RESPONSE CHARACTERISTICS OF STRUCTURES HAVING IRREGULARITY SUBJECTED TO VERTICAL EXCITATIONS

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Abstract :- Recent earthquake in india has shown that most structures are not designed for seismic loads and if they are designed for seismic loads the irregularities of structures are ignored. In general, buildings are only designed considering gravity loading. The IS code are not properly practiced thus resulting into higher damage to the structure when subjected to earthquake. This work describes various RC frame structures having various types of irregularities keeping all other parameters common. All of the frames were analysed using IS 1893-Part-1:2002. By the end result, it's been interpreted the base frame (regular) evolves least story drifts while the structure with floating columns shows maximum storey drifts on the soft story levels. Thus complex shaped structures in present day scenario getting common but these structure are great threat when not properly designed. 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.

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.

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.

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.

II. 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. Building data and specification:-

Live Load	10N/m^2 (for all floors)
	5 kN/m^2(for the roof)
Dead Load	12 kN/m^2 + 8kN/m^2
Density of RCC considered	25 kN/m^3
Depth of beam	450mm
Width of beam	250mm
Dimension of column	300mm x 300mm
Dimension of structure	15m x 15m (in plan)
Height of each floor	3.5m
City	Pune
Earthquake Zone	V
Damping Ratio	5%
Type of building	Important
Importance factor	1
Type of Soil	Medium
Type of structure	Special Moment Resisting Frame

Loading Combinations used :-

1.EL X(+VE)
2.EL X(-VE)
3.DL
4.LL
5.1.5(DL+LL)
6.1.2(DL+LL+EL X+VE)
7.1.2(DL+LL - EL X-VE)
8.1.5(DL+EL X+VE)
9.1.5(DL-EL 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).

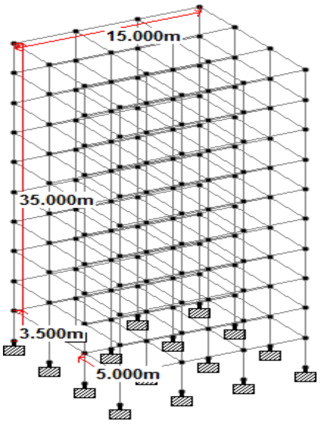


Figure 1: Ideal Frame

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:-

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 = 0.450×0.25 m ; Column size = 0.30×0.30 ; Beam Length = 5 m ; Column Length = 3.5 m ; Dead load = 12 KN/m2 ; Live Load = 10KN/m2.

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.

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

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.

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.

FRAME-6: In this frame the intermediate columns are removed making the ground story soft and thus an irregularity is introduced in the building.

FRAME-7: The frame is made irregular by removing the end columns and placing the intermediate columns in it.

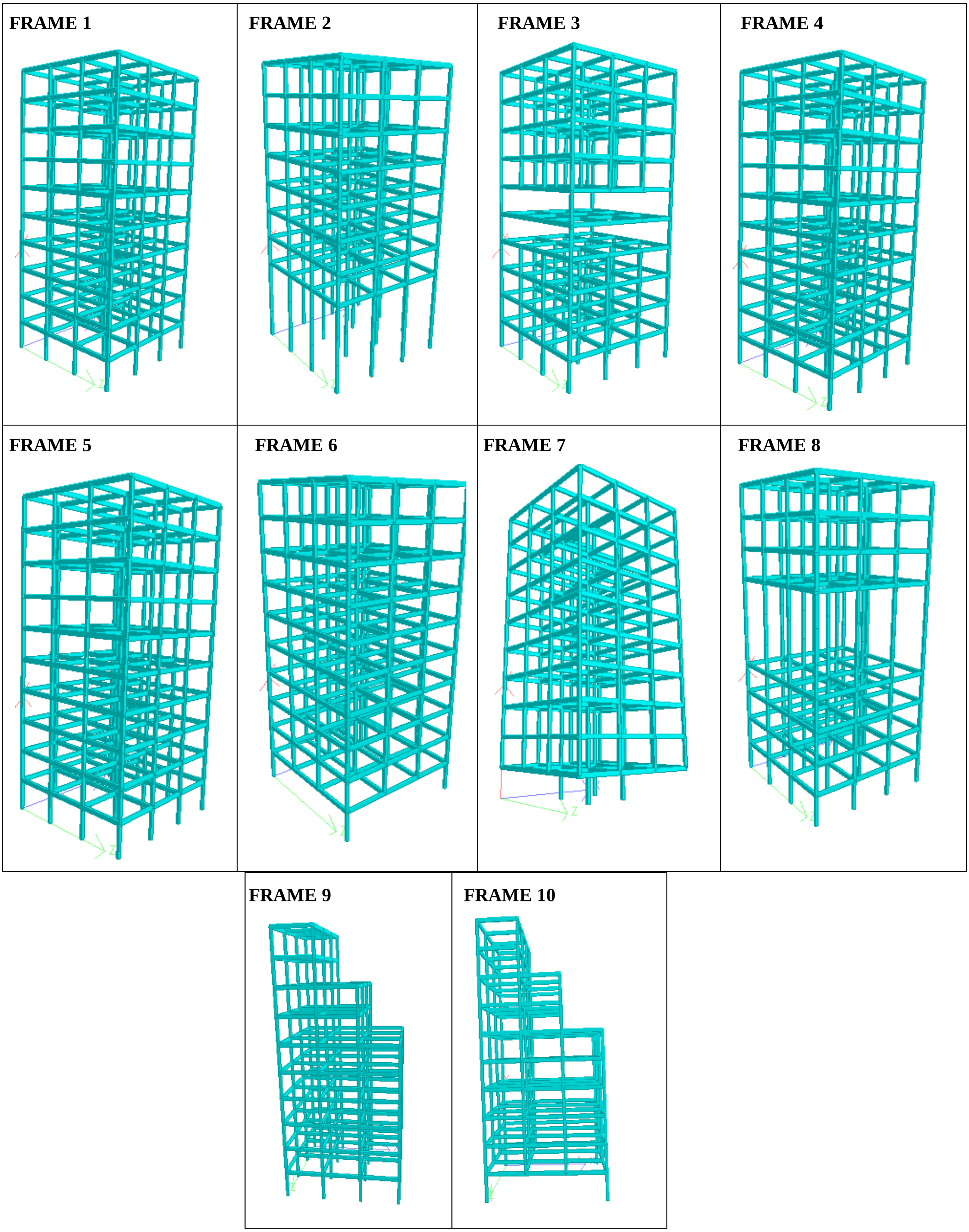
FRAME-8:This frame has 4th and 5th storeys soft. No floor beams (horizontal) have been provided which makes these two storeys soft.

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.

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 1 Arrangement of frames



III. RESULT

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 1 Shear force (in kN) comparison between members

	MEMBER	A	B
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
	387	97.52	337.42
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 2 Bending moment (in kNm) comparison between member

	MEMBER	A	B
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 3 Axial force (in kN) comparison between members

	MEMBER	A	B
STRUCTURE 1(A) & 2(B)	31	1288.17	715.38
	35	1094.63	715.38
	39	904.29	712
	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

Figure 2 Chart of Max shear force in member (unit kN)

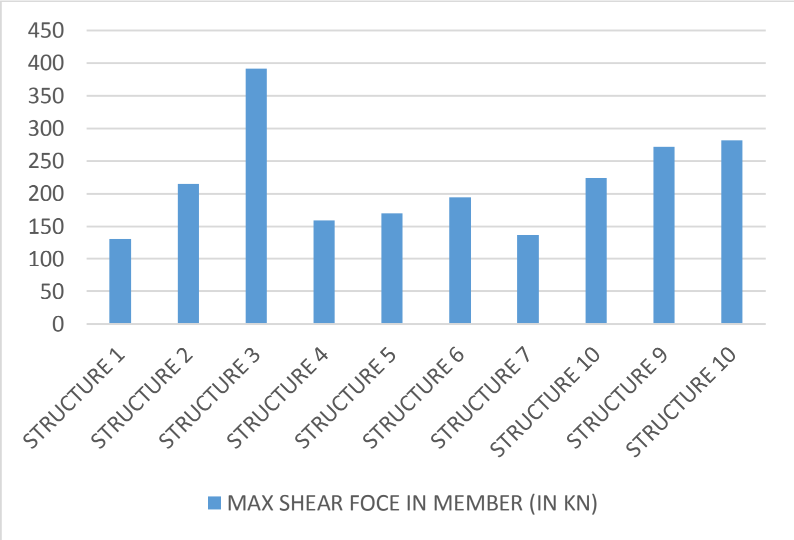


Figure 3 Chart of Max bending moment in member (unit kNm)

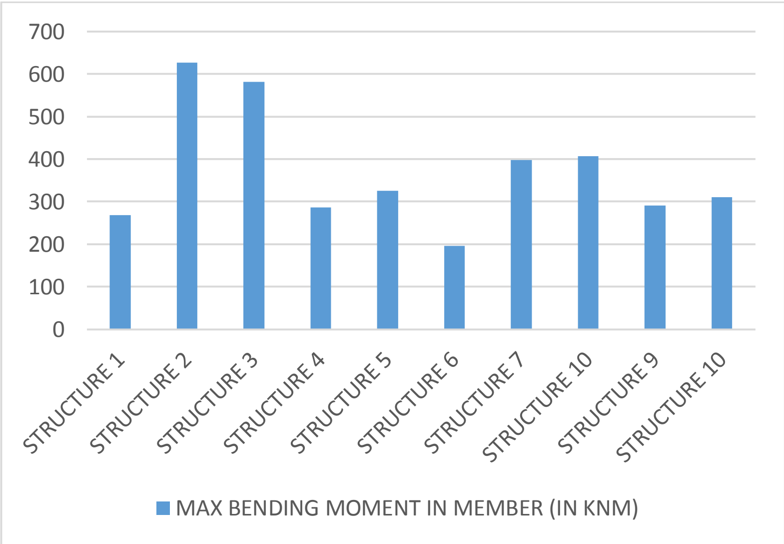
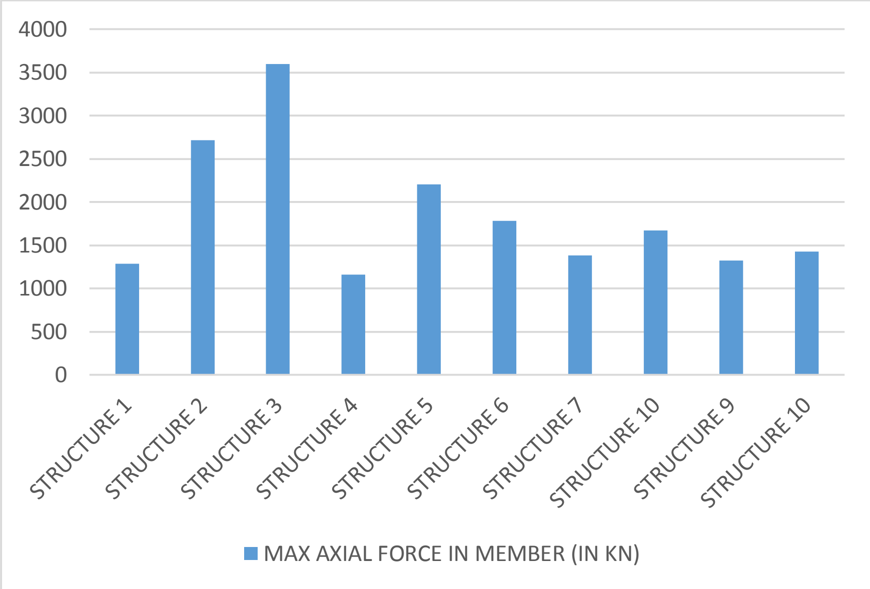


Figure 4 Chart of Max axial force in member (unit kN)

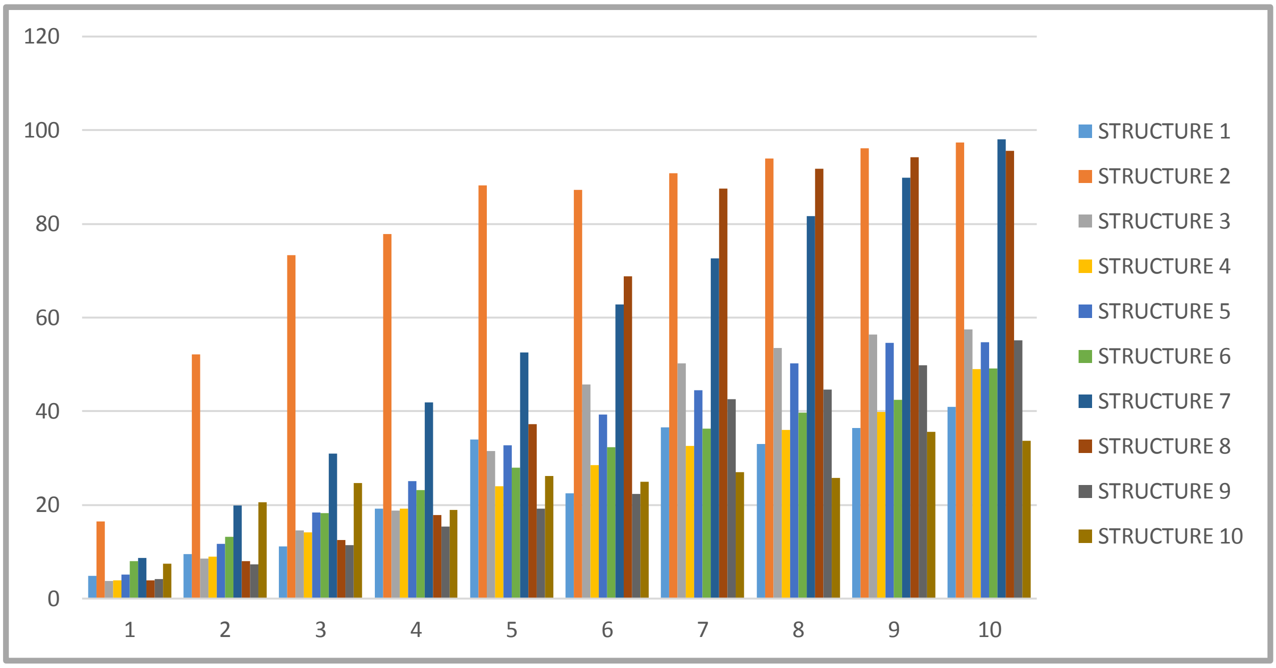


RESULTS OF STOREY DISPLACEMENTS

Table 4 Storey Displacement UX in X direction (Unit - mm)

	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame 8	Frame 9	Frame 10
STOREY	UX	UX	UX	UX	UX	UX	UX	UX	UX	UX
10	40.88	97.39	57.43	48.99	54.79	42.44	98.1	95.57	55.13	33.64
9	36.46	96.12	56.33	39.88	54.59	49.11	89.87	94.18	49.89	35.68
8	32.96	93.89	53.54	35.96	50.28	39.66	81.67	91.79	44.68	25.77
7	36.58	90.87	50.19	32.58	44.47	36.35	72.58	87.54	42.58	26.95
6	22.54	87.26	45.78	28.53	39.25	32.39	62.8	68.84	22.37	24.95
5	34.01	88.21	31.52	24.01	32.68	27.95	52.51	37.28	19.16	26.15
4	19.16	77.84	18.79	19.16	25.06	23.19	41.84	17.89	15.46	18.98
3	11.12	73.38	14.53	14.12	18.37	18.24	30.92	12.55	11.48	24.64
2	9.51	52.15	8.63	9.01	11.68	13.23	19.84	7.983	7.36	20.65
1	4.94	16.45	3.77	3.95	5.11	8.039	8.645	3.915	4.23	7.492

Figure 5 Chart of storey displacement in x direction (unit - mm)



IV. CONCLUSION

1. Considering the storey displacement, the frame and structure with floating columns frame 7 may be the most fragile since it suffers the highest displacement as the base frame and structure exhibits the very least displacement.

2. So far as storey drift is concerned, frame two (with bottom 2 soft storeys) may be the most fragile since it's the maximum storey drift which changes abruptly.

3. Frame 8 also shows pattern that is similar for bottom 2 storeys.

4. Storey shear is however maximum in frame 4 (with 3rd and 6th storeys major). It may be inferred naturally the frame and structure with floating columns represents the even worse situation since it faces the highest displacement and is very susceptible to damages under this particular lateral loading.

5. While, on the flip side it could be observed that the base frame and structure contains the very least drift and displacement, hence least vulnerable to the harm. The starting frame and structure that is ideal develops least story drifts while the structure with floating column shows maximum storey drifts on soft story levels.

6. The evaluation too demonstrates that irregularities are unsafe for the buildings and also it's crucial that you have regular and simpler shapes of frames in addition to even load distribution within the construction.

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