Evaluation of Soil-Structure Interaction Effects on Multistory RCC Structure

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Abstract - *During earthquake the behavior of any structure is influenced not only by the response of the superstructure, but also by the response of the soil beneath. Structural failures in past have shown the significance of soil-structure interaction (SSI) effects. The present study focuses on SSI analysis of a symmetric 13 story RC Space frame shear wall building over soft soil and subjected to seismic loading. The transient analysis of structure-soil-foundation system is carried out using ETAB software. Earthquake motion in time domain corresponding to Zone V of IS 1893:2002 designs. Seismic coefficient method is used to excite the model of soil-structure system. For integrating the SSI effect, one type of soils based on values of elastic modulus of soil, Poisson ratio and shear modulus are considered. Responses in terms of variation in natural period, base shear, deflection, and column forces, obtained from the analysis of the SSI model are compared with that obtained from conventional method assuming rigidity at the base of the structure. The results show that the SSI effects are significant in altering the seismic response full shear wall at central bay and basement wall below plinth in combination is the alternative for minimizing the effects of SSI.*

Key Words: *Special Moment Resisting Frame (SMRF), basement wall, Dual System, natural period, Storey Displacement, Base Shear, column forces etc…*

1. INTRODUCTION

Soil conditions have a great deal to do with damage to structures during earthquakes. Foundation motions deviate from free-field motions for two principal reasons: (1) the imposition of stiff foundation systems on (or in) a geologic medium experiencing no uniform shaking will result in foundation motions being reduced relative to those in the free-field and (2) inertial forces developed in the structure will cause base shear and moment, which in turn will induce relative foundation/free-field motions due to the foundation compliance. These phenomena are commonly termed Soil-Structure Interaction (SSI). The general SSI problem is subdivided into kinematic SSI, which is concerned with first factor identified above, and inertial SSI, which is concerned with the second factor. Depending mainly on the relative stiffness of the soil and structure, SSI can have an impact on the response of the structure.

Analyses of soil-structure interaction frequently involve the prediction of deformations and Stresses, both in the surrounding soil mass and over areas of contact with the loading boundaries.

The interaction among the structure, foundation and soil medium beneath the foundation vary the real seismic behavior of the structure considerably as found by the consideration of the structure alone. The process in which independent response of the Soil and structure influences each other is referred to as Soil-Structure Interaction (SSI). Implication of soil-structure interaction effects helps the designer to assess the inertial forces and real displacements of the soil-foundation structure system exactly under the influence of free field motion. The effects of soil flexibility are mostly ignored.

2. MATHEMTICAL FORMULATION

Component	Description	Data
Frame	Number of storey	13
	Number of bays in X and Y Direction	3
	Storey height	3 m
	Bay width in X direction	4 m
	Bay width in Y direction	4 m
	Thickness of all slabs	0.15 m
	Elastic modulus of concrete	$25x10^6$ KN/m^2
	Poisson's ratio of concrete	0.15
Foundation Soil	Modulus of elasticity of Soil	25000 KN/m^2
	Poisson's ratio of Soil	0.3

To examine the structure-foundation- soil system, soil is treated as a homogenous, isotropic and elastic half space medium. The inputs considered for the linear analysis of structure are shear modulus of soil (G), Young modulus

(E) and Poisson's ratio (V). The interaction between foundation and soil depends on the elastic properties of foundation soil and foundation dimensions. The foundation flexibility in the analysis is considered by means of replacing the foundation by statically equivalent springs. Modeling of foundation soil has been done by using spring constants as shown below, according to the equations given by Pais and Kausel.

1. Translation along X-axis $= GB/(2-\nu)[3.4(L/B)^{0.65}+1.2]$
2. Translation along Y-axis$=GB/(2-\nu)[3.4(L/B)^{0.65}+0.4(L/B)+0.8]$
3. Translation along Z-axis $= GB/(1-\nu)[1.55(L/B)^{0.75}+0.8]$
4. Rocking about X-axis $= GB^3/(1-\nu)[0.4(L/B)+0.1)]$
5. Rocking about y-axis $=GB^3/(1-\nu)[0.47(L/B)^{2.4}+0.034)]$
6. Torsion about Z-axis $= GB^3 [0.53(L/B)^{2.45}+0.51]$

Where

G = Shear modulus $= E/2(1+V)$

E= Modulus Elasticity of Soil

L=Length of footing

B= width of footing

V = Poisson ratio of soil

Fig no 1and 2 shows plan, isometric views for combination with fully shear wall at central bay and basement wall below plinth.

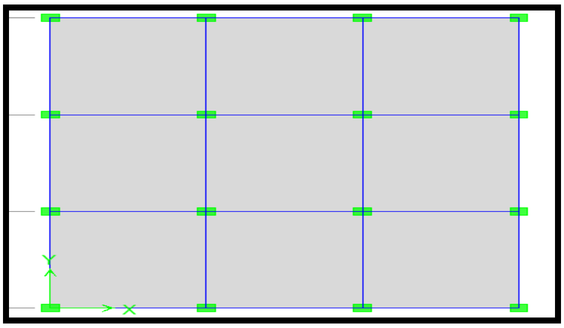

Fig -1: Plan of Building

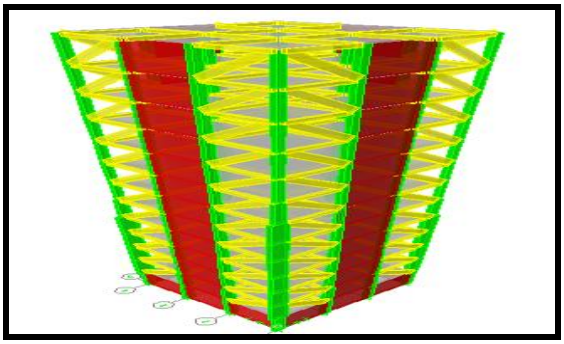

Fig -2: Isometric View of Building

3. Results and Discussion

Following section presents the change in lateral natural period, lateral deflection, and base shear and column forces of three dimensional model of integrated soil-foundation-RC building accounting the effect of soil–structure interaction.

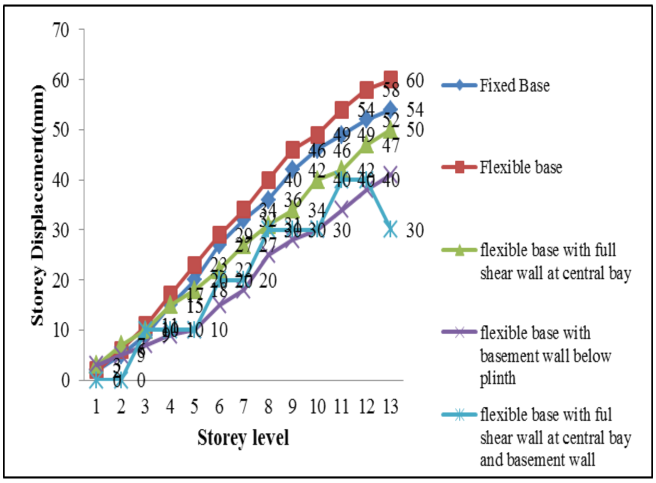

Chart -1: storey displacement versus storey level for bare frame

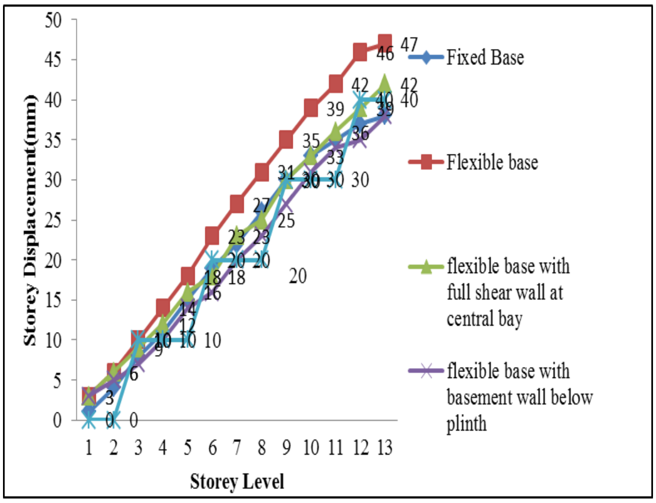

Chart -2: storey displacement versus storey level for Infill Frame

Storey displacement is more for flexible base as compared to fixed base.

The flexible base with basement wall provided below plinth on the periphery of building and shear wall at central bay in combination storey displacement reduces as compared to flexible base.

Table -1: Analysis results for bare frame for different parameters

Bare Frame								
	Without shear wall		With full shear wall		With basement wall		With full shear wall and basement wall	
	Fixed Base	Flexible Base	Fixed Base	Flexible Base	Fixed Base	Flexible Base	Fixed Base	Flexible Base
Period(T)	3.2	3.45	1.53	2.51	2.87	3.18	1.41	2.04
Base Shear(V_B)	613	560	1158	732	656	493	826	575
Column Axial Force (P_u) (KN)	2716	2972	3119	1660	303	895	1507	1322
Column Moment (M_u) (KNm)	330	1677	91	937	18	796	91	714

Table -2: Analysis results for frame with infill for different parameters

Frame with Infill								
	Without shear wall		With full shear wall		With basement wall		With full shear wall and basement wall	
	Fixed Base	Flexible Base	Fixed Base	Flexible Base	Fixed Base	Flexible Base	Fixed Base	Flexible Base
Period(T)	2.09	2.51	1.24	2.04	1.92	2.31	1.16	1.84
Base Shear(V_B)	918	771	1473	902	1044	800	1114	664
Column Axial Force (P_u) (KN)	2699	2849	2990	1605	466	949	1114	1106
Column Moment (M_u) (KNm)	348	1879	89	1227	29	1707	64	777

The natural period of building with flexible base are more than the corresponding values of the same building with fixed base system. This is because of Influence of soil flexibility beneath the foundation and therefore there is reduction in overall stiffness of the building which results into the increase of natural period of the system. Due to introduction of Basement wall provided below plinth on the periphery of building and shear wall at central bay in combination it is reduced for both bare and frame with infill.

The interaction effect causes significant redistribution of Axial force in Column member.
There is increase in axial force in corner column for flexible base as compared to fixed base. However with the introduction of basement wall provided below plinth on the periphery of building and shear wall at central bay in combination for flexible base axial force in column is reduces in case of both bare and frame with infill.
The interaction analysis produce higher bending moment in column as compared to non-interaction analysis .due to introduction of basement wall

provided below plinth on the periphery of building and shear wall at central bay in combination bending moment in column is reduced tremdously.

4 CONCULSION

[1] The natural period of the structure is usually longer when it is analyzed as flexible base systems.
[2] The value of base shear of structures is lower in buildings with consideration of soil flexibility than the conventional method.
[3] Due to soil flexibility lateral displacement is increases as compared to fixed base.
[4] Basement walls located below plinth periphery of the multistoried building and fully shear wall at central bay in combination for flexible base gives lesser value of displacement and fundamental time period.
[5] The soil-structure interaction effect causes redistribution of the axial forces in column members.
[6] The soil-structure interaction analysis produce higher bending moments in columns as compared to when soil-structure interaction is not done.
[7] Basement walls located below plinth periphery of the multistoried building and fully shear wall at central bay in combination for flexible base gives lesser values of bending moment in column

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