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Response Spectrum Method for the Analysis of a Vertically Irregular R.C. Building under Seismic Forces Considering Soil Structure Interaction- an Overviewwith Case Study

Nawaraj Kapil[1], Karthik.N.M[2,]Dr.Rajendra.S[3,]Vijay.K[4,] Likhitha.R[5]
[1]*P.G Student, Department of Civil Engineering, N.C.E.T, Bangalore, India.*
[2]*Assistant Professor, Department of Civil Engineering, C.M.R.I.T, Bangalore, India*
[3]*HOD(PG), Department of Civil Engineering, N.C.E.T ,Bangalore, India*
[4]*Associate Professor, Department of Civil Engineering, N.C.E.T, Bangalore, India*
[5]*Assistant Professor, Department of Civil Engineering, N.C.E.T, Bangalore, India*

ABSTRACT:Irrégularités are not avoidable in construction of Buildings, However the behaviour of structures with thèseirrégularités must be studied. Thèseirrégularités are responsible for structural collapse of Buildings under the action of dynamicloads. In thispaper, attempt has been made to study the seismic behaviour of the vertically irregular structure with and withoutsoil structure Interaction. The structure modelled have been alreadyconstructed and modelling was carried out using E-Tabs Software and analysed by ResponseSpectumAnalysis.

KEYWORDS-Displacement, Storey Shear, Storey Drifts, Overturning Moment, Base Shear and Soil Structure Interaction.

I. INTRODUCTION

In Earthquake Resistance Design, a structure depends upon the inelastic behavior in order to resist the ground motion. Based on the current scenario, many structural Buildings have irregular configuration both in plan and elevation which leads to damage of the structure element, when hit by an earthquake. In such cases, we need to examine the structure against such disaster caused by the seismic waves. Irregularities cannot be avoided but the behaviour of the irregular structure must be studied properly. The structural building considered in this case study has been already constructed in hilly terrain-SIKKIM, which falls under seismic zone IV.

II. STRUCTURAL IRREGULARITIES AS PER I.S 1893(P1):2002

As per I.S 1893(part1):2002, The breakdown of the structure starts at the point of weakness or faults and this faults spring up due to varying load path with respect to mass, stiffness, strength and geometry of the structure, these discontinuity are termed as Irregular Structures.
It is sub categorized into two types:

1. HORIZONTAL IRREGULARITIES:

1.a*Torsion Irregularity:*

Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse\ to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure

1.b*Re-entrant Corners:*

Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond there-entrant corner are greater than 15 percent of its plan dimension in the given direction.

1. c*Diaphragm Discontinuity:*

Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.

1. d*Out-of-Plane Offsets:*

Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.

1. eNon-parallel Systems:

The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

2. VERTICAL IRREGULARITIES:

2. a*Stiffness Irregularity —Soft Storey*

A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

2. b*Stiffness Irregularity —Extreme Soft Store:*

A extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above. For example, buildings on STILTS will fall under this category.

2. cMass *Irregularity:*

Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. The irregularity need not be considered in case of roofs.

2. dVertical Geometric Irregularity:

Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey

2. eDiscontinuity in Capacity— Weak Storey:

A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above, The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.

III. SOIL STRUCTURE INTERACTION

Soil Structure Interaction can be defined as the coupling of the structure and the soil during an Earthquake. It is one of the most flourishing areas of research for structural engineer. SSI is influenced by two types of loading .i.e. Dynamic loading and static loading. Basically, engineers neglect SSI while designing ordinary structure as they evaluate the structure under the assumption of fixed based dynamic response. When the structure is hit by the seismic waves, these waves tend to generate vibrations or motion on the structure. In order to resist the motion, the structure needs to overcome its own inertia force which in result deals with SSI.

There are two types of primary issues of soil structure interaction:

- Inertial Interaction.
- Kinematic Interaction.

When soil undergoes deformation and stress, they induce base shear and moments in the vibrating structure. Such cases lead to dynamic response of the structure by creating dynamic interacting system between soil and the structure. This type of interaction is known as Inertial Interaction.

When seismic waves enter the soil, a discontinuity in medium of wave propagation is encountered at the interface of foundation and soil. This leads to reflection, scattering deflection, refraction of seismic waves at soil foundation interface along with change in nature of ground motion. Slippage occurs across the soil foundation interface which is affected by wave propagation in elastic medium. This phenomenon due to the wave propagation consideration is known as Kinematic Interaction.

IV. STRUCTURAL DETAILING

The structural building considered has been already constructed in Sikkim, India. It is vertically irregular in nature and comprises of B-3 and G+4. The total area comprises of 18.01m x 16.92 m. The soil condition of the structure is dense gravel soil with soil bearing capacity of 180 kN/m^2. The grade of concrete used is M30 and grade of steel is Fe 500. The loads considered are: Dead load of 1 kN/m^2, Live Loads of 3 kN/m^2, 4 kN/m^2 and 5 kN/m^2 respectively. The frame Loads provided were of 11 kN/m as exterior wall load and 5.08 kN/m as partition wall load. The structure was modeled and response spectrum analysis was carried out using E-tabs software. The same structure was analyzed considering soil structure interaction for X and Y direction respectively. The material properties of a structure are shown in Table 1, frame properties of beam are shown in Table2, frame properties of slab are shown in Table 3 and frame properties of column are shown in Table 4. The frame loads are shown in Table 5 and the shell loads are shown in Table 6.

Table 1: Material properties of a structure considered

SL.NO	MATERIAL PROPERTIES	VALUES	UNIT
1	Characteristic compressive strength of concrete	M 30	kN/m^2
2	Characteristic strength of reinforcement	Fe 500	kN/m^2

Table 2: Frame Properties of beam

SL. NO	PROPERTIES	DIMENSION	UNITS
1	Beam(B1)	500X400	mm
2	Beam(B2)	600x600	mm

Table 3: Frame Properties of slab

SL. NO	PROPERTIES	DIMENSION	UNITS
1	Slab(S1)	127	mm

Table 4: Frame Properties of column

SL. NO	PROPERTIES	DIMENSION	UNITS
1	Column (C1)	400X300	mm
2	Column (C2)	500X450	mm
3	Column (C3)	600X500	mm
4	Column (C4)	300X400	mm
5	Column (C5)	500X400`	mm

Table 5: Frame loads

SL. NO	FRAME LOAD	VALUES	UNITS
1	Exterior wall load	11.65	kN/m
2	Partition wall load	5.08	kN/m

Table 6: Shell loads

SL. NO	SHELL LOAD	VALUES	UNITS
1	Dead Load	1	kN/m^2
2	Live load	3	kN/m^2
3	Live load	4	kN/m^2
4	Live load	5	kN/m^2
5	Floor Finish	1	kN/m^2

V. RESULTS

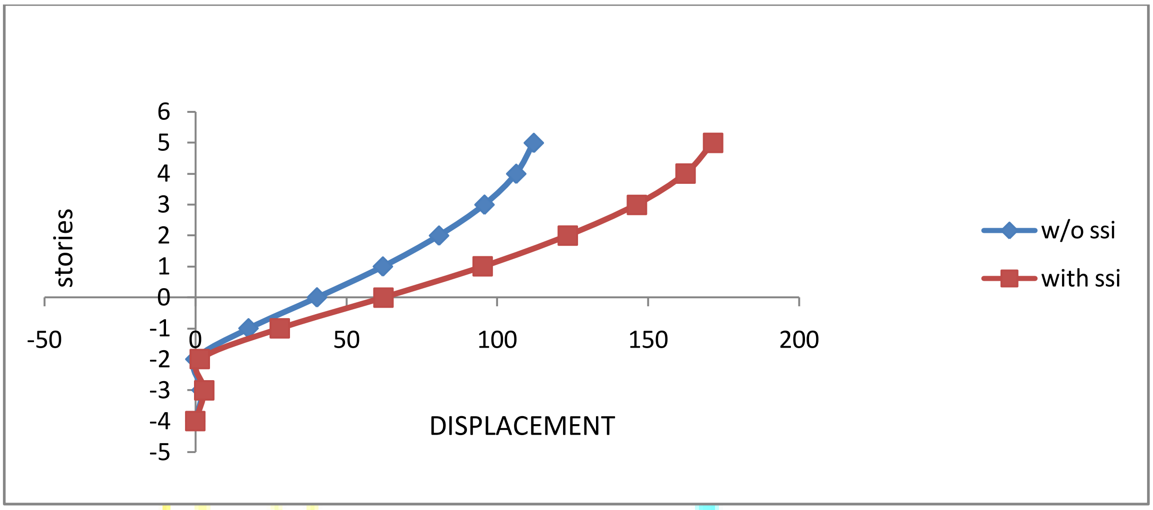
After analysis of the structure, seismic weight was obtained and base shear was calculated. The base shear calculated manually was compared to that obtained from E-Tabs. The seismic weight and base shear of the structure are shown in Table 7 and Table 8 respectively. The parameters considered such as Displacement and Story Shear was calculated and compared considering with and without soil structure interaction for both X and Y direction respectively.

Table 7: Seismic Weight

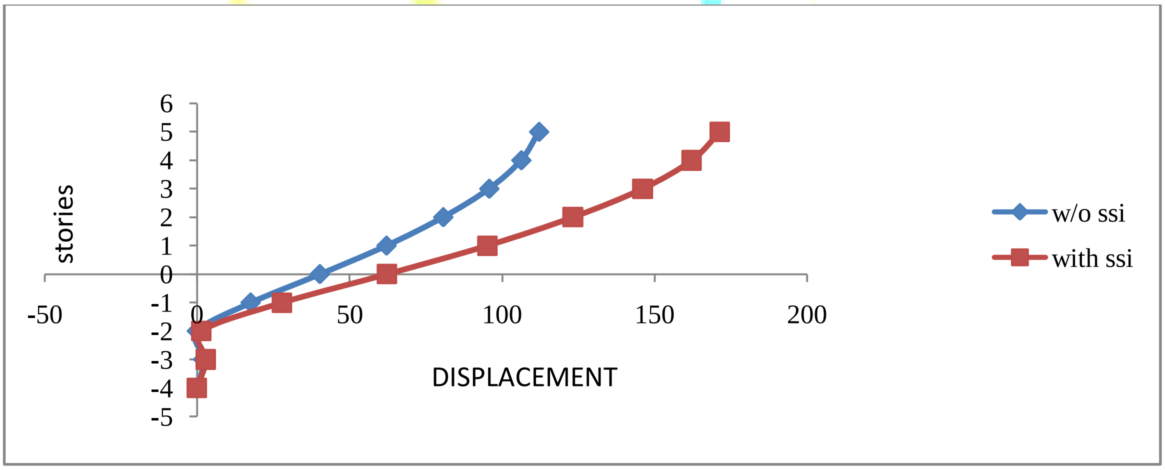
SL. NO	Seismic weight	VALUES	UNITS
1	Dead Load	13834.1368	kN
2	Live Load	1506.8116	kN
3	Floor Load	1766.6434	kN
4	Wall Load	12797.0864	kN

Table 8: Base Shear

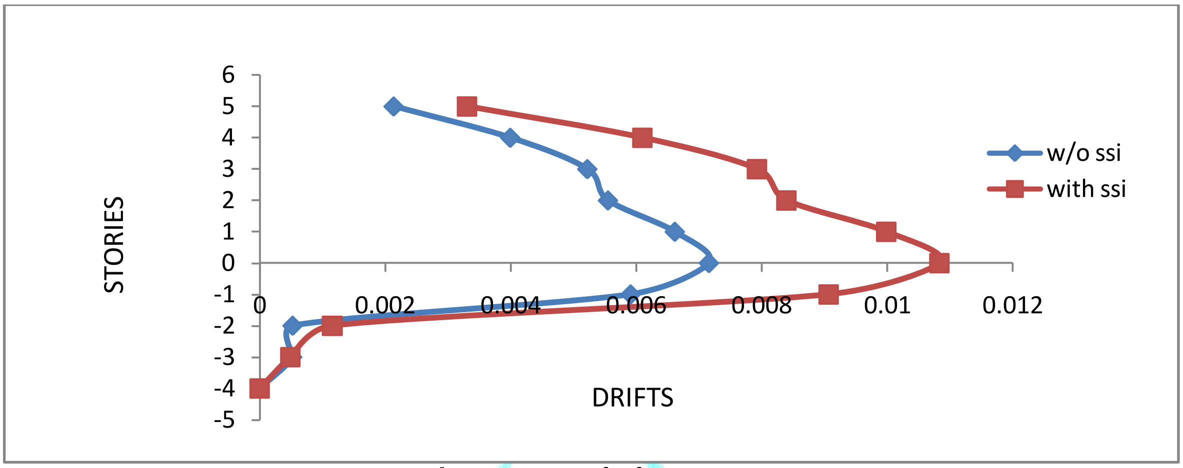
SL NO	BASE SHEAR	VALUES	UNITS
1	X direction(V_{BX})	945.94	kN
2	Y direction(V_{BY})	952.404	kN



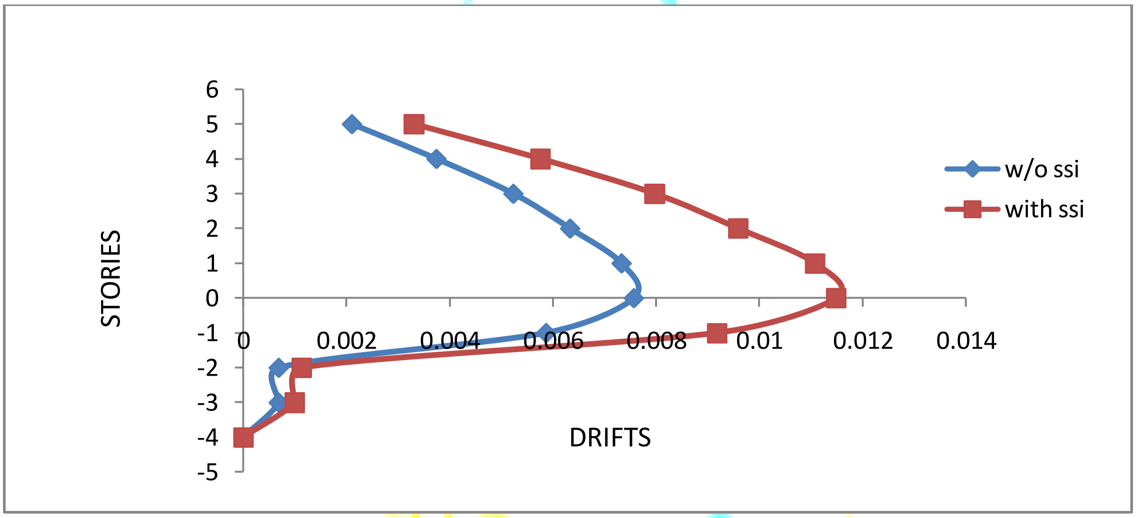
Graph .1 Maximum Storeys Displacement for X direction



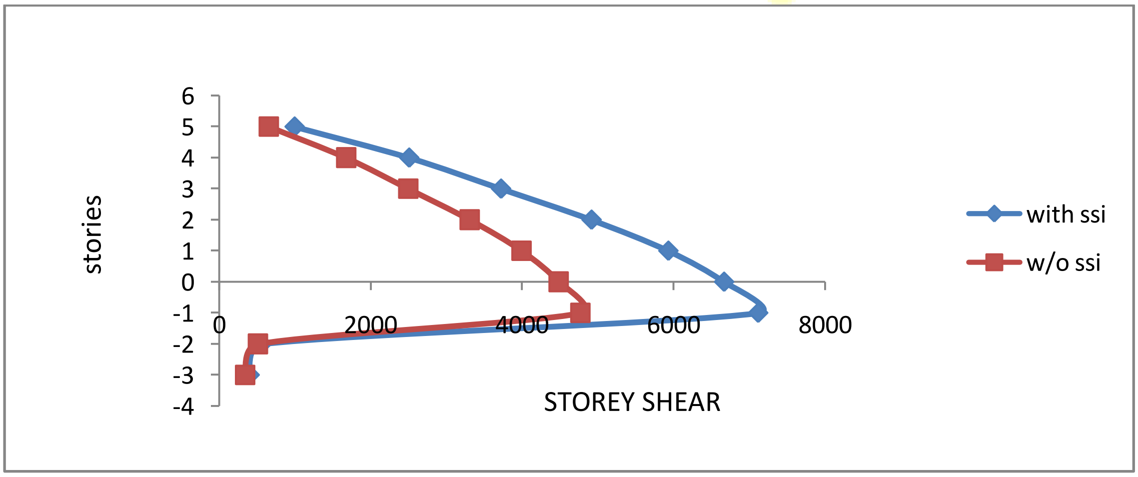
Graph .2 Maximum Storey Displacements for Y Direction



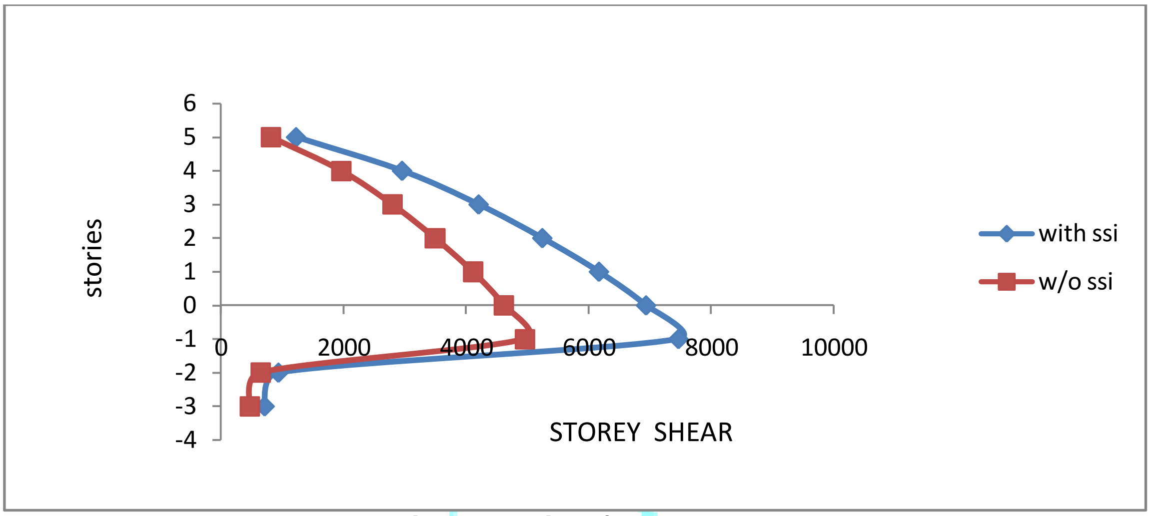
Graph .3 Storey Drifts for X Direction



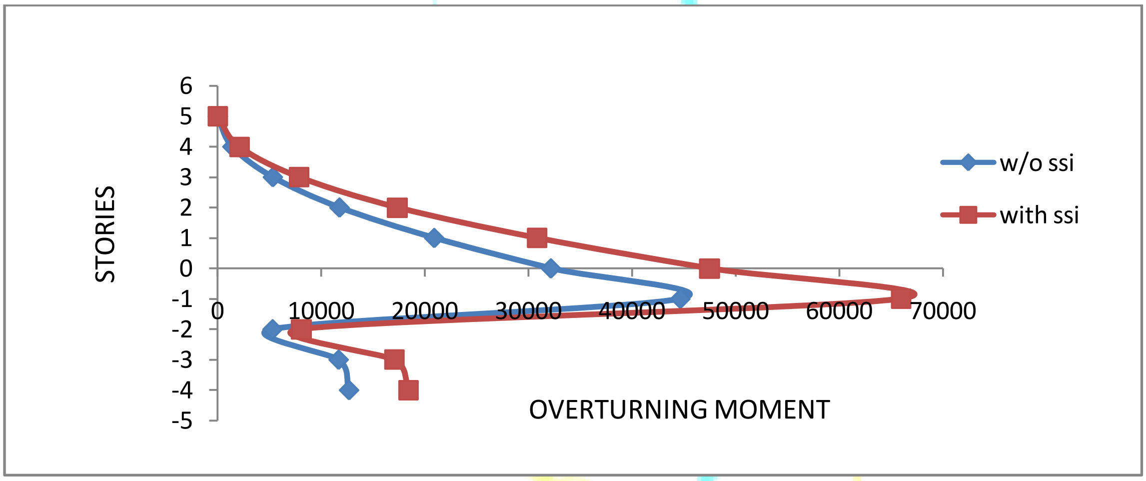
Graph .4 Storey Drifts for Y Direction



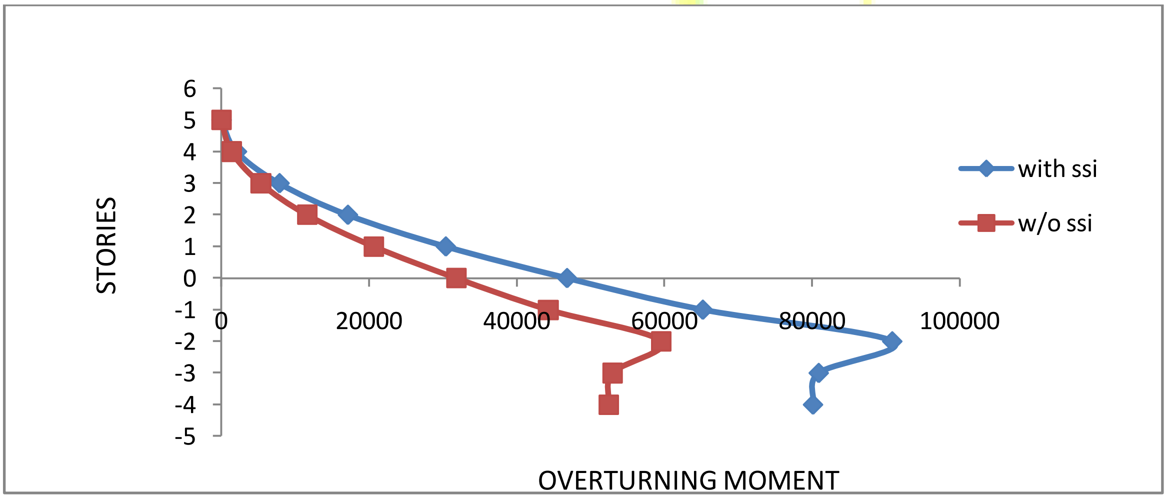
Graph .5 Storey Shear for X Direction



Graph .6 Storey shear for Y Direction



Graph .7 Overturning Moment for X Direction



Graph. 8 Overturning Moment for Y Direction

VI. CONCLUSION

From the above study, the parameters considered were compared and the following conclusion were drawn:

1. From Graph 1; the structure undergoes 53.52 % more displacement when SSI is taken into consideration comparative to without soil structure interaction in x direction.
2. From Graph 2; the structure undergoes 52.95 % more displacement when SSI is taken into consideration comparative to without soil structure interaction in y direction.
3. From graph 3; the comparative drift at respective stories for RS in X Direction with and without SSI, here the drift at ground level is 0.00367 larger with SSI than without SSI. So 51.2% more drift is observed when the SSI is taken in to account comparative to without SSI. Maximum drift is observed in ground level as the stiffness and fixity conditions changes between the stories.
4. From Graph 4; the comparative drift at respective stories for RS in Y Direction with and without SSI, here the drift at ground level is 0.00391 larger with SSI than without SSI.So 51.65 % more drift is observed when the SSI is taken in to account comparative to without SSI. Maximum drift is observed in ground level as the stiffness and fixity conditions changes between the stories.
5. From graph 5; 49.14 % more story shear was observed when soil structure interaction was taken into consideration comparative to without soil structure interaction in x direction.
6. From graph 6; 71.32 % more story shear was observed when soil structure interaction was taken into consideration comparative to without soil structure interaction in y direction.
7. From Graph 7, the comparative Overturning Moment at respective stories for RS in X Direction with and without SSI, here the Overturning Moment at basement 1 is 21286.3 kN-m larger with SSI than without SSI. So 47.66 % more Overturning Moment is observed when the SSI is taken in to account comparative to without SSI.
8. From Graph 8, the comparative Overturning Moment at respective stories for RS in Y Direction with and without SSI, here the Overturning Moment at basement 2 is 31341.7 kN-m larger with SSI than without SSI.So 52.6 % more Overturning Moment is observed when the SSI is taken in to account comparative to without SSI.Due to vertical irregularities and large lateral spacing between the foundations in Y direction, the overturning moment is more in basement 2 than in basement 1in Y axis.

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