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PARAMETRIC STUDY OF R.C FRAMES CONSIDERING SOIL STRUCTURE INTERACTION

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In conventional method of design of raft foundation, base flexibility due to soil mass is ignored. The purpose of this study is, to understand the effect of soil flexibility on the performance of the building frames resting on raft foundation. The Soil Structure Interaction (SSI) study is carried out on symmetrical building space frame of 4bay in both x and y direction, for 10 storey to 25 storey building frame with raft foundation under fixed base and flexible base condition. In this analysis three types of soil i.e. Hard, Medium hard and Soft Soil are used for soil structure interaction (SSI) study. The analysis carried out using Equivalent Static Method (ESM) in accordance with IS1893-2002. The soil flexibility is incorporated in the analysis by using Winkler approach (Spring Model). SAP-2000 software. is used to model fixed base and flexible base. The effect of SSI on various dynamic properties i.e. natural time period and base shear are discussed. The comparison is made between the non-interaction (non-SSI) and soil structure interaction (SSI) analyses with fixed base and flexible base conditions.

Index Terms: Raft foundation, Soil Structure Interaction, Seismic Response, Equivalent Static Method, , Winkler Method

1. Introduction

It has conventionally been considered that soil-structure interaction (SSI) has 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 spectrums, which attain constants acceleration up to a certain period, and thereafter decreases monotonically with period. Considering soil structure interaction makes a structure interaction makes a structure more flexible and thus, increasing the natural time period of the structure compared to the corresponding rigidly supported structure. Interaction effect is ignored to simplify the mathematical model but neglecting the interaction between soils and structures may result in a design that is either unnecessarily costly or unsafe. The SSI analysis is done by the Raft foundation and providing spring of equivalent stiffness (Discrete Support) to the raft foundation. A more rational solution of soil-structure interaction problem can be achieved with computational validity and accuracy by appropriate analysis. Winkler's idealization (1867)[1] represents the soil medium as a system of identical but mutually independent, closely spaced, discrete, linearly elastic springs. According to this idealization, deformation of foundation due to applied load is confined to loaded regions only. George Gazetas (1991)[2] has presented complete set of algebraic formulas and dimensionless charts for readily computing the dynamic stiffness (K) and damping coefficient (c) of foundation harmonically oscillating in a homogenous half space. Shekharchandra Datta (2002)[3] presented possible alternative models for the purpose of soil structure interaction analysis. Winkler hypothesis despite its obvious limitation, yields reasonable performance and it is very easy to exercise. B.R. Jayalaxmi et al (2009) [5] studied earthquake response of multistoried RC frame with soil structure interaction effects by modeling structure–foundation-soil system by Finite Element Method. Seismic response buildings considering SSI exhibit variation based on frequency content of motion and stiffness of soil.

2. Methodology

Hard Soil, Medium Hard Soil and Soft Soil are the three types of soil over which the building frames are considered to be resting. The properties of soil with the elastic constant of these three soils are considered as per Bowel's (The soils are designated as per the modulus of Elasticity as shown in the Table. No.1).[6]

Table I Soil Elastic Constants

Soil Type	**Designa-tion**	**Modulus of Elasticity (kN/m^2)**	**Poisson's Ratio (μ)**	**Unit Weight (γ) (kN/m^3)**
Hard soil	E-45000	45000	0.4	16
Medium hard soil	E-25000	25000	0.4	16
Soft soil	E-15000	15000	0.4	16

Symmetric frames of 4 bays 10 storey, 15 storey, 20 storey and 25 storey are considered. The details of the building frames are given in Table II.

Table II Geometric and Material Properties of Frame, Footing and Soil Mass:

Component	Description	Data
Frames	Number of storey's	10,15,20,25
	Number of bays in X direction	4
	Number of bays in Y direction	4
	Storey Height in (M)	3.2m
	Bay width in X direction	6m
	Bay width in Y direction	6m
	Size of beam	0.23m X 0.4m
	Size of column	As per design
	Thickness of Slab	0.125m
Foundation	Raft foundation	26m x 26m, 1.05 m depth
	Elastic modulus of Concrete	2.5 x 10^7 kN/m^2
	Poisson's ratio of Concrete	0.2
Soil	Modulus Elasticity of Soil	45000, 25000,15000 kN/m^2
	Poissions ratio of Soil	0.4

2.1 SSI Mode Consider for Study

Effect of this soil for SSI is considered by considering equivalent springs with 6 DOF. The stiffness along these 6 degrees of freedom is determined as per George Gazetas 'Formula and charts for impedances of surface and embedded foundations'[2]is shown in Table III.

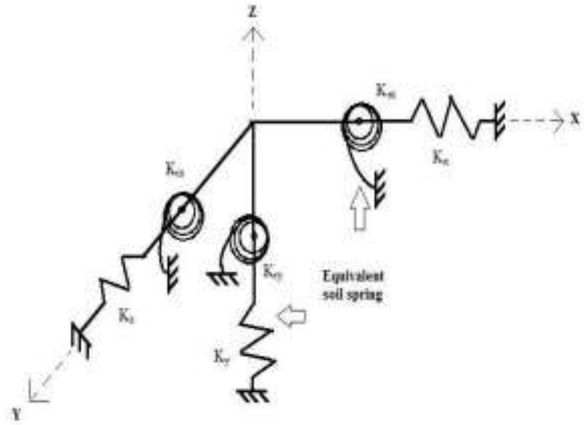

Fig.1 Equivalent Spring Stiffness

where in Fig.1, *K_x, K_y and Kz are stiffness of equivalent soil springs along the translation degree of freedom along X, Y and Zdirectin.. K_{rx}, K_{ry},and K_{rz} are Stiffness of equivalent rotational soil springs along the rotational degree of freedom along X, Y and Zdirection.*

Table III Spring Stiffness (George Gazeta)

Degrees of freedom	**Stiffness of equivalent soil spring**
Vertical	$[2GL/(1-v)](0.73+1.54\chi^{0.75})$ with $\chi = A_b/4L^2$
Horizontal (lateral direction)	$[2GL/(2-v)](2+2.50\chi^{0.85})$ with $\chi = A_b/4L^2$
Horizontal (longitudinal direction)	$[2GL/(2-v)](2+2.50\chi^{0.85})-[0.2/(0.75-v)]GL[1-(B/L)]$ with $\chi = A_b/4L^2$
Rocking (about longitudinal)	$[G/(1-v)]I_{bx}^{0.75}(L/B)^{0.25}[2.4+0.5(B/L)]$
Rocking (about lateral)	$[G/(1-v)]I_{by}^{0.75}(L/B)^{0.15}$
Torsion	$3.5G\, I_{bz}^{0.75}(B/L)^{0.4}(I_{bz}/B^4)^{0.2}$

where, A_b= Area of the foundation considered; B and L= Half-width and half-length of a rectangular foundation, respectively; I_{bx}, I_{by}, and I_{bz} = Moment of inertia of the foundation area with respect to longitudinal, lateral and vertical axes, respectively.

The values of stiffness for various types of soils considered for study are calculated as per Table III and are shown in Table IV.

Table IV Spring Stiffness Values

Stiffness of Equivalent Soil Spring (kN/m)			
Soil Type	E-45000	E-25000	E-15000
Horizontal (longitudinal direction)	618221.35	343456.3	206073.78
Horizontal (lateral direction)	710058.08	394476.71	236686.03
Vertical	865485.36	480825.2	288495.12
Rocking (about the longitudinal)	9781321.8	5434067.7	3260440.6
Rocking (about the lateral)	90879376	50488542	30293125
Torsion	13844535	7691408.4	4614845

Symmetric building frames of (4x4x10), (4x4x15), (4x4x20) and (4x4x25) resting on raft foundation are considered.

2.2 Placement Of Springs

The building is designed as per IS code (IS 456:2000).The dimensions of all element the structure are considered as per the design. The depth of foundation is calculated and as per design , the constant depth is considered for all the frame , to analyze and compare the behavior of the structure for various base conditions. The details of the building frame and placement of the springs are shown in Fig.2 and 3. The springs are kept as per the guidelines of Sekhar Chandra Dutta, Koushik Bhattacharya, Rana Roy (2004) [4] considered low-rise building frames resting on shallow foundations, viz. isolated and grid foundation. Influence of soil–structure interaction on elastic and inelastic range responses of such building frames due to seismic excitations has been examined in details.

This frames are modeled in SAP software for the further analysis. The SAP models are as shown in Fig.4 and 5.

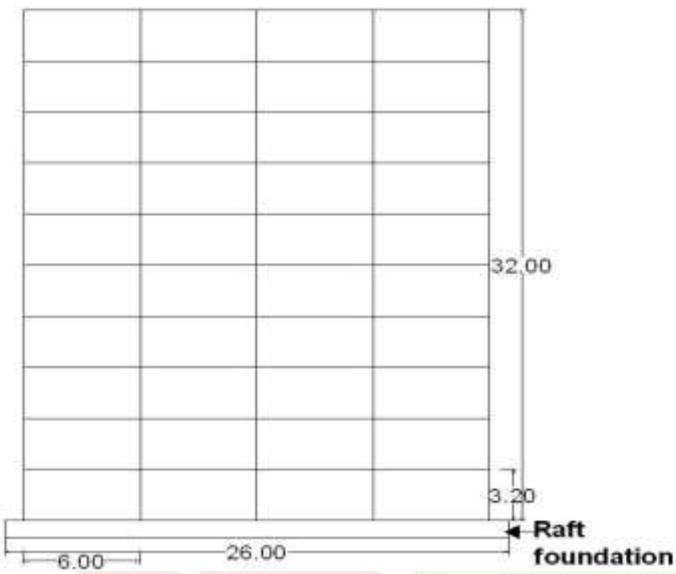

Fig. 2 Frame Details

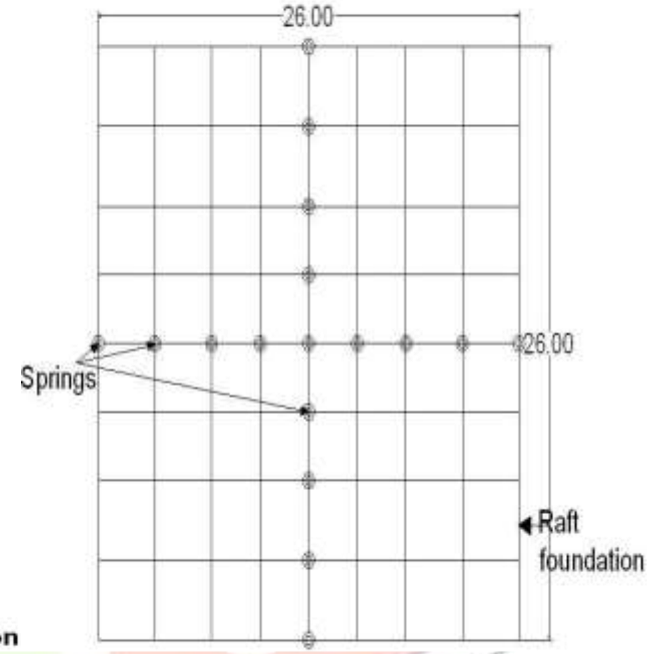

Fig. 3 Spring placement

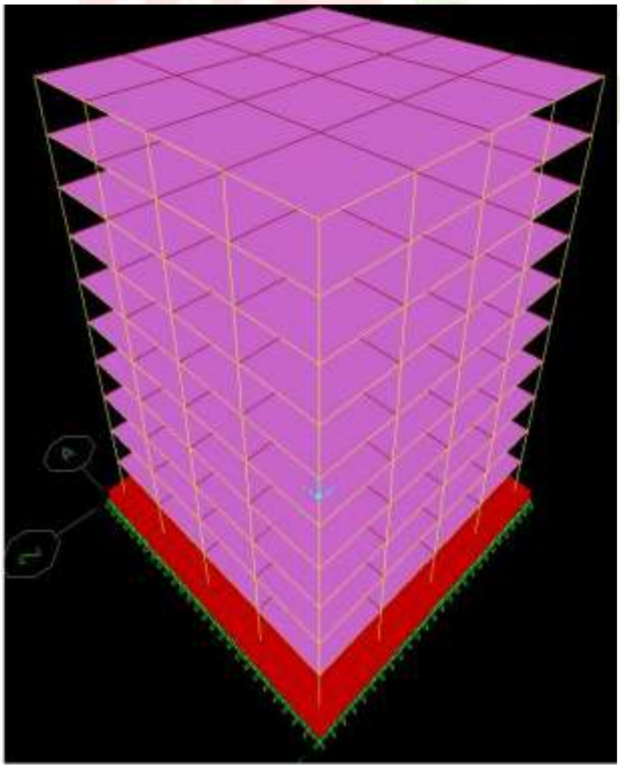

Fig.4: Raft Model

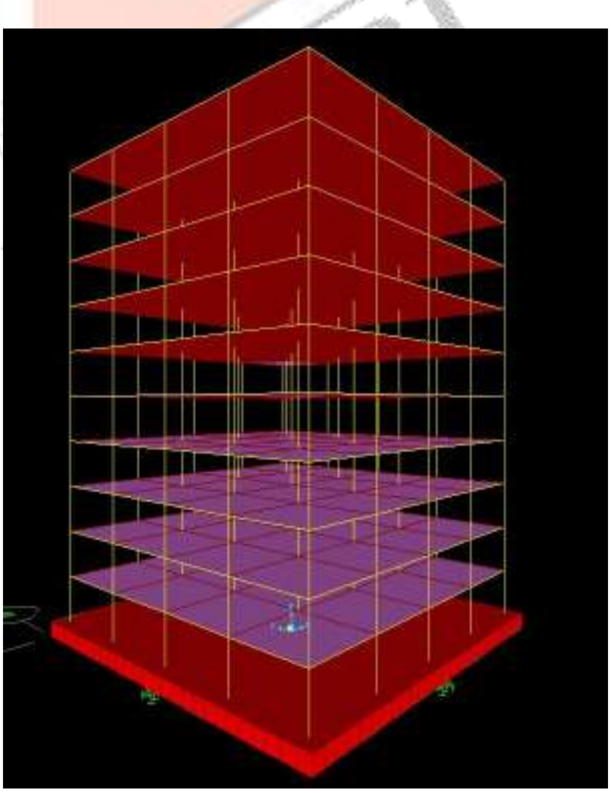

Fig. 5: Spring Model

3. Parametric Study

The present study is carried out to evaluate the effects of SSI for R.C framed structure. Four types of frames (4x4x10), (4x4x15), (4x4x20) and (4x4x25) are considered for the analysis. This analysis is carried over an raft foundation with fixed base and flexible base.

Equivalent Static Method is used to Carry out the analysis as per IS 1893:2002. The analysis of fixed base model and flexible base model are performed in SAP2000. From this analysis effects of SSI on various parameters like Base Shear and time period are presented and discussed accordingly.

3.1 Base Shear

The variation in Base shear of the fixed base and flexible base structure are shown in the Fig. 6. For (4x4x10) . (4x4x15), (4x4x20) and (4x4x25) building frames.

- For the given building frames it is observed that base shear is increases with increase in soil flexibility.
- The same tread is observed for all the building frames.
- The rate of increase in base shear for hard soil to medium hard soil is more, where as it is negligible for medium hard soil to soft soil.
- For the given base condition the percentage increase in base shear is lesser for low rise building as compare to high rise building.
- With increase in soil flexibility and building height base shear increases with higher rate.
- From Fig. No 6 it is observed that, 60-70% increment in base shear from hard to soft soil.

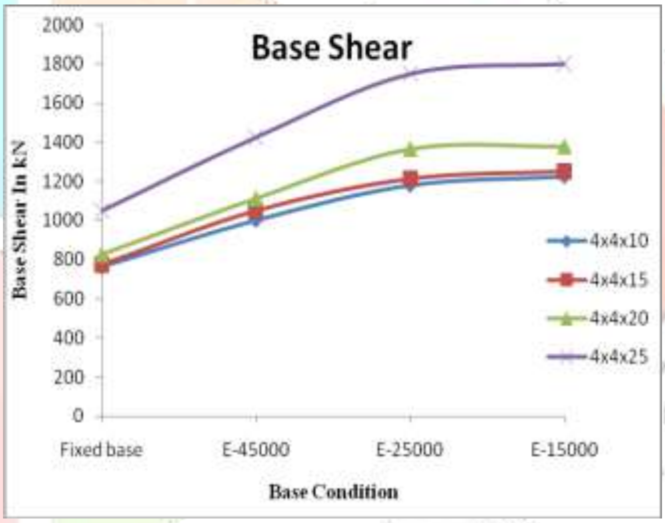

Fig.6 Base Shear of structures for different support condition for all frames.

3.2 Natural Time period

The variation in natural Time Period of the fixed base and flexible base structure are shown in the Fig. 7. for (4x4x10),(4x4x15), (4x4x20) and (4x4x25) building frames.

- For the given building frames it is observed that time period is increases with increase in soil flexibility.
- The rate of increase in time period for hard soil to medium hard soil is more, where as it is negligible for medium hard soil to soft soil.
- For the given base condition the percentage increase in time period is lesser for low rise building as compare to high rise building.
- With increase in soil flexibility and building height time period increases with higher rate.
- From Fig. No 7 it is observed that, 6-12% increment in time period from hard to soft soil.

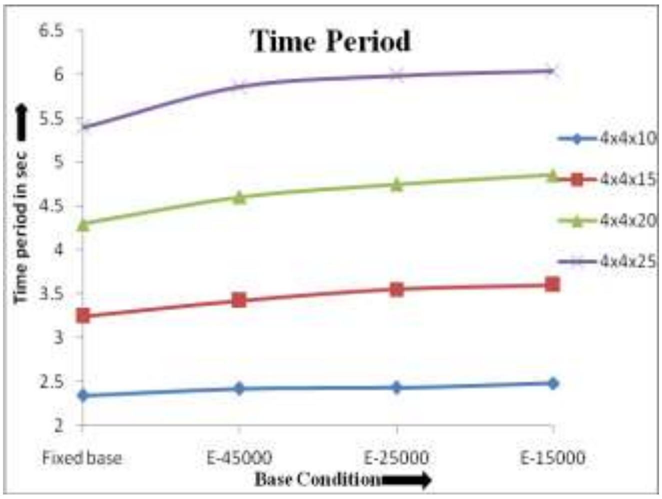

Fig.7 Natural Time period for different support condition for all frames.

4. Conclusion

1) The Base shear of the structure increases due to SSI effect. For soft soil the effect is more as compare hard soil. The percentage variations are lesser for low rise building and increases with increase in story height. The increase in soil flexibility and story height the Base Shear increase in higher rate.
2) Increase in soil flexibility Natural time period is also increase. Natural time period is a primary parameter which regulates the seismic lateral response of the building frames. The effect of soft soil the effect is more prominent as compare to hard soil. Thus evaluation of this parameter without considering SSI effect may cause major error in seismic design.

5. References

[1] Winkler (1867) proposed a foundation model consisting of closely spaced independent linear springs. These models are used to consider the flexibility of soil in the analysis of structures.
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