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Seismic Vulnerability of RC Building With and Without Soft Storey Effect Using Pushover Analysis

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Abstract: *A soft storey is one which has less resistance to earthquake forces than the other storeys; Buildings containing soft stories are extremely vulnerable to earthquake collapses, since one floor is flexible compared to others. Vulnerability of buildings is important in causing risk to life hence special consideration is necessary for such soft storey RC buildings. In the present study, analytical investigation of a RC building by considering the effect of soft storey situated in seismic Zone-V of India, in accordance with IS 1893-2002 (part-1), is taken as an example and the various analytical approaches (linear static and nonlinear static analysis) are performed on the building to identify the seismic demand and also pushover analysis is performed to determine the performance levels, and Capacity spectrum of the considered, also Storey Shear is compared for 3 models by using Finite Element Software Package ETAB's 9.7.4 version.*

Key words: *Linear static analysis, non linear static analysis, Pushover analysis, , Performance levels, Capacity demand ,Performance point.*

I. Introduction

According to IS 189-2002 (part1) "A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above." Now a day's open storeys are unavoidable construction in practice for many practical reasons, a building may have larger public spaces such as lobbies, large meeting rooms or open-plan retail space. In urban locations, residential buildings sometimes have fewer walls at the ground level to allow for parking underneath the building, but these soft storey buildings has poor performance during past earthquakes. In the present study, seismic performance of 3D building frame was studied. Performance of R.C. frame was evaluated varying storey level and location of the soft storey. The main objective of the study was to investigate the behaviour of multi-storey, multi-bay soft storey and to evaluate their performance levels when subjected to earthquake loading.

1.1 Current Practice

Currently, FEMA 356 (Pre standard and commentary for the seismic rehabilitation of buildings) and FEMA 440 (Improvement of Nonlinear Static Seismic Analysis Procedures).The focus is on anticipated recommendations to improve inelastic analysis procedures as currently documented in FEMA 356 and ATC 40 serve as the source documents for future design code. Based on performance-based design methodology, FEMA 356 specifies the following procedures in the design for an existing building to be retrofitted by energy dissipation dampers.

- Preliminary design, including sizing of the devices
- Device prototype testing
- Final design of the rehabilitated building to meet the target performance level.

For the performance-based design, a structural analysis is needed to obtain the building seismic performance. Although there are four analysis procedures specified in FEMA 356 Prestandard, the linear static procedure is the most efficient for preliminary design purpose. To account for the damping from adding VED's, FEMA 356 specifies a damping modification factor to reduce the seismic effect (pseudo lateral load in a given horizontal direction) on the structure.

II. Methods of Seismic Evaluation

There are different methods of analysis provides different degrees of accuracy. Currently seismic evaluation of buildings can be divided into two categories:

a. Qualitative method
b. Analytical method

The Qualitative methods are based on the available background information on the structures, past performance of the similar structures under severe earthquakes, visual inspection report and some non-destructive test results, etc.

Analytical Methods

Analysis methods are broadly classified as linear static, linear dynamic, nonlinear static and nonlinear dynamic methods.

2.1 Linear Static Analysis (Equivalent Static Analysis)

In linear static procedures the building is modelled as an equivalent single degree of freedom (SDOF) system with a linear static stiffness and an equivalent viscous damping. The seismic input is modelled by an equivalent lateral force with the objective to produce the same stresses and strains as the earthquake it represents.

This procedure does not in and require dynamic analysis, however, it accounts for the dynamics of building in an approximate manner. The static method is a simplest one; it requires less computational effort and is based on formulae given in code of practice. First, the design Base Shear is computed for the whole building and it is then distributed along the height of buildings. The lateral forces at each floor level, thus obtained are distributed to individual lateral load resisting elements. The procedure generally used for the Equivalent static analysis is explained below:

(i) Determination of fundamental natural period

(Ta) of the buildings $Ta = 0.075*h^{0.075}$ Moment resisting RC frame building without brick infill wall.

$Ta = 0.085*h^{0.075}$Moment resisting steel frame building without brick infill walls.

$Ta = 0.09*h /\sqrt{d}$ All other buildings, including moment resisting RC frame building with brick infill walls.

Where,

h - Is the height of the building in meters

d- Is the base dimension of building at plinth level in m, along the considered direction of lateral force.

(ii) Determination of base shear (VB) of the building

$$VB = Ah \times W$$

Where,

Ah=Z*I*Sa/2Rg is the design, horizontal seismic coefficient, which depends on the seismic zone. Factor (Z), importance factor (I), response, reduction factor (R) and the average response acceleration coefficients (Sa/g). Sa/g in turn depends on the nature of foundation soil (rock, medium or soft soil sites), natural period and the damping of the structure.

(iii) Distribution of design base shear

The design Base Shear VB thus obtained shall be distributed along the height of the building as per the following expression:

Where, Q_i is the design lateral force,

W_i is the seismic weight,

Hi is the height of the i^{th} floor measured from the base and n is the number of stories in the building.

2.2 Nonlinear static Analysis (Pushover Analysis)

The pushover analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The load is incrementally increased in accordance with a certain predefined pattern. The analysis is carried out up to failure, thus it enables determination of collapse load and ductility capacity. On a building frame, plastic rotation is monitored, and a plot of the total Base Shear versus Displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness.

2.3 Performance Objectives

A performance objective has two essential parts - a damage state and a level of seismic hazard. Seismic performance is described by designating the maximum allowable damage state (performance level) for an identified seismic hazard (earthquake ground motion). A performance objective may include consideration of damage states for several levels of ground motion and would then be termed a dual or multiple-level performance objective.

The target performance objective is split into Structural Performance Level (SP-n, where n is the designated number) and Non-structural Performance Level (NP-n, where n is the designated letter). These may be specified independently; however the combination of the two determines the overall Building Performance level shown in Fig 1.Structural Performance Levels is shown in the Table 1:

TABLE 1: Structural Performance Levels

PERFORMANCE LEVELS	STRUCTURAL PERFORMANCE	NON-STRUCTURAL PERFORMANCE
Operational (O)	Very light damage. No permanent drift Substantially original strength and stiffness.	Negligible damage.
Immediate Occupancy(IO)	Light damage. No permanent drift, Substantially original strength & stiffness. Minor cracking. Elevators can be restarted. Fire protection operable.	Power and other utilities are available. Equipment's and content secure may not operate due to mechanical.
Life Safety (LS)	Moderate damage. Some permanent drift. Residual strength & stiffness in all stories. Gravity elements function. Building may be beyond economical repair.	Falling hazard. mitigated But extensive system damage.
Collapse Prevention (CP)	Severe damage. Large permanent Drifts. Little residual strength & Stiffness, Gravity elements function. Some exits blocked, Building near Collapse.	Extensive damage

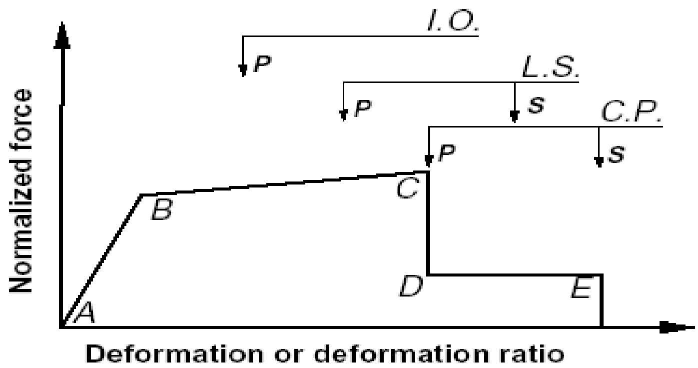


Fig 1: force deformation for performance levels

The owner, architect, and structural engineer then decide upon the desired condition of the structure after a range of ground shakings, or Building Performance Level. The Building Performance Level is a function of the post event conditions of the structural and non - structural components of the structure.

III. Purpose of Pushover Analysis

The purpose of pushover analysis is to evaluate the expected performance of structural systems by estimating performance of a structural system by estimating its strength and deformation demands in design of earthquakes by means of static inelastic analysis and comparing these demands to available capacities at the performance levels of interest. The evaluation is based on an assessment of important performance parameters, including global drift, inter-storey drift, inelastic element deformations (either absolute or normalized with respect to a yield value), deformations between elements, and element connection forces (for elements and connections that cannot sustain inelastic deformations). The inelastic static pushover analysis can be viewed as a method for predicting seismic force and deformation demands, which accounts in an approximate manner for the redistribution of internal forces that no longer can be resisted within the elastic range of structural behaviour. The pushover is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis.

Table 5: Performance levels for G+5 Building Model in longitudinal direction PUSHX. The above Table 5 indicates the range of overall performance level of G+5 storey building model in PUSH X direction which lies in between A to IO.

The above Table 6 indicates the range of overall performance level of G+11 storey building model in PUSH X direction which lies in between A to IO.

Performance Point of the Building using Capacity Spectrum Method

Performance point can be obtained by superimposing capacity spectrum and demand spectrum and the intersection point of these two curves is performance point. Fig 8 shows superimposing demand spectrum and capacity spectrum.

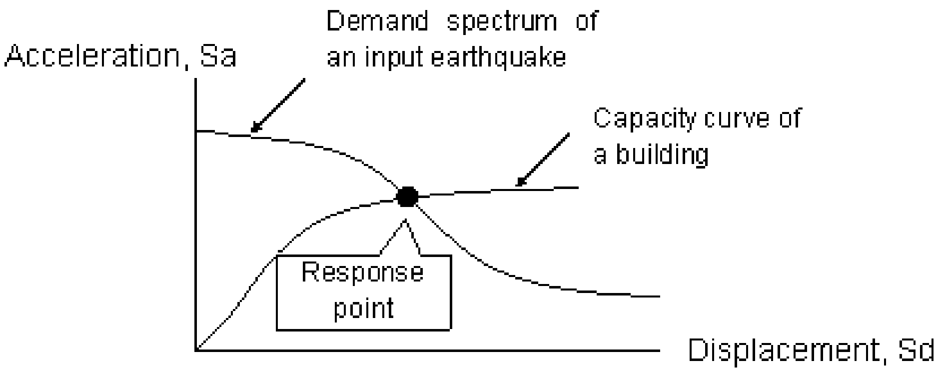


Fig 2: Performance Point of the Building using Capacity Spectrum Method

IV. Descriptions Of The Building Considered

The structure used in this study is a building of reinforced concrete of 10 storeys with 6 bays along longitudinal direction and 6 bays along transverse direction (Fig.2, Fig.3 and Fig.4.). The beams are of sections 0.3mx 0.6m and the columns are of sections 0.5m x 0.5m and the height of first storey is 3.5m and other stories are 3m with the thickness of the slab is 125mm. Live load on the roof slab is 1.5 kN/m^2 and live load on each floor is 3 kN/m^2 finishes is 2 kN/m^2 on roof and 1.75 kN/m^2 on each floor. Concrete cube compressive strength, f_{ck} = 25 N/mm^2 (M25).Characteristic strength of reinforcing steel, f_y = 415 N/mm^2 (Fe415).Modulus of Elasticity of concrete, E = 25 kN/mm^2.Unit weight of concrete = 25 kN/m^3.Model-1;Without soft sorey

Model-2;With first storey as soft storey

Model-3;With middle storey as soft storey

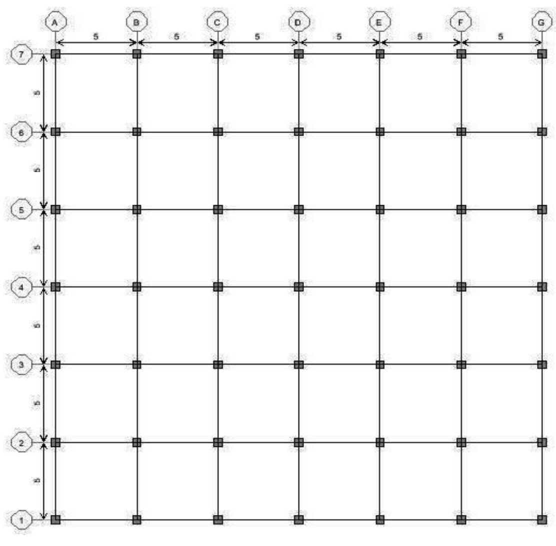


Figure2: Plan of 10 Storey Building Modelled (from ETABS 9.7.4)

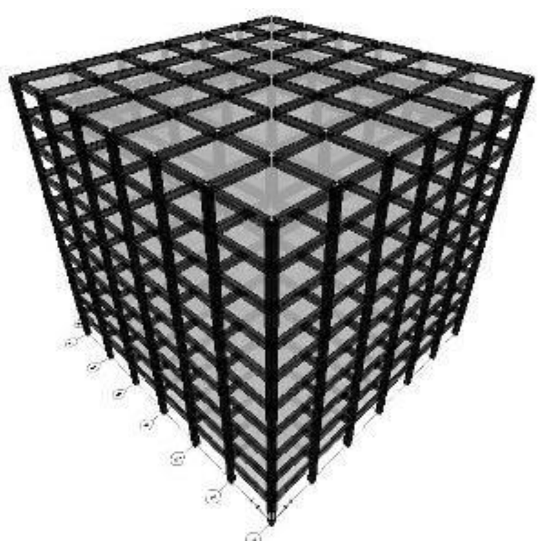


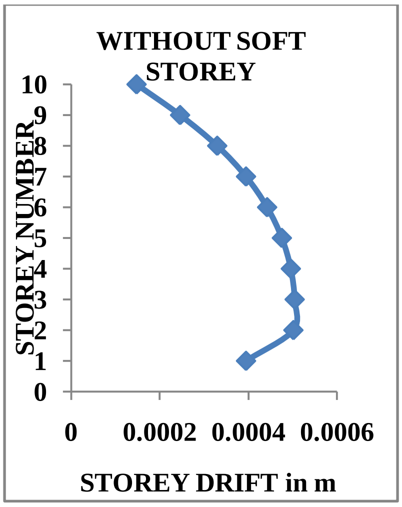
Figure3: 3D view of 10 Storey Building Model-1

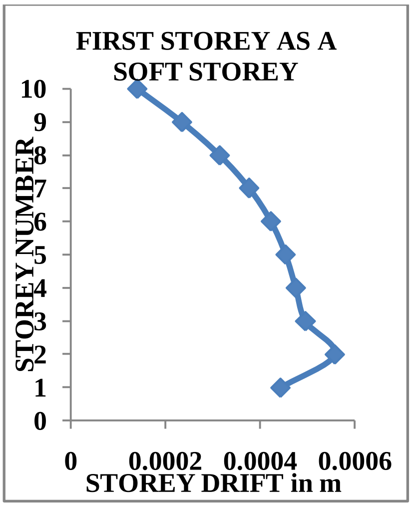
4.0 RESULTS AND DISCUSSION

4.1 Storey drift

Table2: Data for Storey drift for 10 storey building in longitudinal direction EQX

MODEL 1		***MODEL 2***		***MODEL 3***	
STOREY NUMBER	***STOREY DRIFT in m***	***STOREY NUMBER***	***STOREY DRIFT in m***	***STOREY NUMBER***	***STOREY DRIFT in m***
10	0.000148	10	0.000141	10	0.000147
9	0.000246	9	0.000235	9	0.000244
8	0.00033	8	0.000315	8	0.000328
7	0.000395	7	0.000377	7	0.000403
6	0.000443	6	0.000423	6	0.000511
5	0.000476	5	0.000454	5	0.00053
4	0.000496	4	0.000475	4	0.000486
3	0.000505	3	0.000496	3	0.000483
2	0.000502	2	0.000557	2	0.000478
1	0.000395	1	0.000443	1	0.000376





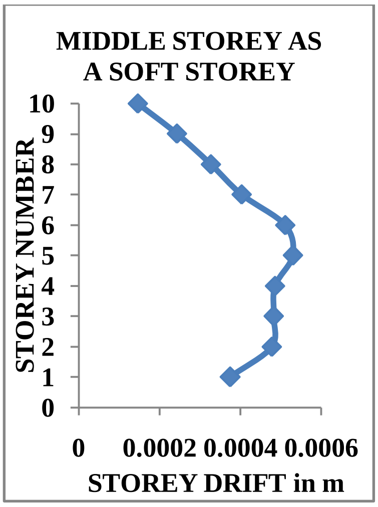


Figure: 5 Storey drift for Model-1 along EQX, Figure:6 Storey drift for Model-2 along EQX, Figure:7 Storey drift for Model-3 along EQX

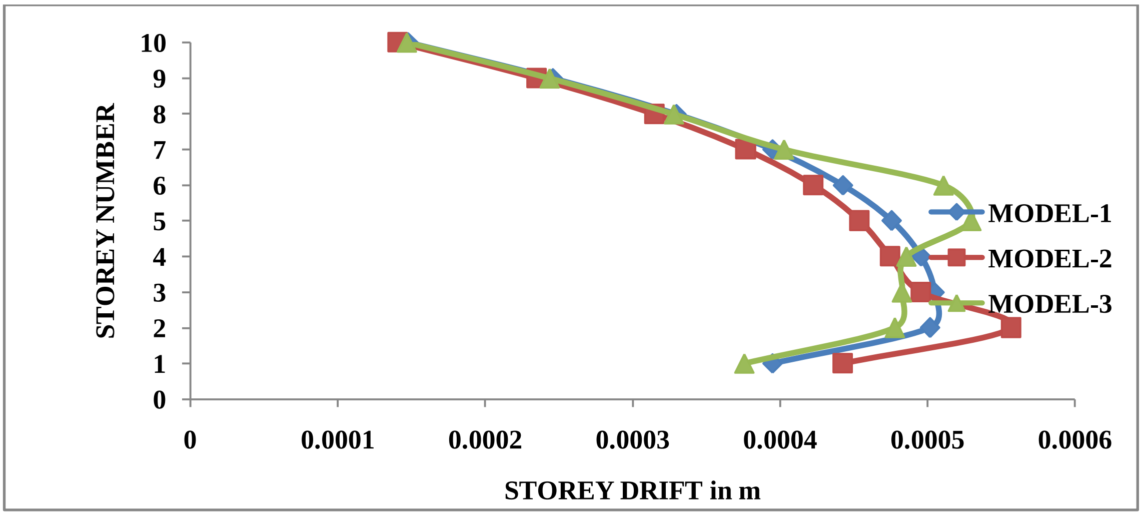


Figure:8 Storey drift comparison for Model-1, Model-2, Model-3 along EQX

Table3: Data for Storey drift for 10 storey building in longitudinal direction PUSH X

MODEL1		***MODEL 2***		***MODEL 3***	
STOREY NUMBER	***STOREY DRIFT in m***	***STOREY NUMBER***	***STOREY DRIFT in m***	***STOREY NUMBER***	***STOREY DRIFT in m***
10	0.001933	10	0.001797	10	0.001818
9	0.004767	9	0.004497	9	0.004632
8	0.008695	8	0.008333	8	0.008653
7	0.012847	7	0.01246	7	0.013007
6	0.016387	6	0.016007	6	0.016856
5	0.019181	5	0.018355	5	0.01882
4	0.019609	4	0.019039	4	0.018558
3	0.017371	3	0.017755	3	0.01658
2	0.013402	2	0.014228	2	0.012633
1	0.006034	1	0.006584	1	0.005659

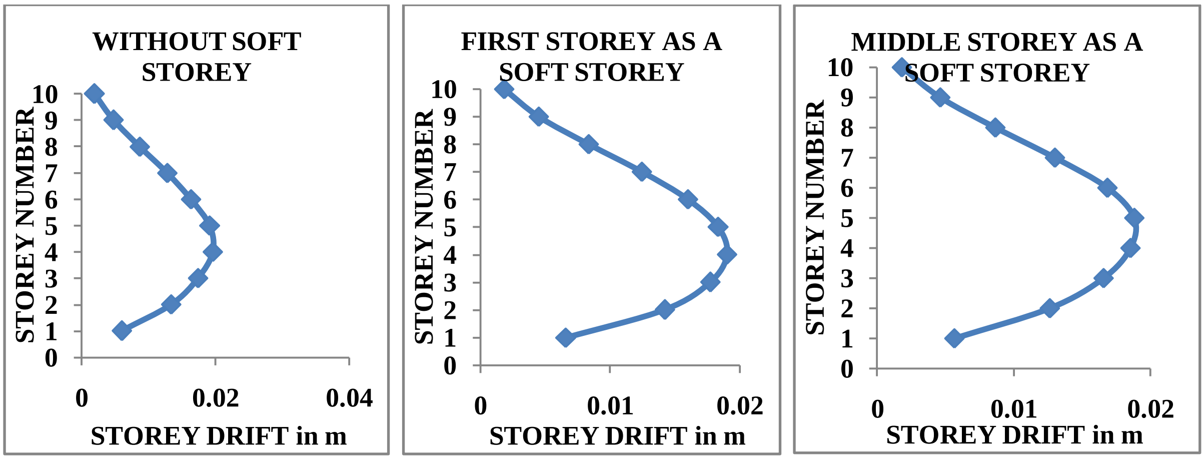


Figure:9 Storey drift for Model-1 along PUSH X,Figure:10 Storey drift for Model-2 along PUSH X, Figure:11 Storey drift for Model-3 along PUSH X

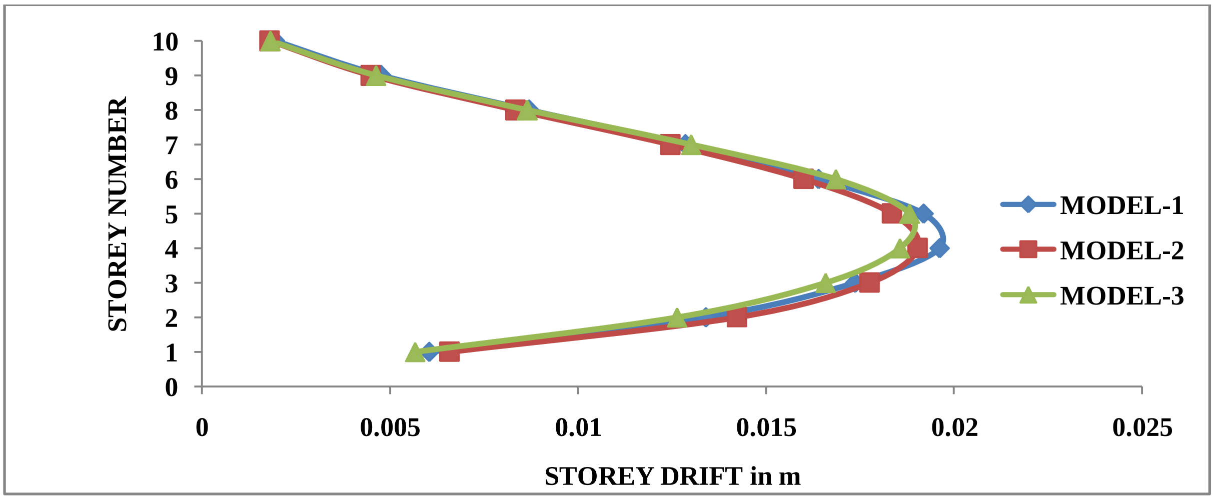
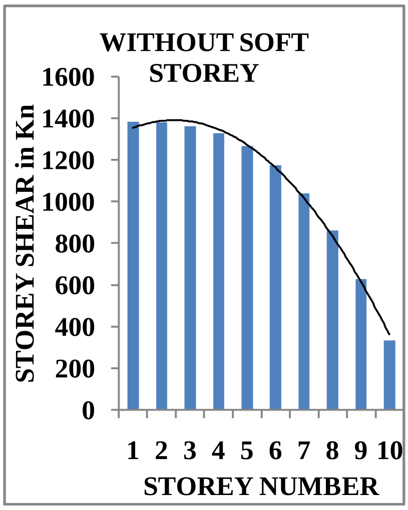


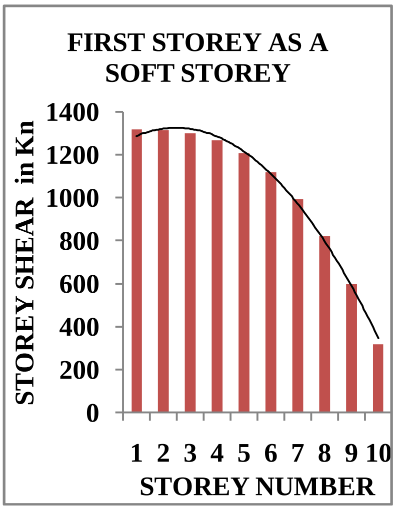
Figure:12 Storey drift comparison for Model-1, Model-2, Model-3 along PUSH X

4.2 Storey shear

Table4: Data for Storey shear for 10 storey building in longitudinal direction EQX

MODEL1		*MODEL 2*		*MODEL 3*	
STOREY NUMBER	*STOREY SHEAR in Kn*	*STOREY NUMBER*	*STOREY SHEAR in Kn*	*STOREY NUMBER*	*STOREY SHEAR in Kn*
1	1383.57	1	1315.85	1	1315.85
2	1378.77	2	1312.89	2	1311.11
3	1362.37	3	1299.28	3	1294.92
4	1327.32	4	1265.86	4	1260.33
5	1266.66	5	1208	5	1200.44
6	1173.37	6	1119.04	6	1141.16
7	1040.48	7	992.3	7	1027.06
8	861	8	821.13	8	849.89
9	627.94	9	598.86	9	619.84
10	334.31	10	318.83	10	329.99





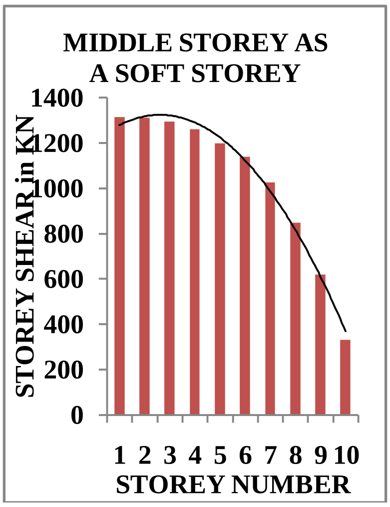


Figure:13 Storey shear for Model-1 along EQX,Figure:14 Storey shear for Model-2 along EQX,Figure:15 Storey shear for Model-3 along EQX

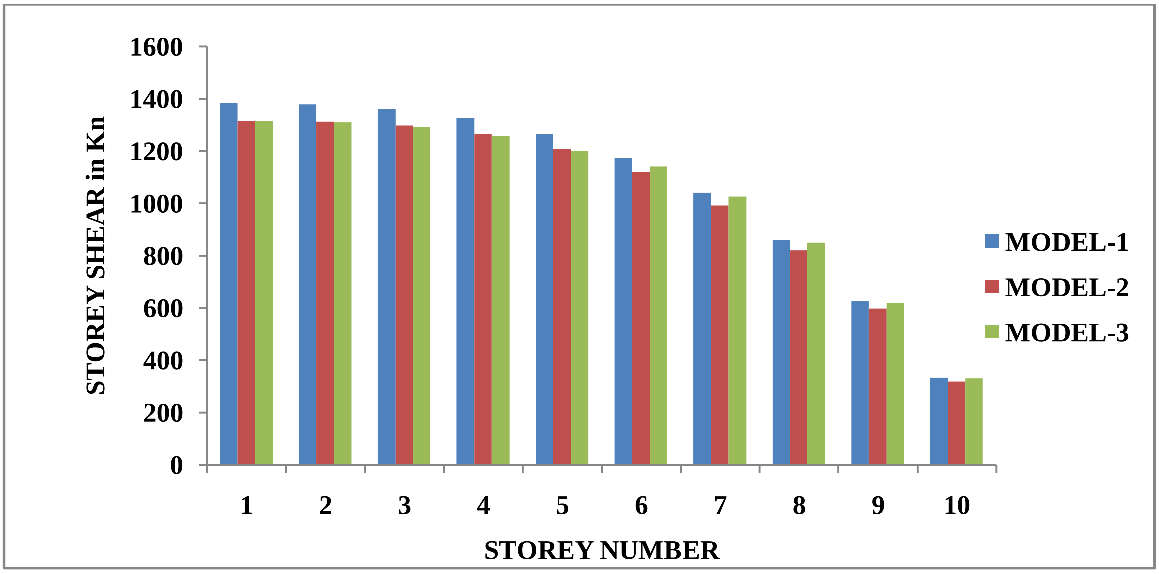
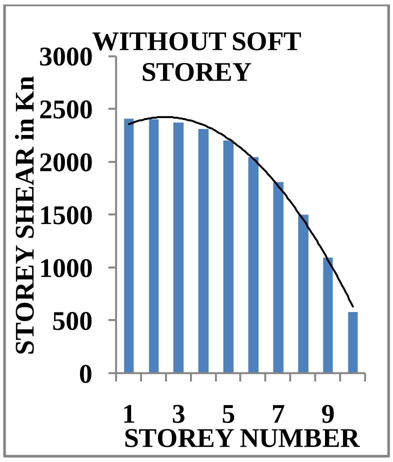
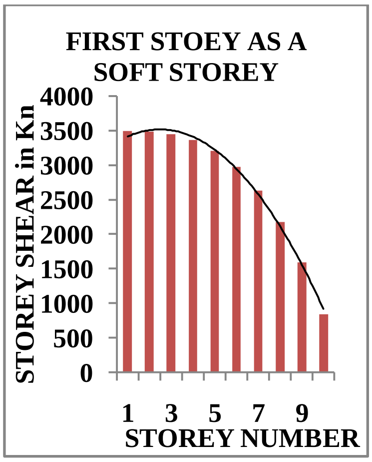


Figure:16 Storey shear comparison for Model-1, Model-2, Model-3 along EQX

Table5: Data for Storey shear for 10 storey building in longitudinal direction PUSH X

MODEL1		***MODEL 2***		***MODEL 3***	
STOREY NUMBER	***STOREY SHEAR in kN***	***STOREY NUMBER***	***STOREY SHEAR in kN***	***STOREY NUMBER***	***STOREY SHEAR in kN***
1	2407.77	1	3491.07	1	4985.76
2	2399.41	2	3483.2	2	4967.79
3	2370.86	3	3447.1	3	4906.44
4	2309.88	4	3358.43	4	4775.38
5	2204.3	5	3204.93	5	4548.47
6	2041.97	6	2968.9	6	4323.84
7	1810.71	7	2632.67	7	3891.52
8	1498.37	8	2178.54	8	3220.24
9	1092.78	9	1588.83	9	2348.56
10	581.78	10	845.87	10	1250.34





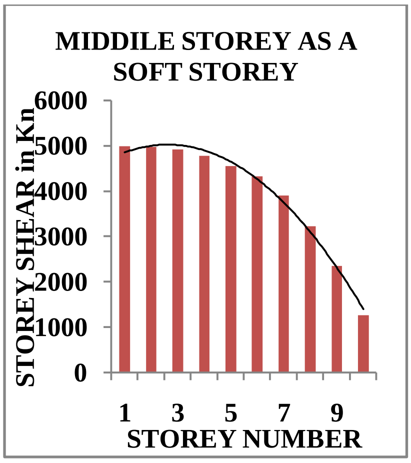


Figure:17 Storey shear for Model-1 along PUSH X,Figure:18 Storey shear for Model-2 along PUSH X, Figure:19 Storey shear for Model-3 along PUSH X

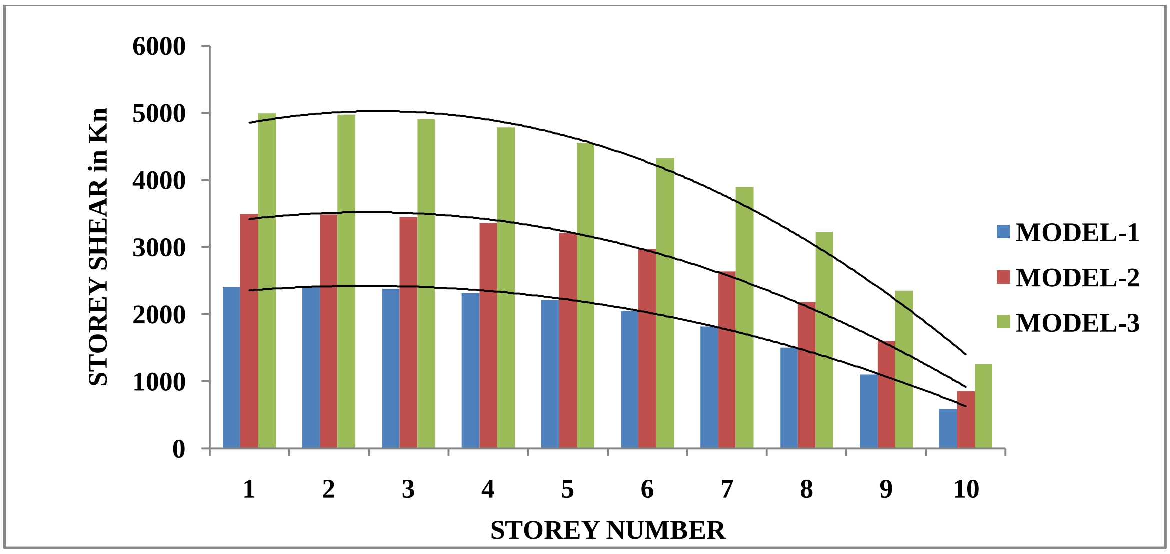


Figure: 20 Storey shear comparison for Model-1, Model-2, Model-3 along PUSH X

Table6: Data for Storey drift for 10 storey building in longitudinal direction EQX & PUSH X

STOREY DRIFT COMPARISON						
STOREY	***MODEL-1***		***MODEL-2***		***MODEL-3***	
	EQX	***PUSH X***	***EQX***	***PUSH X***	***EQX***	***PUSH X***
1	0.000148	0.001933	0.000141	0.001797	0.000147	0.001818
2	0.000246	0.004767	0.000235	0.004497	0.000244	0.004632
3	0.00033	0.008695	0.000315	0.008333	0.000328	0.008653
4	0.000395	0.012847	0.000377	0.01246	0.000403	0.013007
5	0.000443	0.016387	0.000423	0.016007	0.000511	0.016856
6	0.000476	0.019181	0.000454	0.018355	0.00053	0.01882
7	0.000496	0.019609	0.000475	0.019039	0.000486	0.018558
8	0.000505	0.017371	0.000496	0.017755	0.000483	0.01658
9	0.000502	0.013402	0.000557	0.014228	0.000478	0.012633
10	0.000395	0.006034	0.000443	0.006584	0.000376	0.005659

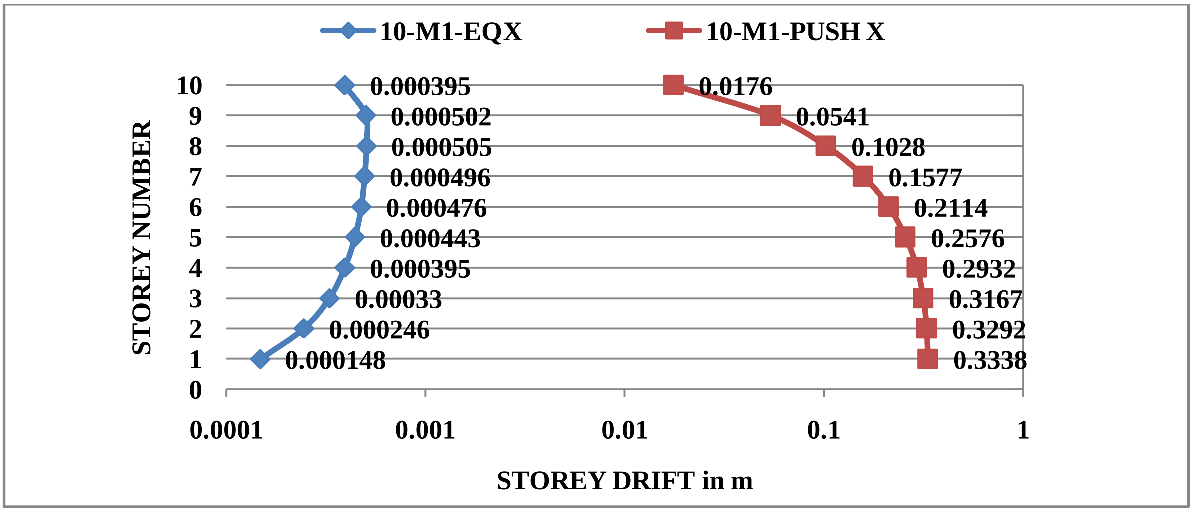


Figure: 20 Storey drift comparison for Model-1 along EQX and PUSH X

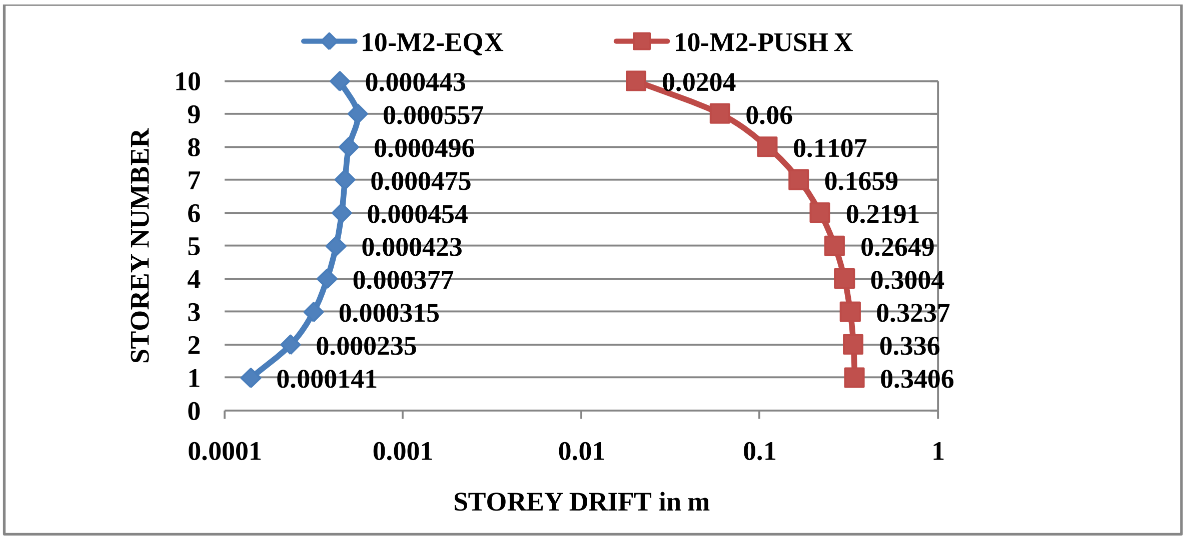


Figure: 21 Storey drift comparison for Model-2 along EQX and PUSH X

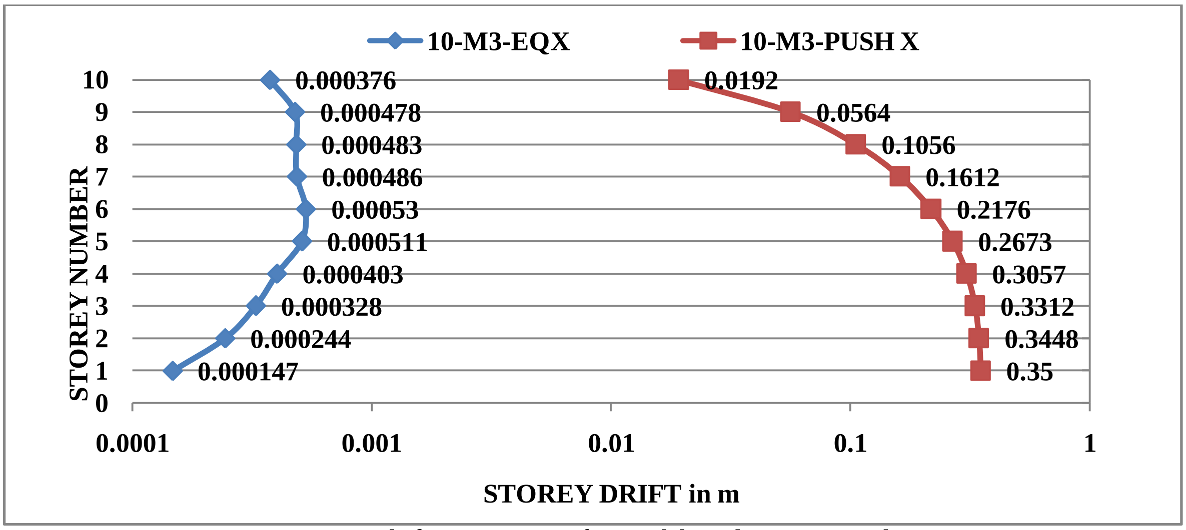


Figure: 22 Storey drift comparison for Model-3 along EQX and PUSH X

Table7: Data for Storey shear for 10 storey building in longitudinal direction EQX & PUSH X

STOREY SHEAR COMPARISON						
STOREY	***MODEL-1***		***MODEL-2***		***MODEL-3***	
	EQX	***PUSH X***	***EQX***	***PUSH X***	***EQX***	***PUSH X***
1	1383.57	2407.77	1315.85	3491.07	1315.85	4985.76
2	1378.77	2399.41	1312.89	3483.2	1311.11	4967.79
3	1362.37	2370.86	1299.28	3447.1	1294.92	4906.44
4	1327.32	2309.88	1265.86	3358.43	1260.33	4775.38
5	1266.66	2204.3	1208	3204.93	1200.44	4548.47
6	1173.37	2041.97	1119.04	2968.9	1141.16	4323.84
7	1040.48	1810.71	992.3	2632.67	1027.06	3891.52
8	861	1498.37	821.13	2178.54	849.89	3220.24
9	627.94	1092.78	598.86	1588.83	619.84	2348.56
10	334.31	581.78	318.83	845.87	329.99	1250.34

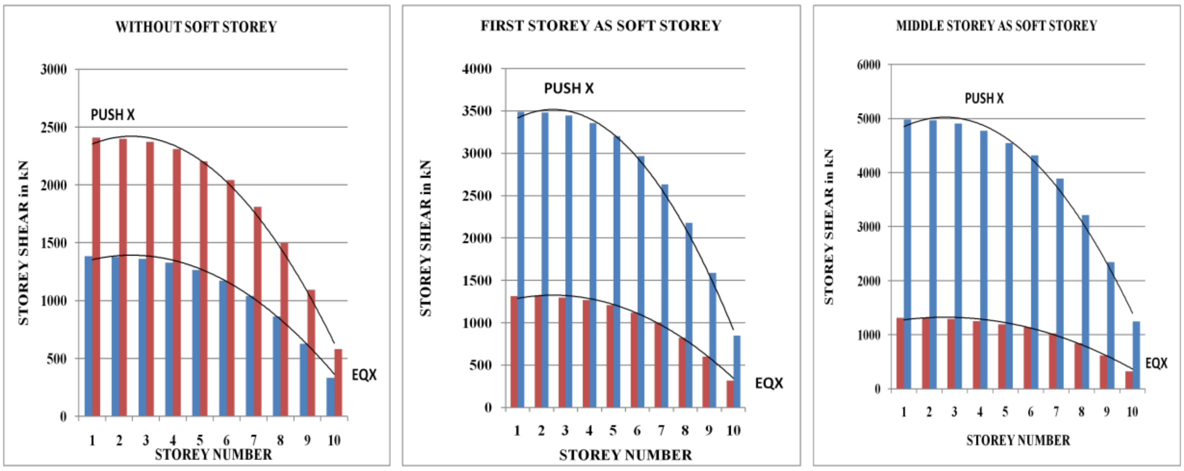


Figure:23 Storey shear comparison for Model-1 along EQX and PUSH X,Figure:24 Storey shear comparison for Model-2 along EQX and PUSH X,Figure:25 Storey shear comparison for Model-3 along EQX and PUSH X

4.3 Pushover curve

Table8: Data for Pushover curve for 10 storey building Model-1

Step	***Displacement***	***Base Force***
0	2.62E-05	0
1	0.0246	2839.8311
2	0.0408	3968.291
3	0.046	4107.5303
4	0.1084	4682.0269
5	0.2441	5418.3188
6	0.3595	5906.5449
7	0.3595	5358.1396
8	0.3615	5423.0996
9	0.3338	2407.7725

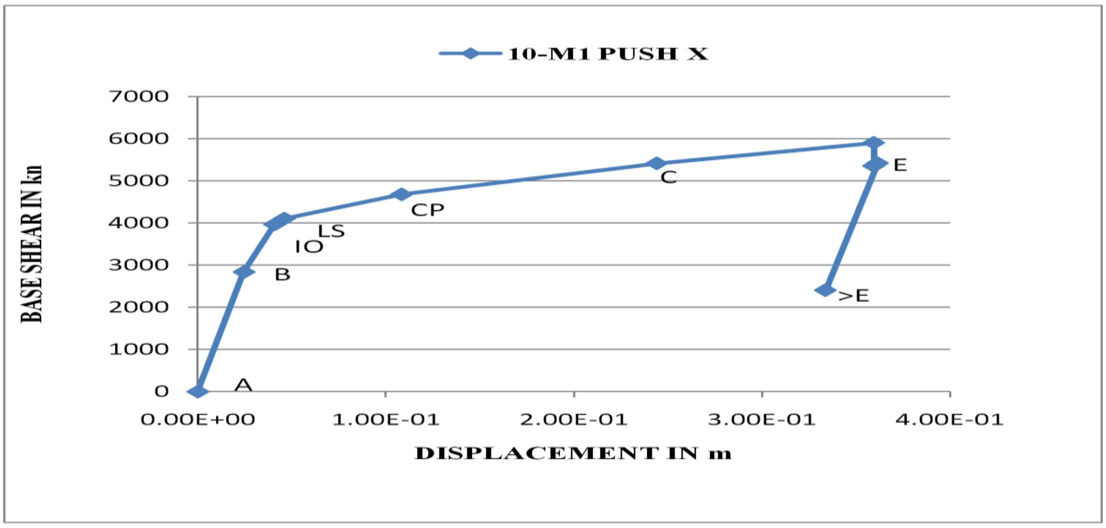


Figure:26 Pushover curve for Model-1

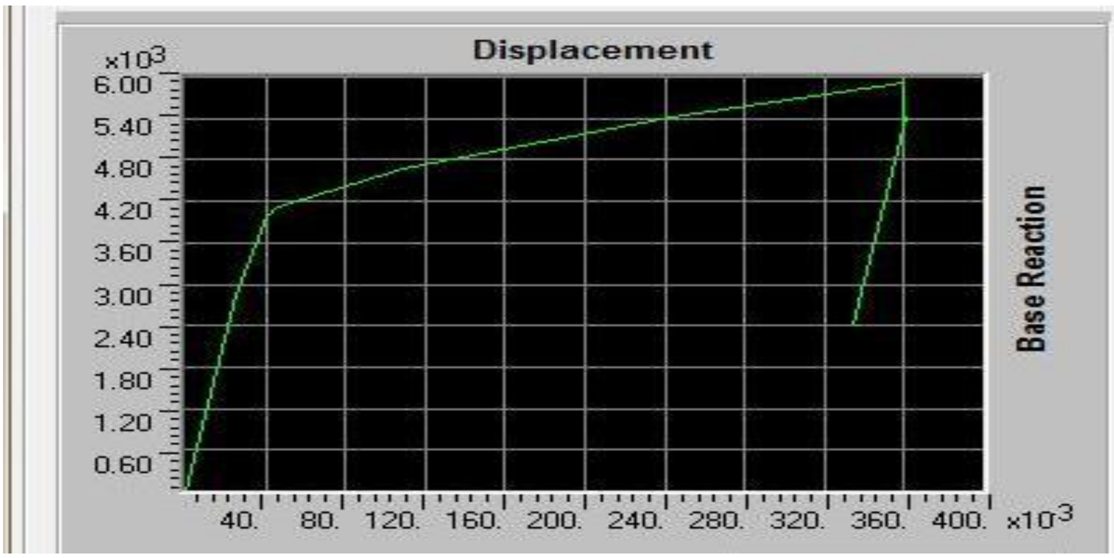


Figure: 27 Pushover curve for Model-1 from ETAB 9.7.4

Table9: Data for Pushover curve for 10 storey building Model-2

Step	***Displacement***	***Base Force***
0	2.58E-05	0
1	0.0236	2602.5703
2	0.0364	3563.0684
3	0.0437	3832.4939
4	0.0787	4295.6494
5	0.2109	5130.2783
6	0.3347	5679.7065
7	0.3601	5780.4019
8	0.3406	3491.0718

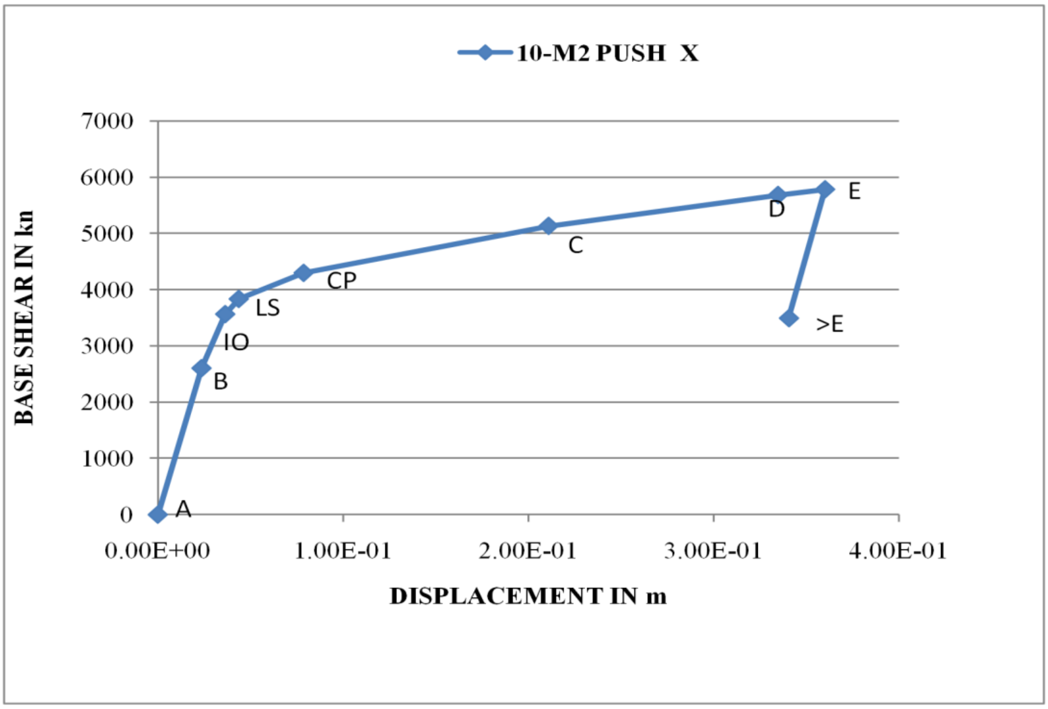


Figure: 28 Pushover curve for Model-2

Table10: Data for Pushover curve for 10 storey building Model-3

Step	***Displacement***	***Base Force***	***A-B***
0	2.46E-05	0	4241
1	0.0254	2770.2466	3933
2	0.0397	3704.5022	3846
3	0.0444	3876.3352	3618
4	0.1666	4772.3354	3506
5	0.2909	5356.1021	3486
6	0.3539	5606.5405	3486
7	0.35	4985.7607	4244

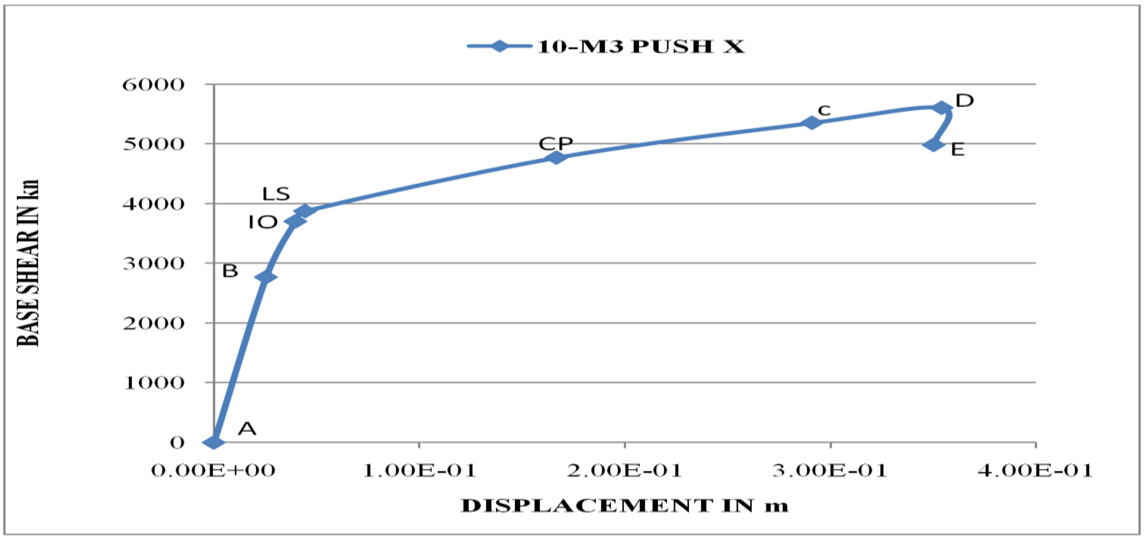


Figure:29 Pushover curve for Model-3

4.4 Performance points

Table 10: Data for Spectral displacement and Spectral acceleration for capacity curve and demand curve for 10 storey building Model-1

Step	*Sd(C)*	*Sa(C)*	*Sd(D)*	*Sa(D)*
0	0	0	0.128	0.312
1	0.019	0.046	0.128	0.312
2	0.032	0.063	0.115	0.23
3	0.036	0.065	0.111	0.202
4	0.089	0.075	0.129	0.109
5	0.198	0.09	0.172	0.078
6	0.286	0.1	0.198	0.069
7	0.287	0.091	0.199	0.063
8	0.288	0.092	0.199	0.063

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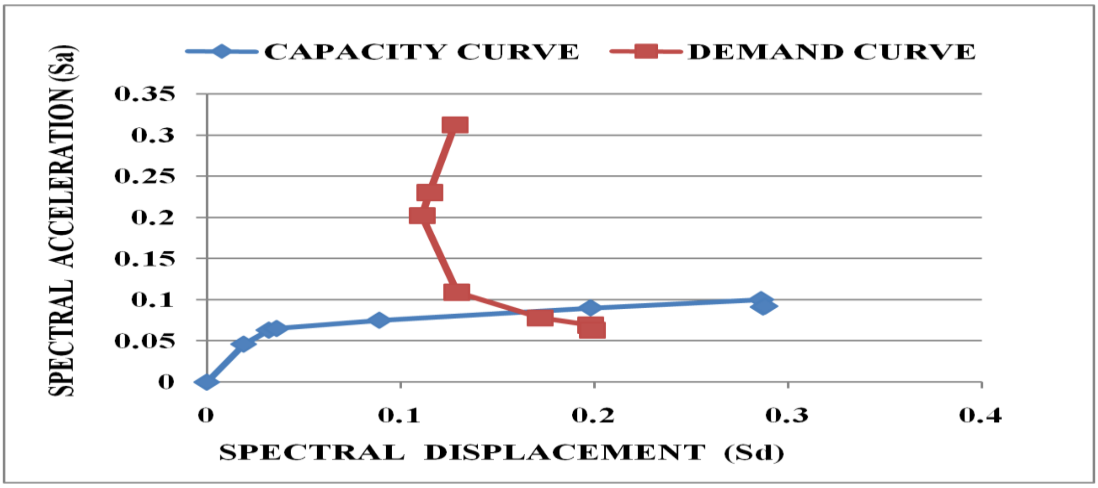

Figure: 30 Performance point for Model-1

Table 11: Data for Spectral displacement and Spectral acceleration for capacity curve and demand curve for 10 storey building Model-2

Step	***Sd(C)***	***Sa(C)***	***Sd(D)***	***Sa(D)***
0	0	0	0.131	0.304
1	0.018	0.042	0.131	0.304
2	0.028	0.057	0.119	0.239
3	0.035	0.061	0.114	0.201
4	0.065	0.068	0.12	0.126
5	0.174	0.085	0.168	0.082
6	0.27	0.096	0.197	0.07
7	0.289	0.098	0.202	0.068

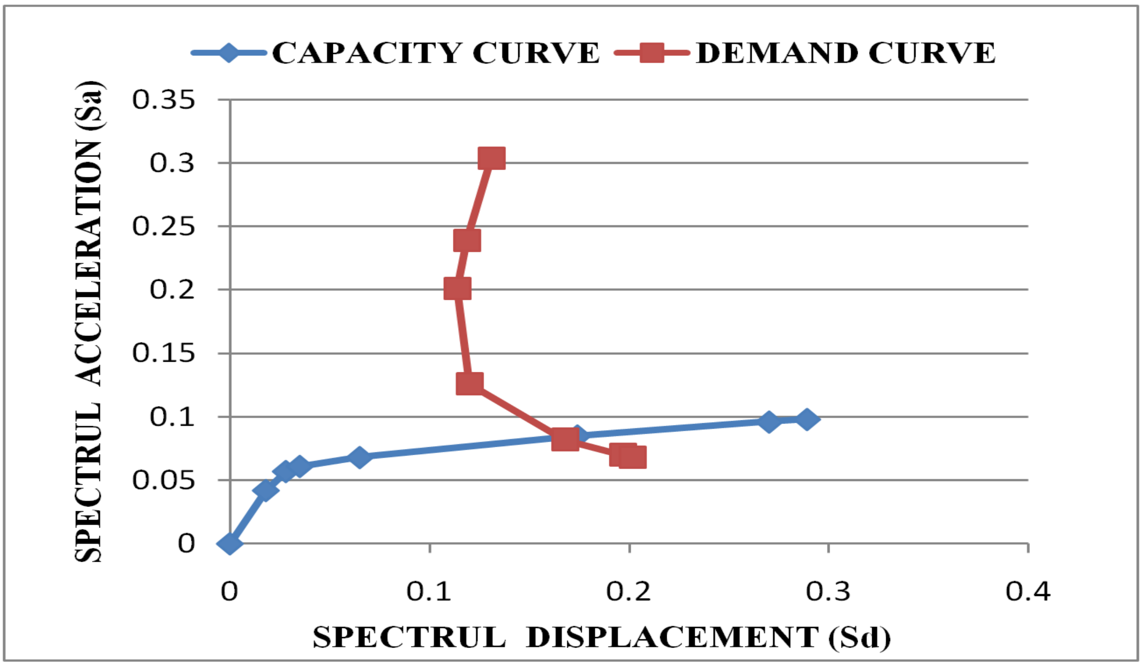

Figure:31 Performance point for Model-2

Table 12: Data for Spectral displacement and Spectral acceleration for capacity curve and demand curve for 10 storey building Model-3

Step	***Sd(C)***	***Sa(C)***	***Sd(D)***	***Sa(D)***
0	0	0	0.127	0.313
1	0.019	0.048	0.127	0.313
2	0.031	0.064	0.114	0.236
3	0.035	0.067	0.112	0.216
4	0.137	0.084	0.149	0.091
5	0.236	0.096	0.182	0.074
6	0.284	0.102	0.195	0.07

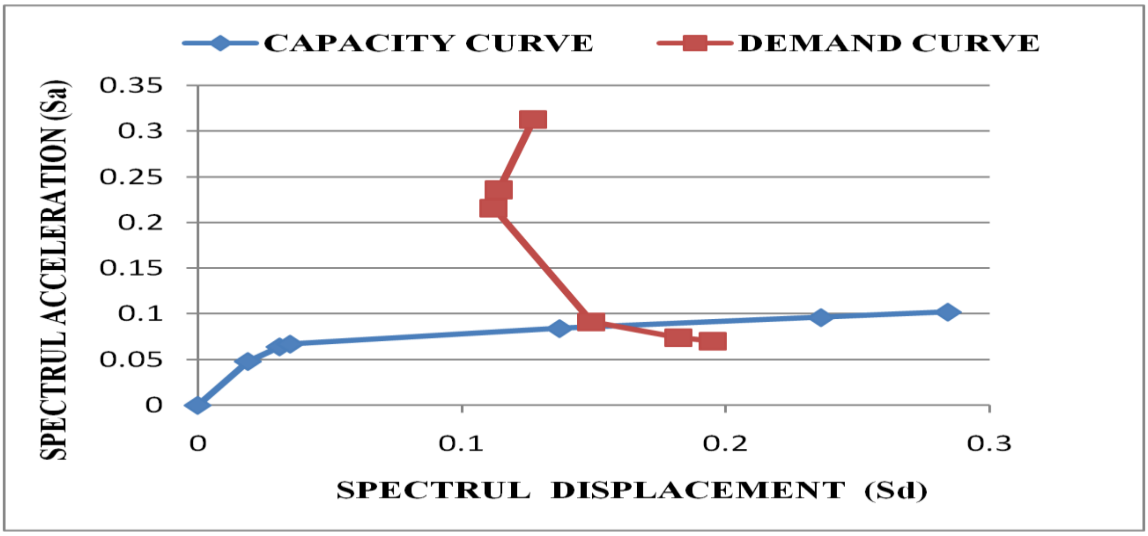

Figure:32 Performance point for Model-3

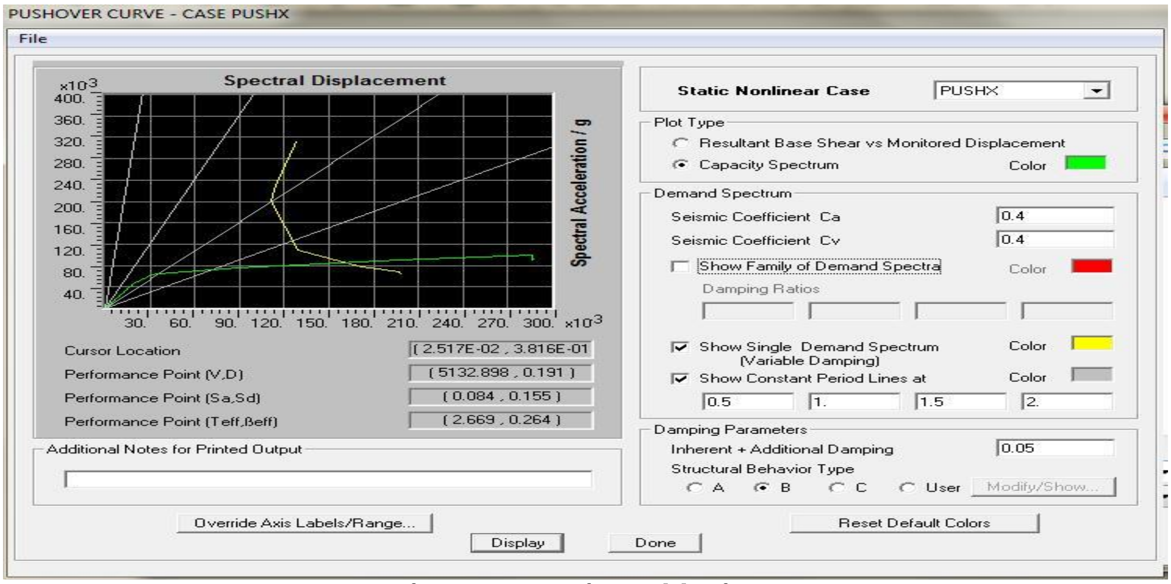

Figure:33 Performance point for Model-1 from ETAB 9.7.4

4.5 Performance levels

Table13: Data for Peformance levels for 10 storey building Model-1

Step	*Displacement*	*Base Force*	*A-B*	*B-IO*	*IO-LS*	*LS-CP*	*CP-C*	*C-D*	*D-E*	*>E*	*TOTAL*
0	2.62E-05	0	4338	2	0	0	0	0	0	0	4340
1	0.0246	2839.8311	4010	330	0	0	0	0	0	0	4340
2	0.0408	3968.291	3884	456	0	0	0	0	0	0	4340
3	0.046	4107.5303	3717	480	143	0	0	0	0	0	4340
4	0.1084	4682.0269	3609	163	232	336	0	0	0	0	4340
5	0.2441	5418.3188	3542	126	154	488	0	30	0	0	4340
6	0.3595	5906.5449	3542	126	154	476	0	0	42	0	4340
7	0.3595	5358.1396	3542	126	154	466	0	10	42	0	4340
8	0.3615	5423.0996	3542	126	154	466	0	0	52	0	4340
9	0.3338	2407.7725	4340	0	0	0	0	0	0	0	4340

Table14: Data for Peformance levels for 10 storey building Model-2

Displacement	*Base Force*	*A-B*	*B-IO*	*IO-LS*	*LS-CP*	*CP-C*	*C-D*	*D-E*	*>E*	*TOTAL*
2.58E-05	0	4241	3	0	0	0	0	0	0	4244
0.0236	2602.5703	3977	267	0	0	0	0	0	0	4244
0.0364	3563.0684	3861	383	0	0	0	0	0	0	4244
0.0437	3832.4939	3734	510	0	0	0	0	0	0	4244
0.0787	4295.6494	3566	198	234	246	0	0	0	0	4244
0.2109	5130.2783	3488	163	131	462	0	0	0	0	4244
0.3347	5679.7065	3472	151	106	488	0	27	0	0	4244
0.3601	5780.4019	3472	151	106	480	0	0	35	0	4244
0.3406	3491.0718	4244	0	0	0	0	0	0	0	4244

Table15: Data for Performance levels for 10 storey building Model-3

Step	*Displacement*	*Base Force*	*A-B*	*B-IO*	*IO-LS*	*LS-CP*	*CP-C*	*C-D*	*D-E*	*>E*	*TOTAL*
0	2.46E-05	0	4241	3	0	0	0	0	0	0	4244
1	0.0254	2770.2466	3933	311	0	0	0	0	0	0	4244
2	0.0397	3704.5022	3846	398	0	0	0	0	0	0	4244
3	0.0444	3876.3352	3618	208	418	0	0	0	0	0	4244
4	0.1666	4772.3354	3506	174	168	396	0	0	0	0	4244
5	0.2909	5356.1021	3486	127	176	448	0	7	0	0	4244
6	0.3539	5606.5405	3486	127	176	428	0	3	24	0	4244
7	0.35	4985.7607	4244	0	0	0	0	0	0	0	4244

V. Conclusion

1. The results obtained in terms of pushover demand, capacity spectrum gave an insight into the real behaviour of structures.
2. The model with soft storey having greater storey drift rather than the model without soft storey.
3. The overall performance level for G+9 storey Building Models were found between B-IO.
4. The performance point is determined for G+9 storey Building Model-1 in PUSH X direction at S_a = 0.084,S_d = 0.155.
5. Storey Shear obtained from pushover analysis is much more greater than storey shear obtained from equivalent static analysis as shown in Table:7
6. Pushover curve is obtained by plotting displacement along X axis and base shear along Y axis which gives the non linear behaviour of considered model as shown in fig.27
7. Capacity of building is determined by capacity spectrum analysis.

REFERENCES

Journal Papers:

[1] Applied Technology Council (ATC-40) (1996) prepared a report on Seismic evaluation and retrofit of concrete buildings sponsored by California Safety Commission.

[2] Ashraf Habibullah and Stephen Pyle, (Published in Structure Magazine, Winter, 1998)"Practical Three Dimensional Nonlinear Static Pushover Analysis".

[3] Federal Emergency Management Agency (FEMA 273) NEHRP GUIDLINES (1997) developed a set of technically sound, nationally applicable guidelines (with commentary) for the seismic rehabilitation of buildings.

[4] Federal emergency management agency (FEMA 356), Nov 2000, is a report on Prestandard and commentary for the seismic rehabilitation of buildings prepared by American society of civil engineers.

[5] IS 1893-2002(Part-1), "Criteria for Earthquake resistant design of structures", General provisions and buildings, Bureau of Indian Standards, New Delhi.

[6] Mrugesh D. Shah and Sumant, B. Patel, "Non-linear static Analysis of R.C. Frames", (2011).

[7] L. Teresa Guevara-Perez, Journal paper on "Soft Story" and "Weak Story" in Earthquake Resistant Design: A Multidisciplinary Approach

[8] Amit V. Khandve, International Journal on " Seismic Response of RC Frame Buildings with Soft Storeys"

[9] Susanta Banerjee , International Journal on "Inelastic Seismic Analysis of Reinforced Concrete Frame Building with Soft Storey "

[10] M.R. Amin ,prepared a journal on "Effect of soft storey on multistoried reinforced concrete building frame"