iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: XI Month of publication: November 2022

DOI: https://doi.org/10.22214/ijraset.2022.47708

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue XI Nov 2022- Available at www.ijraset.com

Comparative Analysis on Inclined Column by Using Staad Pro under Lateral Loads at Different Positions

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Abstract: Advances in construction technology, materials, structural systems and analytical methods for analysis and design facilitated the growth of high-rise buildings. Structural design of high-risebuildings is governed by lateral loads due to wind or earthquake. Lateral load resistance of structure is provided by interior structural system or exterior structural system. Usually shear wall core, braced frame and their combination with frames are interior system, where lateral load is resisted by centrally located elements. While framed tube, braced tube structural system resists lateral loads by elements provided on periphery of structure. It is very importantthat the selected structural system is such that the structural elements are utilized effectively while satisfying design requirements. Recently Inclined columns structural system is adopted in tall buildings due to its structural efficiency and flexibility in architectural planning. Compared to closely spaced vertical columns in framed tube. Inclined column should be placed at the exterior surface of the building. Due to inclined columns lateral loads are resisted by axial action of the diagonal compared to bending of vertical columns in framed structure. Inclined column structures generally do not require core because lateral shear canbe carried by the diagonals on the periphery of building. Analysis and design of G+9 storey building is presented. A regular floor plan of 36 m × 36 m size is considered. Staad pro software is used for modelling and analysis of structural members. All structural members aredesigned as per IS 456:2000 considering all load combinations. Dynamic along wind and across wind are considered for analysis and design of the structure. Load distribution in system is also studied for G+9 storey building. Similarly, analysis and design of G+9 storey vertical column structures is carried out with and without weak storey. Comparison ofanalysis results in terms of time period, top storey displacement and inter-storey drift will be presented in this study with or without inclined column in frame structure.

I. INTRODUCTION

Soft storey is a common building weakness. The term soft storey explains one level of a building that is appreciably more flexible than the stories above it and the floors or the foundation under it. A soft storey can be defined on the basis of the stiffness of the adjacent floor stiffness, building can be said to be soft storey or week storey if the stiffness of that particular level is less than 70 % with respect to floor instantly above it or less than 80 % of average stiffness oft the three floors above it. Some building in which height of floor is greater in ground these type of building is knowing as Open Ground storey buildings or soft storey. The weak or soft storey commonly exists at the ground storey level, but it might be at any other storey level. Soft storeybuildings have a lot of open space for example, parking garage, restaurants or floors with lots of windows. The behavior of soft storey building in an earthquake is very crucial because the soft storey building is more flexible in seismic condition, vibration is happening in the soft storey building so we provide shear wall in a soft storey building (shear wall resists the effect of an earthquake).

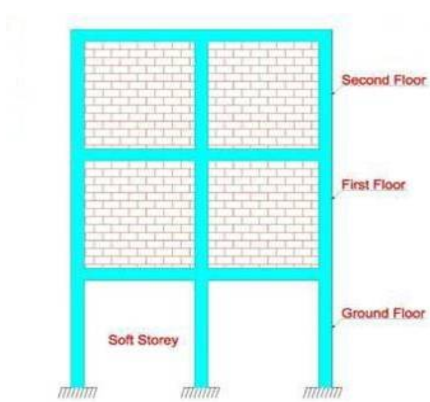

Fig. 1. 1 Soft Storey Building

Reinforced concrete frame structures have become a common form of construction with masonryinfill in urban and semi urban areas in the world. The infill framed structures are made and analyzed by the combination of a moment resisting plane frame and infill masonry walls. The infill masonry may be of brick, concrete blocks, or stones. Ideally in present time the reinforced concrete frame is filled with bricks as non-structural wall for partition of the rooms because of itsadvantages such as, thermal insulation, durability, cost and simple construction technique.

Nowadays, many buildings are constructed having a unique feature i.e. the ground floor remains open, which means the columns in the ground floor do not have any partition walls between them. This type of structure (Fig. 1.2) having no infill masonry walls in ground floor, but having infill masonry walls in all the upper floors, are called Open Ground Storey (OGS) Buildings. This open ground floor structure is also termed as a structure with 'soft storey at Ground Floor'. OGS buildings are also known as open first storey building (when the floor numbering starts with one from the ground floor itself), pilots, or stilted buildings. Open first storey is nowadays unavoidable feature for the most of the urban multi-storey buildings because social and functional needs for parking, restaurant, commercial use etc. are compelling to provide an open first Storey in high rise structure. Parking has become a necessary feature for the most of urban multistoried buildings as the population is increasing at a very fast rate in urban areas leading to crisis of vehicle parking space. Hence the trend has been to use the ground floor of the building itself for parking purpose.

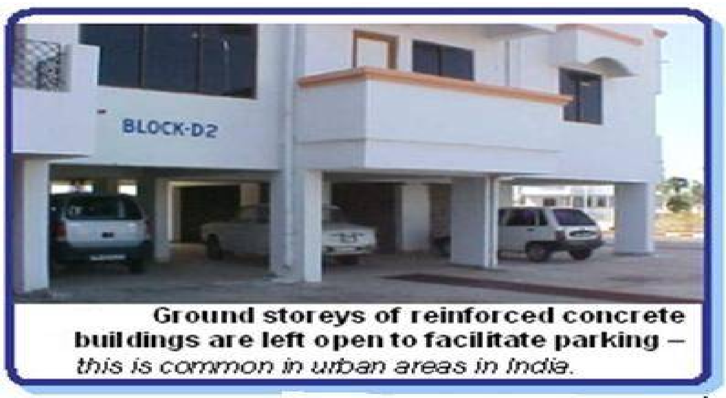

Fig. 1. 2 Model Of A Building With Soft Storey At Ground Floor

There is major advantage of this type of buildings functioning, but from the seismic performancepoint of view, such structures are considered to have increased vulnerability. Though multi- storied buildings with parking floor (soft storey) are vulnerable to collapse due to seismic forces,their construction is still popular. The Soft Storey buildings are usually designed as framed structures without regard to structural action of wall (masonry infill walls). In India current structural design methods, infill walls are considered as non-structural element and their strength and stiffness are ignored during analysis and design. The effect of infill panels on RC framed structures if subjected to earthquake is widely accepted and has been subjected to numerous experimental and analytical investigations over last 5 decades.

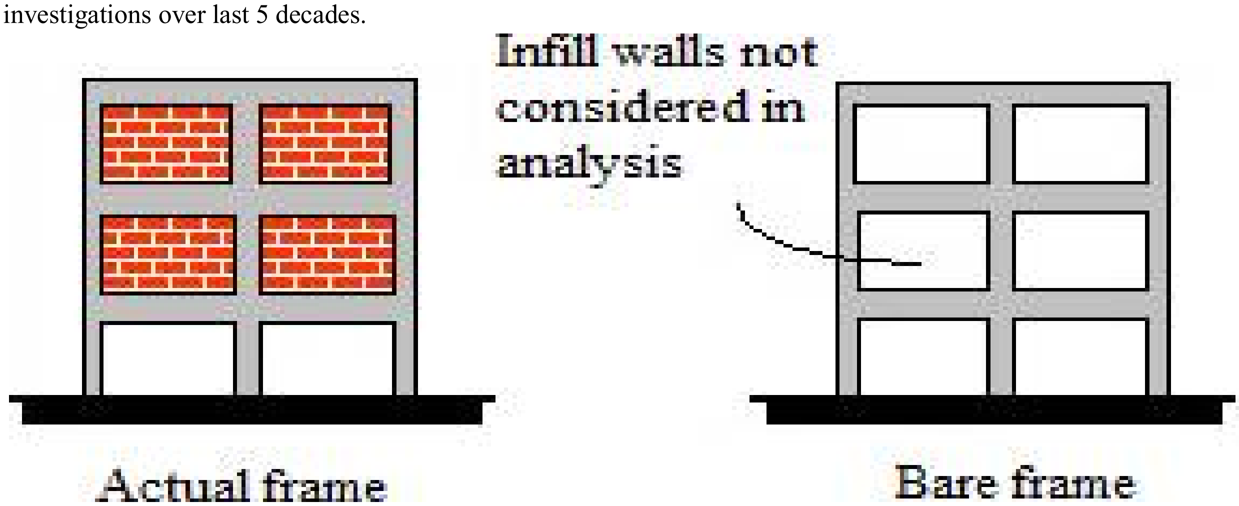

FIG. 1. 3 SOFT STOREY BUILDING ANALYSED AS PER PREVALENT PRACTICE

A. Behaviour Of Soft Stories In Earthquake And Wind Load

Since the presence of a soft storey which has less rigidity than other stories and if this point was not taken into consideration, it causes the construction to be affected by the earthquake because columns in this portion are forced by the earthquake more than the ones in the other parts of the building. Studies conducted suggest that walls raise the rigidity at a certain degree in theconstruction of buildings.

Behaviour of construction is divided into two parts, from the point where there is no soft storey, the building with equal rigidity between the stories; the displacement of the peak points at the moment of an earthquake causes the other building with a soft storey to get damaged because theconstruction with a soft storey cannot show the same rigidity. For example, the top point of a ten-storey building with no soft storey performs 10-unit displacement, another building with the same specification but having a soft storey at the entry floor and with no necessary precautioncan show the same displacement 10-unit at this floor level. According to this outcome, a soft storey in the upper stories of the building is not so effective.

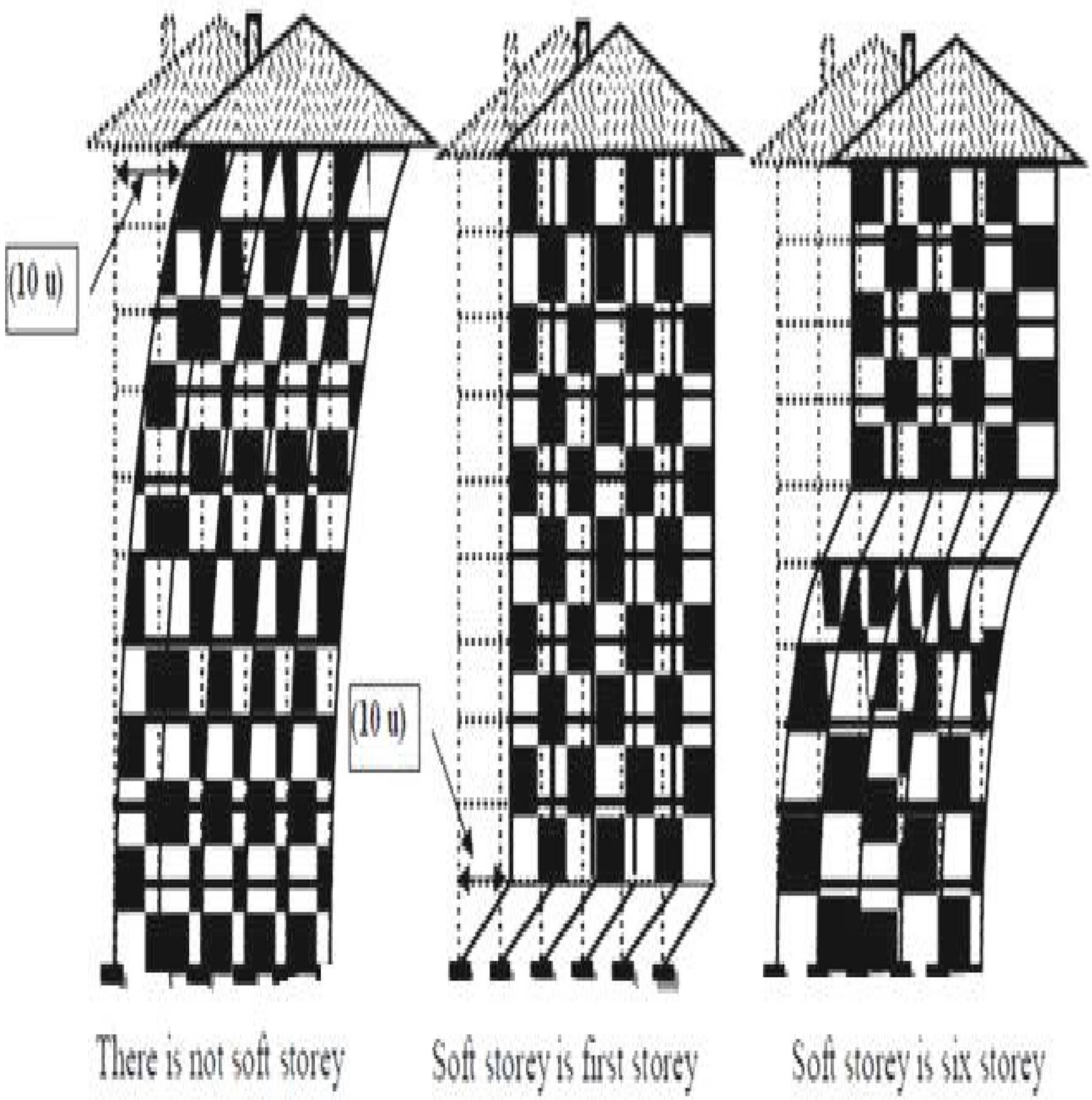

FIG. 1. 4 Behavior Of Soft Storey Building

Where; "u" is the displacement

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue XI Nov 2022- Available at www.ijraset.com

II. METHODOLOGY

The present research work deals with comparative study of behavior of soft storey building frames by considering geometrical configurations of building under earthquake loading and wind loading. The framed buildings are subjected to lateral loads and vibrations because of earthquake and wind load therefore lateral load analysis is necessary for these framed structures. The fixed base system is analyzed by employing equivalent inclined column frame structures in seismic and wind loading by means of STAAD Pro software. The responses of the same building frames are studied and evaluated the best position of soft floor which satisfies lateral loadings.

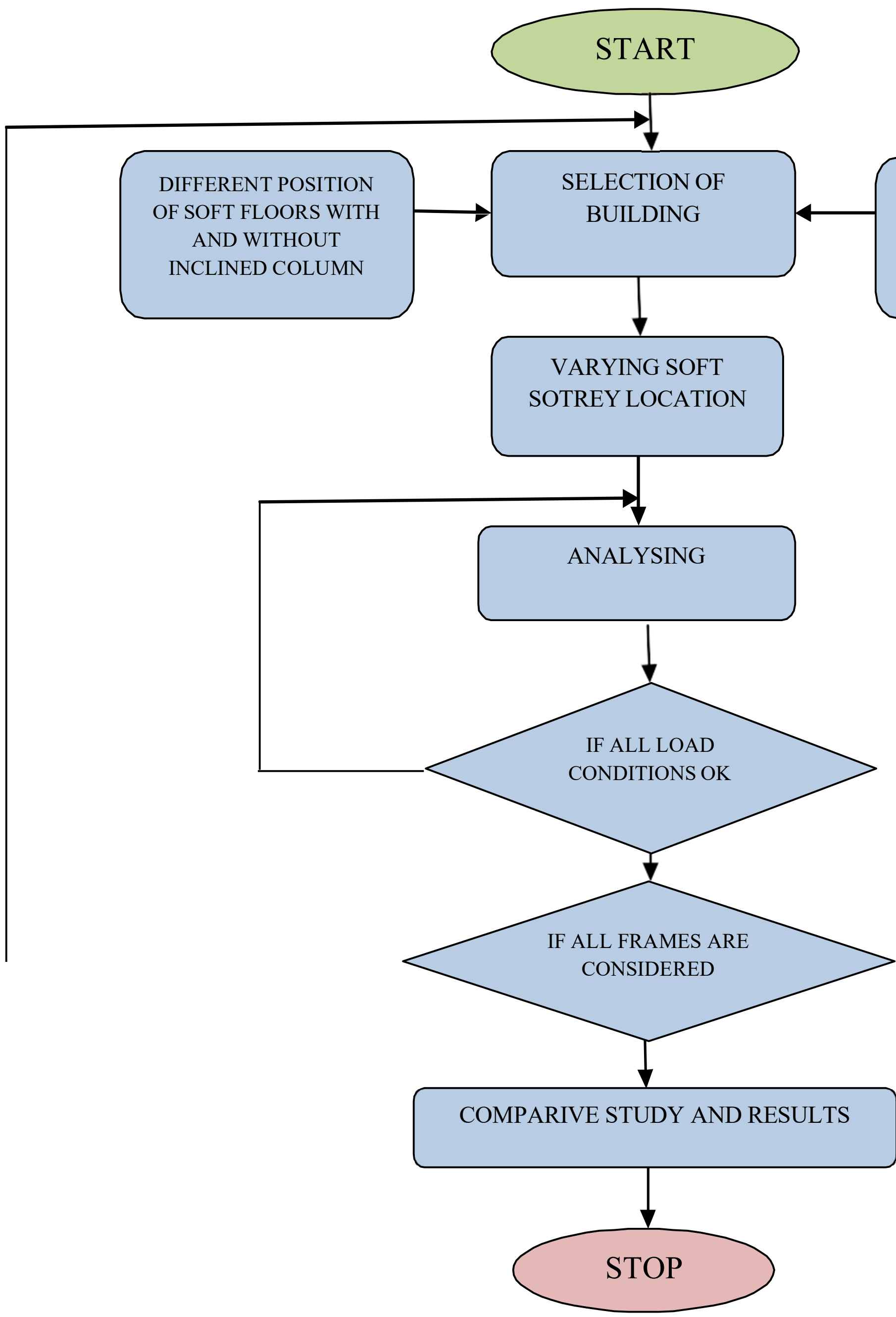

FIG. 3. 1 The Flow Chart Of Work

A. The Problem Formulation

1) *Step-1* Selection of building geometry and Seismic zone: The behavior of all the models is studied for Zone II of Seismic zones of India as per IS code 875 PART II-1987 for which zone factor (Z) is 0.10

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2) *Step-2* Selecting geometry of 10 stories (G+9) of plan area 36m x 36m

TABLE 3. 1 TOTAL PROBLEM IN EARTHQUAKE ANALYSES

SR. NO.	Cases performed	Case No.	Seismic zone	Inclined column
1.	Building without Soft Storey Without Inclined Column	I	1 (zone -II, Bhopal)	Without Inclined Column
2.	Ground Floor Soft Storey, Without Inclined Column	II	1 (zone -II, Bhopal)	Without Inclined Column
3.	2nd Floor Soft Storey, Without Inclined Column	III	1 (zone -II, Bhopal)	Without Inclined Column
4.	4th Floor Soft Storey, Without Inclined Column	IV	1 (zone -II, Bhopal)	Without Inclined Column
5.	6th Floor Soft Storey, Without Inclined Column	V	1 (zone -II, Bhopal)	Without Inclined Column
6.	8th Floor Soft Storey, Without Inclined Column	VI	1 (zone -II, Bhopal)	Without Inclined Column
7.	Top Floor Soft Storey, Without Inclined Column	VII	1 (zone -II, Bhopal)	Without Inclined Column
8.	Ground Floor Soft Storey, With Inclined Column inHorizontally Placed floor	VIII	1 (zone -II, Bhopal)	With Inclined Column
9.	2nd Floor Soft Storey, With Inclined Column in Horizontally Placed floor	IX	1 (zone -II, Bhopal)	With Inclined Column
10.	4th Floor Soft Storey, WithInclined Column in Horizontally Placed floor	X	1 (zone -II, Bhopal)	With Inclined Column
11.	6th Floor Soft Storey, WithInclined Column in Horizontally Placed floor	XI	1 (zone -II, Bhopal)	With Inclined Column
12.	8th Floor Soft Storey, WithInclined Column in Horizontally Placed floor	XII	1 (zone -II, Bhopal)	With Inclined Column
13.	Top Floor Soft Storey, WithInclined Column in Horizontally Placed floor	XIII	1 (zone -II, Bhopal)	With Inclined Column
14.	Ground Floor Soft Storey,With Inclined Column at Corners of building	XIV	1 (zone -II, Bhopal)	With Inclined Column
15.	2nd Floor Soft Storey, WithInclined Column at Corners of building	XV	1 (zone -II, Bhopal)	With Inclined Column
16.	4th Floor Soft Storey, With Inclined Column at Cornersof building	XVI	1 (zone -II, Bhopal)	With Inclined Column
17.	6th Floor Soft Storey, WithInclined Column at Corners	XVII	1 (zone -II, Bhopal)	With Inclined Column

	of building			
18.	8th Floor Soft Storey, WithInclined Column at Corners of building	XVIII	1 (zone -II, Bhopal)	With Inclined Column
19.	Top Floor Soft Storey, WithInclined Column at Corners of building	XIX	1 (zone -II, Bhopal)	With Inclined Column
20.	Ground Floor Soft Storey,With Inclined Column at Centre of building	XX	1 (zone -II, Bhopal)	With Inclined Column
21.	2nd Floor Soft Storey, With Inclined Column at Centreof building	XXI	1 (zone -II, Bhopal)	With Inclined Column
22.	4th Floor Soft Storey, With Inclined Column at Centreof building	XXII	1 (zone -II, Bhopal)	With Inclined Column
23.	6th Floor Soft Storey, WithInclined Column at Centre of building	XXIII	1 (zone -II, Bhopal)	With Inclined Column
24.	8th Floor Soft Storey, WithInclined Column at Centre of building	XXIV	1 (zone -II, Bhopal)	With Inclined Column
25.	Top Floor Soft Storey, With Inclined Column at Centreof building	XXV	1 (zone -II, Bhopal)	With Inclined Column

TABLE 3. 2 TOTAL PROBLEM IN WIND ANALYSES

SR. NO.	Cases performed	Case No.	Wind Zone	Inclined column
1.	Building without Soft Storey Without Inclined Column	I	1 (Vb= 39m/s, Bhopal)	Without Inclined Column
2.	Ground Floor Soft Storey, Without Inclined Column	II	1 (Vb= 39m/s, Bhopal)	Without Inclined Column
3.	2nd Floor Soft Storey,Without Inclined Column	III	1 (Vb= 39m/s, Bhopal)	Without Inclined Column
4.	4nd Floor Soft Storey, Without Inclined Column	IV	1 (Vb= 39m/s, Bhopal)	Without Inclined Column
5.	Ground Floor SoftStorey, With Inclined Column	V	1 (Vb= 39m/s, Bhopal)	With Inclined Column
6.	2nd Floor Soft Storey, With Inclined Column	VI	1 (Vb= 39m/s, Bhopal)	With Inclined Column
7.	4th Floor Soft Storey, With Inclined Column	VII	1 (Vb= 39m/s, Bhopal)	With Inclined Column

So, total 7 problems are analyzed in Staad

3) *Step-3* Modelling of soft stories floor wise.
4) *Step-4* Selection of Equivalent inclined column (200 mm x 200 mm) and above I to VII Cases considered.
5) *Step-5* Formation of load combination

Types of Primary Loads and Load Combinations: The structural systems are subjected to Primary Load and Load Combinations Cases as per I.S. 875 (Part I, Part II, Part III and Part V). and IS-1893 Part I-2016 framed are given in Table 3.3

TABLE 3. 3 NUMBER OF LOAD CASES IN EARTHQUAKE AND WIND LOADCALCULATIONS

Load case no.	Load Case Details
1.	E.Q. IN X_DIR.
2.	E.Q. IN Z_DIR.
3.	DEAD LOAD
4.	LIVE LOAD
5.	W.L. IN X_DIR.
6.	W.L. IN Z_DIR.
7.	1.5 (DL + LL)
8.	1.5 (DL + EQ_X)
9.	1.5 (DL – EQ_X)
10.	1.5 (DL + EQ_Z)
11.	1.5 (DL – EQ_Z)
12.	1.2 (DL + LL + EQ_X)
13.	1.2 (DL + LL – EQ_X)
14.	1.2 (DL + LL + EQ_Z)
15.	1.2 (DL + LL – EQ_Z)
16.	1.5 (DL + W.L. _X)
17.	1.5 (DL – W.L. _X)
18.	1.5 (DL + W.L. _Z)
19.	1.5 (DL – W.L. _Z)
20.	1.2 (DL + LL + W.L._X)
21.	1.2 (DL + LL – W.L. _X)
22.	1.2 (DL + LL + W.L. _Z)
23.	1.2 (DL + LL – W.L. _Z)
24.	0.9 DL + EQ_X
25.	0.9 DL – EQ_X
26.	0.9 DL + EQ_Z
27.	0.9 DL – EQ_Z

6) *Step-6* Modelling of building frames in STAAD.Pro software
7) *Step-7* Analysis of building frames with and without soft stories cases from given seismic zoneand each load combination.
8) *Step-8* Comparative study with graph and tables by maximum moments, displacement, storiesdisplacement, drift, axial force and shear force.

III. MATERIAL AND GEOMETRICAL PROPERTIES

Following properties of material have been considered in the modeling -Density of RCC: 25 KN/m^3
Density of Masonry: 20 KN/m^3 (Assumed)Poisson's ratio: 0.17
Young's modulus of concrete: $5000\sqrt{fck}$

The foundation depth is considered at 1.5 m below ground level and the normal floor height is 3m and soft floor height is considered as 4.2m. 3x3m grid and 12x12m plan is considered with G+5 stories in building is considered.

A. Loading Conditions

Following loads are considered for analysis -

1) *Dead Loads:* As per IS: 875 (part-1) 1987Self-weight of slab

   Slab = 0.15 x 25 = 3.75 KN/m^2 (slab thick. 150 mm assumed)Floor Finish load = 1 KN/m^2

   For External Walls

   Masonry Wall Load (floor height 3m) = 0.2 m x 2.5 m x 20 KN/m^3 = 10.0 KN/m Masonry Wall Load (floor height 4.2m) = 0.2 m x 3.7 m x 20 KN/m^3 = 14.8 KN/m**For Internal Walls**

   Masonry Wall Load (floor height 3m) = 0.1 m x 2.5 m x 20 KN/m^3 = 5.0 KN/m Masonry Wall Load (floor height 4.2m) = 0.1 m x 3.7 m x 20 KN/m^3 = 7.4 KN/m**For Parapet Walls**

   Masonry Wall Load (wall height 1m) = 0.1 m x 1.0 m x 20 KN/m^3 = 2.0 KN/m

2) *Live Loads:* As per IS: 875 (part-2) 1987Live Load on typical floors = 3 KN/m^2
3) *Earth Quake Loads for Case I:* All Structures are analyzed for earthquake zone IIThe earthquake calculation is as per IS: 1893 [2002]

   a. Earth Quake Zone-II (Table - 2)
   b. Importance Factor: 1 (Table - 6)
   c. Response Reduction Factor: 5 (Table - 7)
   d. Damping: 5% (Table - 3)
   e. Soil Type: Medium Soil (Assumed)
   f. Period in X direction (P_X):

$$\frac{0.09*h}{\sqrt{dx}}$$ seconds Clause 7.6.2

Period in X direction (PX) = 0.09x18/√12 = 0.467

   g. Period in Z direction (P_z): $\frac{0.09*h}{\sqrt{dz}}$ ~~seconds Cl~~ause 7.6.2 [21]

Period in X direction (P_z) = 0.09x18/√12 = 0.467Where, h = height of the building

d_x= length of building in x direction

and d_z= length of building in z direction

So, Sa/g = 2.5 (as per code)

Ah_X = (Z/2 x I/R x Sa/g)

= 0.1/2 x 1.5/5 x 2.5

= 0.0375

(Z/2 x I/R x Sa/g)0.1/2 x 1.5/5 x 2.5

Ah_Z =

=

= 0.0375

V = Ah x W

Where, V = Base shear

W = weight of structure =16758 kNV_x = 0.0375 x 16758 = 628.425 kN

V_z = 0.0375 x 16758 = 628.425 kN

4) Earth Quake Loads Case II to VII:

All Structures are analyzed for earthquake zone II The earthquake calculation is as per IS: 1893 [2002]

a. Earth Quake Zone-II (Table - 2)

b. Importance Factor: 1 (Table - 6)

c. Response Reduction Factor: 5 (Table - 7)

d. Damping: 5% (Table - 3)

e. Soil Type: Medium Soil (Assumed)

f. Period in X direction (P_X): $\frac{0.09*h}{\sqrt{dx}}$ seconds Clause 7.6.2

Period in X direction (PX) = 0.09x18/√12 = 0.467

g. Period in Z direction (P_z):

$\frac{0.09*h}{\sqrt{dz}}$ seconds Clause 7.6.2 [21]

Period in X direction (P_z) = 0.09x18/√12 = 0.467Where, h = height of the building

d_x= length of building in x direction

and d_z= length of building in z direction

So, Sa/g = 2.5 (as per code)

Ah_X = (Z/2 x I/R x Sa/g)

= 0.1/2 x 1.5/5 x 2.5

= 0.0375

(Z/2 x I/R x Sa/g)0.1/2 x 1.5/5 x 2.5

Ah_Z =

=

= 0.0375

V = Ah x W

Where, V = Base shear

W = weight of structure

V_x = 0.0375 x 17033 = 638.737 kN

V_z = 0.0375 x 33037.83 = 638.737 kN

5) Wind Load

All the building frames are analyzed for wind zones I (39 m/s). The wind loads areresulting for following wind parameters as per IS: 875(Part-3)

$$P_z = 0.6 \times V_z^2$$

Where,

P_z Design wind pressure in N/m^2 at height z

V_z Design wind speed at any height z in m/s

$$V_z = V_b x k_1 x k_2 x k_3$$

IV. STRUCTURAL MODELLING

A. *Structural Models*

Structural models for different cases are shown in below

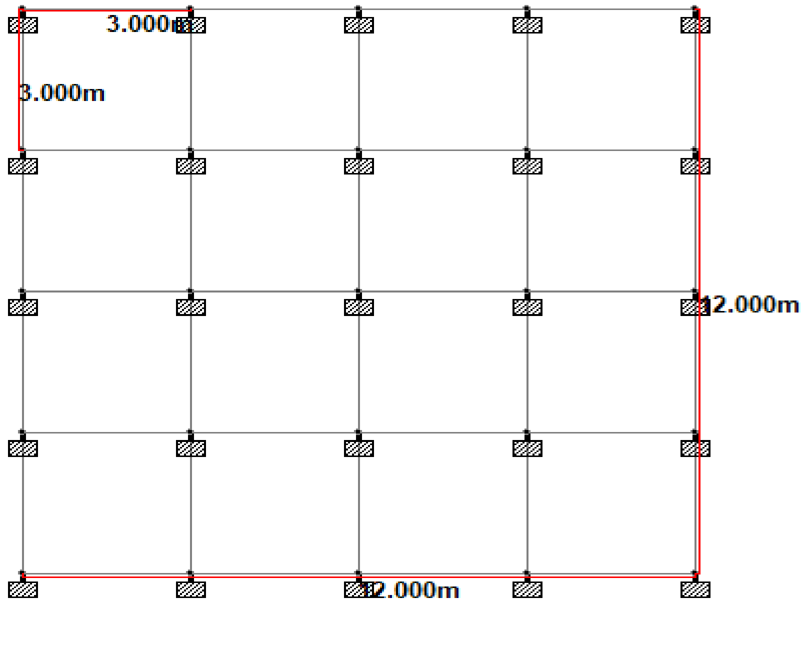

FIG. 4. 1: Structural Geometric Plan

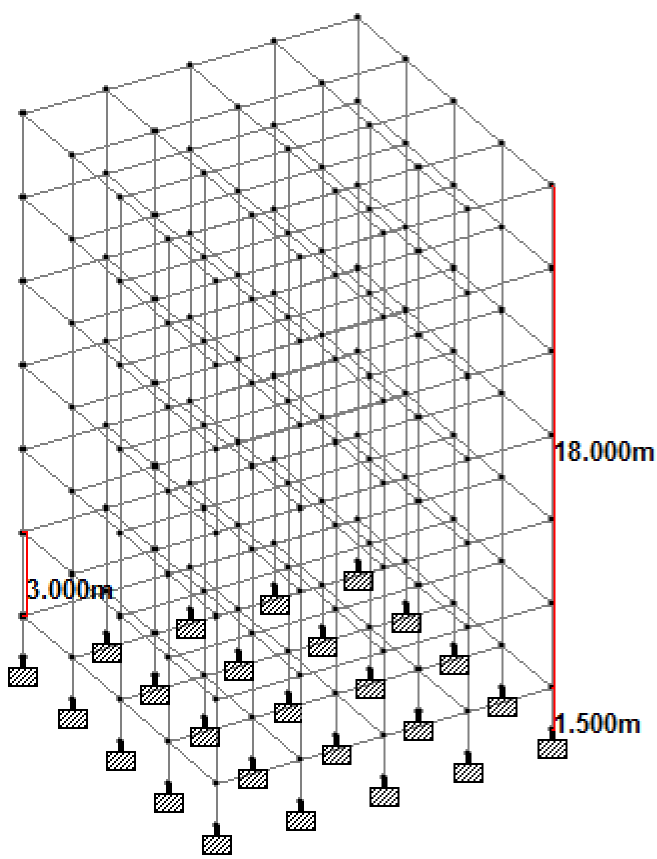

FIG. 4. 2 : Isometric View Of Geometry

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B. Different Positions Of Soft Storey Models

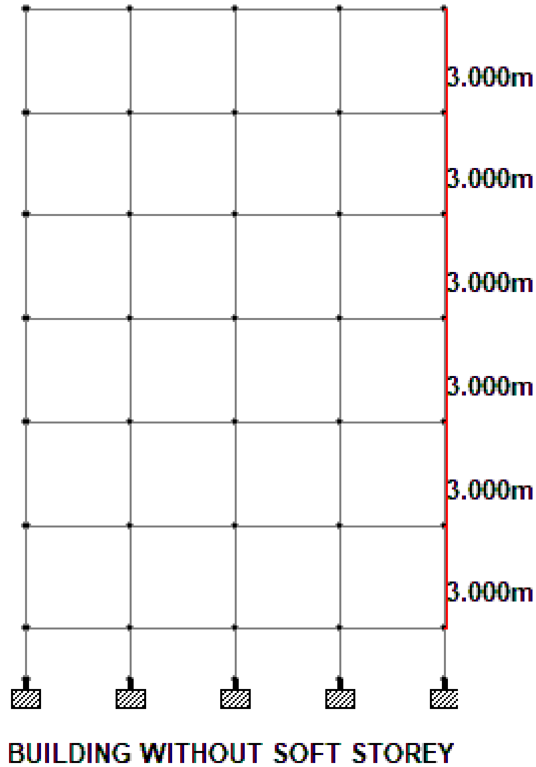

FIG. 4. 3 Building Without Soft Storey (CASE-I)

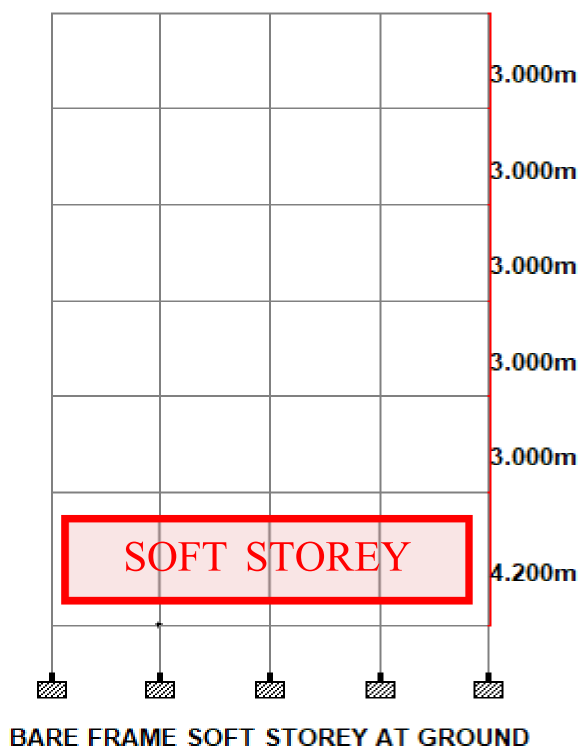

FIG. 4. 4: SOFT STOREY AT GROUND FLOOR (CASE-II)

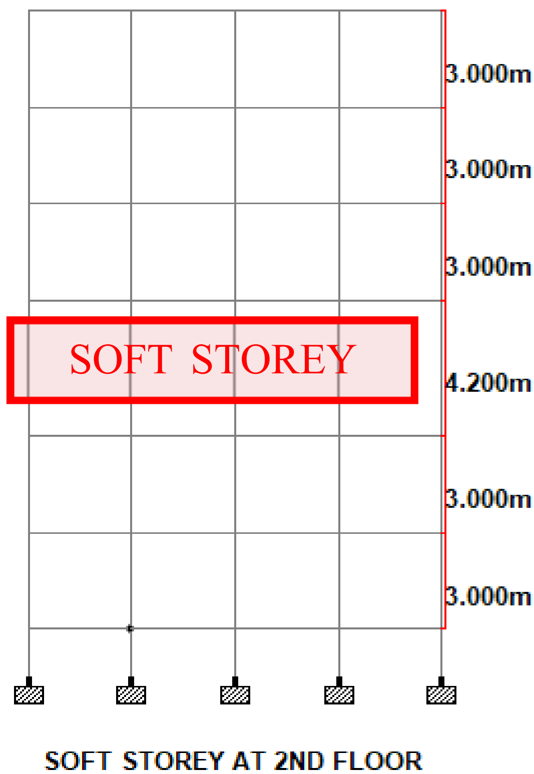

FIG. 4. 5: Soft Storey AT 2ND Floor (CASE III)

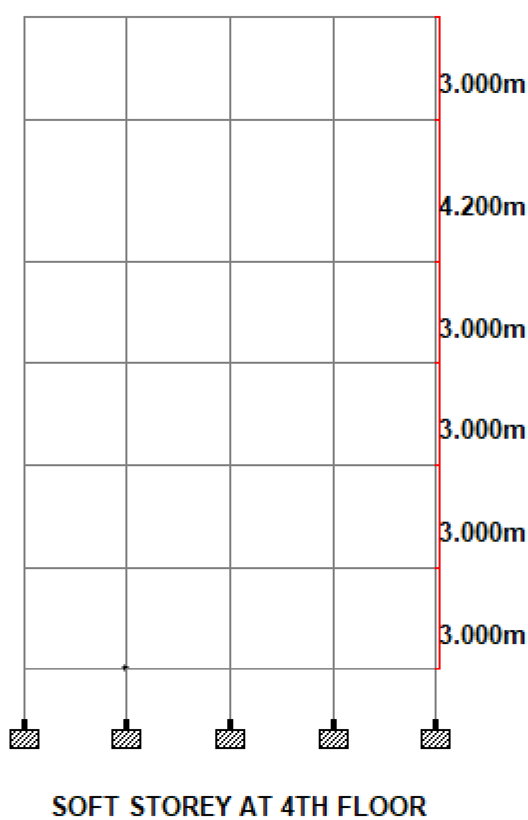

FIG. 4. 6 SOFT STOREY AT 4TH FLOOR (CASE IV)

FIG. 4. 7 Ground Floor Soft Storey With Inclined Column (CASE V)

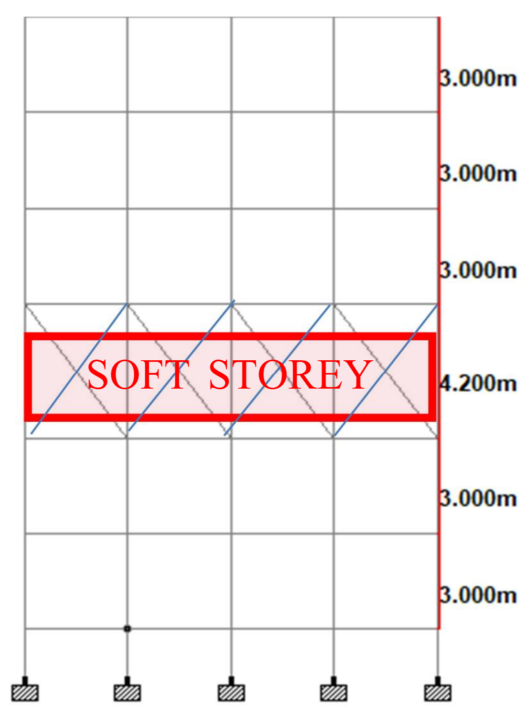

FIG. 4. 8 SECOND FLOOR SOFT STOREY WITH INCLNED COLUMN (CASE VI)

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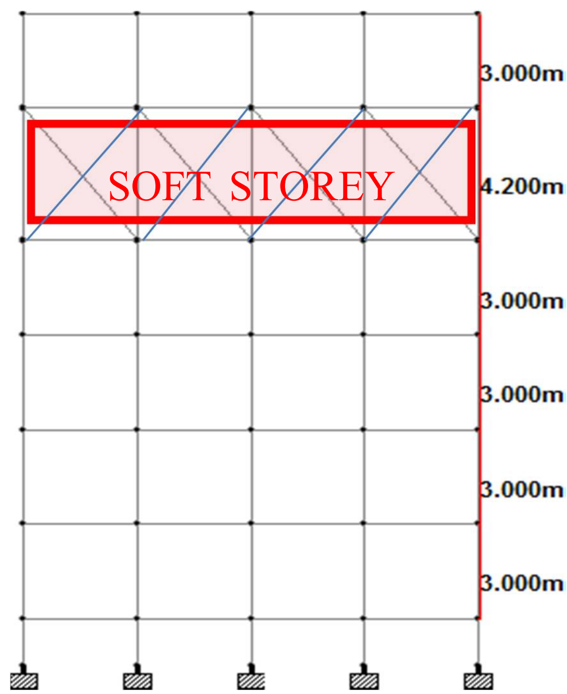

FIG. 4. 9 Fourth Floor Soft Storey With Inclned Column (CASE VII)

C. Different Positions Of Inclined Column 3-D Models

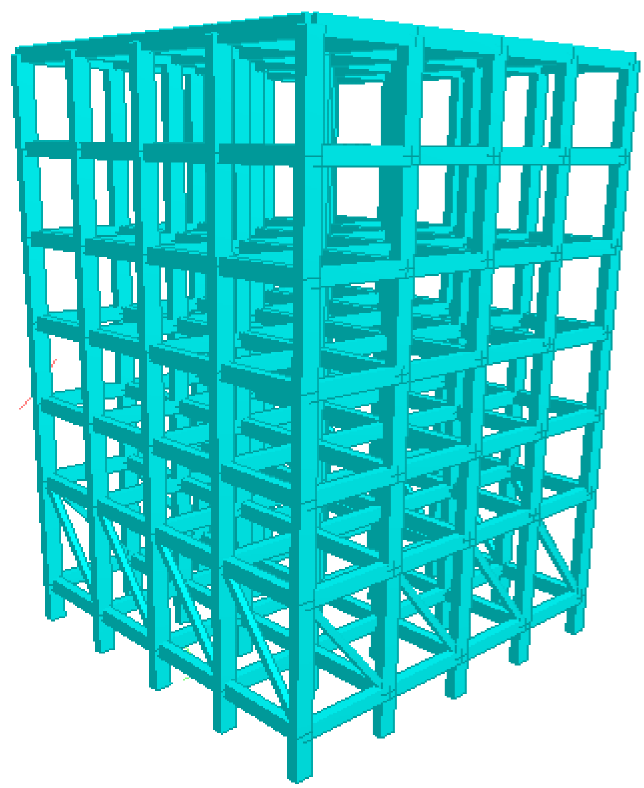

FIG. 4. 10 3D View Of Ground Floor Soft Storey With InclinedColumn Render View

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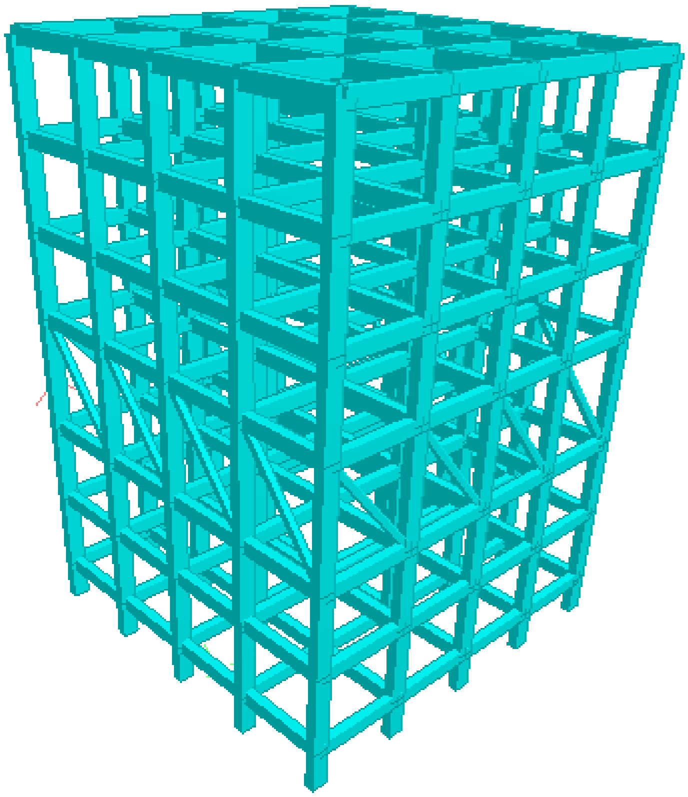
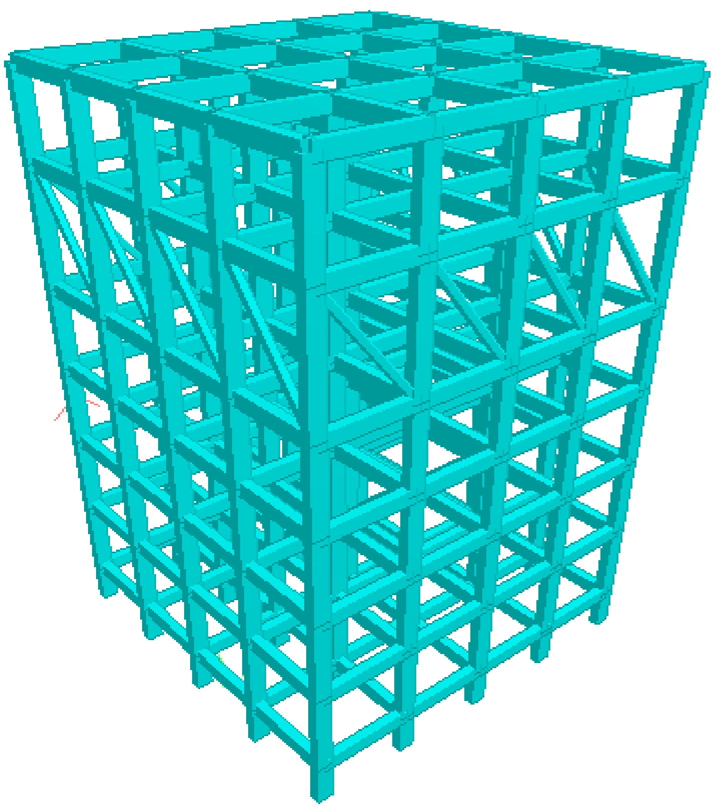


FIG. 4. 10 Second Floor Soft Storey With Inclined Column RenderView



Fourth Floor Soft Storey With Inclined Column Render View

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D. Different Positions of Loading

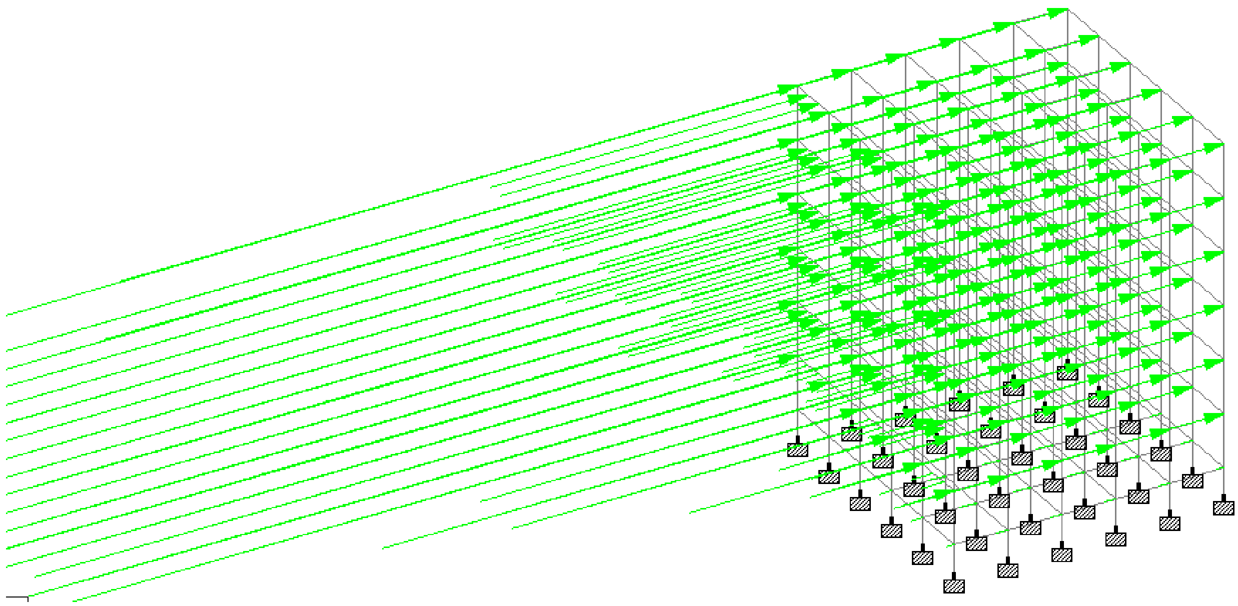

FIG. 4. 11 Seismic Loading In X Direction

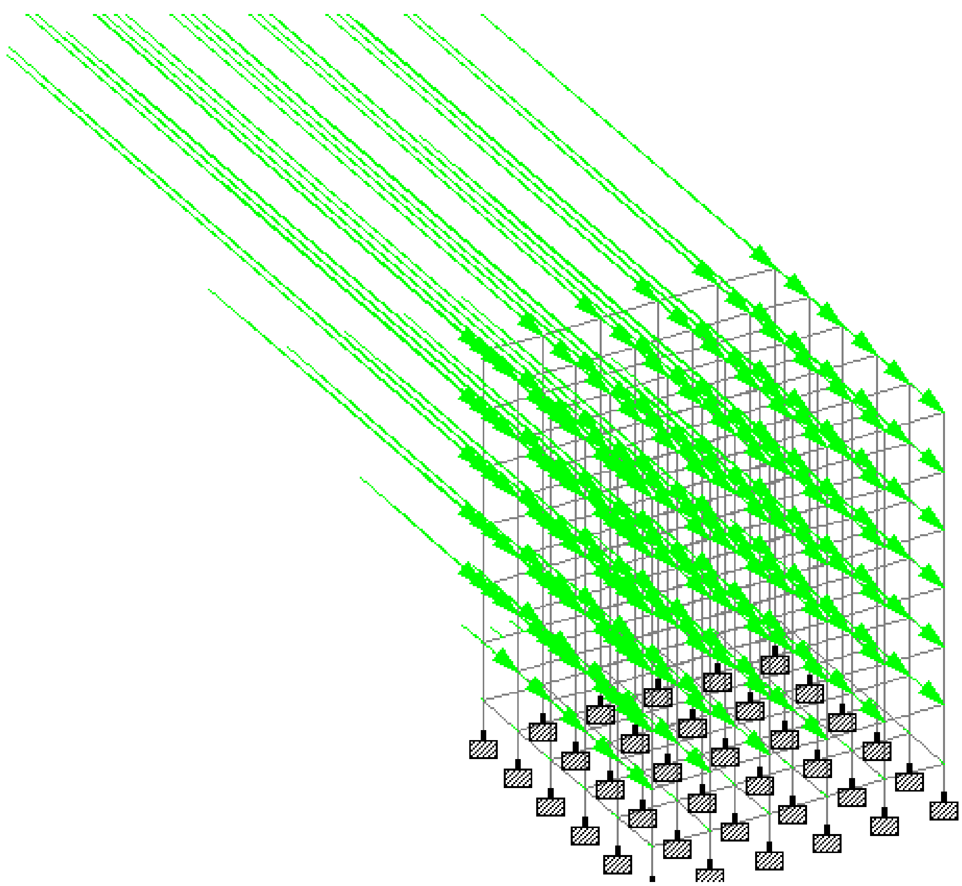

FIG. 4. 12 Seismic Loading in Z Direction

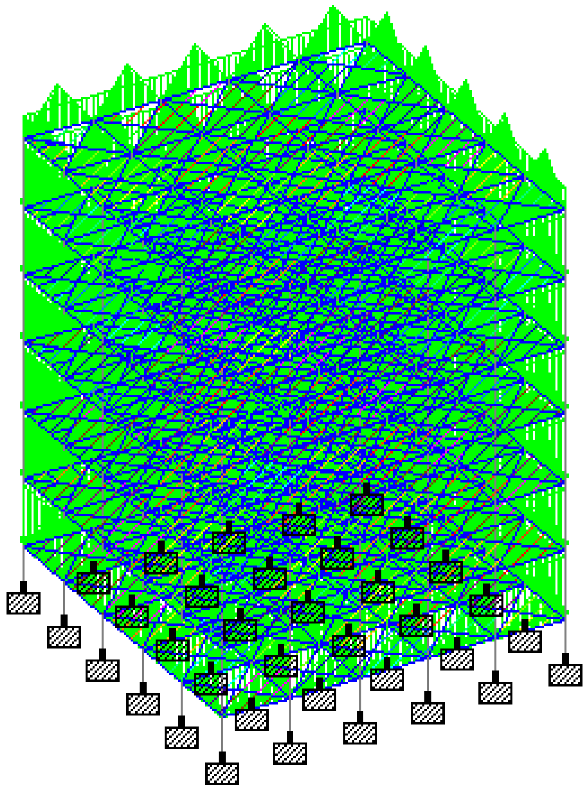

FIG. 4. 13 Dead Load

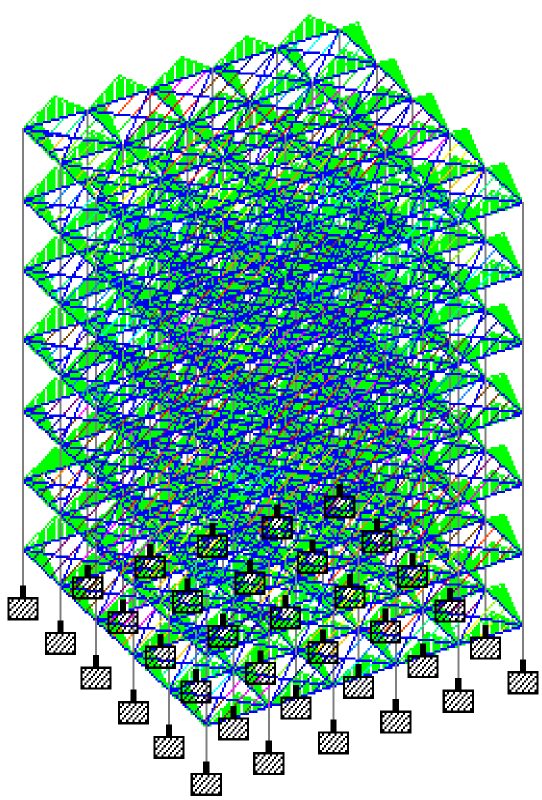

FIG. 4. 14 Live Load

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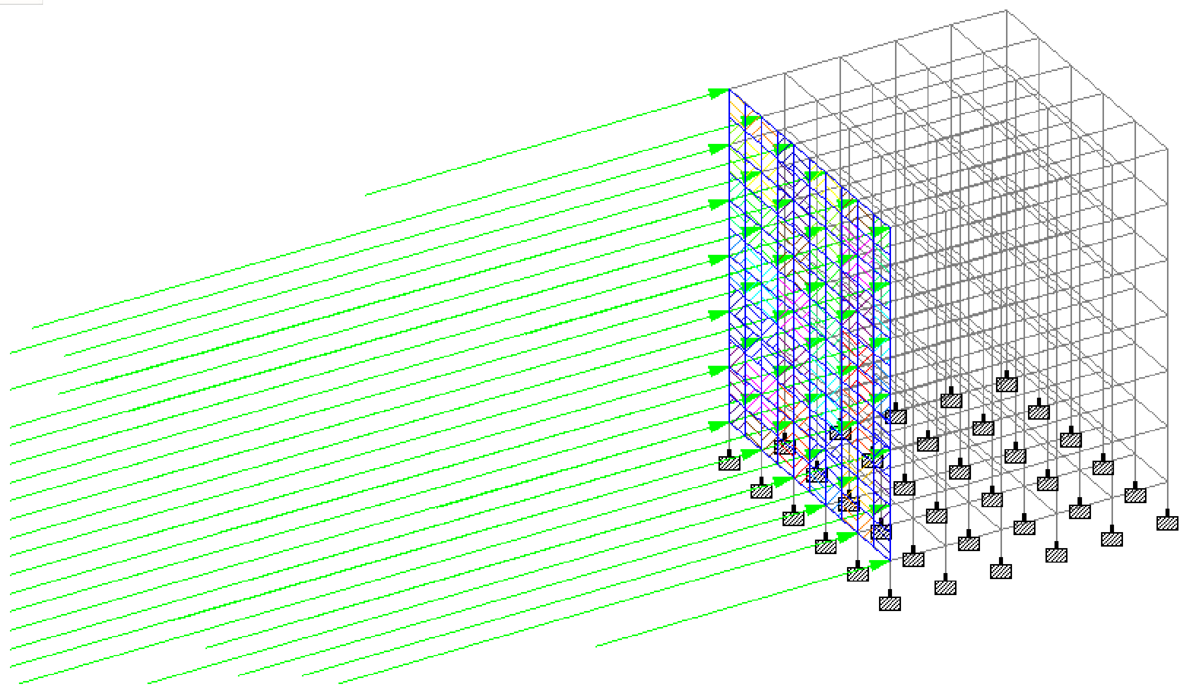

FIG. 4. 17 Wind Loading In X Direction

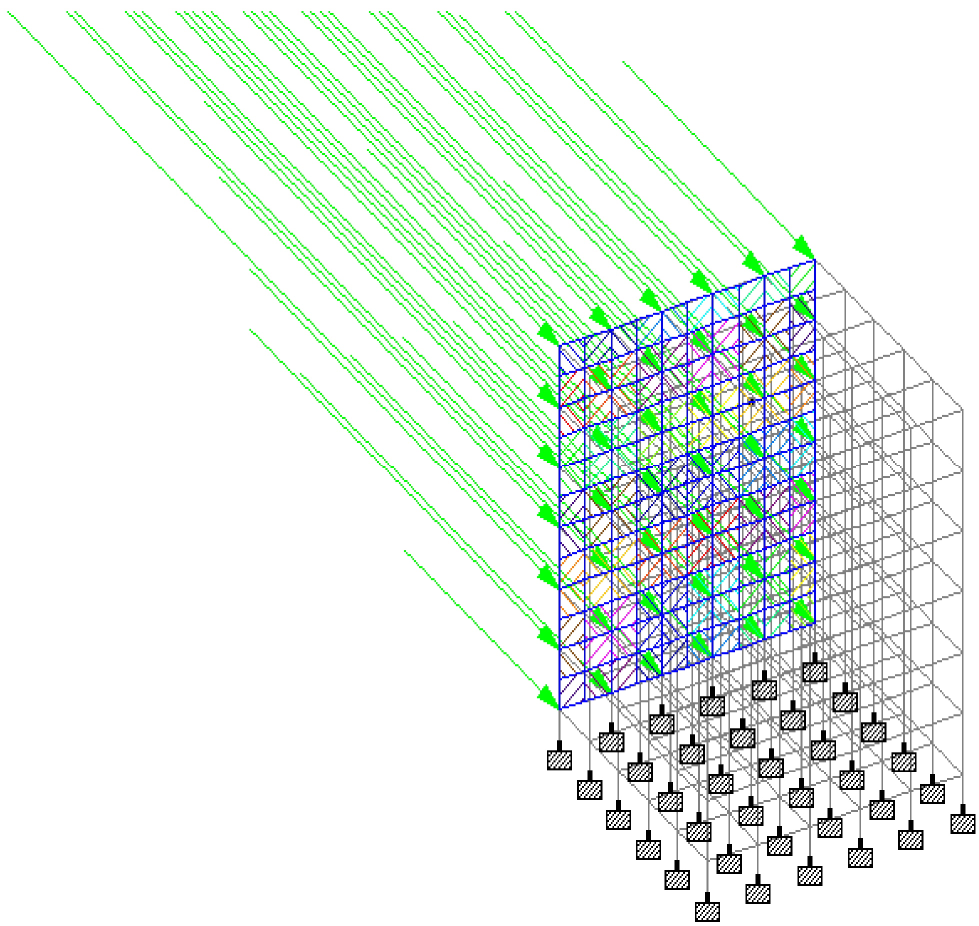

FIG. 4. 18 Wind Loading In Z Direction

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V. ANALYSIS AND RESULTS

A. Maximum Displacement

Maximum displacement in X direction for all cases are given in Fig. 5.1and Table 5.1

MAXIMUM DISPLACEMENT (MM) IN X DIRECTION				
SOFT STOREY	WITHOUT INCLINED COLUMN	CORNER INCLINED COLUMN	CENTER INCLINED COLUMN	HORIZONTAL LYPLACED INCLINED COLUMN
WITHOUT SOFT STOREY	44.652			
GROUND STOREY SOFT	43.614	38.904	38.341	41.562
2nd STOREY SOFT	46.459	41.576	40.888	44.206
4TH STOREY SOFT	46.35	41.692	41.055	44.666
6TH STOREY SOFT	46.783	42.428	41.778	45.845
8TH STOREY SOFT	33.485	30.641	30.26	33.324
TOP STOREY SOFT	32.761	29.999	29.646	32.759

Table 5. 1 Maximum Displacements In X Direction

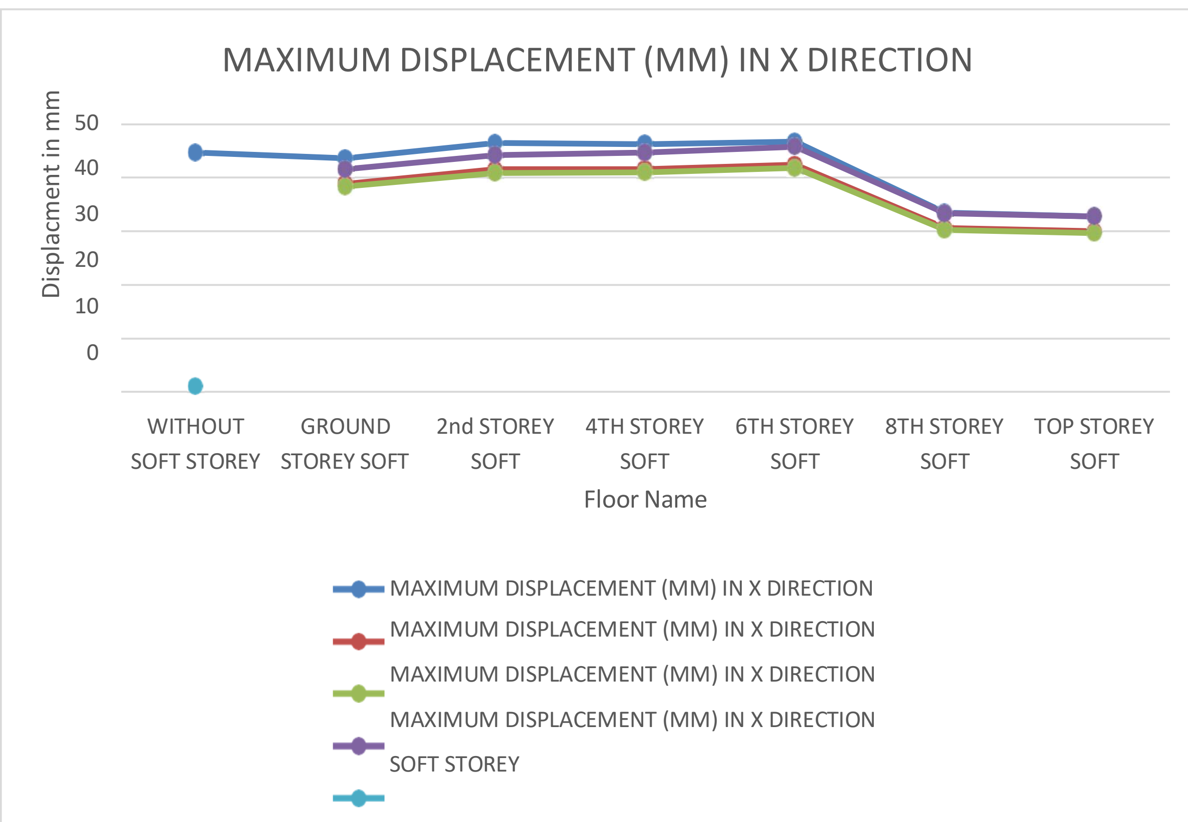

FIG. 5. 1 Maximum Displacement in X Direction

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B. *Beam Forces*

1) *Maximum Bending Moment*

Maximum Bending Moment for all cases are given in Fig. 5.3 and Table 5.3

Maximum Bending Moment in building					
Floor	Straight Bare Frame	Bare Frame With Weak Storey	Bare Frame With Weak Storey and inclined column horizontally	Bare Frame With Weak Storey and inclined column at corners	Bare Frame With Weak Storey and inclined column at centre
0	245.555	232.633	237.043	325.567	310.51
2	245.555	234.047	292.756	324.302	335.104
4	245.555	233.359	292.756	319.482	314.859
6	245.555	239.154	255.477	317.779	313.043
8	245.555	187.334	187.937	238.493	225.236
TOP	245.555	186.72	186.675	238.206	224.723

Table 5. 2 Bending Moment (KN-M) IN Beam In X Direction

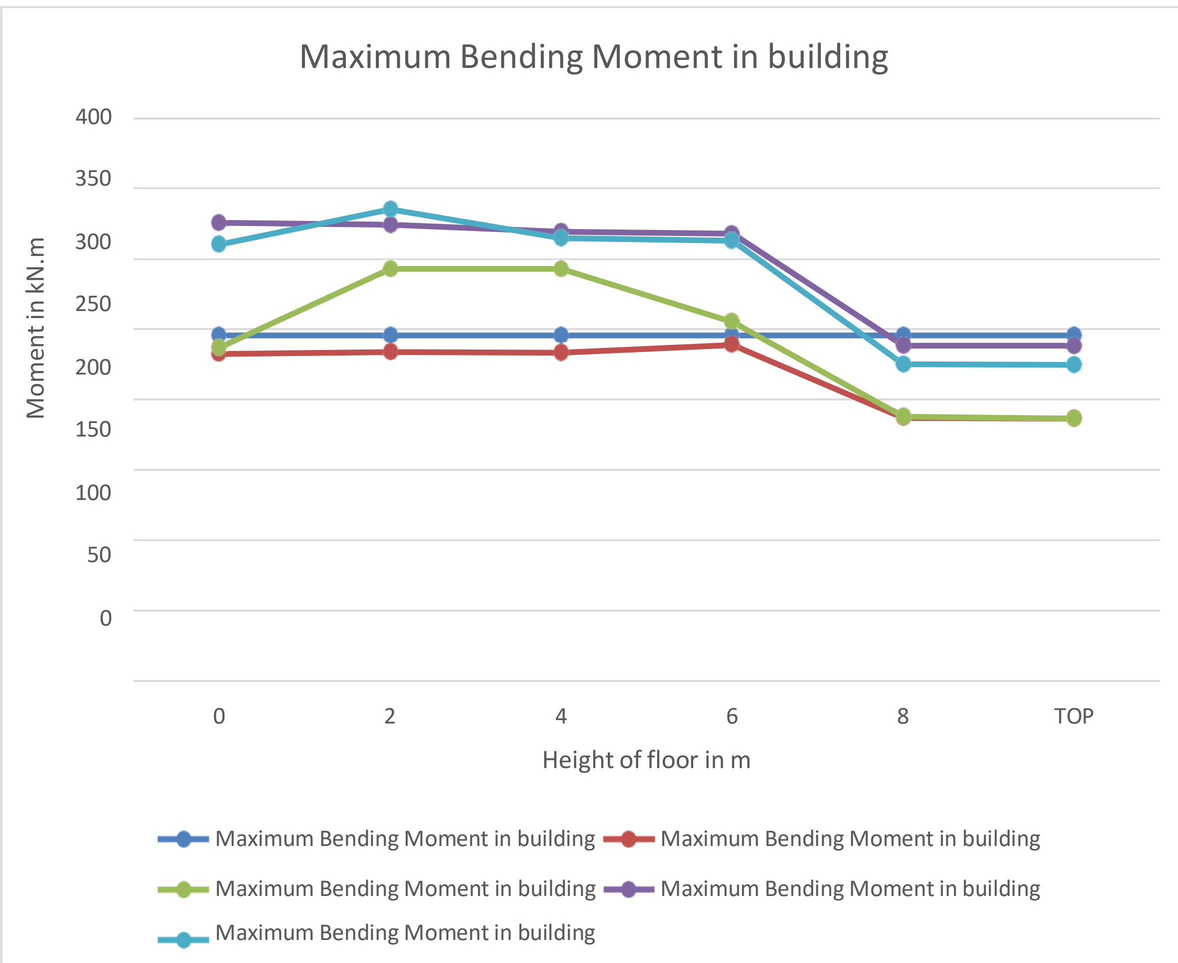

FIG. 5. 2 Bending Moment (KN-M) in Beam

C. *Shear Force*

Maximum Shear Force in X direction for all cases are given in Fig. 5.4 and Fig. 5.4

	Maximum Shear force in building				
Floor	Straight Bare Frame (kN)	Bare Frame With Weak Storey (kN)	Bare Frame With Weak Storey and inclined column horizontally (kN)	Bare Frame With Weak Storey and inclined column at corners (kN)	Bare Frame With Weak Storey and inclined column at centre (kN)
0	177.451	175.039	172.188	175.097	172.257
2	177.451	191.999	188.706	185.139	183.539
4	177.451	191.771	188.706	186.13	184.798
6	177.451	185.956	184.718	181.984	180.144
8	177.451	181.815	182.636	183.506	182.172
TOP	177.451	182.186	182.939	183.995	182.196

Table 5. 4 Shear Force (KN) in Beam in X Direction

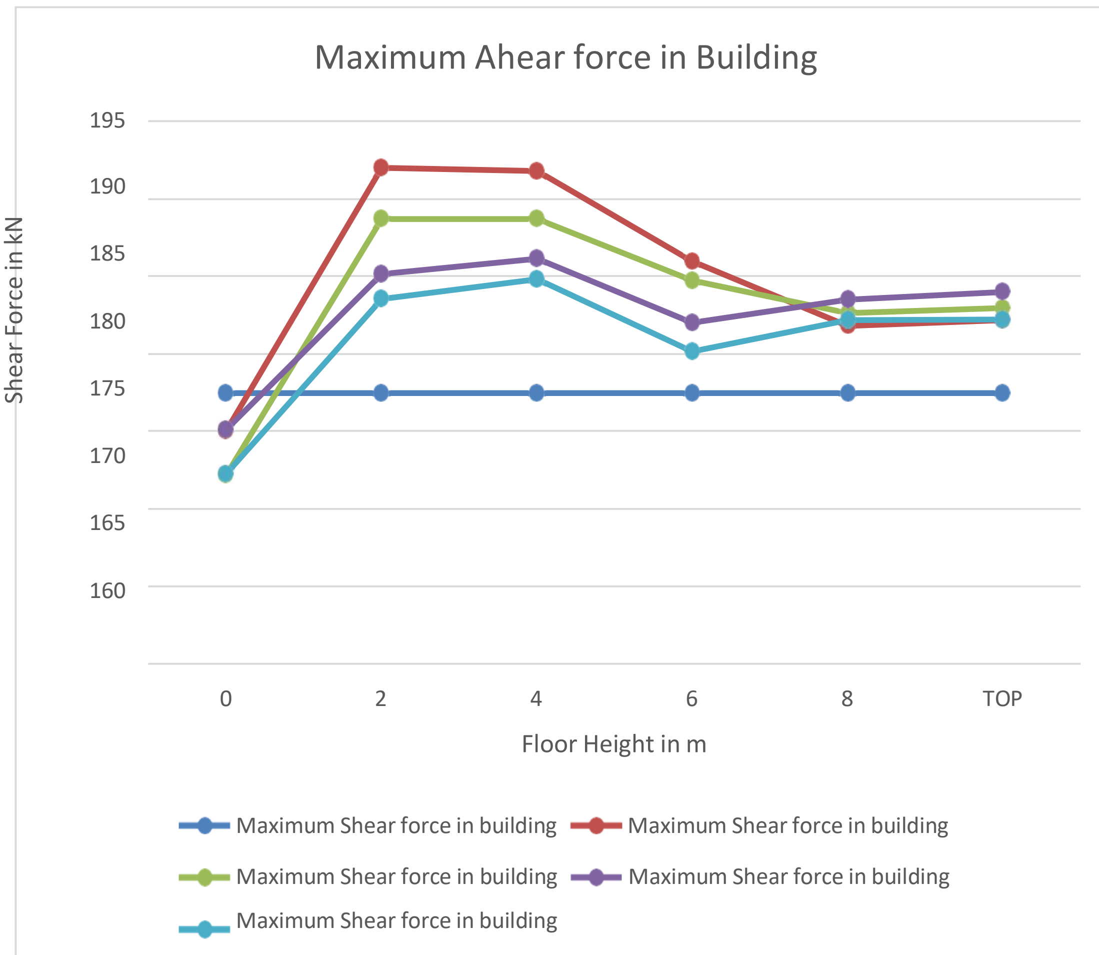

FIG. 5. 4 Shear Force (KN) in Beam in X Direction

Maximum Shear Force in Z direction for all cases are given in Table 5.6 and Fig. 5.6

	Maximum Shear force in building Fz				
Floor	Straight Bare Frame (kN)	Bare Frame With Weak Storey (kN)	Bare Frame With Weak Storey and inclined column horizontally (kN)	Bare Frame With Weak Storey and inclined column at corners (kN)	Bare Frame With Weak Storey and inclined column at centre (kN)
0	113.864	103.541	147.136	175.365	169.298
2	113.864	107.559	142.665	170.112	180.281
4	113.864	109.182	142.665	167.604	169.609
6	113.864	111.175	124.122	166.821	168.669
8	113.864	98.845	99.224	128.576	122.742
TOP	113.864	89.351	89.041	128.47	122.484

Table 5. 3 Shear Force (KN) in Beam in Z Direction

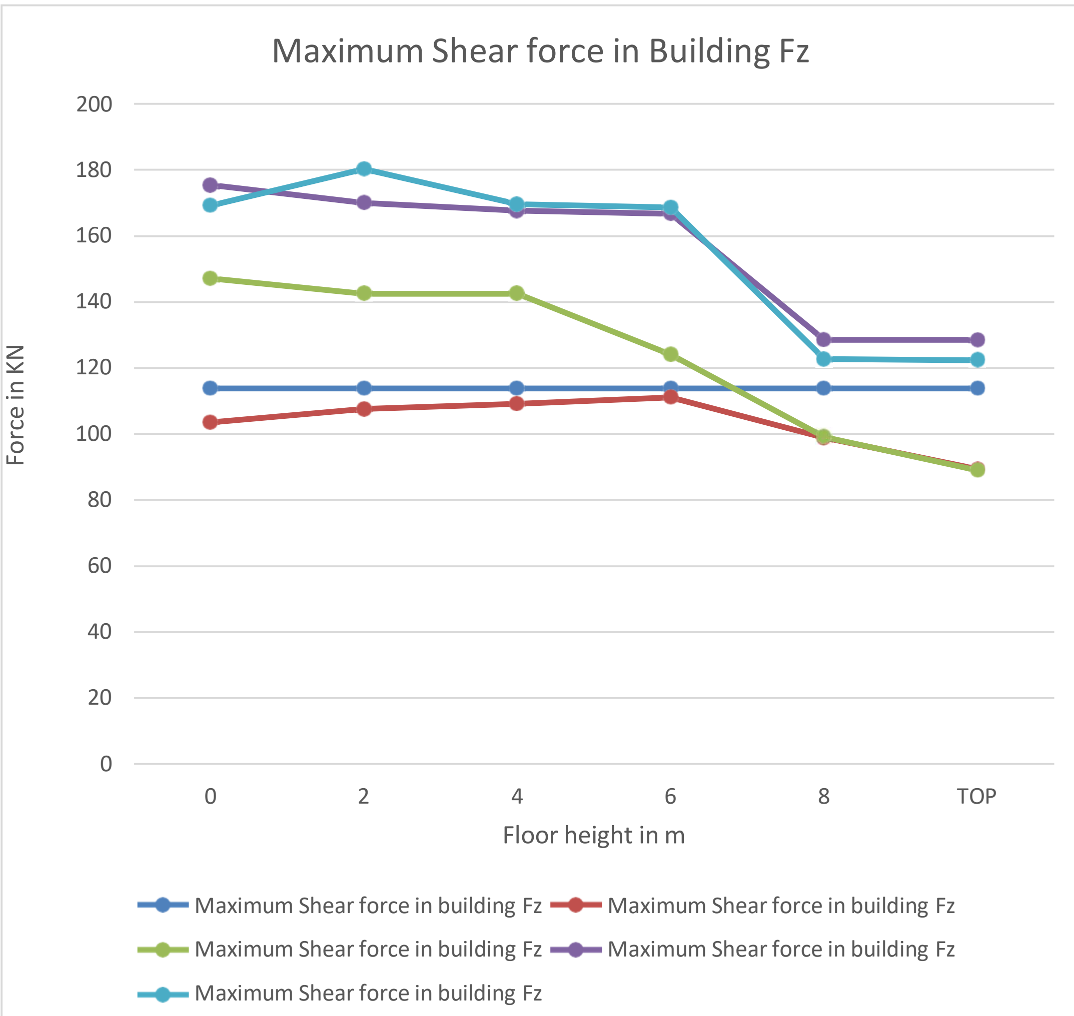

FIG. 5. 3 SHEAR FORCE (KN) IN BEAM IN Z DIRECTION

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5.1.3 STOREY DISPLACEMENT

Average Storey Displacement																										
		Soft Strorey without inclied column						Soft Storey with inclined column Horizontally Floor						Soft Storey With Inclined Column at Corners of building						Soft Storey With Inclined Column at Centre of building						
Height of storey	Straight Fram	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor
0	2.691	2.593	2.506	2.494	2.534	1.83	1.83	2.139	2.485	2.489	2.54	1.837	1.836	2.23	2.221	2.219	2.261	1.641	1.641	2.208	2.201	2.198	2.241	1.627	1.627
3	7.337	9.682	7.005	6.923	7.03	5.078	5.077	6.999	6.844	6.922	7.046	5.095	5.094	7.315	5.603	5.577	5.693	4.139	4.139	7.171	5.507	5.481	5.6	4.075	4.076
6	12.429	14.623	12.181	11.801	11.963	8.639	8.637	11.351	11.39	11.78	11.989	8.668	8.666	10.926	9.39	9.211	9.396	6.834	6.833	10.636	9.152	8.978	9.169	6.677	6.679
9	17.546	19.326	20.222	16.766	16.931	12.221	12.217	15.923	17.024	16.623	16.962	12.262	12.259	14.453	15.216	12.945	13.169	9.576	9.573	13.997	14.722	12.543	12.777	9.306	9.308
12	22.527	23.835	25.281	21.835	21.789	15.713	15.705	20.409	21.45	21.137	21.807	15.765	15.76	17.908	19.033	16.776	16.913	12.29	12.283	17.265	18.341	16.182	16.338	11.893	11.894
15	27.253	28.089	29.846	29.269	26.46	19.035	19.02	24.665	25.87	26.451	26.385	19.097	19.088	21.232	22.581	22.358	20.566	14.916	14.902	20.39	21.684	21.464	19.793	14.382	14.379
18	31.601	31.989	33.985	33.702	30.961	22.107	22.078	28.572	29.979	30.324	30.459	22.173	22.159	24.342	25.875	25.831	24.118	17.39	17.364	23.297	24.768	24.72	23.135	16.713	16.701
21	35.433	35.417	37.612	37.418	37.057	24.852	24.786	32.007	33.603	33.908	34.919	24.889	24.877	27.148	28.836	28.847	28.917	19.646	19.593	25.894	27.519	27.524	27.628	18.824	18.789
24	38.597	38.24	40.598	40.44	40.325	27.232	27.047	34.836	36.591	36.9	37.751	27.102	27.131	29.533	31.354	31.39	31.625	21.643	21.507	28.078	29.833	29.861	30.126	20.676	20.564
27	40.944	40.33	42.81	42.671	42.631	29.984	28.796	36.931	38.805	39.124	39.951	29.19	28.796	31.396	33.315	33.367	33.656	23.996	23.045	29.743	31.598	31.64	31.96	22.829	21.966
30	42.412	41.638	44.195	44.067	44.054	31.124	30.498	38.242	40.191	40.517	41.345	30.142	30.123	32.656	34.6379	34.706	35.017	25.058	24.612	30.826	32.747	32.797	33.14	23.761	23.353

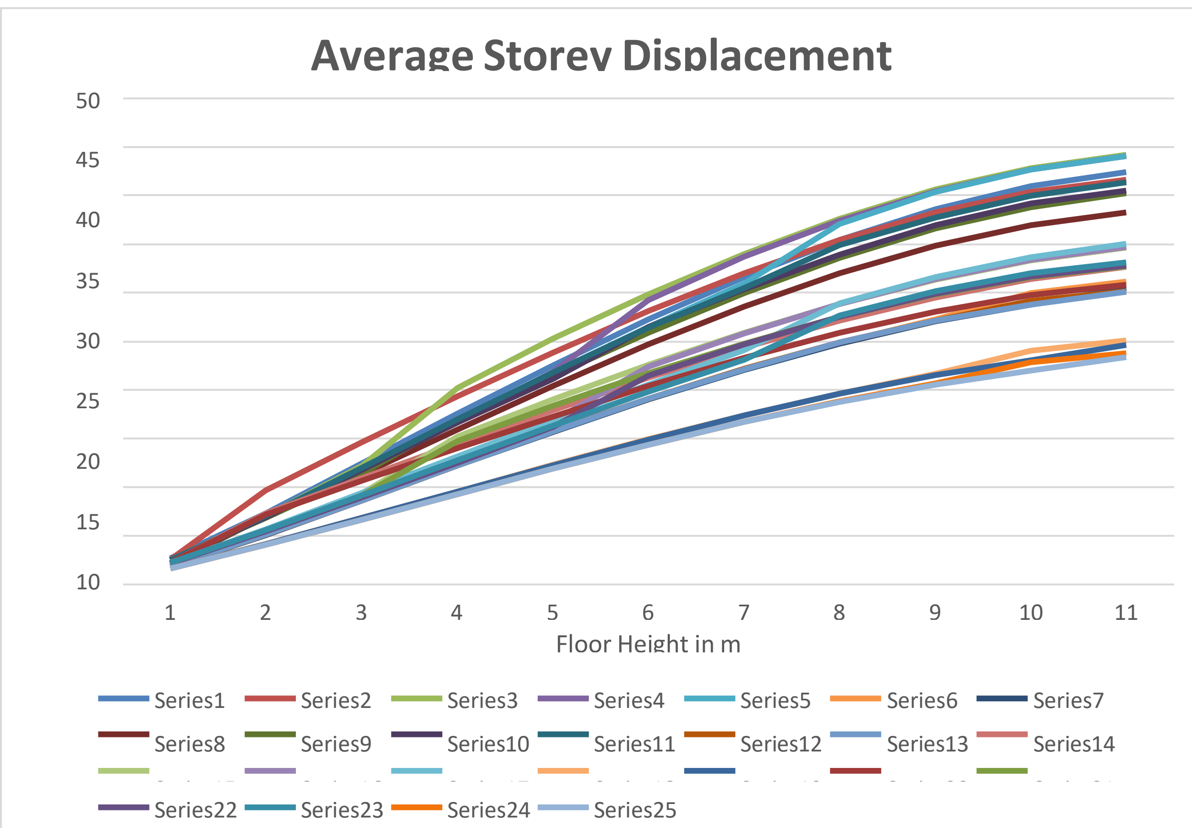

FIG. 5. 4 Storey Average Displacement IN X Direction

D. Axial Force

Axial force for all cases are given in Fig. 5.13 and Table 5.13

Maximum Axial force in building					
Floor	Straight Bare Frame (kN)	Bare Frame With Weak Storey (kN)	Bare Frame With Weak Storey and inclined column horizontally (kN)	Bare Frame With Weak Storey and inclined column at corners (kN)	Bare Frame With Weak Storey and inclined column at centre (kN)
0	6858.733	6783.229	6783.227	6783.224	6783.102
2	6858.733	7053.776	7053.758	7053.772	7053.644
4	6858.733	7053.922	7053.758	7053.92	7053.775
6	6858.733	6783.747	6783.701	6783.746	6783.591
8	6858.733	6783.944	6783.882	6783.945	6783.774
TOP	6858.733	6781.527	6781.486	6781.524	6781.443

Table 5. 5 Axial Force (KN) In Column

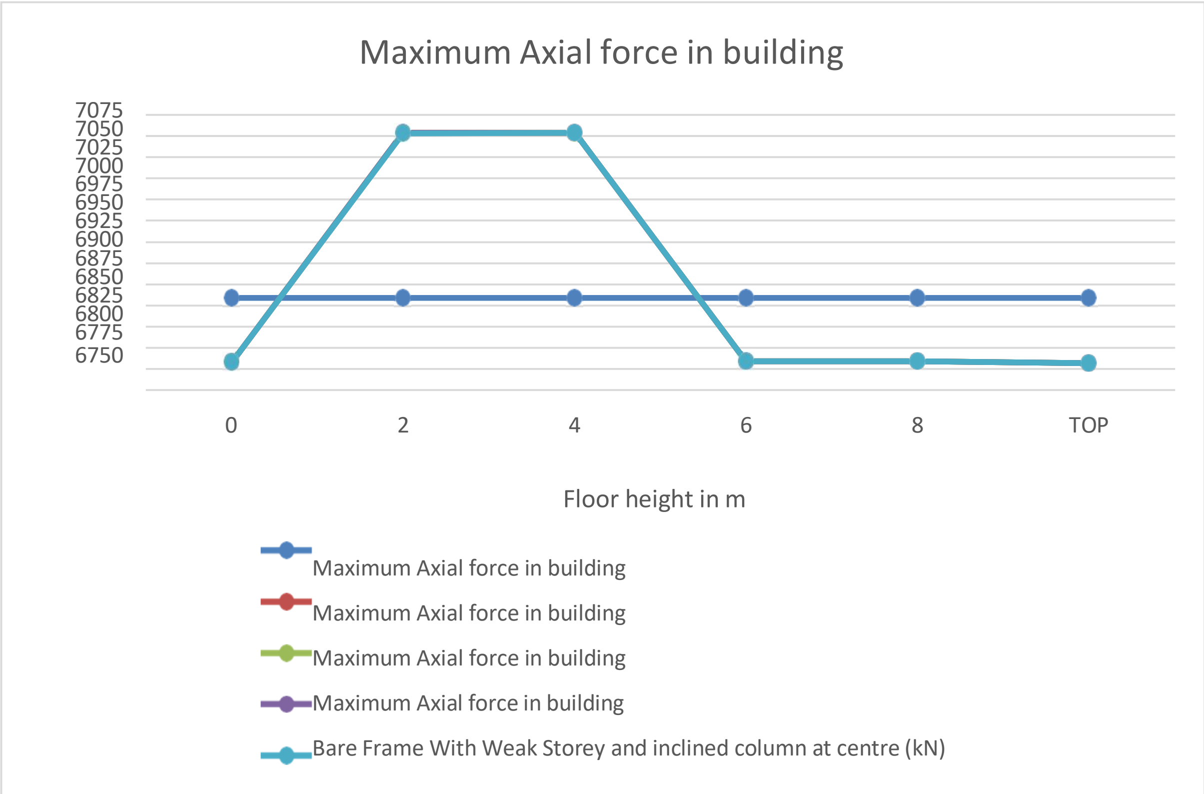

FIG. 5. 5 Axial Force (KN) in Column

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E. Storey Drift

Storey Drift Displacement

		Soft Strorey without inclied column						Soft Storey with inclined column Horizontally Floor						Soft Storey With Inclined Column at Corners of building						Soft Storey With Inclined Column at Centre of building					
ight of torey	Straight Fram	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor	Ground Floor	2nd Floor	4th Floor	6th Floor	8th Floor	Top Floor
0	2.691	2.593	2.506	2.494	2.534	1.83	1.83	2.139	2.485	2.489	2.54	1.837	1.836	2.23	2.221	2.219	2.261	1.641	1.641	2.208	2.201	2.198	2.241	1.627	1.627
3	4.646	7.089	4.499	4.429	4.496	3.248	3.247	4.86	4.359	4.433	4.506	3.258	3.258	5.085	3.382	3.358	3.432	2.498	2.498	4.963	3.306	3.283	3.359	2.448	2.449
6	5.092	4.941	5.176	4.878	4.933	3.561	3.56	4.352	4.546	4.858	4.943	3.573	3.572	3.611	3.787	3.634	3.703	2.695	2.694	3.465	3.645	3.497	3.569	2.602	2.603
9	5.117	4.703	8.041	4.965	4.968	3.582	3.58	4.572	5.634	4.843	4.973	3.594	3.593	3.527	5.826	3.734	3.773	2.742	2.74	3.361	5.57	3.565	3.608	2.629	2.629
12	4.981	4.509	5.059	5.069	4.858	3.492	3.488	4.486	4.426	4.514	4.845	3.503	3.501	3.455	3.817	3.831	3.744	2.714	2.71	3.268	3.619	3.639	3.561	2.587	2.586
15	4.726	4.254	4.565	7.434	4.671	3.322	3.315	4.256	4.42	5.314	4.578	3.332	3.328	3.324	3.548	5.582	3.653	2.626	2.619	3.125	3.343	5.282	3.455	2.489	2.485
18	4.348	3.9	4.139	4.433	4.501	3.072	3.058	3.907	4.109	3.873	4.074	3.076	3.071	3.11	3.294	3.473	3.552	2.474	2.462	2.907	3.084	3.256	3.342	2.331	2.322
21	3.832	3.428	3.627	3.716	6.096	2.745	2.708	3.435	3.624	3.584	4.46	2.716	2.718	2.806	2.961	3.016	4.799	2.256	2.229	2.597	2.751	2.804	4.493	2.111	2.088
24	3.164	2.823	2.986	3.022	3.268	2.38	2.261	2.829	2.988	2.992	2.832	2.213	2.254	2.385	2.518	2.543	2.708	1.997	1.914	2.184	2.314	2.337	2.498	1.852	1.775
27	2.347	2.09	2.212	2.231	2.306	2.752	1.749	2.095	2.214	2.224	2.2	2.088	1.665	1.863	1.961	1.977	2.031	2.353	1.538	1.665	1.765	1.779	1.834	2.153	1.402
30	1.468	1.308	1.385	1.396	1.423	1.14	1.702	1.311	1.386	1.393	1.394	0.952	1.327	1.26	1.3229	1.339	1.361	1.062	1.567	1.083	1.149	1.157	1.18	0.932	1.387

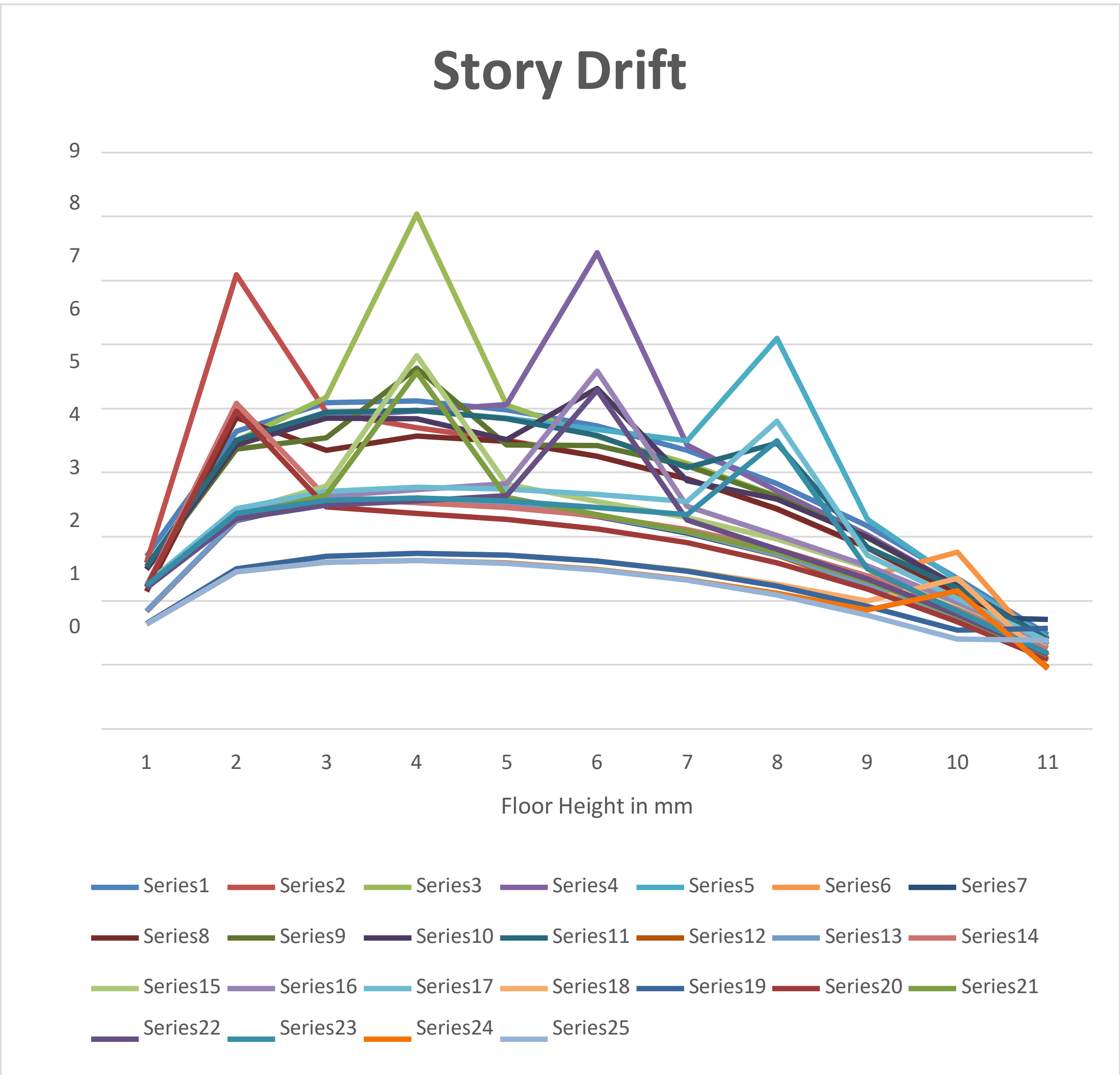

FIG. 5. 6 Drift (MM) in with Soft Storey Structur

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VI. RESULT & DISCUSSION

Following is the salient result discussion of this study-

A. Bending Moment

1) Considering maximum moment, it is observed that soft storey at ground floor without inclined column is critical in X direction and critical at second floor in Z direction whensoft storey is stiffed with inclined column. Equivalent inclined column shows poor performance when 2nd storey is soft floor. So it can be concluded that soft storey at middle floor must be avoided.
2) It is seen from the bending moment results that structure is most stable in non-soft floorconditions, but if it is necessary to provide soft floor in high rise building structure mustbe stiffened at soft floor with the help of inclined column and position of soft floor mustbe at higher level.

B. Shear Force

1) Considering shear force, it is observed that soft storey at ground floor without inclinedcolumn is critical in X direction and critical at second floor in Z direction when soft storey is stiffed with inclined column. Equivalent inclined column shows poor performance when 2nd storey is soft floor. So it can be concluded that soft storey at middle floor must be avoided.
2) It is seen from the shear force results that structure is most stable in non-soft floor conditions, but if it is necessary to provide soft floor in high rise building structure mustbe stiffened at soft floor with the help of inclined column and position of soft floor mustbe at higher level.

C. Maximum Displacement

Considering maximum displacement in worst loading combination, maximum displacement is observed in soft storey at second floor without inclined column and minimum when building is without soft storey. But if it is necessary to provide soft storey in the building then it should be placed at higher level of building with inclinedcolumn at soft floor.

D. Axial Force

It is observed that maximum axial force is generated due to worst load combination ofearthquake loading or horizontal wind loading case at fourth floor soft storey without inclined column and minimum axial force generation at fourth floor soft storey with inclined column.

E. Storey Displacement

1) Storey displacement is maximum when we place soft storey at higher level of building ascompared to the bottom floors.
2) Result of analysis shows that storey displacement is maximum at case where soft storeyat fourth floor without inclined column and it is minimum in a building when building without soft storey and without inclined column.

F. Drift

Drift is observed maximum in building where soft storey at higher level without inclinedcolumn, but if we provide inclined column at same level this means if soft storey is provided at higher level bottom storey of structure will have less drift.

G. Overall Summary

Providing Soft storey at higher with equivalent inclined column produces better results against lateral loading of earthquake and wind loads in form of minimum forces results ofMoments, Shear Force, Maximum Displacement, Axial Forces and Drift. Only Storey displacement results shows that soft storey at bottom floors is effective.

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

1) From above results it is observed that equivalent inclined column strengthens the structure from the soft storey. It is clear that CASE-III (building frame with soft storey at ground floor and without equivalent inclined column) is most critical and CASE-1 (building without soft storey and without inclined column) is best and efficient one, while CASE-VII (soft storey at higher floor with inclined column) is second best.

2) Means providing equivalent inclined column at soft floor will reduces moment, shear force, displacement, storey displacement and drift. The analyses of high rise building with different floor conditions studied under the effect of seismic and wind load condition.
3) So, it is concluded that Equivalent inclined column not only strengthen structure but also provide better stiffness and it is found that soft floor at higher level is more stable in building frame structure which also justify the purpose of the work.
4) Purpose of preparing this report is to find the soft storey location(level) in a high risebuilding, so has to have minimum effect of external forces on the structural stability.
5) This study will provide the results against various locations of soft floor with or without placing inclined columns in the building frame. Results are based on the behavior of building against the lateral forces (Earth quake and wind Forces) as analyzed by software Staad pro.

B. *Future Scope Of The Study*

1) In this study RCC framed structures have been considered. The study can be extended tosteel frame structures.
2) In this study fixed supports have been provided. The study can be extended consideringdifferent support conditions.
3) This study considered only one seismic zone viz. zone-II. In further study more seismiczones can be included.
4) This study deals with plane terrain condition and in further study sloping ground can beconsidered.
5) In this study thermal effects have not been considered in further study the same can beconsidered.

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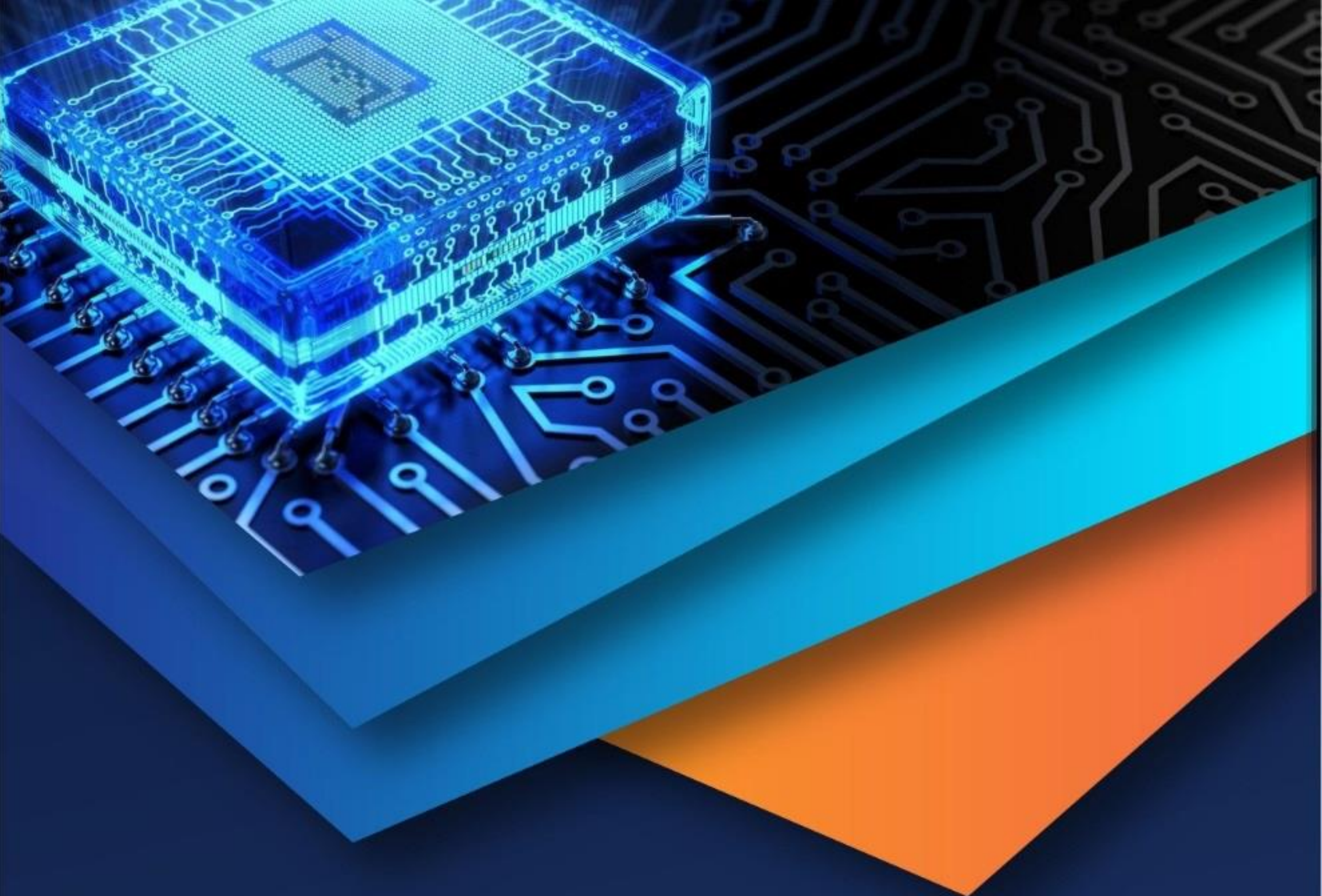

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