Nonlinear Static Pushover Analysis of Medium Rise and High-Rise Building

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ABSTRACT

Pushover analysis is an elegant tool to visualise the performance level of a building under a given earthquake. The purpose of the paper is to summarize the Non Linear static Pushover analysis of medium rise RC bare frame and high rise RC infilled structure with soft stories at different levels using ETABS software. Results concluded that due to the introduction of soft stories in the higher level the intensity of hinge formation becomes lower and lower and at the same time displacement and base shear increases

Keywords : Pushover Analysis, Hinges, Base Shear,, Displacement

I. INTRODUCTION

Seismic design can be viewed as a two step process. The first and usually most important one, is the conception of an effective structural system that needs to be configured with due regard to all the important seismic performance objectives, ranging from serviceability considerations to life safety and collapse prevention. This step comprises the art of seismic engineering, since no rigid rules can,or should, be imposed on the engineer's creativity to devise a system that not only fulfils seismic performance objectives, but also pays tribute to functional and economic constraints imposed by owner, the architect and other professionals involved in the design and construction of a building. By default, this process of creation is based on judgement, experience and understanding of seismic behaviour, rather than rigorous mathematical formulation. Rules of thumb for strength and stiffness targets, based on the fundamental knowledge of ground motion and elastic and inelastic dynamic response characteristics,

should suffice to configure and rough size an effective structural system.

Elaborate mathematical/physical models can only be built once a structural system has been created. Such modles are needed to evaluate seismic performance of an existing system and to modify component behaviour characteristics (strength, stiffness, deformation capacity) to better suit the specified performance criteria. This second step of the design process should involve a demand/capacity evaluation at all the important performance levels, which requires identification of important capacity parameters and prescription of acceptable values of these parameters, as well as the prediction of the demands imposed by ground motions.

II. METHODS AND MATERIAL

A. Purpose of the pushover analysis

The purpose of the pushover analysis is to evaluate the expected performance of a structural system by estimating its strength and deformation demands in

design earthquakes by means of a static inelastic analysis and comparing these demands to available capacities at the performance levels of interest. The evaluation is based on the assessment of important performance parameters, including global drift, interstorey drift, inelastic element deformations (either absolute or normalised with respect ta a yield value), deformations between elements and element and connection forces(for elements and connections that cannot sustain inelastic deformation).

The inelastic static pushover analysis can be viewed as a method for predicting seismic force and deformation methods, which accounts in an approximate manner for the redistribution of internal forces occurring when the structure is subjected to inertia forces that no longer can be resisted within the elastic range of structural behaviourThe push over is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis

The following steps stated below.

- Identification of location of weak points in the structure(or potential failure modes)
- Identification of the critical regions in which the deformation demands are expected to be high and that have to become the focus through detailing.
- Determination of force demands on brittle members, such as axial force demands on columns, moment demands on beam-column connections.
- The realistic force demands on potentially brittle elements, such as axial force demands on columns, force demands on brace connection, moment demands on beam to column connections, shear force demands in deep

reinforced concrete spandrel beams, shear force demands in unreinforced masonry wall peirs, etc.
- Estimates of the deformations demands for elements that have to form in elastically in order to dissipate the energy imparted to the structures.

Verification of the completeness and adequacy of load path, considering all the elements of the structural system, all the connections, the stiff non-structural elements of significant strength, and the foundation system

B. Pushover analysis background

Non linear static pushover analysis has become the most commonly used method to determine the nonlinear behaviour of the building structures in the recent years. In this simplified method, a capacity curve is obtained which shows the relation of base shear and roof displacement. This curve represents the behaviour of the building structure under increasing base shear forces. As the capacities of the members of the lateral force resisting system exceed their yield limits during the increasing of the base shear force, the slope of the force deformation curve will change, and hence the nonlinear behaviour can be represented. In the pushover analysis, the applied lateral forces to a model are increased in a regular manner depending on the initial load pattern. Member forces are calculated for each step andt he stiffness of the members whose capacities are exceeded is changed according to the hinge properties in the next step of analysis. The pushover analysis can be performed considering the control over the force or displacement. Force control option is useful when the magnitude of the load is known clearly, and the structure is expected to support that load.

The displacement control is useful when the magnitude of the load is unknown and displacements are searched. The recent advent of performance based design has brought the nonlinear static pushover analysis procedure to the forefront. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behaviour and load reversals being estimated by using a modified monotonic force deformation criteria and with damping approximations

C. Modelling and analysis

The general finite element package ETABS has been used for the modelling and analysis. It is a versatile and user-friendly program that offers a wide scope of features like static and dynamic analysis, nonlinear dynamic analysis and nonlinear static pushover analysis, etc. These features and many more, make ETABS the state-of-the-art in structural analysis programs.

Nonlinear static pushover analysis is a very powerful feature offered in the nonlinear version of ETABS Pushover analysis can be performed on both two and three dimensional structural models. In ETABS pushover analysis can consist of any number of pushover cases and each pushover case can have a different distribution of lateral load on the structure. A pushover case may start from zero initial conditions, or it may start from the end of a previous pushover case. ETABS can also perform pushover analysis as either force-controlled or displacement-controlled.

III. RESULTS AND DISCUSSION

NUMERICAL STUDY 1. Push Over Analysis of Medium Rise RC building

A 5 storey building has been analyzed using Nonlinear static pushover analysis method. The building consists of 5bays along length and width. The end bays are 5.5m, intermediate bays are 5m and central bay is 3m along both the direction. The size of the beam is 500mmX300mm and size of the column is 450mmX300mm. the building

Table 1.1 Building description

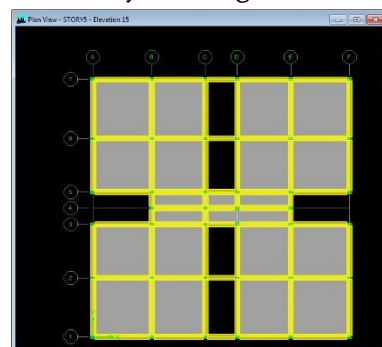| Sl no	Title	Description
1	No of storey	5
2	Size of Beam	500mmx300mm
3	Size of Column	450mmx300mm
4	Earthquake Zone	II
5	Soil type	Medium
6	Importance factor	1
7	Zone factor	0.16
8	Storey height	3m
9	Grade of Steel and Concrete	Fe415 and M30

Plan of the five storey building

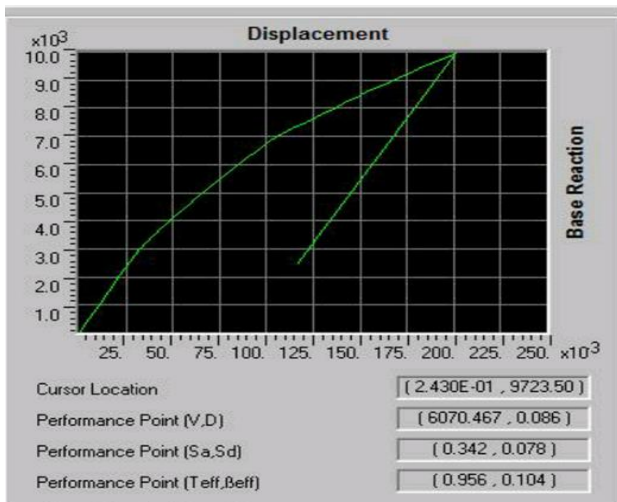Fig 1.1(a) pushover curve for five storey building

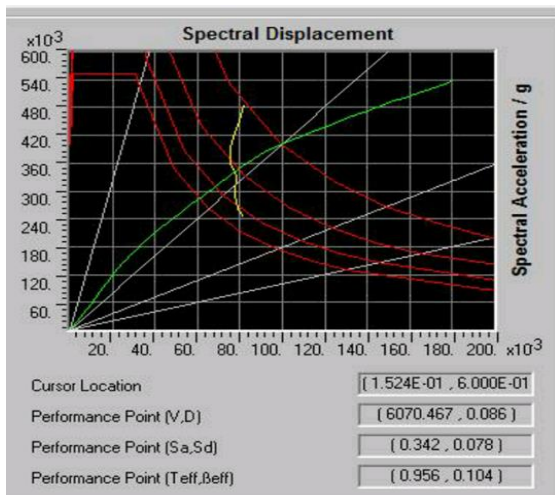Fig 1.1(b) capacity demand spectrum for five storey building
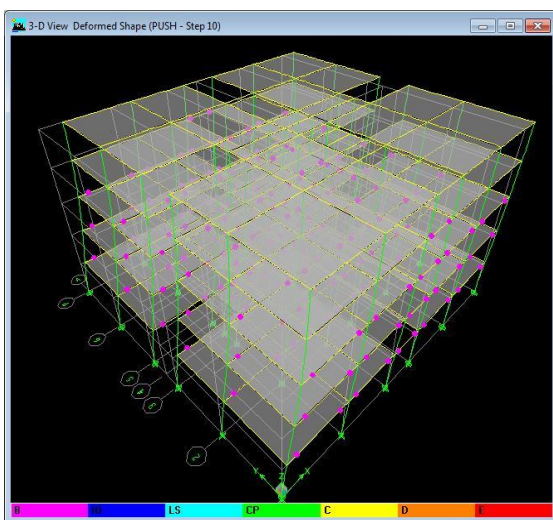

Fig 1.1(c) hinge levels for five storey building

**Table 1.2** : Stepwise displacement and base force for five storey building

Step	Displacement	Base Force
0	0	0
1	0.0052	494.9527
2	0.0104	989.9053
3	0.0156	1484.858
4	0.0208	1979.811
5	0.0217	2069.908
6	0.0271	2554.388
7	0.0328	3017.408
8	0.039	3442.906
9	0.0454	3829.466
10	0.0516	4196.145
11	0.0575	4530.473
12	0.0629	4822.346
13	0.0688	5144.571
14	0.0771	5595.889
15	0.0829	5906.718
16	0.0893	6241.359
17	0.095	6520.306
18	0.1017	6817.089
19	0.1087	7088.877
20	0.1139	7262.456
21	0.1191	7436.035
22	0.1243	7609.614
23	0.1295	7783.193
24	0.1368	8029.041
25	0.142	8202.586
26	0.1482	8406.963
27	0.1541	8597.975
28	0.1615	8822.205
29	0.1702	9075.472
30	0.1758	9236.729
31	0.181	9385.303
32	0.1873	9564.24
33	0.1947	9777.944
34	0.1999	9923.796
35	0.2013	9959.591
36	0.116	2451.538

Numerical study 2 : Push Over Analysis of Tall Buildings with Soft Stories at Different Levels

A 22 storey building has been analysed using non linear static pushover analysis method. The building consists of 22 storeys with soft storey at different levels in addition to one at ground floor using ETABS. The objective of this study is to see the variation of load displacement graph and to check the maximum base shear and displacement of the frame with soft stories at different levels.

Table 2.1 Building Description

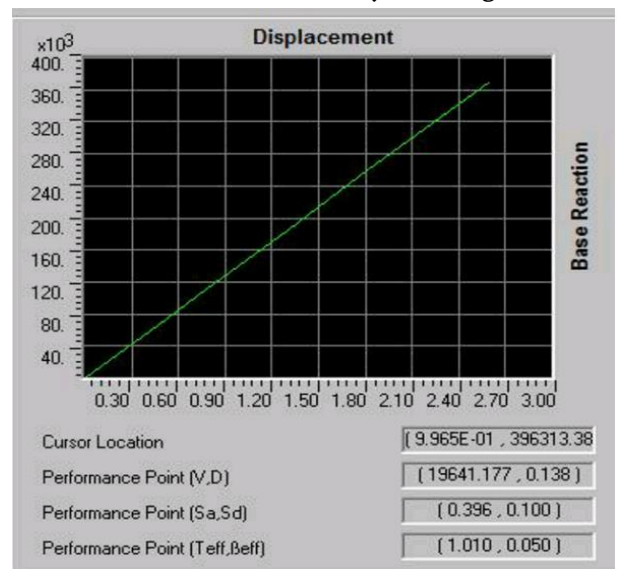| Sl no	Title	Description
1	No of storey	20
2	Size of Beam	300mmx500mm
3	Size of Column	300mmx600mm and 300mmx1200mm
4	Earthquake Zone	V
5	Soil type	Medium
6	Importance factor	1
7	Zone factor	0.36
8	Storey height	3m
9	Grade of Steel and Concrete	Fe415 and M20
10	Weight density of brick Masonry	20KN/m3
11	Weight Density of RC material	25KN/m3
12	Thickness of slab	150mm
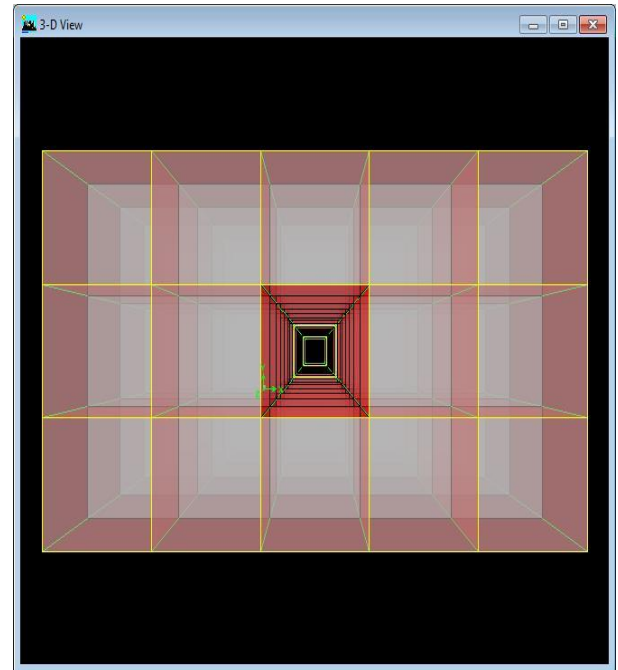
Plan of the 22 storey building
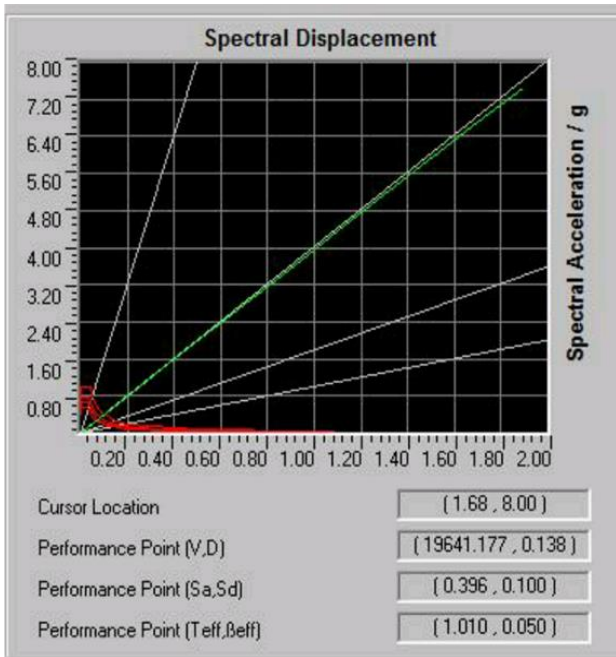

Fig 2.1(a) pushover curve for 22 storey building

Fig 2.1(b)capacity demand spectrum

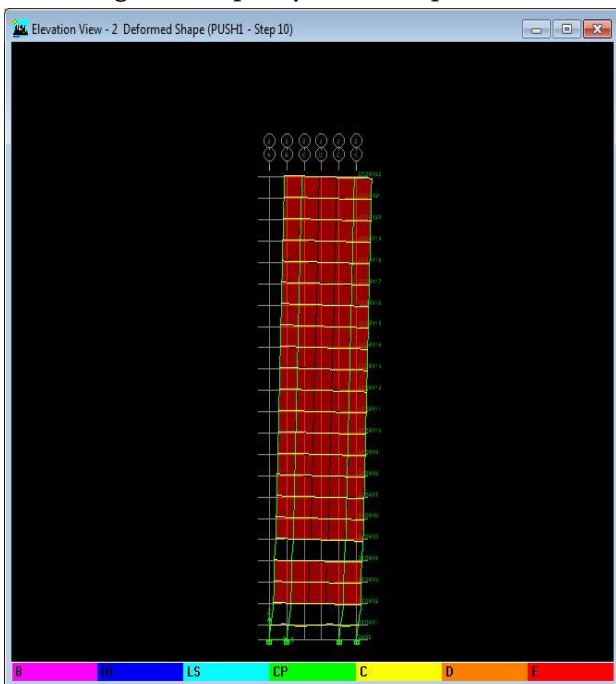|	
Cursor Location	(1.68 , 8.00)
Performance Point (V,D)	(19641.177 , 0.138)
Performance Point (Sa,Sd)	(0.396 , 0.100)
Performance Point (Teff,ßeff)	(1.010 , 0.050)

Fig 2.1(c) hinge levels of 22 storey building with soft storey for 22 storey building ground level and third floor

Table 2.2 : Stepwise displacement and base force for soft storey at ground level and third floor

Step	Displacement	Base Force
0	0	0
1	0.26	37029.2188
2	0.52	74056.6094
3	0.78	111081.5
4	1.04	148103.1563
5	1.2999	185120.6875
6	1.5599	222133.0313
7	1.8198	259138.8594
8	2.0798	296136.5625
9	2.3397	333123.9688
10	2.5996	370098.1875

IV. CONCLUSION

1. Pushover analysis is an elegant tool to visualise the performance level of a building under a given earthquake.

2. Due to the introduction of soft stories in the higher level the intensity of hinge formation becomes lower and lower and at the same time displacement and base shear increases.

3. The pushover curve obtained for the 5-storey building describes that the maximum base force is 6070 KN for a corresponding displacement of 0.086m

4. The structural effective time period with respect to spectral acceleration for the 5-storey building 0.342 and 0.078 respectively

5. The structural effective time period with respect to spectral acceleration for the 22 storey building 0.396 and 0.050 respectively

6. The pushover curve obtained for the 22-storey building describes that the maximum base force is 19641.17 KN for a corresponding displacement of 0.138m, however no definite conclusion could be drawn on the formation of hinges in the 22 storied structure, this may be due to introduction of soft stories at different levels.

V.   REFERENCES

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