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Performing Pushover Analysis on High Rise Building With and Without Shear Wall

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Abstract - *Currently the seismic design of reinforced concrete structure is subjected to a concern earthquake are the only natural disasters that may wipe out human life and financial source. by doing response spectrum method to a structure subjected to a static loading. The RC shear walls are better used in the structure to reduce the lateral forces occurring due to the earthquake in tall structures. The behavior of RC shear wall structure is significantly influenced by distributing stiffness and the mass of the building and the soil structures.In this study RC frame models with and without shear wall are subjected to the pushover analysis. To track the ultimate yield point and the targeted displacement and performance point as well. Structure is symmetrical with 5 bays in X direction and 5 bays in Y direction area of the building is (25m X 25m). The models are Bare frame, shear wall at centre ,Shear wall at Exterior and lastly Shear wall at corners these models are analyzed in Etab's 2017 software and the results are determined and compared with each one of the models*

Key Words: *seismic design*, Pushover Analysis, non-linear Static Analysis ,Hinges

1.INTRODUCTION

Any structure that is subjected to seismic loading needs extensive knowledge of how the structure will behave under significant in elastic deformation. Unlike, seismic loads behave differently understanding the behavior of inelastic deformation is necessary to predict structural behavior under seismic loads. Pushover analysis also known as non-linear static analysis is a process used to assess structures loaded beyond their elastic range. The non-linear static push over analysis approach has recently gained precise knowledge to the introduction of performance based design. In a static non-linear process know as push over analysis the amount of structural loading is gradually increasing in the lateral direction according to a predetermined pattern.

The results that can be seen in form of storey forces or displacement or fundamental mode shapes form and it is considered that how modes controls the structure behave. The non-linear behavior of various structural elements by this we come to an consideration that by doing the pushover analysis analysis it show the weak links in the members so that members can be retrofitted by increasing the reinforcement to that members. This analysis is done by many softwares such as Etabs,Staad Pro etc..

1.1 Discription of Pushover Analysis

Pushover analysis also known as non-linear static analysis, has been created over the past 2 decades and has grown to be a prominent analytical method for fast style and unstable performance analysis because it is a comparably simple process. The (FEMA 356, 440, ETC) and (ATC-40) are the two organizations that are developed and advocated for the non-linear static analysis, also called as the pushover analysis which is done as per the American standards. As non- linear static analysis is a procedure for simplified non-linear methods to estimate the seismic behavior of the structure at what force the structure is deformed. These non linear method is an incremental static method which is used generally to determine capacity curve or the demand capacity curve which shows the results in prescribed pattern of the structure. Such that pushing a structure by applying the laterals loads and the controlled displacement at each floor, until the structure reaching to its ultimate condition or at the collapse prevention condition. Push over analysis procedure which helps us to find the weak links in the beams and columns

1.2 Types of Pushover Analysis

- **DCM**
- **CSM**

(DCM) Displacement Co-efficient Method: This method is used to calculate the targeted displacement of the member in the structure.

(CSM) Capacity Spectrum Method: This method is used to calculate the performance point of building at what amount the building is displaced from its origin

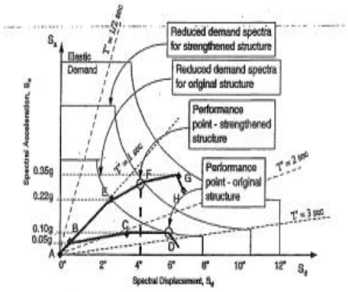


Fig 1.2.1 DCM

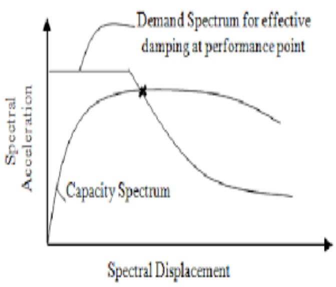


Fig 1.2.2 CSM

2. 1.3 Plastic Hinges

Plastic hinges are the hinges in the structure where the structural element acts in an inelastic behavior. By simply adding the concentrated plastic hinges in the structure for beams, columns and the walls. Elastic behavior happens over the length of the member and the deformation within the elastic limit occurs entirely on the structure. By integrating the plastic strain and the plastic curvature at intervals hinges defined at a length. In the structure distant from 0.1% to 0.9% hinges were created on each member of the structure. A set of hinges can be described to represent plasticity that is spread along the length, many hinges can be located at a same spot. Deformation may occur due to force and the displacement on the model. Below figures shows operational levels and the hinges created on each floor

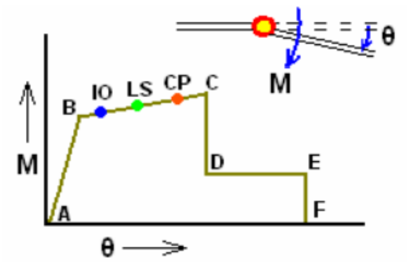


Fig 1.1 Building Performance level

Acceptance Criteria

IO- Immediate Occupancy

LS- Life Safety

CP- Collapse Prevention

2.0 Description of the building

For the purpose of design, multistory structure is considered with G+15 storeys having a dimension of 25mX25m.Thickness of slab is considered 150mm throughout the analysis. Floor height is considered 3m.Columns and Beams are described in below table. The dead load is 1 kN/m² and live load 2kN/m² .For the seismic analysis ,the structure is considered in zone V ,importance factor is taken 1 and soil type is taken as medium.The shear wall systems with various configuration are located having width of 200mm all over the design.

Sl No	Discription	
1	No of Storey	G+15
2	Typical Floor Height	3m
3	Ground Floor Height	3m
4	Plan Dimension	25*25m
5	Beam Size	0.3*0.45m
6	Column Size	0.4*0.4m
7	Thickness of Slab	0.15m
8	Concrete Grade	M25
9	Rebar Grade	Fe500
10	Thickness of Shear Wall	200mm
11	Floor Finish	1kN/m²
12	Live load	2kN/m²
13	Seismic load as per IS	1893-2016
14	Importance Factor	1
15	Zone	V

2.1 Methodology

- Finalizing the structure. Analysing and design the model firstly with response spectrum to check whether all members are passing
- After analyzing the model. Adding the load cases to the structure and changing the dead load to the non-linear static from there method will start working
- After that adding the cases for Push-X and Push-Y as a non linear static analysis by giving load cases on it
- Applying the hinge properties to members of the structures i.e beams and columns and walls
- Assigning the hinges properties to the members distant from 0.1% to 0.9% on each member
- After the hinges. Hinge over write should be done it will divide it in 0.1
- Run analysis is done only on dead load ,Push-X, Push-Y rest all loads do not Run
- Checking the hinges that are created at each step of the members
- Check the story responses and the capacity curve
- Hinge curves

2.2 MODELS

BARE FRAME

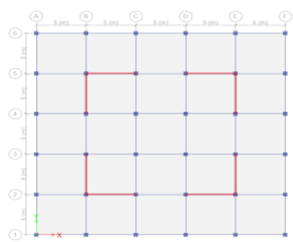


Fig 2.2.1 Plan View

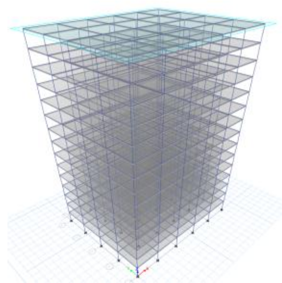


Fig 2.2.2 3D Model

SHEAR WALL AT CENTRE

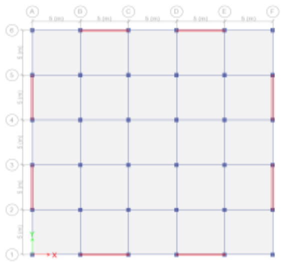


Fig 2.2.3 Plan View

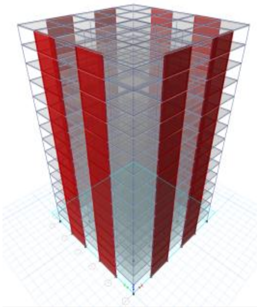


Fig 2.2.4 3D Model

SHEAR WALL AT EXTERIOR

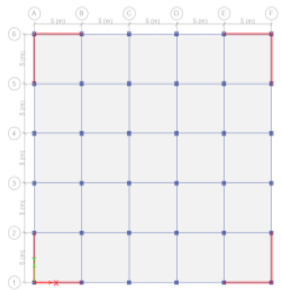


Fig 2.2.5 Plan View

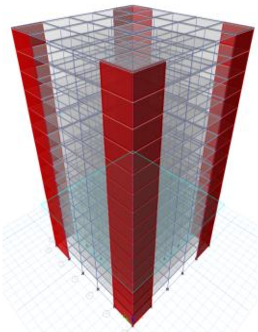


Fig 2.2.6 3D model

SHEAR WALL AT CORNER

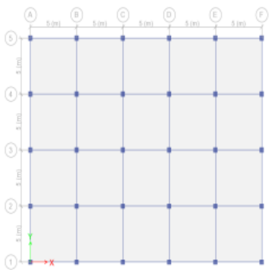


Fig 2.2.7 Plan view

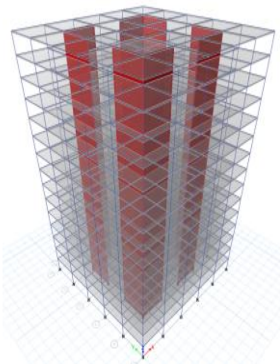
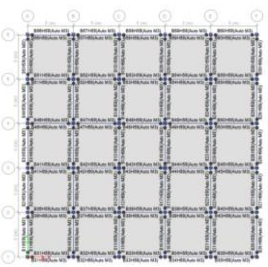
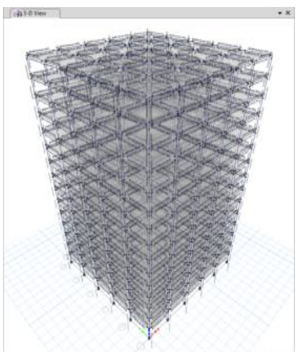


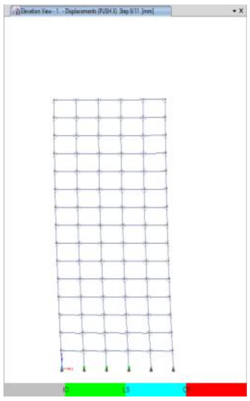
Fig 2.2.8 3D Model

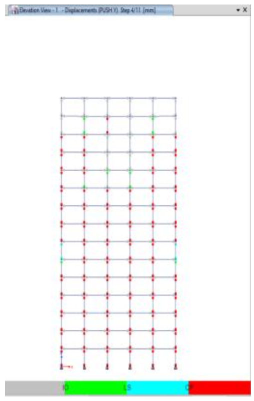
2.3 HINGES





Hinges formartion on each member of the structure from a distant of 0.1% to 0.9% by this weak links can be determined





Above figures shows the formation of hinges in both the direction X and Y same as for all 3 models with Shear wall

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO
	mm	kN						
0	0	0	5760	0	0	0	0	5760
1	-0.0003006	4052.661	5756	4	0	0	0	5760
2	-0.0003869	5568.145	5500	260	0	0	0	5760
3	-0.0004022	6077.88	5364	396	0	0	0	5760
4	-0.0004052	6238.607	5332	428	0	0	0	5760
5	-0.0004082	6582.483	5248	512	0	0	0	5760
6	-0.0004127	6655.358	5232	528	0	0	0	5760
7	-0.0004131	6666.689	5224	536	0	0	0	5760
8	-0.0004132	6676.689	5220	540	0	0	0	5760
9	-0.0004132	6677.321	5220	540	0	0	0	5760
10	-0.0004133	6687.597	5212	548	0	0	0	5760
11	-0.0004133	6697.859	5212	548	0	0	0	5760
12	-0.0004133	6697.86	5212	548	0	0	0	5760

X- Direction

Step	Monitored Displ	Base Force	A-B	B-C	C-D	D-E	>E	A-IO
	mm	kN						
0	0	0	5760	0	0	0	0	5760
1	-30	1294.7676	5760	0	0	0	0	5760
2	-60	2589.5353	5760	0	0	0	0	5760
3	-90	3884.3029	5760	0	0	0	0	5760
4	-93.901	4052.6608	5756	4	0	0	0	5760
5	-125.893	5415.8834	5556	204	0	0	0	5760
6	-156.416	6660.6683	5224	536	0	0	0	5760
7	-187.977	7889.0307	4956	804	0	0	0	5760
8	-219.903	9064.13	4804	956	0	0	0	5756
9	-253.763	10195.151	4656	1104	0	0	0	5736
10	-283.832	11161.49	4496	1260	4	0	0	5684
11	-300	11643.907	4380	1368	12	0	0	5684

Y-Direction

2.4 RESULTS IN TABLE

Story	Load Case	MODEL 1 BARE FRAME kN	MODEL 2 SW @ CENTRE kN	MODEL 3 SW @ EXTERIOR kN	MODEL 4 SW @ CORNERS kN
15	PUSH-X Max	1290.18	4070.19	3781.82	4070.19
14	PUSH-X Max	1203.77	3796.60	3527.62	3796.60
13	PUSH-X Max	1117.47	3523.30	3273.68	3523.30
12	PUSH-X Max	1031.16	3250.00	3019.74	3250.00
11	PUSH-X Max	944.86	2976.69	2765.79	2976.69
10	PUSH-X Max	858.56	2703.39	2511.85	2703.39
9	PUSH-X Max	772.26	2430.09	2257.91	2430.09
8	PUSH-X Max	685.96	2156.78	2003.97	2156.78
7	PUSH-X Max	599.65	1883.48	1750.03	1883.48
6	PUSH-X Max	513.35	1610.17	1496.09	1610.17
5	PUSH-X Max	427.05	1336.87	1242.15	1336.87
4	PUSH-X Max	340.75	1063.57	988.21	1063.57
3	PUSH-X Max	254.45	790.26	734.27	790.26
2	PUSH-X Max	168.14	516.96	480.33	516.96
1	PUSH-X Max	81.84	243.66	226.39	243.66

Table 1.1 Storey Forces in X-Direction

Story	Load Case	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		BARE FRAME kN	SW @ CENTRE kN	SW @ EXTERIOR kN	SW @ CORNERS kN
15	PUSH-Y Max	4038.29	3801.15	3605.59	3801.15
14	PUSH-Y Max	3767.83	3545.65	3363.23	3545.65
13	PUSH-Y Max	3497.70	3290.41	3121.12	3290.41
12	PUSH-Y Max	3227.57	3035.17	2879.02	3035.17
11	PUSH-Y Max	2957.44	2779.93	2636.91	2779.93
10	PUSH-Y Max	2687.32	2524.69	2394.80	2524.69
9	PUSH-Y Max	2417.19	2269.46	2152.70	2269.46
8	PUSH-Y Max	2147.06	2014.22	1910.59	2014.22
7	PUSH-Y Max	1876.93	1758.98	1668.48	1758.98
6	PUSH-Y Max	1606.81	1503.74	1426.38	1503.74
5	PUSH-Y Max	1336.68	1248.50	1184.27	1248.50
4	PUSH-Y Max	1066.55	993.26	942.16	993.26
3	PUSH-Y Max	796.42	738.03	700.06	738.03
2	PUSH-Y Max	526.29	482.79	457.95	482.79
1	PUSH-Y Max	256.17	227.55	215.84	227.55

Table 1.2 Storey Forces in Y-Direction

Story	Load Case	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		BARE FRAME mm	SW @ CENTRE mm	SW @ EXTERIOR mm	SW @ CORNERS mm
15	PUSH-X Max	30.02	30.05	30.03	30.051
14	PUSH-X Max	29.57	27.95	28.32	27.95
13	PUSH-X Max	28.90	25.82	26.48	25.818
12	PUSH-X Max	27.99	23.63	24.56	23.629
11	PUSH-X Max	26.84	21.37	22.52	21.371
10	PUSH-X Max	25.44	19.05	20.35	19.052
9	PUSH-X Max	23.80	16.69	18.07	16.69
8	PUSH-X Max	21.92	14.30	15.68	14.304
7	PUSH-X Max	19.80	11.93	13.23	11.925
6	PUSH-X Max	17.45	9.59	10.75	9.591
5	PUSH-X Max	14.87	7.35	8.30	7.347
4	PUSH-X Max	12.06	5.25	5.96	5.251
3	PUSH-X Max	9.02	3.37	3.83	3.371
2	PUSH-X Max	5.77	1.79	2.03	1.794
1	PUSH-X Max	2.42	0.63	0.69	0.626

Table 1.3 Storey Displacements in X-Direction

Story	Load Case	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		BARE FRAME mm	SW @ CENTRE mm	SW @ EXTERIOR mm	SW @ CORNERS mm
15	PUSH-Y Max	93.93	28.05	28.62	28.052
14	PUSH-Y Max	92.55	26.09	26.99	26.087
13	PUSH-Y Max	90.46	24.10	25.24	24.097
12	PUSH-Y Max	87.61	22.05	23.41	22.053
11	PUSH-Y Max	84.00	19.95	21.47	19.945
10	PUSH-Y Max	79.62	17.78	19.40	17.781
9	PUSH-Y Max	74.49	15.58	17.22	15.575
8	PUSH-Y Max	68.61	13.35	14.95	13.348
7	PUSH-Y Max	61.98	11.13	12.61	11.128
6	PUSH-Y Max	54.62	8.95	10.24	8.949
5	PUSH-Y Max	46.53	6.86	7.91	6.855
4	PUSH-Y Max	37.73	4.90	5.68	4.899
3	PUSH-Y Max	28.23	3.15	3.65	3.145
2	PUSH-Y Max	18.07	1.67	1.93	1.674
1	PUSH-Y Max	7.56	0.58	0.66	0.584

Table 1.4 Storey Displacements in Y-Direction

Story	Load Case	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		BARE FRAME	SW @ CENTRE	SW @ EXTERIOR	SW @ CORNERS
		kN/mm²	kN/mm²	kN/mm²	kN/mm²
15	PUSH-X Max	42.97	135.44	125.93	135.44
14	PUSH-X Max	40.71	135.84	124.56	135.84
13	PUSH-X Max	38.67	136.47	123.61	136.47
12	PUSH-X Max	36.84	137.54	122.94	137.54
11	PUSH-X Max	35.21	139.29	122.81	139.29
10	PUSH-X Max	33.75	141.90	123.41	141.90
9	PUSH-X Max	32.45	145.60	124.96	145.60
8	PUSH-X Max	31.29	150.78	127.77	150.78
7	PUSH-X Max	30.28	157.94	132.30	157.94
6	PUSH-X Max	29.42	167.88	139.20	167.88
5	PUSH-X Max	28.72	181.96	149.66	181.96
4	PUSH-X Max	28.27	202.55	165.72	202.55
3	PUSH-X Max	28.21	234.43	191.67	234.43
2	PUSH-X Max	29.13	288.16	236.85	288.16
1	PUSH-X Max	33.87	389.23	326.69	389.23

Table 1.5 Storey Stiffness in X-Direction

Story	Load Case	MODEL 1	MODEL 2	MODEL 3	MODEL 4
		BARE FRAME	SW @ CENTRE	SW @ EXTERIOR	SW @ CORNERS
		kN/mm²	kN/mm²	kN/mm²	kN/mm²
15	PUSH-Y Max	42.99	135.50	125.97	135.50
14	PUSH-Y Max	40.71	135.92	124.60	135.92
13	PUSH-Y Max	38.67	136.55	123.64	136.55
12	PUSH-Y Max	36.84	137.63	122.98	137.63
11	PUSH-Y Max	35.21	139.38	122.85	139.38
10	PUSH-Y Max	33.75	141.99	123.45	141.99
9	PUSH-Y Max	32.45	145.71	125.00	145.71
8	PUSH-Y Max	31.29	150.90	127.82	150.90
7	PUSH-Y Max	30.28	158.07	132.35	158.07
6	PUSH-Y Max	29.42	168.03	139.27	168.03
5	PUSH-Y Max	28.73	182.13	149.72	182.13
4	PUSH-Y Max	28.27	202.75	165.82	202.75
3	PUSH-Y Max	28.22	234.67	191.74	234.67
2	PUSH-Y Max	29.13	288.40	237.03	288.40
1	PUSH-Y Max	33.90	389.64	327.04	389.64

Table 1.6 Storey Stiffness in Y-Direction

2.4. PUSHOVER ANALYSIS GRAPHS

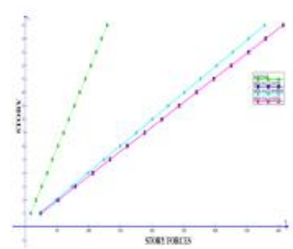


Fig 2.4.1 Push forces in x direction

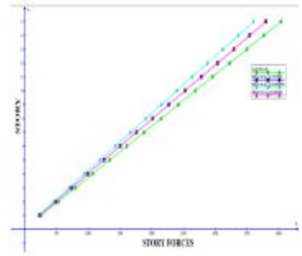


Fig 2.4.2 Push Forces in Y Direction

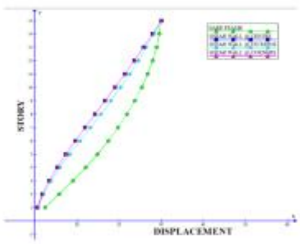


Fig 2.4.3 Push Displacement in X direction

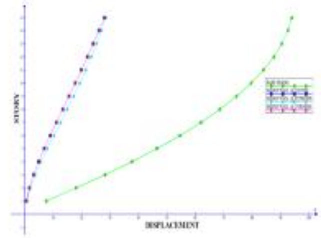


Fig 2.4.3 Push Displacement in X direction

Table 1.7 Base Shear Vs Targeted Displacement

MODELS	BASE SHEAR	TARGETED
		DISPLACEMENT IN
	kN	mm
MODEL 1	11623.21	340.21
MODEL 2	12032.07	279.54
MODEL 3	8639.37	329.07
MODEL 4	8727.32	314.73

2.5 RESULTS AND DISCUSSION

As we have seen that the resistance of horizontal forces or lateral forces are more on the structure to reduce such forces on the structure the shear wall are used to reduce the upcoming forces on the structure.

As we know that most of the forces are resisted by the shear wall to increase the stiffness and decrease the displacement of the structure. As a structural Engineer need to determine the better positioning of the shear wall in the structure.

Before doing the pushover analysis the structure is analyzed by the response spectrum method to applying all the earthquake loads on the structure in both the bays of X and Y direction of the structure.

The models which are modeled in the Etab's software are (Bare Frame ,Shear Wall at Centre SW1,Shear Wall at Exterior SW2,and lastly Shear wall at Corners SW3 where height of the shear wall is maintained as per the height of the structure which is 45m in all structure .

All the transitional values are taken from the software and prepared a Excel sheet for Story forces , story displacement ,story stiffness and the natural time period were observed by comparing all the models forces are in increasing in rest 3 models because of shear wall by that coming to a point the stiffness is increasing and displacement is decreasing as per our models the base shear is more in the model 2 and displacement is less.

This work shows that the results which are obtained for G+15 multistory building understanding the behavior of the model which are subjected to the DL+LL and the load combination are response are taken as output

The percentage variation from model to model story forces are more in model 2 7% as compared with other 3 models

The percentage of stiffness is more in model 2 10% and the displacement is more in model 1 70%

The results of the models are concluded that the base shear is more in model 2 and displacement is also less

It is concluded that the Shear wall at Centre is better positioning in the building which reduces the maximum lateral forces and the structure will behave more stiff in the seismic zones.

3. CONCLUSIONS

As the study of the all literature we come to an understand how the behavior occurs due to non linear static analysis .Pushover Analysis is a non linear analysis which is used to calculate the seismic behavior of the structure by applying the hinges to the beams, columns and walls by intersecting demand curve and capacity curve

Providing the shear wall is the most important point in the building which reduces the maximum lateral forces in the building .Models with and without shear walls the comparison with RC Frame with shear wall structure seemed to better perform in major seismic. With this project we concluded that model 2 shear wall at Centre is the best place to install in the RC structure.

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