Pushover Analysis of G+13 Building With Soft Storey At Different Level

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Abstract- *Earthquakes have resulted in enormous destruction of life and property in couple of decades all around the globe, including India. The major factor contributing to this destruction is attributable to failure of structures due to earthquakes. Responsiveness is now being given to the assessment of the sufficiency of strength in framed RCC structures to resist solid ground motions. The seismic reaction of RCC building frame in terms of performance point and the earthquake forces on Reinforced building frame with the help of pushover analysis is carried out in this project. In this method of analysis, a model of the building is exposed to a lateral load. Pushover analysis can afford a substantial insight into the weak links in seismic concert of a structure, and we can know the weak zones in the structure. In this project, effort has been made to investigate the effect of Shear wall n lateral displacement and Base Shear in RCC Frames. RCC Frames with G+13 is considered, one with soft storey and other with normal building in L-shape. The pushover analysis of the RCC building frame is carried out by structural analysis and design software ETABS. Also, comparison of simulation results for models with and without shear wall is included as the part of the project report*

Keywords- Pushover Analysis, ETABS, Soft Storey etc.

I. INTRODUCTION

The term earthquake can be used to describe any kind of seismic event which may be either natural or initiated by humans, which generates seismic waves. Earthquakes are caused commonly by rupture of geological faults; but they can also be triggered by other events like volcanic activity, mine blasts, landslides and nuclear tests. There are many buildings that have primary structural system, which do not meet the current seismic requirements and suffer extensive damage during the earthquake. According to the Seismic zoning Map of IS: 1893-2002, India is divided into four zones on the basis of seismic activities. They are zone II, zone III, zone IV and zone V.

Generally, loads on these structures are only gravity loads and result in elastic structural behaviour. However, under a Strong seismic event, a structure may actually be subjected to forces beyond its elastic limit. Since. To make or attain this objective, simplified linear elastic methods are not suitable. Thus the structural designer has developed a new method of design and seismic procedure that include performance based structure towards nonlinear technique.

Analysis methods are classified as linear static, linear dynamic, nonlinear static and nonlinear dynamic analysis. In these the first two is appropriate only if the structural loads are low and stress strains within elastic limit. During earthquake the structural loading can reach to collapse load and therefore the material stresses are on top of yield stresses. Therefore during this case material nonlinearity and geometrical nonlinearity must to be incorporated into the analysis to acquire good results. Pushover analysis provides simple approach to analyze nonlinear static behavior of the building. So in this paper discus about pushover analysis with the help of performance levels, pushover curve, and pushover analysis procedure.

1.1 OBJECTIVES

- To study the performance of RC plane frames under lateral loads (Earthquake loads).
- To perform Linear Analysis and Non-Linear Analysis.
- To study the performance of R.C.C structure with or without soft storey with respect to Different parameters such as story drift, story displacement, base shear, etc.
- To study the variation of pushover curve for a framed structure with shear wall and for a framed structure with soft storey.

II. LITERATURE REVIEW

Sangeetha.S "Pushover Analysis for Seismic Assessment of RCC Building" (IRJET) Volume: 04 Issue: 06 | June -2017

The rapid discharge of energy in the earth's crust forms seismic waves which arrive at various instance of time with different intensity levels are called as earthquake. It causes the random ground motion in all directions, radiating from epicenter, which causes structure to vibrate due to which induce inertia forces in them. Many existing structures are seismically deficient due to lack of awareness regarding seismic behavior of structures. Due to this, there is vital requirement to converse this situation and do the seismic assessment of existing and proposed structures. The seismic reaction of RCC building frame in terms of performance point and the earthquake forces on Reinforced building frame with the help of pushover analysis is carried out in this project. In this method of analysis, a model of the building is exposed to a lateral load and the force of the lateral load is slowly increased. With the result the series of cracks, yielding, plastic hinge establishment, and failure of numerous structural components is recorded. Pushover analysis can afford a substantial insight into the weak links in seismic concert of a structure, and we can know the weak zones in the structure. In the present study an existing building frame is designed and evaluated as per Indian standard and suggests the recommended retrofitting methods to strengthen the existing structure. The pushover analysis of the RCC building frame is carried out by structural analysis and design software SAP 2000

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This paper highlights the importance of explicitly recognizing the presence of the open first storey in the analysis of the building and for immediate measures to prevent the indiscriminate use of soft first storey in buildings. Alternate measures, involving stiffness balance of the open first storey and the storey above, are proposed to reduce the irregularity introduced by the open first storey. The structural engineering profession has been using the nonlinear static procedure (NSP) or pushover analysis. Modeling for such analysis requires the determination of the nonlinear properties of each component in the structure, quantified by strength and deformation capacities, which depend on the modeling assumptions. Pushover analysis is carried out for either user-defined nonlinear hinge properties or default-hinge properties, available in some programs based on the FEMA-356 and ATC-40 guidelines. This paper aims to evaluate the zone –II selected reinforced concrete building to conduct the non-linear static analysis (Pushover Analysis). The pushover analysis shows the pushover curves, capacity spectrum, plastic hinges, and performance level of the building. This non-linear static analysis gives better understanding and more accurate seismic performance of buildings of the damage or failure element.

III. SYSTEM DEVELOPMENT

Presently three building models of G + 13 has been modeled for RCC, for different position of shear wall situated in zone III with subsoil Type medium -II, having shear wall thickness of 200mm. The modelling is done in ETAB software. All the buildings are subjected to same earthquake loading to check their seismic behavior for same storey and storey height. For the analysis of these models' various methods of seismic analysis are available but for present work both linear static and non-linear static method is used. Details of the methods are as given below.

- **Design Lateral Force at Each Floor in Each Mode :**

$$Qik= Ak\emptyset ikPk\ Wi$$

Where,

Ak = Design horizontal acceleration spectrum value
Øik = Mode shape coefficient at floor i in mode k
Wi = Seismic weight of floor i.
Pk = Modal participation factor .

- **Modal Participation Factor**:

$$\Gamma = \frac{\sum M_n \bar{u}_n}{\sum M_n \bar{u}_n^2}$$

- **Story Shear Force in Each Mode**:

Acting in story i in mode k is given by

$$\mathbf{Vik= \sum Qik}\boldsymbol{nj=i}\mathbf{+1}$$

Story shear force due to all modes considered. The peak story shear force (Vi) in story i due to all modes considered is obtained by combining those due to the individual modes by various methods such as SRSS, CQC or absolute sum method etc.

3.1 Response Spectrum Method

This method is also known as modal method or modal superposition method. The method is applicable to those structures where modes other than the fundamental one significantly affect the response of the structure. In particular, it is applicable to analysis of forces and deformations in multi-story buildings due to medium intensity ground shaking, which causes a moderately large but essentially linear response in the structure. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode using smooth design spectra that are the average of several earthquake motions.

In seismic coefficient method (single mode method), only one mode of vibration was considered. The time period for this mode was obtained in a very simplistic fashion without performing the free vibration analysis. In response spectrum method, the natural periods and mode shapes obtained using free vibration analysis are used to obtain seismic force.

3.2 Push Over Analysis

Pushover analysis is an iterative procedure, looked upon as an alternative for the conventional analysis procedures. Pushover analysis of multi-storied RCC framed buildings subjected to increasing lateral forces is carried out until the desired performance level (target displacement) is reached. The promise of performance based seismic engineering (PBSE) is to produce structures with predictable seismic performance. Pushover analysis is a static non-linear procedure in which the magnitude of the structural loading along the lateral direction of the structure is incrementally increased in accordance with a certain pre-defined pattern. With increase in magnitude of lateral loading, the progressive non-linear behavior of various structural elements is captured, and the weak links and failure modes of the structure are identified. After this progressive post elastic analysis of the structure the designer can make necessary changes in the design configuration to obtained desired plastic hinge sequence under the applied lateral loads. In addition, pushover analysis is also used to ascertain the capability of the structure to withstand a certain level of input motion defined in terms of a response spectrum.

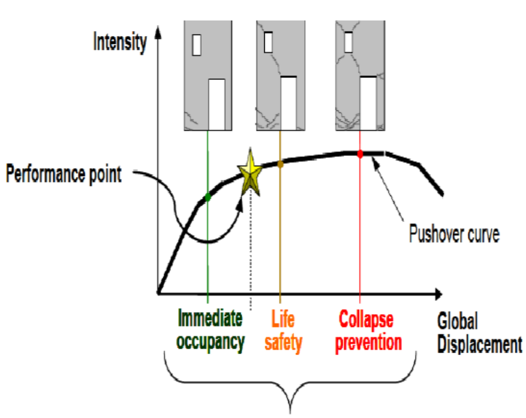


Fig 2: Performance levels with pushover curve

IV. RESULTS AND OBSERVATIONS

4.1 MODELS IN ETABS 2016

Model Details
Bay Size: 40 x 40 m
Storey: G+13
Concrete: M25
Steel: Fe500
Column Size: 380 x 400 mm
Beam Size: 250 x380 mm
Slab Thickness: 150 mm
Shear Wall: 200 mm

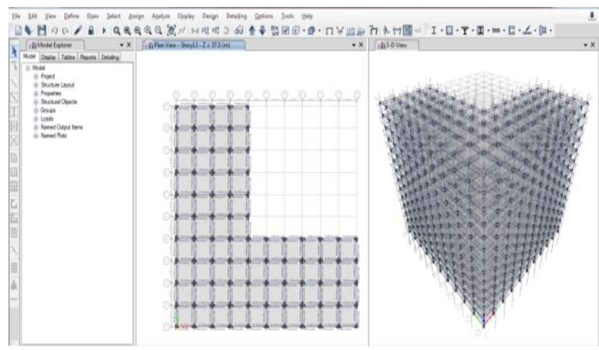


Fig 3: L shape building G+13 without soft storey

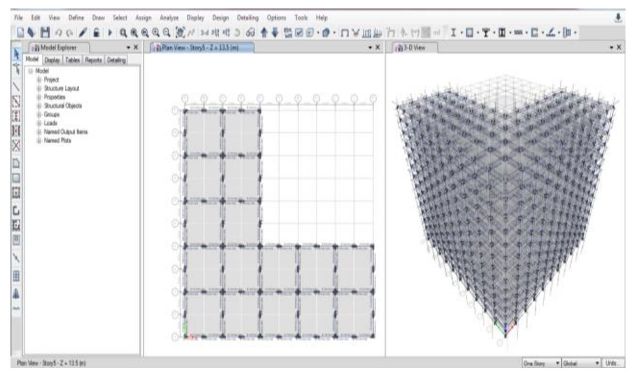


Fig 4: L shape building G+13 with soft storey at 5th floor

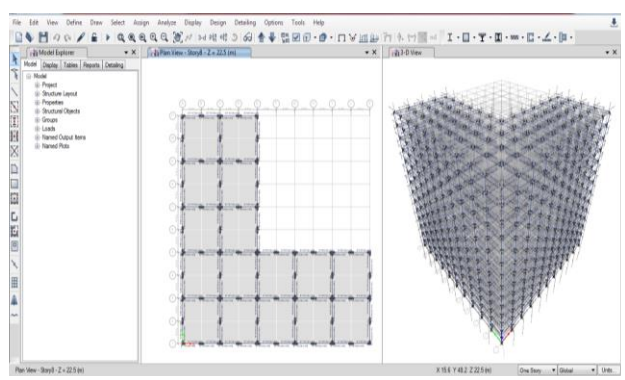


Fig 5: L shape building G+13 with soft storey at 8th floor

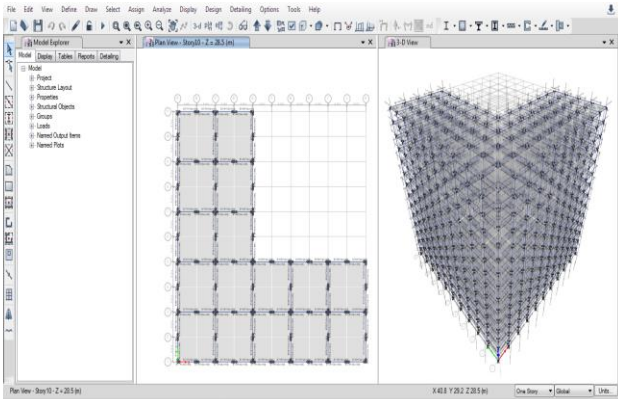
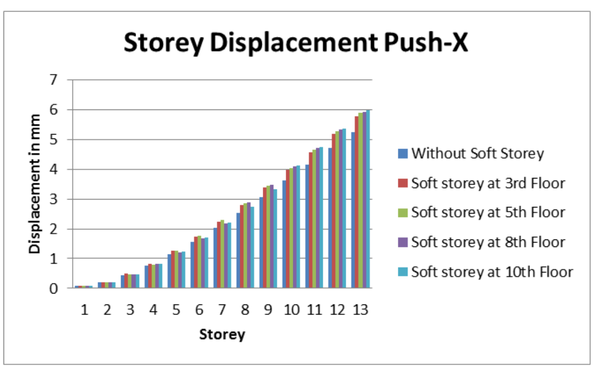


Fig 6: L shape building G+13 with soft storey at 10th floor

A. RESULTS OF THE MODELS

Table 1 Storey Displacement PUSH-X

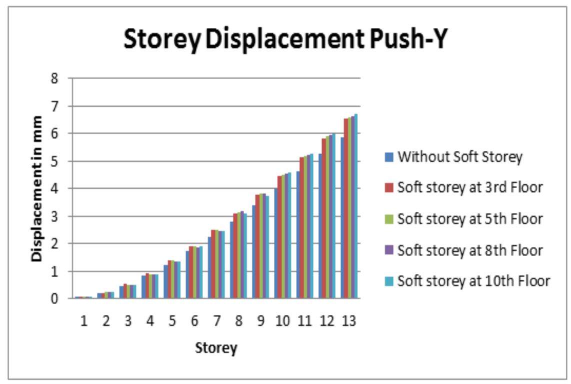
Story	Without Soft Storey	Soft Storey At 3rd Floor	Soft Storey At 5th Floor	Soft Storey At 8th Floor	Soft Storey At 10th Floor
1	0.0434	0.0455	0.0460	0.0464	0.0468
2	0.1977	0.2075	0.2095	0.2115	0.2135
3	0.44	0.484	0.4664	0.4708	0.4752
4	0.7573	0.8330	0.8027	0.8103	0.8178
5	1.1372	1.2509	1.2736	1.2168	1.2281
6	1.5685	1.7253	1.7567	1.6782	1.6939
7	2.0407	2.2447	2.2855	2.1835	2.2039
8	2.5441	2.7985	2.8493	2.8748	2.7476
9	3.0698	3.3767	3.4381	3.4688	3.3153
10	3.6097	3.9706	4.0428	4.0789	4.1150
11	4.1565	4.5721	4.6552	4.6968	4.7384
12	4.7039	5.1742	5.2683	5.31540	5.3624
13	5.247	5.7717	5.8766	5.9291	5.9815



Graph 1 Storey Displacement PUSH-X

Table 2 Storey Displacement Push-Y

Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.0471	0.0503	0.0508	0.0513	0.0518
2	0.2135	0.2284	0.2305	0.2327	0.2348
3	0.4776	0.5301	0.5158	0.5205	0.5253
4	0.8256	0.9164	0.8916	0.8999	0.9081
5	1.2446	1.3815	1.3939	1.3566	1.3690
6	1.7227	1.9121	1.9294	1.8777	1.8949
7	2.2488	2.4961	2.5186	2.4511	2.4736
8	2.8123	3.1216	3.1497	3.1778	3.0935
9	3.4037	3.7781	3.8121	3.8461	3.7440
10	4.014	4.4555	4.4956	4.5358	4.5759
11	4.6353	5.1451	5.1915	5.2378	5.2842
12	5.2606	5.8392	5.8918	5.9444	5.9970
13	5.8842	6.5314	6.5903	6.6491	6.7079



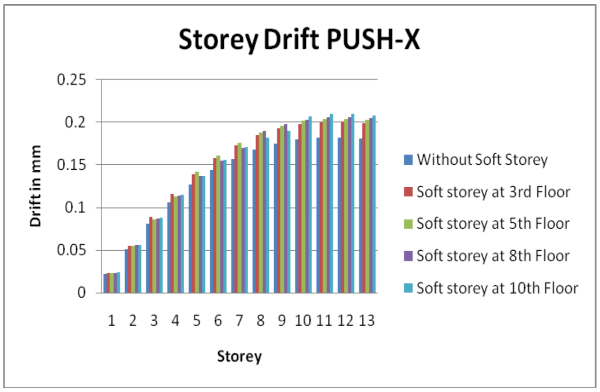
Graph 2 Storey Displacement Push-Y

4.2 Storey Drift

Storey Drift PUSH-X

Table 3 Storey Drift Push-X

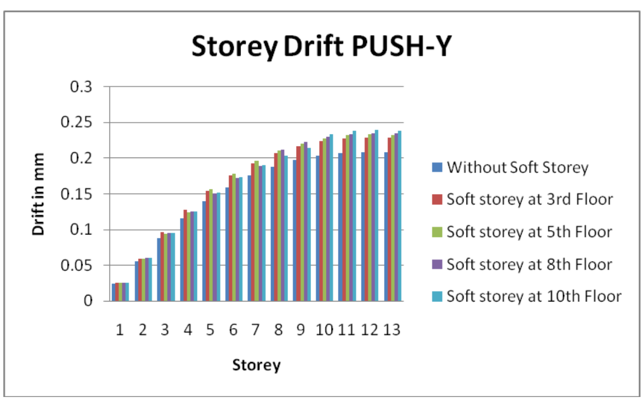
Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.0217	0.0230	0.0232	0.0234	0.0235
2	0.0514	0.0545	0.0550	0.0555	0.0558
3	0.0807	0.0888	0.0864	0.0872	0.0876
4	0.1057	0.1163	0.1131	0.1142	0.1147
5	0.1266	0.1393	0.1418	0.1367	0.1374
6	0.1437	0.1581	0.1610	0.1552	0.1559
7	0.1573	0.1731	0.1762	0.1699	0.1707
8	0.1678	0.1845	0.1879	0.1896	0.1820
9	0.1752	0.1927	0.1962	0.1980	0.1901
10	0.1799	0.1979	0.2015	0.2033	0.2069
11	0.1822	0.2004	0.2041	0.2059	0.2096
12	0.1824	0.2007	0.2043	0.2062	0.2098
13	0.1810	0.1991	0.2027	0.2045	0.2081



Graph 3: Storey Drift PUSH-X

Table 4 Storey Drift Push-X

Story	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	0.0235	0.0249	0.0252	0.0254	0.0255
2	0.0554	0.0588	0.0593	0.0599	0.0601
3	0.0880	0.0968	0.0941	0.0950	0.0954
4	0.1160	0.1276	0.1241	0.1252	0.1258
5	0.1396	0.1536	0.1564	0.1508	0.1515
6	0.1593	0.1753	0.1784	0.1721	0.1729
7	0.1753	0.1928	0.1963	0.1893	0.1902
8	0.1878	0.2066	0.2103	0.2122	0.2038
9	0.1971	0.2168	0.2207	0.2227	0.2138
10	0.2034	0.2237	0.2278	0.2298	0.2339
11	0.2070	0.2278	0.2319	0.2340	0.2381
12	0.2084	0.2292	0.2334	0.2355	0.2396
13	0.2078	0.2286	0.2328	0.2348	0.2390

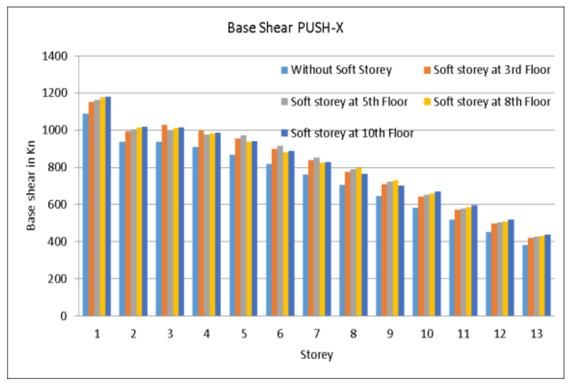


Graph 4: Storey Drift PUSH-Y

4.3 Base Shear

Table 5 Base Shear PUSH-X

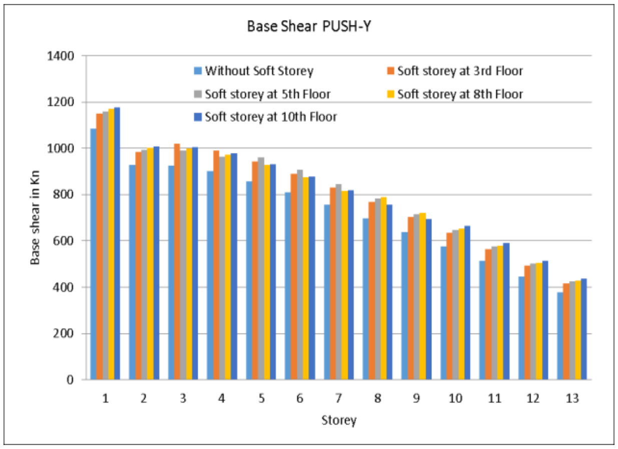
Storey	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	1087.97	1153.248	1164.128	1175.008	1180.447
2	938.9	995.234	1004.623	1014.012	1018.707
3	936.85	1030.535	1002.43	1011.798	1016.482
4	910.71	1001.781	974.4597	983.5668	988.1204
5	867.46	954.206	971.5552	936.8568	941.1941
6	817.25	898.975	915.32	882.63	886.7163
7	762.86	839.146	854.4032	823.8888	827.7031
8	705.41	775.951	790.0592	797.1133	765.3699
9	645.37	709.907	722.8144	729.2681	700.2265
10	582.98	641.278	652.9376	658.7674	670.427
11	518.33	570.163	580.5296	585.7129	596.0795
12	451.43	496.573	505.6016	510.1159	519.1445
13	382.16	420.376	428.0192	431.8408	439.484



Graph 5: Base Shear at PUSH-X

Table 6 Base Shear PUSH-Y

Storey	Without Soft Storey	Soft storey at 3rd Floor	Soft storey at 5th Floor	Soft storey at 8th Floor	Soft storey at 10th Floor
1	1083.84	1148.87	1159.709	1170.547	1175.966
2	928.94	984.6764	993.9658	1003.255	1007.9
3	926.14	1018.754	990.9698	1000.231	1004.862
4	901.14	991.254	964.2198	973.2312	977.7369
5	858.45	944.295	961.464	927.126	931.4183
6	808.88	889.768	905.9456	873.5904	877.6348
7	755.18	830.698	845.8016	815.5944	819.3703
8	698.46	768.306	782.2752	789.2598	757.8291
9	639.19	703.109	715.8928	722.2847	693.5212
10	577.57	635.327	646.8784	652.6541	664.2055
11	513.68	565.048	575.3216	580.4584	590.732
12	447.53	492.283	501.2336	505.7089	514.6595
13	378.95	416.845	424.424	428.2135	435.7925



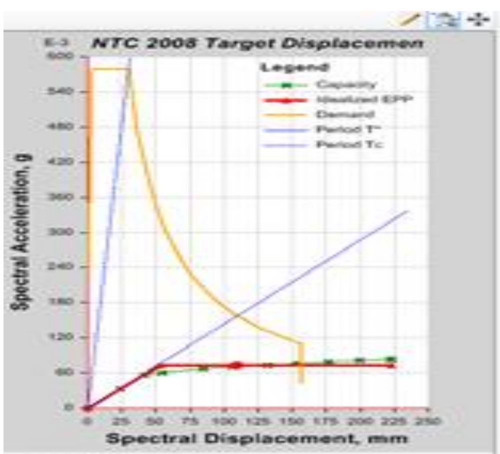
Graph 1: Base Shear at PUSHY

4.4 Static Pushover Results

Results of Pushover analysis for 8th and 10th floor demonstrate maximum stability and maximum tolerance against seismic events on structures.

Result of the same are graphically represented as below:

Graph 5: Pushover Curve PUSHX for 8th floor



Graph 6: Pushover Curve PUSHX for 10thth floor

V. CONCLUSION

Design Pushover analysis was carried out on 13 storey building models as per IS 1893: 2002 (part 1). 5 different models were selected, and analysis was done using ETABs 2016. Storey displacement, storey drift, Storey stiffness and Base shear of each model are obtained as results and comparative study was carried out for finding model with better performance.

1. Maximum yielding occurs at the soft storey, because of soft stories maximum plastic hinges are forming though the base force is increasing.
2. As we shifted soft storey to higher level, yielding is less than lower-level soft storey and lower intensity hinges are forming after maximum number of pushover steps.
3. As we shift soft storey to higher level it can be seen from pushover and capacity spectrum curve that period goes on reducing from 0.716 Sec. for 3rd floor soft storey to 0.446 Sec. at 10th floor soft storey.
4. Which means soft storey is safer at higher level in high rise building. Most of the hinges developed in the beams and few in the columns.
5. It is observed that plastic hinges are developed in columns of ground level soft storey which is not acceptable criteria for safe design.
6. Shear wall gives high stiffness to the structure so as the structure will be stable. Applying shear wall can effectively reduce the displacement and Storey-drift of the structure. This will reduce the destruction comes from lateral loads such as an earthquake. Earlier studies showed that shear wall gives different performance based on its position in structures.
7. Based on the analysis, the placement of shear wall at the corners of structure symmetrically gives the best performance to reduce the displacement. It can reduce the displacement up to 25% (X-dir.) and 35% (Y-dir.), so we can suggest assigning shear wall while using soft storey at low and mid-level of the building.

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