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Seismic Assessment of Vertical Irregular Buildings

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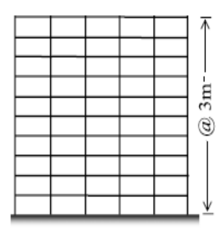
Abstract—*Irregular buildings are common in modern period because of its architectural importance. The irregularities are defined based upon IS 1893 -2002(part 1) code. In this paper, 4 different stepped building has been compared with that of regular one. Here regular building having G+9 storey and also consider varies discontinuity at different floor and analysis using by SAP2000. In order to identify the most vulnerable building among the models considered, the various analytical approaches are performed to identify the seismic demands in both linear and nonlinear way .Compared the ratio of shear forces to seismic weight due to RSA (SAP2000), and Time History Analysis(El-Centro earthquake) both in X as well as Y direction. The inter-storey drift ratio of various irregular models has been compared with that of the regular building. The effect of different lateral load patterns on the performance of various irregular buildings in pushover analysis has been compared. The inter-storey drift ratios due to push over analysis has been compared of various models. The target displacement, yield displacement, yield force, ultimate shear force, ductility capacity and ductility capacity hasbeen compared with the regularmodel. Ductility behavior of irregular building are found weaker than that of regular building, So avoid irregular in building as much as possible.*

Keywords: *Stepped building, push over analysis, response spectra analysis, time history analysis*

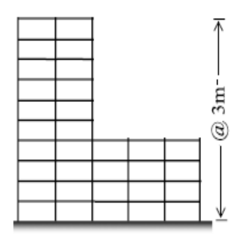
1. INTRODUCTION

Importance of irregular buildings has increased tremendously because of the modern architectural influence. In order to cope up with current trends and style, the shape of the building may leads to irregular.Earthquake is a natural phenomenon associated with violent shaking of the ground. It may result in the release of large amount of strain energy as seismic waves travels in all directions through the Earth's layers, which result in reflect and refract at surface. This may result in the irregular earthquake ground motion generally initiates at locations of structural weaknesses present in buildings. In some cases, the weaknesses in the building may be created by discontinuities in stiffness, strength or mass between adjacent stories. Hence it is imperative to study the structural behaviour of the buildings with irregularities In earthquake, damages to structures depends upon the material that the structure is made up of, type of ground over which building is constructed, and the type of earthquake wave (motion) .

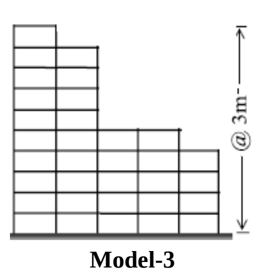
Distribution of mass, stiffness and strength along the height of building.It is well know that, if building is irregular in nature, then excessive stresses or forces get developed in certain portion and they cause serious damages. The response of irregular building is studied in past and large number of literature is available. Influence of bi-directional seismic excitations on the inelastic behaviour of in-plan irregular systems having one symmetric axis, one storey building with orthogonal resisting elements[8], seismic design procedures of base isolated system, high rise building with vertical irregular in nature, irregular structures by nonlinear response history analysis , seismic codes still allow the use of static analysis and supply formulations of equivalent static eccentricities, which should provide a safe estimate of the elastic design, on-linear pushover analysis of irregular building. Further in most of engineers are using computer software for analysis, it will alsocreate some problem in analysis. Thus various factors of the structure which contributes causes ofthefailure.



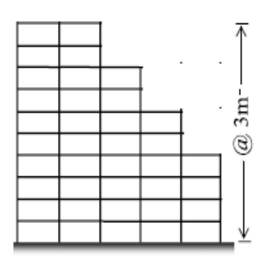
Model-1



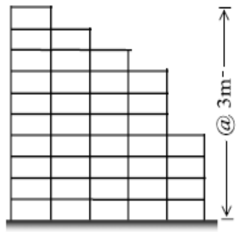
Model-2



Model-3



Model-4



Model-5

Fig. 1: Elevation of Models

In this paper, building with vertical irregularities is considered. Asymmetric reinforced concrete frames using pushover analysis. Objective of this paper is to understand, effect of irregular building over the regular building having the same storey height. For this comparative study, 5 models has been considered of G+9 storey, .one is of regular nature and other four of irregular configuration. Model-1, which is perfectly symmetric building, Model2, Model 3, Model 4 are vertical irregular based as per IS 1893 2002(part 1) which is defined in Table 1. All the five Models are analysed using, Response Spectrum Analysis (RSA), Time History Analysis (THA) and also push over analysis and their results are compared. This comparison helps in assessing the effect of vertical irregular building over regular one onthe seismic response of building.

2. DETAILS OF MODELS

Table 1: Condition for vertical irregularity (IS 1893-2002(PART1))

Type of irregularity		
Model 1	**No irregularity**	
Model 2	L2>1.5L1 20>1.5X12 = 18	Setback
Model 3	A/L = 16/20 = 0.8 > 0.25	Setback
Model 4	A/L = 12/20 = 0.6 > 0.25	Setback
Model 5	A/L = 16/20= 0.8 > 0.25	Setback

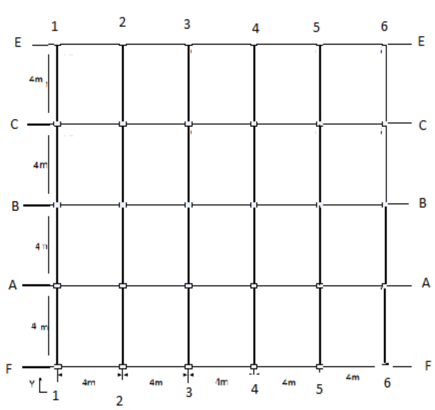


Fig. 2: Plan of the models

Plan of Model 1 are shown in Fig. 2 and elevation of all the models is different and shown in Fig. 1. All the columns are of size 0.45m x 0.4m, beam size is 0.35m x 0.3m, 0.23m thick in filled wall is provided. Grade of concrete isM25, Parameters are taken from IS1893-2002(part 1) Soil type is considered as medium soil, seismic zone V and damping is 5%. Floor live load is 3KN/m^2 and roof live load is 1KN/m^2. Height of all building models is 30 m. The condition for vertical irregularity of the different models has given in the table1.

3. ANALYSIS DETAILS

3.1 Response Spectra Analysis (RSA)

The RSA is performed with SAP for all five building models. The response spectrum obtained from IS 1893 (part 1):2002. Five modes are used. Medium soilcondition is considered. The ratio shear forces to seismic weight of RSA inboth X and Y direction has been obtained and byinter-storey drift ratio curve for the different models of RSA in X and Y directions was found out and is given in Fig. 4 and 5. The results of time period, modal mass in various modes in x and y direction of force has been calculatedand shown in Fig. 6

3.2 Time History Analysis (THA)

Recorded ground acceleration Time history of El-Centro earthquake is used. (Figure.3).the peak ground acceleration is 0.35g which is quite close to Z=0.36 of IS 1893(part 1):2002, zone V. Time history of El-centro earthquake is shown in Fig. 3. The ratio of shear forces to seismic weight of THA in X and Y direction has been obtained as shown in Fig. 4 and 5 and by scaling, inter-storey drift ratio curve for the different models of THA in X and Y directions was found out and is given in Fig. 6.

Table 2: Time period and model particapation factor for various models

	Time period in X(sec)	Model mass in X(%)	Cumulative model mass (X)	Time period in Y(sec)	Model mass in Y(%)	Cumulative model mass (X)
Model 1	2.22	80.28	80.28	2.34	80.55	80.55
	0.71	9.21	90.21	0.75	9.93	90.48
Model 2	1.98	71.33	71.33	2.18	63.17	63.17
	0.74	16.63	87.97	1.58	8.92	72.09
	0.40	4.08	92.06	0.76	16.73	88.83
				0.42	3.61	92.45
Model 3	1.82	73.97	73.96	2.07	59.85	59.85
	0.70	14.02	87.99	1.42	15.90	75.75
	0.37	4.35	92.34	0.71	13.05	88.80
				0.39	3.376	92.18
Model 4	1.84	75.15	75.15	2.10	59.52	59.52
	0.71	12.40	87.53	1.41	18.01	77.54
	0.40	4.65	92.17	0.71	9.70	87.23

				0.65	1.15	88.38
				0.41	4.25	92.65
Model 5	1.81	76.67	76.62	2.06	59.574	59.57
	0.66	11.57	88.198	1.48	19.006	78.58
	0.39	4.01	92.20	0.69	7.27	85.84
				0.60	3.54	89.39
				0.40	3.06	92.46

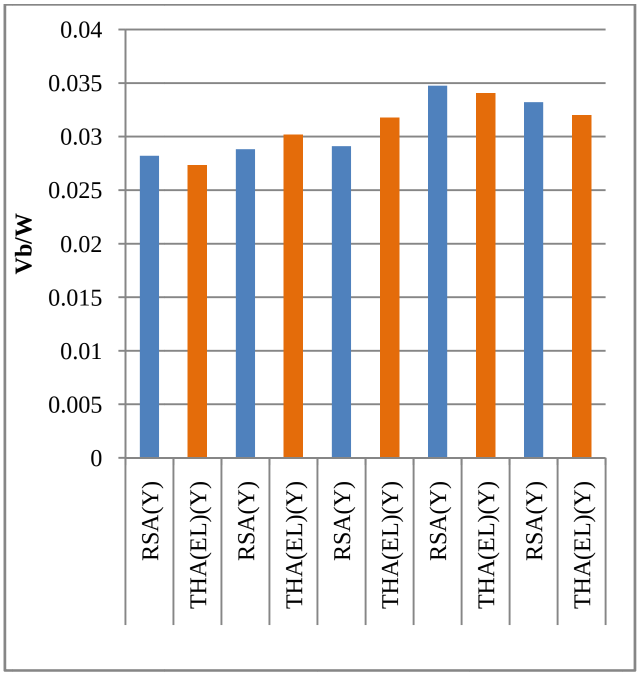


Fig. 4: Ratio of Base shear ESAX and RSAX to Sesmic Weight for different models

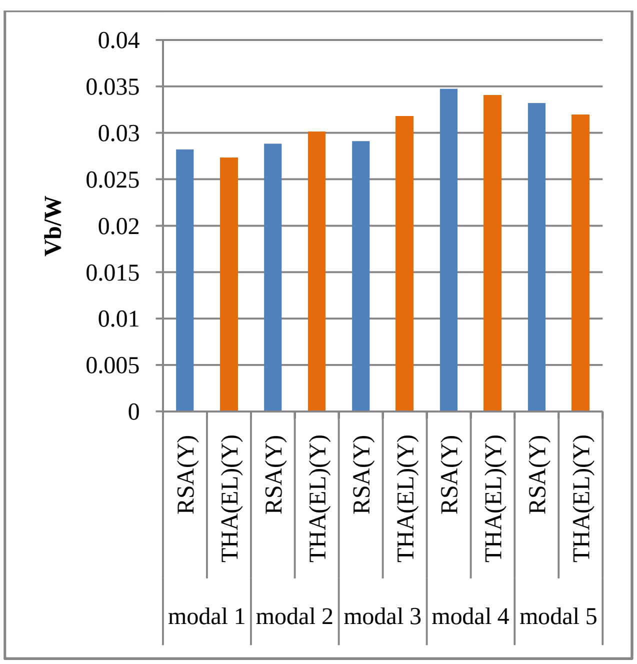
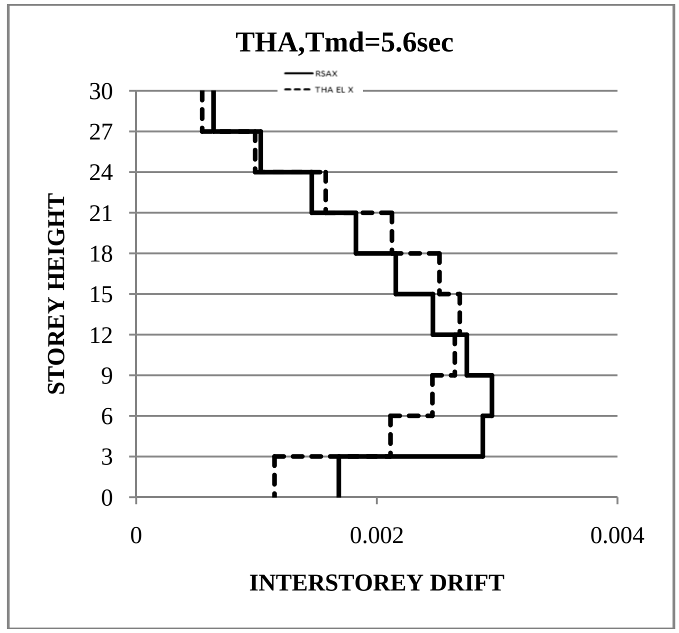


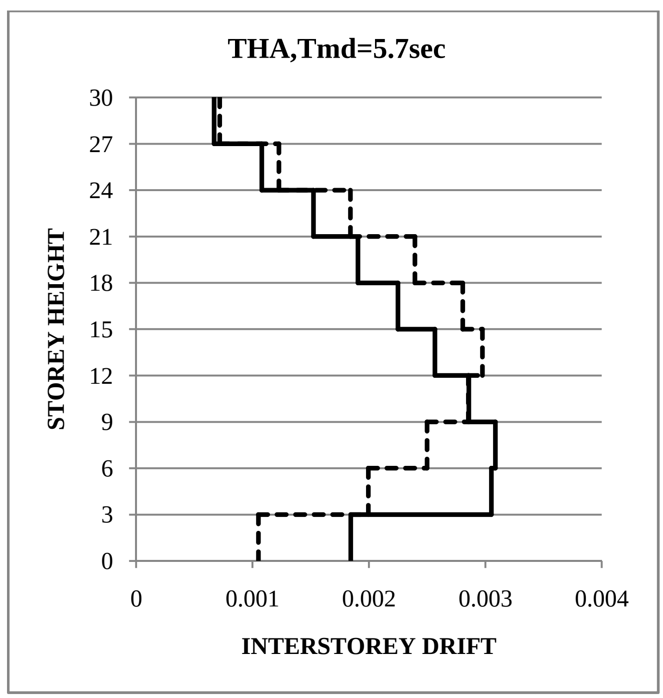
Fig. 5: Ratio of Base shear ESAY and RSAY to Sesmic Weight for different models

4. INTER-STOREY DRIFT RATIO

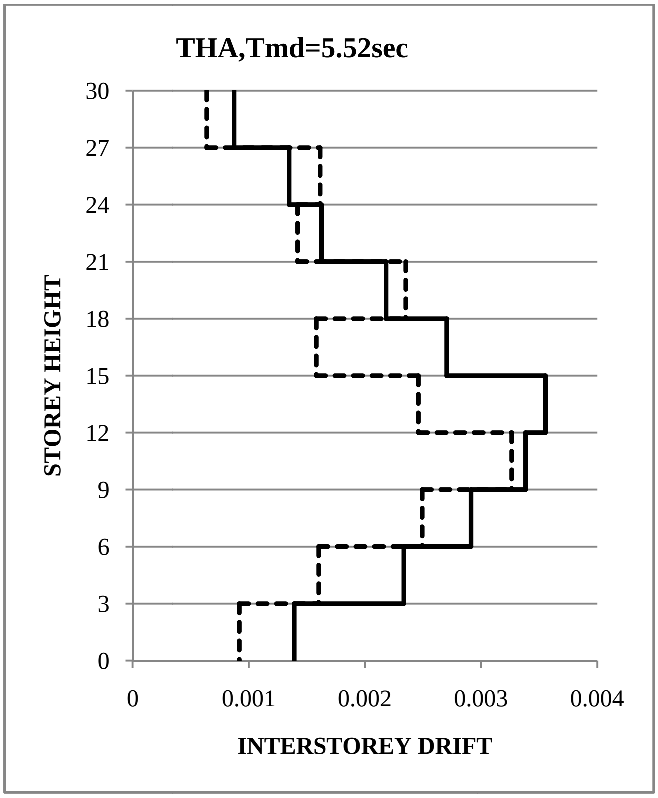
According to IS 1893-2002, maximum allowable inter-storey drift ratio of the building should not go beyond 0.004.Here various models , inter-storey drift ratio has been obtained in both x and (RSA) y direction for both Response Spectra Analysisand also for Time History Analysis (THA).Maximum displaced time of the top floor of the building is being considered.



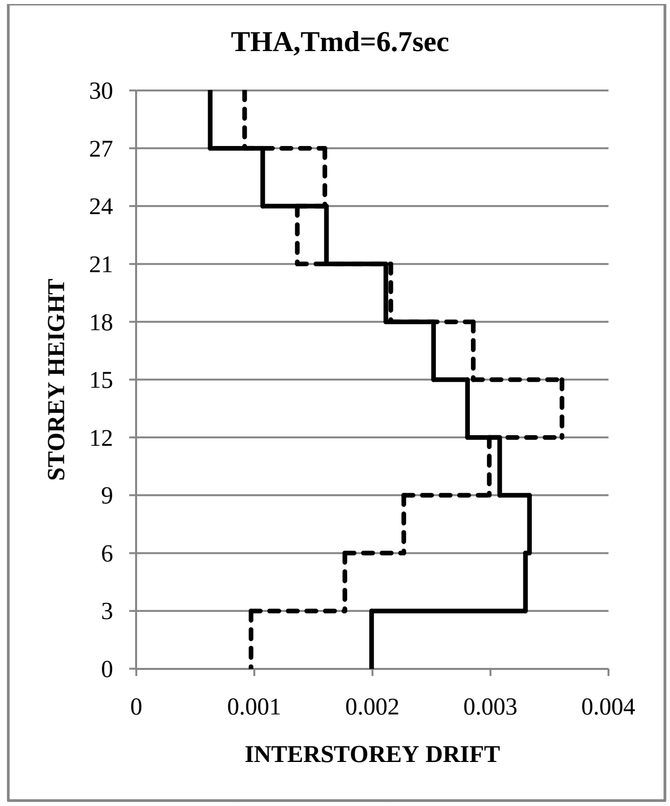
(a)



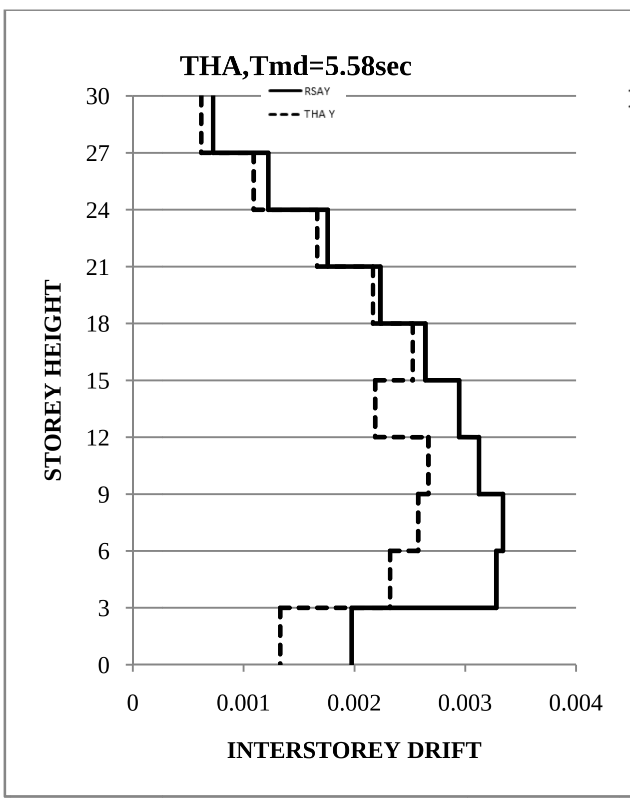
(b)


THA,Tmd=5.52sec
STOREY HEIGHT
INTERSTOREY DRIFT

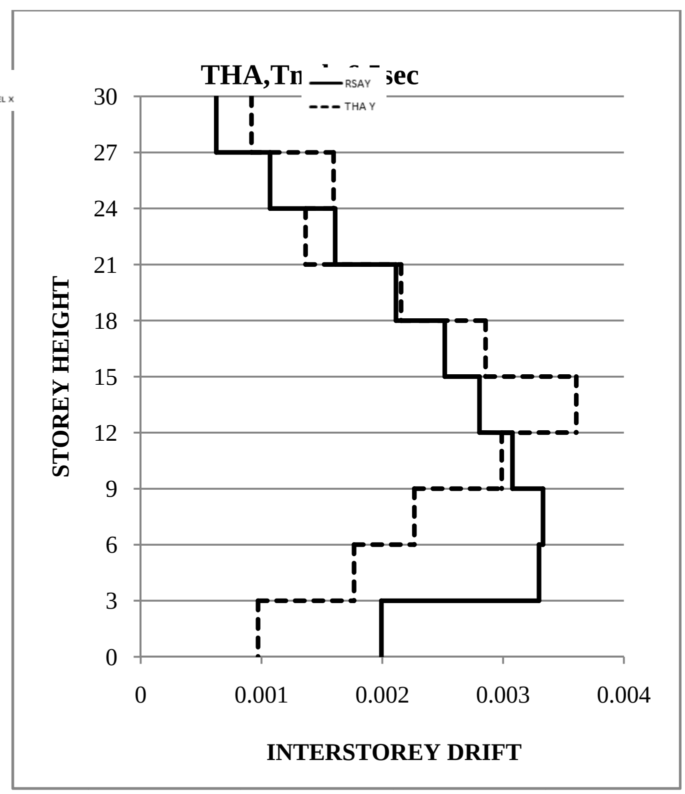
(c)


THA,Tmd=6.7sec
STOREY HEIGHT
INTERSTOREY DRIFT

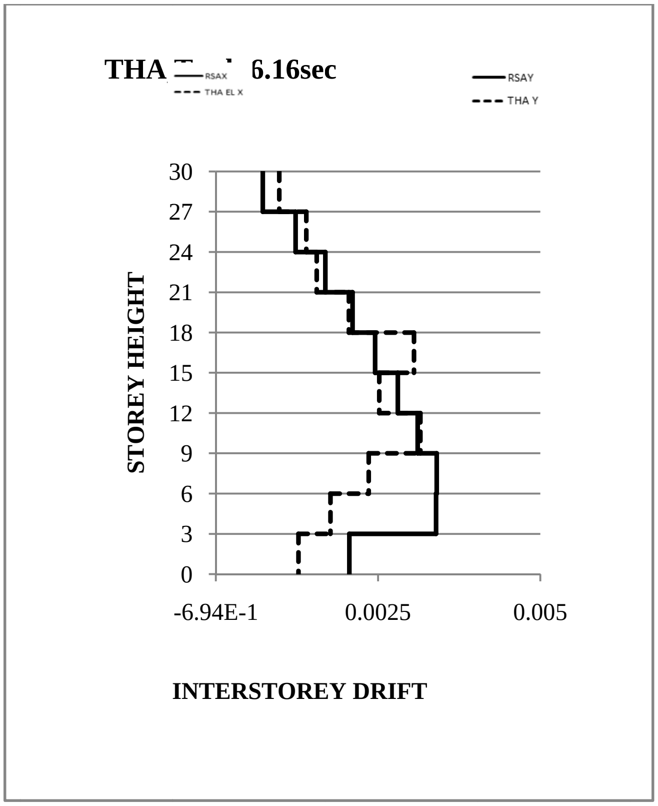
(e)


THA,Tmd=5.58sec
RSAY
THA Y
STOREY HEIGHT
INTERSTOREY DRIFT

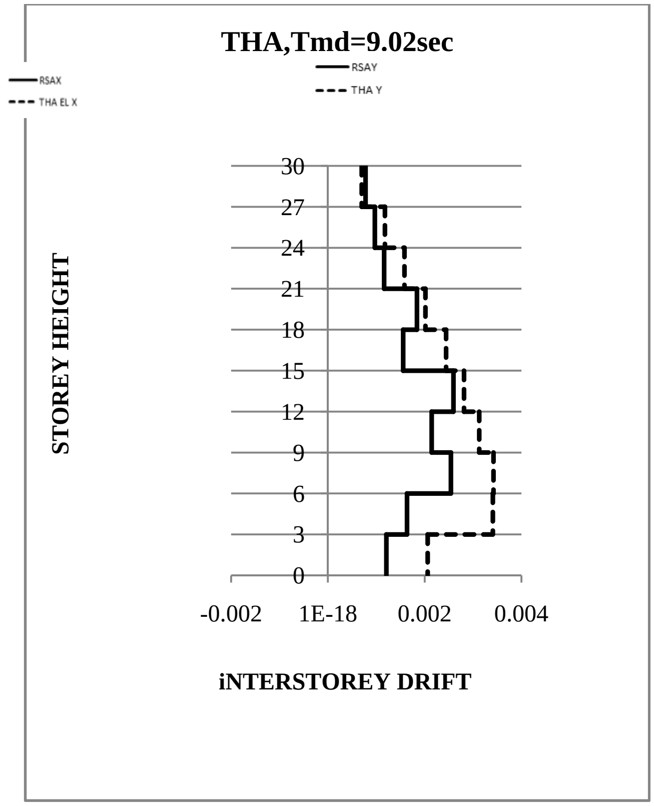
(d)


RSAY
THA Y
STOREY HEIGHT
INTERSTOREY DRIFT

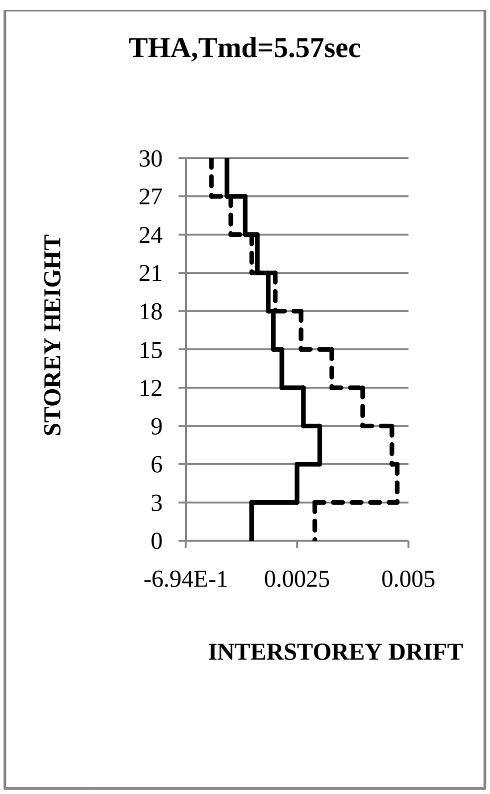
(e)


THA 6.16sec
RSAX
THA EL X
RSAY
THA Y
STOREY HEIGHT
30
27
24
21
18
15
12
9
6
3
0
-6.94E-1
0.0025
0.005
INTERSTOREY DRIFT

(f)


THA,Tmd=9.02sec
RSAX
THA EL X
RSAY
THA Y
STOREY HEIGHT
30
27
24
21
18
15
12
9
6
3
0
-0.002
1E-18
0.002
0.004
iNTERSTOREY DRIFT

(h)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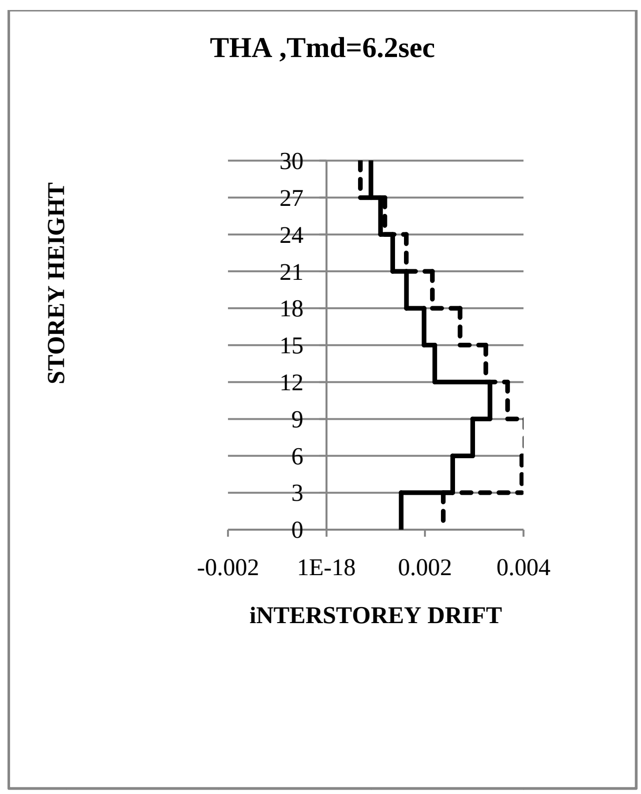
STOREY HEIGHT
30
27
24
21
18
15
12
9
6
3
0
-6.94E-1
0.0025
0.005
INTERSTOREY DRIFT

(g)


THA ,Tmd=6.2sec
STOREY HEIGHT
30
27
24
21
18
15
12
9
6
3
0
-0.002
1E-18
0.002
0.004
iNTERSTOREY DRIFT

(i)

Fig. 6.Inter-storey drift of different models-(a) and (b) represent inter-storey drift in X and Y direction of model 1, (c) and (d) represent inter-storey drift in X and Y direction of model 2

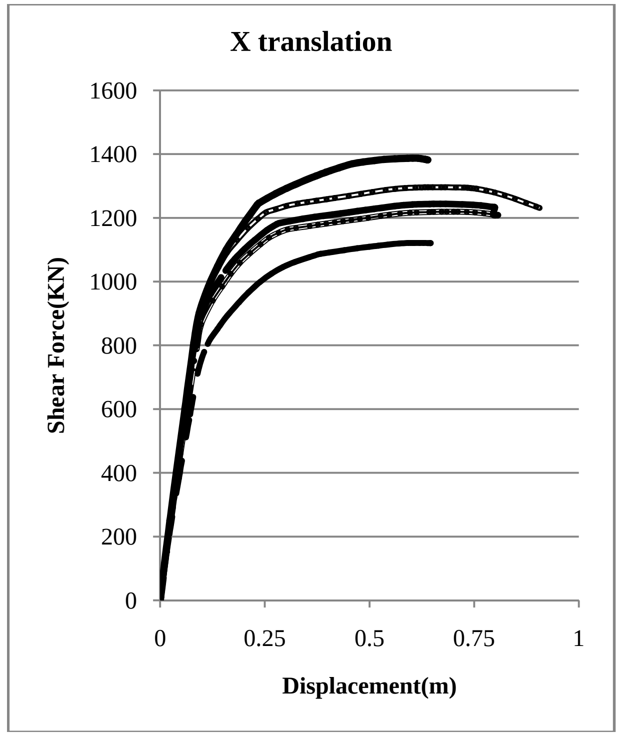
, (e) and (f) represent inter-storey drift in X and Y direction of model 3 , (g) and (h) represent inter-storey drift in X and Y direction of model 4 and -(a) and (b) represent inter-storey drift in X and Y direction of model 5(frame selected element at coordinate x=0, y=0) T_{md}=Time at max displacement

5. PUSH OVER ANALYSIS

Pushover analysis is one of the analysis methods recommended by Euro-code and FEMA 273. Pushover analysis provides valuable insights on many response characteristics like force Demand on Potentially brittle elements, Consequences of strength deterioration of individual elements on structural behaviour, Identification of critical regions in which the deformation demands are expected to be high and that have to become the focus of through detailing and identification of strength discontinuities in plan or elevation that will lead to changes in dynamic characteristics in the inelastic region. Is a technique by which a structure is subjected to a incremental lateral load of certain shape. The sequence of cracks, yielding, plastic hinge formation and failure of various structural components are noted. The structural deficiencies are observed and rectified. The iterative analysis and design goes on until the design satisfies pre-established criteria. The performance criteria are generally defined as Target displacement of the structure at roof level.

For irregular building, push over analysis is a quantitative approach and here analysis is done for the comparative study

Pushover curve is a plot drawn between base shear along vertical axis and roof displacement along horizontal axis. Performance point of the structure in various stages can be obtained from pushover curve. The various performance levels for a building are expressed in terms of a base shear carried versus roof displacement curve . The range AB is elastic range, B to IO is the range of immediate occupancy IO to LS is the range of life safety and LS to CP is the range of collapse prevention. When a hinge reaches point C on its force-displacement curve that hinge must begin to drop load]. If all the hinges are within the CP limit then the structure is still said to be safe. On the contrary, if the hinges formed are beyond CP limit then it is said that the structure collapses.



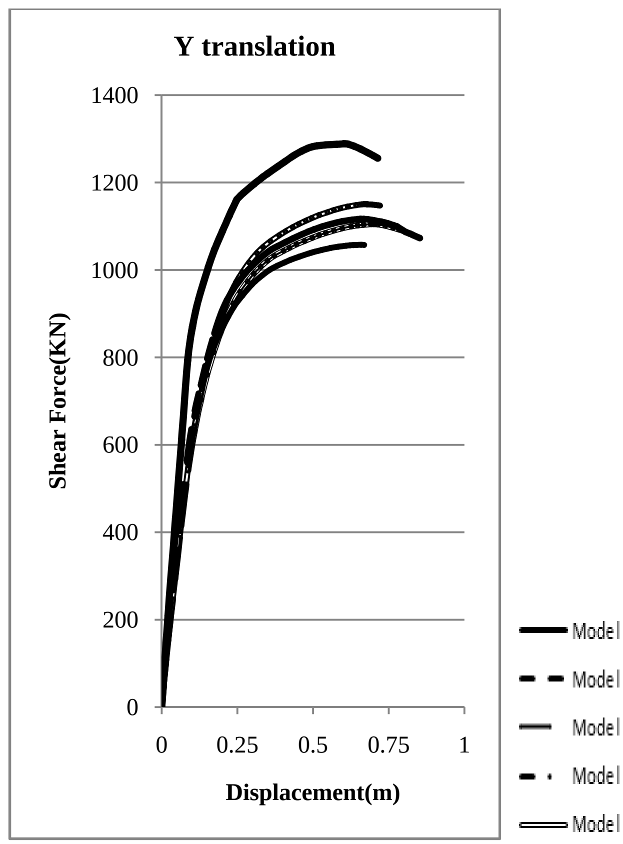


Fig. 7: Comparison of push over curves in x and y direction for different models

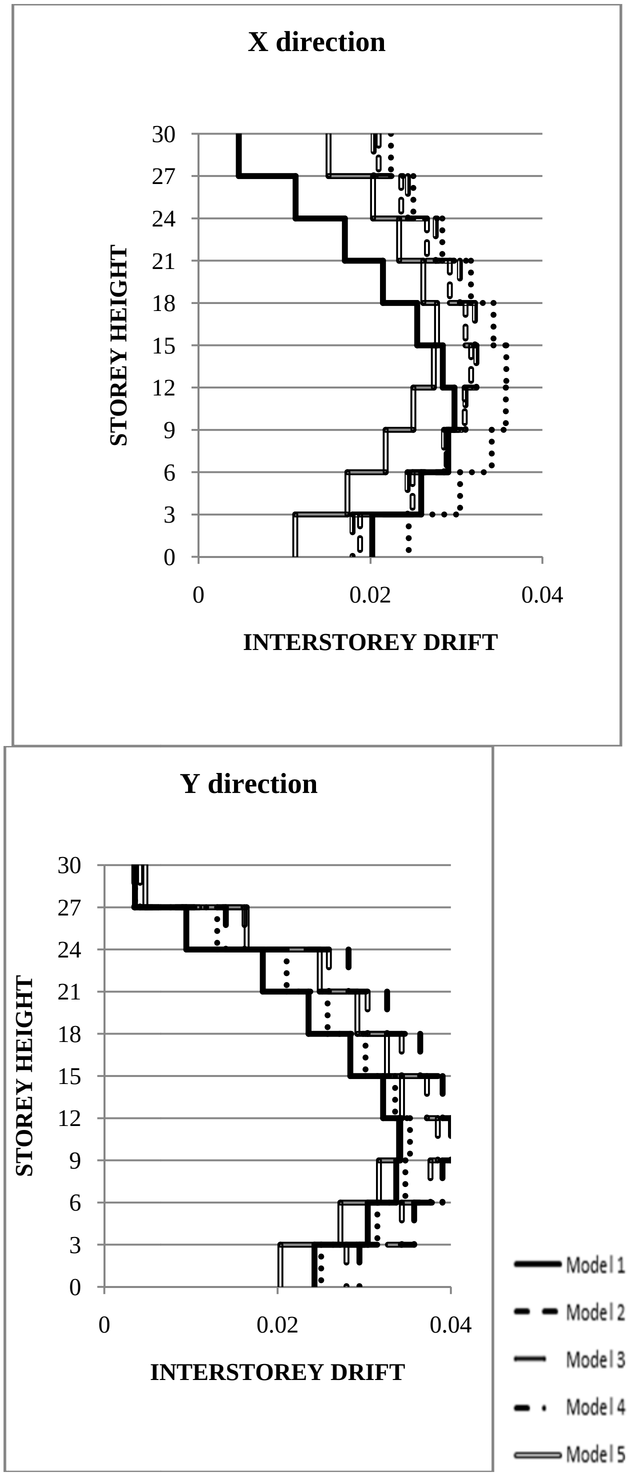


Fig. 8: Inter-story drift ratio from push over analysis in x and y direction for different models

6. DUCTILITY CAPACITY DUCTILITY DEMAND

From push over curve obtained from these five different models, we can find out the target displacement, yielddisplacement, yieldforce, ultimate displacement and ultimate stress.. From given values, Ductility Capacity and Ductility Demand can be find out. Ductility Demand is the ratio of Ultimate Displacement to the Yield Displacement and Ductility Capacity is the ratio of Target Displacement to the Yield Displacement.

Table 3: Various parameters from push over curve

	Direction	Target displacement (m)	Yield displacement (m)	Yield force (KN)	Ultimate displacement (m)	Ultimate stress (KN)
Model 1	X	0.29	0.12	1088.58	0.75	1481.25
	Y	0.31	0.13	1197.69	0.71	1397.25
Model 2	X	0.195	0.093	945.69	0.60	1102.21
	Y	0.21	0.093	868.52	0.66	1078.35
Model 3	X	0.22	0.091	1010.1	0.66	1198.55
	Y	0.23	0.10	984.25	0.66	1187.65
Model 4	X	0.21	0.103	1059.25	0.70	1167.25
	Y	0.23	0.089	925.245	0.63	1101.35
Model 5	X	0.23	0.11	1004.25	0.68	1221.21
	Y	0.224	0.09	982.25	0.61	1167.25

Table 4: Comparing Ductility capacity and Ductility Demand of various models

	Direction	Ductility Capacity	Ductility demand
MODEL 1	X	7.36	2.93
	Y	6.80	2.96
MODEL 2	X	5.44	2.09
	Y	6.08	2.27
MODEL 3	X	6.17	2.18
	Y	5.22	1.86
MODEL 4	X	4.90	2.07
	Y	6.03	2.19
MODEL 5	X	5.20	2.15
	Y	5.21	2.08

7. DISCUSSION AND CONCLUSION

It is known that vertical irregularity in building is one of the most important factors for poor seismic response. Performances of buildings in the past earthquakes have demonstrated this point. InIS 1893 (part 1):2002, has given detailed description about various types of irregularities of building. In the present study, five types of buildings are studies. The first type is a regular building with perfect symmetry, second, third, fourth and fifth building having set back irregularities where percentage of floor area is different at different height.. These five types of buildings are analysed using Response Spectrum Analysis (RSA), Linear Time

History Analysis (THA) and Push over Analysis (POA). The ratio of base shear force due RSA and THA in both X and Y direction to that of the seismic weight of the building is found lesser for regular than that of regular one. The irregular building model having more inter-storey drift both in X any Y direction of RSA and THA(El-Centro earthquake).Out of it, it has been observed that in X direction inter-storey drift will be more compared to y direction because in x direction building possess more irregular in than in Y direction. As from push over curves, . The yield displacement, target displacement, yield shear force, ultimateshear force of regular building is found to be more than irregular building both in X and Y direction.Also, Ductility capacity and ductility demand of regular building is found to be more than that of irregular building in both X and Y direction. For buildings having irregular in nature, it has been suggestto go for non linear analysis.

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