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NON-LINEAR STATIC ANALYSIS ON RCC FRAME WITH AND WITHOUT VERTICAL IRREGULARITY

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ABSTRACT

To model the complex behavior of reinforced concrete analytically in its non-linear zone is difficult. This has led engineers in the past to rely heavily on empirical formulas which were derived from numerous experiments for the design of reinforced concrete structures. For structural design and assessment of reinforced concrete members, the non-linear analysis has become an important tool. The method can be used to study the behavior of reinforced concrete structures including force redistribution. This analysis of the nonlinear response of RC structures to be carried out in a routine fashion. It helps in the investigation of the behavior of the structure under different loading conditions, its load deflection behavior and the cracks pattern. In the present study, Pushover analysis on RCC frames using ETABS with and without vertical irregularity under the loading has been carried out with the intention to investigate the relative importance of several factors in the non-linear analysis of RCC frames and compared. This includes the variation in load displacement graph i.e. Pushover curve, Storey shears, Inter storey drifts, Lateral displacements, Hinge properties, Performance point.

KEYWORDS: Pushover anlysis,Storeyshear,Hingeproperties.

1. INTRODUCTION

The pushover is expected to provide information on many response characteristics that cannot be obtained from an elastic static or dynamic analysis. The following are the examples of such response characteristics: The realistic force demands on potentially brittle elements, such as axial force demands on columns, force demands on brace connections, moment demands on beam to column connections, shear force demands in reinforced concrete beams, etc. Estimates of the deformations demands for elements that have to form inelastically in order to dissipate the energy imparted to the structure Consequences of the strength deterioration of individual elements on behavior of the structural system. Identification of the critical regions in which the deformation demands are expected to be high and that have to become the focus through detailing.Identification of the strength discontinuous in plan elevation that will lead to changes in the dynamic characteristics in elastic range.Estimates of the inter story drifts that account for strength or stiffness discontinuities and that may be used to control the damages and to evaluate P-Delta effects. Verification of the completeness and adequacy of load path, considering all the elements of the structural systems, all the connections.

1.1 Background

Nonlinear static analysis, or pushover analysis, has been developed over the past twenty years and has become the preferred analysis procedure for design and seismic performance evaluation purposes as the procedure is relatively simple and considers post- elastic behavior. However, the procedure involves certain approximations and simplifications that some amount of variation is always expected to exist in seismic demand prediction of pushover analysis. Although, pushover analysis has been shown to capture essential structural response characteristics under seismic action, the accuracy and the reliability of push over analysis in predicting global and local seismic demands for all structures have been a subject of discussion and improved pushover procedures have been proposed to overcome the certain limitations of traditional pushover procedures. However, the improved procedures are mostly computationally demanding and conceptually complex that use of such procedures is impractical in engineering profession and codes. As traditional pushover analysis is widely used for design and seismic performance evaluation purposes, its limitations, weaknesses and the accuracy of its predictions in routine application should be identified by studying the factors affecting the pushover predictions. In other words, the applicability of pushover analysis in predicting seismic demands should be investigated for low, mid and high-rise structures by identifying certain issues such as modeling nonlinear member behavior, computational scheme of the procedure, variations in the predictions of various lateral load patterns utilized in traditional pushover analysis, efficiency of invariant lateral load patterns in representing higher mode effects and accurate estimation of target displacement at which seismic demand prediction of pushover procedure is performed. (Wang. et. 2006)[17]

1.2 Different Hinge Properties in Pushover Analysis on ETABS

There are four types of hinge properties in ETABS. They are default hinge properties; user defined hinge properties and generated hinge properties. Only default hinge properties and user-defined hinge properties can be assigned to frame elements. When these hinge properties are assigned to a frame

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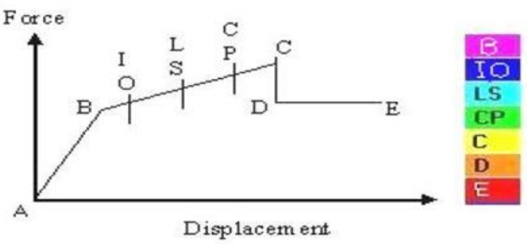
element, the program automatically creates a different generated hinge property for each and every hinge.

1.3PUSHOVER ANALYSIS

Pushover Analysis option will allow engineers to perform pushover analysis as per FEMA -356 and ATC-40. Pushover analysis is a static, nonlinear procedure using simplified nonlinear technique to estimate seismic structural deformations. It is an incremental static analysis used to determine the force-displacement relationship, or thecapacity curve, for a structure or structural element.

Fig 1 Capacity curve

The analysis involves applying horizontal loads, in a



prescribed pattern, to the structure incrementally, i.e. pushing the structure and plotting the total applied shear force and associated lateral displacement at each increment, until the structure or collapse condition. (sermin, 2005)

Pushover analysis is a technique by which a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniform). The intensity of the lateral load is slowly increased and the sequence of cracks, yielding, plastic hinge formation, and failure of various structural components is recorded. Pushover analysis can provide a significant insight into the weak links in seismic performance of a structure. A series of iterations are usually required during which, the structural deficiencies observed in one iteration, are rectified and followed by another. This iterative analysis and design process continues until the design satisfies pre-established performance criteria. The performance criteria for pushover analysis are generally established as the desired state of the building given roof-top or spectral displacement amplitude. Static Nonlinear Analysis technique, also known as sequential yield analysis, or simply “pushover” analysis has gained significant popularity during the past few years. It is the one of the three analysis techniques recommended by FEMA-273/274 and a main component of the Spectrum Capacity Analysis method (ATC-40). Proper application can provide valuable insights into the expected performance of structural systems and components. Misuse can lead to an erroneous understanding of the

2. LITERATURE REVIEW

The practical difficulties associated with the non linear direct numerical integration of the equations of motion leads to the use of non linear static pushover analysis of structures[1]. The uncertainties in structural demand and capacity should be considered [2]. Performance based seismic design of tall buildings in the U.S is presented [3].summarized the nonlinear static analytical procedure (Pushover) as introduced by ATC-40 has been utilized for the evaluation of existing design of a new reinforced concrete frame[4]. In this paper he presented a method for the determination of the parameters of plastic hinge properties (PHP) for structure containing RC wall in the pushover analysis is proposed [5].

3. MODELLING IN ETABS

3.1 Description of Structure

Three six storied structure are modeled using ETABS software. Model01 is a regular structure; Model02 & Model03 are irregular structures with vertical irregularities. The percentages of vertical irregularity for Model02 & Model03 are modeled as per codal provisions (IS: 1893-1(2002)) table5.

3.2 MATERIAL PROPERTIES

The material usedfor construction is Reinforced concrete with M-25 grade concrete and fe415 grade reinforcing steel. The Stress-Strain relationship used is as per I.S.456:2000. The basic material properties used are as follows:
Modulus of Elasticity of steel, Es = 21,0000MPa
Modulus of Elasticity of concrete, EC = 25,000 MPa
Characteristic strength of concrete, fck = 25 MPa

Modulus of Elasticity of steel, Es = 21,0000MPa

Modulus of Elasticity of concrete, EC = 25,000 MPa

Characteristic strength of concrete, fck = 25 MPa
Yield stress for steel, fy = 415 MPaUltimate strain in bending, Ɛcu =0.

Table.01 Percentage of Vertical Irregularity

SR.NO	DESIGNATION	TYPE OF FRAME	PERCENTAGE OF IRREGULARITY
1	MODEL01	REGULAR	-
2	MODEL02	IRREGULAR	400%
3	MODEL03	IRREGULAR	533%

3.3 MODEL GEOMETRY

The structure analyzed is a six-storied, four bays along X-direction and four bays along Y-direction ordinary moment-resisting frame of reinforced concrete with properties as specified above. The concrete floors are modeled as rigid. The details of the model are given as:

Number of stories = 7

Baywidth along X-direction = 3.5meters

Bay width along Y-direction = 3.5meters

Plan of Building:

The plan of the building is shown in the Fig. 2 the plans of all the three models are same

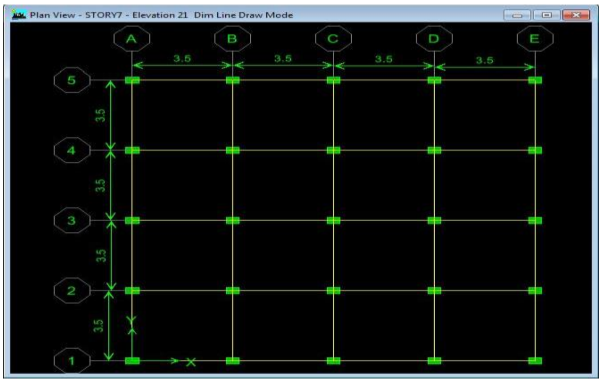


Fig 2 Plan view

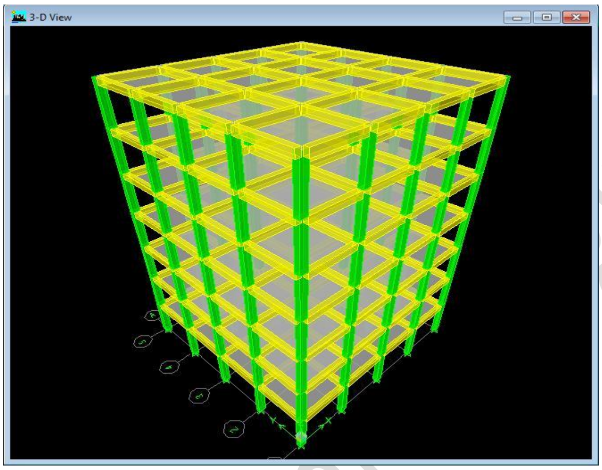


Fig 3 ELEVATION OF MODEL01

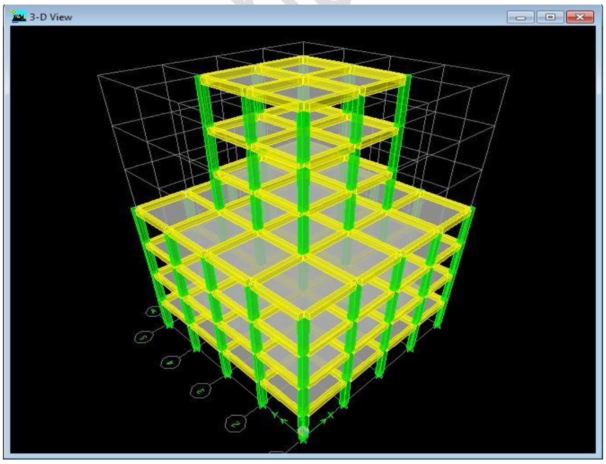


Fig.4Elevation of MODEL02

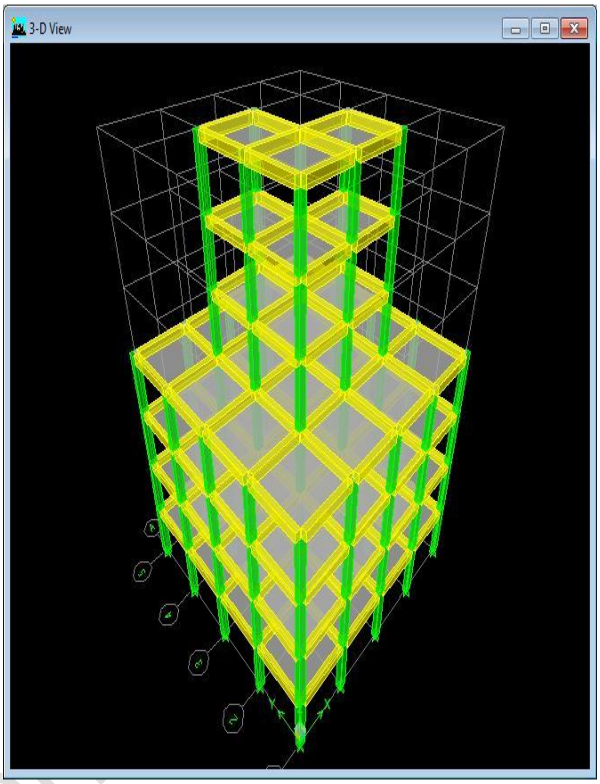


Fig.5 Elevation ofMODEL 03

3.4 Section dimensions

Beam sections dimension is figured below:

Model 01, Model 02& Modal 03 have the beam dimension as300x450mm

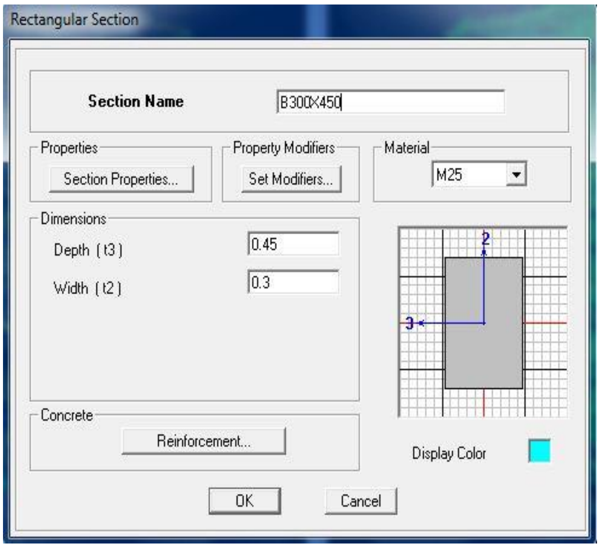


Fig. 6 Section Dimensions Of Beam

Column sections dimension is figured below:

- Model 01, Model 02& Modal 03 have the beam dimension as300x450mm

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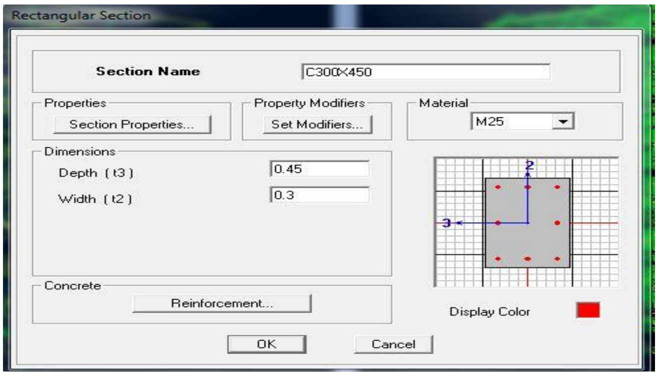

Fig. 7 Section Dimensions Of the Column

PUSHOVER CURVE

Step	Displacement	Base Force	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0000	0.0000	1460	10	0	0	0	0	0	0	1470
1	0.0243	1053.1156	1395	75	0	0	0	0	0	0	1470
2	0.0279	1182.0121	1345	125	0	0	0	0	0	0	1470
3	0.0307	1227.6641	1290	180	0	0	0	0	0	0	1470
4	0.0434	1305.3585	1255	215	0	0	0	0	0	0	1470
5	0.0600	1362.2271	1240	45	75	110	0	0	0	0	1470
6	0.1568	1485.2028	1165	120	0	180	0	5	0	0	1470
7	0.2358	1549.6584	1165	120	0	180	0	0	5	0	1470
8	0.2358	1475.2948	1165	120	0	170	0	10	5	0	1470
9	0.2372	1496.9869	1160	125	0	160	0	0	10	15	1470
10	0.2372	921.7965	1160	125	0	160	0	0	10	15	1470
11	0.2388	933.6603	1160	125	0	160	0	0	5	20	1470
12	0.2411	939.4470	1160	125	0	160	0	0	5	20	1470
13	0.2345	863.4354	1470	0	0	0	0	0	0	0	1470

Fig 11 Tabular data for Pushover Curve

4. RESULTS AND DISCUSSIONS

The results of Analysis of RCCframes. Analysis of RCC frames under the static loads has been performed using ETABS software. The analysis results of the models i.e. frame with and without vertical irregularity of six storey full scale reinforced concrete structures under Monotonic Push-over Loads. This is followed by load deflection curve pushover table, deformed shapes and mode shapes of the frames.

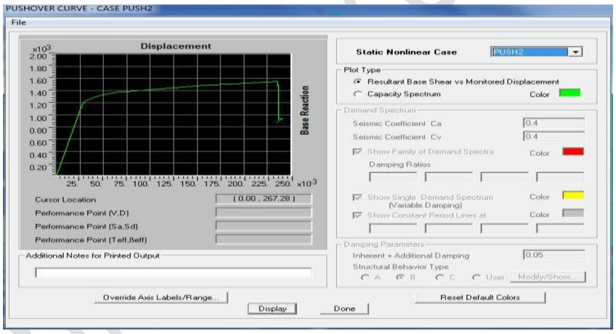

Fig.12 Pushover Curve of Model 1

MODE SHAPES OF MODEL01:

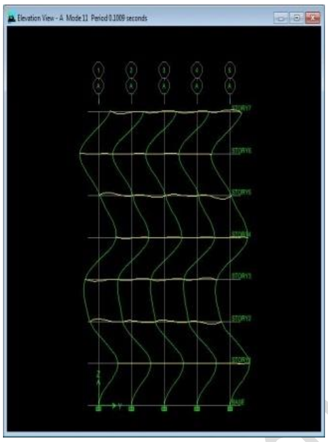

Fig. 8 Mode 11

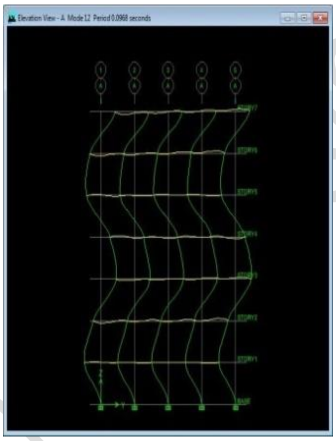

Fig. 9 Mode 12

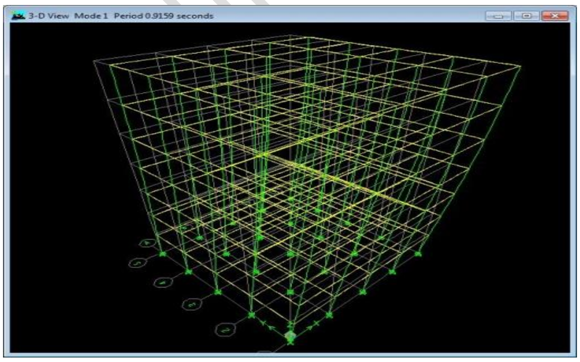

Fig. 10 Hinge formations

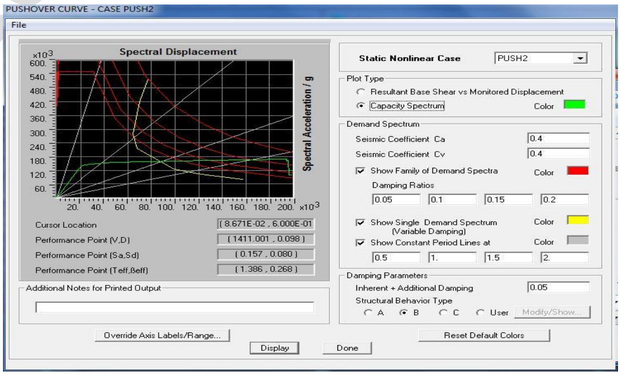

Fig 13 PerformancePoint of Model 01

MODE SHAPES OF MODEL02:

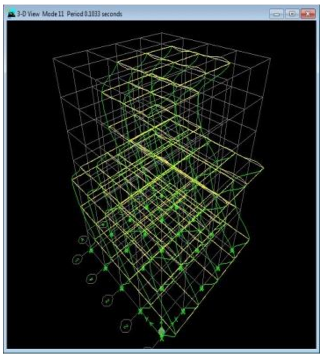

Fig .14 Mode 11

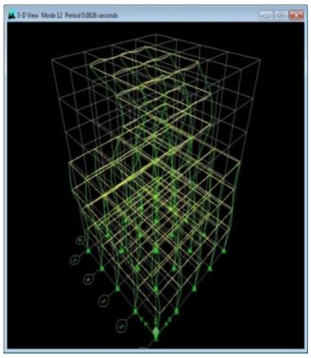

Fig.15 Modes 12

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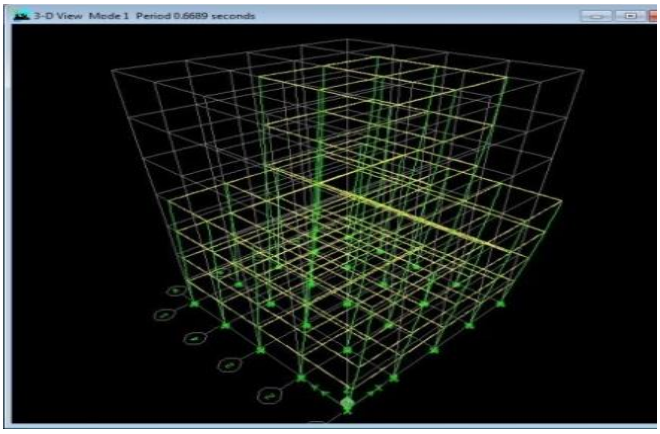
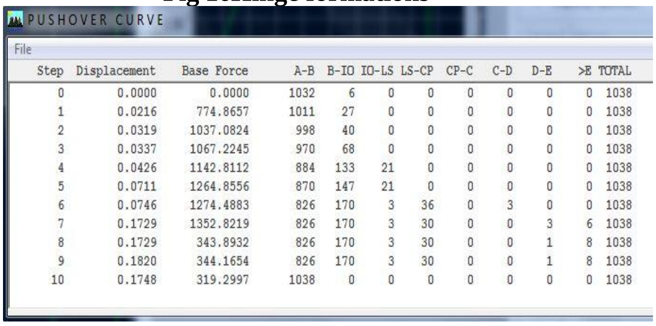


Fig 16Hinge formations


PUSHOVER CURVE
File

Step	Displacement	Base Force	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	TOTAL
0	0.0000	0.0000	1032	6	0	0	0	0	0	0	1038
1	0.0216	774.8657	1011	27	0	0	0	0	0	0	1038
2	0.0319	1037.0824	998	40	0	0	0	0	0	0	1038
3	0.0337	1067.2245	970	68	0	0	0	0	0	0	1038
4	0.0426	1142.8112	884	133	21	0	0	0	0	0	1038
5	0.0711	1264.8556	870	147	21	0	0	0	0	0	1038
6	0.0746	1274.4883	826	170	3	36	0	3	0	0	1038
7	0.1729	1352.8219	826	170	3	30	0	0	3	6	1038
8	0.1729	343.8932	826	170	3	30	0	0	1	8	1038
9	0.1820	344.1654	826	170	3	30	0	0	1	8	1038
10	0.1748	319.2997	1038	0	0	0	0	0	0	0	1038

Fig. 17 Pushover curve of Model 2

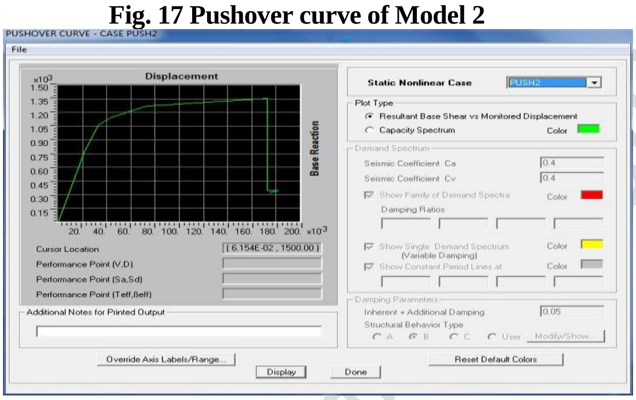


Fig 18 Tabular data for Pushover curve

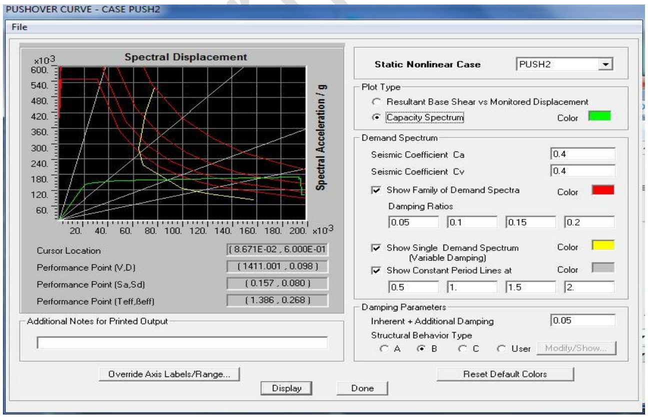


Fig 19 Performance point of Model 2

MODE SHAPES OF MODEL03:

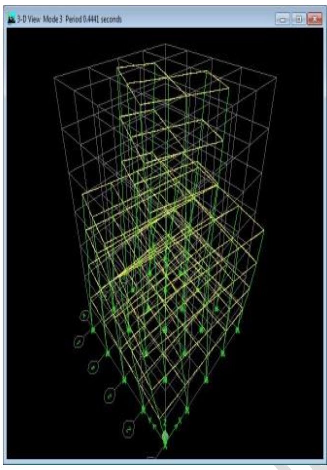


Fig. 20Mode 11

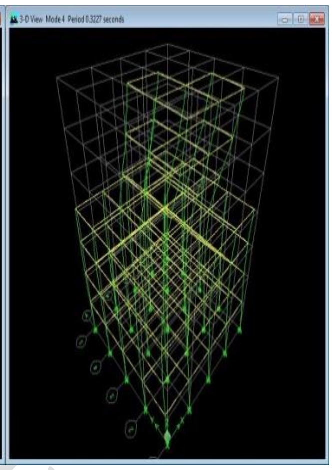


Fig. 21 Mode 12

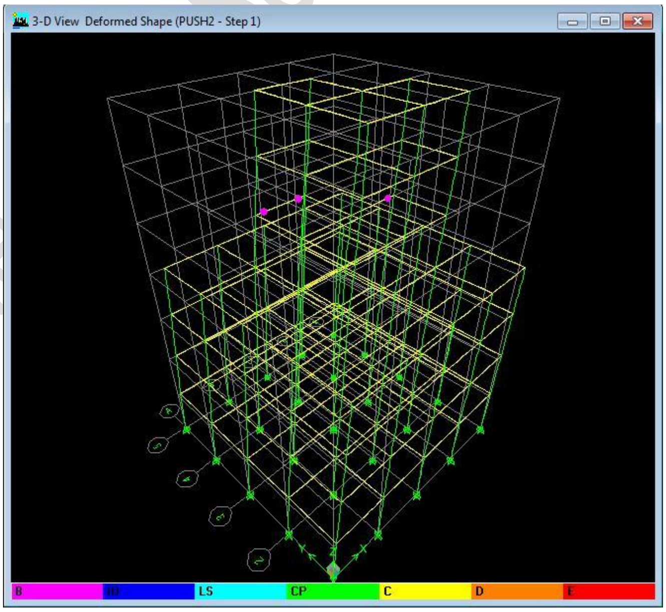


Fig 22Hinge formations

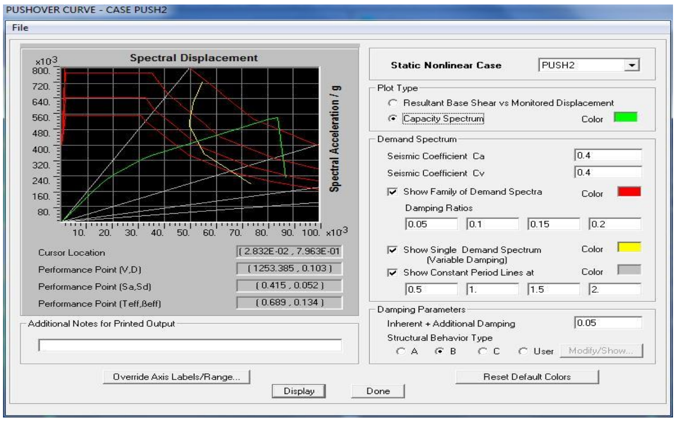


Fig 23 performance point of model 3

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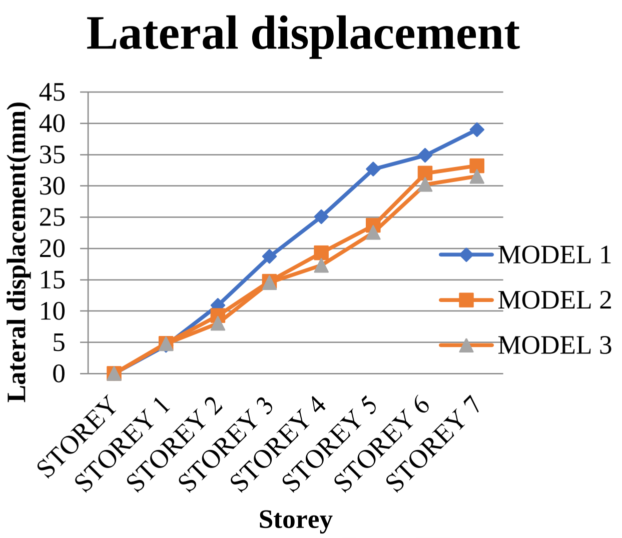
TABLE.02 PUSHOVER RESULTS

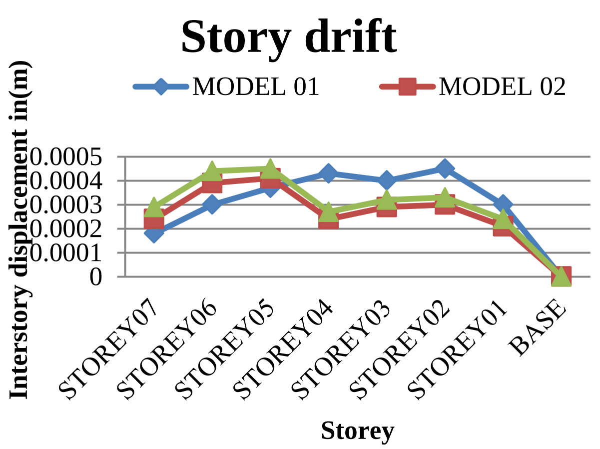
Frame type	G+6 STOREY	G+6 STOREY
	Performance Point X(KN)	Displacement X (m)
Frame model 01	1411.11	0.098
Frame model 02	1294.984	0.100
Frame model 03	1253.385	0.103

From the table above it can be observe that the performance of the structure decreased from regular Model011411kN to Model 02 1294.984 & Model 03 1253.385 and the corresponding displacements also decreased as the percentage of vertical irregularity increased.

GRAPH 01:

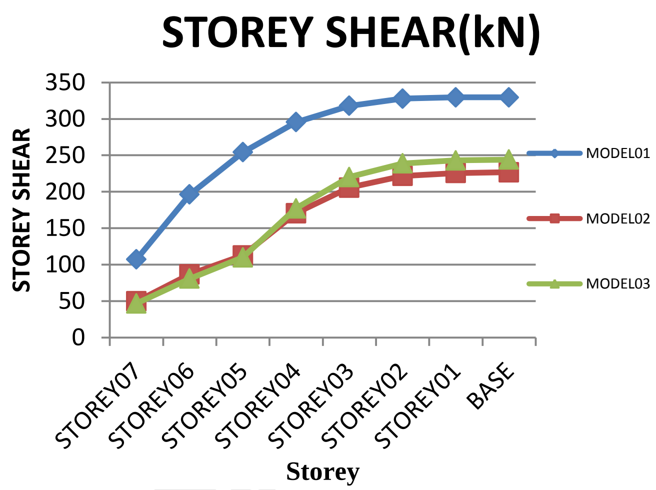


GRAPH 02:



Inter storey drift plot

GRAPH 03:



Storey shear graph

5. CONCLUSIONS AND RECOMMENDATIONS

The main observations and conclusions drawn are summarized below: The performance point of the regular structure i.e. Model01 shows high performance 1411.11kN when compared to Model 02 1294.984kN and Model 03 1253.385Knwhich have vertical irregularity.

1. The displacement of the regular structure Mole 01 is less when compared to Model 02 & Model 03.The regular frame shows the displacement of .098m but due to vertical irregularity it reduces to 0.100 m for 400% irregularity Model02 & 0.103m for 533% irregularity Model 03.
2. The change in percentage of vertical irregularity causes change in storey drift; as the percentage increases with reduce in storey drift.
3. The change in percentage of vertical irregularity also cause change in storey shear as the regular frame shows the storey shear of 327.78 kN at the base, but due to change in vertical irregularity it reduces to 226.34 kN for 400% irregularity and 242.41kN for 533% irregularity.
4. From the above discussion, the seismic performance of the irregular building is reduces by 8-9% for 400% vertical irregularity and 11-12% for 533% vertical irregularity when compared to symmetric base model.

5.1 RECOMMENDATIONS

The literature review and analysis procedure utilized in this thesis has provided useful insight for future application of ETABS for analysis. It helps in comparing the results with regular and irregular structures. Modeling the RCC frame in ETABS software gives good results which can be included in future research.

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