OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

"Effect of soil structure interaction (SSI) on the analysis and design of RC framed buildings"

Dange Swati [1], L. G. Kalurkar [2]

*(Student of Structural Engineering, Jawaharlal Nehru Engineering College /Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India)

**(Assistant Professor in Department of Civil Engineering, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India)

***ABSTRACT**:- Response of a structure subjected to gravity and lateral loads depends on the boundary conditions assigned at the base of structure in numerical modeling. Most of the structures are analyzed considering fixed base, but in reality, foundation is not fixed. The fixity depends on the interaction between the soil and foundation. In most of the cases base of a structure undergoes small amount of rotation because of flexibility induced by soil especially at the time of earthquake. Difference in boundary conditions used in analysis and in actual conditions will lead to improper estimation of the design forces; to reduce such effects in numerical analysis fixed base of structure can be replaced by springs or structure base resting on soil to obtain results closer to that of actual base conditions. Stiffness of the spring depends on geotechnical parameters as well as on the dimensions of the foundation. In the present paper an attempt is made to understand the difference between the values of shear force values and bending moment values in fixed base support and spring base support by using SAP2000 software. Stiffness of springs for spring base structure is calculated as per ATC-40 guidelines. In this paper static linear analysis is done which contains gravity load analysis and equivalent load analysis.*

***Keywords:** - Soil structure interaction, fixed base, spring base, linear and dynamic analysis*

I. INTRODUCTION

In general practice analysis of superstructure with fixed base is done separately and reactions are used in designing substructure, in this type of analysis interaction between foundation and soil is neglected by assuming fixity at the base; soil is assumed to be rigid as a result actual base condition effect on the structure response is neglected. The base condition of the structure depends upon the geotechnical parameters of soil media on which the structure is standing. Former can be cohesive or cohesion less based on site conditions. The fixity of the structure solely does not depend on those characteristics of the soil. Structure is considered to have fixed base due to the difficulties faced in considering base as flexible. Generally base is considered as fixed in design codes to simplify the design procedure. In real world, upliftment of the foundation is affected both by vertical loads and lateral loads, which is not in case of theoretical fixed base structure. To take into account the effect on structure due to soil structure interaction, it is very important to consider the actual base condition in performing seismic analysis using design packages. Response of the structure can be known from linear and nonlinear analysis. The linear static analysis in which the gravity load analysis and the equivalent static analysis is done for getting the values of shear force and bending moments. From these values we can design the structure in safe way and economically.

II. NUMERICAL MODELING

Effect of soil in analysis can be considered by two approaches; Structural (Substructure) and Continuum (Direct) approach. In structural approach soil is represented by structural elements like spring, in continuum approach soil and structure is modeled together [3]. In substructure method in place of fixity, resistance offered by the foundation from soil is represented by springs having stiffness equivalent to that of soil. When foundation is considered as rigid in numerical modeling, then at base 3 springs are provided for 2D structure and 6 springs are provided for 3D structure. Figure: 1 shows arrangement of springs at the base in three directions corresponding to the stiffness direction offered by foundation and soil.

For the current study a frame of span 3 m and height 3 m with column and beam dimensions 0.3 x 0.3 m and 0.25 x 0.3 m respectively is considered with following boundary conditions:

1. Fixed Base
2. Spring Base

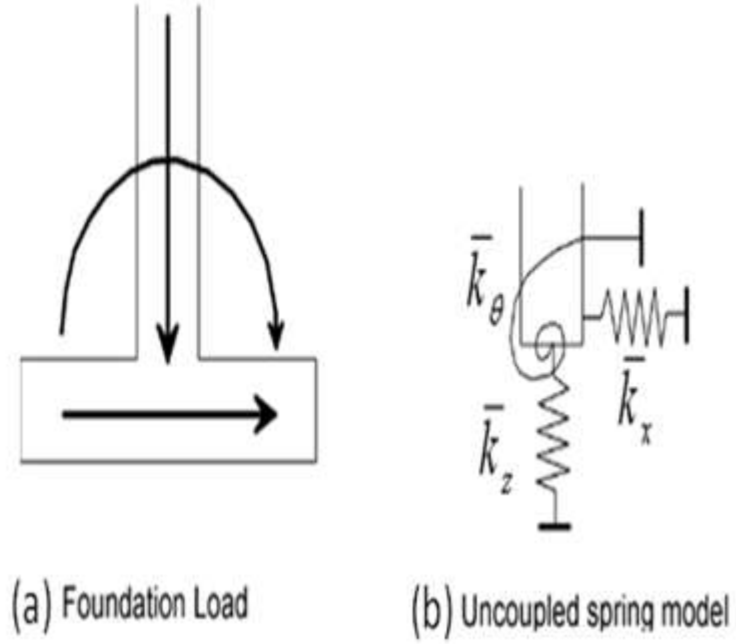

Fig.1 Spring Model

Frame considered is designed for gravity loads as per IS: 456 (2000)

2.1 Fixed Base Model

Technique which is adopted to analyze RC frame with fixed base;

- Finite Element Method using SAP2000 package.
- Building Analysis using ETAB software

The reason behind analyzing fixed frame in SAP2000 software is to make the calculations simple.

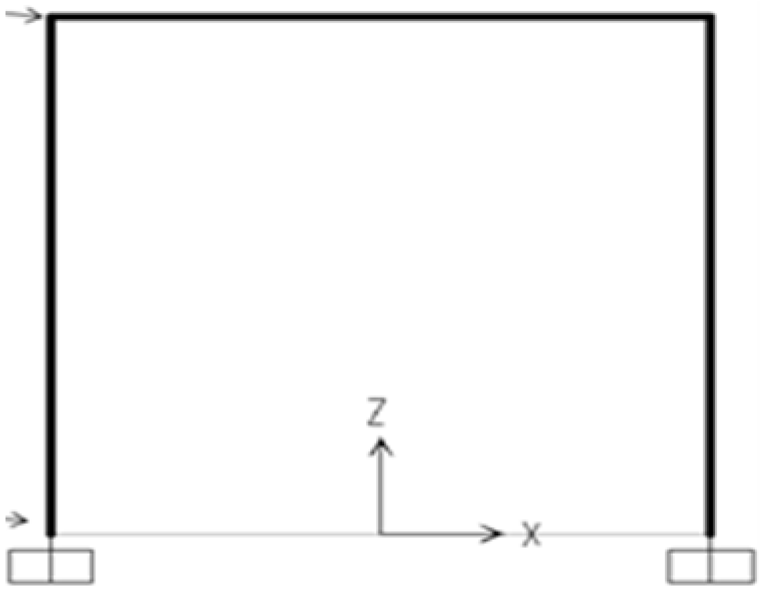

Fig. 2 RC frame model with fixed base SAP2000

2.2 Spring Base Model

To model RC frame with spring base, geotechnical parameters are converted into stiffness of spring as per ATC-40.Stiffness of spring is calculated along three directions i.e. vertical, horizontal and rotation about Y-axis. Three mechanisms, related to axial, shear or rotation can lead to soil failure. In order to accommodate these three mechanisms, springs at the base of the structure are provided with calculated stiffness .The first mechanism, associated with axial, is the punching of the soil. The second mechanism, associated with shear, is a translation mechanism (sliding of the foundation) with the activation of a passive zone in front of the foundation and an active zone behind the foundation. The last mechanism, associated with rotation, is a global rotation with active and passive zones around the foundation.

2.2.1Stiffness Calculations

In spring base model the stiffness values are calculated using the American standard code procedure (ATC 40). The stiffness values calculated using this code are along vertical, horizontal and rotational direction, given at the base slab of the retaining wall.

The stiffness of soil is calculated using the following equations referring the American Standard Code ATC 40 (Cl.No. 10.4.1.1).

Table: 1 Calculation of Stiffness of the Soil as Per ATC -40

Stiffness Intensities	Corresponding Stiffness Parameters
	Vertical Direction
$k_z = \frac{K_z}{LB}$	$K_z = \frac{GL}{1-\mu}\left[0.73 + 1.54\left(\frac{B}{L}\right)^{0.75}\right]$
	Horizontal Direction
$k_y = \frac{K_z}{Ld}$	$K_y = \frac{GL}{2-\mu}\left[2 + 2.5\left(\frac{B}{L}\right)^{0.85}\right]$
$k_x = \frac{K_z}{Bd}$	$K_x = \frac{GL}{2-\mu}\left[2 + 2.5\left(\frac{B}{L}\right)^{0.85}\right] - \frac{GL}{0.75-\mu}\left[0.1\left(1-\left(\frac{B}{L}\right)\right)\right]$
	Rotation Direction
$k_{\theta x} = \frac{K_{\theta x}}{I_x}$	$K_{\theta x} = \frac{G}{1-\mu} I_x^{0.75}\left(\frac{L}{B}\right)^{0.25}\left(2.4 + 0.5\left(\frac{B}{L}\right)\right)$
$k_{\theta y} = \frac{K_{\theta y}}{I_y}$	$K_{\theta y} = \frac{G}{1-\mu} I_y^{0.75}\left[3\left(\frac{L}{B}\right)^{0.15}\right]$

Stiffness Values:

From ATC – 40, We are getting following values,
Translation 1 = 74280
Translation 2 = 74280
Translation 3 = 30330
Rotation About 1 = 319525
Rotation About 2 = 312445
Time Period of Fixed Base Model = 0.41 sec
Time Period of Spring Base Model = 0.84 sec

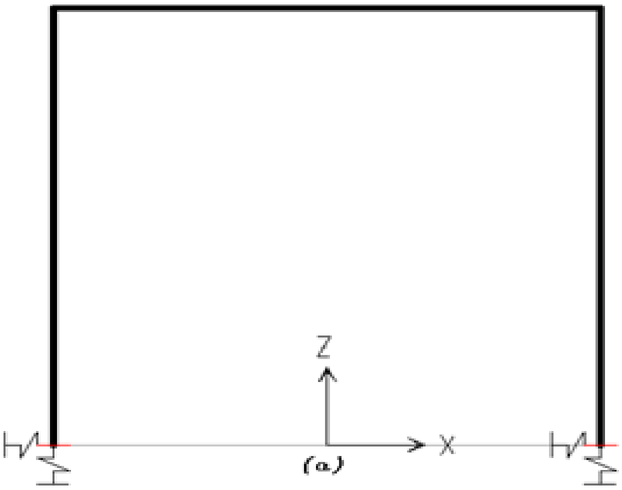

Fig. 3 Frame Model →

III. ANALYSIS TECHNIQUE

For analysis, SAP2000 package is used which is based on finite element methodology. FEM is numerical technique used to analyze different boundary condition systems to obtain approximate solutions. In this study FEM is used to perform both linear and nonlinear analysis for frame with fixed base and frame with springs at the base using SAP2000 package.

The parameters considered while analysis of the building are as follows. These are considered from IS 1893 (Part I):2002.

Table: 2 Parameters considered for Analysis

Description	Value	References
Safe Bearing Capacity of subsoil	160 kN/m^2	Journal Paper
Density of concrete	25 kN/m^2	Journal Paper
Live load	3 kN/m^2	-
Importance Factor (I)	1.0	IS1893 (Part I) :2002
Seismic Zone	Zone II	IS1893 (Part I) :2002
Zone Factor (Z)	0.10	IS1893 (Part I) :2002
Unit weight of soil	15 KN/m^3	-
Uncorrected SPT Value (N)	20	Journal Paper

Here in this analysis, the consideration of some load conditions according to IS:1893(Part1)-2002.These are – Consider dead load as DL, live load as LL ,earthquake load in X- direction as EQX , earthquake load in Y-direction as EQY.

Table: 3

Combinations	Description
Combination 1	**1.5DL +1.5LL**
Combination 2	**1.2DL +1.2LL**
Combination 3	**1.5DL +1.5 EQX**
Combination 4	**1.5DL – 1.5EQX**
Combination 5	**1.5DL + 1.5EQY**
Combination 6	**1.5DL – 1.5 EQY**
Combination 7	**0.9 DL +1.5 EQX**
Combination 8	**0.9 DL -1.5EQX**
Combination 9	**0.9 DL +1.5 EQY**
Combination 10	**0.9DL – 1.5EQY**

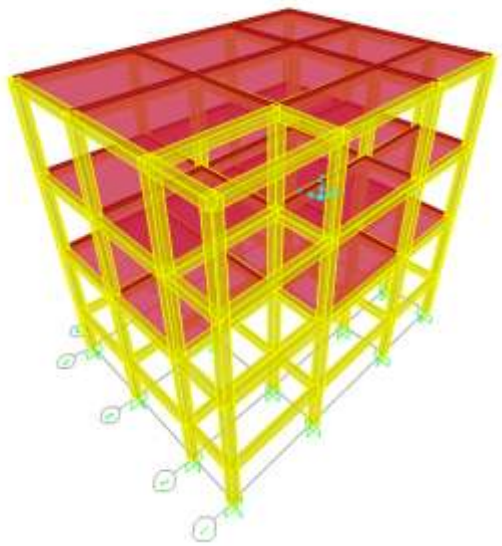

Fig.4 Fixed Base Building Model in SAP2000

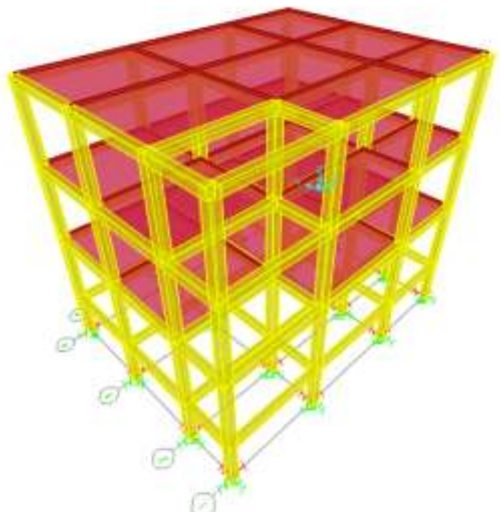

Fig.5 Spring Base Building Model in SAP2000

IV. RESULTS AND INTERPRETATIONS

Table 4: Moments and Shear forces comparison for spring and fixed base

4.1 For Combination 1 (Loading Condition)

Beam No.	Fixed Base Model		Spring Base Model	
	Left End Bending Moment	Right End Bending Moment	Left End Bending Moment	Right End Bending Moment
144	-13.4685	-12.1717	-3.503	-18.268
141	-12.0298	-11.0015	-3.7828	-15.22
138	-8.5266	-8.1903	-13.1785	-9.0364
147	-14.1169	-13.5874	-10.6209	-13.7438

4.2For Combination 2

Beam No.	**Fixed Base Model**		**Spring Base Model**	
	Left End Bending Moment	**Right End Bending Moment**	**Left End Bending Moment**	**Right End Bending Moment**
144	**-10.7748**	**-10.1736**	**-2.8024**	**-14.6144**
141	**-9.6238**	**-8.8012**	**-3.0263**	**-12.176**
138	**-10.4352**	**-9.7268**	**-10.5428**	**-7.2292**
147	**-8.4011**	**-10.885**	**-8.4968**	**-10.9950**

Static linear analysis results are shown in Table. Compared design forces are from gravity load only the effect will differ in case of lateral load. From this observation it can be stated that base condition of frame effect the design forces.

The work done by taking two types of building models, with same loading conditions in both buildings but only the variation in boundary conditions. Firstly the data is considering fixed base model and then spring base model. Usually the building is constructed by considering hard strata at its boundary conditions i.e. fixed base model. But it is not necessary that every time there will be hard strata at the boundary conditions. Sometimes there will be loose soil and then the spring base model should be applied is concluded from some results.

In equivalent static analysis considering three loading conditions i.e. dead load, COMBINATION 1, COMBINATION 2. Firstly the data considered is the two internal beam of top floor i.e. beam no. 144 and 141.The left end bending moment of beam in fixed base model are compared with left end bending moments in spring base model & same in case of right end bending moments in beam of fixed base model are compared with right end bending moments in spring base model. Also for the column the bending moment at the top in fixed base model is compared with the bending moment at top in spring base model. And same is in case of bottom bending moment values of fixed base and spring base.

Internal frames of spring base model will have less moment and shear force values compared to the internal frames of fixed base model .In other words the work done shows the percentage of variation is less and it ranges from 0.4 % to 5 % for shear force and -17% to 1.15% for bending moment values. Here , in this case the data considered is frame 2 and frame 3 are internal frames and frame 1 and frame 4 are external frames.

Here the work done in two types of building analysis. The first one is gravity load analysis and the other one is equivalent static analysis .From both analysis the work done shows that there are variations in values of shear force and bending moment values .So it indicate that what work is to be done is design by considering always fixed base is not correct .Instead of that the data considered to check type of soil, all properties of ground and then to decide whether to take fixed base or spring base.

When the same G + 2 building model is analyzed in SAP2000 software, the values for time period are obtained.

Table: 5 For time period

Type Of Model	Fixed Base Model	Spring Base Model
Time Period	0.8935 seconds	0.9593 seconds

From the above table, time period of spring base model is more flexible than the time period of fixed base model. In the case of high rise structure, this time period plays measure role.

V. CONCLUSIONS

Study done clearly shows that base support condition has an impact on the behaviour of structure which can be clearly observed from linear static analysis. Soil structure interaction should be considered in analysis though it is difficult to go for continuum modelling but structure approach can be used in analysis. Finally it concludes that the always consideration of fixed base while designing the building is not correct .The soil structure may vary its conditions i.e. loose soil or soft soil, hard strata etc. from place to place depending on which the support condition of the structure should be decided. For high rise structure, the time period (mostly in dynamic analysis) plays an important role. As building height increases, we will observe more difference in the time period that means soil structure interaction is necessary.

The possible application of the soil structure interaction will play a major role in designing the important structures such as high rise commercial buildings, retaining walls, dams and power plants etc.

REFERENCES

[1]. S Bhargavi, Ramancharla Pradeep Kumar, Seismic behavior of fixed and flexible 2d RC frame: A case Study, National conference on advances in civil engineering and infrastructure development, Hyderabad, 2014.

[2]. Caselunghe Aron & Eriksson Jonas. Structural Element Approaches for Soil-Structure Interaction. MS report Chalmers University of Technology 2012

[3]. Jonathan P. Stewart University of California, Los Angeles. Overview of Soil-Structure Interaction Principles. Stewart University of California, Los Angeles.

[4]. Damien Dreier .Influence of soil-structure interaction on structural behavior of integral bridge piers. PhD Symposium in Stuttgart, Germany 2008.

[5]. Applied Technology Council ATC-40. Seismic Evaluation & Retrofit of concrete Buildings.Volume.1 1996 IS:1893(Part 1) -2002.

[6]. Aniket N. B., Effects of soil structure interaction on cantilever retaining wall, Master of technology diss, International Institute of Information Technology, Hyderabad, 2014.