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RESEARCH ARTICLE

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EFFECT OF SOFT STOREY ON TALL BUILDINGS AT VARIOUS STOREIS BY PUSHOVER ANALYSIS

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ABSTRACT

In an attempt to investigate the effect of soft storey for multistoried reinforced concrete building models (5, 10, and 15 storey) with both regular and irregular building plans were analyzed. Masonary walls are provided for the stories other than soft stories. Earthquake load was provided at each diaphragm's mass centre as a source of lateral load. The soft storey level was altered from ground floor to top floor for each model and equivalent static analysis was carried away using ETABS 9.7.4 analysis package. Results show a general changing pattern in lateral drift, displacement and storey shear irrespective to building height and location of soft storey.

KEYWORDS: Soft Storey, Tall Building, Pushover Analysis, Irregular Building, Earthquake Behavior, Stiffness, Masonry Infill.

INTRODUCTION

India at present is fast growing economy, which brings about demands in increase of infrastructure facilities along with the growth of population. The demand of land in urban regions is increasing day by day. It is imperative that land available for farming and agriculture remains intact. To cater the land demand in these regions, vertical development is the only option. This type of development brings challenges to counteract additional lateral loads due to wind and earthquake. This demands changes in the current structural system which needs to be implemented to resist these forces. Much research has been carried which describes the suitability of various lateral load resisting system against deformation and shear exerted due to the earthquake and wind forces.

Soft story irregularity is one of the main reasons of building damages during recent earthquakes in the world as mentioned in almost all reconnaissance reports and studies soft story may arise not only because of sudden changes in the structural system (like the height of the stories) but also due to abrupt changes in amount of infill walls between stories which are usually not considered as a part of the load bearing system. This study aims to investigate soft story behavior using nonlinear static analysis for tall RC buildings which are thought to be the most vulnerable in existing building stock. Nonlinear static analyses are performed using

ETABS 9.7.4. Beam and column elements are modeled as nonlinear frame elements with lumped plasticity by defining plastic hinges at both ends of beams and columns. Effect of infill walls is provided to the other stories. The outcomes are useful to better understand soft story damages during past earthquakes and to emphasize the effect of infill walls on the behavior.

MODELING OF THE BUILDING

The entire analysis has done for all the 3D models using ETABS Nonlinear version software. The results are tabulated in order to focus the parameters such as base shear, story drift and lateral displacements in linear analysis. In Nonlinear analysis, the identification of plastic hinges at various performance levels, Performance point and capacity of various models were studied. Types of buildings considered for present study are:

Regular Building: it is modeled with symmetrical plan and elevation in three different heights, i.e 5, 10 and 15 storeis, shown in fig 1 below.

L-Shaped Building: it's a plan irregular building, as shown in fig 2, modeled for 5, 10, and 15 stories.

T-Shaped Building: it's a plan irregular building, as shown in fig 3, modeled for 5, 10, and 15 stories.

Plus-Shaped Building: it's a plan irregular building, as shown in fig 4, modeled for 5, 10, and 15 stories.

G1 Type Building: it's a vertical irregular building, as shown in fig 5, modeled for 5, 10, and 15 stories.

G2 Type Building: it's a vertical irregular building, as shown in fig 2, modeled for 5, 10, and 15 stories.

Stiffness Type Building: it's a vertical irregular building, in which stiffness are varied by increasing the column height of the particular storey, as shown in fig 2, modeled for 5, 10, and 15 stories.

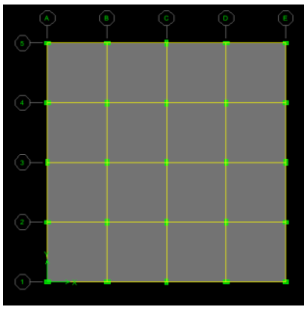


Fig1:Plan of Regular Building

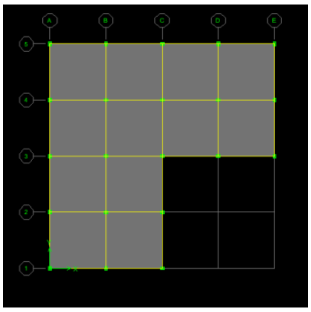


Fig 2:Plan of L-Shaped Building

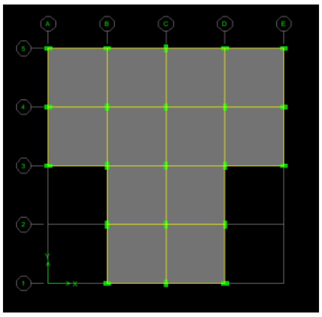


Fig 3:Plan of T-Shaped Building

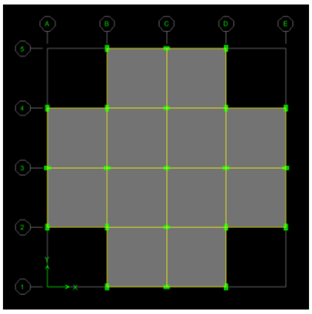


Fig 4:Plan of Plus-Shaped Building

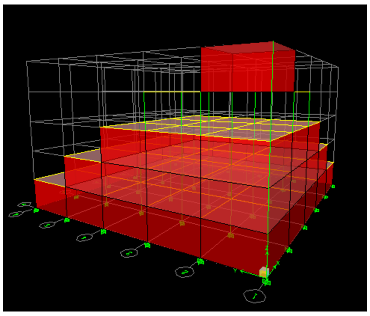


Fig 5: 3D View of G1 Type Building

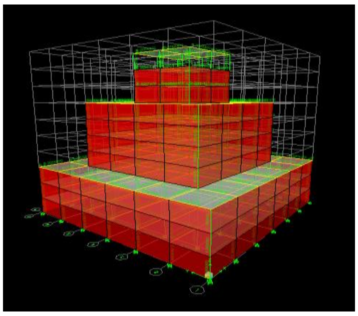


Fig 6: 3D View of G2 Type Building

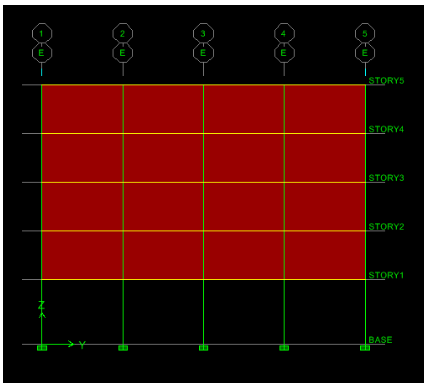


Fig 7: Elevation of Stiffness Type Building

METHODOLOGY

The software used for the present study is ETABS 9.7.4. It is product of Computers and Structures, Berkeley, USA. ETABS9.7.4 is used for analyzing general structures including bridges, stadiums, towers, industrial plants, offshore structures, buildings, dam, silos, etc. It is a fully integrated program that allows model creation, modification, execution of analysis, design optimization, and results review from within a single interface. ETABS 9.7.4 is a standalone finite element based structural program for analysis and design of civil structures. It offers an intuitive, yet powerful user interface with many tools to aid in quick and accurate construction of models, along with sophisticated technique needed to do most complex projects.

The analysis is carried out by both linear static and nonlinear static methods in accordance with IS-1893-2002 (part-1), to study the performance levels and performance points of the building. Building data used for modeling all kinds of the buildings are tabulated below:

Table 1: Building Data Used For Modeling

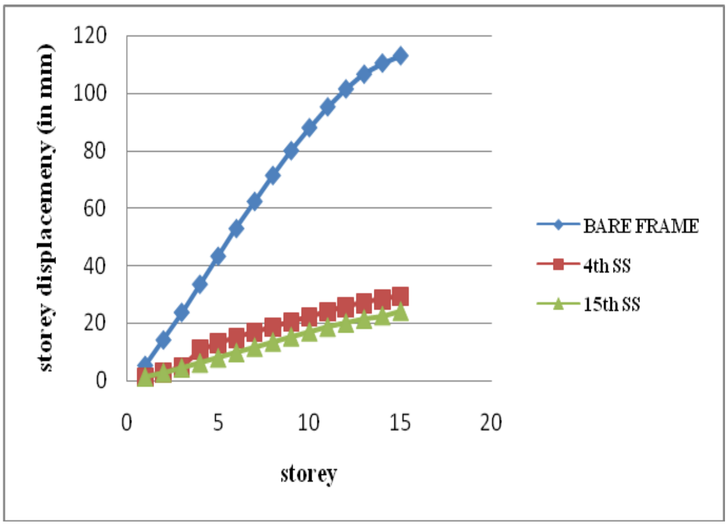
PARAMETERS	5 storey	10 storey	15 storey
Seismic Zone	V	V	V
Seismic Zone Factor	0.36	0.36	0.36
Response Reduction Factor	5	5	5
Height of Building	16 m	31 m	46 m
Thickness of infill Wall	0.23 m	0.23 m	0.23 m
Thickness of Slab	0.120 m	0.120 m	0.120 m
Beam Size	0.25 X 0.35 m^2	0.3 X 0.4 m^2	0.3 X 0.45 m^2
Column Size	0.25 X 0.35 m^2	0.3 X 0.5 m^2	0.3 X 0.6 m^2
Live Load	3 kN/m^2	3 kN/m^2	3 kN/m^2
Floor Finish	1 kN/m^2	1 kN/m^2	1 kN/m^2
Material Properties	M25 Grade of Concrete Fe 415 Grade of Steel	M25 Grade of Concrete Fe 415 Grade of Steel	M25 Grade of Concrete Fe 415 Grade of Steel

RESULTS AND DISCUSSION

In the present study, non-linear response of RC frame high rise building with soft storey at different levels in addition to one at ground floor using ETABS under the loading has been carried out. The objective of this study is to see the variation of load- displacement graph and check the maximum base shear and displacement of the frame with soft stories at different levels. Following are the graphs drawn for the regular 15 storey building using linear static analysis.

Table 2: Lateral displacement of 15 storey regular building

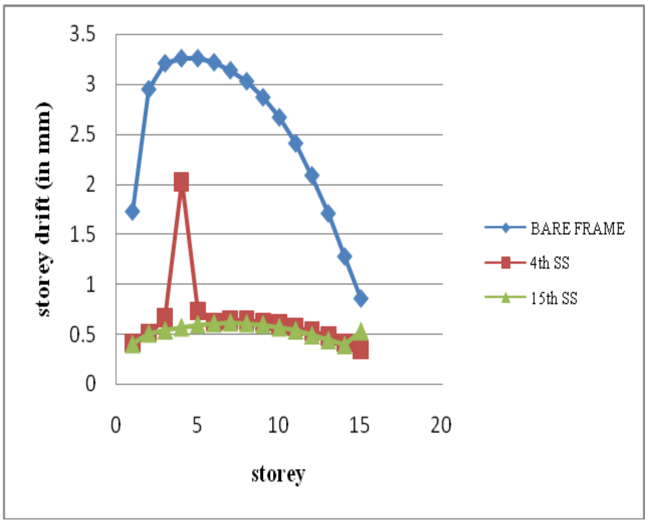
STOREY	DISPLACEMENT (in mm)		
	BARE FRAME	4th SS	15th SS
1	5.1792	1.2212	1.2078
2	14.0296	2.7348	2.7364
3	23.6444	4.7173	4.3656
4	33.425	10.7934	6.0887
5	43.1931	12.9781	7.8786
6	52.8425	14.8442	9.7098
7	62.2687	16.7633	11.5554
8	71.3552	18.6697	13.3877
9	79.971	20.54	15.1775
10	87.9703	22.3445	16.8948
11	95.1928	24.0533	18.5085
12	101.465	25.6355	19.988
13	106.6062	27.0606	21.2965
14	110.4524	28.2965	22.4597
15	113.0307	29.3261	24.0595



Graph 1: Comparison of lateral displacement of bare frame with maximum and minimum top storey displacements

Table 3: Storey drift of 15 storey regular building

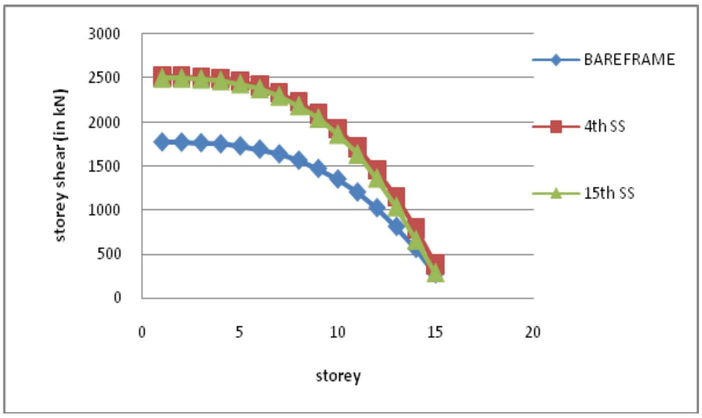
STOREY	STOREY DRIFT (in mm)		
	BARE FRAME	4th SS	15th SS
1	1.73	0.41	0.4
2	2.95	0.51	0.51
3	3.21	0.66	0.54
4	3.26	2.03	0.57
5	3.26	0.73	0.6
6	3.22	0.62	0.61
7	3.14	0.64	0.62
8	3.03	0.64	0.61
9	2.87	0.62	0.6
10	2.67	0.6	0.57
11	2.41	0.57	0.54
12	2.09	0.53	0.49
13	1.71	0.48	0.44
14	1.28	0.412	0.39
15	0.86	0.34	0.53



Graph 2: comparison of storey drifts of bare frame with maximum and minimum storey drifts.

Table 4: Storey shear of 15 storey regular building

STOREY	STOREY SHEAR (in kN)		
	BARE FRAME	4th SS	15th SS
1	1777.62	2522	2507.32
2	1776.13	2519.88	2505.06
3	1770.19	2511.41	2496.02
4	1756.82	2495.3	2475.69
5	1733.06	2466.67	2439.55
6	1695.94	2413.71	2383.08
7	1642.47	2337.45	2301.77
8	1569.7	2233.65	2191.09
9	1474.66	2098.07	2046.53
10	1354.37	1926.48	1863.58
11	1205.86	1714.63	1637.7
12	1026.16	1458.3	1364.39
13	812.31	1153.25	1039.14
14	561.33	795.24	657.41
15	270.26	380.03	283.43



Graph 3: comparison of storey drifts of bare frame with maximum and minimum storey Shear.

For other than regular building types of models, results of maximum and minimum displacements, drifts and storey shear are tabulated in the Table 5, Table 6, and Table 7 respectively.

Table 4: lateral displacement of plan and vertical irregular buildings of 5, 10 and 15 storied buildings

	DISPLACEMENT (mm)		
BUILDING TYPE	BARE FRAME	MAX	MIN
L-5 STOREY	41.813	6.3454	3.2868
L-10 STOREY	51.392	12.684	8.765
L-15 STOREY	108.744	29.533	24.035
T-5 STOREY	44.491	6.1943	3.5372
T-10 STOREY	59.4166	13.1184	9.123
T-15 STOREY	111.639	29.2145	23.8701
Plus-5 STOREY	42.881	6.66	3.5
Plus-10 STOREY	55.9028	14.031	9.881
Plus-15 STOREY	104.79	31.148	26.277
G1-5 STOREY	24.1656	6.8712	3.419
G1-10 STOREY	52.682	18.945	10.934
G1-15 STOREY	97.854	35.9501	25.4768
G2-5 STOREY	26.15	8.551	4.451
G2-10 STOREY	41.296	8.868	6.124
G2-15 STOREY	88.943	26.005	21.209
5-STIFFNESS	35.6372	14.002	7.031
10-STIFFNESS	66.159	18.7509	10.9342
15-STIFFNESS	118.543	35.9501	25.4768

Table 5: Storey drift of plan and vertical irregular buildings of 5, 10 and 15 storied buildings

	STOREY DRIFT (mm)		
BUILDING TYPE	BARE FRAME	MAX	MIN
L-5 STOREY	3.635	1.654	0.645
L-10 STOREY	2.68	1.612	0.427
L-15 STOREY	3.134	1.963	0.53
T-5 STOREY	3.869	1.588	0.654
T-10 STOREY	2.621	1.657	0.422
T-15 STOREY	2.75	1.951	0.615
Plus-5 STOREY	3.72	1.712	0.668
Plus-10 STOREY	2.417	1.731	0.451
Plus-15 STOREY	5.816	1.802	0.575
G1-5 STOREY	2.098	1.987	0.656
G1-10 STOREY	2.317	2.577	0.68
G1-15 STOREY	2.732	2.991	0.704
G2-5 STOREY	2.384	2.416	1.058
G2-10 STOREY	2.229	0.962	0.562
G2-15 STOREY	2.676	1.821	0.774
5-STIFFNESS	2.766	3.097	1.37
10-STIFFNESS	2.779	2.564	0.68
15-STIFFNESS	3.281	2.991	0.704

Table 6: Storey shear of plan and vertical irregular buildings of 5, 10 and 15 storied buildings

	STOREY SHEAR (kN)		
BUILDING TYPE	BARE FRAME	MAX	MIN
L-5 STOREY	656.05	564.44	564.444
L-10 STOREY	810.65	1281.11	1281.11
L-15 STOREY	1377.7	2106.66	2106.66
T-5 STOREY	656.09	564.47	564.47
T-10 STOREY	865.88	1325.32	1325.32
T-15 STOREY	1377.33	2107.03	2107.03
Plus-5 STOREY	656.09	564.47	564.47
Plus-10 STOREY	865.88	1325.32	1325.32
Plus-15 STOREY	1377.33	2107.03	2107.03
G1-5 STOREY	337.79	466.17	493.19
G1-10 STOREY	782.42	1584.82	1584.82
G1-15 STOREY	1235.17	2527.51	2512.82
G2-5 STOREY	459.76	635.43	635.43
G2-10 STOREY	1255.73	1661.71	1661.71
G2-15 STOREY	2036.2	2752.38	2779.41
5-STIFFNESS	479.82	670.23	670.23
10-STIFFNESS	1123.08	1584.82	1584.82
15-STIFFNESS	1780.37	2527.51	2512.82

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LOCATION OF HINGE STATUS

The performance levels and location of plastic hinges are observed in all regular, plan irregular and vertical irregular building models. It is seen that the pushover analysis was including some number of steps. It has been observed that, on subsequent push to building, hinges started forming in beams first. Initially hinges were in B-IO stage and subsequently proceeding to IO-LS and LS-CP stage. At performance point, hinges were in LS-CP range, overall performance of the building is said to be within Life safety and Collapse prevention, for building model for PUSH X direction.

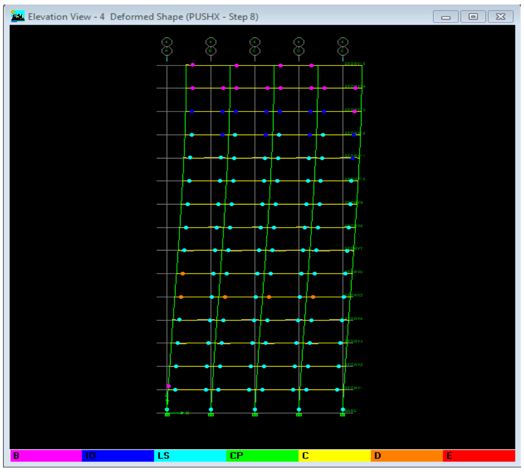

Fig 8: hinge formation in 15 storey bare framed building

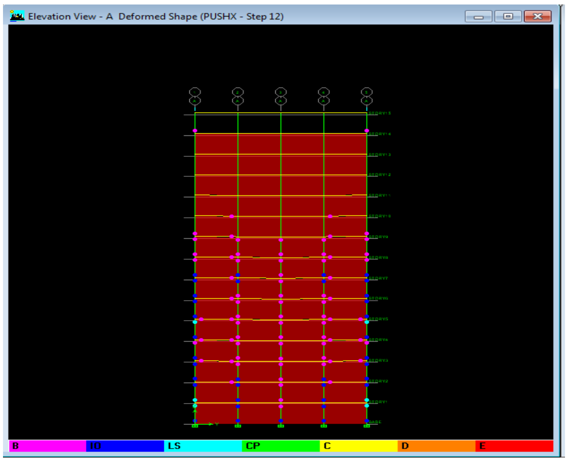

Fig 9: hinge formation in 15 storey building having 15th storey as soft storey

CONCLUSION

This study summarizes the review of the performance based seismic analysis of the tall building having soft storey at various levels in the building using pushover analysis. The building is designed for the load as per IS 456-2000, using finite element software package ETAB's 9.7.4**.** The tall building is located in the severe seismic zone-v of India, which needs an assessment of seismic vulnerability under various available techniques in order to safe guard the human life for future earthquakes.

In the present project work an analytical investigation of both regular and irregular shaped building is made and various analytical approaches linear static (equivalent static analysis) and nonlinear static method (pushover analysis) are performed on the building model having 5, 10 and 15 storeys, in all the models, to study and identify the seismic behavior of the building and to compare the various results obtained from both linear static and nonlinear static analysis.

The usage of pushover analysis identifies highlights and emphasize the effect of correct lateral load pattern, which can regulate detrimental influence on seismic performance of buildings, also pushover analysis is performed for the various building models located in zone-v in accordance with IS-1893-2002(part-1), to study the performance levels and performance points of the building.

Base shear increases with the increase in mass and number of storeys of the building, also base shear obtained from pushover analysis is much more than the base shear obtained from the equivalent static analysis.

Storey displacements, storey drifts and storey shears obtained from pushover analysis are about twice the storey displacements, storey drifts and storey shears of equivalent static analysis, thus storey displacements, storey drift and storey shear increases with increase in the number of storeys, mass and height of the building.

Also, we can conclude that as the number of storey increases lateral load carrying capacity does not increase but corresponding displacement increases. The behavior of properly detailed reinforced concrete frame building is adequate as Indicated by the intersection of the demand and capacity curves and the distribution of Hinges in the beam and the column. Most of the hinges developed in the beam and few in the column.

The results obtained in terms of demand, capacity and plastic hinges gave an insight into the real behavior of structures. It is advisable to provide soft storey at higher levels in addition to ground soft storey.

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