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Response Characteristics of Structures Having Irregularity Subjected to Vertical Excitation

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***Abstract*— In india recent studies on different earthquakes have shown that the structures or building are not designed for seismic loads and even if the seismic loads are taken into consideration the irregularities and the effect of irregularities in the structure is skipped. In very general perspective the buildings are only designed for gravity loads. The IS standards are not taken into account while designing, resulting into higher destruction of the structure when it is subjected to an earthquake. The complex shaped structures in current day scenario getting very common due to architectural elegance but these structure are great threat when not properly designed. In this work various RC structures are formed having various different types of irregularities in them. All the remaining parameters such as sections of beams and columns, material properties, loading conditions and combinations, support conditions are common in all structures for a fair comparison . All of the frames were analysed using standards mention in IS 1893-Part-1:2002. By the end result, it's been interpreted the base frame with no irregularity evolves least story drifts while the structure with floating columns shows maximum storey drifts on the soft story levels. Thus, such buildings must be designed effectively taking proper care of the dynamic behaviour of the Structure.**

Keywords*— Dynamic response, Structural irregularity, Mass irregularity, Stiffness irregularity, Open Ground Storey building, Stepped building.

I. INTRODUCTION

Irregularities in structures are typical function in today's modern times. Aesthetics of the structure is given a great importance and thus all planning are done from initial stage of the structure making the structure irregular. Irregularities in structures makes the structure more vulnerable at the time of earthquakes. At the time of earthquake the failure starts at the weak spot of the structure and the weak zone in the structure lies where the mass, geometry, stiffness etc changes of the structure. The irregularities in structure also arise due to unexpected change in strength at a specific floor in the structure, even for an experienced and intelligent structural engineer it is a difficult task to avoid such conditions. Hence the focus of existing study is assessing the relative performances of typical vertically irregular structures in a probabilistic domain. Due to scarcity of land in large number of structures ground floor is planned as parking floor thus making this floor as OGS storey, also the floors above the ground floors are proposed with setbacks for proper ventilation and aesthetic purposes making it a stepped kind of building. Recent studies have shown that the OGS of soft storey kind of building have collapsed and has shown negative results when subjected to ground excitations.

IS code 1893 have defined the vertical irregularities within the structure this irregularities in mainly due to change in height, change in bay size, change in stiffness, change in strength and mass of the structure. Thus in area with high seismic vulnerabilities it is important to consider the above factors. IS code 1893:2002 specifies two types of irregularities. [1] Plane irregularities, [2] Vertical irregularities. This study mainly focus on vertical irregularities.

Vertical irregularities are of six types:-

A. ***Stiffness Irregularity** - (Soft Storey)*:- A storey having lateral stiffness less than 70% of the above storey or less than 80% of the average of above 3 stories.

B. ***Stiffness Irregularity - (Extreme Soft Storey)*** :- A storey having lateral stiffness less than 60% of the above storey or less than 70% of the average of above 3 stories.

C. ***Mass Irregularity***:- When the seismic weight of any storey is 200% of its adjacent storeys mass irregularity occurs.

D. ***Vertical Geometric Irregularity***:- Vertical Geometric Irregularity occurs when the horizontal dimension of lateral force resisting unit is more than 130% of adjacent storey.

E. ***In plane discontinuity in vertical lateral force resisting elements***:- Occurs when the in-plane dimension offset is greater then its adjacent offset dimension.

F. ***Discontinuity in capacity - (Weak storey)***:- When the storey's lateral strength is less than 80% of the storey above the storey is said to be weak storey.

When this types of irregularities are present in the buildings the building may be classified into different types as follows:-

1. ***OGS (open ground storey) building***:- In this structure the ground storey is kept open for the use of parking i.e no walls are been provided at this level of the structure, thus irregularity is been induced making the structure less stiff.

2. ***Stepped Building***:- In this structure the upper floors are proposed with upper setbacks for proper ventilation, aesthetic purpose, and also to compliance with "floor area ratio" in the building by-laws.

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3. ***Bare frame buildings***:- Usually while developing the building the walls are not erected thus making the hole structure more prone to lateral loads. In the seismic point of view this is more vulnerable because lateral load are totally resisted by the bare frame.

4. ***Infilled masonry building***:- In this building the frame structure is filled with masonry walls thus masonry walls transfers the forces in the compressive action acting diagonally in the opposite path to the beams below. Thus making the complete structure more stiff.

II. PROBLEM STATEMENT

A large numbers of structures are designed to withstand live and dead loads only, individuals are not aware of earthquake resistant design of structure even if they are most of them avoid taking seismic factors into account while designing. In the seismic vulnerable areas like zone IV and zone V one must consider earthquake factors. In this thesis a framed structure having G+9 stories is considered, the structure is intended for the use of residential purpose. The ground storey is planned as a parking floor thus making the structure an OGS type of building. The symmetrical configuration pattern is taken and complete analysis is been carried out using live load, dead load, and seismic loads in the STADDPro V8i software.

III. METHODOLOGY

A 10 storey RCC frame in considered in this study. In total 10 frames are been created in which a base frame having no irregularity is compared to all other frames having different irregularities. All the seismic parameters are set according to the IS 1893(Part-1) - 2002 and the model is analysed using STAAD Pro software. The base structure is symmetrical in plan and also is vertical direction having same storey height throughout. The structure is 15m x 15m in plan.

Table 1 Building data specification

	Building data specification	
	Specification	***info***
1	Live load	10 kN/m^2 & 5 kN/m^2
2	Dead load	12 kN/m^2 & 8kN/m^2
3	Density of RCC considered	25 kN/m3
4	Depth of beam	450mm
5	Width of beam	250mm
6	Dimension of column	300mm x 300mm
7	Dimension of structure	15m x 15m (in plan)
8	Height of each floor	3.5m
9	City	Pune
10	Earthquake Zone	V
11	Damping Ratio	5%
12	Importance factor	1
13	Type of Soil	Medium
14	Type of structure	Special Moment Resisting Frame

A. *Loading Combinations used:-*

1. EL X+ve
2. EL X-ve
3. DL
4. LL
5. 1.5DL + 1.5LL
6. 1.2DL + 1.2LL + 1.2EL X+ve
7. 1.2DL + 1.2LL + 1.2EL X-ve
8. 1.5DL + 1.5EL X+ve
9. 1.5DL + 1.5EL X-ve
10. 0.9DL + 1.5EL X+ve
11. 0.9DL + 1.5EL X-ve

Abbrivations :- (EL = EARTHQUAKE LOAD, DL = DEAD LOAD, LL = LIVE LOAD).

B. *Arrangements of frames*

Arranging the frames as per irregularities and considering the regular frame as the base comparison frame all the types of frames that are being used are as follows-

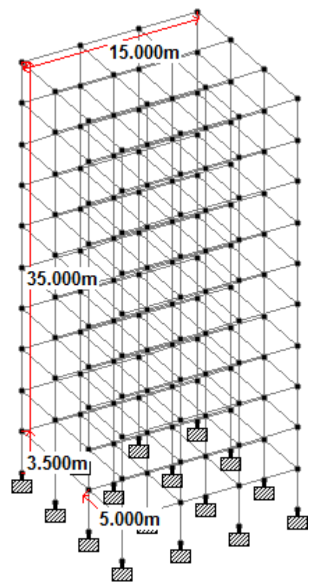

Figure 1 Ideal Base Frame

1. *Frame 1*:- This is the basic and ten storey frame having height of 3.5m and the bay width of 5m. The basic specifications of the building are: Dimensions of the beam = 0.450×0.250m ; Column size = 0.30×0.30 ; Beam Length = 5 m ; Column Length = 3.5 m ; Dead load = 12 KN/m^2 ; Live Load = 10KN/m^2.

2. *Frame 2*:- Frame having 1st and 2nd storeys soft. No floor slab has been provided which makes these two storeys less stiff, i.e. softer.

3. *Frame 3*:- This frame has 4th and 5th storeys soft. No floor columns (Vertical) have been provided which makes these two storeys soft.

4. *Frame 4*:- Frame with heavy loading on 3rd and 6th storeys. Two storeys of the building, i.e. 3rd and 6th storeys carry heavier loads, hence making the building irregular.

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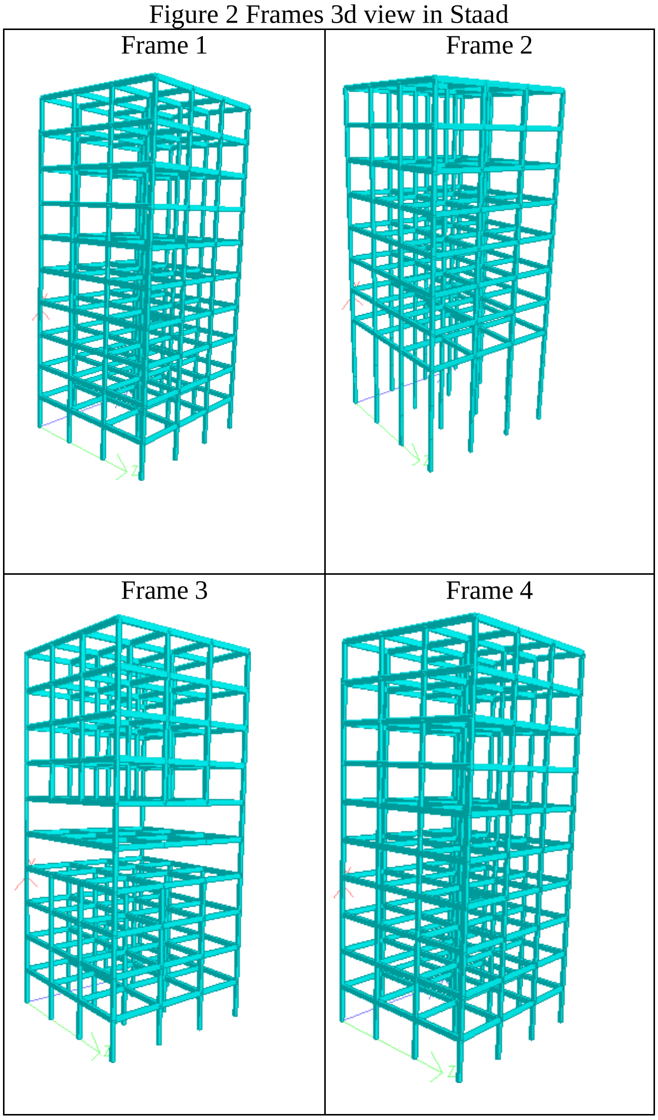
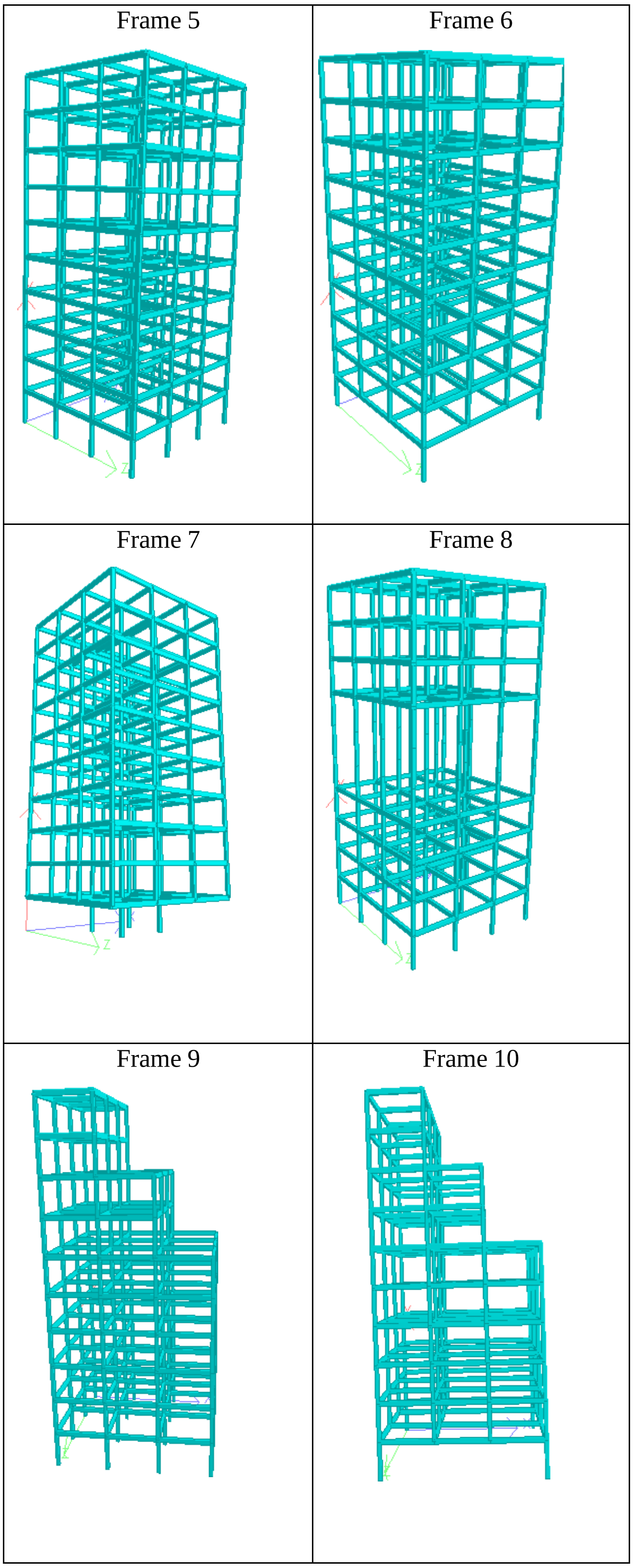
5. *Frame 5*:- The frame carries heavier loading on the Top story, e.g. in the top story swimming pool has been introduced hence making the top storey heavy, and the building becomes irregular.
6. *Frame 6*:- In this frame the intermediate columns are removed making the ground story soft and thus an irregularity is introduced in the building.
7. *Frame 7*:- The frame is made irregular by removing the end columns and placing the intermediate columns in it.
8. *Frame 8*:- This frame has 4th and 5th storeys soft. No floor beams (horizontal) have been provided which makes these two storeys soft.
9. *Frame 9*:- In this frame the geometry of building is changed by changing the height of building in three bays and hence introducing the irregularity in the building.
10. *Frame 10*:- In this frame along with geometric irregularity the intermediate columns are removed, irregularity is introduced by doing so.

All the frames arranged in the above said manner are shown in the figure below:-

Figure 2 Frames 3d view in Staad





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IV. RESULT

A. Comparison of structure - Every irregular structure is compared with the regular framework and the following variation is seen. The member which are in contrast with the regular structure member are taken into consideration ie the member which are in contrast to base frame members are compared and shear force, bending moment & axial force tables are formed.

Table 2 Shear Force Comparison in members

	Shear Force (kN) in members		
	Member	*A (kN)*	*B (kN)*
Structure 1(A) & 2(B)	31	130.07	114.9
	35	111.36	114.82
	39	104.56	114.57
	43	95.55	63.44
Structure 1(A) & 3(B)	51	78.8	391.66
	307	97.61	337.42
	271	78.75	391.66
Structure 1(A) & 4(B)	283	41.26	47.69
	279	57.36	65.15
	275	69.62	69.62
	271	78.75	78.75
Structure 1(A) & 5(B)	28	41.26	40.2
	73	57.36	55.5
	74	69.62	67.5
Structure 1(A) & 6(B)	278	69.98	51.91
	274	78.8	54.15
	275	69.62	52.09
	271	78.75	54.29
Structure 1(A) & 7(B)	51	54.15	78.8
	47	54.84	86.95
	278	51.97	69.68
	274	54.15	78.8
Structure 1(A) & 8(B)	276	113.09	66.37
	272	126.69	66.5
	268	138.35	66.25
Structure 1(A) & 9(B)	211	130.48	101.94
	243	61.82	75.11
	281	94.71	91.85
	168	97.38	87.63
Structure 1(A) & 10(B)	211	103.48	125.74
	243	61.82	186.42
	281	94.71	139.48
	168	97.38	235.77

Table 3 Bending Moment Comparison in members

	Bending Moment (kNm) in members		
	Member	*A (kN)*	*B (kN)*
Structure 1(A) & 2(B)	31	268.19	626.9
	35	194.88	224.73
	39	184.84	578.12
	43	169.67	151.85
Structure 1(A) & 3(B)	51	140.42	804.3
	307	271.59	881.02
	271	140.42	804.3
	387	271.38	881.02
Structure 1(A) & 4(B)	283	80.1	94.14
	279	105.3	114.13
	275	125.29	125.29
	271	190.42	140.42
Structure 1(A) & 5(B)	28	80.1	94.14
	73	105.32	100
	74	125.29	125.29
Structure 1(A) & 6(B)	278	125.39	92.5
	274	140.52	95.48
	275	125.29	92.72
	271	140.42	95.73
Structure 1(A) & 7(B)	51	95.48	140.52
	47	96.63	154.59
	278	92.5	125.39
	274	95.48	140.52
Structure 1(A) & 8(B)	276	199.88	348.34
	272	223.13	116.74
	268	243.46	348.54
Structure 1(A) & 9(B)	211	183.94	199.83
	243	154.57	193.84
	281	168.83	180.69
	168	271.68	224.55
Structure 1(A) & 10(B)	211	183.94	243.25
	243	154.57	470.98
	281	168.83	273.16
	168	271.68	437.05

Table 4 Axial Force Comparison in members

	Axial Force (kN) in members		
	Member	*A (kN)*	*B (kN)*
Structure 1(A) & 2(B)	31	1288.17	715.38
	35	1094.63	715.38
	39	904.29	712

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	Axial Force (kN) in members		
	Member	***A (kN)***	***B (kN)***
	43	726.59	641.38
Structure 1(A) & 3(B)	51	478.01	3599.9
	307	4.8	149.47
	271	478.01	3599.9
	387	5.14	149.47
Structure 1(A) & 4(B)	283	201.2	235.11
	279	295.81	635.9
	275	387.92	1032.67
	271	478.01	1159.77
Structure 1(A) & 5(B)	28	26.3	22.02
	73	30	29.19
	74	24.5	22.02
Structure 1(A) & 6(B)	278	387.92	158.82
	274	478.01	171.38
	275	387.92	158.34
	271	478.01	170.95
Structure 1(A) & 7(B)	51	171.38	478.01
	47	167.85	565.48
	278	158.82	387.92
	274	171.38	478.01
Structure 1(A) & 8(B)	276	676.34	669.58
	272	832.52	669.55
	268	987.65	669.55
Structure 1(A) & 9(B)	211	915.55	150.81
	243	8.82	62.87
	281	519.32	83.27
	168	3.62	99.67
Structure 1(A) & 10(B)	211	915.55	152.36
	243	8.82	138.68
	281	519.32	328.86
	168	3.62	218.01

Chart 1. Maximum Shear force in members

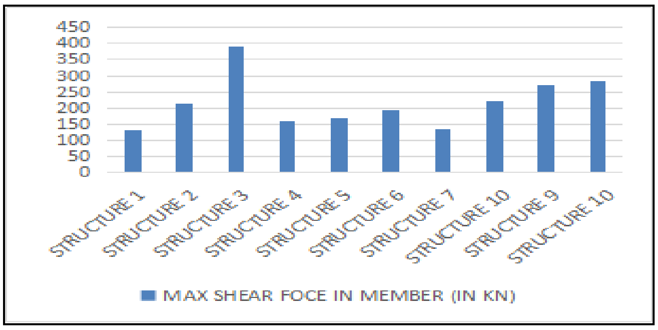


Chart 2. Maximum Bending Moment in members

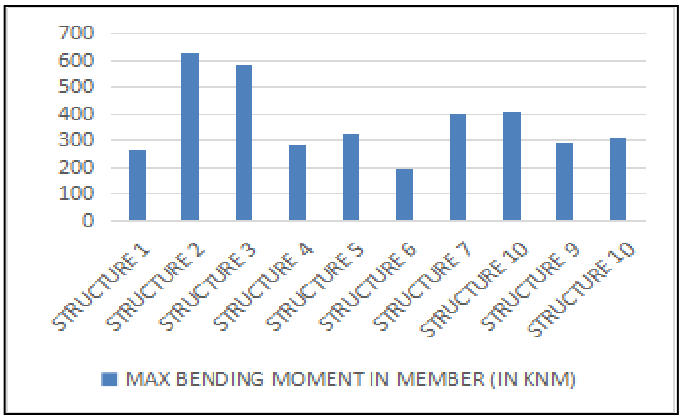
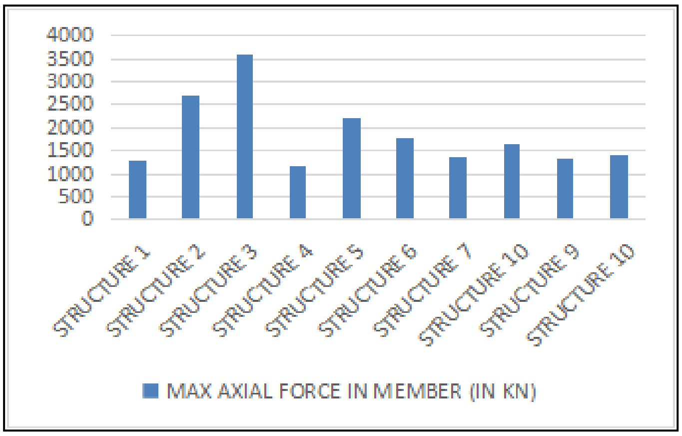


Chart 3. Maximum Axial Force in members



B. Storey Displacement

Table 5 Storey Displacement in X-direction (mm)

Storey	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5
10	40.88	97.39	57.43	48.99	54.79
9	36.46	96.12	56.33	39.88	54.59
8	32.96	93.89	53.54	35.96	50.28
7	36.58	90.87	50.19	32.58	44.47
6	22.54	87.26	45.78	28.53	39.25
5	34.01	88.21	31.52	24.01	32.68
4	19.16	77.84	18.79	19.16	25.06
3	11.12	73.38	14.53	14.12	18.37
2	9.51	52.15	8.63	9.01	11.68
1	4.94	16.45	3.77	3.95	5.11

Table 6 Storey Displacement in X-direction (mm)

Storey	Frame 6	Frame 7	Frame 8	Frame 9	Frame 10
10	42.44	98.1	95.57	55.13	33.64
9	49.11	89.87	94.18	49.89	35.68
8	39.66	81.67	91.79	44.68	25.77
7	36.35	72.58	87.54	42.58	26.95
6	32.39	62.8	68.84	22.37	24.95
5	27.95	52.51	37.28	19.16	26.15
4	23.19	41.84	17.89	15.46	18.98
3	18.24	30.92	12.55	11.48	24.64
2	13.23	19.84	7.983	7.36	20.65
1	8.039	8.645	3.915	4.23	7.492

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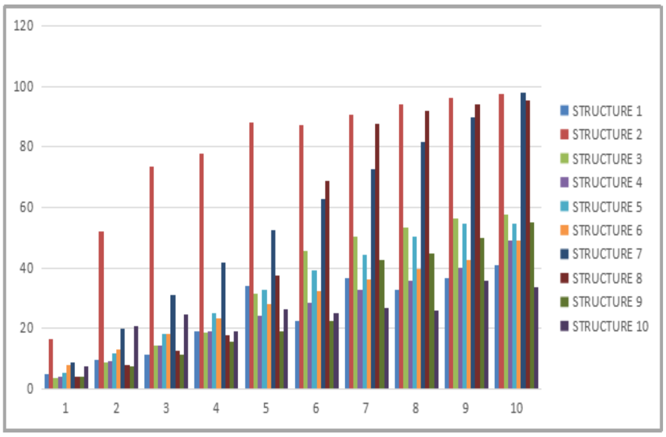
Chart 4. Storey displacement in x-direction(mm)



V. CONCLUSION

1. Considering the storey displacement data, the structure and the frame having floating columns frame no.7 is most fragile because it shows high displacement in top storey level also form the ground storey it shows high displacement except frame no.2.

2. Considering Storey drift the frame and structure having OGS (open ground storey) shows the highest storey drift at bottom storey thus this structure is more fragile and can result into plastic hinged deformation of columns at ground storey level.

3. Frame no. 8 shows very similar storey drifts as frame no.2 at the mid height of the structure.

4. When we take storey shear into consideration frame no. 4 (with 3^{rd} and 6^{th} storey major) shows maximum shear. From this it may be concluded that the frame and structure with floating column shows highest displacement thus are in worse condition and are suspected to fail under current loading circumstances.

5. As we observed every detail regarding the base frame I.e the frame no.1 it shows very least drift and displacement, thus is very safe considering other structure. When this frame is compared to frames with soft storey's it is observed that the soft storey structures shows highest storey drifts.

6. Thus the evaluation demonstrates that the structure without irregularities is safe and the structures with irregularities are unsafe. It is crucial to have regular and simple shaped buildings in addition to even distribution of load throughout the structure.

VI. REFERENCES

[1] Afarani, M., and Nicknam, A. (2012). "Assessment of Collapse Safety of Stiffness Irregular SMRF Structures According to IDA Approach." J. Basic and Applied Scientific Research, 2 (7), 6566-6573.

[2] FEMA 356 (2000). "Pre-standard and Commentary for the Seismic Rehabilitation of Buildings." J. ASCE, USA.

[3] Jeong, S.H., and Elnashai, A.S., (2006). "fragility analysis of buildings with plan irregularities." 4th International Conference on Earthquake Engineering, Paper No. 145.October 12-13.

[4] Tantala, M. W.,and Deodatis,G (2002). "Development of seismic fragility curves for tall buildings." 15th ASCE engg mechanics conference, june 2-5, Columbia university, New york.

[5] Murat, S. K., and Zekeria, P. (2006) "Fragility analysis of mid-rise R/C frame buildings." J. Earthquake Engineering and Structural Dynamics, 28 1603–26.

[6] Rota, M., Penna, A., and Magenes, G. (2010). "A methodology for deriving analytical fragility curves for masonry buildings based on stochastic nonlinear analyses." J. Engineering Structures 32 1312_1323.

[7] Erberik, A.M. (2008). "Fragility-based assessment of typical mid-rise and low- rise RC buildings in Turkey." J. Engineering Structures, 30 1360–1374.

[8] Guneyisi, E.M., and Altay, G. (2008). "Seismic fragility assessment of effectiveness of viscous dampers in R/C buildings under scenario earthquakes." J. Structural Safety, 30 461–480.

[9] Samoah, M. (2012). "Generation of analytical fragility curves for Ghanaian non-ductile reinforced concrete frame buildings." J. Physical Sciences Vol. 7(19), pp. 2735-2744.

[10] Rajeev, P., and Tesfamariam, S. (2012). "Seismic fragilities for reinforced concrete buildings with consideration of irregularities." J. Structural Safety, 39 1–13.

[11] Sarkar, P., Meher, A., Prasad., Menon, D. (2010). "Vertical geometric irregularity in stepped building frames." J. Engineering Structures, 2175_2182.

[12] Scarlet, A. (1997). "Design of Soft Stories – A simplified energy approach.",J. Earthquake Spectra. 13. 305-315.

[13] Hashmi, A. K., and Madan. A. (2008). "Damage forecast for masonry infilled reinforced concrete framed buildings subjected to earthquakes in India." J. Current Science. 94. 61-73.

[14] Sahoo, D. R. (2012). "Seismic Strengthening of Reinforced Concrete Framed Structures-Using Steel Caging and Aluminium Shear Yielding Dampers", Lambert Academic Publishing GmbH & Co. KG, Germany.

[15] Patel, S. (2012). "Earthquake Resistant Design Of Low-Rise Open Ground Storey Framed Building." M. Tech Thesis, National Institute of Technology, Rourkela.