krx	51648	216560	784793	KN-m/deg
2.0	1.5	Kry	83527	350228	1269193	KN-m/deg
2.0	1.5	Kt	80003	335453	121549	KN-m/deg

III. INPUT DESIGN DATA FOR BUILDING

Material Properties :

Concrete

i. E_c = 25×10^6 KN/m^2

ii. ρ_c = 25 KN/m^3

Brick masonry

i. $E_m = 13.8 \times 10^6$ KN/m^2

ii. $P_m = 20$ KN/m^3

Assumed Dead load intensities :

i. Floor finishes = 1.0 KN/m^2

ii. Roof finishes = 2.0 KN/m^2

Live load intensities :

i. Roof = 1.5 KN/m^2

ii. Floor = 3.0 KN/m^2

Member properties :

i. Thickness of Slab = 0.120 m

ii. Column size = (0.40 m × 0.50 m)

iii. Beam size = (0.30 m × 0.40 m)

iv. Thickness of wall = 0.230 m

Earthquake load : As per IS-1893 (Part 1) – 2002
Type of soil : Type II, Medium as per IS: 1893
Typical storey height is 3.5 m and Depth of foundation below ground: 1.5 m
Earthquake live load on slab as per IS: 1893-2002 (Part 1) is calculated as:

i. Roof = 0

ii. Floor = 0.25 × 3.0 = 0.75 KN/m^2

Seismic Zone = Zone III

Type of Building = Public

IV. METHOD OF ANALYSIS

The analyses of the building are carried out using ETABS computer program. The following topics describe some of the important areas in the modeling.

While defining the type of behavior of wall and slab section in ETABS there are three options available namely shell type, membrane type, and plate type behavior.

In the present analysis all the slab is given membrane type behavior to provide in plane stiffness. The slab sections are modeled as rigid diaphragms by using the rigid diaphragm option in the assign menu. By modeling the slab as rigid diaphragms the masses of the floor are automatically lumped at their center of gravity.

In the analysis property data area, the mass per unit volume, weight per unit volume, modulus of elasticity, Poisson's ratio should be specified for each material defined. The mass per unit volume is used in calculating the self-mass of the structure. The weight per unit volume is used in calculating the self-weight of the structure.

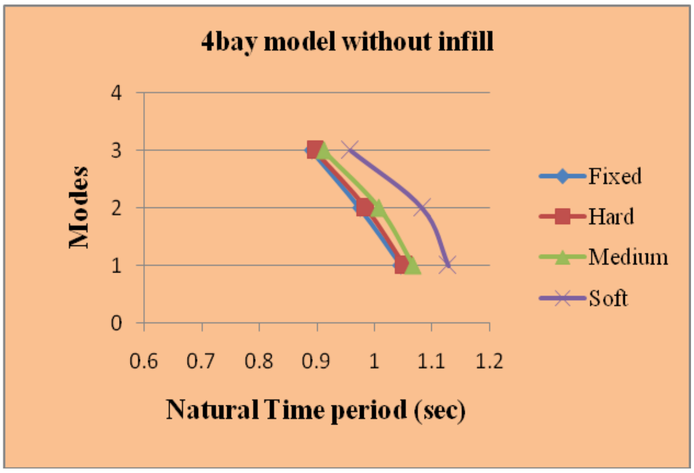
Using ETABS four distinct analyses are carried on buildings, namely:

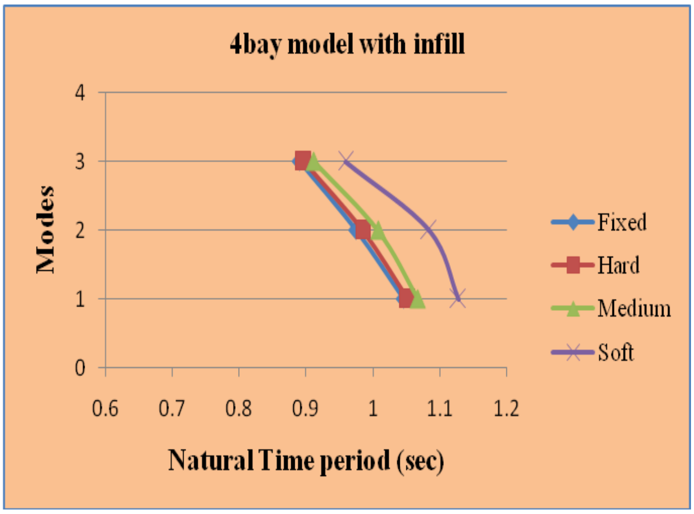
a. Gravity Load Analysis
b. Equivalent Static Analysis
c. Response Spectrum Analysis
d. Non Linear Static (Push-over) Analysis

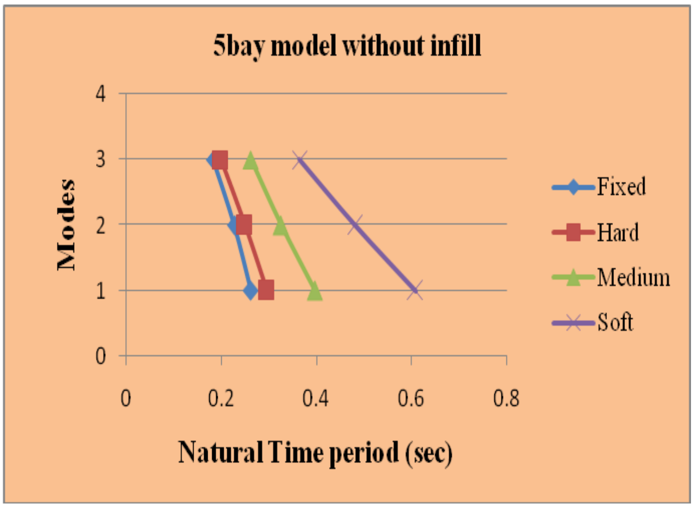
V. RESULTS OF PARAMETRIC STUDY

a. Natural Time Period

The natural periods obtained from various building models by analytical (ETABS) are shown in graphs below. Referring graphs it can be seen that building frames with in-fill exhibits considerable increase in natural period due to the effects of Soil-Structure Interaction. The natural periods of 4 no of 5bay building bare frame models are nearly 3.78, 3.38, and 2.92, 2.17 times greater compared to infilled frame model for fixed, hard, medium and soft soil condition. The natural periods of 5 no of 4bay building bare frame models are nearly 3.19, 2.85, and 2.17, 1.5 times greater compared to infilled frame model for fixed, hard, medium and soft soil conditions.







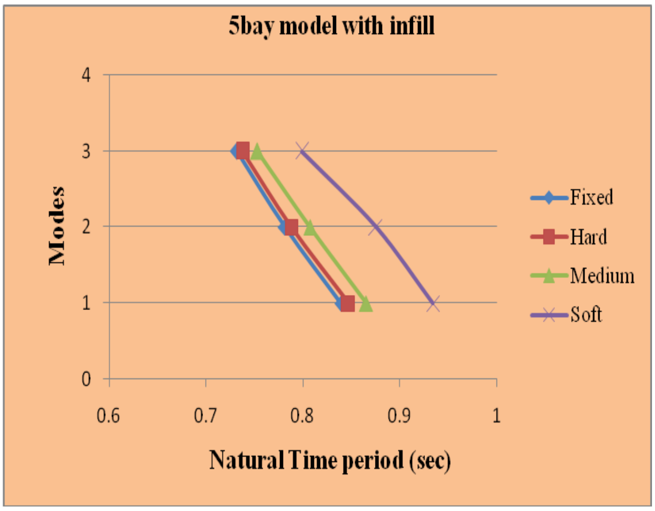


Figure 3 Natural time periods for different building models

b. Base Shear Variation

It can be observed from figure below that in all four models base shear for soft soil condition is considerably greater than other soil conditions. The increase in base shear is due to the consideration of masonry in-fill modeled as equivalent diagonal strut as force distribution is proportional to stiffness of member. Hence we should not ignore the effect of soil-structure interaction and masonry infill.

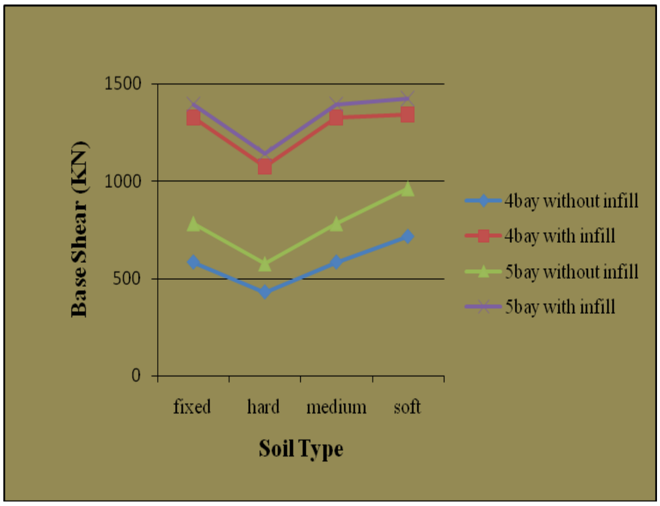
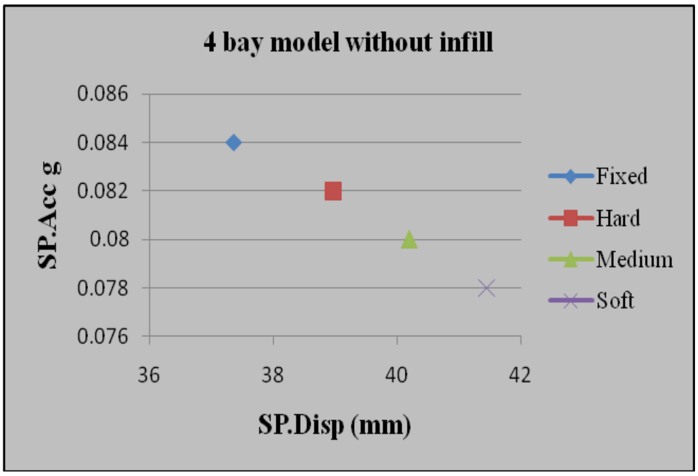
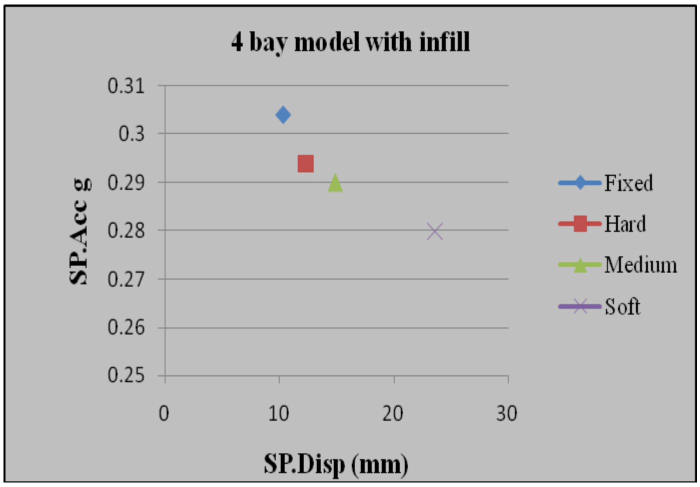


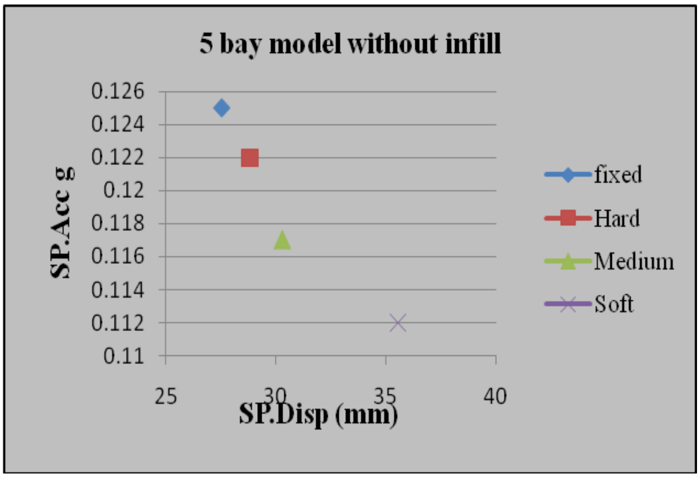
Figure 4 Base shear variations for different building models

c. Location of performance points

For different building models with different soil conditions (non linear static) pushover analysis is performed to investigate the performance point of the buildings in terms of displacement. For pushover analysis the various pushover cases are considered such as push gravity, push X, push Y. After pushover analysis the demand curve and capacity curves are obtained to get the performance point of the structure. The performance point is obtained as per ATC 40 capacity spectrum method.







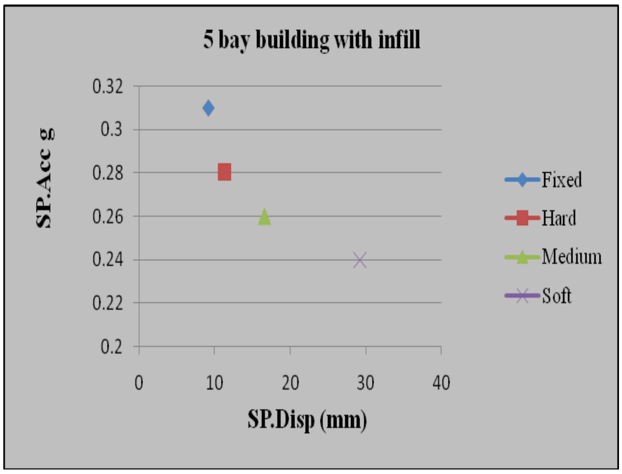


Figure 5 Location of Performance Point for Different Building Models

d. Maximum Axial Loads

From graph below it can be observed that the effect of soil structure interaction on maximum axial load is more in buildings with infill than buildings without infill.

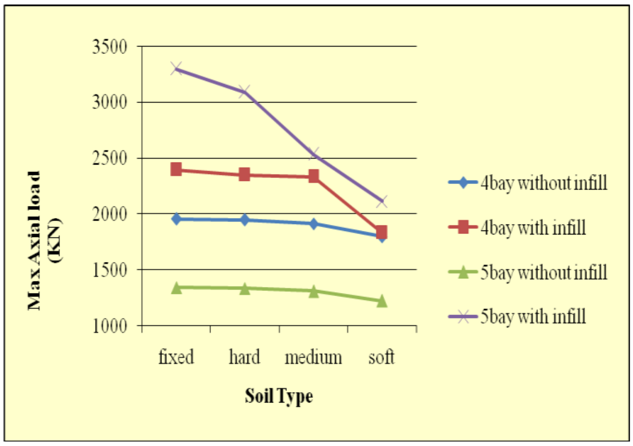


Figure 6 Maximum Axial Load Variations for Different Building Models

e. Maximum Bending Moment

From graph below it can be observed that the effect of soil structure interaction on maximum bending moment is more in buildings without infill than buildings with infill.

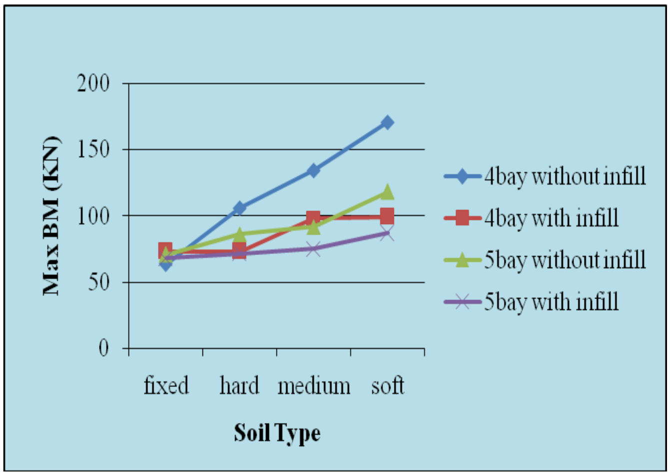
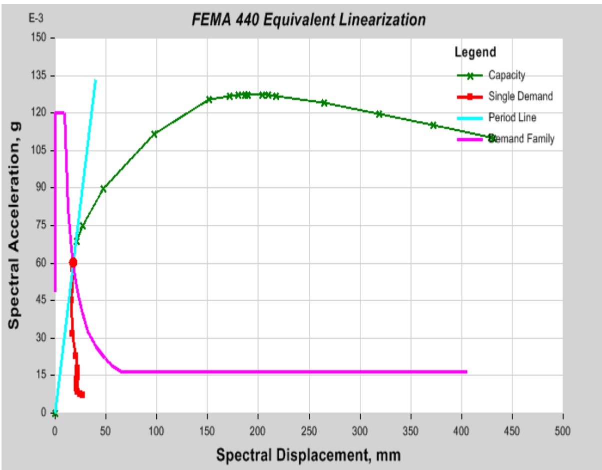


Figure 7 Maximum Bending Moment Variation for Different Building Models

f. Pushover analysis results

Load case: PX



Load case: PY

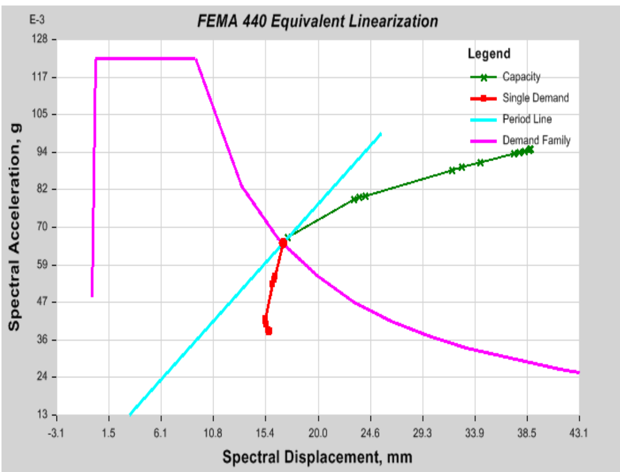


Figure 8 Pushover Curve for 4bay building without infill (fixed condition)

CONCLUSION

I. The study shows that the effects of Soil-Structure Interaction significantly alter the lateral natural periods and base shear of any structural system. Thus, evaluation of these parameters without considering Soil-Structure Interaction may cause serious errors in seismic design.

II. Soil-Structure Interaction has greater influence on building frame with more number of bays or lesser bay width. The effect of SSI is insignificant if the stiffness due to brick in-fill is not considered.

III. Soil-Structure Interaction has greater influence on building footing resting on soft soil and this influence decreases as the soil becomes hard.

IV. Beam Moments are observed to be increased due to SSI effect. For stiff soil the difference is less compared to soft soil.

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