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PERFORMANCE BASED EVALUATION OF RCC BUILDING WITH DUAL SYSTEM

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ABSTRACT

Building performance is an indicator of how well a structure supports the defined needs of its users. Acceptable performance indicates acceptable (or tolerable) levels of damage or condition that allow uninterrupted facility operation. Consequently, performance-based design is the process or methodology used by design professionals to create buildings that protect functionality and the continued availability of services.

In this Paper a 10 story building is designed using E-tabs software and a nonlinear static analysis is carried out using point plastic hinge model. The designed building was modelled and the hinges or possible failure locations were assigned. The stiffness of the building was increased due to the slab present and this was incorporated in the model using diaphragm. And finally the building is Evaluated as per its performance as per FEMA guidelines.

Keywords: Building performance, performance-based design, nonlinear static analysis, FEMA guidelines.

1. INTRODUCTION

With an aim to communicate the safety-related decisions, the design practice is focused on the predictive method of assessing potential seismic performance, known as performance-based seismic design. PBSD is a generalized design philosophy in which design criteria are expressed in terms of achieving stated performance objectives when the structure is subjected to the stated levels of seismic hazard. PBSD permits the design and construction of buildings with a realistic and reliable understanding of the risk to life, occupancy, and economic loss that may occur because of future seismic events.

Seismic hazard and Damage state are the two essential parts of a Performance Objective. Seismic performance is described by designating the maximum allowable damage state (performance level) for an identified seismic hazard (earthquake ground motion). The various Performance levels are described below.

Performance level	Performance description
Fully operational	Continuous service, negligible damage
Operational	Safe for occupancy, light damage, repairs for Non-essential operation
Life safety	Moderate damage, life safety protection, repair may be possible but impractical
Near collapse	Severe damage, collapse prevented, falling Non-structural elements
Collapse	

2. MATERIALS AND MODELLING

Methodology

1. Carry out literature review to understand the PBSD philosophy.
2. Prepared a Structural framing floor plan in AUTOCAD.
3. Model the building in ETABS 2017 as per Indian earthquake codes (static earthquake model and then convert it into dynamic earthquake model).
4. Analysis of the building using Dynamic analysis approach.
5. Develop Non-linear hinge properties for each frame section.

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6. Analysis of the building Non-linear Static analysis approach.
7. Analyze the results.
8. Evaluate the performance of the structure as per FEMA guidelines.

Modeling

Building description

1. Type of building: Residential building
2. Nos. of buildings: 1
3. Nos. floors: Ground floor + 10 floors + terrace
4. Floor heights: 2.9 m
5. Base dimension of building: 40 m X 24 m
6. Total height of building (Above ground): 34.8 m
7. Aspect Ratio (Height / width): 1.45

Structural Elements

1. The building is designed as per Indian earthquake codes using Dynamic Response Spectrum Analysis.
2. Modal participation of the building is checked.
3. Torsion of the building is under control.
4. Steel percentages in beam, columns and shear walls are under the limit given by IS 456:2000 and IS 1893:2016.

Structural Element	Cross section (mm x mm)
Beam	150 x 500 230 x 600 230 x 700
Column	300 x 600 300 x 800 300 x 900
Shear Wall	230 mm thk 300 mm thk

Structural system

1. Horizontal Floor System – Beam & slabs
2. Lateral load resisting system – Special M.R. Frames with ductile shear walls (Dual system)

Material properties

Material Properties		
Sr. No.	Design Parameter	Value
1	Unit weight of concrete	25 kN/m3
2	Characteristic Strength of concrete	40 MPa
3	Characteristic Strength of Steel	500 MPa
4	Damping ratio	5%

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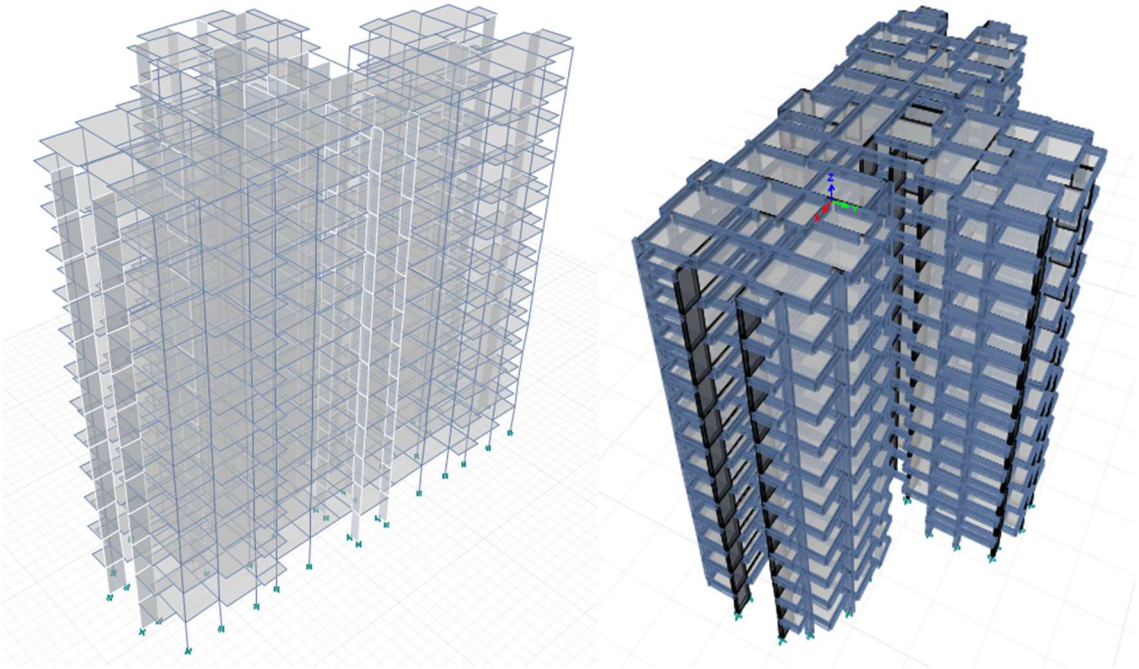

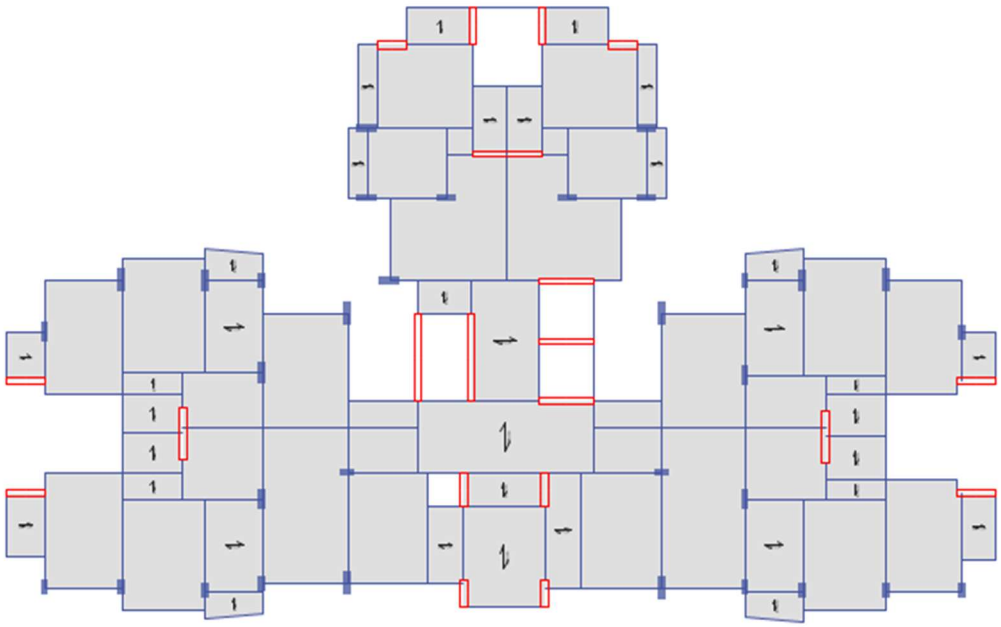

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Pushover loads

1. **Loads for DESIGN BASED EARTHQUAKE (DBE)**

Story	Load (Kn) in X direction	Load (Kn) in Y direction
Terrace	1075.55	925.44
10th	934.48	801.82
9th	772.3	662.66
8th	625.56	536.76
7th	494.27	424.10
6th	378.42	324.74
5th	278.02	238.56
4th	193.07	165.67
3rd	123.56	106.00
2nd	69.50	59.64
1st	30.89	26.50
Ground	7.72	6.60

2. **Loads for MAXIMUM CONSIDERED EARTHQUAKE (MCE)**

Story	Load (Kn) in X direction	Load (Kn) in Y direction
Terrace	2151.10	1850.88
10th	1863.96	160.64
9th	1544.60	1325.30
8th	1251.12	1073.52
7th	998.540	848.214
6th	756.854	649.48
5th	556.056	477.12
4th	386.14	331.34
3rd	247.12	212.0
2nd	139.00	119.28
1st	61.78	53.00
Ground	15.44	13.24

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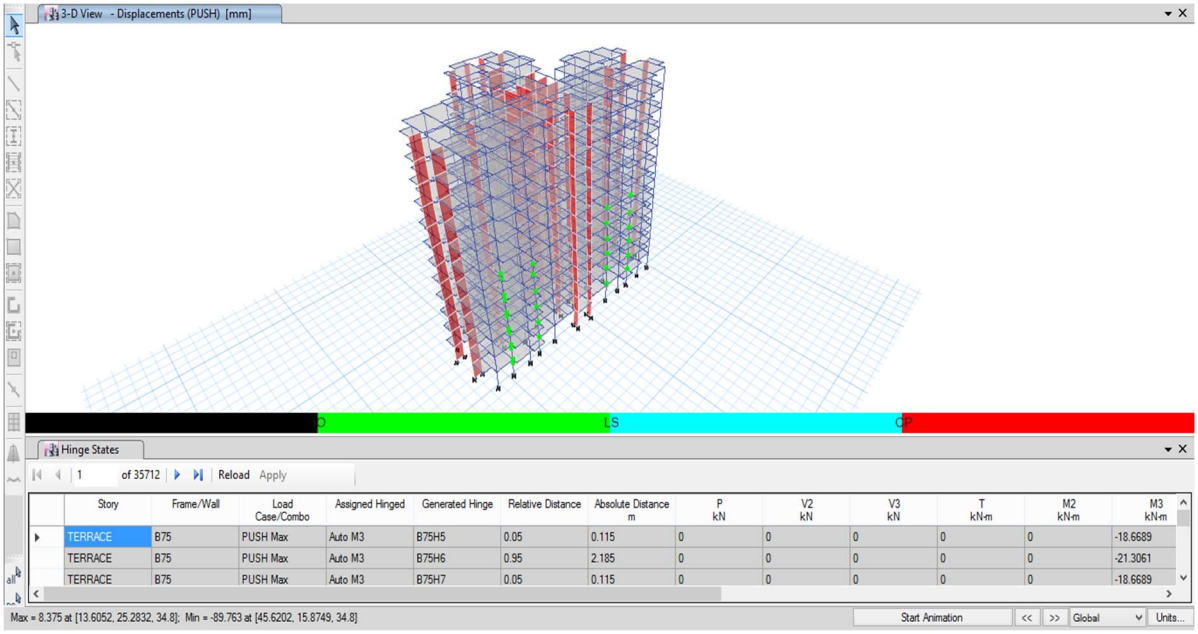
3. RESULTS AND DISCUSSION

Hinge results DBE -X



		Story Drift Ratio		Story Displacement	
Story	Elevation	X-Dir	Y-Dir	X-Dir	Y-Dir
TERRACE	34.8	0.0017623	0.000122	89.763	10.14
10	31.9	0.0020058	0.000161	84.643	9.785
9	29	0.0023249	0.000214	78.814	9.315
8	26.1	0.0026528	0.000261	72.055	8.693
7	23.2	0.0029477	0.000301	64.342	7.935
6	20.3	0.0031780	0.000338	55.77	7.06
5	17.4	0.0033160	0.000372	46.528	6.077
4	14.5	**0.0033338**	0.000398	36.883	4.996
3	11.6	0.0032046	0.000408	27.184	3.839
2	8.7	0.0028872	0.000395	17.858	2.655
1	5.8	0.0022702	0.000350	9.454	1.506
GR	2.9	0.0009756	0.000169281	2.843	0.491
BASE	0	0	0	0.000003555	7.234E-07

1. All beams and shear walls are in Fully Operational levels.
2. Some beams and columns in lower story are in Immediate Occupancy (Operational).
3. Max story drift is 0.0033 in x dir.
4. Max story displacement is 89.763mm in x dir.

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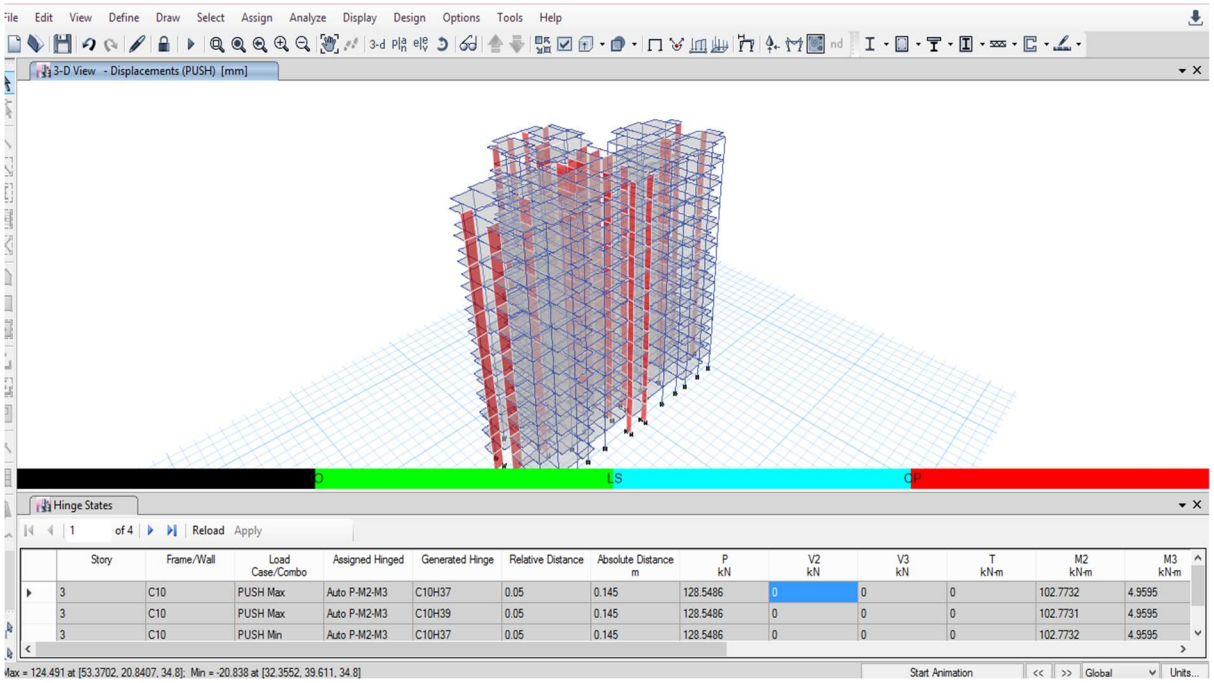
Hinge results DBE -Y



		Story Drift Ratio		Story Displacement	
Story	Elevation	X-Dir	Y-Dir	X-Dir	Y-Dir
TERRACE	34.8	0.00037	0.00227	28.0713	124.4913
10	31.9	0.00047	0.00265	26.92616	117.9063
9	29	0.00060	0.00315	25.48454	110.19731
8	26.1	0.00075	0.00366	23.64040	101.06074
7	23.2	0.00088	0.00413	21.36365	90.425901
6	20.3	0.00099	0.00449	18.68750	78.437409
5	17.4	0.00106	0.00471	15.69030	65.396756
4	14.5	0.00108	0.00474	12.47843	51.719017
3	11.6	0.00105	0.00456	9.194208	37.945653
2	8.7	0.00095	0.00408	6.007178	24.714560
1	5.8	0.00072	0.00312	3.129544	12.877478
GR	2.9	0.000304	0.001318	0.922332	3.820975
BASE	0	0	0	8.89428E-07	4.93212E-0

1. All beams, columns and shear walls are in Fully Operational levels.
2. Max story drift is 0.0047 in y dir.
3. Max story displacement is 124.5 mm in y dir.

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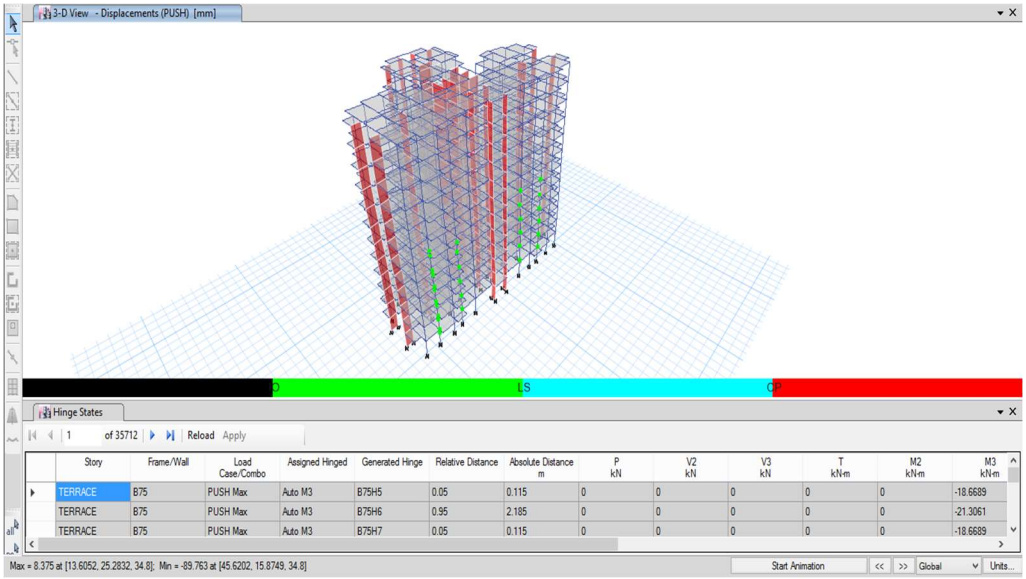
Hinge results MCE -X loads



		Story Drift Ratio		Story Displacement	
Story	Elevation	X-Dir	Y-Dir	X-Dir	Y-Dir
TERRACE	34.8	0.00199	0.000125	-98.205	-1.171
10	31.9	0.002265	0.000165	-92.535	-1.11
9	29	0.002631	0.000219	-86.152	-1.046
8	26.1	0.003014	0.000269	-78.769	-0.965
7	23.2	0.003365	0.00032	-70.336	-0.869
6	20.3	0.003644	0.000369	-60.944	-0.757
5	17.4	0.003816	0.000412	-50.8	-0.633
4	14.5	0.003848	0.000443	-40.209	-0.501
3	11.6	0.003709	0.000453	-29.565	-0.367
2	8.7	0.003346	0.000439	-19.339	-0.24
1	5.8	0.002621	0.000386	-10.155	-0.126
GR	2.9	0.001117	0.000185	-3.016	-0.037
BASE	0	0	0	0	0

1. All beams and shear walls are in Fully Operational levels.
2. Some columns in lower story are in Immediate Occupancy (Operational).
3. One column fails or lies in Collapse prevention level (near collapse)
4. Max story drift is 0.0038 in y dir.
5. Max story displacement is 98.02 mm in y dir.

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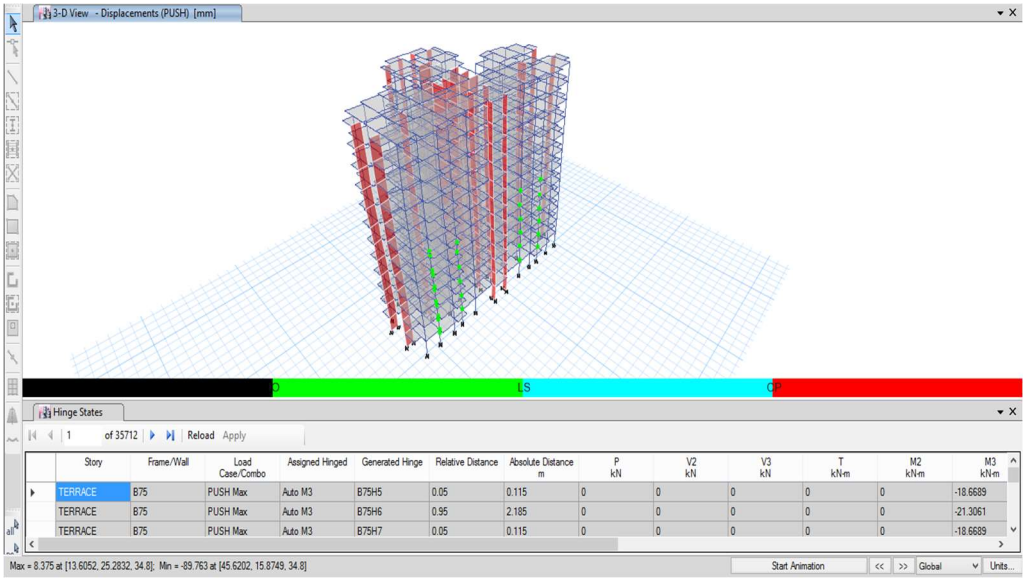
Hinge results MCE -Y loads



		Story Drift Ratio		Story Displacement	
Story	Elevation	X-Dir	Y-Dir	X-Dir	Y-Dir
TERRACE	34.8	0.000378	0.002271	28.072	124.492
10	31.9	0.000476	0.002658	26.927	117.907
9	29	0.000609	0.003151	25.485	110.198
8	26.1	0.000751	0.003667	23.641	101.062
7	23.2	0.000883	0.004134	21.364	90.427
6	20.3	0.00099	0.004497	18.688	78.438
5	17.4	0.001061	0.004717	15.69	65.397
4	14.5	0.001084	0.004749	12.479	51.719
3	11.6	0.001052	0.004562	9.194	37.946
2	8.7	0.00095	0.004082	6.007	24.715
1	5.8	0.000729	0.003123	3.13	12.878
GR	2.9	0.000304	0.001318	0.922	3.821
BASE	0	0	0	8.894E-07	0.000004932

1. All beams and shear walls are in Fully Operational levels.
2. Some columns in lower story are in Immediate Occupancy (operational).
3. Max story drift is 0.0047 in y dir.
4. Max story displacement is 124 mm in y dir.

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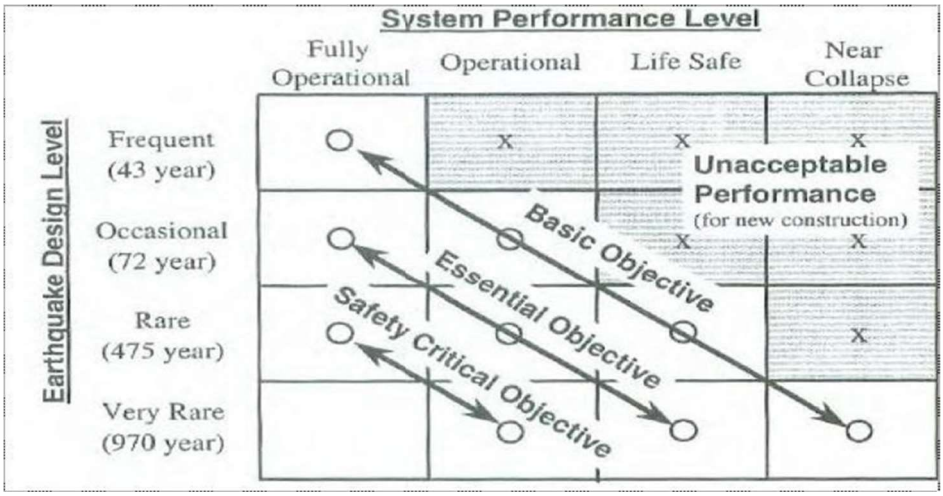
4. SUMMARY AND CONCLUSIONS

- In the present study a Residential building is designed as per Indian standard i.e. IS 456:2000 and IS 1893:2016 using an industrially trusted Software Etabs.
- The main objective of this Project was to check the kind of performance a building can give when designed as per Indian Standards.

- After the designing of the proposed Residential building, literature review was carried about the concepts of Performance Based Design Approach which is quite famous in western countries where an Owner can choose the kind of performance he needs/wants from his building.
- It also helps the Government in setting up laws which makes it compulsory for important public buildings and residential buildings to follow a particular desired Performance Level.
- In Etabs the defining and modeling part was carried out which was followed by Pushover Analysis.
- The following table shows the story drift values and its corresponding performance description.

Performance level	Performance description	Story drift
Fully operational	Continuous service, negligible damage	<0.2 %
Operational	Safe for occupancy, light damage, repairs for Non-essential operation	<0.5 %
Life safety	Moderate damage, life safety protection, repair may be possible but impractical	<1.5 %
Near collapse	Severe damage, collapse prevented, falling Non-structural elements	<2.5 %
Collapse		>2.5 %



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Conclusions

- ❖ Pushover analysis was performed in ETABS v 2017 with default non-linear parameters for DBE and MCE in both the global directions. Following are the important conclusion made from the following study:-
- ❖ The building is stronger in Y direction therefore most of the columns were oriented along X axis giving a fair behavior in fundamental modes of vibrations.
- ❖ Current design makes the building strong enough to remain Fully Operational during DBE and Operational during MCE events.
- ❖ Also by studying the drift ratios of the structure and drift ration limitations given in FEMA we can say that building is in between Fully Operational and Operational level.
- ❖ As per system performance levels given in FEMA, Basic objective of any structure under MCE and DBE is Life safety level.
- ❖ Thus results in this study show that Indian Standard is very conservative in its approach.

- ❖ Performance Based Seismic design, though iterative and requires high computing time, is an excellent alternative to the current design approach which fails to give exact idea of safety.

Final Conclusion

It can be conclude that,

- Code provides same design considerations for all type of buildings (Govt. offices, residential, commercials, public buildings etc.)
- Designer can go out of the boundaries laid by codes to design the building as per clients performance requirements and can provide a more economic design than Indian code.
- PBD is an iterative process and does require sophisticated computing power. POA takes lot of time and does depend upon computational power of the machine.
- Hence a considerable rise in Structural Designers remuneration is required to promote the use of PBD in practice.

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