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Pushover Analysis of Sir M Visvesvaraya Block Nmamit Nitte

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Abstract: Pushover analysis is one of the most-used nonlinear static procedures for the seismic assessment of structures, due to its simplicity, efficiency in modeling and low computational time. The previous studies about pushover analysis are almost based on symmetric building structures and unidirectional earthquake excitation. This analysis is conducted to evaluate the seismic capacities of an existing asymmetric-plan building. The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi storey building frame with the help of pushover analysis are carried out. In the present study the building frame is designed as per IS 456:2000 and IS 1893:2002. We should also go through ATC-40, FEMA 356. To get knowledge of pushover analysis we have to learn Etabs and should practice to analysis a RC building. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis and design software ETABS (Version 19).
Keywords: Pushover analysis, RC building, Performance Point, Etabs, code book

I. INTRODUCTION

A. General 1.1

Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformations. Structures redesign themselves during earthquakes. As individual components of a structure yield or fail, the dynamic forces on the building are shifted to other components. A pushover analysis simulates this phenomenon by applying loads until the weak link in the structure is found and then revising the model to incorporate the changes in the structure caused by the weak link. A second iteration indicates how the loads are redistributed. The structure is “pushed” again until the second weak link is discovered. This process continues until a yield pattern for the whole structure under seismic loading is identified.

The need for a simple method to predict the non-linear behavior of a structure under seismic loads saw light in what is now popularly known as the Pushover Analysis (PA). It can help demonstrate how progressive failure in buildings really occurs, and identify the mode of final failure. Putting simply, PA is a non-linear analysis procedure to estimate the strength capacity of a structure beyond its elastic limit (meaning Limit State) up to its ultimate strength in the post-elastic range. In the process, the method also predicts potential weak areas in the structure, by keeping track of the sequence of damages of each and every member in the structure (by use of what are called ‘hinges’ they hold).

B. Pushover vs. Conventional Analysis

In order to understand PA, the best approach would be to first see the similarities between PA and the conventional seismic analysis (SA), both Seismic Coefficient and Response Spectrum methods described in IS:1893-2002 for SA, which most of the readers are familiar with, and then see how they are different:

Both SA and PA apply lateral load of a predefined vertical distribution pattern on the structure. In SA, the lateral load is distributed either parabolically (in Seismic Coefficient method) or proportional to the modal combination (in the direct combination method of Response Spectrum). In PA, the distribution is proportional to height raised to the power of ‘k’, where k (equivalent to ‘2’ in the equation under Cl. 7.7.1 in IS:1893-2002) can be equal to 0 (uniform distribution), 1 (the inverted triangle distribution), 2 (parabolic distribution as in the seismic coefficient method) or a calculated value between 1 and 2, the value of k being based on the time period T of the structure, as per the FEMA 356 (where k is given a value of 2 if $T \geq 2.5$ seconds, a value of 1 if $T \leq 0.5$ seconds and interpolated for intermediate values of T). The distribution can also be proportional to either the first mode shape, or a combination of modes.

In both SA and PA, the maximum lateral load estimated for the structure is calculated based on the fundamental time period of the structure. And the last point above is precisely where the difference starts.

While in SA the initial time period is taken to be a constant (equal to its initial value), in PA this is continuously re-calculated as the analysis progresses. The differences between the procedures are as follows:

- SA uses an elastic model, while PA uses a non-linear model. In the latter this is incorporated in the form of non-linear hinges inserted into an otherwise linear elastic model which one generates using a common structural analysis & design software package (like SAP2000 or ETABS), having facilities for PA.

C. *The Hinges*

Hinges are points on a structure where one expects cracking and yielding to occur in relatively higher intensity so that they show high flexural (or shear) displacement, as it approaches its ultimate strength under cyclic loading. These are locations where one expects to see cross diagonal cracks in an actual building structure after a seismic mayhem, and they are found to be at the either ends of beams and columns, the ‘cross’ of the cracks being at a small distance from the joint – that is where one is expected to insert the hinges in the beams and columns of the corresponding computer analysis model. Hinges are of various types – namely, flexural hinges, shear hinges and axial hinges. The first two are inserted into the ends of beams and columns. Since the presence of masonry infill have significant influence on the seismic behavior of the structure, modeling them using equivalent diagonal struts is common in PA, unlike in the conventional analysis, where its inclusion is a rarity. The axial hinges are inserted at either ends of the diagonal struts thus modeled, to simulate cracking of infill during analysis. Basically, a hinge represents localized force-displacement relation of a member through its elastic and inelastic phases under seismic loads. For example, a flexural hinge represents the moment-rotation relation of a beam of which a typical one is as represented in Fig.1. AB represents the linear elastic range from unloaded state A to its effective yield B, followed by an inelastic but linear response of reduced (ductile) stiffness from B to C. CD shows a sudden reduction in load resistance, followed by a reduced resistance from D to E, and finally a total loss of resistance from E to F. Hinges are inserted in the structural members of a framed structure typically as shown in Fig.2. These hinges have non-linear states defined as ‘Immediate Occupancy’ (IO), ‘Life Safety’ (LS) and ‘Collapse Prevention’ (CP) within its ductile range. This is usually done by dividing B-C into four parts and denoting IO, LS and CP, which are states of each individual hinges (in spite of the fact that the structure as a whole too have these states defined by drift limits). There are different criteria for dividing the segment BC. For instance, one such specification is at 10%, 60%, and 90% of the segment BC for IO, LS and CP respectively (Inel & Ozmen, 2006).

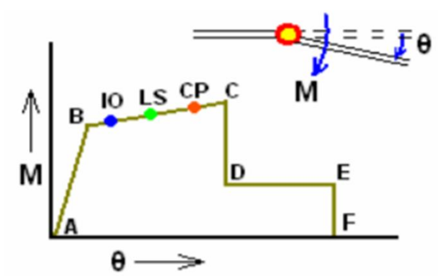


Fig 1.1- Typical Flexural Hinge Property

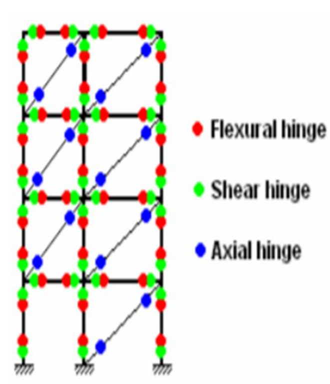


Fig 1.2- Typical Locations of Hinges

D. Two Stage Design Approach

Although hinge properties can be obtained from charts of average values included in FEMA356, ATC-40 and FEMA 440 (which are only rough estimates), for accurate results one requires the details of reinforcement provided in order to calculate exact hinge properties. And one has to design the structure in order to obtain the reinforcement details. This means that PA is meant to be a second stage analysis. Thus, the emerging methodology to an accurate seismic design is:

1) First a linear seismic analysis based on which a primary structural design is done.
2) Insertion of hinges determined based on the design.
3) A pushover analysis.
4) Modification of the design and detailing, wherever necessary, based on the Pushover analysis.

E. Limitations

As such the method appears complete and sound, yet there are many aspects which are unresolved, which include incorporation of torsional effects of buildings, problems faced due to use of diagonal struts, etc. The most addressed (but yet unresolved) issue is that the procedure basically takes into account only the fundamental mode (as can be seen in the procedure for transforming Vb and roof top to Sa and Sd, explained earlier), assuming it to be the predominant response and does not consider effects of higher modes.

The two Limitations are:

One of the fundamental simplifications underlying the concept of PA is that considers the structure as a single degree of freedom system, which in reality it hardly is.

And that means the structure model, with numerous joints with lumped masses, is assumed to be equivalent to a single vertical strut fixed at bottom with a single (but considerable) mass lumped at the top.

II. OBJECTIVE

When an existing structure has deficiencies in seismic resisting capacity.

When the structure becoming seismically inadequate to a later upgradation of the seismic code & is to be retrofitted to meet the present seismic demands.

To analyze the structure in terms of Base shear, Story drift, Story displacement by performing the Pushover Spectrum Analysis.

III. LITERATUREVIEW

1) *Rahul Rana, Limin Jin and Atila Zekioglu, "PUSHOVER ANALYSIS OF A 19 STORY CONCRETE SHEAR WALL BUILDING", (2004).*

Pushover analysis was performed on a nineteen story, slender concrete tower building located in San Francisco with a gross area of 430,000 square feet. Lateral system of the building consists of concrete shear walls. The building is newly designed conforming to 1997 Uniform Building Code, and pushover analysis was performed to verify code's underlying intent of Life Safety performance under design earthquake. Procedure followed for carrying out the analysis and results are presented in this paper.

2) *Chung- Yue Wang and Shaing-Yung Ho, "Pushover Analysis for Structure Containing RC Walls", (2007).*

In this paper, a method for the determination of the parameters of plastic hinge properties (PHP) for structure containing RC wall in the pushover analysis is proposed. Nonlinear relationship between the lateral shear force and lateral deformation of RC wall is calculated first by the Response-2000 and Membrane-2000 code. The PHP (plastic hinge properties) value of each parameter for the pushover analysis function of SAP2000 or ETABS is defined as the product of two parameters α and β . Values ofα at states of cracking, ultimate strength and failure of the concrete wall under shear loading can be determined respectively from the calculations by Response-2000. While the corresponding β value of each PHP parameter is obtained from the regression equations calibrated from the experimental results of pushover tests of RC frame-wall specimens. The accuracy of this newly proposed method is verified by other experimental results. It shows that the presented method can effectively assist engineers to conduct the performance design of structure containing RC shear wall using the SAP2000 or ETABS codes.

3) *Hardik Bhensdadia, Siddharth Shah. "Pushover analysis of RC frame structure with floating column and soft story in different earthquake zones", (2015).*

Open first story and Floating column are typical features in the modern multi-storey constructions in urban India. Such features are highly undesirable in buildings built in seismically active areas; this has been verified in numerous experiences of strong shaking during the past earthquakes like Bhuj 2001. In this study an attempt is made to reveal the effects of floating column & soft story in different earthquake zones by seismic analysis. For this purpose Push over analysis is adopted because this analysis will yield performance level of building for design capacity (displacement) carried out up to failure, it helps determination of collapse load and ductility capacity of the structure. To achieve this objective, three RC bare frame structures with G+4, G+9, G+15 stories respectively will be analysed and compared the base force and displacement of RC bare frame structure with G+4, G+9, G+15 stories in different earthquake zones like Rajkot, Jamnagar and Bhuj using ETABS.

4) Govind M.Kiran K.Shetty K.Anil Hegde, "Nonlinear static pushover analysis of irregular space frame structure with and without t shaped columns", (2014).

The static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The expectation is that the pushover analysis will provide adequate information on seismic demands imposed by the design ground motion on the structural system and its components. The recent advent of structural design for a particular level of earthquake performance, such as immediate post-earthquake occupancy, (termed as performance-based earthquake engineering), has resulted in guidelines such as ATC-40, FEMA-356 and standards such as ASCE-41. Among the different types of analysis, pushover analysis comes forward because of its optimal accuracy, efficiency and ease of use. In the present study, the behaviour of G+20 storied R.C frame buildings (H shape in plan, with and without T shaped column) subjected to earthquake, located in seismic zone III is discussed briefly using ETABS software. Gravity loads and laterals loads as per IS 1893-2002 are applied on the structure and it is designed using IS 456. Displacement control pushover analysis is carried out.

5) S.C.Pednekar, H.S.Chore, S. B.Patil, "Pushover Analysis of Reinforced Concrete Structures",(2015)

The present study gives an effect of increase in number of storey on seismic responses by performing pushover analysis. Reinforced concrete structures of G+4, G+5 and G+ 6 storey have been modeled and analyzed using CSi ETABS 9.7.4 software. Comparison of seismic responses of the structure in terms of base shear, time period and displacement has been done by performing nonlinear static pushover analysis. From analysis results it has been observed that base shear and spectral acceleration is reduced, whereas displacement, time period, spectral displacement is increased as the number of storey increases. Analysis also shows location of plastic hinges at performance point of the structures with different number of storey.

6) Vaseem Inamdar & Arun Kumar, "Pushover Analysis of Complex Steel Frame with Bracing Using Etabs", (2014).

Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In the present study, pushover analysis of complex steel frame building was investigated. These investigations were based on stiffness and ductility. This paper is intended to compare the performance of structure by using ISMB and ISNB (hollow pipes) steel sections as bracing element on 15-story complex steel frame. Displacement analyses were performed using the Extended 3D Analysis of Building Systems (ETABS) software for investigating stiffness of these system and pushover analysis were performed. The results of these outputs indicated that performance of structure greatly influenced by the way and sections adopted for bracing system.

F. S. Saisaran, V. Yogendra Durga Prasad, T. Venkat Das, "Push Over Analysis for Concrete Structures at Sesimic Zone-3 using Etabs Software", (2016).

In this paper we are going to discuss about the analysis on the RC building frame, i.e., 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 the capacity curve for a structure or structural element. The analysis involves applying of 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 loads at each increment until the structure or collapse condition. In technique a computer model of the building is subjected to a lateral load of a certain shape (i.e., inverted triangular or uniformly). 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 the structure.

The seismic response of RC building frame in terms of performance point and the effect of earthquake forces on multi story building frame with the help of pushover analysis is carried out in this paper. In the present study a building frame is designed as per Indian standard i.e., IS 456:2000 and IS 1893:2002. The main objective of this study is to check the kind of performance a building can give when designed as per Indian Standards. The pushover analysis of the building frame is carried out by using structural analysis by software E-tabs at only zone-3 earthquake.

G. R. Shahrin & T.R. Hossain, "Seismic performance evaluation of residential buildings in Dhaka city by using pushover analysis." (2011)

Bangladesh is situated in moderate earthquake prone region. Major metropolitan cities of our country are under serious threat because of faulty design and construction of structures. Weak buildings designed without seismic consideration could be vulnerable to damage even under low levels of ground shaking from distant earthquakes. So, the structural engineers now-a-days are more concerned about the different earthquake analysis procedures. According to BNBC (2006) the buildings are designed according to equivalent static force method, response spectrum method and time history analysis. But the actual performance of a structure can be hardly found by these methods. Nonlinear inelastic pushover analysis provides a better understanding about the actual behavior of the struc-tures during earthquake. The pushover analysis which is not very familiar to many structural engineers has wide range of applications in the seismic evaluation and retrofit of structure. There are mainly two guidelines of this analysis-FEMA and ATC 40. The paper mainly follows the procedures of ATC 40 in evaluating the seismic performance of residential buildings in Dhaka. The present study investigates as well as compares the performances of bare, full in filed and soft ground storey buildings. For different loading conditions resem-bling the practical situations of Dhaka city, the performances of these structures are analyzed with the help of capacity curve, capacity spectrum, deflection, drift and seismic performance level. The performance of an in filled frame is found to be much better than a bare frame structure. It is seen that consideration of effect of the infill leads to significant change in the capacity. Investigation of buildings with soft storey shows that soft storey mechanism reduces the performance of the structure significantly and makes them most vulnerable type of construction in earthquake prone areas.

H. M. A. Ismaeil, "Pushover Analysis of Existing 3 Stories RC Flat slab Building." (2013)

A three-stories hospital existing reinforced concrete building in the city of Khartoum-Sudan, subjected to seismic loads, was analysed. The Sudan is not free from earthquakes, it has experienced many earthquakes during the recent history, and the previous studies on this field demonstrated this argument. This paper is focused on the study of seismic performance of the existing hospital buildings in the Sudan. Plastic hinge is used to represent the failure mode in the beams and columns when the member yields. The pushover analysis was performed on the building using SAP2000 software (Ver.14) [1] and equivalent static method according to UBC 97 [2]. The principles of Performance Based Seismic Engineering are used to govern the analysis, where inelastic structural analysis is combined with the seismic hazard to calculate expected seismic performance of a structure. Base shear versus tip displacement curve of the structure, called pushover curve, is an essential outcomes of pushover analysis. The pushover analysis is carried out in both X and Y directions. Default hinge properties, available in some programs based on the FEMA -356 [3] and Applied Technology Council (ATC-40) [4] guidelines are used for each member. One case study has been chosen for this purpose. The evaluation has proved that the three stories hospital building is seismically safe.

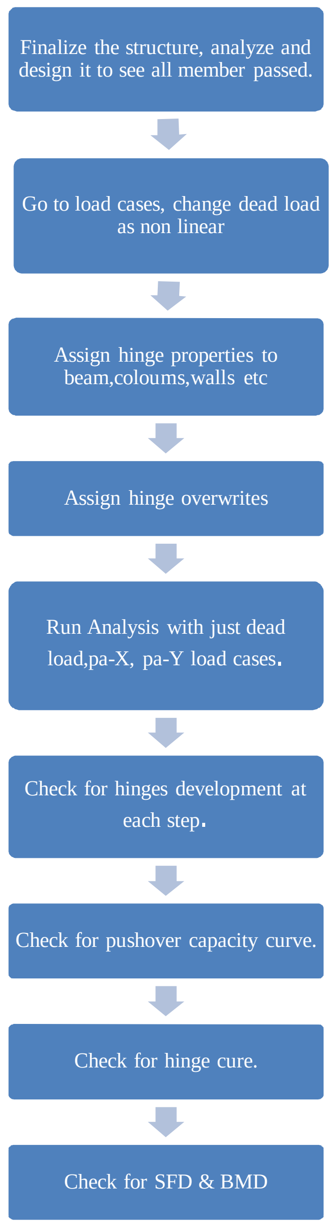
I. Jyothi J Nair, Biju Mathew "Comparative Study Between Conventional and Adaptive Pushover Analysis Using ETABS Software."(2015)

Earthquakes have severely damaged the structures which are already built. Due to this there is large number of deaths, injuries and economic loss. Therefore, there is an urgent need for seismic evaluation of structures. The concept of performance based seismic engineering using pushover analysis is a modern and popular tool to earthquake resistant design due to its simplicity and better seismic assessment of existing and new structures. It gives better understanding of the structural behavior during the strong earthquake ground motion. The present study gives an effect of increase in number of storeys on seismic responses by performing pushover analysis. Reinforced concrete structures of have been modeled and analyzed using ETABS software. Comparison of seismic responses of the structure in terms of base shear, time period and displacement has been done by performing nonlinear static pushover analysis. To consider the effect of higher modes in predicting the seismic responses of buildings, as well as the progressive changes in the dynamic characteristics during the nonlinear analysis, an adaptive force-based multimode pushover (AFMP) procedure is presented. This procedure is an adaptive version of the single-run multimode pushover (SMP) procedure that it is envisaged to be an enhancement of the previously proposed procedure.

Analysis also shows location of plastic hinges at performance point of the structures with different number of storeys. This paper concentrate on the comparative study between two types of analysis in midrise and the irregular RC building.

IV. METHODOLOGY

The push over analysis of a structure is a static non-linear analysis under permanent vertical loads and gradually increasing lateral loads. The equivalent static lateral loads approximately represent earthquake induced forces. A plot of the total base shear versus top displacement in a structure is obtained by this analysis that would indicate any premature failure or weakness. The analysis is carried out up to frame, and thus it enables determination of collapse load and ductility capacity. On a building frame, and plastic rotation is monitored, and lateral inelastic forces versus displacement response for the complete structure is analytically computed. This type of analysis enables weakness in the structure to be identified.



V. WORK CARRIED OUT

- Literature study is carried out
- Learned ETABS Software
- Learned to execute pushover analysis using Etabs on a sample drawing.
- Learning to execute pushover analysis using Etabs on civil block.

A. *What is etabs?*

ETABS is an engineering software product that caters to multi-story building analysis and design. Modeling tools and templates, code-based load prescriptions, analysis methods and solution techniques, all coordinate with the grid-like geometry unique to this class of structure.

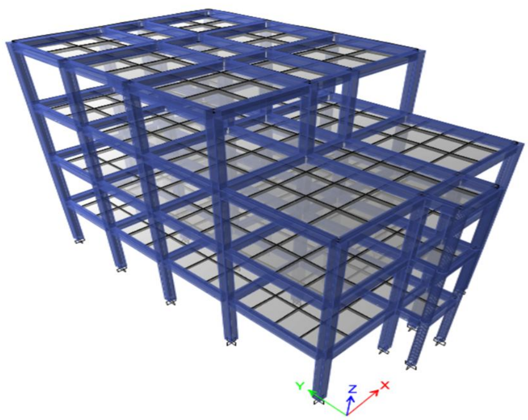


Fig 5.1- Extruded 3D View of G+3 Plan

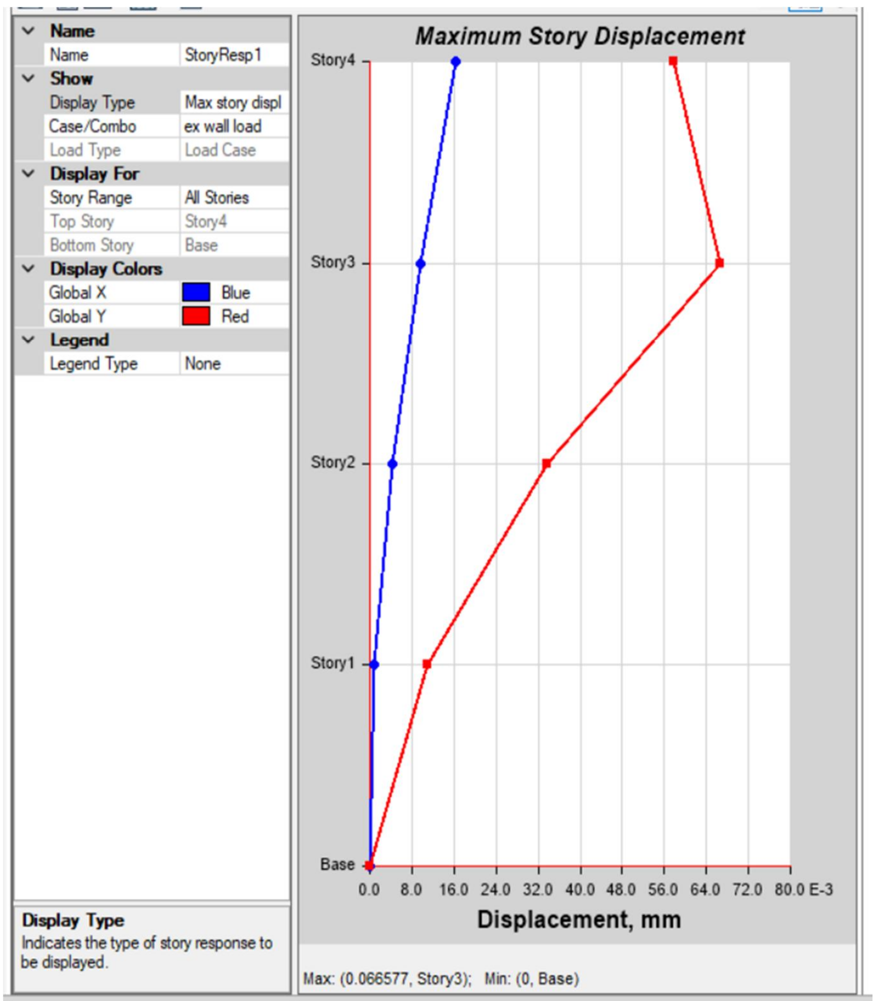


Fig 5.2- Displacement Due to Wall Load

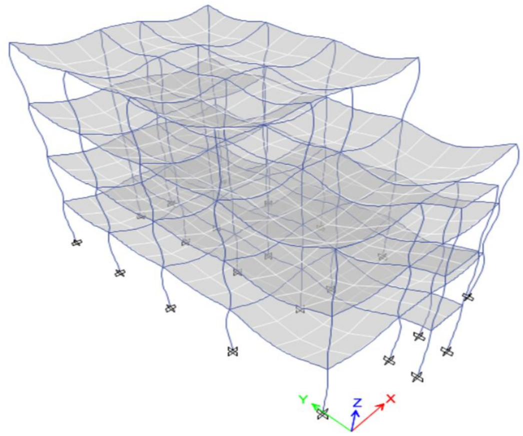


Fig 5.3- Structural Analysis

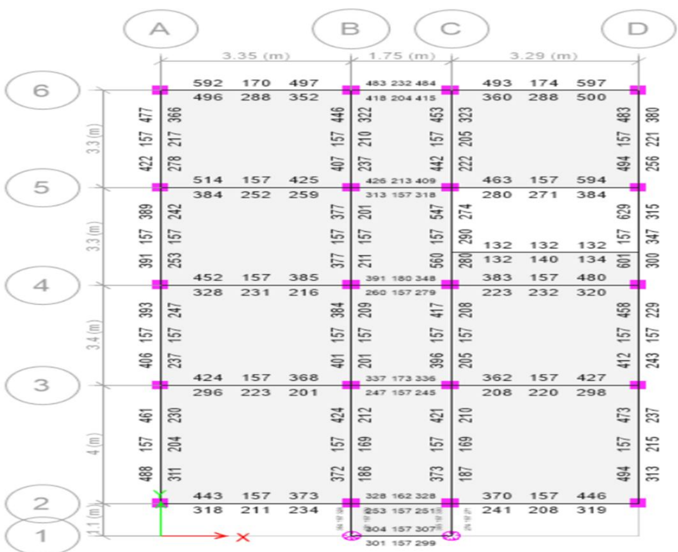
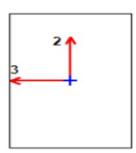


Fig 5.4- Reinforcement Detail of 1st Floor

ETABS Concrete Frame Design

IS 456:2000 + IS 13920:2016 Beam Section Design



Beam Element Details Type: Ductile Frame (Summary)

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF
Story1	B21	134	beam 230x350	DConS7	3140	3290	1

Section Properties

b (mm)	h (mm)	b_f (mm)	d_s (mm)	d_{ct} (mm)	d_{cb} (mm)
230	350	230	0	33	33

Material Properties

E_c (MPa)	f_{ck} (MPa)	Lt.Wt Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
22360.68	20	1	500	500

Design Code Parameters

γ_C	γ_S
1.5	1.15

Factored Forces and Moments

Factored M_{u3} kN-m	Factored T_u kN-m	Factored V_{u2} kN	Factored P_u kN
-65.5163	3.4026	67.4591	0.1116

Design Moments, M_{u3} & M_t

Factored Moment kN-m	Factored M_t kN-m	Positive Moment kN-m	Negative Moment kN-m
-65.5163	5.0473	0	-70.5636

Design Moment and Flexural Reinforcement for Moment, M_{u3} & T_u

	Design -Moment kN-m	Design +Moment kN-m	-Moment Rebar mm²	+Moment Rebar mm²	Minimum Rebar mm²	Required Rebar mm²
Top (+2 Axis)	-70.5636		594	0	594	157
Bottom (-2 Axis)		0	297	0	0	297

Geometric Properties (Part 1 of 2)

Beam Label	Section Property	Length	Section Width	Section Depth	Distance to Top Rebar Center
1546	BEAM	3.75 m	600 mm	750 mm	50 mm

Geometric Properties (Part 2 of 2)

Distance to Bot Rebar Center
50 mm

Material Properties

Concrete Comp. Strength	Concrete Modulus	Longitudinal Rebar Yield	Shear Rebar Yield
30 MPa	27386.13 MPa	500 MPa	500 MPa

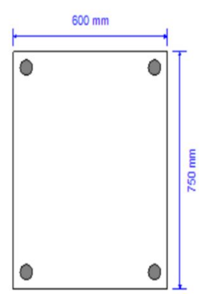


Fig 5.5- Detailing of Singly Supported Beam

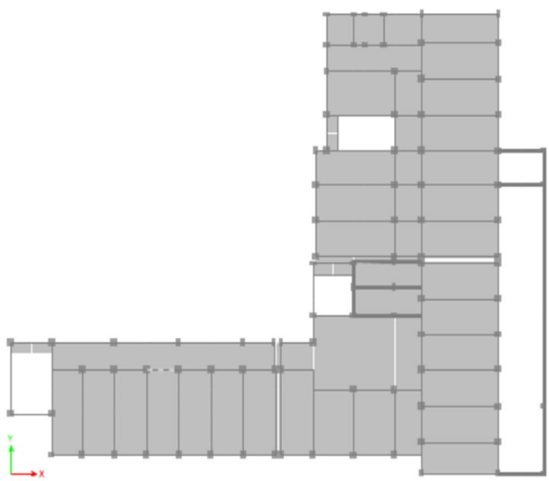


Fig 5.6- Plan View of "Sir M VISVESHWARAYA BLOCK", NMAMIT Nitte

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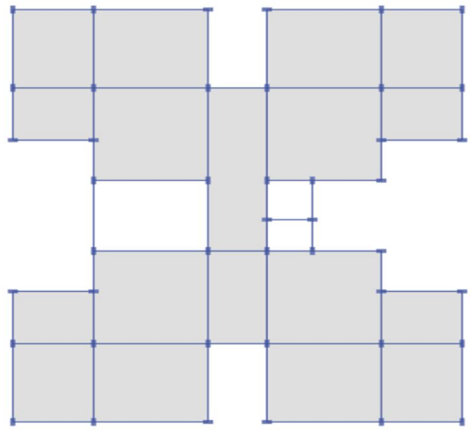


Fig 5.7- Architectural Plan

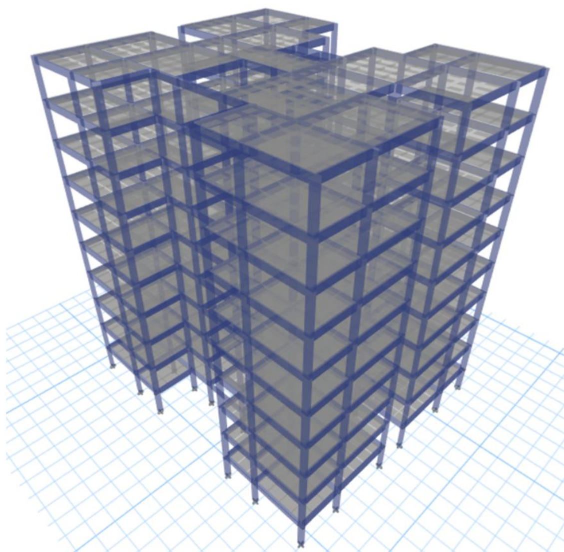


Fig 5.8- 3D Model

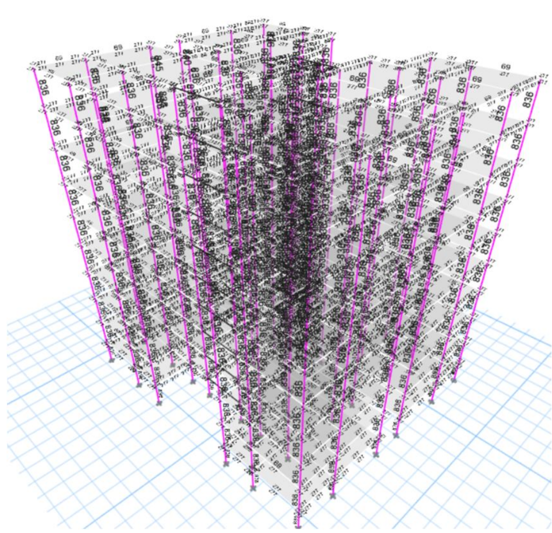


Fig 5.9- Analysed Structure

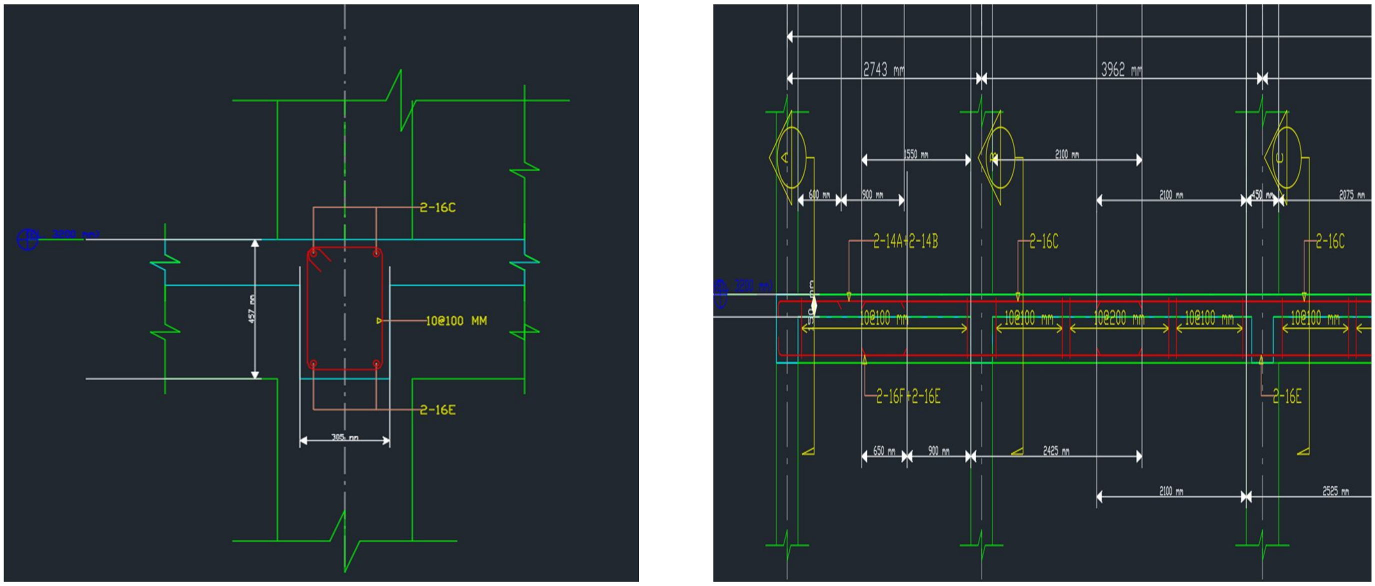


Fig 5.10- Beam Detailing in CSI Detailing 2018

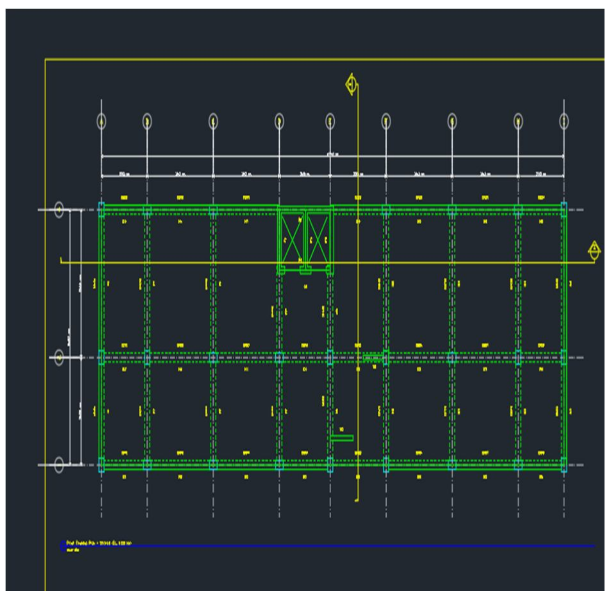
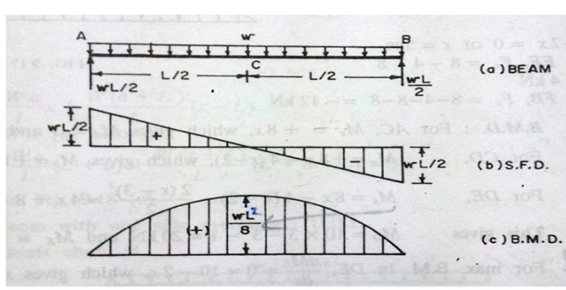


Fig 5.11- Slab Detailing in CSI detailing 2018



Length of beam = **5m**

W = **8 KN/m**

$R_A = R_B$ = W*L/2 = (8*5)/2 = **20 KN**

SF = W*L/2 = (8*5)/2 = **20 KN**

BM = $WL^2/8 = (8*5^2)/8$ = **25 KN-m**

Fig 5.12- B.M, SF and Deflection Diagram

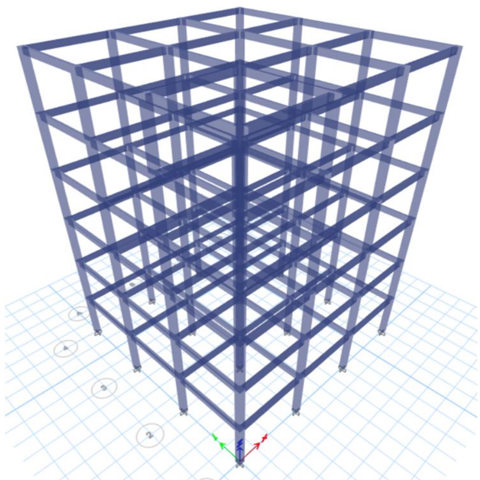


Fig 5.13- Pushover Analysis on G+5 BUILDING

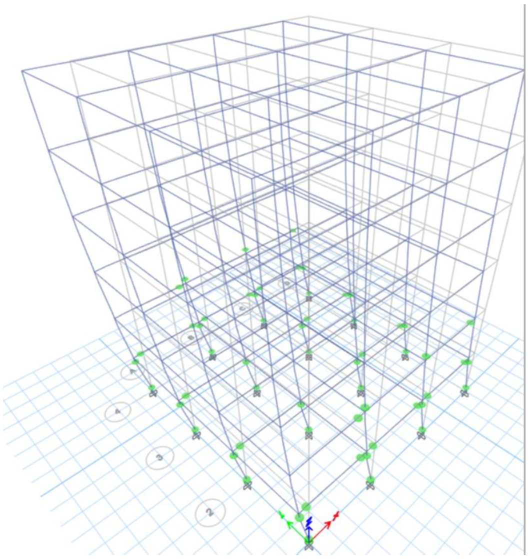


Fig 5.14- Hinge movement on PA –X Direction

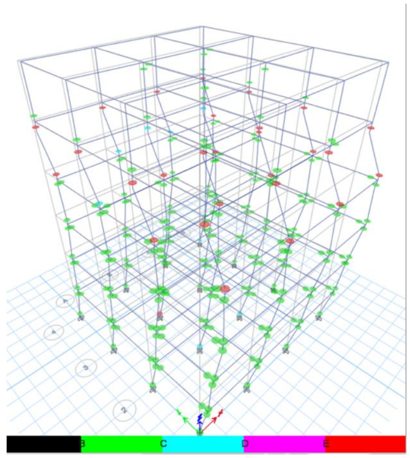


Fig 5.15- Hinge movement on PA – Y Direction

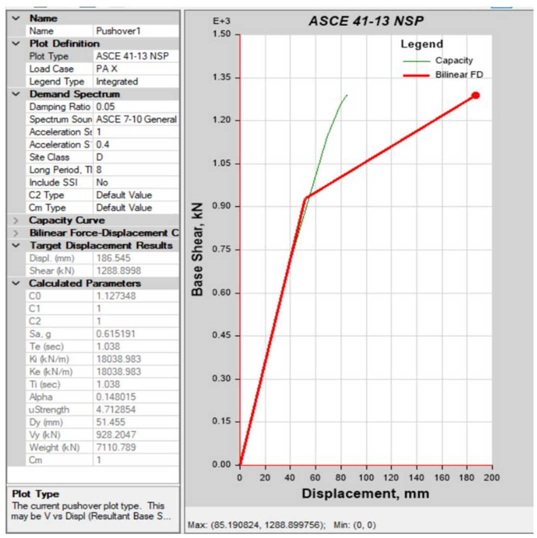


Fig 5.16- Static Pushover Curve

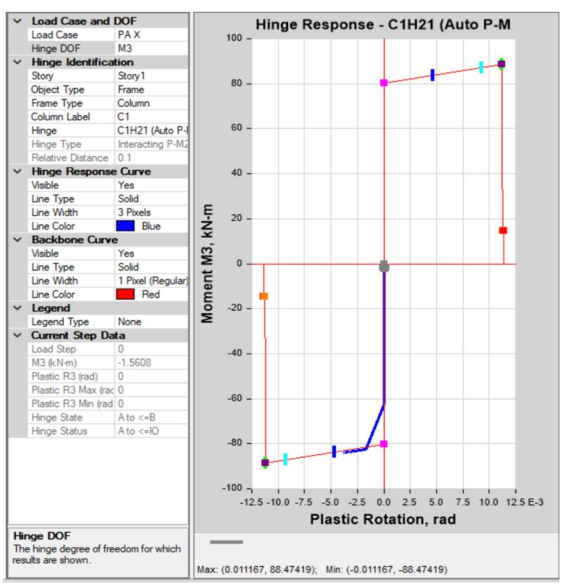


Fig 5.17- Hinge Result Due to PA-X

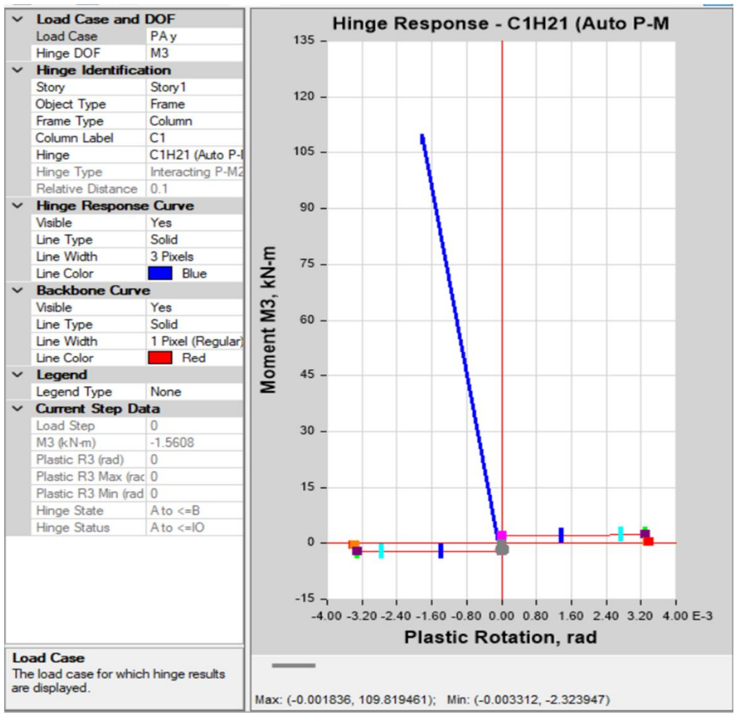


Fig 5.18- Hinge Results Due to PA-Y

VI. COLLEGE BUILDING BLOCK

Analysis done in Etabs should be checked manually with help of IS 456, IS 1893:2016(PART-1).

Should go through the codal provisions ATC-40, FEMA 356.

Two more tall structures should be analyzed in Etabs.

Pushover Analysis should be performed on a structure and it should be checked manually using code book.

At last Pushover Analysis should be performed on the project model “Sir M Vishwesharayya block, NMAMIT, Nitte

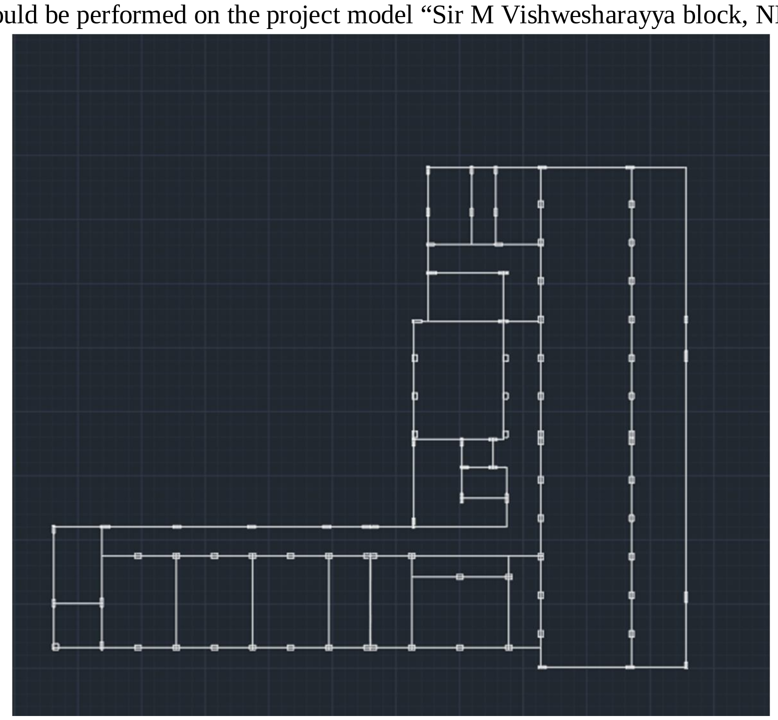


Fig 6.1- Civil Block Centre Line Diagram

A. Description Of Frame Structure

A G+7 storied building is analyzed by Pushover analysis and this structure is designed according to IS 1893:2016 and is located in Zone 3. The material properties are M30 grade concrete and Fe-415 steel.

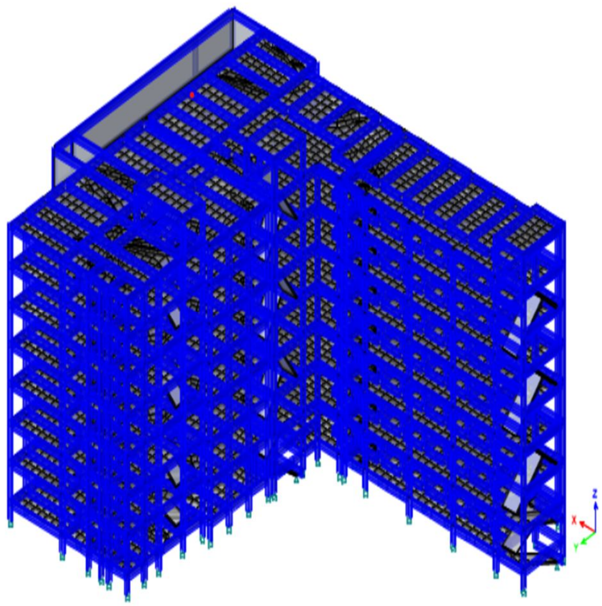


Fig 6.2- 3D View of G+7 College Building Block

B. Specifiation Of Structure

Type of structure	Multistorey RC frame
Floor to Floor height	3.5 m
Soil type	Type-II (Medium Soil)
Damping	5%
Support conditions	Fixed
Importance Factor, I	1
Response Reduction Factor	5
Size of Beam	(500*600)
Size of Column C1	(600*450)
Size of Column C2	(230*750)
Size of Column C3	(450*600)
Size of Column C4	(750*230)
Slab Thickness	150mm
Live load	$2KN/m^2$
Dead load of Beam	7.5KN/m
Dead load of Column C1	6.75KN/m
Dead load of Column C2	4.31KN/m
Dead load of Column C3	6.75KN/m
Dead load of Column C4	4.31KN/m
Dead load of Slab	$3.75KN/m^2$
Seismic zone factor	0.24
Soil type	2

C. Modeling Approach

The general finite element package ETABS has been used for analyses. A three-dimensional model of each structure has been created to undertake the non-linear analysis. The existing model and loading structure shown in figure. Beams and columns are modelled as non-linear frame elements with lumped plasticity at the start and the end each element. ETABS provides default hinge.

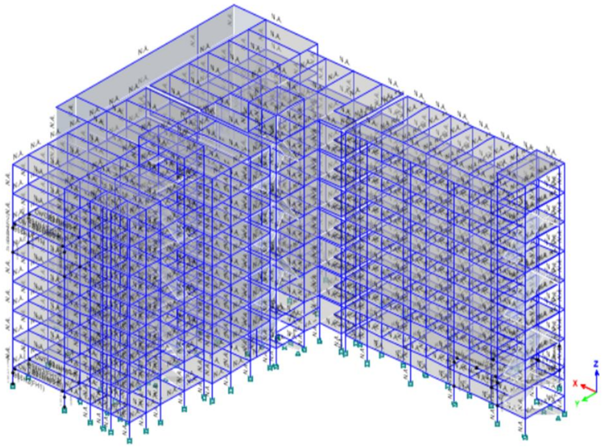


Fig 6.3- Frame Hinge Details

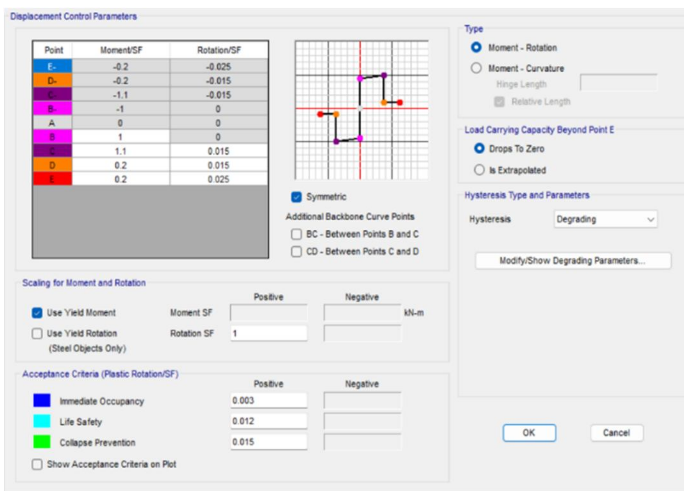


Fig 6.4- Defined Hinge Details

D. Modal Analysis

Modal Pushover Analysis (MPA) considering the effect of higher modes on the structural performance. It is an improved pushover analysis by the combination of the responses of each mode with a constant lateral load pattern. The total response is determined from the response of each mode by a certain rule. Since the higher modes are taken into consideration, the modal pushover analysis has a superior accuracy and fits the actual solution better. The response spectrum analysis (RSA) is also introduced in this thesis which is shown to be equivalent to the modal pushover analysis for elastic systems. The advantage of modal pushover analysis lies in its accuracy and simplicity for nonlinear analysis. Nevertheless, the lateral load patterns for MPA are assumed to be constant after yielding, an approximation similar to the pushover analysis, which induces issues that must be solved in the future.

The evaluation is based on an assessment of important performance parameters, including floor displacements, inter-story drift ratios, column shears, inelastic element deformations between elements, and element and connection forces. The inelastic static pushover analysis is regarded as an effective method for predicting seismic forces and deformation demands, which approximately accounts for the redistribution of internal forces that occurs when the structure is subjected to inertia forces that can no longer be resisted within the elastic range of structural behavior

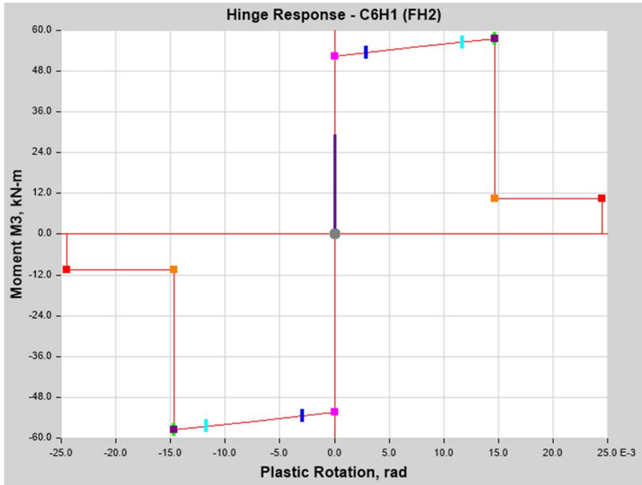


Fig6.5- Column Hinge Response Curve

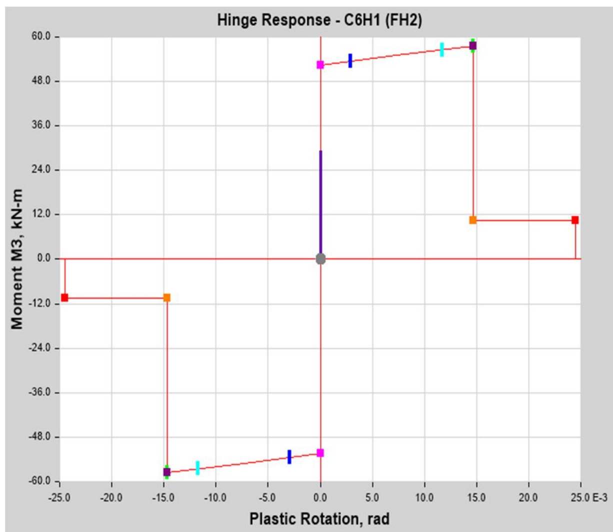


Fig6.6- Beam Hinge Response Curve

Fig6.7- Pushover Response Curve along X-Direction

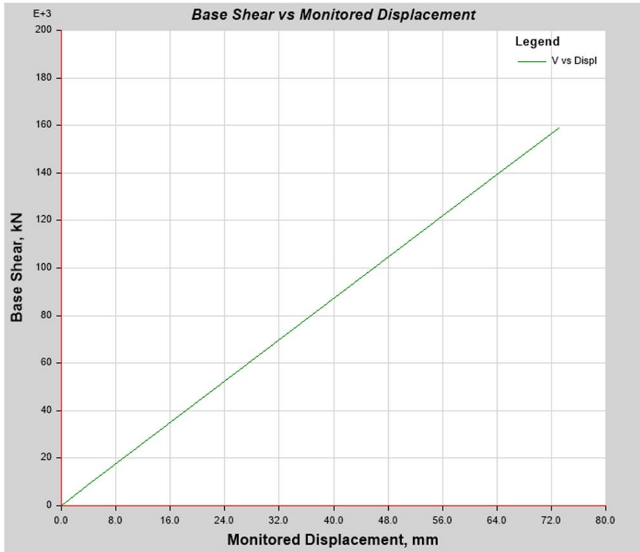


Fig6.8- Pushover Response Curve along Y-Direction

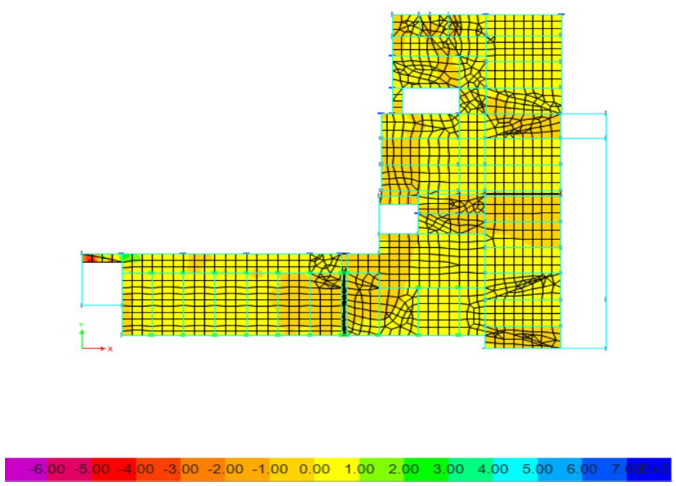


Fig6.9- 1st Floor Shell Stress Diagram

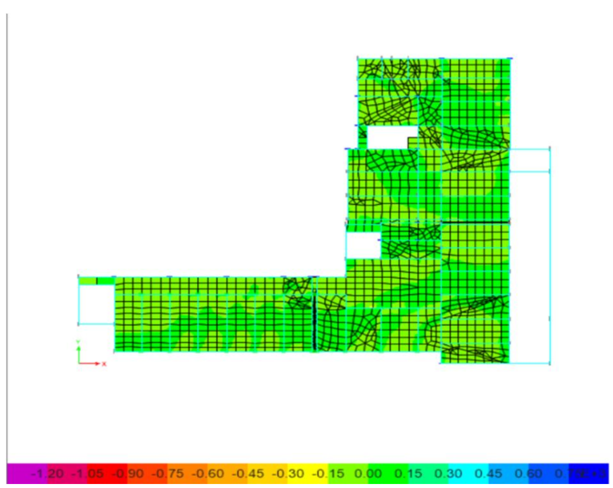


Fig6.10- Top Floor Shell Stress Diagram

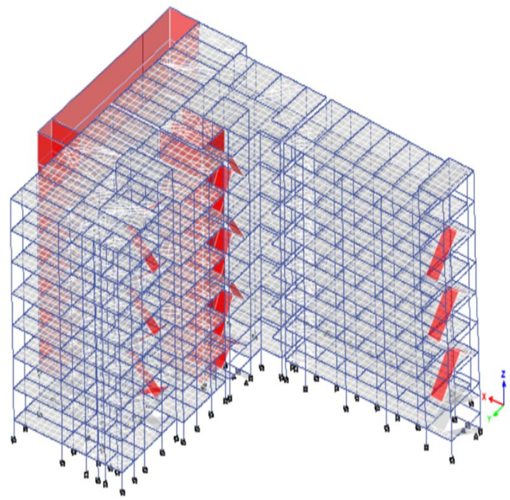


Fig6.11- 1st Floor Mode Shape Diagram

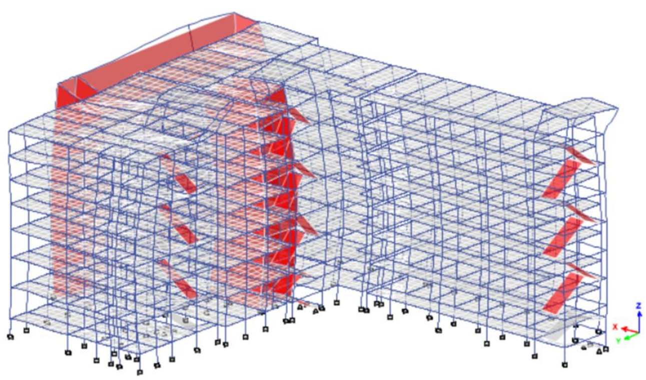


Fig6.12- Top Floor Mode Shape Diagram

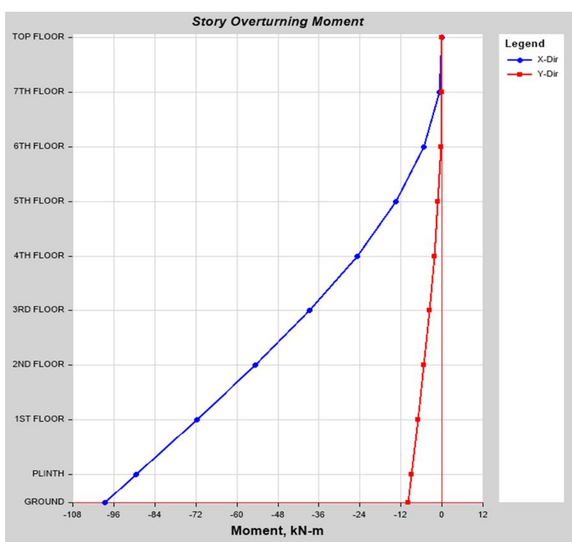


Fig6.13- Overturning Moment Diagram

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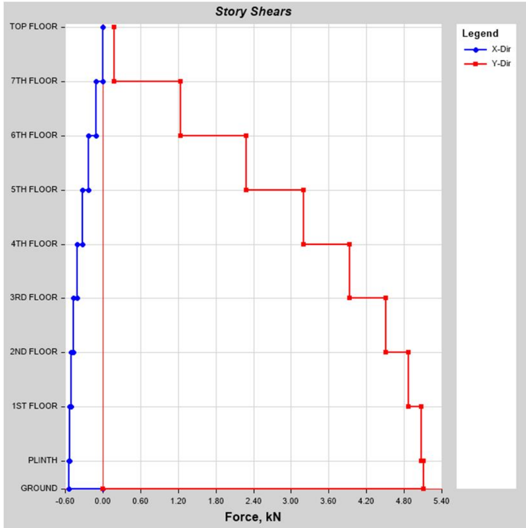

Fig6.14- Shear Force Diagram

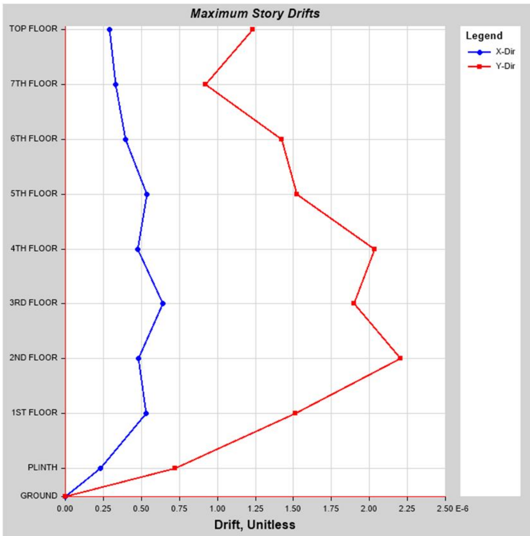

Fig6.15- Story Drift Diagram

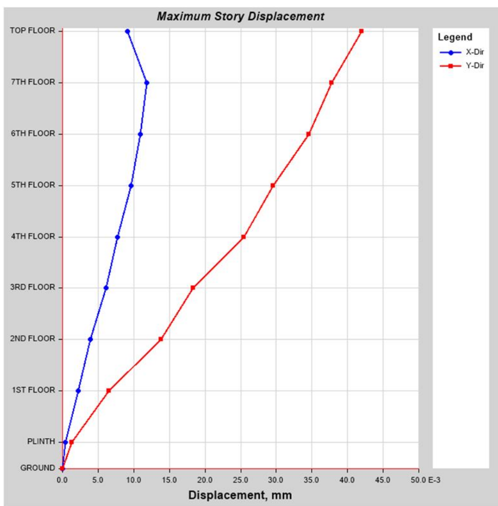

Fig6.16 Story Displacement Diagram

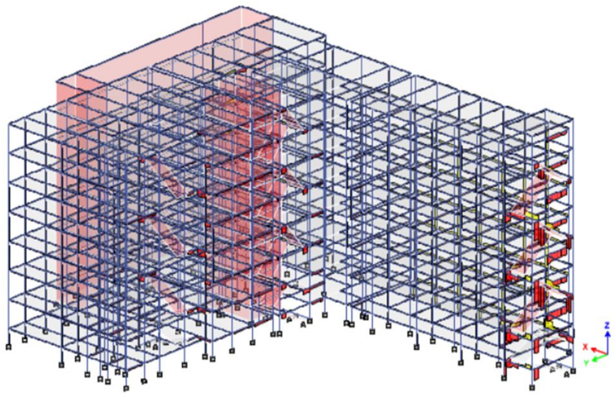

Fig6.17- Story Shear Force Diagram

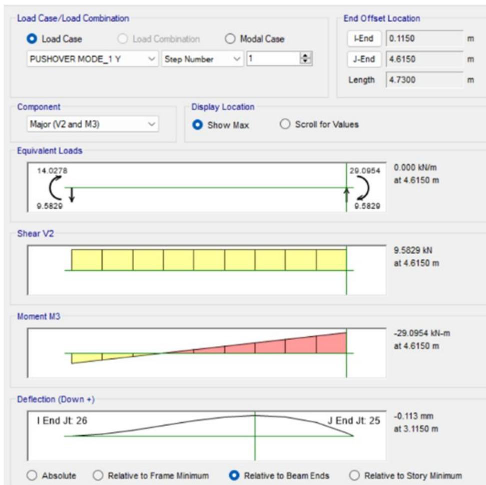

Fig6.18- Combined SF, BM and Deflection Diagram

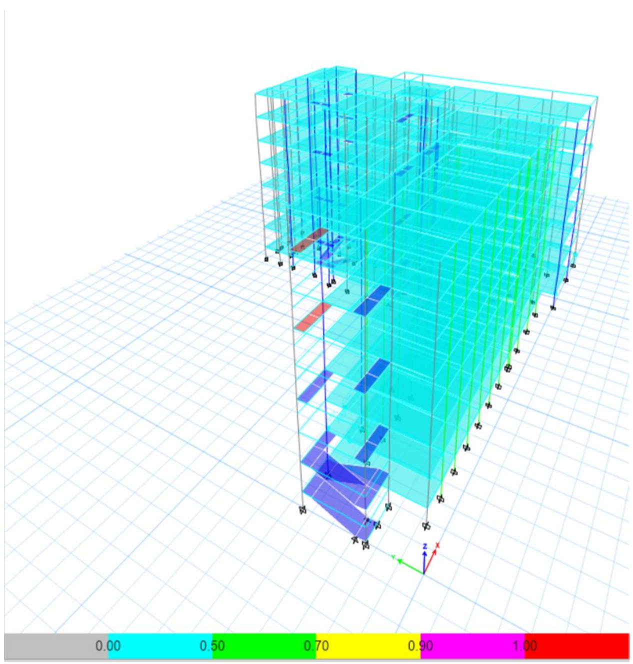

Fig6.19- Performance Point Level

VII. CONCLUSION

Pushover analysis has been the preferred method for seismic performance due to its simplicity and has been viewed as an attractive alternative to the nonlinear time history analysis.

The model overestimates the base shear at performance point and ultimate capacity with large margin of safety which may not the real scenario of the existing building as cracks exist due to service loads.

Pushover analysis was carried out separately in the X and Y directions. The resulting pushover curves in terms of Base shear – Displacement given for both X and Y direction separately. The slope of the pushover curve is gradually changed with increase in the lateral displacement of the building. This is due to the progressive formation of plastic hinges in beam and column throughout the structure.

From the results obtained in Y-direction exceeding the limit level between life safety (LS) and collapse prevention (CP), This means that the building requires retrofitting at extreme failure.

As the performance point of the building lies within the limit no need of retrofitting is recommended. Hence the structure is safe.

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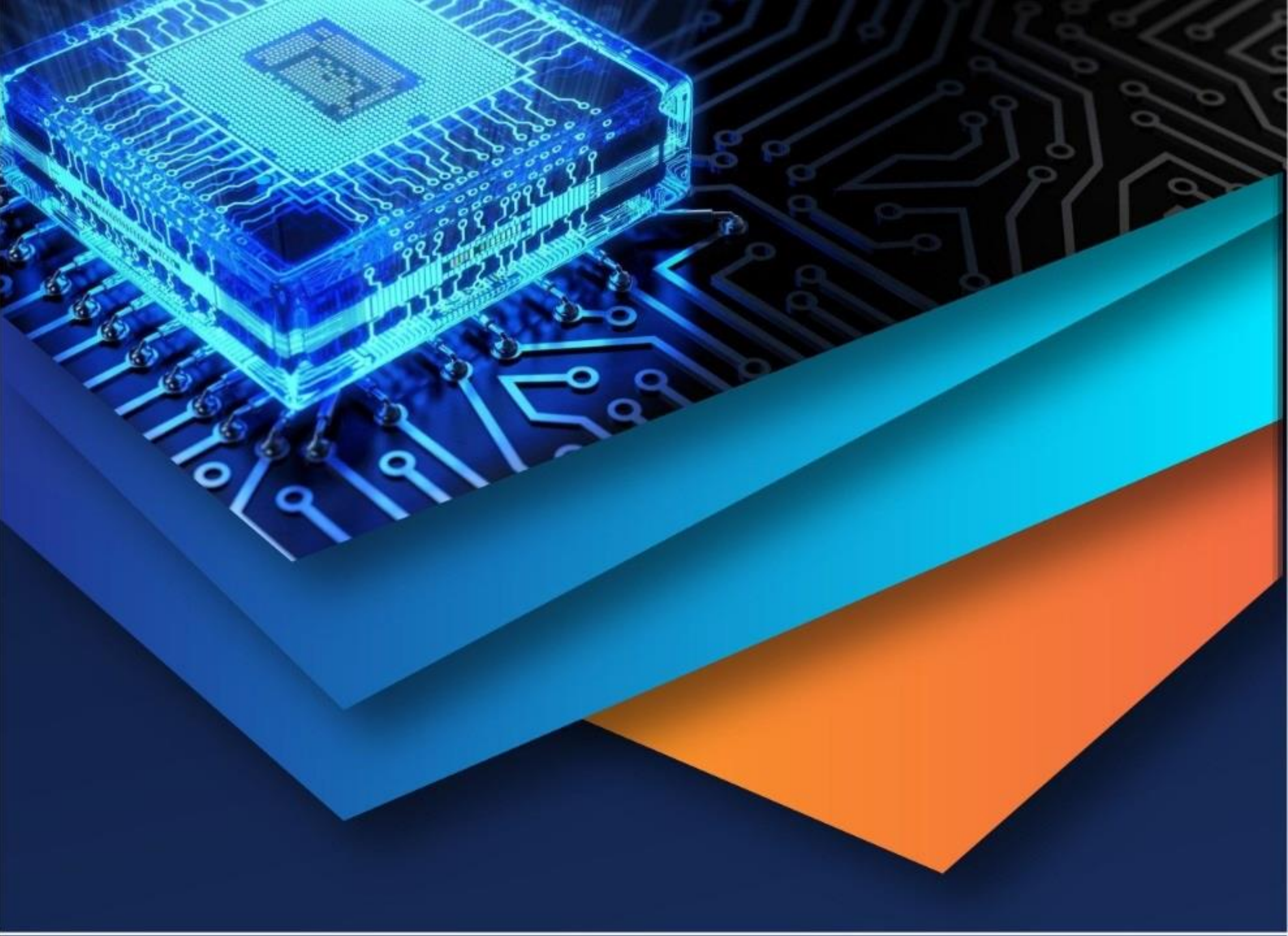

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