International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Seismic Analysis of RC Frame with the Variation of Position of Soft Storey

Vikram Singh Kushwah[1], **Ravi Dwivedi**[2]

[1]Student, R. G. P. V., Bhopal, Madhya Pradesh, India

[2]Guide, R. G. P. V., Bhopal, Madhya Pradesh, India

Abstract: ***Uncertainties involved and behavior studies are vital for all civil engineering structures. Many buildings in the present scenario have irregular configurations both in plan and elevation .The objective of the paper is to carry out Equivalent static analysis of vertically irregular RC building frames in which Stiffness irregularity was considered for different stories at a time. These irregularities are provided as per clause 7.1 of IS 1893 (part1)2002 code. According to our observation in case of displacement for all the position of soft storey excluded ground position, top 3 storey positions for soft storey should be safer as compare to middle storey position of soft storey. In case of maximum stresses in column for all positions of soft storey excluded ground storey give same result (approx.) except 3rd position of soft storey. So position soft storey at 3rd is most unsafe for structure in case of stresses in column. In case of maximum stresses in beam for all positions of soft storey excluded ground storey if middle storeys of structure are soft than beams are more stressed as compare to position at top and bottom storeys. In case of maximum shear force in beam for all positions of soft storey excluded ground storey give same result (approx.) except 1st position of soft storey. So position of soft storey at 1st is most unsafe for structure in case of shear force in beam. In case of storey drift for all positions of soft storey excluded ground storey give same result (approx.) except 1st position of soft storey. So position of soft storey at 1st is most unsafe for structure in case of storey drift. For all the cases displacement, stresses, shear force and storey drift we found that top 3 positions in the stiffness irregular structure are most safer position of the soft storey in the structure. Soft computing tool and commercial software staad.pro V8i (select series 5) is used for modeling and analysis.***

Keywords: Static, Seismic, RC Frame, Stiffness irregularity, IS 1893 (part1)2002, Soft storey

1. Introduction

Many urban multistory buildings in India today have open first storey as an unavoidable feature. This is primarily being adopted to accommodate parking or reception lobbies in the first storeys. Similarly in many multistory have demand of Intermediate soft story for the purpose of Auditorium, Cinema halls etc. As per clause 7.1 of IS 1893 (part1)2002 code, a building shall be considered stiffness irregular as following criteria

(a)Stiffness irregularity-Soft Storey: A soft storey is one in which the lateral stiffness is less than 70 % of that in the storey above or less than 80 % of the average lateral stiffness of three storeys above.

(b)Stiffness irregularity-Extreme Soft Storey: A extreme soft storey is one in which the lateral stiffness is less than 60 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.

1.1 Seismic Analysis

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. In the past the buildings were designed just for gravity loads and seismic analysis is a recent development. There are different types of earthquake analysis methods like Equivalent Static analysis, Response Spectrum Analysis and Time History Analysis. Equivalent lateral force or static analysis is used in this research work.

1.1.1Equivalent static analysis method

Seismic analysis of most of the structures is still carried out on the basis of lateral force assumed to be equivalent to the actual loading. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of structures in terms of lateral force according to the IS 1893 (part1)2002.

2. Objective

The basic objective of this research was to evaluate the maximum displacement; maximum stresses, maximum shear force and storey drift variation with variation of the position of soft storey in the RC frame and found the suitable Intermediate position in the frame where the soft storey can be provided.

3. Structural Modeling

Soft computing tool and commercial software staad.pro V8i (select series 5) is used for modeling and analysis. As per clause 7.8.1of code IS 1893 (part1)2002 in this research paper we considered a RC frame structure of height 92.75m for both regular and stiffness irregular RC frame structure.

The Regular frame is shown in frame 1 in figure 1.Soft storey is provided at first storey of regular structure as shown in figure 3 and analysis was done on this stiffness irregular structure. Similarly soft storey was provided on the second storey of Regular structure as shown in figure 4 and rest of structure in frame is similar to the Regular structure. This type of framing is continuously done up to (G+25)th storey.

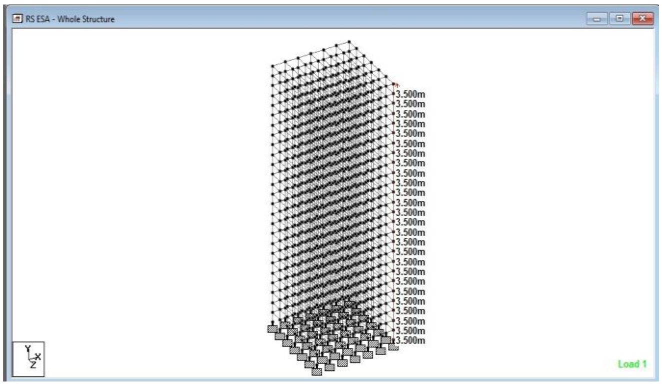

Figure 1: 3D view of regular structure of 26 storeys

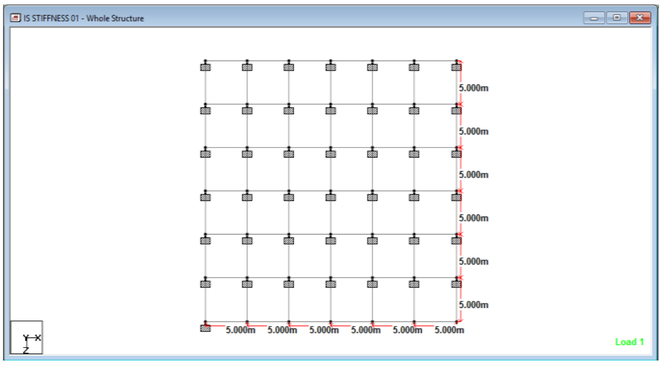

Figure 2: Plan of regular structure

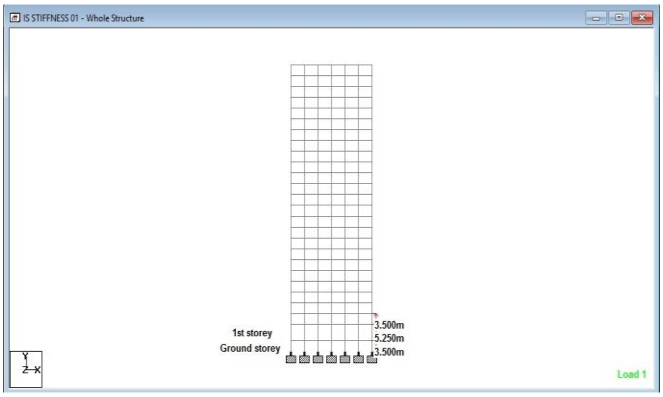

Figure 3:2D view of Irregular RC frame with soft storey at Ground storey

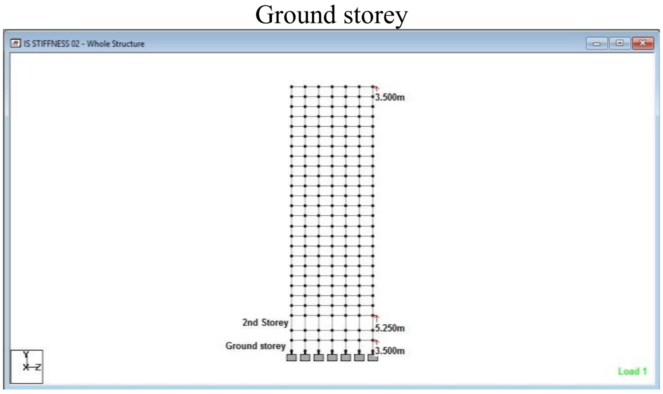

Figure 4:2D view of Irregular RC frame with soft storey at 1st storey

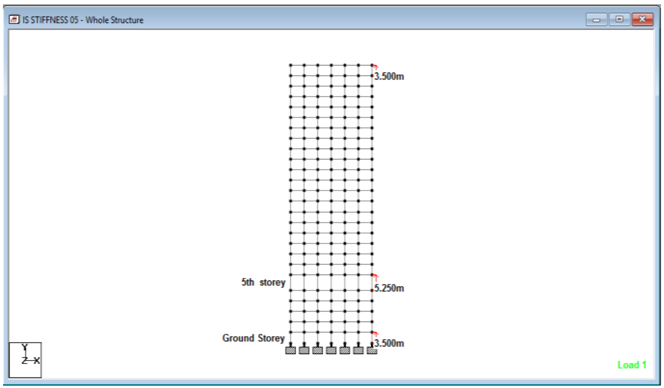

Figure 5:2D view of Irregular RC frame with soft storey at 4th storey

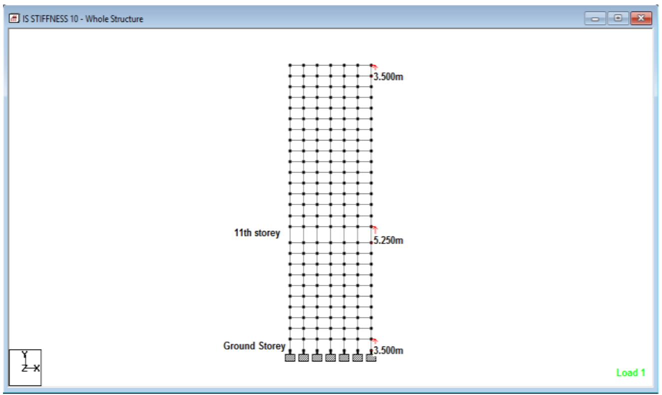

Figure 6:2D view of Irregular RC frame with soft storey at 10th storey

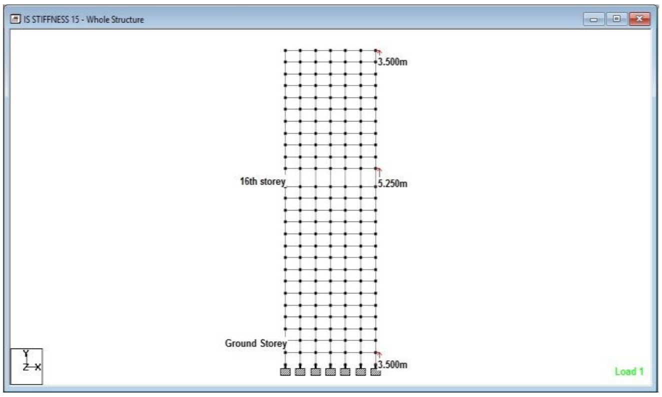

Figure 7:2D view of Irregular RC frame with soft storey at 15th storey

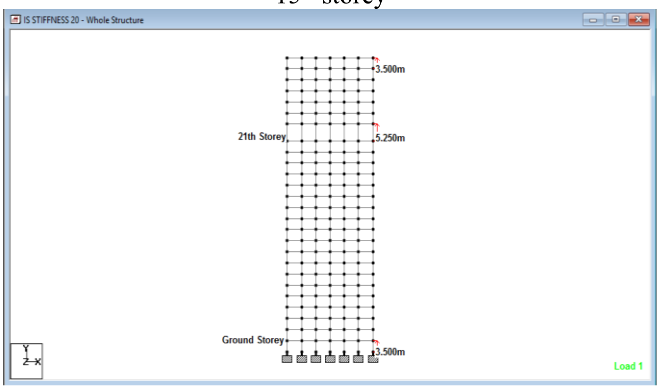

Figure 8:2D view of Irregular RC frame with soft storey at 20th storey

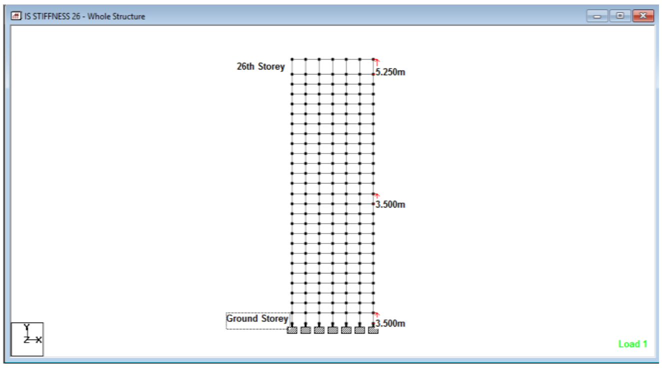

Figure 9:2D view of Irregular RC frame with soft storey at 25th storey

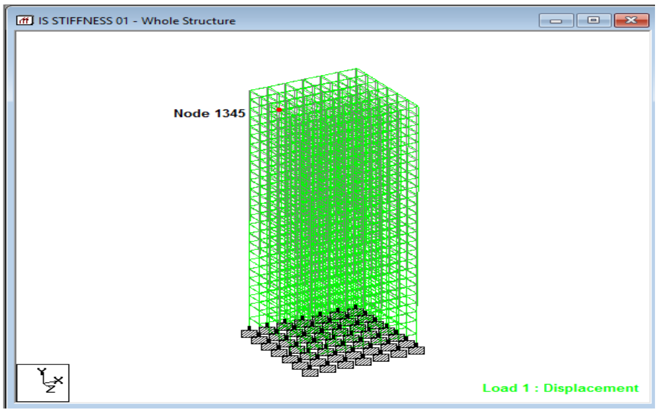

Figure 10: Position of Node 1345 in 3D view of Structure

Stiffness irregularity as a soft storey is shown in the figure 3 to figure 9.The position of soft storey is changed one by one from ground Storey to 25th storey and analysis of frames was done one by one from ground Storey to 25th storey.

Table 1: Specification of structure

Specification	Values/Type
Live Load	3kN/m2
Density of RCC considered	25kN/m3
Thickness of slab	150mm
Depth of beam	300mm
Width of beam	300mm
Dimension of Column	800x800mm
Density of infill	20kN/m3
Thickness of outside wall	200mm
Thickness of inner partition	150mm
Height of each floor	3.5m
Earthquake Zone	IV
Type of Soil	Rocky
Type of structure	SMRF
Type of support	Fixed support
Height of soft storey	5.25m
No of beams	2184
No of columns	1274
Total number of members	3458

4. Result and Discussion

Equivalent static analysis was performed on regular and various irregular RC structure using Staad.pro V8i (select series 5). The variation of displacement, stresses, shear force and storey drift with the variation of soft storey at different position in the structure. To find the displacement variation we considered a single node of a structure where the probability of displacement is maximum as shown in figure 10 on which displacement was found with the variation of position of soft storey in the structure.

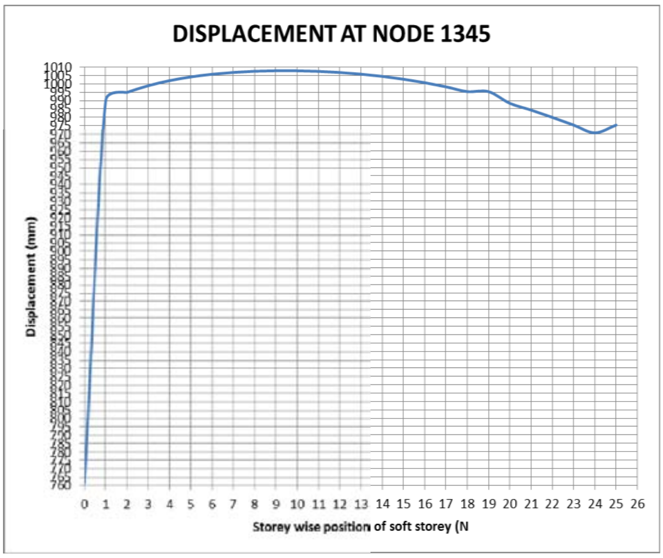

Figure 11: Graph between N and Displacement at node 1345

Table 2: Displacement at Node 1345

Storey wise position of Soft storey(N)	Displacement (mm)
Ground Storey	761.2634
1	989.9396
2	994.9434
3	998.9312
4	1001.9792
5	1004.2144
6	1005.8146
7	1006.9068
8	1007.5926
9	1007.8974
10	1007.872
11	1007.5164
12	1006.856
13	1005.8654
14	1004.5446
15	1002.8428
16	1000.76
17	998.2962
18	995.426
19	995.426
20	988.441
21	984.377
22	980.0082
23	975.4108
24	970.7626
25	975.4108

From the Result as shown in table 2 of analysis graph was plotted as shown in figure 11 between Storey wise position of soft storey (N) and displacement. Another graph was plotted in between height of structure (H) and Displacement at the storey nodes (shown in Figure12) for different position of soft storey as shown in figure 13. In figure 13 storey (G+4)th represent that 5th storey is a soft storey and rest of structure was as regular structure.

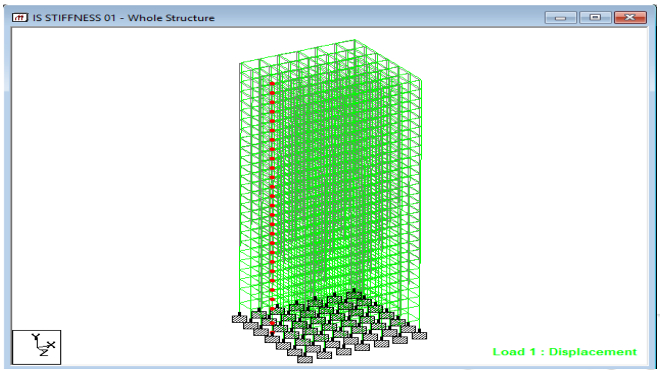

Figure 14: 3D view of Position of storey nodes

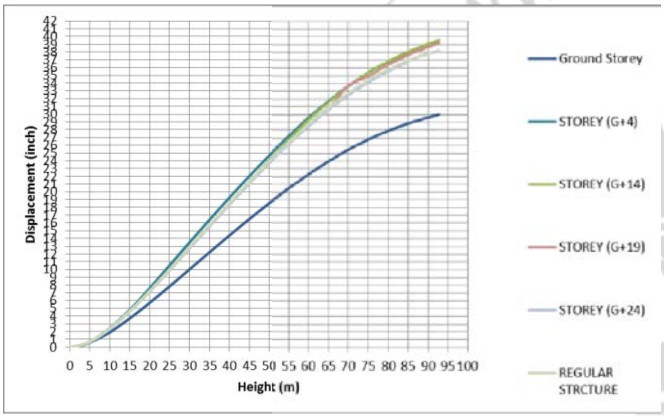

Figure 13: Graph between Height (H) and Displacement

To find the compressive Stress variation in column we considered a column in the structure where the probability of compressive stress is maximum whose position is shown in plan and elevation in figure 14 and 15 respectively. Table 3 Shows values of maximum compressive stress at column 1174 at the different position of soft storey in the RC frame structure.

Table 3: Maximum compressive stress at column 1174

Storey no (N)	Compressive stresses (N/mm^2)
Ground Storey	27.58
1	31.179
2	31.106
3	44.91
4	30.85
5	30.915
6	30.899
7	30.902
8	30.889
9	30.895
10	30.979
11	30.967
12	31.009
13	31.104
14	31.15
15	31.197
16	31.245
17	31.293
18	31.342
19	31.342
20	31.44
21	31.44
22	31.489
23	31.712
24	31.569
25	31.712

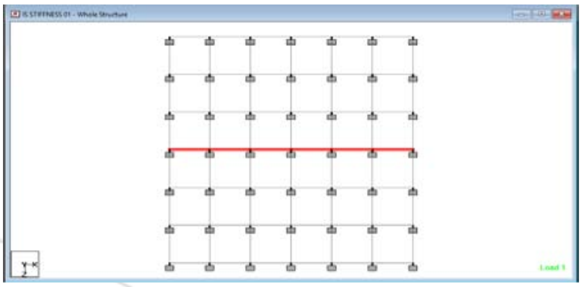

Figure 14: Position of Frame in plan of the structure

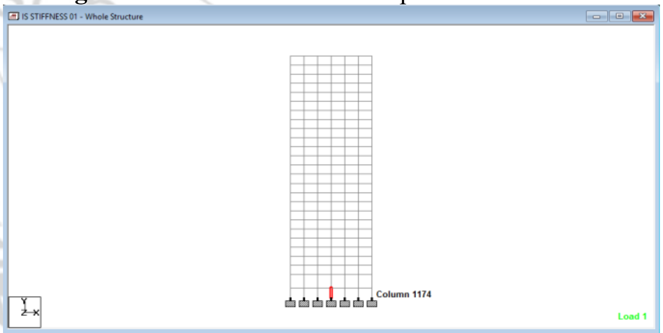

Figure 15: Position of Column in frame

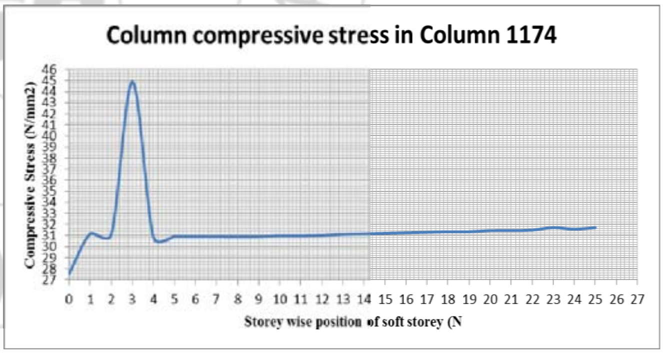

Figure 16: Variation of Compressive stress with N in column 1174

Figure 16 shows that the variation of Compressive stress in Column 1174 With increase the position of soft storey From ground Storey to storey 25th.

To find the Tensile Stress variation in column we considered a Column in the structure where the probability of tensile stress is maximum whose position is shown in plan and elevation in figure 17 and 18 respectively. Table 4 Shows values of maximum tensile stress at column 2191 at the different position of soft storey in the RC frame structure.

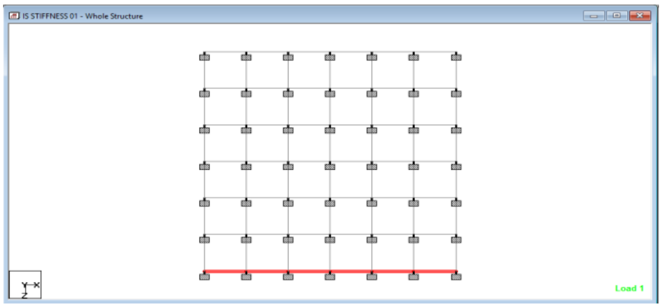

Figure 17: Position of Frame in plan of the structure

Table 4: Maximum tensile stress at column 2191

Storey no (N)	Tensile Stresses (N/mm^2)
Ground Storey	27.58
1	31.179
2	31.106
3	44.91
4	30.85
5	30.915
6	30.899
7	30.902
8	30.889
9	30.895
10	30.979
11	30.967
12	31.009
13	31.104
14	31.15
15	31.197
16	31.245
17	31.293
18	31.342
19	31.342
20	31.44
21	31.44
22	31.489
23	31.712
24	31.569
25	31.712

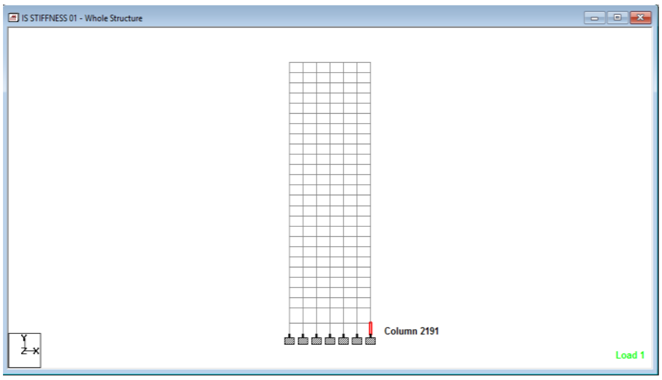

Figure 18: Position of Column in frame

Figure 19 shows that the variation of Compressive stress in Column 1174 With increase the position of soft storey From ground Storey to storey 25th.

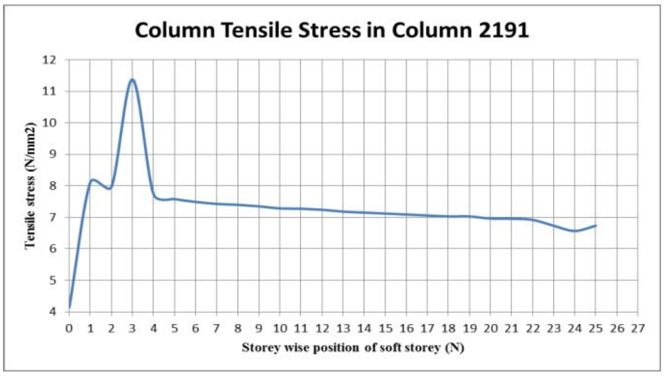

Figure 19: Variation of Tensile stress with N in column 2191

To find the compressive Stress and tensile stress variation in Beam we considered a Beam in the structure where the probability of compressive stress and tensile stress is maximum whose position is shown in plan and elevation in figure 20 and 21 respectively. Table 5 Shows values of maximum compressive stress and tensile stress in Beam 1015 at the different position of soft storey in the RC frame structure.

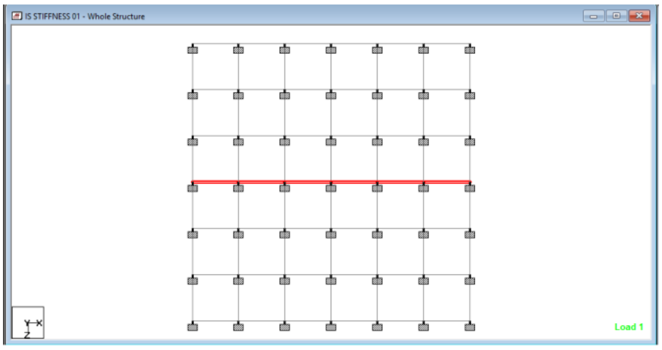

Figure 20: Position of Frame in plan of the structure

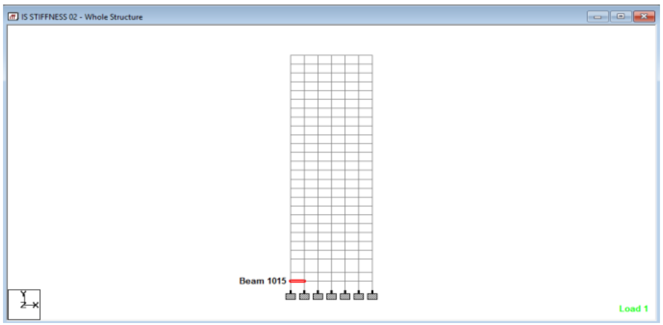

Figure 21: Position of Beam in frame

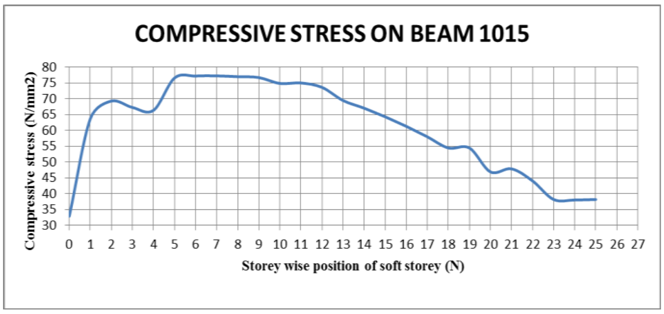

Figure 22: Variation of maximum compressive stress with N in Beam 1015

Figure 22 and 23 shows that the variation of Compressive stress and tensile stress in Beam 1015 respectively With increase the position of soft storey From ground storey to 25th storey.

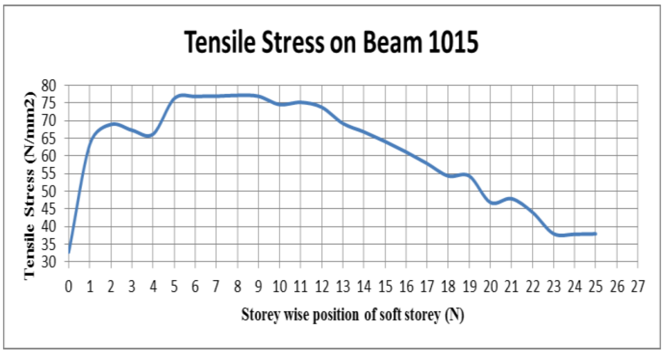

Figure 23: Variation of tensile stress with N in Beam 1015

Table 5: Maximum Compressive and tensile stress in beam 1015

Storey no (N)	Compressive stresses (N/mm^2)	Tensile Stresses ((N/mm^2)
Ground Storey	32.867	27.58
1	63.714	31.179
2	69.276	31.106
3	67.253	44.91
4	66.355	30.85
5	76.59	30.915
6	77.195	30.899
7	77.236	30.902
8	76.977	30.889
9	76.712	30.895
10	74.846	30.979
11	74.99	30.967
12	73.609	31.009
13	69.447	31.104
14	67.031	31.15
15	64.31	31.197
16	61.291	31.245
17	57.993	31.293
18	54.447	31.342
19	54.447	31.342
20	46.876	31.44
21	47.858	31.44
22	44.017	31.489
23	38.158	31.712
24	38.004	31.569
25	38.158	31.712

For the selected beams as shown in figure 24, graph was plotted in between height of structure (H) and maximum Compressive stresses for the selected beam for different position when ground storey, 5,10,15,20 and 25 are soft as shown in figure 25.

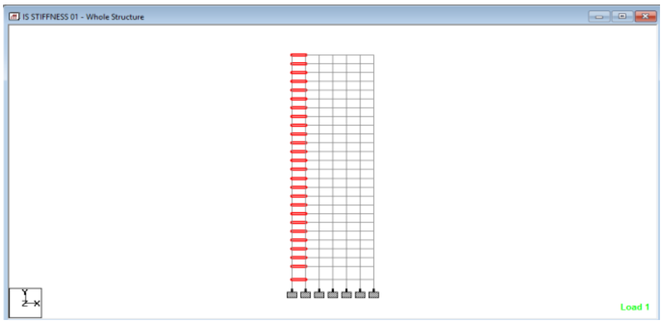

Figure 24: 2D view of selected beam

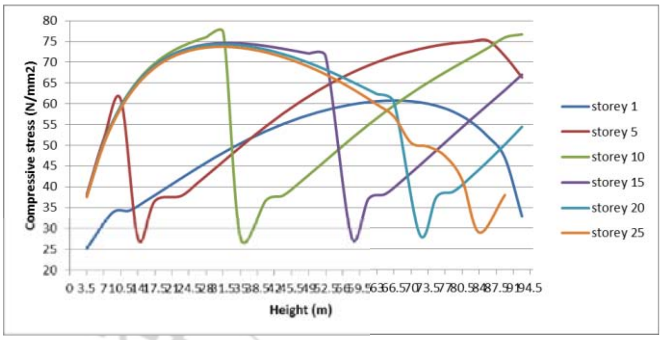

Figure 25: Graph between Height and maximum compressive stress in the selected beams

To find the Maximum Shear force variation in structure we considered a node of a beam in the structure where the probability of Shear force is maximum whose position is shown in plan and elevation in figure 26 and 27 respectively. Table 6 Shows values of maximum shear force at node 575 at the different position of soft storey in the RC frame structure.

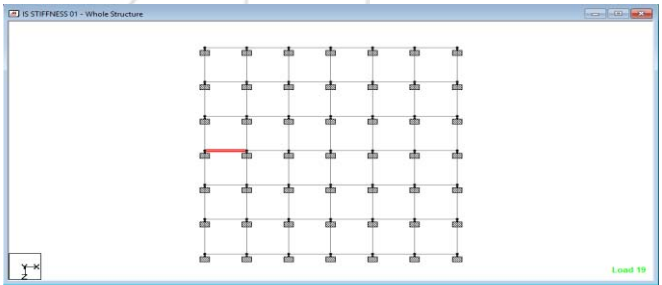

Figure 26: Position of beam in plan of the structure

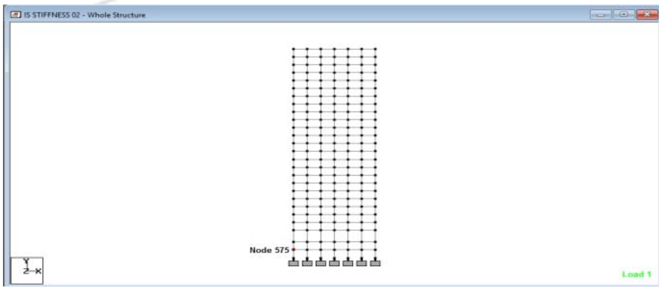

Figure 27: Position of node 575 in 2D frame of Structure

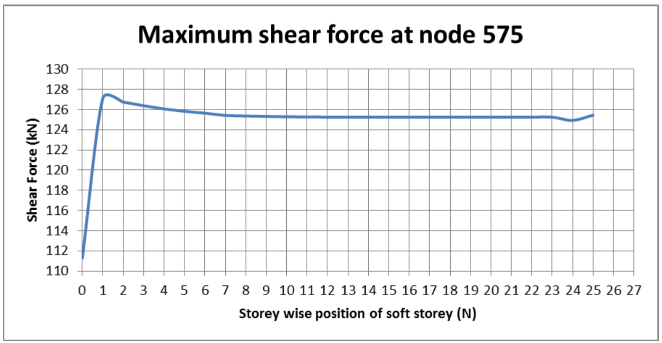

Figure 28: Variation of maximum shear force at node 575 with N

Table 6: Maximum Shear force at Node 575

Storey wise position of Soft storey (N)	Maximum shear force(kN)
Ground storey	111.283
1	127.089
2	126.742
3	126.377
4	126.061
5	125.822
6	125.641
7	125.418
8	125.355
9	125.314
10	125.283
11	125.263
12	125.253
13	125.245
14	125.241
15	125.239
16	125.238
17	125.238
18	125.238
19	125.238
20	125.241
21	125.24
22	125.242
23	125.247
24	124.926
25	125.446

To find the maximum storey drift variation in structure we considered a node at height of 3.5m in the structure. Table 7 shows the values of storey drift at the height 3.5m at the different position of soft storey in the structure and the variation of storey drift with N is shown in figure 29

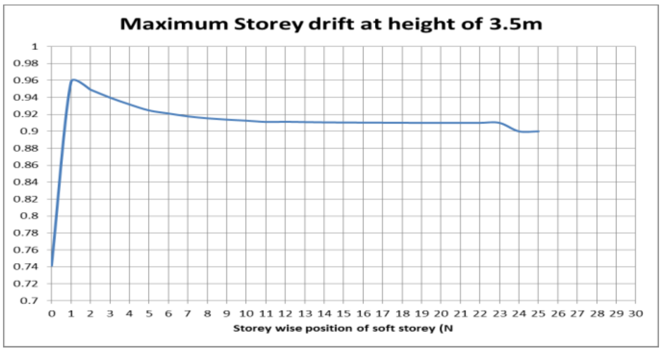

Figure 29: Variation of maximum storey drift at height 3.5m

Table 7: Maximum storey drift at height 3.5m 568

Storey wise position of Soft storey (N)	Maximum Storey drift at height 3.5 m
0	0.7413
1	0.9583
2	0.9492
3	0.9398
4	0.9318
5	0.9247
6	0.9211
7	0.9177
8	0.9154
9	0.9138
10	0.9126
11	0.9111
12	0.9113
13	0.9109
14	0.9106
15	0.9104
16	0.9103
17	0.9102
18	0.9101
19	0.91
20	0.91
21	0.91
22	0.91
23	0.91
24	0.9
25	0.9

5. Conclusion

According to Equivalent Static analysis results for the displacement at a node in the stiffness irregular structure, it was found that when ground storey was soft storey displacement was minimum, on changing the position of soft storey from 1st to 25th Storey displacement at node was change suddenly at position 2nd and displacement was maximum at position 10th. Displacement of top node was found maximum in all the position of soft storey. Nodes displacements with respect to height of the structure for the different position of soft storey found not remarkable change.

In case of compressive stresses in Ground storey central column we found that maximum stress was developed when 3rd storey was soft. Compressive stress was suddenly increased in column when position of soft storey change from ground to 3rd and suddenly decreases when position of soft storey was changed from 3rd to 4th storey. After 4th storey changing the position of soft storey compressive stress was found not remarkable change.

In case of tensile stresses in bottom storey corner column we found that maximum stress was developed when 3rd storey was soft. Tensile stress was suddenly increased in column when position of soft storey change from ground to 3rd and suddenly decreases when position of soft storey was changed from 3rd to 4th storey. After 4th storey changing the position of soft storey tensile stress was found not remarkable change.

In case of compressive stresses in bottom storey corner beam, we found that maximum stress was developed when 5th storey was soft. Compressive stress was decreased but not suddenly in beam when position of soft storey change from 5th storey to 25th storey. It was found that compressive stress was minimum when ground and top storey were soft.

In case of tensile stresses in bottom storey corner beam, we found that maximum stress was developed when 5th storey was soft. Tensile stress was decreased but not suddenly in beam when position of soft storey change from 5th storey to 25th storey. It was found that tensile stress was minimum when ground and top storey were soft.

From variation of Compressive stress in bottom storey corner beam with respect to height for the position of soft storey at storey 0, 5,10,15,20 and 25th it was found that the pattern of variation was approximately same.

In case of shear force in bottom storey middle frame corner beam node it was found that shear force was maximum when 1st storey was soft and minimum when ground storey was soft. After changing the position of soft storey from 2nd storey to 25th storey there is no remarkable change and variation of shear force was negligible.

In case of storey drift it was found that storey drift was maximum when 1st storey was soft and minimum when ground storey was soft. After changing the position of soft storey from 2nd storey to 25th storey there is no remarkable change and variation of storey drift was negligible.

It was concluded that in case of displacement for all the position of soft storey excluded ground position, top 3 storey position for soft storey should be safer as compare to middle storey position of soft storey. In case of maximum stresses in column for all positions of soft storey excluded ground storey Give same result (approx.) except 3rd position of soft storey. So position soft storey at 3rd is most unsafe for structure in case of stresses in column. In case of maximum stresses in beam for all positions of soft storey excluded ground storey if middle storeys of structure are soft than beams are more stressed as compare to position at top and bottom storeys. In case of maximum shear force in beam for all positions of soft storey excluded ground storey give same result (approx.) except 1st position of soft storey. So position of soft storey at 1st is most unsafe for structure in case of shear force in beam. In case of storey drift for all positions of soft storey excluded ground storey give same result (approx.) except 1st position of soft storey. So position of soft storey at 1st is most unsafe for structure in case of storey drift. For all the cases displacement, stresses, shear force and storey drift we found that top 3 positions in the stiffness irregular structure are most safer position of the soft storey in the structure.

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