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Analysis of Asymmetrical Building with Shear Wall under Seismic Loading

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Abstract:*Earthquakein inhabited areas throughout the globe may cause intensive harm to the varied structures that lead to harmful damage of social life and massive financial harms. However, the loss can be recognized to the improper design of the structures. In this paper an unsymmetrical building with placement of external and internalshear wall under two different support conditions at the base i.e. fixed and springis analyzed by elastic half space approach. A commercially available software package Staad-Pro 2008 has been used for this purpose. The results of interactive analysis have been compared in terms of axial load, settlements, shear force and bending moments in beams and columns. The interactive analysis shows that axial load in external columns of the building increases in comparison to fixed base case whereas the axial load in the interior columns shows a decreasing trend .The change in bending moment with increasing upto65% and decrease upto 78% in bending moment was observed. The storey drifts also shows variationupto 25% for the interior columns when soil structure interaction (SSI) was incorporated in the analysis.*

Keywords:*Asymmetrical building, loads, shear wall, elastic half space approach.*

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I. Introduction

1.1 General

A multi storied and panelled frame could be a sophisticated statically indeterminate structure. It involves of variety of built-up beams and columns designed which forms a grid. Frames of building are subjected to each vertical still as horizontal hundreds.The capability of the multi-storied building to counteracteffect of horizontal forces can be influenced by the rigidity of joints between the beams and columns.Generally for lower to medium height structures, the analysis and design of structure should be done with relevancy to lateral loads has typically be thereis a way forexamination the vertical load resistancestructurehavingcapability to counteract lateral loads. Though, for high rise buildings, method of vertical load resistance have not ability to repel lateral forces with proficiently; it's renowned that the lateral forces are resisting systems with now like shear walls, braced systems etc. enhance the structural strength characteristics and performance ability of building which is subjected to lateral loads as a result of earthquake excitation induced. Additional, the different positions of shear walls inside the building changes the response of structure.Shear walls are straight vertical members, fabricatedfrom RCC material, of the parallel horizontal forces resistancemethod. Shear wallsmade to resistthe lateral forces acting on structures. Shear walls are straight outer walls in residential buildingsthat normally build a box have capability tosupport building from laterally acting forces .Whereas shear walls have designed and madeappropriately, they must have enoughstiffness and strength to resist the horizontal forces acting in it. It alsorequired selecting the locationof the shear walls by long experience of engineers, in order that most profit will beresulting. Similarly, implementingrealistic approach for structuralbase soil behaviour, a flexible approach analysis making an allowance for SSI, moreover alters the response of structure in terms of maximum bending moment, axial thrust effect, settlement etc. thus response of building in relations of axial forces and effect of bending moment in members, settlement in foundation is needed to be determined, due to situation of shear walls at completely various possible locations and additionally as a result ofeffect of SSI. The occurrence of soil-structure interaction is a lot of prominent in case of multi-storied building frames particularly, when resting on the poor soils, because of chance of hugeun-symmetrical column loads. Neglecting the effect of SSI is most affordable and cheap for the light weight structures in comparatively stiff soil like lower rise buildings and straight forwarded rigid retaining walls. The impact of SSI in structures responsemake a distinction for the heavy weight structures resting on comparatively soft soils as an example high-rise buildings, nuclear-poweredplants and elevated-highways formed on soft soil.

1.2 Objective of Present Study

The study in this paper aims to ascertain the effect of position of shear walls in asymmetrical building frames, thereby finding the optimized location of shear walls in the building. Also affect of SSI on the response of the structure is to be explored for building frames provided with shear wall, and then to evaluate the result of the member forces in the super-structure.

1.3 Scope of Work

The following work presents a linear three-dimensional analysis of the proposed structure-foundation-soil system. An asymmetrical framed building consisting of twelve, eight and six storeys resting on loose soil has been considered for the investigation. In order to meet the objectives of the current study, the following scope of work has been framed.

- Analysis of an asymmetrical building frame, with shear walls, using fixed base approach.
- Analysis of change in response of building, due to change in position of shear walls using fixed base approach.
- Analysis of an asymmetrical building frame structures with shear walls by using flexible approach.
- Then, analysing, the change in response of the building frame, due to change in position of shear walls, using flexible approach.

II. Modelling of Asymmetrical Building

2.1 Building Design

An RC framed irregular building with different heights and with different locations of shear wall located in seismic zone IV has been taken forthe purpose of study. The framed irregular building is twelve-storey, eight-storey and six-storey high as presented in Fig 1. The building inplan is 31.5 m x 31.5m.The supports are assumed to be fixed and fixed butt accordingly.

2.2 Sectional Properties

Table No 1 Various sectional properties

Height of the ground storey	3m
Height of upper storey's	3m
Size of Column	450mm x 450mm
Size of Beam	300mm x 450mm
Size of Slab	125 mm
Roof slab finishing	75 mm
Size of walls	Full brick masonry
No. of bays in X and Z-direction	7
spacing between supports	4.5 m

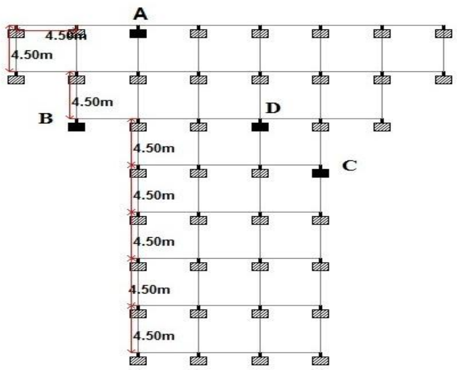

Fig 1 Plan of building

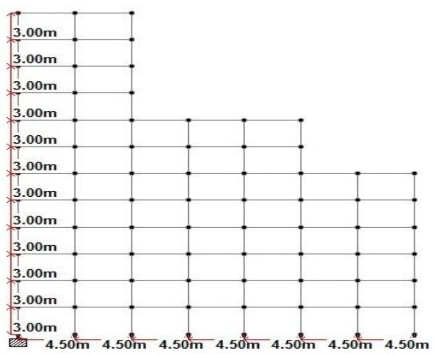

Fig 2 Elevation of building

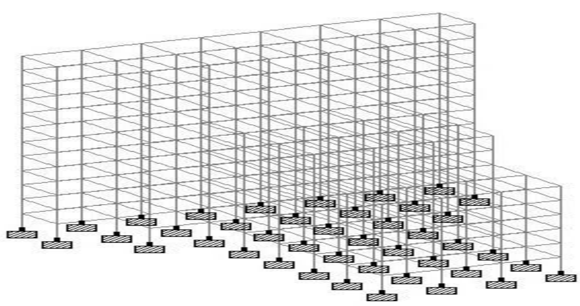

Fig 3 Isometric view of asymmetrical building

2.3 Position of Shear Wall

In this current study, 2 locations of shear walls areincorporated with in the design method.

1. At First, shear walls formedwithin the extreme end position within the external frame of the building, the shear wallsproviding having L shape in the outer frame of the building, and additionally elevate well sortshear wall is providingat the centre frame of the building As shown in Fig No 4
2. At second, shear wallsprovidingwithin the interior frame of the building, equally L formed shear walls shouldbe providing at the acute corners of the frame and additionally the centre position of structure is given with lift well, as shown in Fig No 5

Table No 2 Various cases for analysis

Case No	Location of Shear Walls in Building	Soil Structure Interaction
1	Position of shear wall in external frame	YES
2	Position of shear wall in external frame	NO
3	Position of shear wall in internal frame	YES
4	Position of shear wall in internal frame	NO
5	No shear wall	NO

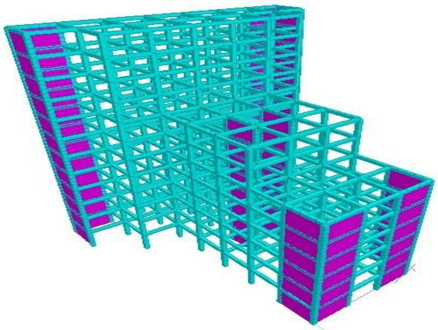

Fig 4 shear wall in External frame

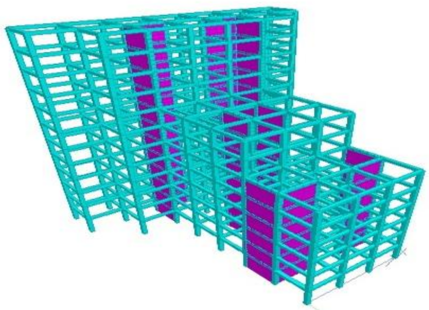

Fig 5 shear wall in internal frame

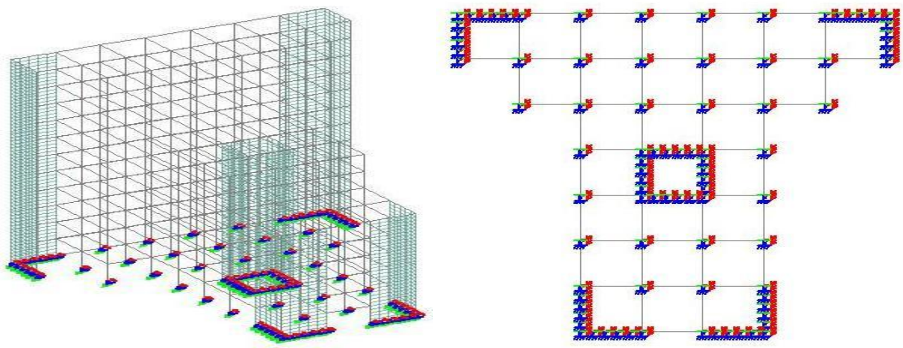

Fig6 Isometric view and Plan of building with shear wall in external Framehaving spring supports

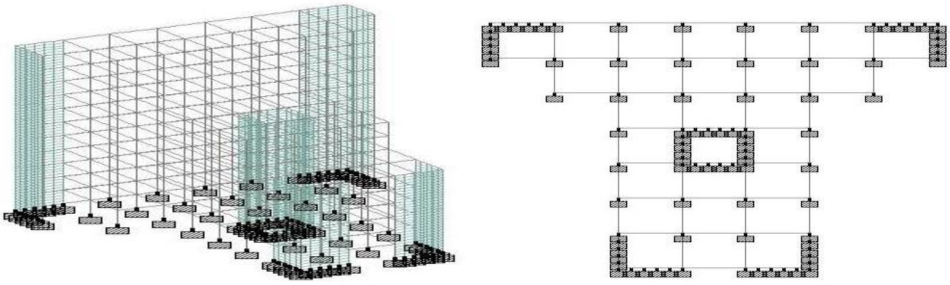

Fig 7 Isometric view and Plan of building with shear wall in external Frame having fixed supports

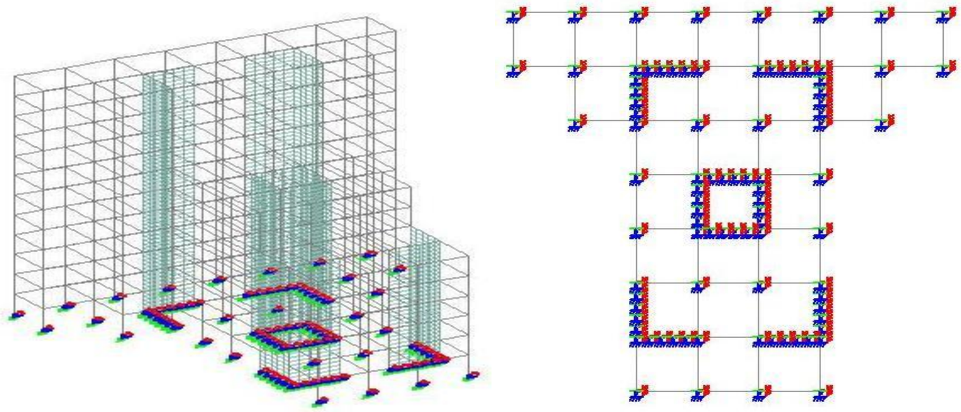

Fig 8 Isometric view and Plan of building with shear wall in internal Frame having spring supports

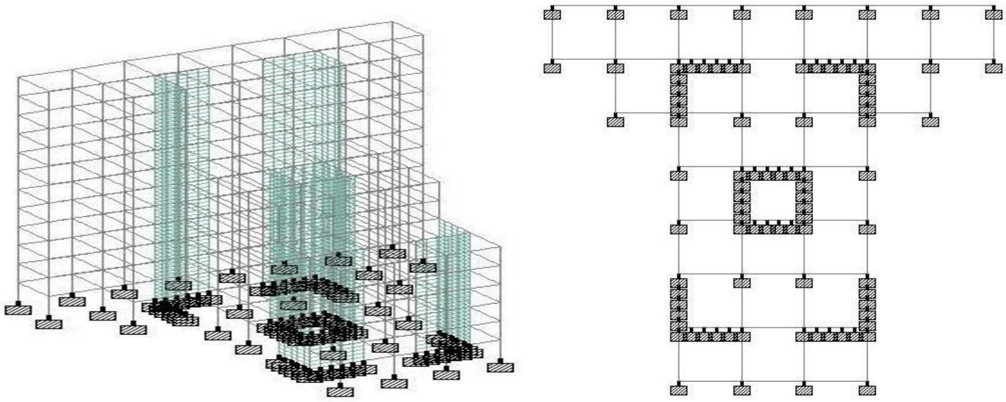

Fig 9 Isometric view and Plan of building with shear wall in internal Frame having fixed supports

III. Analysis and Results

3.1 General

The currentpaper dealing with three D multi-bay RC building supported on footings which is resting on loose soil. The affiliation link between columns and footings may either fixing or fixed but/spring. Though, it'ssupposed here soil provides flexibility against vertical and horizontal displacement, conjointlyrotation atmain nodded points by the side ofjointedge between the footings and soil.The structural analysis and design should be done with the help of software well named as STAAD PRO. Basically, it is depend on stiffness matrix method. During present study, a multi-bay strengthened building be situated analysed for variouskinds of load combination and loads acting i.e. Gravity Load it include self-weight of structural members and suitablecalculation of live load (GL); Seismic or Earthquake load (EL). After the buildings framebe there analysed for most critical load or for variousload combination acting on it.There are 3 different methods particularly named as Winkler, Elastic Half Space & Finite element method which mightbe thereused for interactive analysis of building. Amongst these techniques, elastic half space approach has been utilized in current paper.

3.2 Loads Considered in the Analysis

The following loads should be considered for the analysis of different buildings.

3.2.1 Gravity Loads

The dead load and live load at different floor and roof levels will be considered for currentanalysis are mention below.

- **Dead Load**

Weight of Slab	0.120 x 25	3.000 KN/m^2
Weight of Screed	0.050 x 20	1.000 KN/m^2
Weight of Floor Finish	0.040 x 24	0.960 KN/m^2
Weight of Partition Wall	-	1.000 KN/m^2
Total Dead Load		**5.960 KN/m^2**

- **Live Load**

Imposed load at all floor levels = 3.0 KN/m^2, this live load is reduced by 50% for calculating the seismic weight of the structure as per provisions of IS 1893:2002. No live load is considered on roof when effect of earthquake is taken into account.

3.2.2 Seismic Loads

IS 1893-2002(part I) is used for seismic load calculations. The mass of the building is supposed to be taken at the different floor levels. The weight of all column beams and walls have been equally dispersed to all the floors. The floor load includes the self-weight of the floor and the reduced imposed load as per the codal provisions.The design horizontal lateral loads due to earthquake shall be calculated as follows:

- **Design horizontal seismic coefficient:**

The design horizontal seismic coefficient $\mathbf{A_h}$ for a given structure is calculated with given expressions:-

$\mathbf{A_h} = \frac{Z\ I\ Sa}{2Rg}$ (Providing that for every structure T≤0.1 sec)

The value of $\mathbf{A_h}$ shall be equal to or more than **Z/2**whatsoever the value of R/I.

Z= Zone factor

I = Importance factor dependenton the practicalusage of the structure.

R = Response reduction factor which depends onsupposedseismic damage performance of the structure.

Sa/g =Average response acceleration coefficient used for soil or rockplacesas specified in IS1893:2002 (PART 1).

3.3 Load Combinations

Table 3 load combinations have been considered for the analysis of the building are given as under:

Table 3. Load combinations

Sr. No.	Load Combinations	Sr. No.	Load Combinations
1	SEISMIC X	10	1.5(DL+EQX)
2	SEISMIC Z	11	1.5(DL-EQX)
3	DEAD LOAD	12	1.5(DL+EQZ)
4	LIVE LOAD	13	1.5(DL-EQZ)
5	1.5(DL+LL)	14	0.9DL+1.5EQX
6	1.2(DL+0.5LL+EQX)	15	0.9DL-1.5EQX
7	1.2(DL+0.5LL-EQX)	16	0.9DL+1.5EQZ
8	1.2(DL+0.5LL+EQZ)	17	0.9DL-1.5EQZ
9	1.2(DL+0.5LL-EQZ)		

3.4 Seismic Design Factors Used For Analysis

- Response spectrum factor :- The response reduction factor (R) used for the buildings in this paper is consider as 5 i.e. special RC moment resisting frame (SMRF) shall betaken as these are the basic common structural element being used in earthquake resistant structure.
- Importance Factor: - the importance factor (I) for the subjected buildings is considered as 1.
- Zone Factor: - the seismic zone factor (Z) is taken as 0.36 asfor the selected buildings the structures are supposed to be in the seismic zone V.
- Damping Ratio:- The critical damping for problem structures is consider as 5 % specified for concrete by IS :1893-2002 (part I).
- Soil Type: - The soil type supposed for the design acceleration spectrum in Type I soil i.e. loose Soil.
- Imposed Load: - An imposed uniformly distributed floor load of 4KN/m^2 is assumed for this problem.
- Percentage fall of imposed load for Earthquake: - the design imposed or live load for earthquake assumed to be 50% as per the IS codal provisions.

3.5 Soil Properties

In the present research, the building was supposed to be resting in soil with bearing capacity 100 kN/m^2. The modulus of elasticity (E) and poisson's ratio (μ) has been taken as 17500 kN/m^3 and 0.3 respectively.

3.6 Methods of Analysis

At First,shear walls is analysed forvarious positionsin asymmetrical building frame with of by conventional approach i.e. fixing base by given that a fixed base support while notallowing for the influence of SSI. Further for subsequentsituation, the building frame is analysed by flexible approach that havedifferent spring base conditions, also which is incorporate the influence of flexibility of soil and the footing is supposed to be situated situated on elastic medium. For that particular situation 6 springs, 1 to put up the vertical motion, a pair of tocomprise the translational motion in equivalent horizontal directions and 3rotating springs are providing at the foundation level. For 3rd case, the structure is examined by not considering shear wall and SSI effect. The stiffness properties of the springs shall beexamined by means of the different relations mention by Richart et.al. (1970). Third forthe distinction between all conditions alsorelated with eachbasis of critical axial forces, bending moment effects, shear forces, storey drift & time period.The technique which is used effectively for the analysis was elastic half space approach (Richart, Hall and Woods Approach).

3.6.1 Elastic Half Space Approach

In Elastic half space approach foundation shall be idealised by means that of the vibratory mechanical generatorthrough a base circular in shaperesting onthe ground bottom. The ground is meant an elastic, homogenised, isotropoussemi-infinitekind that is statedas per elastic half space.

3.6.1.1Vertical Spring Constant (K_v)

$$K_v = \frac{4Gr}{(1-\mu)}$$

Where G=dynamic shear modulus
μ= Poisson's ratio
r =Equivalent radius
r =$\sqrt{BL/\pi}$
Where L = longer side of footing
B = shorter side of footing

3.6.1.2Horizontal Spring Constant (Kh)

$$K_h = 32Gr\frac{(1-\mu)}{(7-8\mu)}$$

Where G=dynamic shear modulus
ν = Poisson ratio
r =Equivalent radius
r =$\sqrt{BL/\pi}$
Where L = longer side of footing
B = shorter side of footing

3.6.1.3Rocking Spring Constant (KΦ)

$$K\Phi = \frac{8Gr3}{3(1-\mu)}$$

Where r =$\sqrt[4]{\frac{BL^3}{3\pi}}$

Where G=dynamic shear modulus
r =Equivalent radius
Where L = longer side of footing
B = shorter side of footing

3.6.1.4Torsional Spring Constant (KΩ)

$$K\Phi = \frac{16}{3}Gr3$$

Where r = $\sqrt[4]{\frac{BL(B^2+L^2)}{6\pi}}$

Where G=dynamic shear modulus
r =Equivalent radius
Where L = longer side of footing
B = shorter side of footing

Table 4. Spring Constant Values by Elastic Half Space Approach

Node No.	**Area of Footing**	**Vertical K_v(kN/m)**	**Horizontal K_{hx}(kN/m)**	**Horizontal K_{hz}(kN/m)**	**Rotational $M_{\Phi X}$ (kN-m/deg)**	**Rotational $M_{\Phi Z}$ (kN-m/deg)**	**Rotational $M_{\Phi Y}$ (kN-m/deg)**
9,25,38,46,31,43,33,44,27,39,29,41,19,35	4.5×4.5	97307.00	82922.01	82922.01	429999.41	590153.03	429999.41
1,3,5,6,11,17,57,47,63,61,67,65	4.95×4.95	107307.50	91444.48	91444.48	574977.76	813434.78	574977.76
12,13,14,15,55,53,51,49	4.95×4.5	102307.50	87183.62	87183.62	466409.61	698603.14	466409.61
4,7,23,37,45,59,21,36	4.5×4.95	102307.50	87182.62	87182.62	533252.47	698603.14	533252.47

Table 5 Spring Constant Values by Elastic Half Space Approach

Node No.	**Area of Footing**	**Vertical K_v(kN/m)**	**Horizontal K_{hx}(kN/m)**	**Horizontal K_{hz}(kN/m)**	**Rotational $M_{\Phi X}$ (kN-m/deg)**	**Rotational $M_{\Phi Z}$ (kN-m/deg)**	**Rotational $M_{\Phi Y}$ (kN-m/deg)**
1,3,4,5,6,7,11,12,13,14	13.95×4.95	179999.75	144415.10	144415.10	1256921.30	5315236.01	1256921.30
230,248,254,258,259,272,278,282,283,296,302	13.95×4.95	179999.75	144415.10	144415.10	1256921.30	5315236.01	1256921.30
61,63,65,51,53,55,67,71,73,77,90,87,110,104,128,115,79,75,72,69	9.00×9.00	145384.41	122122.90	122122.90	3461679.70	4846340.00	3461679.70
31,33,35,36,37,38,39,41,43,46	13.50×4.95	177307.44	149261.30	149261.30	1226463.60	5047447.50	1226463.60
83,134,138,139,152,224,211,210,206,200,187	13.50×4.95	177307.44	149261.30	149261.30	1226463.60	5047447.50	1226463.60

Table 6 Spring Constant Values by Elastic Half Space Approach

Node NO.	**Area of Footing**	**Vertical K_v(kN/m)**	**Horizontal K_{hx}(kN/m)**	**Horizontal K_{hz}(kN/m)**	**Rotational $M_{\Phi X}$ (kN-m/deg)**	**Rotational $M_{\Phi Z}$ (kN-m/deg)**	**Rotational $M_{\Phi Y}$ (kN-m/deg)**
9,11,12,13,14,15,36,38,41,44,49	13.95×4.50	171922.84	144400.18	144400.18	1007793.48	4960299.96	1007793.48
85,138,139,158,163,186,187,200,206,210,211	13.95×4.50	171922.84	144400.18	144400.18	1007793.48	4960299.96	1007793.48
61,63,65,51,53,55,67,71,73,77,87,90,110,104,128,115,79,75,72,69	9.00×9.00	145384.41	122222.90	122222.90	3461677.77	4846330.00	3461677.77
21,23,25,27,,29,31,35,37,39,43,45	13.5×4.95	177207.44	149271.30	149271.30	1226464.60	5047457.50	1226464.60
81,134,152,162,176,359,258,254,248,235,234	13.5×4.95	177207.44	149271.30	149271.30	1226464.60	5047457.50	1226464.60

IV. Conclusion

The following conclusions can be drawn from this study:

- Due to presence of shear walls in the external frame of the building, the axial forces in the columns were reduced by 10-15%, in internal column there was a marginal reduction of 2-4%. The shear force was reduced by 10-80% for columns in the lower storeys, and then increased by 50-100% for columns in the top storeys. The bending moment reduced by 10-80% for the columns in lower storeys, but it increased from 15-50% from 6^{th} to top storey.
- Due to presence of shear walls in the external frame of the building, the axial forces in the columns were reduced by 10-15%, in internal column there was a marginal reduction of 2-4%. The shear force was reduced by 10-80% for columns in the lower storeys, and then increased by 50-100% for columns in the top storeys. The bending moment reduced by 10-80% for the columns in lower storeys, but it increased from 15-50% from 6^{th} to top storey.
- By considering SSI effect in the building with shear walls in the external frame, the axial forces increased from 1-15% for columns C1 & C4 (external and internal column), and decreased for columns C2 & C3(external columns) up to 8%.Shear force value decreased up to 8^{th} storey for the columns and then increased from 5-20% in the top storeys. Bending moment reduced from 5-80% up to 7^{th} storey for the columns then increased considerably in the top storeys.
- By considering SSI effect in the building with shear walls in the internal frame, the axial forces increase up to 6% for the columns, but it increased considerably from 3-15% for column C4 (internal column).

- While the influence of shear wall is taken in to consideration at the external frame of the building, storey drift decreases from 30-90% upto 10^{th} storey and then increases in the top storeys from 65-75%. While the influence of shear wall is considered at the internal frame of the building, a decrease of storey drift from 15-90% upto 10^{th} and then an increase from 10-50% in top storeys was observed.
- When SSI is considered and shear walls are providing at the external frame of the building, the storey drift decreases considerably upto 350% in the lower 9 storeys and then increased from 65-75% in the top storeys.
- Similarly the effect of SSI Is considered when shear walls are providing in the internal frame of the building a considerable decrease in the storey drift of about 180% upto 4^{th} storey and then an increase from 10-30% in the top storey was observed.
- When shear walls are provided in the external or internal frame, a decrease in time period of about 45-50% was observed, and an increase of 90-100% was observed in Sa/g value.

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