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EFFECT OF SOIL STRUCTURE INTERACTION ON PARAMETERS OF R.C.BUILDING

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Abstract: This study has been undertaken to investigate the effect of soil structure interaction on various properties of R.C. building. In conventional design of structure soil flexibility is ignored which affects the performance of structure. The attempt has been made to describe the effects of SSI on performance of R.C building.. In present study 3 SSI models fixed base, flexible base and elastic continuum model are used. In this study 3 building frames G+5, G+7, and G+10 with 4 bay in both direction were considered. Three types of soil i.e. hard, ,medium hard and soft soil are used for study. The dynamic analysis of structure is carried out using response spectra of IS:1893-2002. The soil flexibility is incorporated in analysis using Winkler approach. Software analysis is carried out using SAP2000 for given structural models. Various structural parameters i.e. natural time period, base shear, roof displacement, beam moment, and column moment are studied. The comparison is made between the approaches SSI models. The study shows that SSI significantly affects the response of the structure.

***Index Terms* – Soil Structure interaction (SSI), Response spectra, Winkler Method, SAP 2000.**

1. INTRODUCTION

In the period of developing urbanization due to shortage of land , engineers constructs structure on available relatively soft soil which is unsuitable for construction in the past. Also traditional structural engineering methods disregard SSI effects which are acceptable only for light structures on relatively stiff soil. SSI effect become predominant and must be regarded for structures with massive or deep seated foundations slender tall structures and structures supported on very soft soils. The present study focuses on to analyze the effects of soil flexibility on various response of structure. Many researchers have proposed different methods to evaluate effect of soil structure interaction in the past. Hetenyi(1964) considered the interaction among the discrete springs by incorporating an elastic beam or an elastic plate, which undergoes flexural deformation only. Winkler's idealization (1867) represents the soil medium as a system of identical but mutually independent closely spaced discrete, linearly elastic springs. According to spring idealization, deformation of foundation due to applied load is confined to loaded regions only.George Gazetas (1991) 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.

The use of finite element method has attained a sudden spurt to study the complex interactive behavior. It is possible to model many complex conditions with high degree of realism including nonlinear stress-strain behavior, non-homogenous material condition, and change in geometry and so on. Hence for studying SSI, Finite Element Method is observed to be effective. Mohd Ahmed et.al. (2014) studied the analysis of building structure in contact with soil involves an interactive process of stresses and strains developed within the structure and the soil field. Mangade et.al (2014) carried out a parametric study for determining the lengthened natural time period of building frame due to incorporation of effect of SSI .

The objective of the present study is to assess the effect of SSI on various dynamic properties of R.C. frame such as Natural Time period, Base shear, Roof Displacement, Beam moment, Column moment, etc. The above study is carried out by modeling the soil structure using three approaches viz. fixed base , Winkler approach (Spring model) and Elastic Continuum approach (FEM model) to understand & compare the effectiveness of these models.

2. METHODOLOGY

In present study three symmetrical building frames i.e. G+5, G+7, G+10 are considered. Hard soil, Medium hard soil and Soft soil are the three types of soils upon which structural frames are considered to be resting. The properties of soils with elastic constant of these three soils are considered as per Bowel shown in table I. The details of symmetrical space frames, foundation and soil mass considered for study are given in table –II

Table 2.1:- Soil Constants

Soil Type	**Designation**	**Modulus of Elasticity (kN/m^2)**	**Poisson's Ratio (μ)**	**Unit Weight (γ) (kN/m^3)**
Hard soil	E-65000	65000	0.3	18
Medium hard	E-35000	35000	0.3	16
Soft Soil	E-15000	15000	0.4	16

Table 2.2:- Building frame details

DIMENSIONS OF COMPONENTS OF BUILDING					
Bldg. Frame	**Description**	**Column (m X m)**	**Beam (m X m)**	**Footing size (Lx B x T)**	**Slab Thickness (m)**
G+5	For 4-6 storey	0.30 x 0.40	0.30 x 0.45	1.90x2.05x 0.45	0.15
	Up to 3 storey	0.30 x 0.45	0.30 x 0.45		0.15
G+7	For 7-8 storey	0.30 x 0.40	0.30 x 0.45	2.15x2.35x 0.5	0.15
	For 4-6 storey	0.30 x 0.45	0.30 x 0.45		0.15
	Up to 3 storey	0.30 x 0.50	0.30 x 0.45		0.15
G+10	For 9-10storey	0.30 x 0.40	0.30 x 0.45	2.55x2.75x 0.6	0.15
	For 5-8 storey	0.30 x 0.45	0.30 x 0.45		0.15
	Up to 4 storey	0.30 x 0.50	0.30 x 0.45		0.15

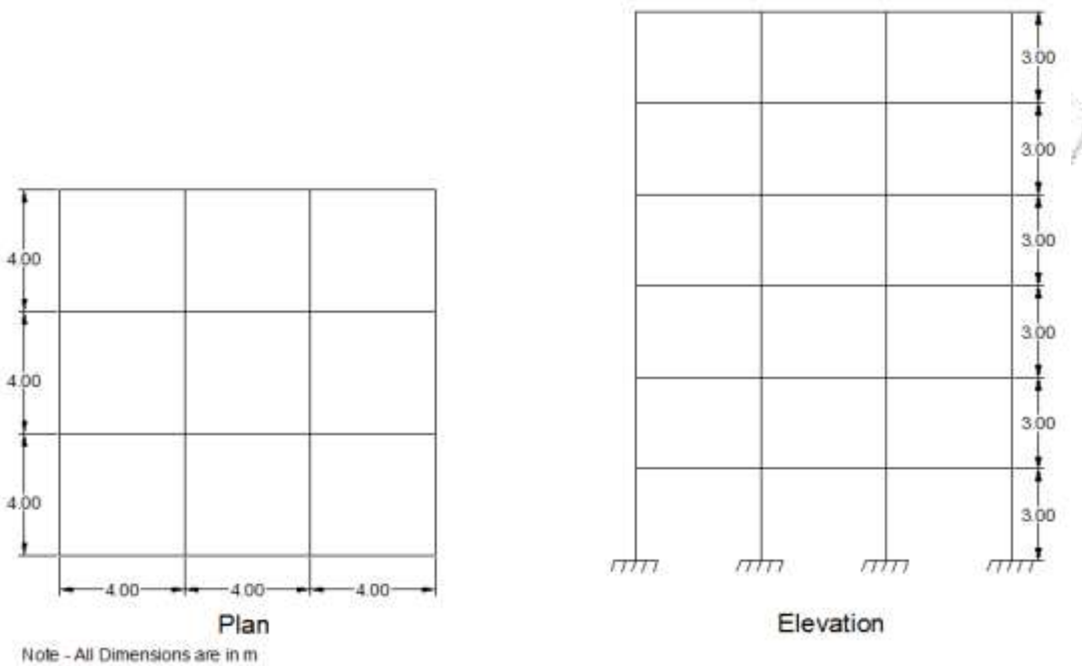

Fig 2.1:- Typical Plan and Elevation of G+5 Building

2.1 Idealization by Winkler approach (Spring Model)

Winkler's idealization represents the soil medium as a system of identical but mutually independent, closely spaced, discrete, linearly elastic springs. In spring (Winkler) model the springs with equivalent soil stiffness are assigned to the foundation base so as to incorporate the effect of soil flexibility in a hypothetical manner yet similar to that in a continuum model.

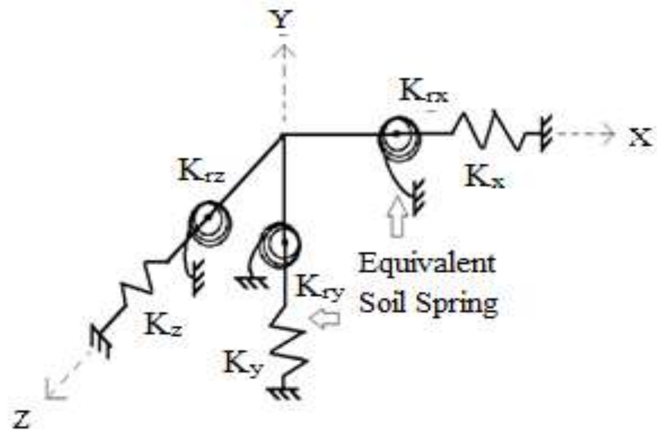

Fig. 2.2:- Equivalent Soil Spring Stiffness along 6 Degrees of Freedom

Where in Fig.1, Ky, Kz =Stiffness of equivalent soil springs along the translation degree of freedom along X, Y and Z axes. Krx, Kry, Krz = Stiffness of equivalent rotational soil springs along the rotational degree of freedom along X, Y and Z-axes.

Table 2.3: - Soil Stiffness for Surface Foundation (FEMA-356 (2000)

Degree of Freedom		Stiffness of foundation at surface (kN/m)		
		G+5	G+7	G+10
$K_{x,sur}$	Horizontal (longitudinal direction)	30358.51	34570.62	40734.84
$K_{y,sur}$	Horizontal (lateral direction)	30559.40	34838.47	41002.69
$K_{z,sur}$	Vertical	41408.11	47164.25	55560.64
$K_{xx,sur}$	Rocking (about the longitudinal)	32554.46	47669.53	78668.64
$K_{yy,sur}$	Rocking (about the lateral)	31479.22	46957.80	76018.30
$K_{zz,sur}$	Torsion	42199.36	62241.70	101948.95

2.2 Idealization by elastic continuum approach (FEM Model)

In this method, the whole soil mass below the foundation which is under the influence of loading is considered. The finite soil mass is considered based on convergence study, with boundary far beyond a region where structural loading has no effect. This is assumed to be at a lateral offset of width of the building on all four sides and depth equal to 1.5 times the width of building. As per this guideline soil bock of 32x32m in plan and having 16m depth beneath the raft foundation is used for the study. The superstructure-foundation-soil system in three-dimensional form is modeled by FEM which is shown in Fig 3.3

3. FINITE ELEMENT MODELLING:-

For FEM modeling SAP-2000 software is used.

3.1 Frame Element

The beams and columns are modeled as frame element. It is a uniaxial element with tension, compression and bending capabilities. The element has six DOF at each node, translations in the nodal x, y, and z directions and rotation about the nodal x, y, and z-axis. The element is defined by two nodes, the cross-sectional area, and the material properties.

3.2 Soil mass

The soil is assumed to be linear, elastic and isotropic material. The slab and foundation are assumed to be elastic. The foundation and soil is discretized as eight nodded brick element. The element is defined by four nodes, thickness, and the material properties. Soil is modeled as a 3D element with different soil properties i.e. shear modulus of soil (G), poison's ratio (μ), unit weight of soil (γ) and modulus of elasticity (E). Using SAP 2000 the 3D modeling of the whole structure-foundation-soil system with soil is developed. Spring model and FEM model are shown in the Fig.2 and Fig.3 respectively which are considered for the study

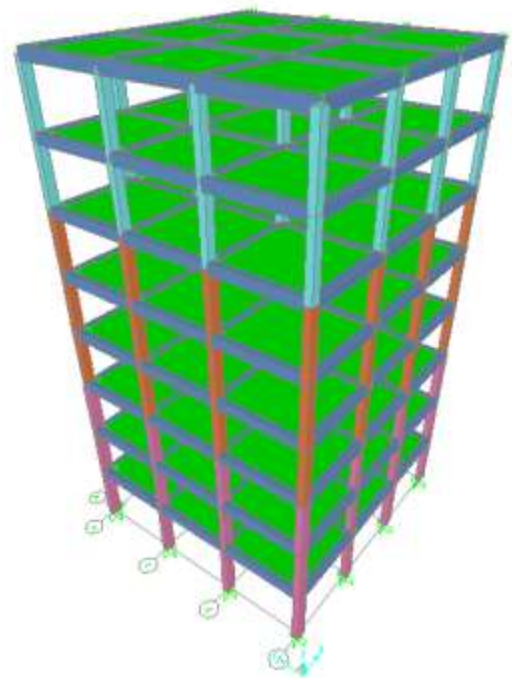

Fig. 3.1:- Fixed Base Model of G+7 Building Frame

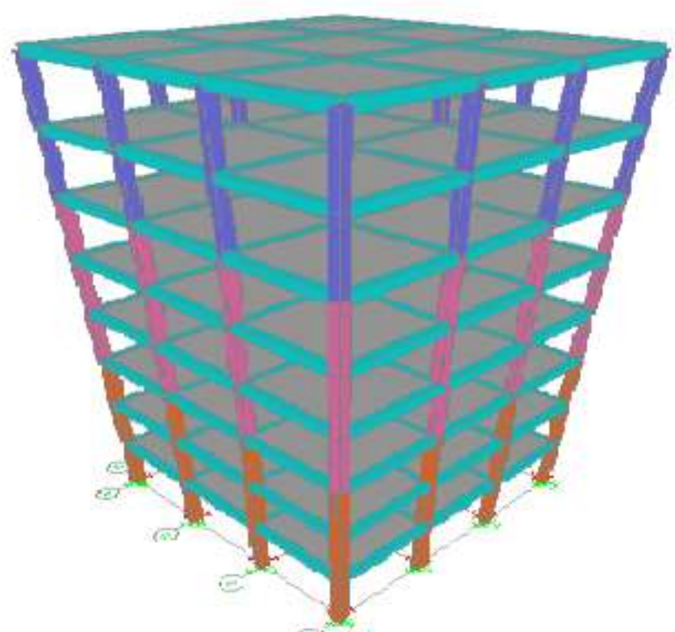

Fig. 3.2:- Spring Model of G+7 Building Frame

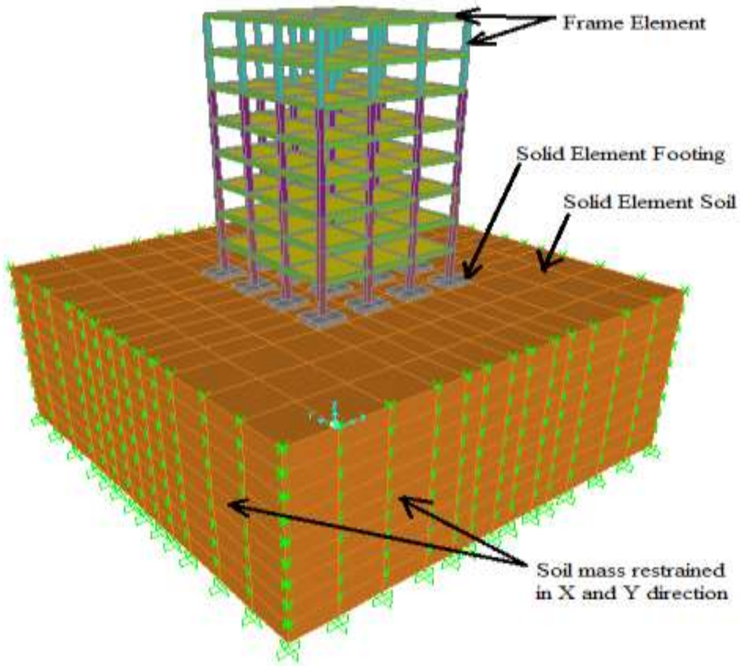

Fig. 3.3:- Elastic Continuum Model of G+7 Building Frame

4. ANALYSIS OF STRUCTURE

The Soil Structure Interaction (SSI) is studied by two approaches i.e. Winkler approach (Spring Model) and Elastic continuum approach (FEM Model). Three R.C.C. framed structures G+5, G+7 and G+10 with isolated footings is analyzed considering fixed base and flexible base Response Spectrum given in IS: 1893-2002 is used for the analysis. The analysis of both the model is performed using SAP 2000. Effects of SSI on different parameters are studied i.e. Natural Time Period, Roof Displacement, Base Shear, and Beam bending moment, Beam shear force Column bending moment and column axial force. These are discussed one by one as followed.

5. RESULTS OF ANALYSIS

5.1 Natural Time Period

The variation in natural time period of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig 5.1

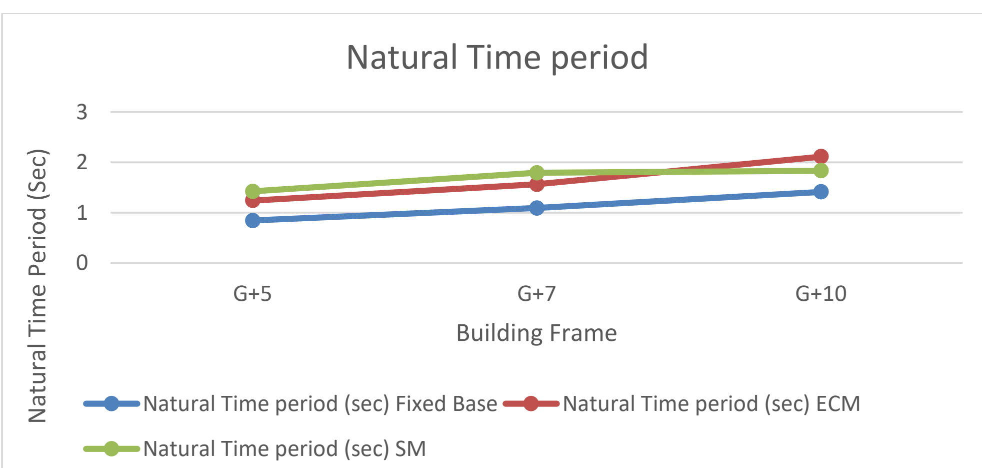

Fig. 5.1:-Variation of Natural Time Period for different support conditions

It is observed from Fig.5.1 that for a building frame with given no of storey the time period is found to be minimum for fixed base condition. The time period increases with the change in base condition from fix to flexible. For a given base condition time period increases with increase in no of storey It is observed that Natural Time period produced by ECM is 10 to 15% higher than SM. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, G+10 and G+12 is 47%, 43%, 49% and 37% respectively.

5.2 Roof Displacement

The variation in roof displacement of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig.

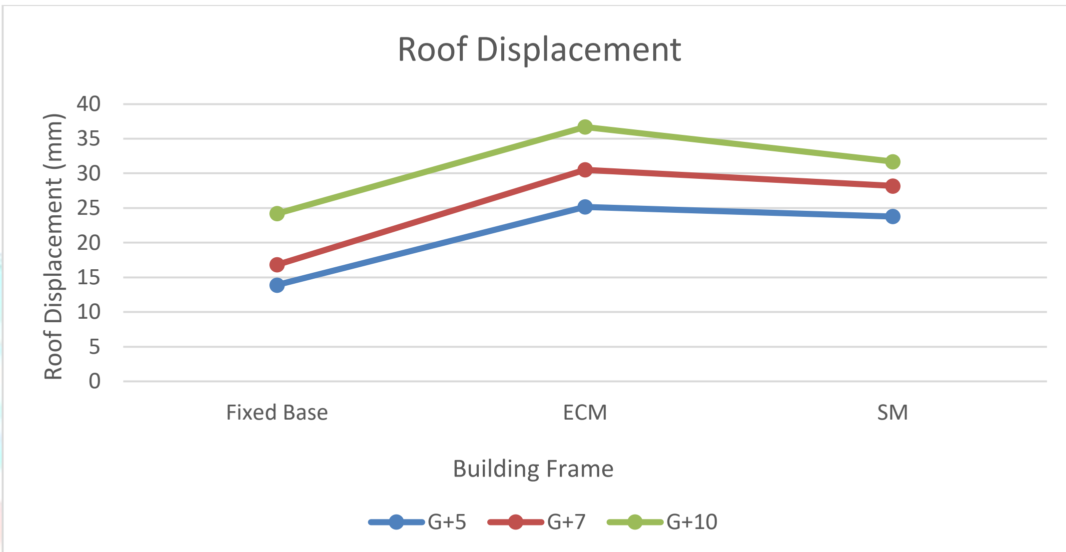

Fig 5.2:- Variation of Roof Displacement for different support conditions

It is observed from Fig. 5.2 that for a given base condition the Roof Displacement goes on increasing with increase in no of storey. Roof Displacement for flexible base is higher than fixed base. The percentage difference in roof displacement between fixed base and flexible base by elastic continuum model for G+5, G+7, G+10 is 81%, 82%, 51% respectively.

5.3 Base Shear

The variation in base shear of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig.5.3

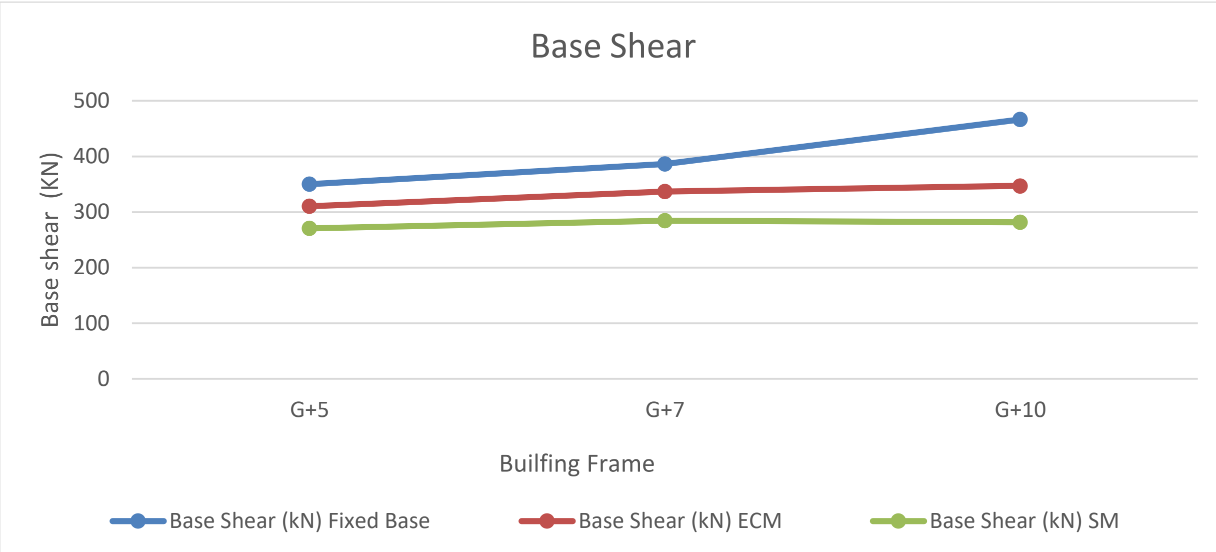

Fig5.3:- Variation of Base Shear for different support condition

It is observed from Fig. 5.3 that for fixed base condition the base shear is observed to be maximum which increases with increase in no of storey with steeper rate. Base Shear for flexible base is lower than fixed base. The percentage difference between fixed base and flexible base is increases as story height increases. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, G+10 and G+12 is 11%, 13%, 25% and 26% respectively.

5.4 Beam Moment

The variations in beam moment of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig. 5.4

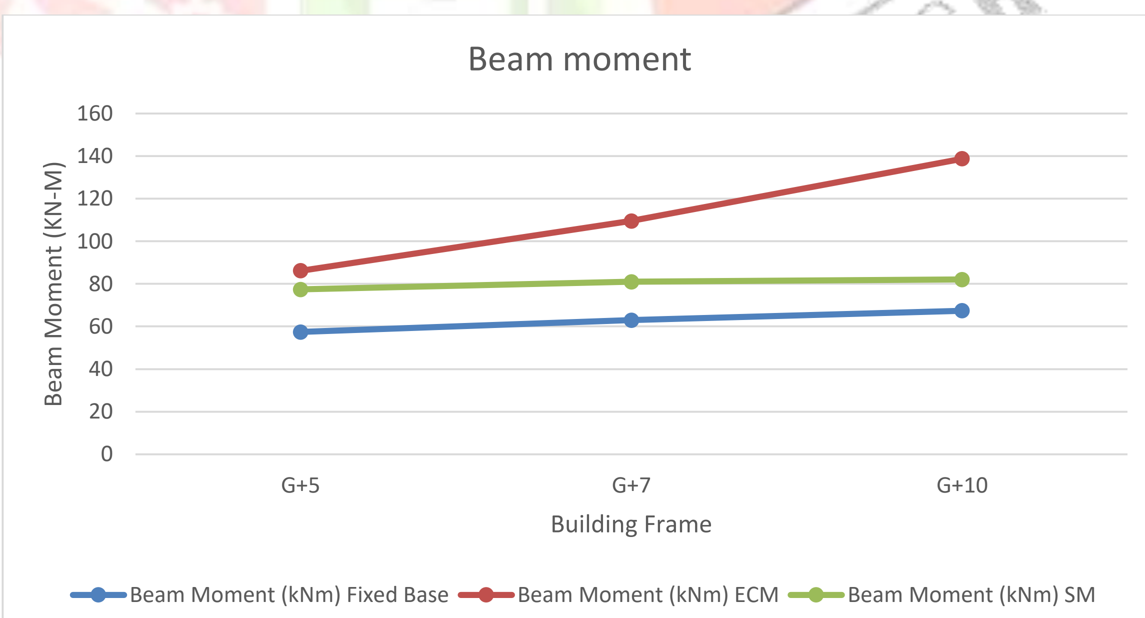

Fig. 5.4:- Variation of Beam Bending Moment for different support conditions

Fig.5.4 shows that bending moment for flexible base is higher than fixed base. There is a moderate increment in the Beam Moment in case of spring model but for ECM model this increase in the Beam Moment is significant. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, and G+ 10 is 50%, 73%, 106% respectively.

5.5 Beam Shear Force

The variation in beam shear force of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig.5.5

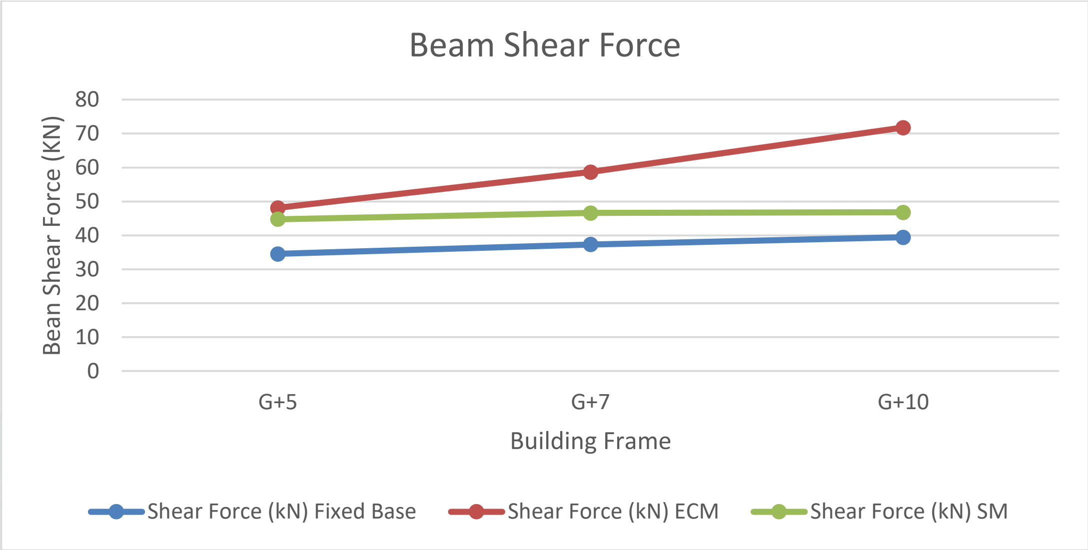

Fig. 5.5:- Variation of Beam Shear Force for different support conditions

It is observed from Fig.5.5 that shear force for flexible base is higher than fixed base. There is a moderate increment in the Shear Force in case of spring model but for ECM model this increase in the Shear Force is significant. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, G+10is 40%, 57%, 82% respectively.

5.6 Column Moment

The variations in column moment of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig5.6

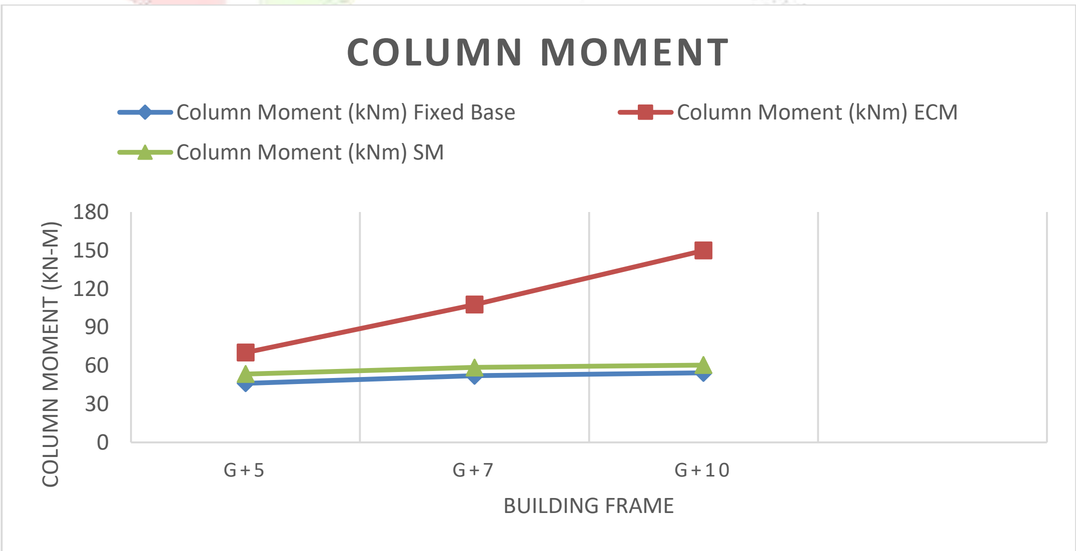

Fig.5.6:- Variation of Column Bending Moment for different support conditions

It is observed from Fig.5.6 that column moment for flexible base is higher than fixed base. There is a moderate increment in the column moment in case of spring model but for ECM model this increase in the column moment is significant. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, and G+ 10 is 52%, 107%, 176% respectively.

5.7 Column Axial Force

The variation in column axial force of structure of fixed base and flexible base for both the models with their values are presented graphically in Fig5.7.

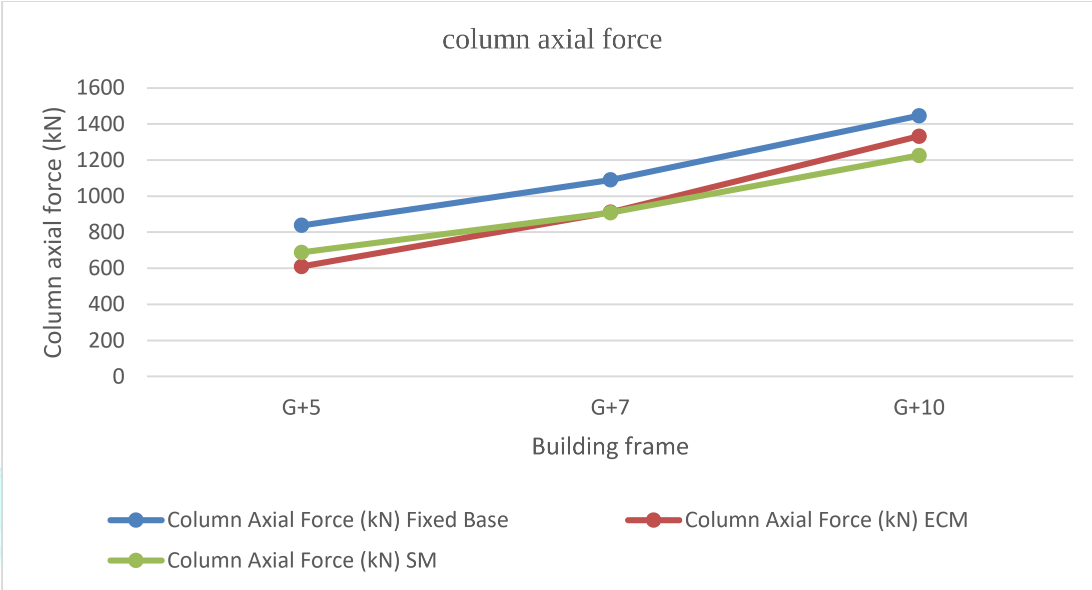

Fig.5.7 Variation of Column Axial Force for different support conditions

It is observed from Fig.5.7 that for fixed base condition the column axial force is observed to be maximum which increases with increase in no of storey with steeper rate. Column axial force for flexible base is lower than fixed base. There is a moderate decrement in the axial force in case of ECM and spring model. The percentage difference between fixed base and flexible base by elastic continuum model for G+5, G+7, G+10 is 27%, 16%, 8% respectively.

6. CONCLUSION

In the present study SSI effect is investigated by the model i.e. spring model and elastic continuum model. The study is carried out for G+5, G+7, G+10 and G+12 storied building frames with and without SSI. Based on the observations, following conclusions are drawn

6.1 The natural period of structure increases due to SSI effect

6.2 Base shear and Axial Force is observed to be decreased due to SSI effect. This is because of the increase in the flexibility of support.

6.3 The structural parameters such as Beam Bending Moment, Beam Shear Force and Column Bending Moment increases due to SSI effect. This is due to P-Δ effect caused by increase in Time Period.

6.4 In case of frame with flexible base condition the SSI effect is producing higher results in case of Elastic Continuum Model as compared spring model this proved that Elastic Continuum Model is more effective than spring model as it considered elastic continuum below foundation which assists to get realistic behavior of structure.

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