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Seismic Drift Control in soft storied RCC buildings

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ABSTRACT
This paper studies Seismic drift demands in RCC Buildings with weak first stories which is very important seeing the present damages all over the World due to earth quake like Kobe and Chi-Chi earth quakes in 1995and 1999 respectively . As we know that in India , Bhuj-Gujrat earth quake on 26th Jan 2001 and Nepal earth quake -2015, were the most destructive events recorded in India and Nepal in terms of deaths and damages to the infrastructure and devastation in the last fifty years., These earthquakes has provides lessons to human society particularly engineers, architects, builders for improving design and planning, practices ,inadequate analysis, design deficiency and even poor quality of construction. It has been observed that the principal reason of failure may be associated to soft stories, floating columns ,mass irregularities and pounding of adjacent structures etc. In this paper focus has been to judge the damages factors which are responsible for the collapse of structure and control measures to be provided for a safe and economic design as per current Indian and foreign codes .An analysis has performed using STAAD-Pro for G+5 multistoried building in different Zones IV and V and drifting results obtained has discussed with respect to safety and damages consideration..

Keywords-: Ductility demand, Inter storey drift, mode shape, soft storey, stiffness.

I. INTRODUCTION

RCC Multistoried building is the most common type of construction practices adopted in many countries ranges G + 5 to G + 10 storey height .The building framing system is generally moment resisting consisting reinforced concrete slab casted monolithically with beams and columns on shallow isolated footings .The upper floor generally constructed with infill walls made of unreinforced bricks ,cut stone , or cement concrete blocks. In the major cities, the ground floor/ basement is often used for commercial and parking purposes, where the infill walls are omitted resulting in soft or weak stories. It is also seen that most of the building have overhanging covered balconies on higher floors .Sometimes Architect often erects a heavy beam from the exterior columns of the building to the end of the balcony on the first floor onwards to allow more parking so a peripheral beam is provided at the end of the erected girder. Thus the infill walls which are present in upper floors and absent in ground floor, creates a floating box type situation and during earth quake these type of buildings vibrates in torsion mode which is undesirable.

1.1 Causes of damages in RCC building

In past earthquake , it is found that there were many causes of building collapse responsible for multiple damages . So it is very difficult to classify damages reasons in term of quantitative manner or percentage wise . but the principle causes of damages of buildings are soft storey ,floating columns ,mass irregularities, poor quality of material , inconsistent seismic performances ,soil and foundation effects, inadequate ductile detailing in structural components etc .So bureau of Indian standard (BIS) has published two codes IS-1893-PART-2002 and IS-13920-1993 for the earth quake resistant design of RCC buildings .the former codes deals with the determination of forces and general considerations of design of buildings and latter code deals with the detailing of RCC structures for ductility requirements. So building should be designed on the basis of above code requirements and building with vertical irregularities like soft storey etc should be designed on the basis of dynamic analysis and inelastic design with greater quality of construction.

1.2 Soft storey failure

we know that multistoried buildings in Metropolitan cities require open taller first storey for parking of vehicles and for retail shopping or banking hall etc owing to the lack of horizontal space and high cost .thus due to the functional requirement, the first storey has lesser strength and stiffness as compared to the upper stories which are stiffened by masonry infill walls .This character of building creates weak storey problem in multistory building. So increased flexibility of the first storey results in extreme deflection which in turn lead to concentration of forces at the second connection accompanied by large plastic deformation..In addition most of the energy developed during the earthquake is dissipated by columns which transform the soft storey into a mechanism .In such cases the collapse is unavoidable. Therefore a soft storey desire a special consideration in analysis and design It has been observed from the survey that the damage is due to collapse and buckling of columns especially where parking places are not covered appropriately . On the contrary the damages is reduced considerably where the parking places are covered adequately It is recognized that this type of failure results ifrom combination of several other unfavourable reasons such as torsion ,excessive mass on the upper floors, P-Delta effects, and lack of ductility in the bottom storey.

II. Geometry and description of model

In the present work, a six storied (G+5) RC frame building is being modeled using computer software STAD-Pro-V8I having storey height 3.6m for each floor with regular plan , building consist five bays in X-direction and nine bays in Y-direction with plan 45 m by 30m having foundation depth 2.4m. the bay width along longitudinal direction is 6.00m and in transverse direction is 5.00m with a column size 0.30mby 0.6 for all the storey and the total height of building is 21.60m..M-25 Grade of concrete With Fe-415 grade of steel is being used for all types of modeling in this study and loading has considered as as IS-875-1987-Part-05 and part -2 and calculation of base shear force etc as per IS-1983-2002-Part-1 with medium type of soil in different zones.

III. Base shear force

We know that as per IS 1893-2002 part-1, the total design lateral force or design seismic base shear (Vb) along any principal direction will be Vb =AhxW (1) Where ,Ah = design horizontal acceleration spectrum, W=seismic weight of the building . Ah=Z/2x I/R x Sa/g …(11), where Z=zone factor varies from 0.1 to 0.36, I=importance factor, R=response reduction factor, Sa/g=average response acceleration coefficient.the vertical distribution of base shear force to different floors:. Qi = Vb. x $W_i h_i^2/\sum W_i h_i^2$... (111) Where Qi = Design lateral force at floor I, Wi = seismic wt. of floor I, Hi = height of floor measured from base ,n= no of stories in the building including certain approximation and assumption as per earth quake codes with amendments.

IV. Result and discussion

Response spectrum analysis has been done using the above parameters for different zones and the post processing results obtained has summarized in the following tables and figures for structure and the average displacement and inter storey drift for different zones has summarized as below.

Table No. 4.1 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-IV)

STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1.000	0.000	REX	0.000	0.000	0.000	0.000	
		REZ	0.000	0.000	0.000	0.000	
2.000	2.400	REX	0.414	0.000	0.414	0.000	
		REZ	0.000	0.834	0.000	0.834	
3.000	6.000	REX	1.791	0.001	1.377	0.001	WITHIN PERMISSIBLE LIMIT
		REZ	0.000	3.574	0.000	2.739	EXCEEDS PERMISSIBLE LIMIT
4.000	9.600	REX	3.223	0.001	1.433	0.001	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	6.200	0.000	2.626	EXCEEDS PERMISSIBLE LIMIT
5.000	13.200	REX	4.489	0.002	1.265	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	8.473	0.000	2.273	EXCEEDS PERMISSIBLE LIMIT
6.000	16.800	REX	5.492	0.002	1.003	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	10.257	0.000	1.784	EXCEEDS PERMISSIBLE LIMIT
7.000	20.400	REX	6.173	0.002	0.681	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	11.447	0.000	1.190	WITHIN PERMISSIBLE LIMIT
8.000	24.000	REX	6.522	0.002	0.350	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	11.992	0.000	0.545	WITHIN PERMISSIBLE LIMIT

Average Displacement and interstorey drift calculation for a bare frame

Table No. 4.2 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-V)							
STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1	0	REX	0	0	0	0	
		REZ	0	0	0	0	
2	2.4	REX	0.6207	0.0003	0.6207	0.0003	
		REZ	0.0001	1.2513	0.0001	1.2513	
3	6	REX	2.6859	0.001	2.0652	0.0008	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0004	5.3604	0.0003	4.1091	EXCEEDS PERMISSIBLE LIMIT
4	9.6	REX	4.8351	0.0018	2.1493	0.0008	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0007	9.2997	0.0003	3.9394	EXCEEDS PERMISSIBLE LIMIT
5	13.2	REX	6.7328	0.0025	1.8977	0.0007	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.001	12.7098	0.0002	3.4101	EXCEEDS PERMISSIBLE LIMIT
6	16.8	REX	8.2374	0.003	1.5046	0.0005	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0012	15.386	0.0002	2.6762	EXCEEDS PERMISSIBLE LIMIT
7	20.4	REX	9.2589	0.0034	1.0215	0.0004	WITHIN PERMISSIBLE LIMIT
		REZ	0.0013	17.171	0.0001	1.785	EXCEEDS PERMISSIBLE LIMIT
8	24	REX	9.7831	0.0033	0.5242	0	WITHIN PERMISSIBLE LIMIT
		REZ	0.0012	17.988	0	0.817	WITHIN PERMISSIBLE LIMIT

<u>Average Displacement and interstorey drift calculation for a bare frame</u>

Table No. 4.3 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-IV)							
STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1.000	0.000	REX	0.000	0.000	0.000	0.000	
		REZ	0.000	0.000	0.000	0.000	
2.000	2.400	REX	0.521	0.000	0.625	0.000	
		REZ	0.000	01.251	0.000	.0.989	
3.000	6.000	REX	5.4029	0.0023	2.897	0.0021	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.000	8.504	0.000	8.551	EXCEEDS PERMISSIBLE LIMIT
4.000	9.600	REX	3.523	0.001	1.449	0.002	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	6.300	0.000	2.7626	EXCEEDS PERMISSIBLE LIMIT
5.000	13.200	REX	4.489	0.002	1.265	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	8.473	0.000	2.273	EXCEEDS PERMISSIBLE LIMIT
6.000	16.800	REX	5.492	0.002	1.003	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	10.257	0.000	1.784	EXCEEDS PERMISSIBLE LIMIT
7.000	20.400	REX	6.173	0.002	0.681	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	11.457	0.000	1.190	WITHIN PERMISSIBLE LIMIT
8.000	24.000	REX	6.522	0.002	0.350	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	12.992	0.000	0.545	WITHIN PERMISSIBLE LIMIT

<u>Average Displacement and interstorey drift calculation for a soft storied at GF</u>

Table No. 4.4 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-V)							
STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1	0	REX	0	0	0	0	
		REZ	0	0	0	0	
2	2.4	REX	1.9207	0.0003	1.9120	0.0003	
		REZ	0.0003	1.7513	0.0001	1.7513	
3	6	REX	7.894	0.003	8.735	0.0099	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0066	9.989	0.0008	10.7893	EXCEEDS PERMISSIBLE LIMIT
4	9.6	REX	4.8351	0.0018	2.1493	0.0008	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0007	9.2997	0.0003	3.9394	EXCEEDS PERMISSIBLE LIMIT
5	13.2	REX	6.7328	0.0025	1.8977	0.0007	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.001	12.7098	0.0002	3.4201	EXCEEDS PERMISSIBLE LIMIT
6	16.8	REX	8.2374	0.003	1.5046	0.0005	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0012	15.387	0.0002	2.6762	EXCEEDS PERMISSIBLE LIMIT
7	20.4	REX	9.2589	0.0034	1.0215	0.0004	WITHIN PERMISSIBLE LIMIT
		REZ	0.0013	17.271	0.0001	1.785	EXCEEDS PERMISSIBLE LIMIT
8	24	REX	9.7831	0.0033	0.5242	0	WITHIN PERMISSIBLE LIMIT
		REZ	0.0012	18.988	0	0.837	WITHIN PERMISSIBLE LIMIT

<u>Average Displacement and interstorey drift calculation for a soft storied at GF</u>

Table No. 4.5 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-IV)							
STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1.000	0.000	REX	0.000	0.000	0.000	0.000	
		REZ	0.000	0.000	0.000	0.000	
2.000	2.400	REX	0.414	0.000	0.414	0.000	
		REZ	0.000	0.834	0.000	0.834	
3.000	6.000	REX	4.118	0.001	6.477	0.001	WITHIN PERMISSIBLE LIMIT
		REZ	0.000	6.574	0.004	4.739	EXCEEDS PERMISSIBLE LIMIT
4.000	9.600	REX	3.223	0.001	1.433	0.001	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	6.200	0.000	2.626	EXCEEDS PERMISSIBLE LIMIT
5.000	13.200	REX	4.489	0.002	1.265	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	8.473	0.000	2.273	EXCEEDS PERMISSIBLE LIMIT
6.000	16.800	REX	5.492	0.002	1.003	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	10.357	0.000	1.784	EXCEEDS PERMISSIBLE LIMIT
7.000	20.400	REX	6.173	0.002	0.681	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	11.447	0.000	1.390	WITHIN PERMISSIBLE LIMIT
8.000	24.000	REX	6.522	0.002	0.350	0.000	WITHIN PERMISSIBLE LIMIT
		REZ	0.001	11.998	0.000	0645	WITHIN PERMISSIBLE LIMIT

<u>Average Displacement and interstorey drift calculation for a bare frame with shear wall at core And enlarging sizes GF columns nearly 20 percentage with respect to IInd floor and above</u>

Table No. 4.6 AVERAGE DISPLACEMENT & INTER STOREY DRIFT (ZONE-V)							
STORY	HEIGHT	LOAD	AVG. DISP (CM)		DRIFT (CM)		REMARK
	(METE)		X	Z	X	Z	
1	0	REX	0	0	0	0	
		REZ	0	0	0	0	
2	2.4	REX	1.207	0.0003	0. 907	0.0003	
		REZ	0.0001	1.4513	0.0001	1.4513	
3	6	REX	6.6859	0.002	2.0652	0.0096	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0056	7.3604	0.0003	7.2091	EXCEEDS PERMISSIBLE LIMIT
4	9.6	REX	4.8351	0.0018	2.1493	0.0008	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0007	9.2997	0.0003	3.9394	EXCEEDS PERMISSIBLE LIMIT
5	13.2	REX	6.7328	0.0025	1.8977	0.0007	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.001	12.7098	0.0002	3.4101	EXCEEDS PERMISSIBLE LIMIT
6	16.8	REX	8.2374	0.003	1.5046	0.0005	EXCEEDS PERMISSIBLE LIMIT
		REZ	0.0012	15.386	0.0002	2.6762	EXCEEDS PERMISSIBLE LIMIT
7	20.4	REX	10.2589	0.0034	1.0215	0.0004	WITHIN PERMISSIBLE LIMIT
		REZ	0.0013	17.171	0.0001	1.785	EXCEEDS PERMISSIBLE LIMIT
8	24	REX	9.7831	0.0033	0.5242	0	WITHIN PERMISSIBLE LIMIT
		REZ	0.0012	18.778	0	0.917	WITHIN PERMISSIBLE LIMIT

Average Displacement and interstorey drift calculation for a bare frame with shear wall at core And enlarging sizes GF columns nearly 20 percentage with respect to IInd floor and above

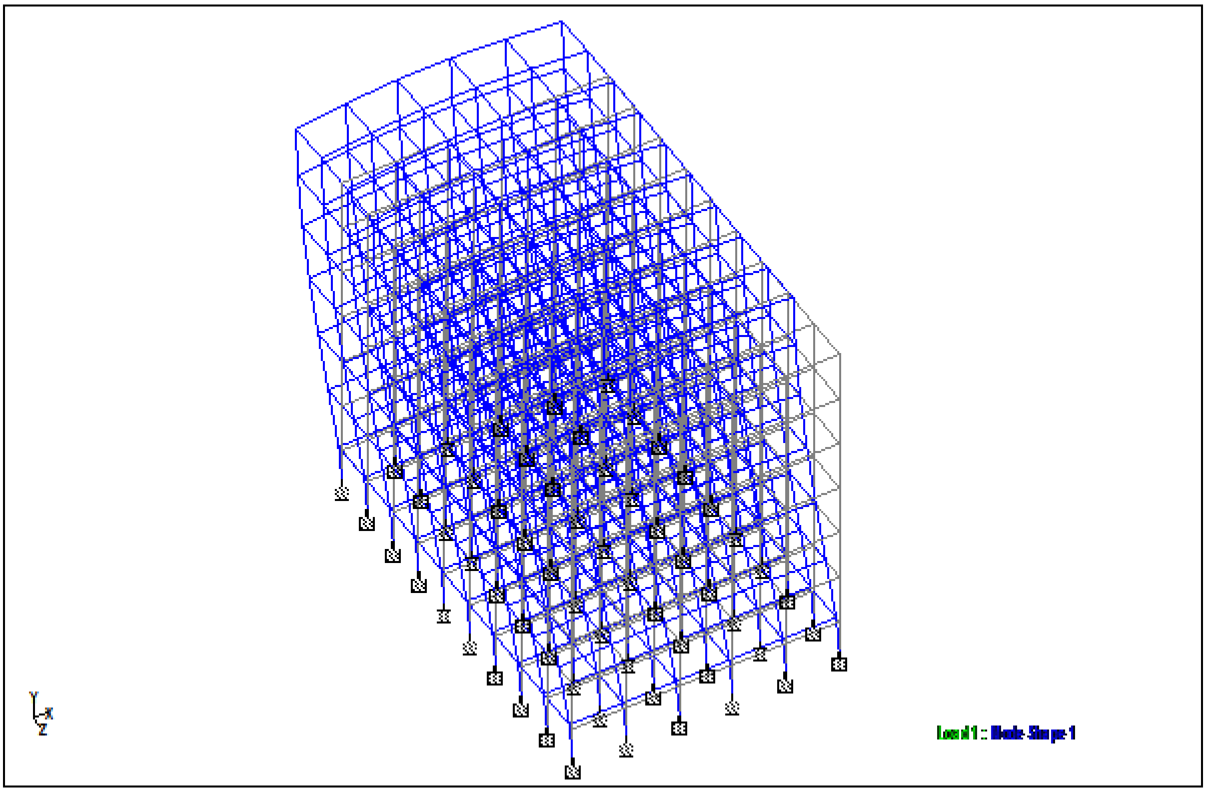

Fig.5.1

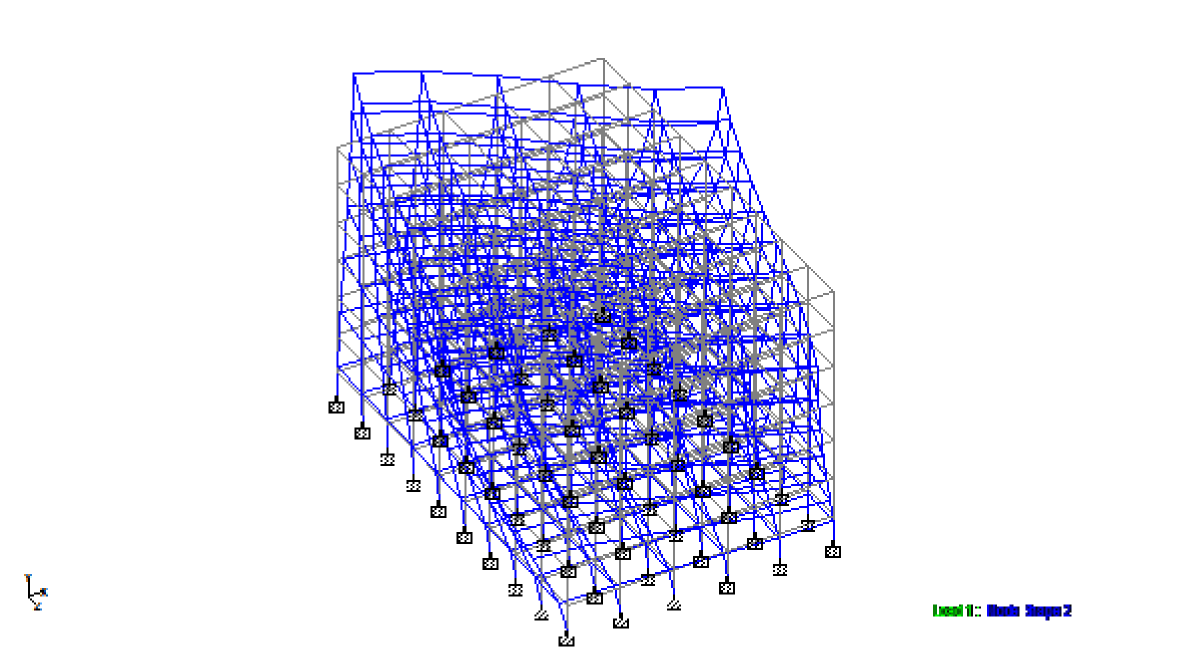

Fig 5.2 Mode shapes of a bare frame building

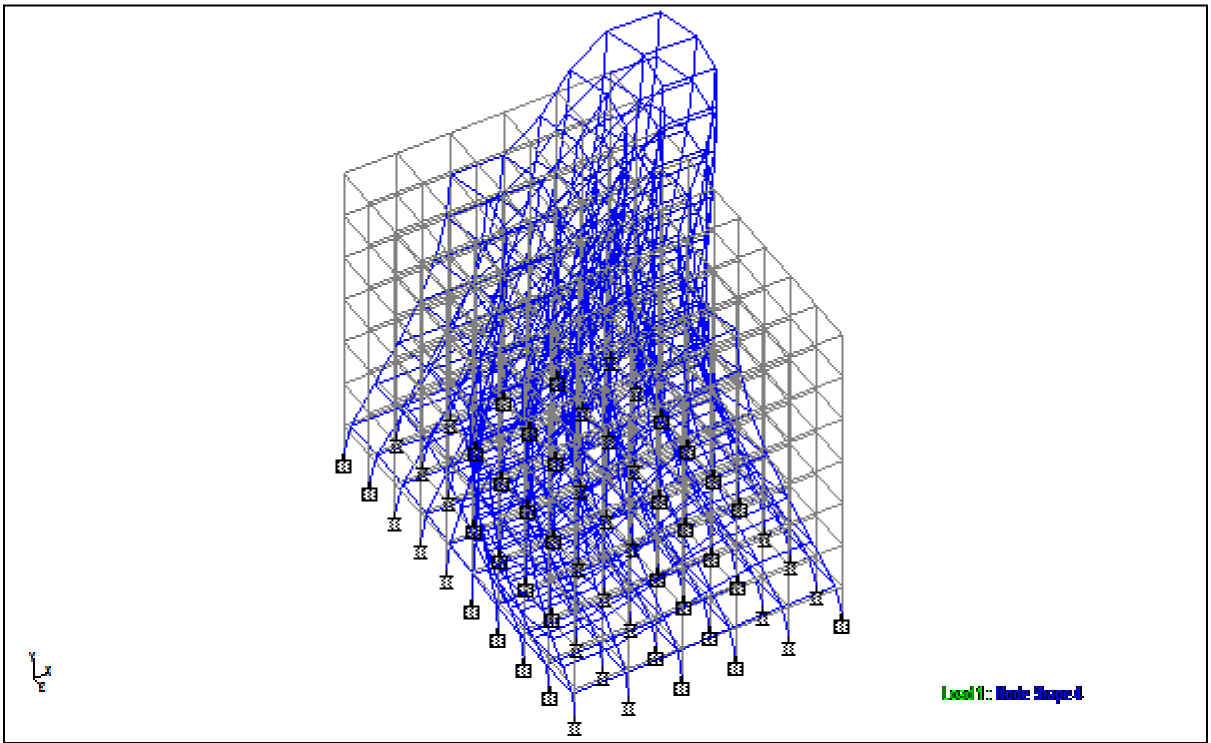

Fig 5.3

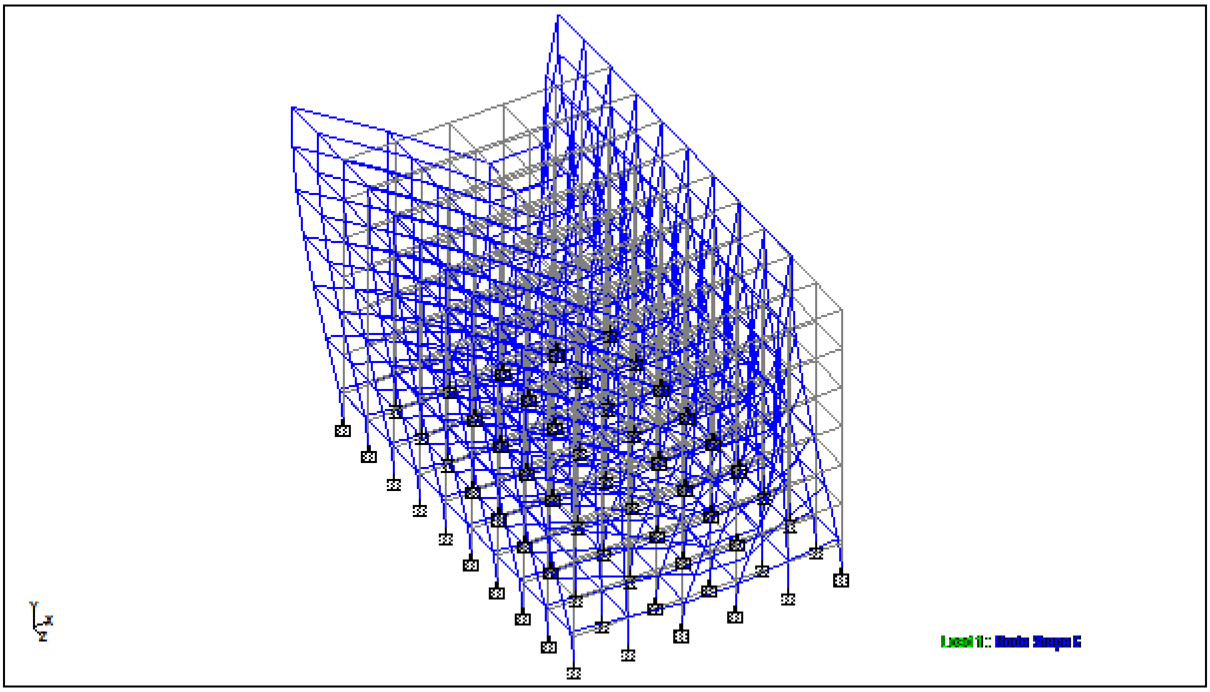

Fig 5.4

Mode shapes of a Soft storied at GF building

(1) From the tables 4.1 to 4.6 ,it is seen that average displacement and interstorey drift is not varying linearly and the figure changes abruptly in case of a soft storey.
(2) During processing it is also seen that for a simple multistory framed building in lower seismic zone II, III there is no problems of drift and building will be safe except severe earth quake.
(3) Due to abrupt change in drift in case of soft storey .it is necessary to control the drift so that sudden collapse can be reduced during earth quake particularly in seismic zone IV,V. thus additional safety measures should be provided at these levels i.e. ductile detailing as per IS code 13920 norms according to the forces and moments to control the drift within tolerance limit of the structure.

V. Conclusions

Thus from the results obtained during processing ,it is clear that for bare frame analysis or for complete stiffened building there is no much problem in drift failure particularly in lower seismic zones. But as we go to higher zones than the ordinary multistory buildings also faces the problem of drift more than the prescribed by the IS code 1893-2002. But this drift can be controlled to much by providing shear wall or by simply enlarging the sizes of the columns and beams without bothering the cost factor.

In case of a soft storey the drift limit goes to much beyond the limit prescribed by different codes .As seen in above tables that at GF to first floor drift is nearly 1.90 times of a simple storey and it is exceeding the critical limit causing sudden collapse during earthquake.

As we again analyze a soft storey by putting a shear wall at core portion and enlarging the columns sizes nearly by 20%with ductile detailing to GF beams, columns then the drift reduced by 60% average with respect to soft storey. It means the drift can be controlled in a soft storey by adopting the above measure including a soft storey on a strong foundation to avoid tilting during earthquake .For the further safety GF to First floor height can be reduced to 2.7instead to 3.2 to 3.5 with architectural type narrow shear wall at outer middle and corner columns so that soft storey stiffness can be achieved with respect to above floors. Hence by adopting above such measure soft storey can be controlled up to a great extent and building damages /collapsing can be limited with over all increase in cost by 20%onlyof ordinary type of buildings.

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