Dynamic Response of Tall Irregular Buildings under Influence of Torsion

Veena V[1] Mr. Guruprasad T N[2] Mr. Naveen Kumar S[3]
[1]M.Tech. Student (CADS) [2,3]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]S.I.E.T Tumkur [3]P.E.S.C.E., Mandya

Abstract— The present study aims at understanding the importance of codal provisions, which are particularly provided for the analysis of torsionally unbalanced structures. IS 1893-2002 Part 1 Code gives the information about number of parameters which influences the irregularity of the structure. However, in the present study, the worst affected irregularity under the influence of torsion are studied, In the present study, dynamic analysis has been performed by Equivalent Lateral Force Method (ELF) i.e., the codal method, for all zones and for all soil types with various irregularities such as mass irregularity, diaphragm irregularity, re-entrant corners irregularity, Non parallel offset irregularity for 10, 15 and 20 storey buildings. The results in the form of torsional moment, fundamental time period and base shear results are compared for different irregularities and the analysis is done with Etabs 9.7 software.

Key words: Equivalent Lateral Force Method, Mass Irregularity, Diaphragm Irregularity, Re-Entrant Corners Irregularity, Non Parallel Offset Irregularity, Torsional Moment, Fundamental Time Period And Base Shear, Etabs 9.7

I. INTRODUCTION

Earthquakes are one of the most demoralizing natural hazards that cause great loss of life and livelihood. An earthquake is a seizure of ground shaking caused by a sudden release of energy in earth's lithosphere. This energy arises due to stresses built up during tectonic processes, which consists of interaction between the crust and the interior of the earth. Human activity also sometimes modifies crustal stresses enough to generate small or even moderate earthquakes, such as the swarms of minor tremors resulting from mining in the Midlands of England, or sometimes larger events induced by the appropriation of large amounts of water behind dams, such as the earthquakes associated with the construction of Koyna dam in central India in 1967.

Earthquake Ground Motions (EQGMs) are the most harmful natural hazards where both economic and life losses occur. Most of the losses are due to building failures or damages. Earthquake can cause damage not only on account of vibrations which results from them but also due to other chain effects like floods, landslides, fires etc. So, it is very important to design the structures to resist, moderate to severe EQGMs depending on its site location and importance of the structure. If the present building is not designed for earthquake then its retrofitting becomes significant.

Dynamic forces are caused by inertia of the structure, which tries to resist ground motions. As the shifting ground carries building foundations along with it, inertia keeps rest of the structure in place for a short while longer. The movement between two parts of the building creates a force, equal to the ground acceleration times mass of the structure. In order to have a minimum force, mass of the building should be as low as possible since there can be no control on the ground acceleration being an act of God! The point of application of this inertial force is the centre of gravity of the mass (CM) on each floor of the building. Once there is a force, there has to be an equal and opposite reaction to balance this force. The inertial force is resisted by the building and the resisting force acts at the centre of rigidity (CR) at each floor of the building.

A. *Objectives of the Study*

The most important objectives of present study include:

1) To study the effect of irregular distribution of mass in plan on the dynamic response of structures.
2) 2. To study the effect of diaphragm discontinuity in the RC frame buildings.
3) To study the effect of plan configurations of a structure and its lateral force resisting system containing re-entrant corners.
4) To study the effect of Non parallel System i.e., the vertical elements resisting the lateral force which are not parallel about major orthogonal axes.
5) To study the effect of discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements etc.

II. MODELING AND ANALYSIS

The modeling and analysis of the building is carried out using ETABS Nonlinear v9.2.0 software package. ETABS is a powerful program developed by Computers and Structures Inc, Berkeley, California, USA which can greatly enhance an engineer's analysis and design capabilities for structures. Part of that power lies in an array of options and features. The other part lies in how simple it is to use.

The basic approach for using the program is very straight forward. The user establishes grid lines, defines material and structural properties, places structural objects relative to the grid lines using point, line and area object tool. All the types of loads that the structure is subjected to, can be defined and assigned to the appropriate structural components. Dynamic analysis properties like mass source, total number of mode shapes and its directions can be defined. The following topics describe some of the important areas in the modelling. Finally, the analysis can be performed and the results are generated in graphical or tabular form that can be printed to a printer or to a file for use in other programs. The following topics describe some of the important areas in the modelling.

A. *Modelling of Regular Buildings:*

Details of regular buildings considered in this work are as follows:
Column size 230X600 mm
Beam size is 230X450 mm
Slab size is 150mm thick

Height of the floor 3m
Live Load on roof slab 1.5 KN/m2
Live Load on floor slab 3KN/m2
Floor Finish on roof slab 1.5 KN/m2
Floor Finish on floor slab 1KN/m2

All the columns are assumed to be fixed at their base Characteristic compressive strength of concrete in slabs is M25 and in Columns and Beams is M30

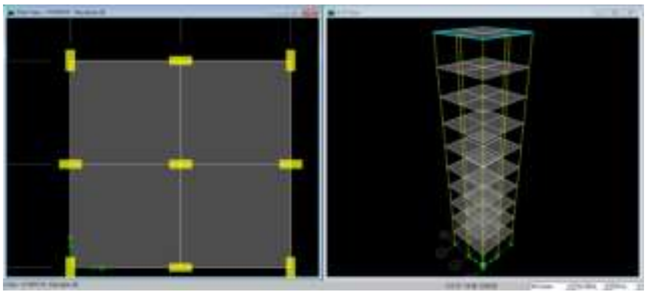

Fig 1: ETABS model screen shot of a regular 10 storied building

The similar models are generated using ETABS with & without irregularities are for 10, 15 & 20 storey's.

B. Modelling In Irregular Buildings:

1) Mass Irregularity

In this irregularity the changes made with respect to Regular building is that the live load is increased more than 200% that of a regular building. Live load considered is 3KN/m2 where as in irregular building it is considered as 7KN/m2 in 4th and 8th floor as per IS 1893-2002 part I.

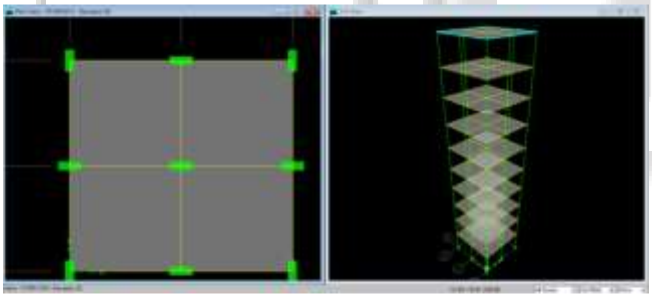

Fig 2: ETABS model screen shot of a mass irregular 10 storied building

2) Diaphragm irregularity

In this irregularity, the changes made with respect to Regular building are Floor area is reduced by 50% as that of regular building as per mentioned in the IS 1893-2002 part I & floor area is reduce by 50 % in alternate floors of the respective irregular building.

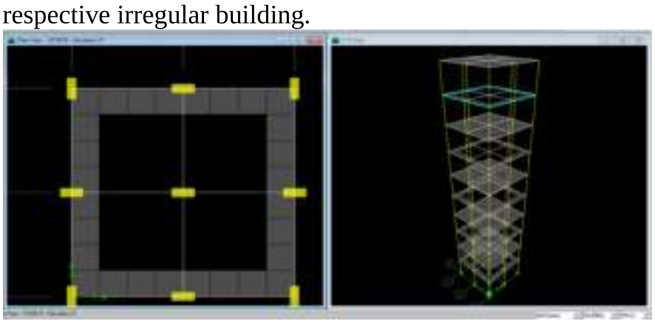

Fig 3: ETABS model screen shot of a diaphragm irregular 10 storied building

3) Re-entrant corners Irregularity

In this irregularity the changes with respect to Regular building is that the one grid has been deleted in order to make it re-entrant according to the IS code with respect to the regular building as per IS 1893-2002 part I.

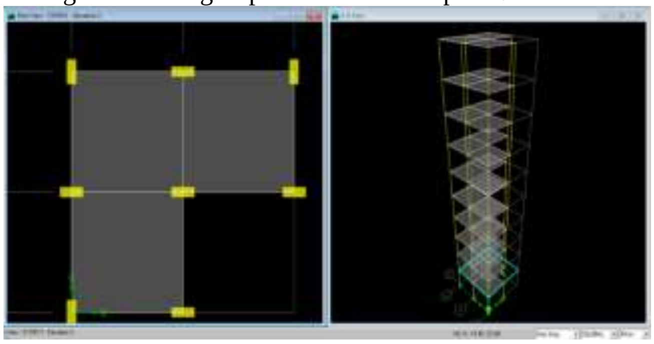

Fig 4: ETABS model screen shot of a re-entrant corners irregular 10 storied building

4) Non parallel Offset Irregularity

In this irregularity the changes with respect to Regular building is that the Shear Walls has been provided which are not parallel compared to that of regular building as per the IS 1893-2002 part I.

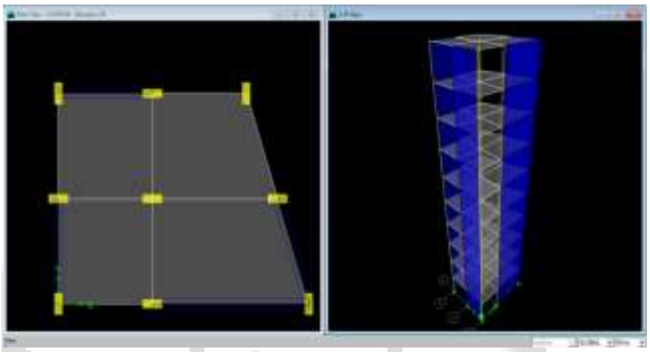

Fig 4: ETABS model screen shot of a Non parallel irregular 10 storied building

III. RESULTS AND DISCUSSIONS

The analysis carried out are equivalent static and seismic analysis, the results are obtained for ten, fifteen and twenty story buildings. The result of Torsional moment, Fundamental time period and Base shear for different models are presented and compared to with different models for different irregularities.

Note: The notations used below are as follows

- R= REGULAR
- IR= IRREGULAR
- REGS1= REGULAR SOIL TYPE 1
- REGS2= REGULAR SOIL TYPE 2
- REGS3= REGULAR SOIL TYPE 3
- IREGS1= IRREGULAR SOIL TYPE 1
- IREGS2= IRREGULAR SOIL TYPE 2
- IREGS3= IRREGULAR SOIL TYPE 3

A. Mass Irregularity

1) Torsional Moment

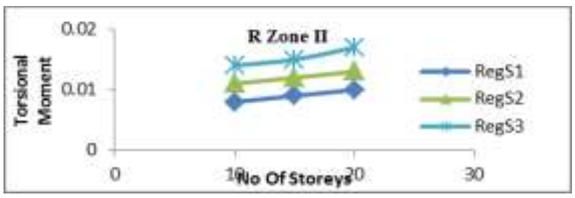

Fig 3.1(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone II

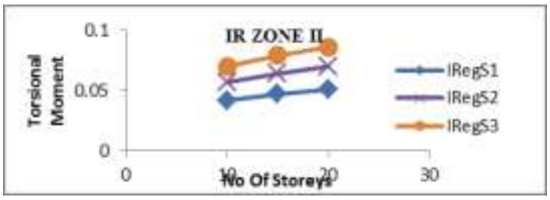

Fig 3.1(b): Torsional moent of 10, 15, 20 storeys for irregular buildings in Zone II

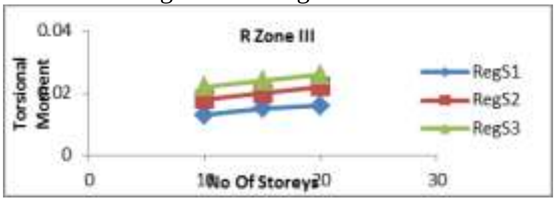

Fig 3.2(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone III

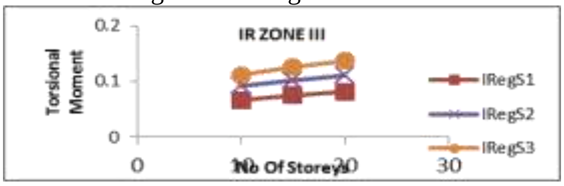

Fig 3.2(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone III

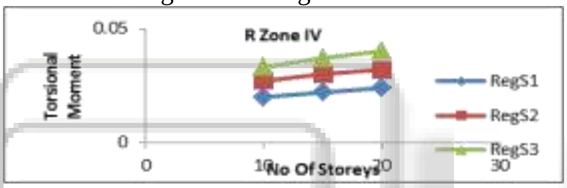

Fig 3.3(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone IV

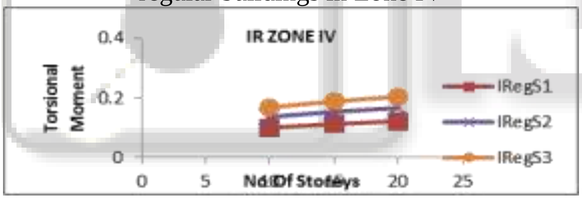

Fig 3.3(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone IV

2) *Base Shear*

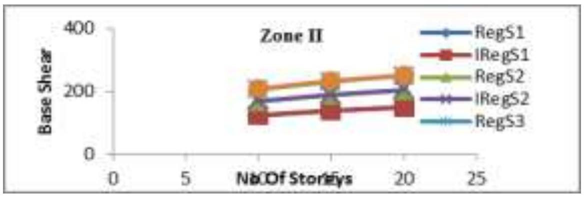

Fig 3.5: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone II

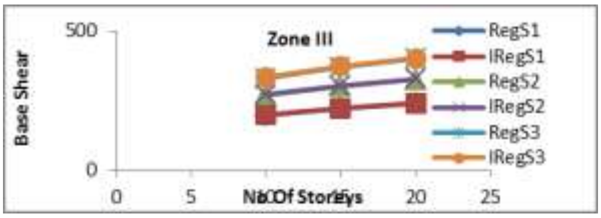

Fig 3.6: Base Shear of 10, 15, 20 storeys for regular and regular buildings in Zone III

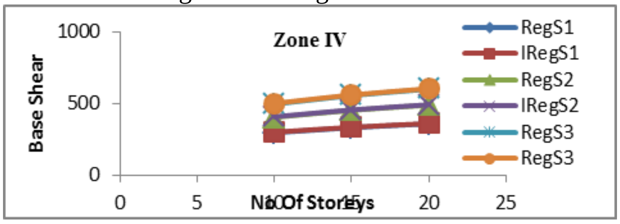

Fig 3.7: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone IV

3) *Torsional Moment*

It is seen in the fig 3.1 (a) to 3.3 (b) for 10, 15, 20 storey buildings are designed for mass irregularity for torsional moment and the torsional moment remains same in all the zones and there is slight change in zone III in 15 storey and 20 storey building that is 4% and 3.73% as shown in the table 3.1 in soil type.

4) *Fundamental Time Period*

It has been shown in the table 3.1 that fundamental period for 10 storey, 15 storey and 20 storey buildings in mass irregularity and we can notice slight increase in fundamental time period in the mass irregular buildings with respect to regular buildings, that is there is 0.57% decrease in the 10 storey building, 0.17% decrease in 15 storey building and 0.02% decrease in 20 storey building with respect to regular buildings.

5) *Base Shear*

It is seen in the fig 3.5 to 3.7 for 10, 15, 20 storey buildings are designed for mass irregularity for Base Shear. The Base Shear is increasing as the number of storey's have been increased which we can see in the above graphs, and the percentage increase is observed in the Base Shear as compared with regular buildings is seen in same fig and the table 3.1 shows that the percentage increase in Base Shear for irregular buildings with respect to regular buildings which is observed to be 0.5 to 1 % in 10, 15 and 20 storey's buildings respectively.

ST- Soil type: SZ: Shear zone: SP- Shear parameter: TM: Torsional moment: FP: Fundamental period: BS: Base shear

ST	**SZ**	**SP**	**Type of buildings**					
			Regular			**irregular**		
			10	15	20	10	15	20
1	Z II	TM (kN-m)	0.008	0.009	0.010	0.008	0.009	0.010
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	124	139	150	125	140	151.00
2	Z II		**Regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.011	0.012	0.013	0.011	0.012	0.013

		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	169	189	204	170	190	205.00
3	Z II		**Regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.014	0.015	0.017	0.014	0.015	0.017
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	207	232	251	209	234	252.00
1	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.013	0.015	0.016	0.013	0.015	0.016
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	198	222	240	200	224	242.00
2	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.018	0.020	0.022	0.018	0.020	0.022
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	270	302	327	273	304	328.00
3	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.022	0.024	0.026	0.022	0.025	0.027
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	331	371	401	335	374	403.00
1	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.020	0.022	0.024	0.020	0.022	0.024
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	298	333	360	301	336	362.00
	IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.027	0.030	0.032	0.027	0.030	0.032
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	405	454	490	409	457	493.000
3	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.033	0.037	0.040	0.033	0.037	0.040
		FP (s)	1.5708	2.5642	3.7465	1.5799	2.5688	3.745
		BS (kN)	497	557	602	502	561	605.000

Table 3.1 Details of torsional moment, fundamental time period and base shear of mass irregularity

B. *Diaphram Irregularity*

1) *Torsional Moments*

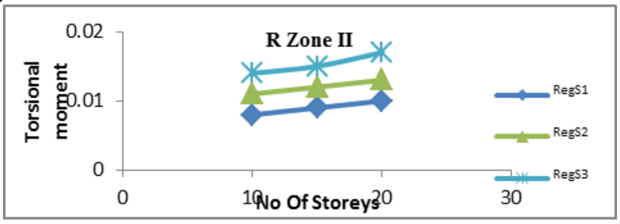

Fig 3.9(a): Torsional moment of 10, 15, 20 storeys for regular buildings Zone II

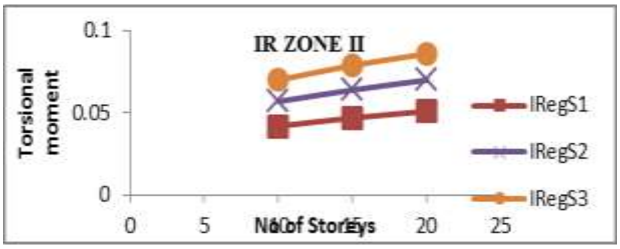

Fig 3.9(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone II

Fig 3.10(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone III

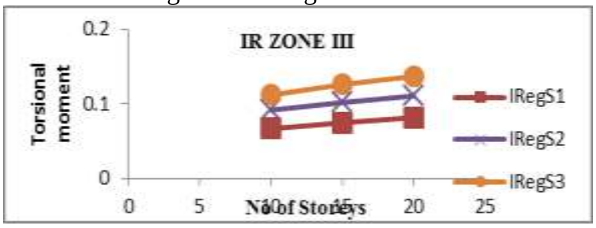

Fig 3.10(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone III

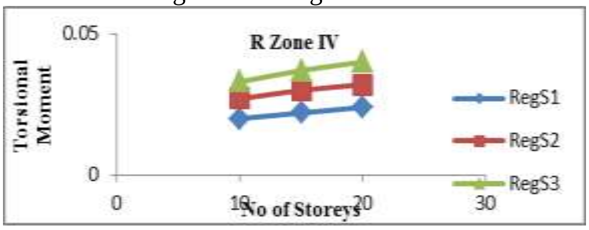

Fig 3.11(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone IV

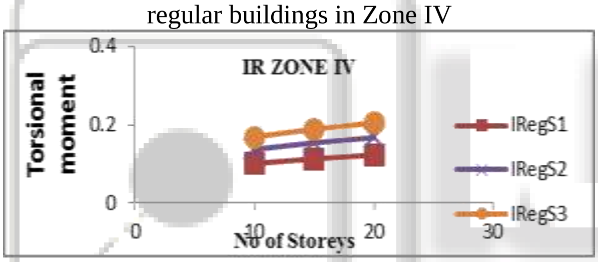

Fig 3.11(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone IV

2) Base Shear

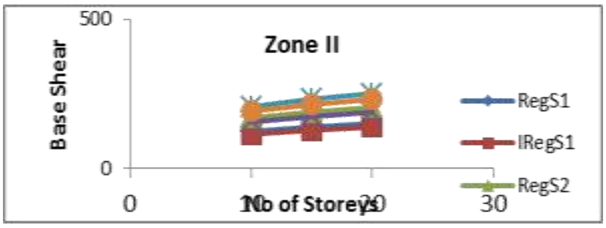

Fig 3.13: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone II

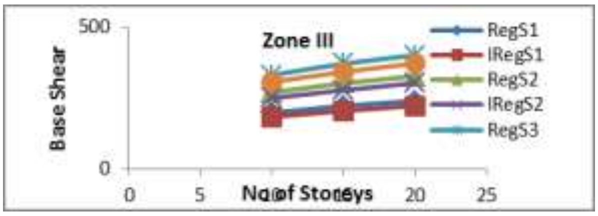

Fig 3.14: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone III

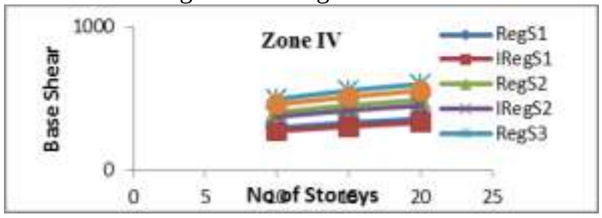

Fig 3.15: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone IV

3) Torsional Moment

It is seen in the fig 3.9(a) to 3.11(b) for 10, 15, 20 storey buildings are designed for diaghram irregularity for torsional moment and the torsional moment is increasing as the number of storey's have been increased which we can see in above graphs, and the torsional moment in irregular buildings is increased as compared with regular buildings is seen in fig 3.9(a) to 3.11(a) and the table 3.2 shows that the percentage increase in torsional moment for irregular buildings with respect to regular buildings are from 18 to 20% in the all the zones.

4) Fundamental Time Period

It has been shown in the table 3.2 that fundamental period for 10 storey, 15 storey and 20 storey buildings in diaphragm irregularity and we can notice slight decrease in fundamental time period in the diaphragm irregular buildings with respect to regular buildings, that is there is 3.64% decrease in the 10 storey building, 4.43% decrease in 15 storey building and 3.82% decrease in 20 storey building with respect to regular buildings.

5) Base Shear

It is seen in the fig 3.13 to 3.15 for 10, 15, 20 storey buildings are designed for diaphragm irregularity for Base Shear. The Base Shear is increasing as the number of storey's have been increased which we can see in the figures, and the percentage increase is observed in the Base Shear as compared with regular buildings is seen in same figures and the table 3.2 shows that the percentage increase in Base Shear for irregular buildings with respect to regular buildings which is observed to be 7 to 9 % in 10, 15 and 20 storey's buildings respectively.

ST	SZ	SP	Type of buildings					
1	Z II		regular			irregular		
			10	15	20	10	15	20
		TM (kN/m)	0.008	0.009	0.010	0.042	0.047	0.051
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	124	139	150	115	128	139
2	Z II		regular			irregular		
			10	15	20	10	15	20
		TM (kN/m)	0.011	0.012	0.013	0.057	0.064	0.070
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086

		BS (KN)	169	189	204	156	174	189
3	Z II		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.014	0.015	0.017	0.070	0.079	0.086
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	207	232	251	192	214	232
1	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.013	0.015	0.016	0.067	0.075	0.082
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	198	222	240	184	205	223
2	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.018	0.020	0.022	0.092	0.102	0.111
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	270	302	327	250	278	303
3	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.022	0.024	0.026	0.112	0.126	0.137
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	331	371	401	307	342	372
1	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.020	0.022	0.024	0.101	0.113	0.123
		FP(S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	298	333	360	275	307	334
2	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.027	0.030	0.032	0.137	0.154	0.167
		FP(S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	405	454	490	375	418	452
3	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM(kN/m)	0.033	0.037	0.040	0.169	0.189	0.205
		FP (S)	1.5708	2.5642	3.7465	1.5155	2.4553	3.6086
		BS (KN)	497	557	602	460	513	558

Table 3.2 Details of torsional moment, fundamental time period and base shear of diaphragm irregularity

C. Re-Entrant Corners Irregularity

1) Torsional Moments

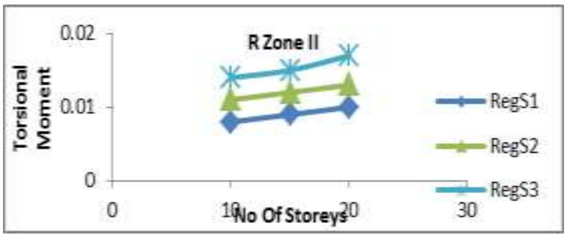

Fig 3.17(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone II

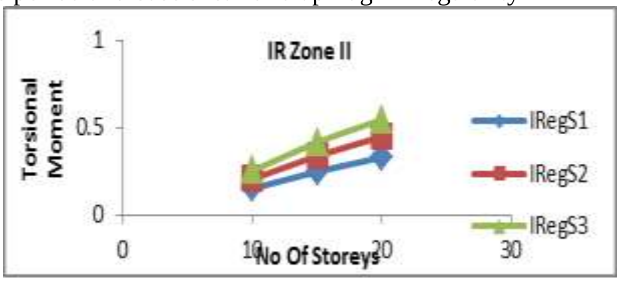

Fig 3.17(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone II

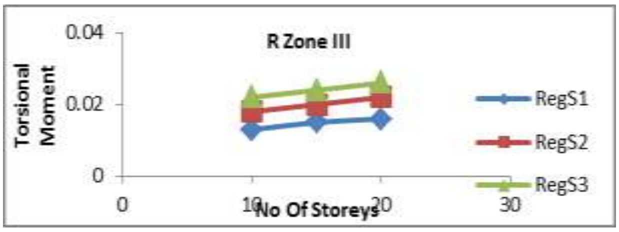

Fig 3.18(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone III

Fig 3.18(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone III

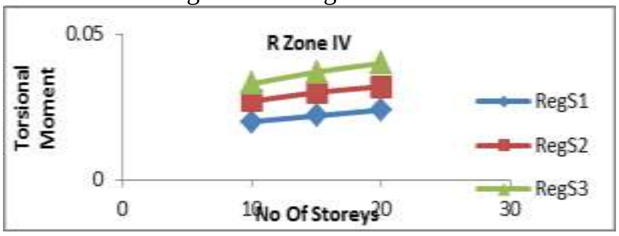

Fig 3.19(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone IV

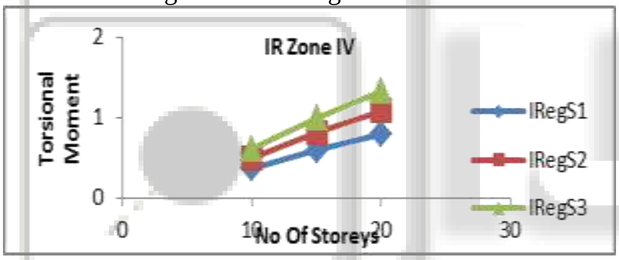

Fig 3.19(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone IV

Base Shear

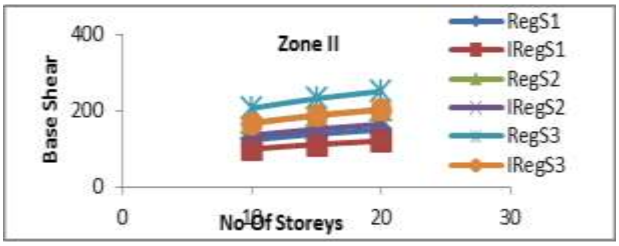

Fig 3.21: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone II

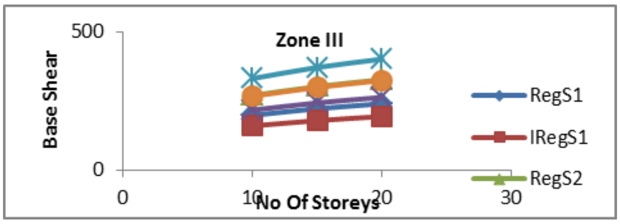

Fig 3.22: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone III

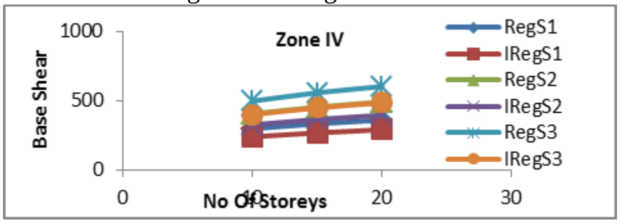

Fig 3.23: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone IV

2) *Torsional Moment*

It is seen in the fig 3.17(a) to 3.19(b) for 10, 15, 20 storey buildings are designed for Re-entrant Irregularity for torsional moment and the torsional moment is increasing as the number of storey's have been increased which we can see in above graphs, and the torsional moment in irregular buildings is increased as compared with regular buildings is seen in table 3.3 and the table shows that the percentage increase in torsional moment for irregular buildings with respect to regular buildings are from 94 to 97 % in the all the zones.

3) *Fundamental Time Period*

It has been shown in the table3.3 that fundamental period for 10 storey, 15 storey and 20 storey buildings in Re-entrant irregularity and we can notice slight decrease in fundamental time period in the out of plane offset irregular buildings with respect to regular buildings, that is there is 1.17% deacrease in the 10 storey building, 0.04% decrease in 15 storey building and 1.57% increase in 20 storey building with respect to regular buildings.

4) *Base Shear*

It is seen in the fig 3.21 to 3.23 for 10, 15, 20 storey buildings are designed for out of plane offset irregularity for Base Shear. The Base Shear is increasing as the number of storey's have been increased which we can see in above graphs, and the percentage increase is observed in the Base Shear as compared with regular buildings is seen in same graphs and the table 3.3 shows that the percentage increase in Base Shear for irregular buildings with respect to regular buildings which is observed to be 23 to 25 % in 10, 15 and 20 Storey's buildings respectively.

ST	**SZ**	**SP**	**Type of buildings**					
1	Z II		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.008	0.009	0.010	0.152	0.249	0.330
		FP (S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	124	139	150	100	112	121
	Z II		**regular**			**irregular**		
			10	15	20	10	15	20

2		TM (kN/m)	0.011	0.012	0.013	0.207	0.338	0.449
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	169	189	204	136	152	165
3	Z II		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.014	0.015	0.017	0.254	0.416	0.547
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	207	232	251	167	187	202
1	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.013	0.015	0.016	0.244	0.398	0.529
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	198	222	240	160	179	194
2	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.018	0.020	0.022	0.332	0.542	0.720
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	270	302	327	217	243	263
3	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.022	0.024	0.026	0.407	0.665	0.884
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	331	371	401	267	299	324
1	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.020	0.022	0.024	0.366	0.597	0.794
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	298	333	360	240	268	291
2	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.027	0.030	0.032	0.498	0.813	1.080
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	405	454	490	326	365	395
3	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN/m)	0.033	0.037	0.040	0.614	0.993	1.326
		FP(S)	1.5708	2.5642	3.7465	1.5525	2.563	3.8064
		BS(KN)	497	557	602	400	448	485

Table 3.3 Details of torsional moment, fundamental time period and base shear of re- entrant irregularity

D. Non Parallel Offset Irregularity

1) Torsional Moment

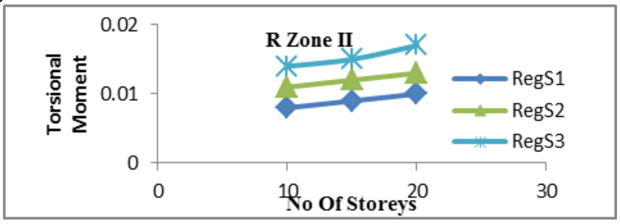

Fig 3.25(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone II

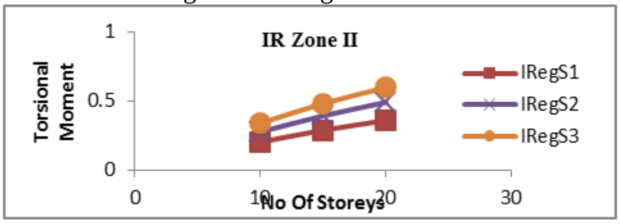

Fig 3.25(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone II

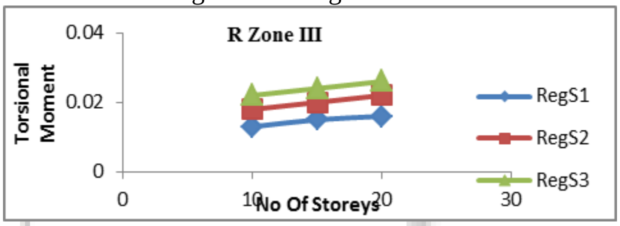

Fig 3.26(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone III

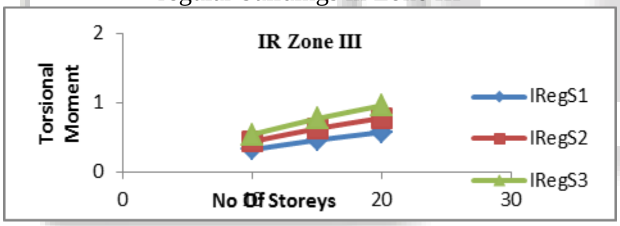

Fig 3.26(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone III

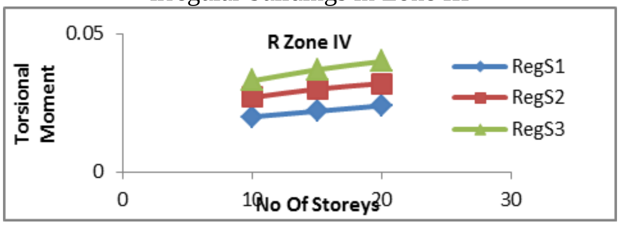

Fig 3.27(a): Torsional moment of 10, 15, 20 storeys for regular buildings in Zone IV

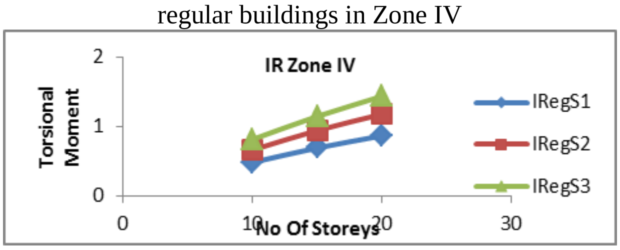

Fig 3.27(b): Torsional moment of 10, 15, 20 storeys for irregular buildings in Zone IV

2) Base Shear

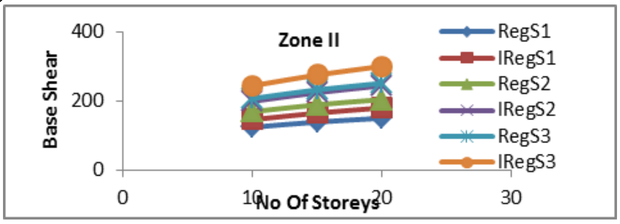

Fig 3.29: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone II

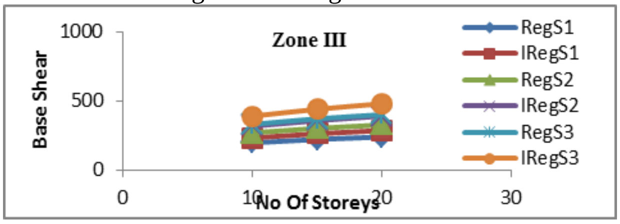

Fig 3.30: Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone III

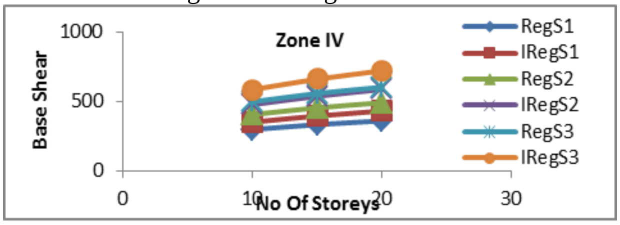

Fig 3.31 Base Shear of 10, 15, 20 storeys for regular and irregular buildings in Zone IV

3) Torsional Moment

It is seen in the fig 3.25(a) to 3.27(b) for 10, 15, 20 storey buildings are designed for non-parallel offset Irregularity for torsional moment and the torsional moment is increasing as the number of storey's have been increased which we can see in the above graphs and the torsional moment in irregular buildings is increased as compared with regular buildings is shown in the table 3.4 and the table shows that the percentage increase in torsional moment for irregular buildings with respect to regular buildings are from 95 to 98 % in the all the zones.

4) Fundamental Time Period

It has been shown in the table 3.4 that fundamental period for 10 storey, 15 storey and 20 storey buildings in Non parallel system irregularity and we can notice huge decrease in fundamental time period in the Non parallel system irregular buildings with respect to regular buildings, that is, there is 127.68% decrease in the 10 storey building, 96.38% decrease in 15 storey building and 79.54. % decrease in 20 storey building with respect to regular buildings.

5) Base Shear

It is seen in the fig 3.29 to 3.31 for 10, 15, 20 storey buildings are designed for non-parallel irregularity for Base Shear. The Base Shear is increasing as the number of storey's have been increased which we can see in above graphs, and the percentage increase is observed is seen in the table 3.4 shows that the percentage increase in Base Shear for irregular buildings with respect to regular buildings which is observed to be 15 to 18 % in 10, 15 and 20 Storey's buildings respectively.

ST	SZ	SP	Type of buildings					
1	Z II		regular			irregular		
			10	15	20	10	15	20

3		TM (kN-m)	0.008	0.009	0.010	0.203	0.288	0.359
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	124	139	150	146	165	180.000
2	Z II		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.011	0.012	0.013	0.276	0.392	0.490
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	169	189	204	199	224	244.000
3	Z II		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.014	0.015	0.017	0.339	0.481	0.597
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	207	232	251	244	275	300.000
1	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.013	0.015	0.016	0.324	0.461	0.574
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	198	222	240	234	263	287.000
2	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.018	0.020	0.022	0.441	0.626	0.778
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	270	302	327	317	358	391.000
3	Z III		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.022	0.024	0.026	0.542	0.770	0.958
		FP(s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	331	371	401	390	440	480.000
1	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.02	0.022	0.024	0.483	0.690	0.865
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	298	333	360	351	395	431.000
2	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.027	0.030	0.032	0.662	0.941	1.176
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087
		BS(kN)	405	454	490	477	537	586.000
3	Z IV		**regular**			**irregular**		
			10	15	20	10	15	20
		TM (kN-m)	0.033	0.037	0.040	0.813	1.144	1.434
		FP (s)	1.5708	2.5642	3.7465	0.6899	1.2991	2.087

		BS(kN)	497	557	602	585	660	720.000

Table 3.4 Details of torsional moment, fundamental time period and base shear of non-parallel irregularity

IV. CONCLUSION

From the study on Mass irregularity following are concluded:

– Torsional moments are high in a 15 storied building compared to 10 and 20 storied building in seismic zone II & founded on soil types 2.
– The effect of variation in the fundamental time period is high in a 10 storied building compared to a 15 or a 20 storied building.

From the study on Diaphragm irregularity following are concluded:

– Torsional moments, fundamental period & base shear increases with the increase in the height of a regular building.
– Torsional moments are high in a 10-15 storied building in seismic zone II & III & founded on soil types 1 & 3.
– Base shear is high in a 15 storied building compared to 10 and 20 storied building in seismic zone III and founded on soil type 2.
– The effect of variation in the fundamental time period is high in a 15 storied building compared to a 10 or a 20 storied building.

From the study on Re-entrant corner irregularity following are concluded:

– The torsional moments, fundamental period & base shear increases with the increase in the height of a regular building.
– Torsional moments are high in a 15 storied building compared to a 10 or 20 storied building in all seismic zone IV founded on soil type3.
– Base shear varies linearly from 10 to 20 storied building in all seismic zones & all soil types.
– The effect of variation in the fundamental time period is high in a 15 storied building compared to a 10 or a 20 storied building.

From the study on Non-parallel irregularity following are concluded:

– The torsional moments, fundamental period & base shear increases with the increase in the height of a regular building.
– Torsional moments are high in 10 to 20 storied building in all seismic zones & all soil types.
– Base shear are high in 10 to 20 storied building in all seismic zones & all soil types.
– The effect of variation in the fundamental time period is high in a 10 storied building compared to a 15 or a 20 storied building.
– A shift in centre of mass and centre of gravity was observed compared to that of regular buildings.

REFERENCES

[1] Babak Rajaee Rad and Perry Adebar "Seismic Design of High-Rise Concrete Walls: Reverse Shear due to Diaphragms below Flexural Hinge"(2009) Vol. 135, No. 8, August 1, 2009. ©ASCE, ISSN 0733-9445/2009/8-916–924.
[2] Ying Zhou and Xilin Lu "Seismic Performance Evaluation of An Irregular High-Rise Building" Paper No. 099, 4th International Conference on Earthquake Engineering Taipei, Taiwan, October 2006.
[3] Devesh P. Soni and Bharat B. Mistry "Qualitative Review Of Seismic Response Of Vertically Irregular Building Frames", Vol. 43, No. 4, December 2006, 121-1pp. 32.
[4] Swaminathan Krishnan "Case studies of damage to 19-storey irregular steel moment-frame buildings under near-source ground motion Seismological Laboratory,(2005) MS 252-21, California Institute of Technology, Pasadena, CA 91125, U.S.A.
[5] Eduardo Miranda and Carlos J. Reyes "Approximate Lateral Drift Demands in Multistory Buildings with Non uniform Stiffness" Vol. 128, No. 7, July 1, 2002. ©ASCE, ISSN 0733-9445/2002/7-840–849.
[6] Chatpan Chintanapakdee and Anil K. Chopra "Seismic Response of Vertically Irregular Frames: Response History and Modal Pushover Analysis" Vol. 130, No. 8, August 1, 2004. ©ASCE,ISSN 0733-9445/2004/8-1177–1185.
[7] Dhiman Basu and Sudhir K. Jain "Seismic Analysis of Asymmetric Buildings with Flexible Floor Diaphragms", Vol. 130, No. 8, August 1, 2004. ©ASCE, ISSN 0733-9445/2004/8-1169–1176.
[8] Kamal C. Sarma and Hojjat Adeli "Comparative Study of Optimum Designs of Steel High RiseBuilding Structures Using Allowable Stress Design and Load and Resistance Factor Design Codes" Vol. 10, No. 1, February 1, 2005. ©ASCE, ISSN 1084-0680/2005/1-12–17.
[9] Yong Lu "Comparative Study of Seismic Behaviour of Multi story Reinforced Concrete Framed Structures" Vol. 128, No. 2, February 1, 2002. ©ASCE, ISSN 0733-9445/2002/2-169–178.
[10] Sherif El-Tawil, P.E., M.ASCE, and Christopher M. Kuenzli "Pushover of Hybrid Coupled Walls. II: Analysis and Behaviour " Vol. 128, No. 10, October 1, 2002. ©ASCE,ISSN 0733-9445/2002/10-1282–1289.
[11] Ahmad J. Durrani, S.T. Mau, Amr Ahmed AbouHashish and Yi Li "EarthQuake Response of Flat-Slab Buildings" Vol.120 No. 3, March, 1994. ©ASCE, ISSN 0733-9445/94/0003-0947.
[12] Juan Carlos De la Llera and Anil K. Chopra "Evaluation of Code Accidental Torsion Provisions From Building Records" Vol.120, No 2, February 1994 ©ASCE, ISSN 0733-9445/94/0002-0597.
[13] IS:1893 (Part 1)-2002 Criteria for Earthquake Resistant Design of Structures, part 1-General provisions and buildings, fifth revision, Bureau of Indian Standards, New Delhi, India.
[14] IS: 456-2000, "Code of Practice for Plain and Reinforced Concrete", Bureau of Indian Standards, New Delhi, India.

