ANALYSIS OF RC BUILDING BY PUSHOVER ANALYSIS IN DIFFERENT SEISMIC ZONE

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ABSTRACT

Structural engineers are facing the challenge of striving for the most efficient and economical design solution. While ensuring that the final design of a building must be serviceable for its intended function, habitable for its occupants and safe over its design life-time. As the our country is the fastest growing country across the globe And need of shelter with higher land cost in major cities like Dhaka where further horizontal expansion is not much possible due to space shortage, we are left with the solution of vertical expansion. Engineers, designers and builders are trying to use different materials to their best advantage Keeping in view the unique properties of each material structurally robust and aesthetically pleasing building Are being constructed by combining the best properties at individual material & at the same time meeting Specific requirements of large span, building load, soil condition, time, flexibility & economy high rise buildings Are best suited solution.

Considering this situation this paper is about the comparison of vulnerability of different seismic zones in Bangladesh. According to BNBC-1993, Bangladesh is divided in three different seismic zones. The behaviors of earthquake forces have been analyzed for both shear wall and without shear wall RCC buildings by ETABS in three different seismic zones. The study shows shear wall buildings performs well than without shear wall buildings in different seismic zones. The base shear, base moment and drifts are higher in zone-3 comparing zone-1 and zone-2.

The Pushover analysis in present study is performed on multistoried frame structures by using ETABS 2009. To achieve this objective, four buildings (2, 3, 4 and 5) stories were analyzed. The result are satisfactory for perfectly designed building.

CHAPTER-1

INTRODUCTION

1.1 General

Earthquake engineering has come a long way since its birth, and it seems to grow rapidly as we gain experience. Each time an earthquake happens, something new is available to learn and the profession grows to accommodate it. Both research and practice used to be mostly concerned with the design of structures that would be safe, in the sense of surviving a seismic event with minimum number of casualties.

A structure designed to higher standards, chosen to meet the specific needs and able to remain functional after a small but relatively frequent event and being safe in a rare destructive earthquake costs slightly higher but still preferred now-a days by building owners.

Pushover analysis is now considered the most simplified inelastic analysis method to find actual behaviour of the structure in earthquake, a powerful analysis method that would accurately analyse structural models and analyse the demand that any level of shaking may impose and specifically, determine the level of shaking that would cause a structure to exceed a specific limit-state, thus failing a given performance objective.

As part of earthquake preparedness, it is essential to undertake a structural vulnerability assessment of properties to determine its resistance level in earthquake and advice necessary steps, such as retrofitting, to rectify any deficiencies. Bangladesh has been classified into three seismic zones such as Zone-I (0.075 g), Zone-II (0.15 g) and Zone-III (0.30 g) as per BangladeshNationalBuildingCode,BNBC-199

1.2 OBJECTIVES:

The main objective of the present study is analysis of building by using Pushover analysis method. The specific objectives are as given below:

1. Application of static analysis according to BNBC 1993.
2. Application of pushover analysis - Non - linear static analysis.
3. Comparison of base shear vs. displacement curve.
4. Checking performance of building by pushover analysis.
5. To determine base shear using pushover analysis in different seismic zones.
6. To determine performance of building by pushover analysis in different zone.

1.3 Methodology:

One of the emerging fields in seismic design of structures is the Performance Based Design. The subject is still in the realm of research and academics, and is only slowly emerging out into the practitioner's arena. Seismic design is slowly transforming from a stage where a linear elastic analysis for a structure was sufficient for both its elastic and ductile design, to a stage where an especially dedicated non-linear procedure is to be done, which finally influences the seismic design as a whole. As stated before, pushover analysis is a static, nonlinear procedure in which the magnitude of the lateral force is incrementally increased, maintaining the predefined distribution pattern along the height of the building. With the increase in the magnitude of the loads, weak links and failure modes of the building are found. Pushover analysis can determine the behavior of a building, including the ultimate load and the maximum inelastic deflection. Local Nonlinear effects are modeled and the structure is pushed until a collapse mechanism gets developed. At each step, the base shear and the roof displacement can be plotted to generate the pushover curve. It gives an idea of the maximum base shear that the structure was capable of resisting at the time of the earthquake. For regular buildings, it can also give a rough idea about the global stiffness of the building. In soft story the displacement will be maximums in nature as they have no sufficient strength to take loads from above story but as the soft story is shifted bottom to top of the structure the results may be found reverse where strength will eventually increase. 2,3,4,and 5 multi - storied building are simulated and checked with the help of finite element software ETABS 9.6 to perform the pushover analysis to meet the objectives of this study. Each and every story is kept soft story for different case to get the changing trend. Earth quake effect is assigned by the software which is done by UBC 94. Wind load is calculated according to Bangladesh National Building Code (BNBC).ATC-40 is used to analysis the hinge formation

Chapter-2

LITERATURE REVIEWS

2.1 General

The use of the nonlinear static analysis (pushover analysis) came in to practice in 1970's but the potential of the pushover analysis has been recognized for last 10-15 years. This procedure is mainly used to estimate the strength and the seismic demand for the structure subjected to selected earthquake. This procedure can be used for checking the adequacy of new structural design as well. The effectiveness of pushover analysis and its computational simplicity brought this procedure in to several seismic guidelines (ATC-40 and FEMA 356) and various design codes in last few years.

1. Assessed seismic performance of a five story reinforced concrete building designed according to the Moroccan seismic code RPS2000. In the first time a set of dynamic analysis are carried out to compute dynamic properties of the building (fundamental period, natural frequencies, deformation modes), in the second time a pushover analysis is performed to assess the seismic performance of the building and detect the locations of the plastic hinges. Pushover analysis was performed using SAP2000. The results obtained from study show that designed building perform well under moderate earthquake, but is vulnerable under severe earthquake.(M. Mouzzoun) et.al (2013)

2.2 Provision for Earthquake Load in BNBC

Bangladesh National Building Code BNBC [1] has different provisions for calculation of earthquake load and analysis procedures for structures subjected to earthquake. Two methods are available in BNBC for determination of seismic lateral forces on primary framing systems.

2.3Equivalent Static Force Method:

In this method the dynamic earthquake effect is represented by an equivalent static load at different levels in proportion to mass at that level. In this process BNBC divided the country into three region of different possible earthquake ground response (0.075g, 0.015g, and 0.25g).

Base Shear, V= ZIC/R *W

Where,

Z = seismic zone co-efficient
I = Structural importance co-efficient
C = Numerical Coefficient = 1.25S/T^ (2/3)

S = Site Coefficient

T = Time Period = $Ct(hn)^{3/4}$

Where,

Ct = 0.083 for moment resisting frame

= 0.073 for reinforced concrete frame and eccentric braced still frame
= 0.049 for all other structural analysis
hn= Height in meter above base

level n R = Response

modification coefficient W =

Total seismic dead load

Lateral force calculated from the above equation known as base shear V, shall be distributed along the height of the structure in accordance with the following equation,

$V = Ft + \sum i\text{=Fi}$ (2.4)

Where,

Fi = Lateral force applied at story level I and
Ft =Concentrated lateral force considered at the top of the building in addition to the force Fn.

2.4Selection of Lateral Force Method in BNBC:

Seismic base isolation is now a days moving towards a very efficient tool in seismic design of structure. Increasing flexibility of structure is well achieved by the insertion of these additional elements between upper structure and foundation as they absorb larger part of seismic energy.

Seismic lateral forces on primary framing systems shall be determined by using either the equivalent static force method or the dynamic response method complying with the restrictions given below:

(1) The equivalent static force method:
The equivalent static force method may be used for the following structures:

(a). All Structures, regular or irregular, in Seismic Zone 1 and Structure Importance Category iv in Seismic Zone 2, except case b (iv) below.

(b). Regular structures less than 75 meters in height with lateral force resistance provided by structural systems listed in BNBC except case b (iv) below.

(c). Irregular structures not more than 20 meters in height.

(2) The dynamic response method:
The dynamic response method may be used for all classes of structure, but shall be used for the structure of the following types.

(a). Structures 75 meters or more in height except as permitted by case a (i) above.

(b). Structures having a stiffness, weight or geometric vertical irregularity of type I, II, III as defined in BNBC.

(c). Structures over 20 meters in height in Seismic Zone 3 not having the same structural system throughout their height.

(d). Structures regular or irregular, located on soil type S4 as defined in BNBC.

Therefore, this is a burning question to design isolation device in context of Bangladesh. Effort has been made in this study to establish an innovative simplified design procedure for isolators incorporated in multi-story building structures. Isolation systems namely lead rubber bearing (LRB) and high damping rubber bearing (HDRB) have been selected for the present schoolwork. Numerical formulation and limiting criteria for design of each element have been engendered. The suitability to incorporate isolation device for seismic control has been sight seen in details.

The study reveals simplified design procedures for LRB and HDRB for multi-storey buildings in Bangladesh. The detail design progression has been proposed to be included in Bangladesh National Building Code (BNBC).

2.5Seismic Zone of Bangladesh:

Bangladesh is a disaster prone country. Disaster management needs to be considered as prime issue for overall development of the country. Bangladesh and adjoining areas is at high seismic risk. In recent past a series of earthquakes has been experienced throughout the country. Earthquake is a cataclysmic event that needs to be addressed in a more concerted way. Earthquake induced large destruction occurs due to vast majority of properties not meeting the earthquake resistant standards in building design. When the vast majority of properties do not meet the earthquake resistance standards in building design, it exposes the occupants the risk of injury or death arising from the building collapse in the event of a major earthquake Bangladesh is divided into three seismic zones as per BNBC. The table below shows the values of zone coefficients of Bangladesh.

Table 2.1: Seismic Zone Factor Z

Zone	1	2	3
Z	0.075	0.15	0.25

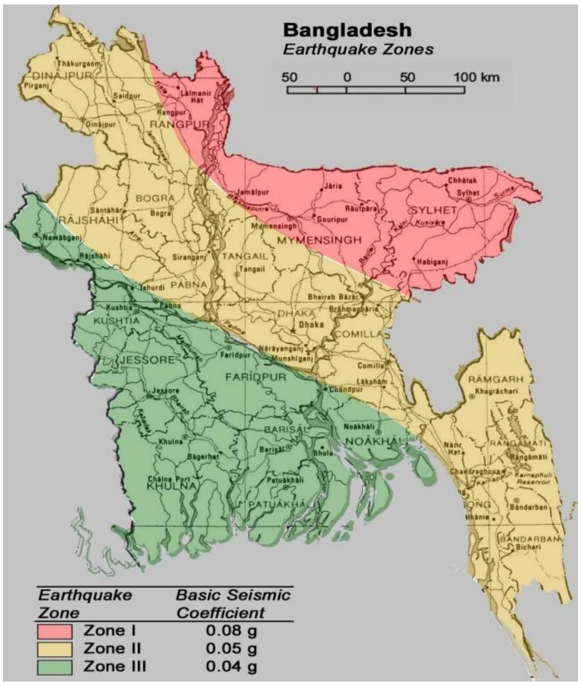


Figure 2.1: Seismic Zoning Map of Bangladesh

2.6 Capacity Curve

A typical capacity curve of a hypothetical structure is shown in Figure

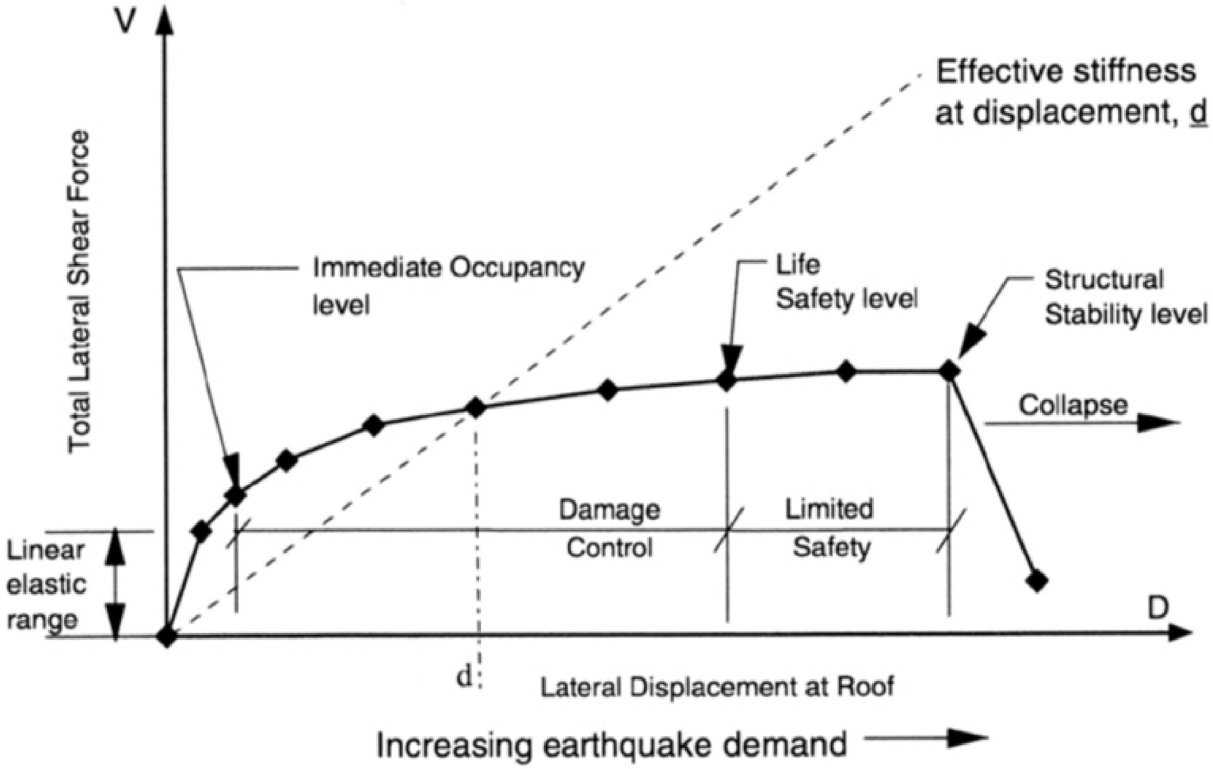


Figure 2.2: Typical Capacity Curve (Adopted from ATC-40)

In Figure 2.2, the discrete points indicated by the symbol '•' represent the occurrence of important events in the lateral response history of the structure. Such an event may be the initiation of yield in a particulars structural element or a particular type of damage.

Each point is determined by a different analysis sequence. Then, by evaluating the cumulative effects of damage sustained at each of the individual events, and the overall behaviour of the structure's increasing lateral displacements, it is possible to determine and indicate on the capacity curve those total structural lateral displacements that represent limits on the various structural performance levels, as has been done in Fig. 2.2.

The process of defining lateral deformation points on the capacity curve at which specific structural performance levels may be said to have occurred requires the exercise of considerable judgment on the part of the engineer. For each of the several structural performance levels and global performance levels defined in this chapter.

2.7 Capacity Spectrum

Capacity Spectrum is the simple representation of capacity curve in ADRS domain. A capacity curve is the representation of base shear to roof displacement. In order to develop the capacity spectrum from a capacity curve it is necessary to a point by point conversion to first mode spectral co-ordinates.

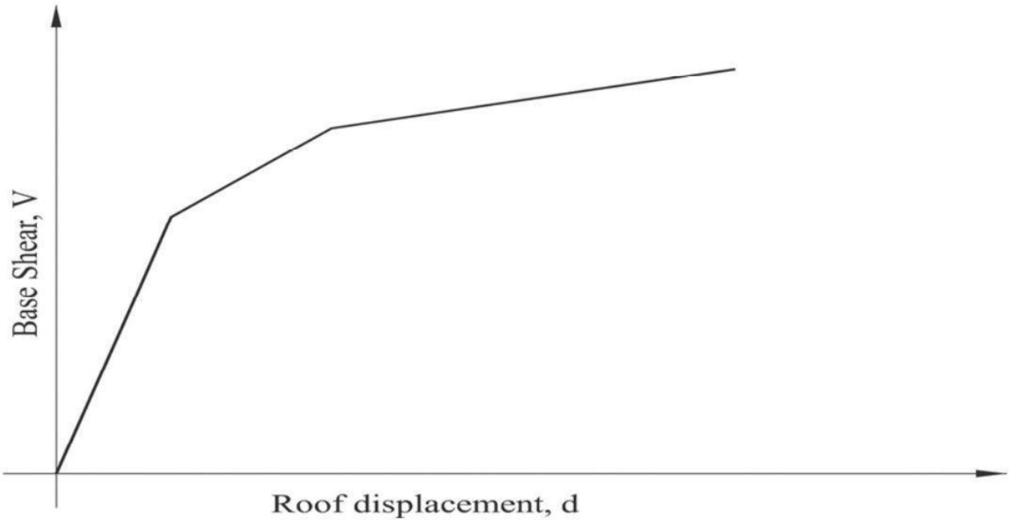


Figure 2.3: A Typical Capacity Curve

Any point corresponding values of base shear, $Vi$and roof deflection, Δimay be converted to the corresponding point of spectral acceleration, $Sai$and spectral displacement, Sdion the capacity spectrum using relation.

CHAPTER-3

ASPECTS OF PUSHOVER ANALYSIS

3.1 Mainstream

Nonlinear static methods are simplified procedures in which the problem of evaluating the maximum expected response of a MDOF system for a specified level of earthquake motion is replaced by response evaluation of its equivalent SDOF system. The common features of these procedures are the use of pushover analysis to characterize the structural system. In pushover analysis both the force distribution and the target displacement are based on the assumptions that the response is controlled by the fundamental mode and that the mode shape remains unchanged after the structure yields. Therefore, the invariant force distributions does not account for the change of load patterns caused by the plastic hinge formation and changes in the stiffness of different structural elements. That could have some effects in the outcome of the method depending on different structural parameters. This paper introduces an adaptive pushover analysis method to improve the accuracy of the currently used pushover analysis in predicting the seismic-induced dynamic demands of the structures. Comparison of the common pushover analyses, adaptive pushover analyses and time-history analyses performed for a number of multiple-bay, short and high-rise steel structures, demonstrates the efficiency of the proposed method.

3.2 System Development

The expected behaviour of structures as observed in physical world cannot be replicated with the high degree of precision hence there is need to develop a system based on the classical approach which will establish a bridge between the physical and stimulated world. To solve the purpose I have developed 9 models in ETABs software. The geometrical loading data, support reactions adopted for both the models for each of the 9 models are kept same to achieve a behaviour pattern. These 9 models are shaped by considering Plan irregularities i.e. the plan area for each structure is same only there is difference of geometry.
The specified shapes of models are as follows,

Table 3.1: Specified shapes of models

Regular Square Shape (S-1)	T-Shape (S-4)	Plus (+) Shape (S-7)
E-Shape (S-2)	L-Shape (S-5)	Square with Core (S-8)
H-Shape (S-3)	C-Shape (S-6)	Rectangle with core (S-9)

3.3 Concrete Frame Design and Loads

There are many software available to completed analysis. We have been used ETABS. All the modeling completed according to the provided architectural design. According to design criteria all the concrete and the steel property should be provided. Frame structure is suitable for performance based analysis by ETABS.

According to code provisions, two types of loads (Gravity and lateral) should be provided. At first the load haves to be defined and then assigned on the structure. ETABS superimposed dead loads have to be assigned and it takes buildings own weight from the structure and its property. According to live loads intended, it has been assigned. UBC 94 should be used for seismic and wind load which is satisfy BNBC.

The structure should be designed from concrete frame design options after running analysis. At first can also be checked the beam and column sections which are assigned. By the nonlinear analysis process takes the column sections, which is design first. The reinforcement to be designed option should be provided, when the column sections defining. For this reasons column reinforcement would be checked when the structure designed.

3.3.1 Frame Nonlinear Hinge Property

Nonlinear force-displacement or moment rotation behavior can be defined by frame Nonlinear Hinge Properties .For this process can be assigned to discrete locations along the length of frame (line) elements. During the static nonlinear (pushover) analysis the nonlinear hinge are used.

3.3.2 Plastic hinges mechanism

Plastic hinge formation for the three building mechanisms have been obtained at different displacements levels.

The hinging patterns are plotted in figures 6, 7 and 8.

Comparison of the figures 6, 7 and 8 reveals that the patterns for the three building are quite similar. Plastic hinges formation starts with beam ends and base columns of lower stories , then propagates to upper stories and continue with yielding of interior intermediate columns in the upper stories.

But since yielding occurs at events B, IO and LS respectively, the amount of damage in the three buildings will be limited.

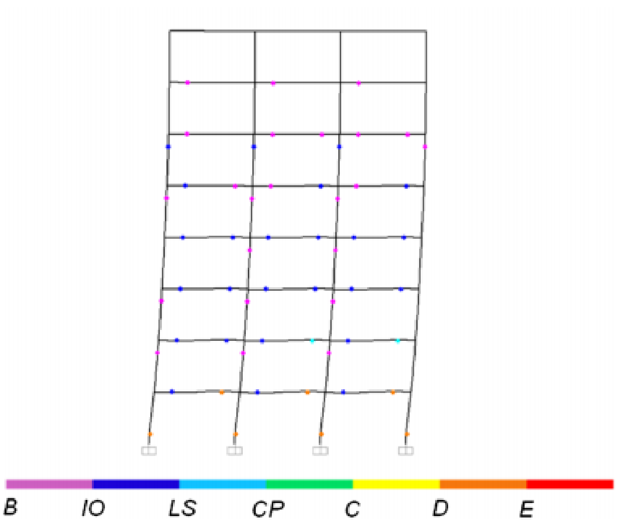


Figure 3.1 : Plastic hinge mechanism

3.4 Static Nonlinear Cases

Any number of cases can consist by static nonlinear analysis. ETABS have been used for the analysis purpose. A Different distribution of load on the structure can have created by each static nonlinear case. From zero initial conditions may start a static nonlinear case or it may start from the results at the end of a previous case. Each analysis case may consist of multiple of construction stages.

3.4.1 Nonlinear static analysis

Nonlinear analysis method are best applied when either geometric or material nonlinearity is considered during structural modelling and analysis. ETABS have been used for the analysis purpose. A different distribution of load on the structure can have created by each static nonlinear case. From zero initial conditions may start a static nonlinear analysis, Existing nonlinear static methods of analysis establish the capacity curve of a structure with respect to the roof displacement. Any number of cases can consist by static nonlinear analysis. ETABS have been used for the analysis purpose. A Different distribution of load on the structure can have created by each static nonlinear case. From zero initial conditions may start a static nonlinear case or it may start from the results at the end of a previous case. Each analysis case may consist of multiple of construction stages.

3.4.2 Monitor

A single displacement component at a single point is called the monitor displacement that is monitored during a static nonlinear analysis. In pushover load case for parameters, to modify the displacement up to which the force deformation curve needs to be monitored. When to terminate a displacement controlled analysis, then the monitored displacement is use to determine.

3.5 Starting point in static nonlinear case

Nonlinear static analysis, commonly referred to as pushover analysis, is a method for determining the ultimate load and deflection capability of a structure. To start the current cases from the end condition of a previously specified static nonlinear case, select the name of the previous case from the previous case drop down list. To start the current cases from the end condition of a previously specified static nonlinear case, select the name of the previous case from the start from previous case drop down list. Typically this option is used for a lateral static nonlinear case to specify that it should start from the end of a gravity static nonlinear case.

3.6 Save Positive Increments Only

The pushover curve to be saved for to get the positive displacement increments, the save positive increments only check box should be checked. In the following example, the solid line represents the pushover curve if the save positive increments only check box is checked (the default) and the dashed line represents the pushover curve if the save positive increments only check box is not checked. Fig showed that positive increment and all increment are saved.

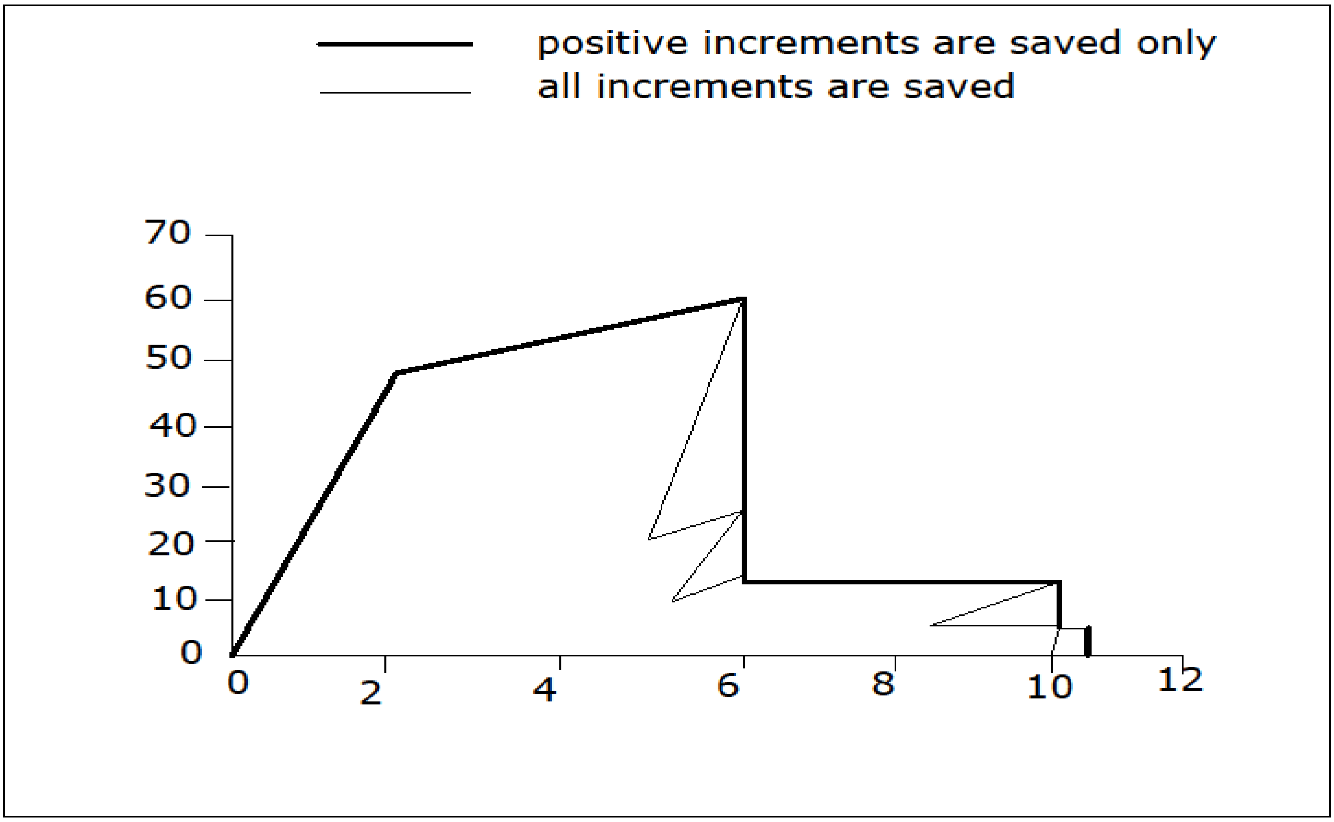


Figure 3.2: Positive Increments of pushover curve

3.7 Key elements of the pushover analysis

Definition of plastic hinges In SAP2000 [6], nonlinear behaviour is assumed to occur within frame elements at concentrated plastic hinges. The default types include an uncoupled moment hinges, an uncoupled axial hinges, an uncoupled shear hinges and a coupled axial force and biaxial bending moment hinges.

- Definition of the control node: control node is the node used to monitor displacements of the structure. Its displacement versus the base-shear forms the capacity (pushover) curve of the structure.

- Developing the pushover curve which includes the evaluation of the force distributions. To have a displacement similar or close to the actual displacement due to earthquake, it is important to consider a force displacement equivalent to the expected distribution of the inertial forces. Different forces distributions can be used to represent the earthquake load intensity.

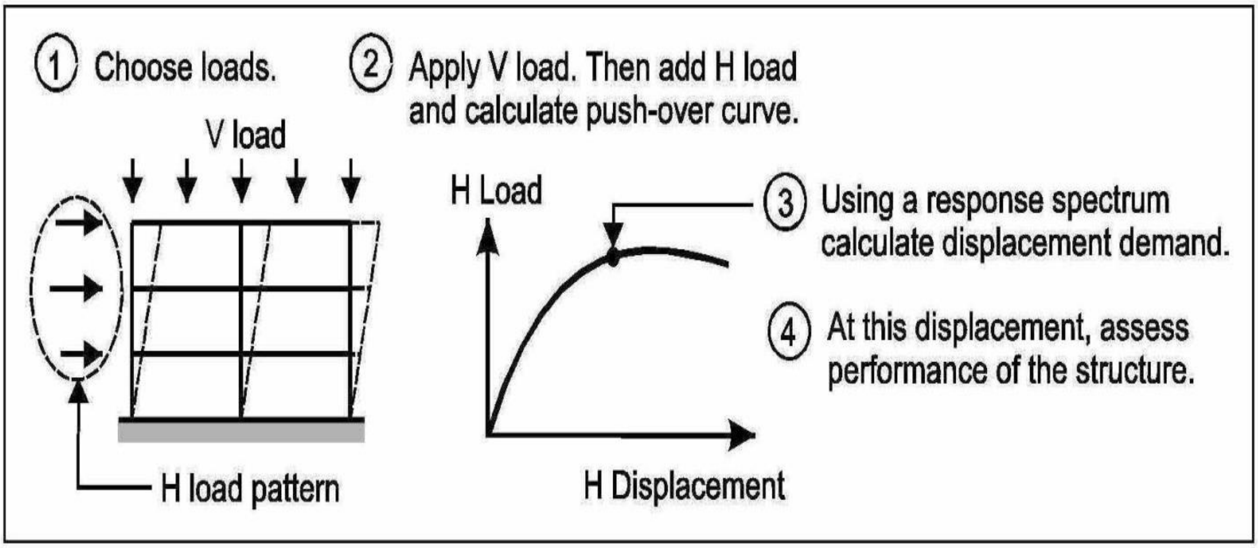


Figure 3.3: . Main steps for static push-over. Step 2 requires nonlinear analysis of the structure. Step 3 can be complex theoretically. Step 4 requires demand-capacity calculations, usually at the member level (beams, columns, connections, etc.).

3.7.1 The Acceleration Displacement Response

Spectra another of the innovative concepts incorporated in the PA is the Acceleration Displacement Response Spectra (ADRS) representation, which merges the V_b vs Δ_{roof} top plot with the Response Spectrum (RS) curve. This is possible due to a relation connecting V_b, Δ_{roof} top and T. First the V_b vs .Δ_{roof} top Cartesian has to be transformed to what is called spectral acceleration (Sa) vs. spectral displacement (Sd) using the relations (ATC-40, 1996)

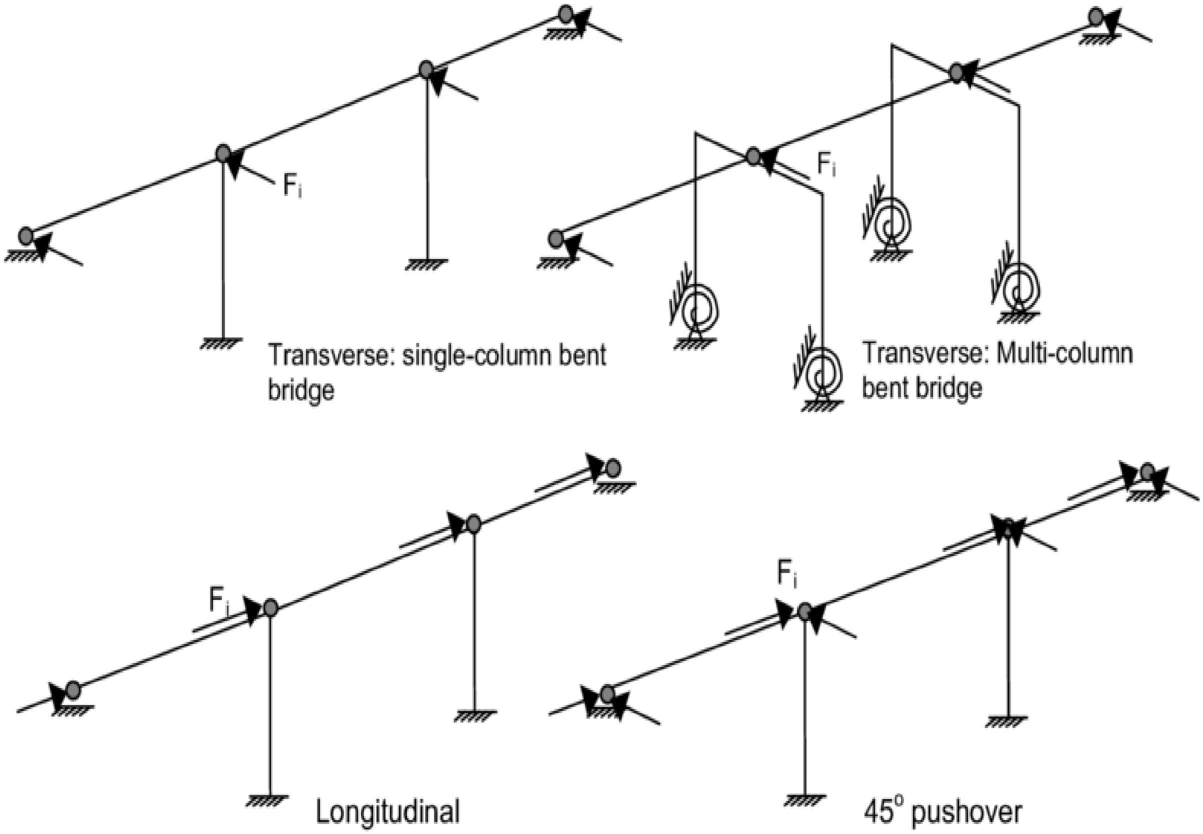


Figure 3.4: Acceleration Displacement Response

3.7.2 The Least Saved Steps for Pushover Analysis

Nonlinear static (pushover) analysis is an effective and simple tool for evaluating the seismic response of structures and offers an attractive choice for the performance-based design. As such, it has generally been used in modern design due to its practicality .ETABS automatically creates steps corresponding to events on the hinge stress-strain curves or to significant nonlinear geometric effects.

The Highest step size restricts by the least saved steps which is used to apply the load in a static nonlinear case .The results of these steps are saved only if they correspond to a significant change in the slope of the pushover curve.

However, the nonlinear plastic design method consumes extensive computational effort for practical structures under numerous load cases. Thus, an efficient element capturing the nonlinear behaviour of a beam-column will be useful.

3.8 Highest Null Steps for Pushover Analysis

Large sample properties of the likelihood function when the true parameter value may be on the boundary of the parameter space are described. Specifically, the asymptotic distribution of the highest null steps estimators. The Highest null steps is used, if necessary, to declare failure in a run before it reaches the specified force or displacement goal. In this representation the Gaussian random variable corresponds to the limit of the normalized score statistic and the estimate of the mean corresponds to the limit of the normalized maximum likelihood estimator The program may be unable to converge on a step when catastrophic failure occurs in the structure, or when the load cannot be increased in a load-controlled analysis.

Thus the limiting distribution of the highest null steps estimator is the same as the distribution of the projection of the Gaussian random variable onto the region of admissible values for the mean. There may also be instances where it is unable to converge in a step because of numerical sensitivity in the solution. So it is very important.

3.8.1 Highest Full Steps for Pushover Analysis

The details of the highest full steps method will depend on the details of the probabilistic model of evolution assumed. The highest full steps limit the total time the analysis will be allowed to run.

There are a very large number of possible models of evolution. For a few of the simpler models, the calculation of the likelihood of an evolutionary tree is outlined. For these models, the maximum likelihood tree will be the same as the “most parsimonious” (or minimum-steps) tree if the probability of change during the evolution of the group is assumed a priori to be very small. ETABS attempts to apply as much of the specified load pattern as possible, but may be restricted by the occurrence of an event, failure to converge within the maximum iterations/step, or a limit on the maximum step size from the minimum number of saved steps. However, most sets of data require too many assumed state changes per character to be compatible with this assumption. Farris (1973) has argued that maximum likelihood and parsimony methods are identical under a much less restrictive set of assumptions.

As a result, a typical static nonlinear analysis may consist of a large number of steps. Additional steps may be required by some member unloading methods to redistribute load.

3.8.2 Highest Iteration and Iteration Tolerance

The approximation of arbitrary two-dimensional curves by polygons is an important technique in image processing. At the end of each step Static equilibrium is checked by static nonlinear analysis. The unbalanced load is calculated as the difference between the externally applied loads and the internal forces in the elements. If the ratio of the unbalanced load magnitude to the applied load magnitude exceeds the iteration tolerance, the unbalanced load is applied to the structure in a second iteration for that step. For many applications, the apparent ideal procedure is to represent lines and boundaries by means of polygons with minimum number of vertices and satisfying a given fit criterion.

These iterations continue until the unbalanced load satisfies the iteration tolerance or the maximum iterations/step is reached. In the latter case, the step size is halved and the load is applied again from the beginning of the step. The maximum distance of the curve from the approximating polygon is chosen as the fit criterion. The results obtained justify the abandonment of the minimum-vertices criterion which is computationally much more expensive.

3.8.3 The Potential of Static Inelastic Analysis Methods

Whereas the potential of static inelastic analysis methods is recognized in earthquake design and assessment, especially in contrast with elastic analysis under scaled forces, they have inherent shortcomings. In this paper Critical issues in the application of inelastic static (pushover) analysis are discussed and their effect on the obtained results appraised. Areas of possible developments that would render the method more applicable to the prediction of dynamic response are explored. New developments towards a fully adaptive pushover method accounting for spread of inelasticity, geometric nonlinearity, full multi-modal, spectral amplification and period elongation, within a framework of modelling of materials are discussed and preliminary results are given.

These developments lead to static analysis results that are closer than ever to inelastic time-history analysis. It is concluded that there is great scope for improvements of this simple and powerful technique that would increase confidence in its employment as the primary tool for seismic analysis in practice.

CHAPTER-4

MODELLING OF STRUCTURES

4.1 General Description of Structure

Four structures representing low, medium and high rise RCC concrete buildings in three different seismic zone are considered in this study. For the present study 2, 3, 4, 5 stories buildings are chosen.

4.2 Material Property

Modulus of Elasticity of Concrete, Ec = 3600ksi

Poisson’s Ratio of Concrete =0.2

Minimum Yield Strength of Steel, Fy = 60 ksi Concrete

Compressive Strength, f’c = 4 ksi

4.3 Model Geometry

The structures analyzes are for 2, 3, 4, 5 storied building as the Geometry of these structures are same but they were analyzed in three seismic zones which are 0.75, 0.15, 0.20.

4.3.1 3 storied RCC building in zone-0.075

Number of bays along X-direction = 4
Number of bays along Y-direction = 4
Base to ground floor height = 6 feet
Story height = 10 feet
Bay width along X-direction = 20feet
Bay width along Y-direction = 20feet

Plan of two storied building is given below:

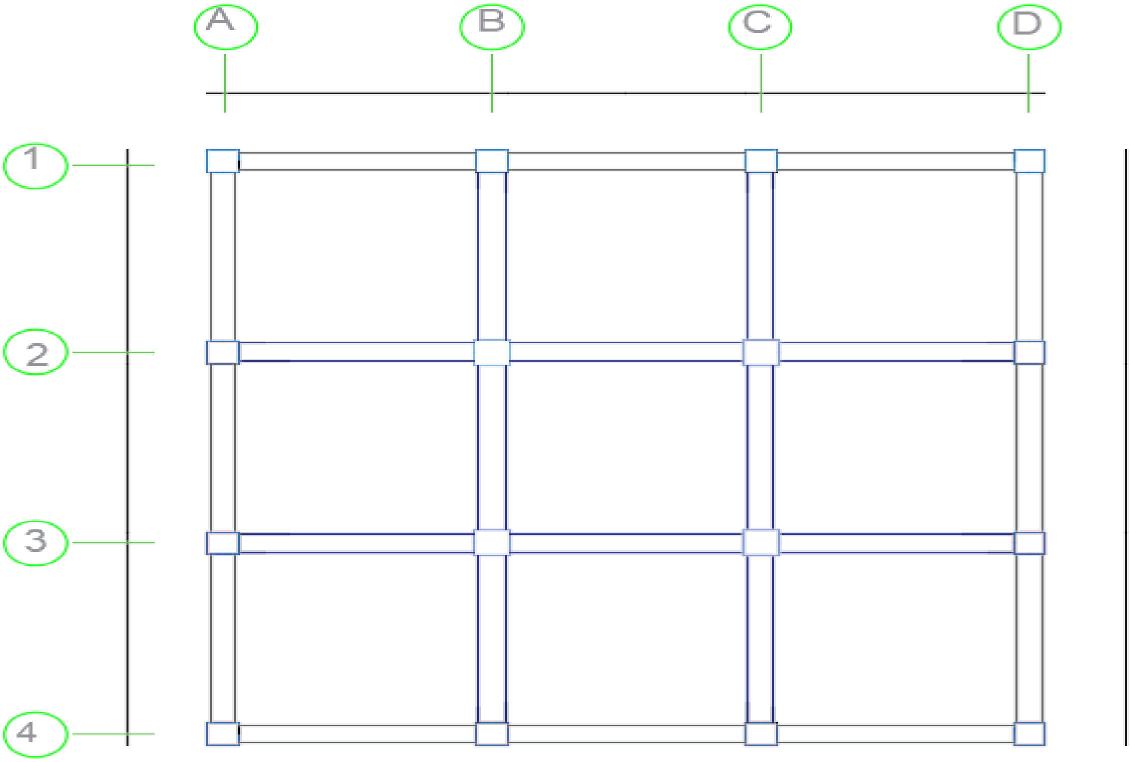


Figure 4.1: Column Layout Plan for 3 storied building

Table 4.1: Column schedule for 3 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	14x14	14x14
C2	16x17	16x17

4.3.2 3 storied RCC building in zone-0.15

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

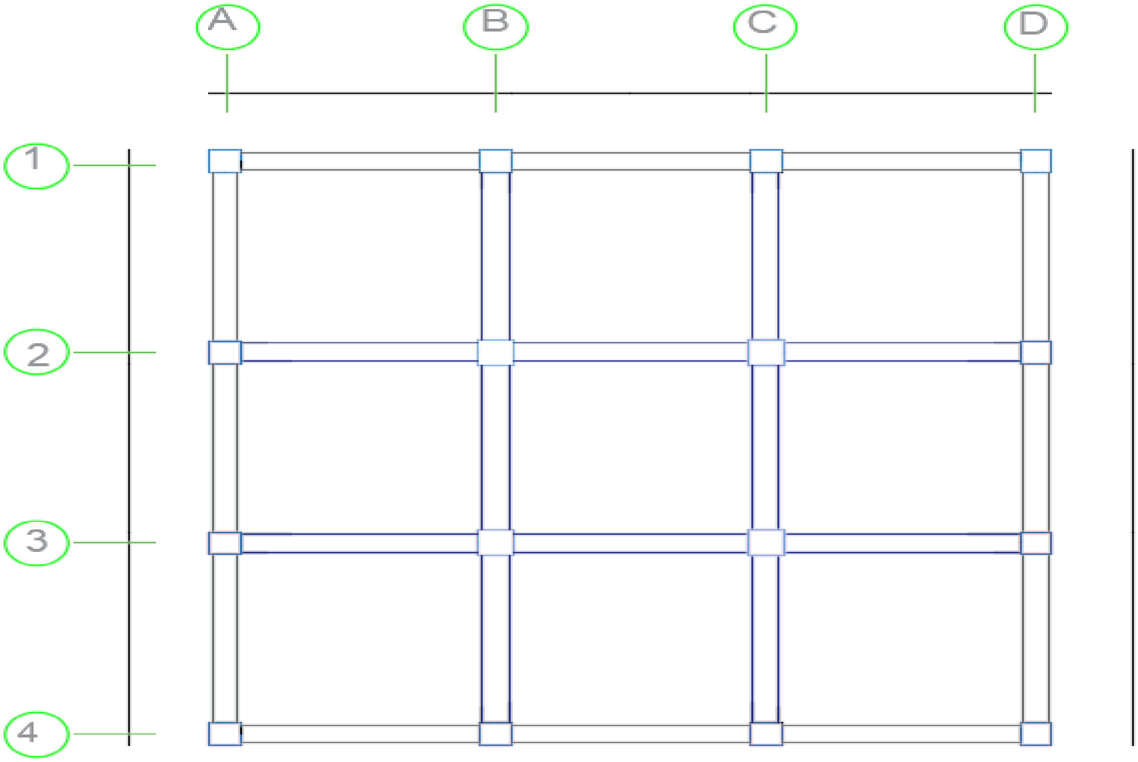


Figure 4.1.1: Column Layout Plan for 3 storied building

Table 4.1.1: Column schedule for 3 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	15x15	15x15
C2	17x19	17x19

4.3.3 3 storied RCC building in zone-0.20

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

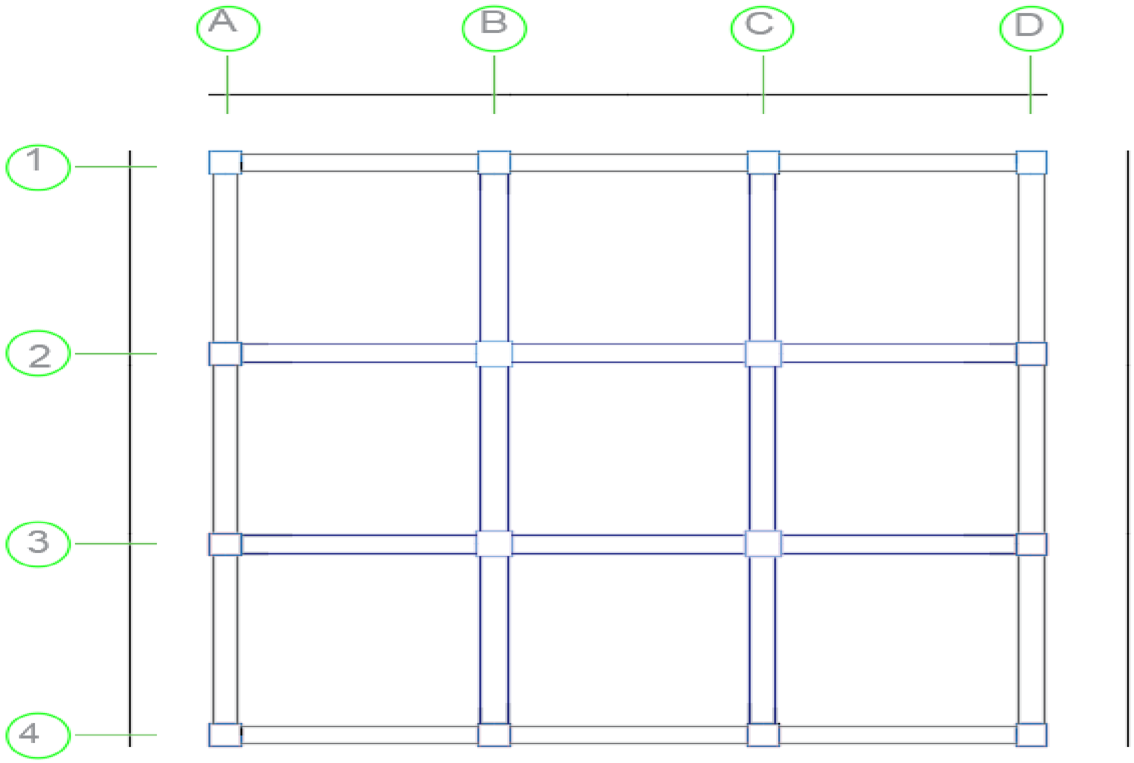


Figure 4.1.2: Column Layout Plan for 3 storied building

Table 4.1.2: Column schedule for 3 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	17x17	17x17
C2	18x20	18x20

4.4.1 4 storied RCC building in zone-0.075

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

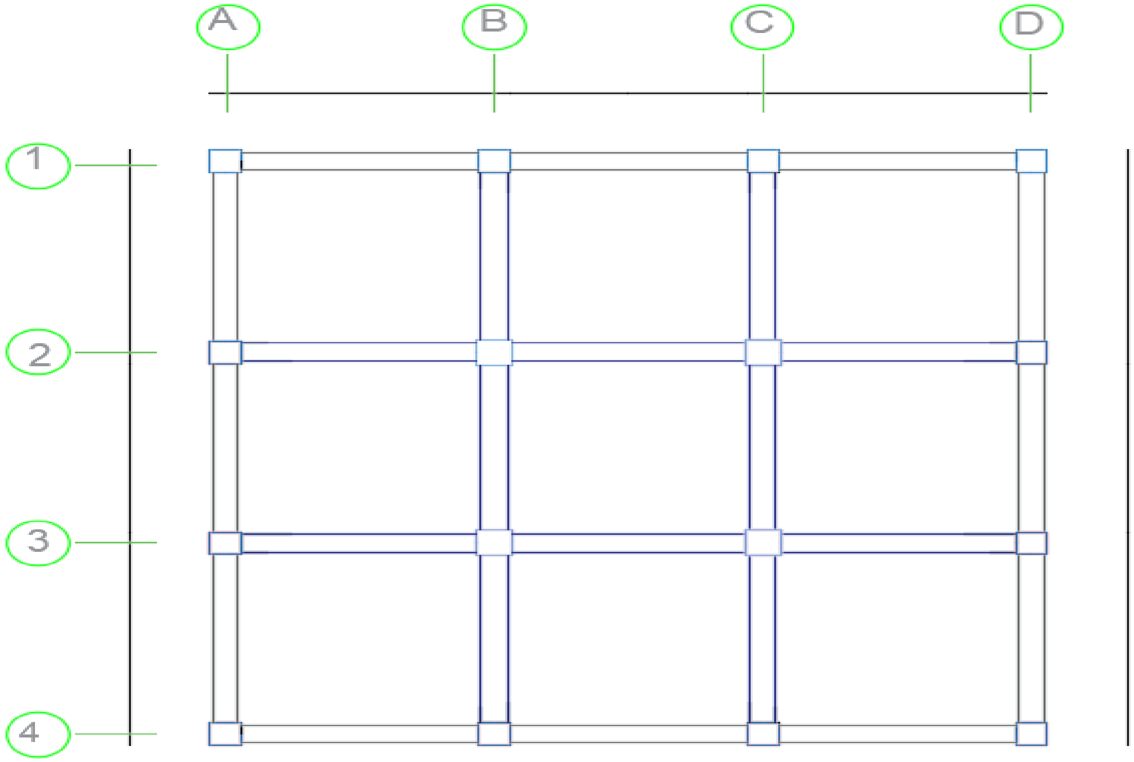


Figure 4.2: Column Layout Plan for 4 storied building

Table 4.2: Column schedule for 4 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	17x17	17x17
C2	18x20	18x20

4.4.14 storied RCC building in zone-0.15

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

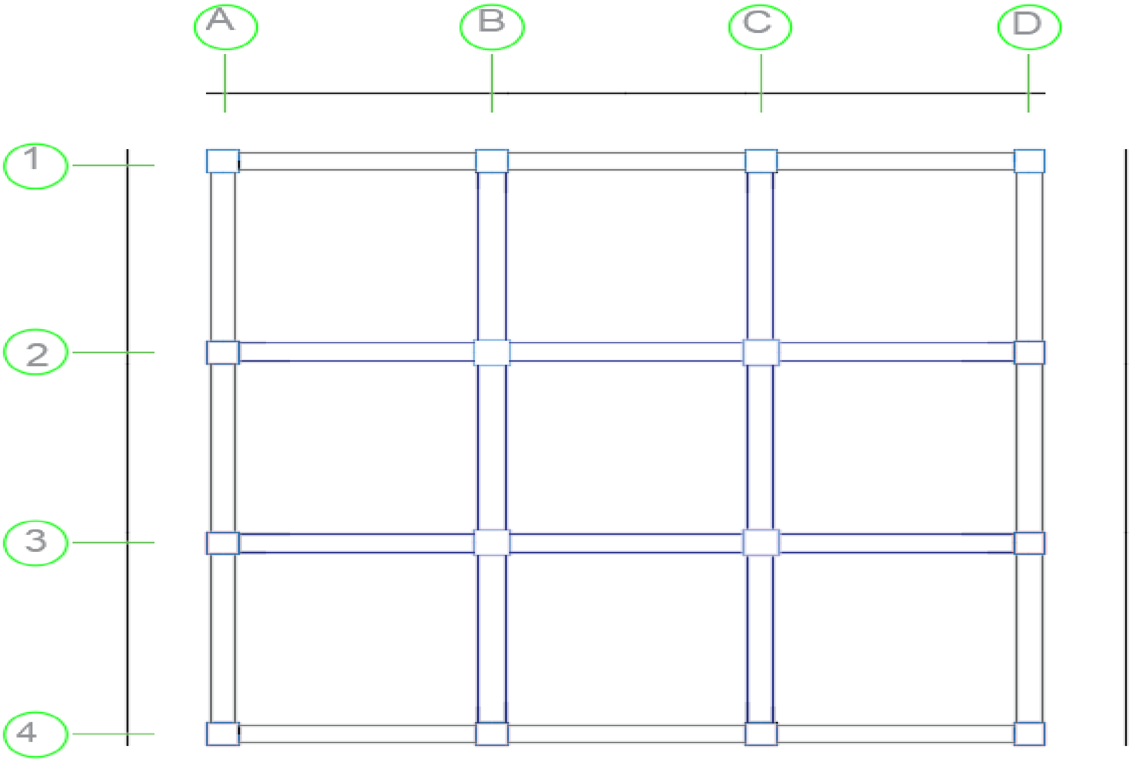


Figure 4.2.1: Column Layout Plan for 4 storied building

Table 4.2.1: Column schedule for 4 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	17x17	17x17
C2	19x20	19x20

4.4.3 4storied RCC building in zone-0.20

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

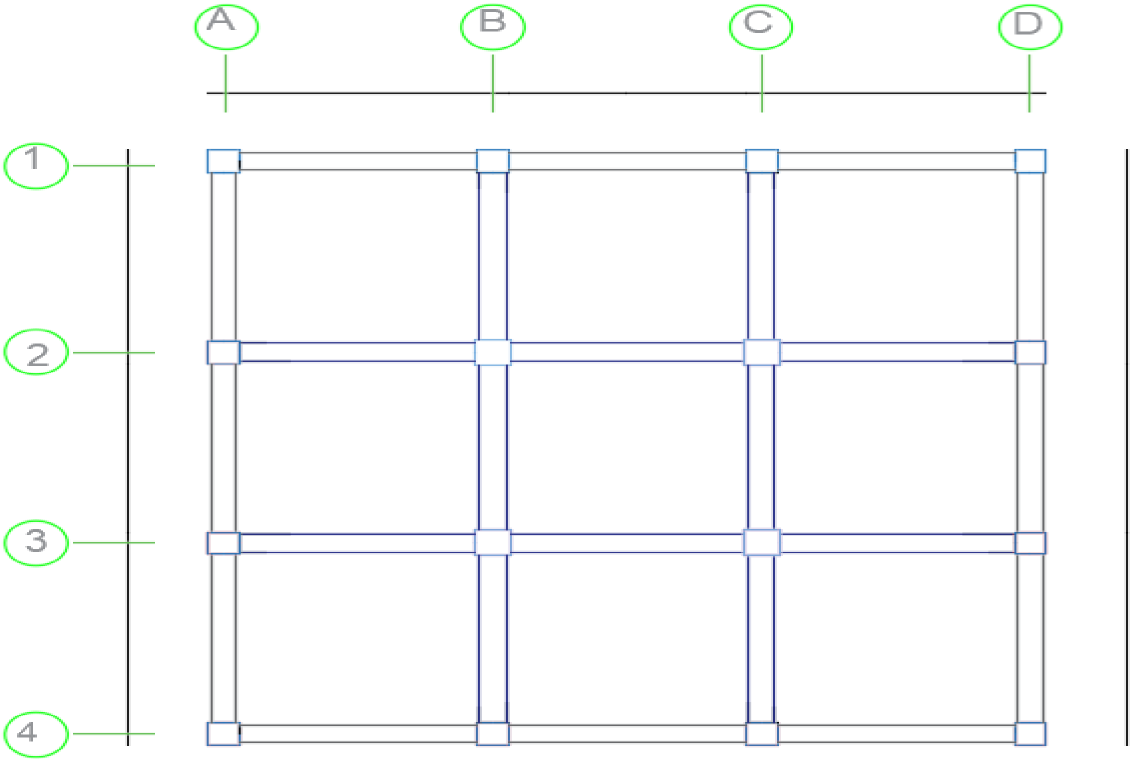


Figure 4.2.2: Column Layout Plan for 4 storied building

Table 4.2.2: Column schedule for 4 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	17x17	17x17
C2	20x22	20x22

4.5.1 5 storied RCC building in zone-0.075

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

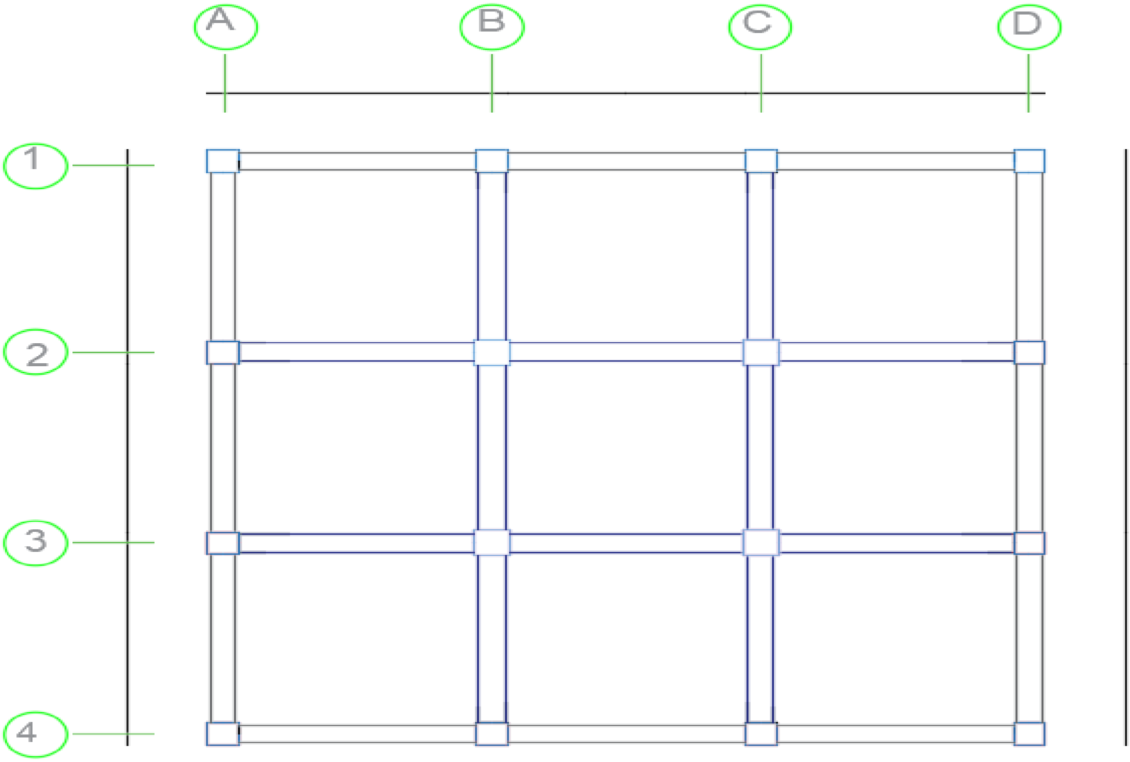


Figure 4.3: Column Layout Plan for 5 storied building

Table 4.3: Column schedule for 5 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	18x18	18x18
C2	22x22	22x22

4.5.2 5 storied RCC building in zone-0.15

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

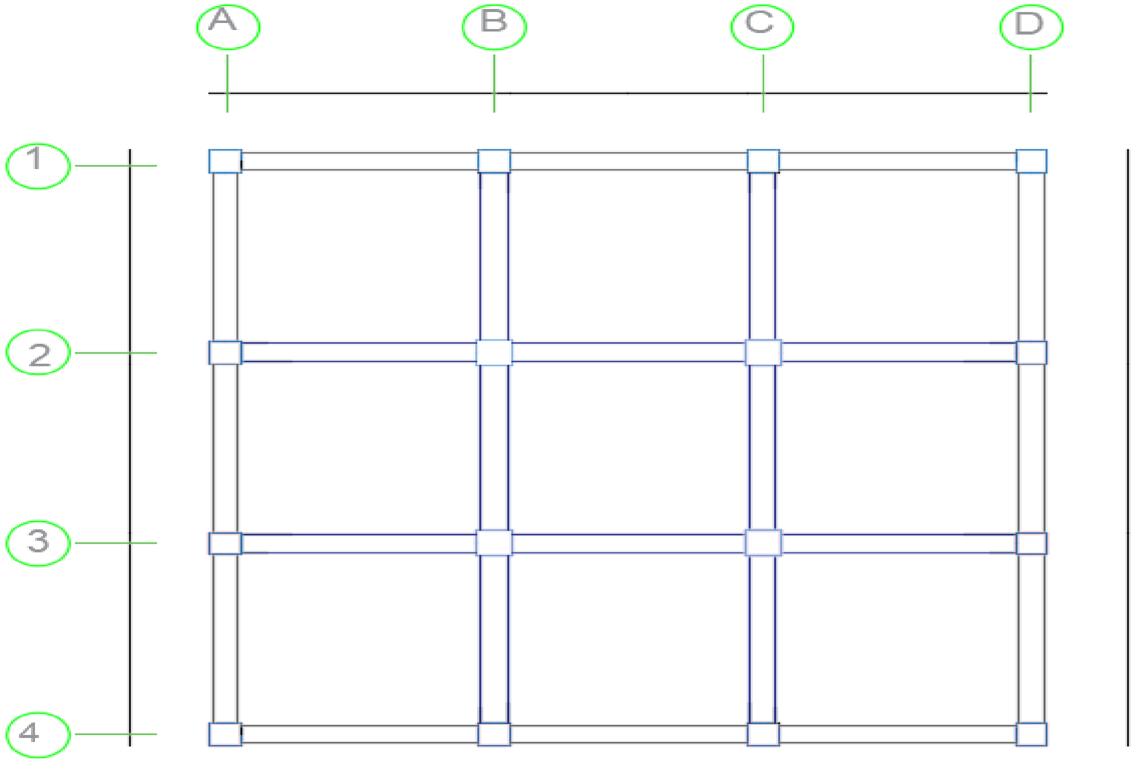


Figure 4.3.1: Column Layout Plan for 5 storied building

Table 4.3.1: Column schedule for 5 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	18x18	18x18
C2	22x23	22x23

4.5.3 5 storied RCC building in zone-0.20

Number of bays along X-direction = 4

Number of bays along Y-direction = 4

Base to ground floor height = 6 feet

Story height = 10 feet

Bay width along X-direction = 20feet

Bay width along Y-direction = 20feet

Plan of two storied building is given below:

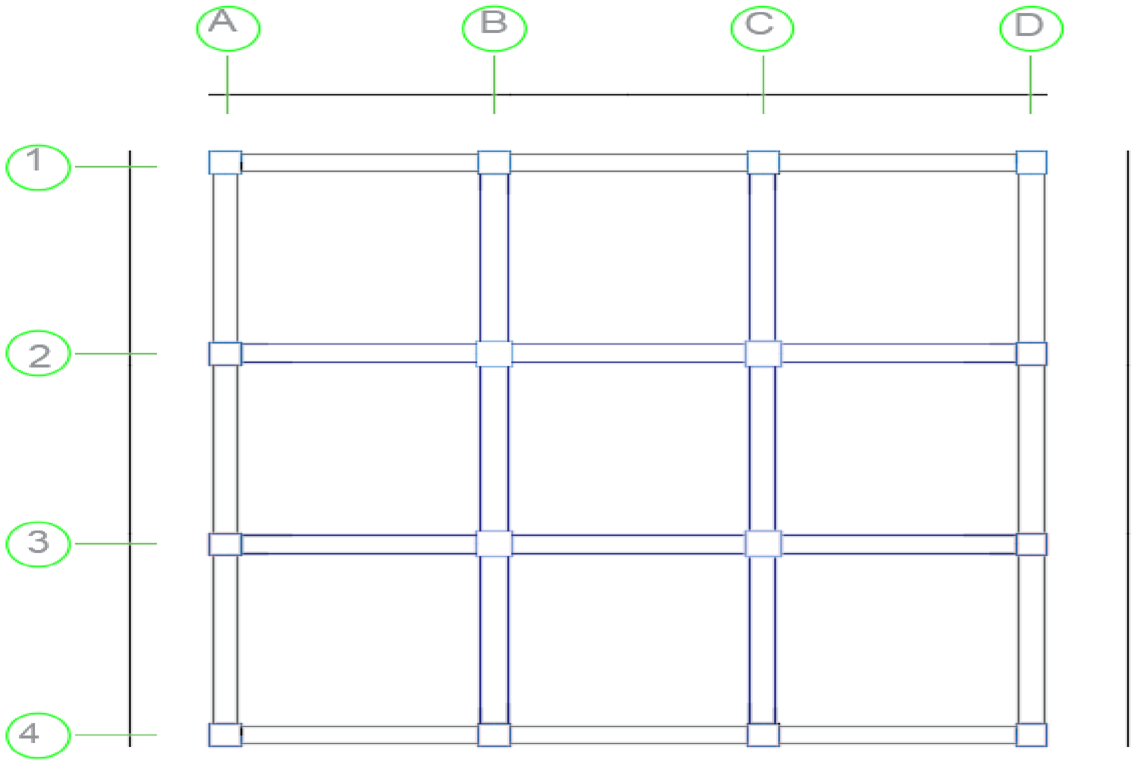


Figure 4.3.2: Column Layout Plan for 5 storied building

Table 4.3.2: Column schedule for 5 storied building

Number of Column	GF and 1st floor	2nd floor to roof
C1	18x18	18x18
C2	24x24	24x24

Loading Condition

Floor Finish = 25psf
Partition Wall = 80psf
Dead Load = 100psf
Live Load = 60psf

Wind load is automatically calculated by program as per UBC94. As per BNBC Site location = Dhaka

Basic wind speed = 141 km/hr.
Exposure = B
Structure importance factor = 1.00

Seismic load is automatically calculated by program as per UBC94. As per BNBC

Numerical Coefficient =8
Site Location = Dhaka

Seismic zone factors Z = 0.075, 0.15, 0.20

Site coefficient, S = 1.5

Structure importance factor, I = 1

Seismic modification factor for RCC building, R = 8

Time period for RCC building, Ct (ft.) = 0.030

CHAPTER-5

RESULTS AND DISSCUSSION

5.1 General

This chapter presents the results of Analysis of RCC and framed buildings in different seismic zone. Analysis of RCC frames under the static loads has been performed using ETABS software. First analysis was performed by considering response spectrum analysis for defining gravity load case and then a lateral pushover analysis was performed in a displacement control manner.

5.2 Non-linear analysis results of RCC buildings

5.2.1 Capacity curve and performance point

The resulting capacity curves for the five buildings are shown in figure 5.1, 5.2, 5.3, 5.4 and 5.5 for 2, 3, 4, and 5 storied buildings respectively. The curves show similar nature. They are initially linear but start to deviate from linearity as the beams and the columns undergo inelastic actions in different seismic zone. When the buildings are pushed well into the inelastic range, the curves become linear again but with smallerslope.

The performance point is determined for serviceability earthquake (SE), design earthquake (DE) and maximum earthquake (ME). Both the capacity curve and the demand curve are plotted here in the same plotted area in ADRS format. The performance point in spectral acceleration versus spectral displacement coordinates. The effective period and effective damping at the performance point.

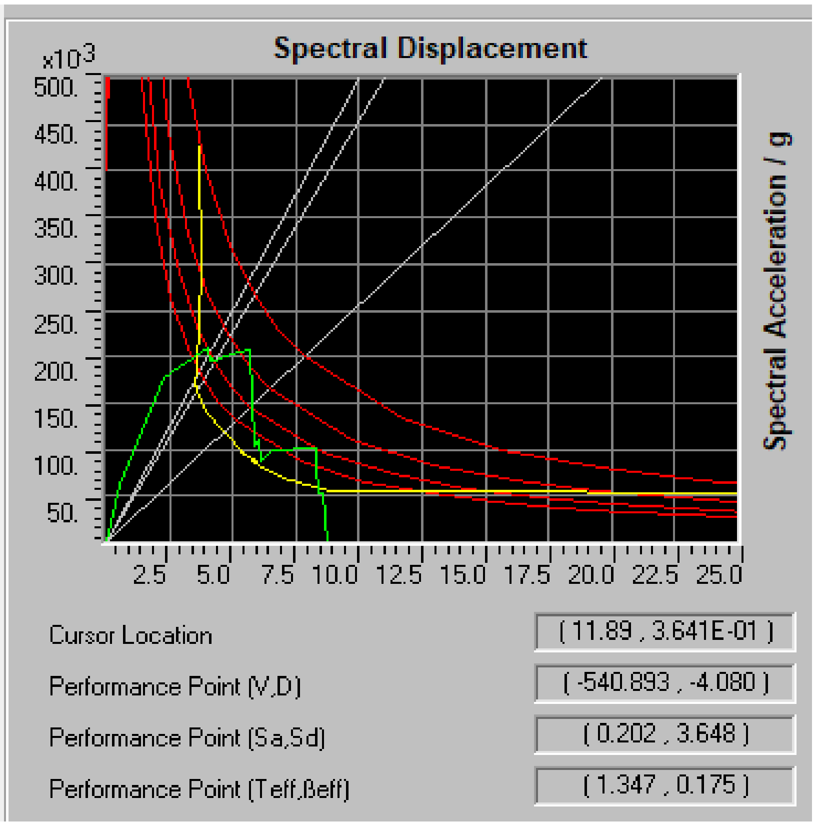
The performance point of 3, 4, and 5 storied building for serviceability earthquake is given below:

Table 5.1: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	540.893
Displacement, D (inch)	4.080

For push –x in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 540.893 kip and the structure can deflect up to 4.080 inch without any damage



Cursor Location (11.89 , 3.641E-01)

Performance Point (V,D) (-540.893 , -4.080)

Performance Point (Sa,Sd) (0.202 , 3.648)

Performance Point (Teff,Beff) (1.347 , 0.175)

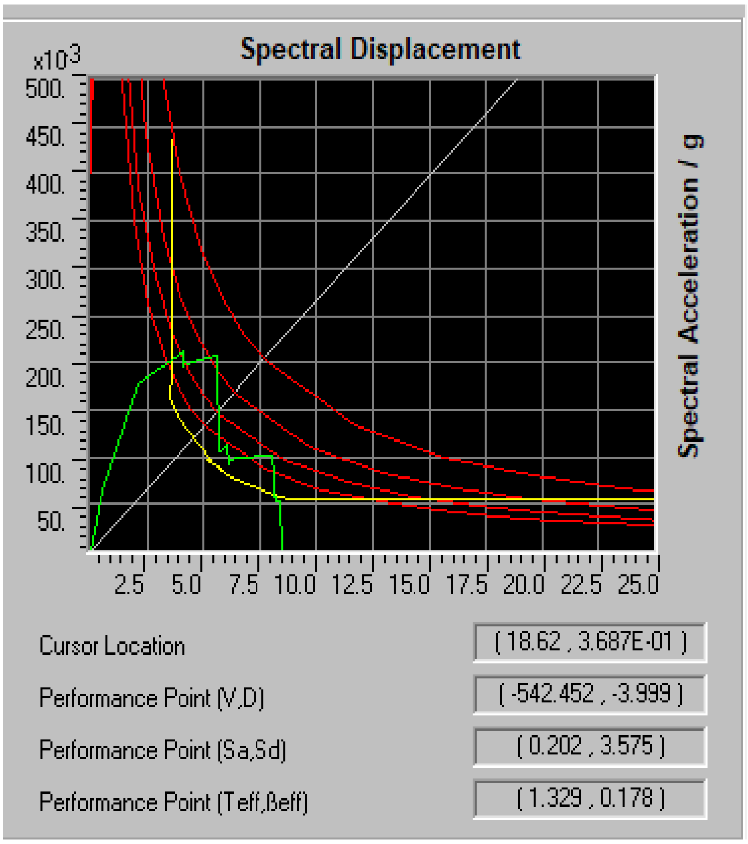
Figure 5.1: Capacity Spectrum of 3 Storied RCC Building in Zone-0.075(push-x)

Table 5.1.1: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	542.425
Displacement, D (inch)	3.999

For push –x in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 542.452 kip and the structure can deflect up to 3.999 inch without any damage



Cursor Location (18.62 , 3.687E-01)

Performance Point (V,D) (-542.452 , -3.999)

Performance Point (Sa,Sd) (0.202 , 3.575)

Performance Point (Teff,ßeff) (1.329 , 0.178)

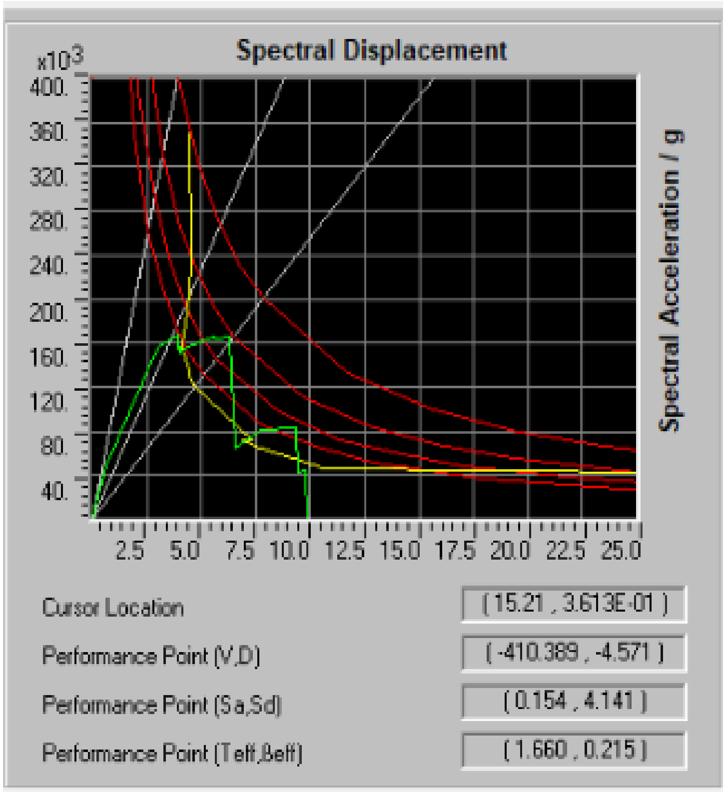
Figure 5.1.1: Capacity Spectrum of 3 Storied RCC Building in Zone-0.15(push-x)

Table 5.1.2: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	410.389
Displacement, D (inch)	4.571

For push –x in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 410.389 kip and the structure can deflect up to 4.571 inch without any damage



Cursor Location (15.21 , 3.613E-01)

Performance Point (V,D) (-410.389 , -4.571)

Performance Point (Sa,Sd) (0.154 , 4.141)

Performance Point (Teff,βeff) (1.660 , 0.215)

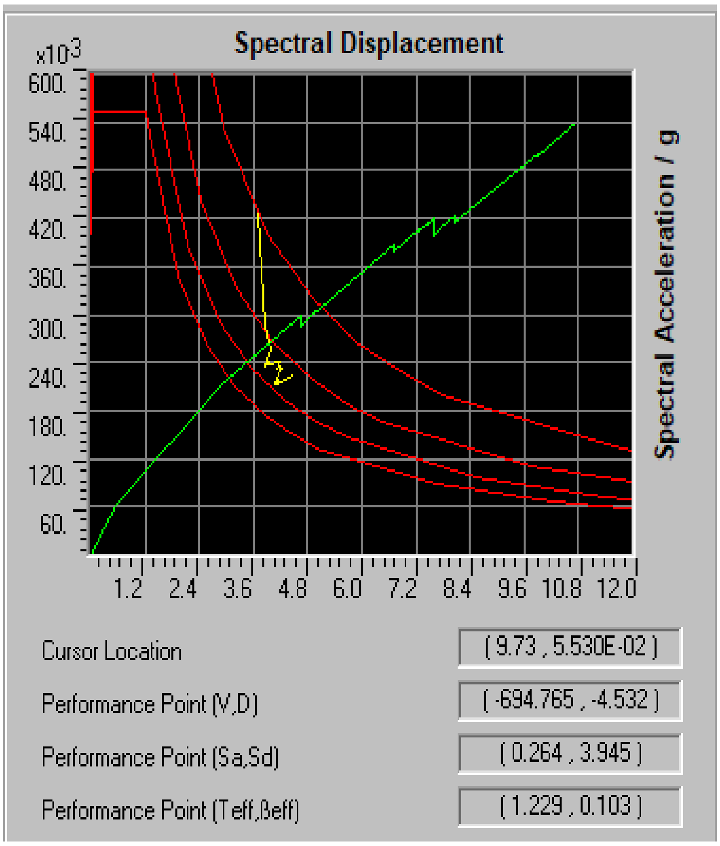
Figure 5.1.2: Capacity Spectrum of 3 Storied RCC Building in Zone-0.20(push-x)

Table 5.1.3: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	694.765
Displacement, D (inch)	4.532

For push –y in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 694.765 kip and the structure can deflect up to 4.532 inch without any damage



Cursor Location (9.73 , 5.530E-02)

Performance Point (V,D) (-694.765 , -4.532)

Performance Point (Sa,Sd) (0.264 , 3.945)

Performance Point (Teff,βeff) (1.229 , 0.103)

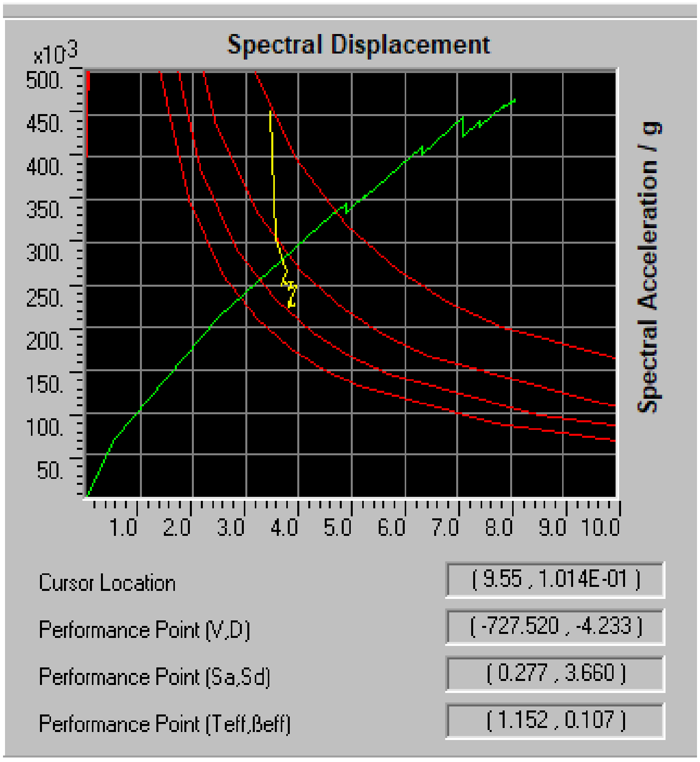
Figure 5.1.3: Capacity Spectrum of 3 Storied RCC Building in Zone-0.075(push-y)

Table 5.1.4: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	727.520
Displacement, D (inch)	4.233

For push –y in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 727.520 kip and the structure can deflect up to 4.233 inch without any damage



Cursor Location (9.55 , 1.014E-01)

Performance Point (V,D) (-727.520 , -4.233)

Performance Point (Sa,Sd) (0.277 , 3.660)

Performance Point (Teff,Beff) (1.152 , 0.107)

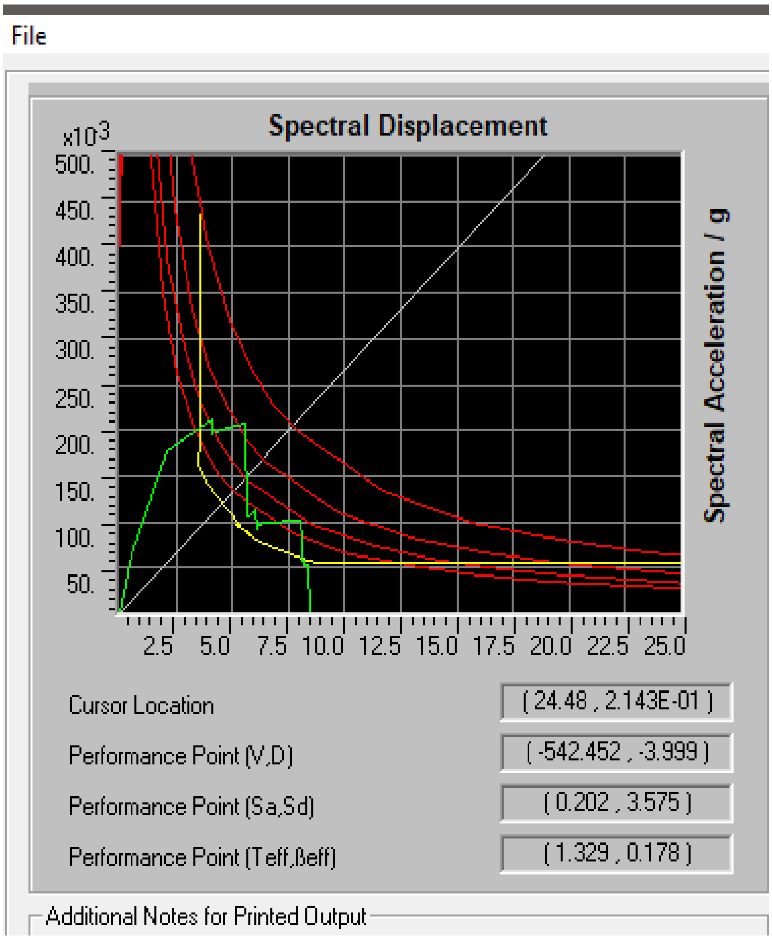
Figure 5.1.4: Capacity Spectrum of 3 Storied RCC Building in Zone-0.15(push-y)

Table 5.1.5: Performance Point of 3 Storied RCC Building

Base Shear, V (kip)	542.452
Displacement, D (inch)	3.999

For push –y in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 542.452kip and the structure can deflect up to 3.999inch without any damage



Cursor Location (24.48 , 2.143E-01)
Performance Point (V,D) (-542.452 , -3.999)
Performance Point (Sa,Sd) (0.202 , 3.575)
Performance Point (Teff,ßeff) (1.329 , 0.178)

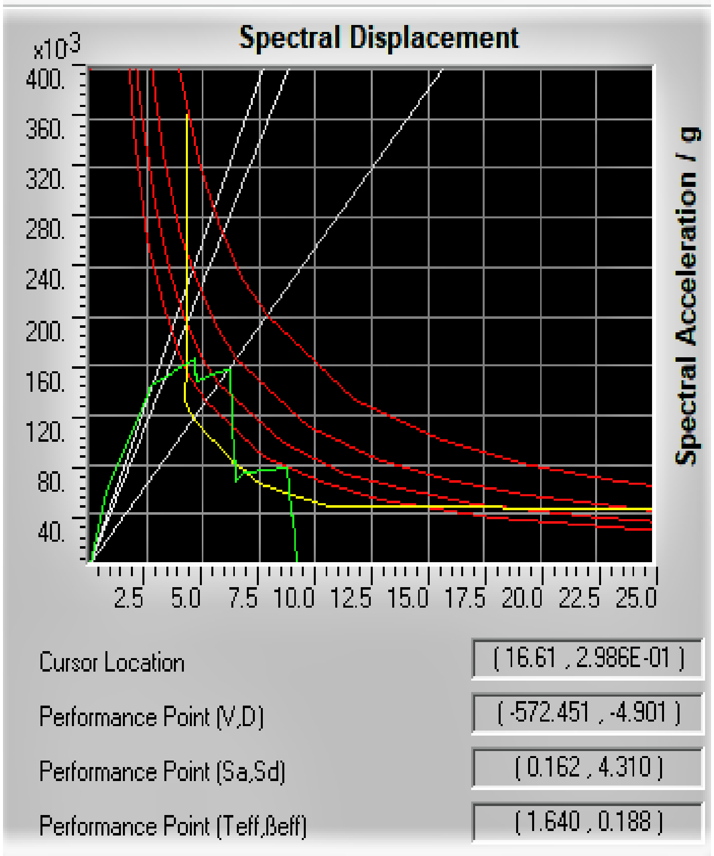
Figure 5.1.5: Capacity Spectrum of 3 Storied RCC Building in Zone-0.20(push-y)

Table 5.2: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	572.451
Displacement, D (inch)	4.901

For push –x in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 572.451kip and the structure can deflect up to 4.901 inch without any damage



Cursor Location (16.61 , 2.986E-01)

Performance Point (V,D) (-572.451 , -4.901)

Performance Point (Sa,Sd) (0.162 , 4.310)

Performance Point (Teff,ßeff) (1.640 , 0.188)

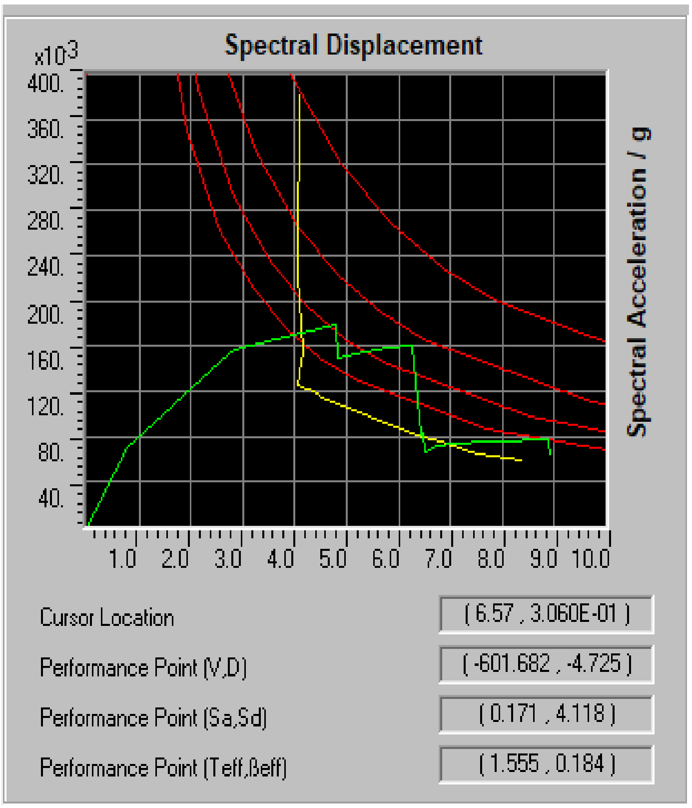
Figure 5.2: Capacity Spectrum of 4 Storied RCC Building in Zone-0.075(push-x)

Table 5.2.1: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	601.682
Displacement, D (inch)	4.725

For push –x in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 601.682kip and the structure can deflect up to 4.725 inch without any damage



Cursor Location (6.57 , 3.060E-01)

Performance Point (V,D) (-601.682 , -4.725)

Performance Point (Sa,Sd) (0.171 , 4.118)

Performance Point (Teff,ßeff) (1.555 , 0.184)

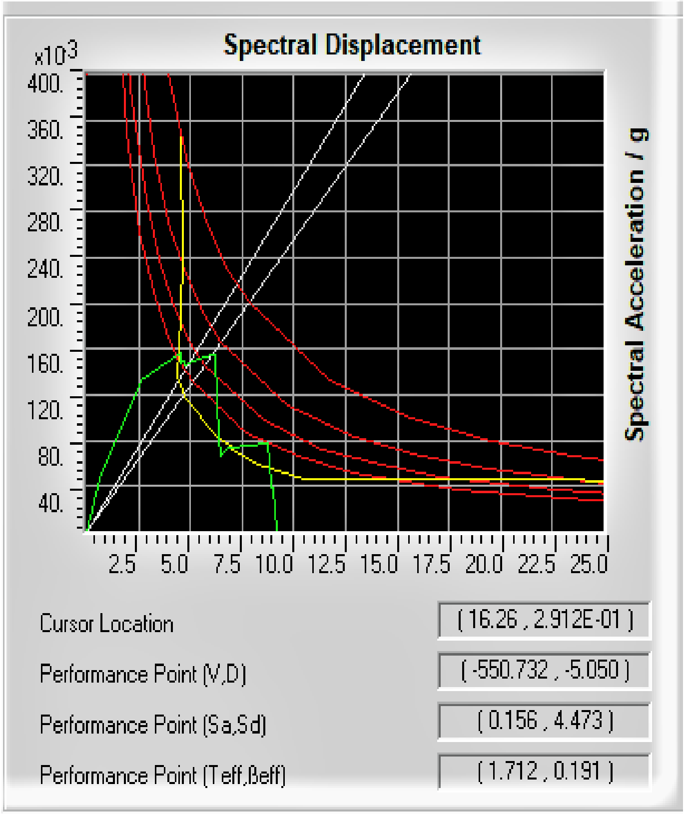
Figure 5.2.1: Capacity Spectrum of 4 Storied RCC Building in Zone-0.15(push-x)

Table5.2.2: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	550.732
Displacement, D (inch)	5.050

For push –x in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 550.732kip and the structure can deflect up to 5.050 inch without any damage



Cursor Location (16.26 , 2.912E-01)

Performance Point (V,D) (-550.732 , -5.050)

Performance Point (Sa,Sd) (0.156 , 4.473)

Performance Point (Teff,βeff) (1.712 , 0.191)

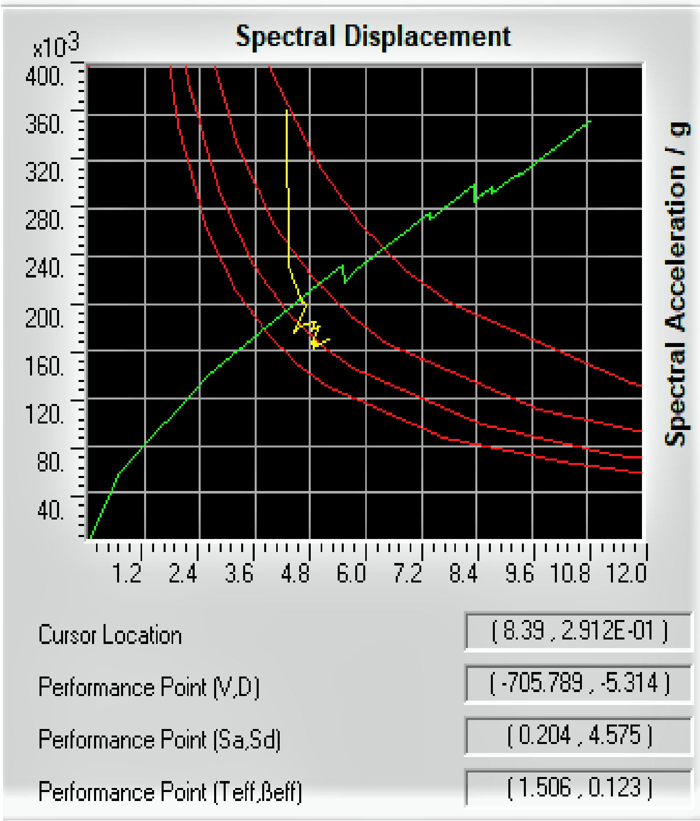
Figure 5.2.2: Capacity Spectrum of 4 Storied RCC Building in Zone-0.20(push-x)

Table 5.2.3: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	705.789
Displacement, D (inch)	5.314

For push –y in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 705.789 kip and the structure can deflect up to 5.314 inch without any damage



Cursor Location (8.39 , 2.912E-01)

Performance Point (V,D) (-705.789 , -5.314)

Performance Point (Sa,Sd) (0.204 , 4.575)

Performance Point (Teff,Beff) (1.506 , 0.123)

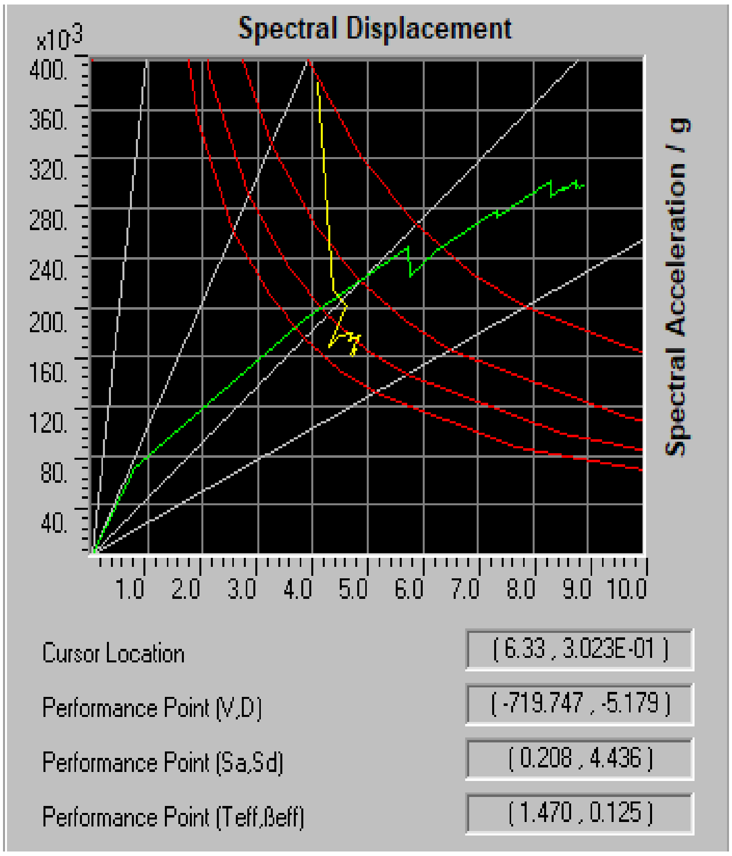
Figure 5.2.3: Capacity Spectrum of 4 Storied RCC Building in Zone-0.075(push-y)

Table 5.2.4: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	719.747
Displacement, D (inch)	5.179

For push –y in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 719.747kip and the structure can deflect up to 5.179 inch without any damage



Cursor Location (6.33 , 3.023E-01)
Performance Point (V,D) (-719.747 , -5.179)
Performance Point (Sa,Sd) (0.208 , 4.436)
Performance Point (Teff,βeff) (1.470 , 0.125)

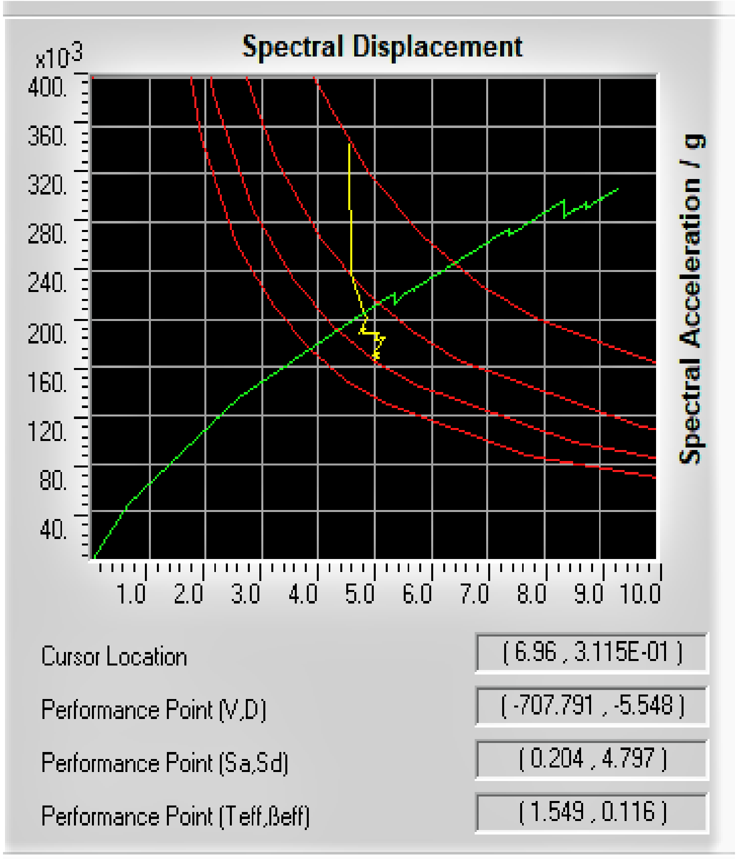
Figure5.2.4.: Capacity Spectrum of 4 Storied RCC Building in Zone-0.15(push-y)

Table 5.3.5: Performance Point of 4 Storied RCC Building

Base Shear, V (kip)	707.791
Displacement, D (inch)	5.548

For push –y in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 707.791kip and the structure can deflect up to 5.548inch without any damage



Cursor Location (6.96 , 3.115E-01)

Performance Point (V,D) (-707.791 , -5.548)

Performance Point (Sa,Sd) (0.204 , 4.797)

Performance Point (Teff,Beff) (1.549 , 0.116)

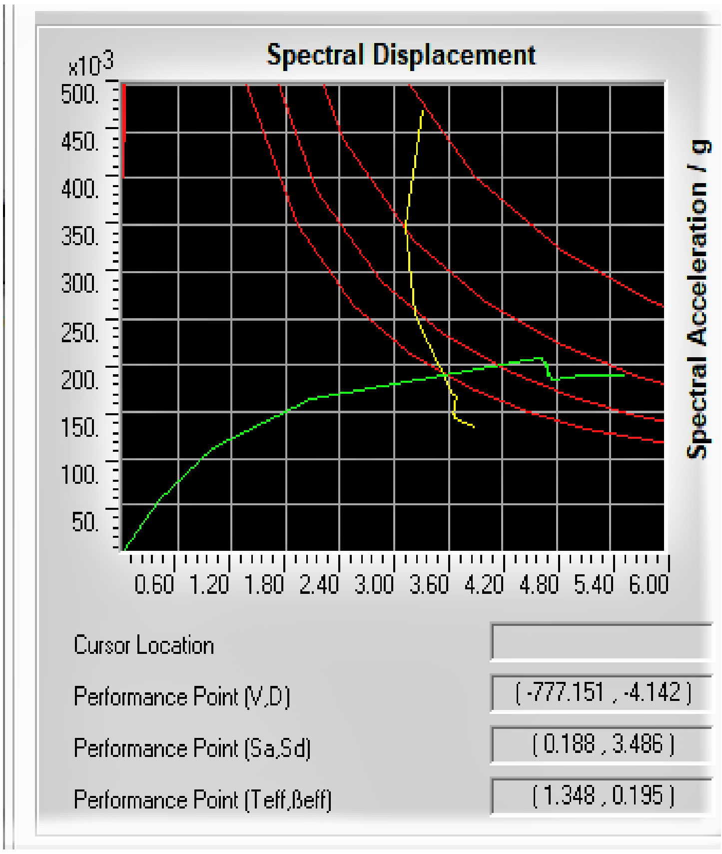
Figure 5.2.5: Capacity Spectrum of 4 Storied RCC Building in Zone-0.20(push-y)

Table 5.3: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	777.151
Displacement, D (inch)	4.142

For push –x in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 777.151kip and the structure can deflect up to 4.142 inch without any damage



Cursor Location

Performance Point (V,D) (-777.151 , -4.142)

Performance Point (Sa,Sd) (0.188 , 3.486)

Performance Point (Teff,ßeff) (1.348 , 0.195)

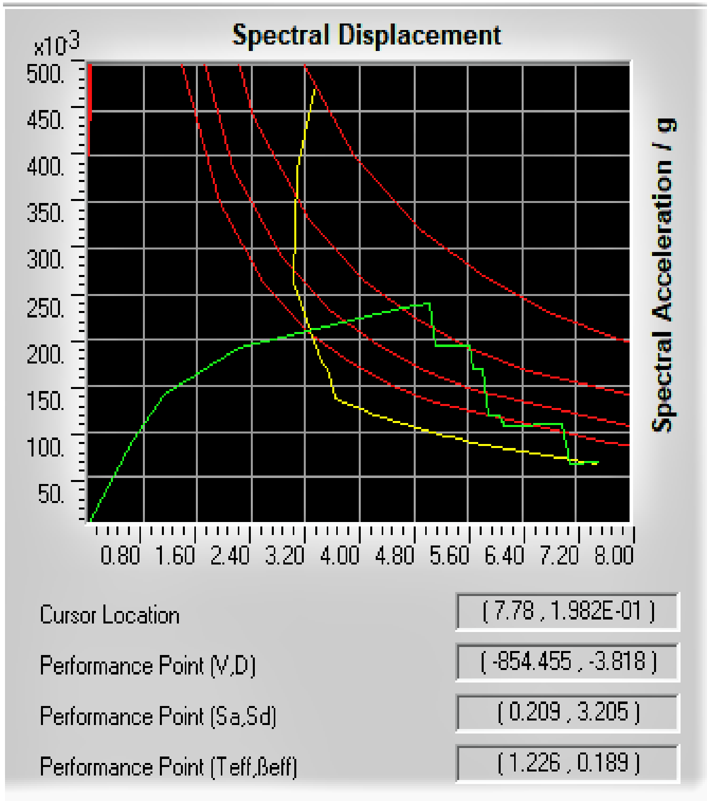
Figure 5.3: Capacity Spectrum of 5 Storied RCC Building in Zone-0.075(push-x)

Table 5.3.1: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	854.455
Displacement, D (inch)	3.818

For push –x in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 854.455kip and the structure can deflect up to 3.818inch without any damage



Cursor Location (7.78 , 1.982E-01)

Performance Point (V,D) (-854.455 , -3.818)

Performance Point (Sa,Sd) (0.209 , 3.205)

Performance Point (Teff,Beff) (1.226 , 0.189)

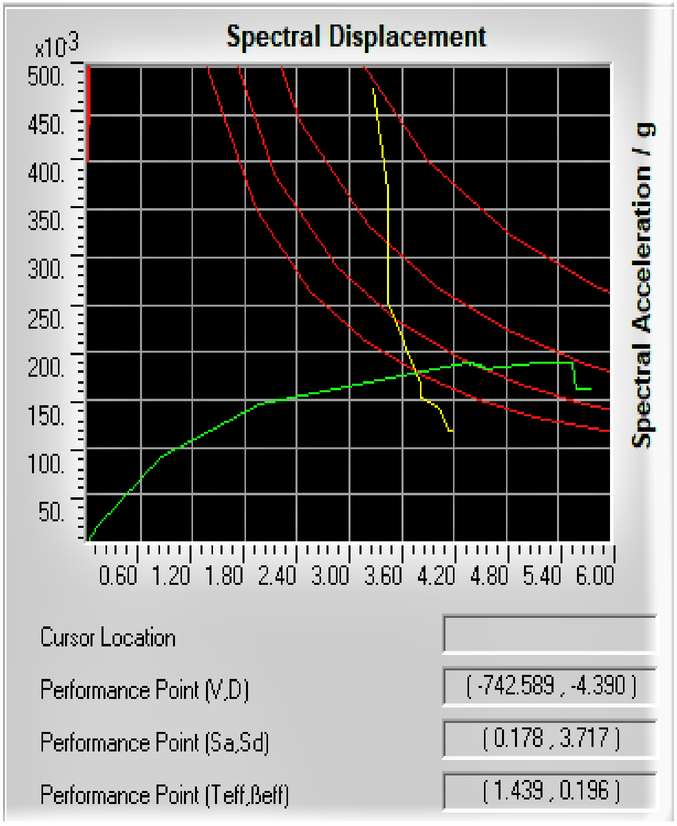
Figure 5.3.1: Capacity Spectrum of 5 Storied RCC Building in Zone-0.15(push-x)

Table 5.3.2: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	742.589
Displacement, D (inch)	4.390

For push –x in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 742.589kip and the structure can deflect up to 4.390inch without any damage



Cursor Location

Performance Point (V,D) (-742.589 , -4.390)

Performance Point (Sa,Sd) (0.178 , 3.717)

Performance Point (Teff,βeff) (1.439 , 0.196)

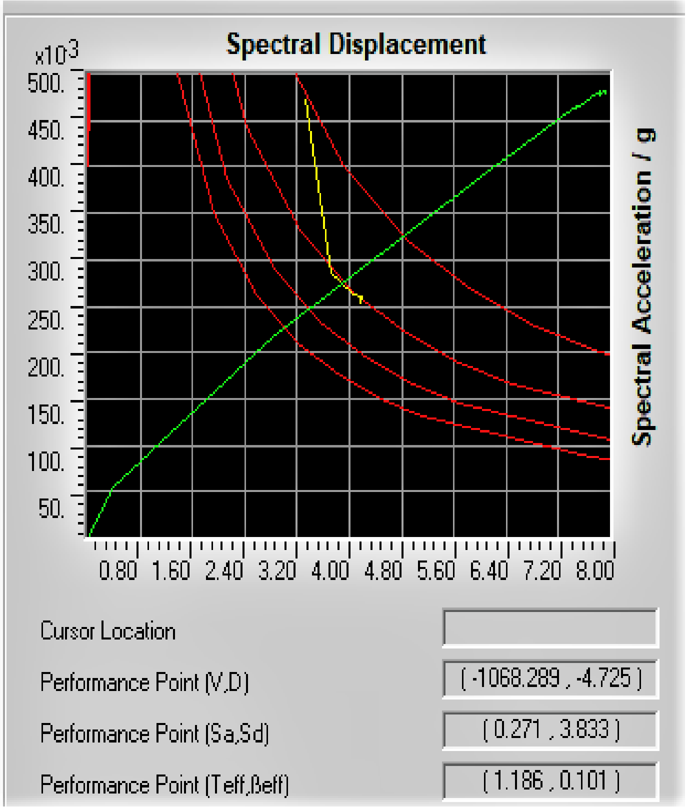
Figure 5.3.2: Capacity Spectrum of 5 Storied RCC Building in Zone-0.20(push-x)

Table 5.3.3: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	1068.289
Displacement, D (inch)	4.725

For push –y in zone 0.075

It is seen that the base shear at (zone- 0.075) the performance point is 1068.289kip and the structure can deflect up to 4.725inch without any damage



Cursor Location	
Performance Point (V,D)	(-1068.289 , -4.725)
Performance Point (Sa,Sd)	(0.271 , 3.833)
Performance Point (Teff,βeff)	(1.186 , 0.101)

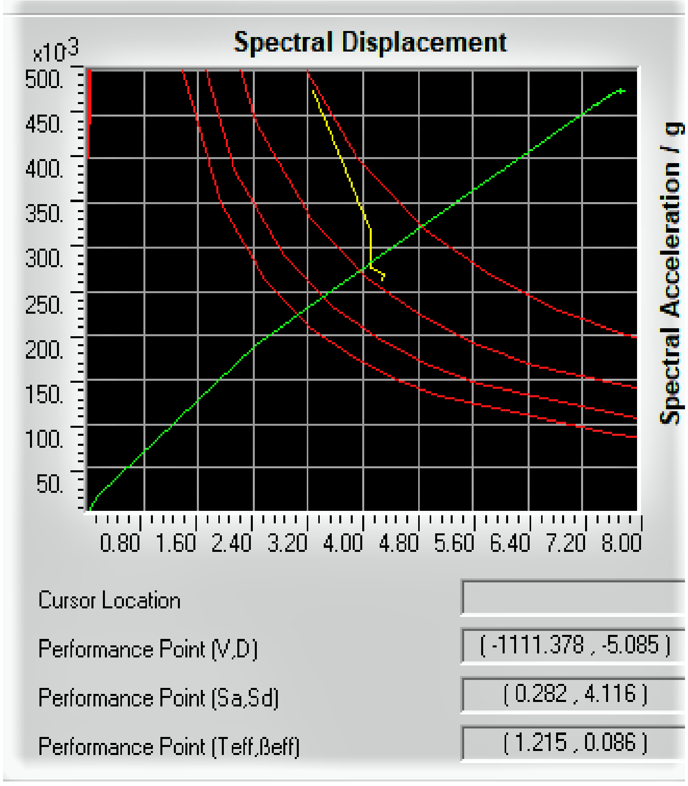
Figure 5.3.3: Capacity Spectrum of 5 Storied RCC Building in Zone-0.075(push-y)

Table 5.3.4: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	1111.378
Displacement, D (inch)	5.085

For push –y in zone 0.15

It is seen that the base shear at (zone- 0.15) the performance point is 1111.378kip and the structure can deflect up to 5.085inch without any damage



Cursor Location

Performance Point (V,D) (-1111.378 , -5.085)

Performance Point (Sa,Sd) (0.282 , 4.116)

Performance Point (Teff,Beff) (1.215 , 0.086)

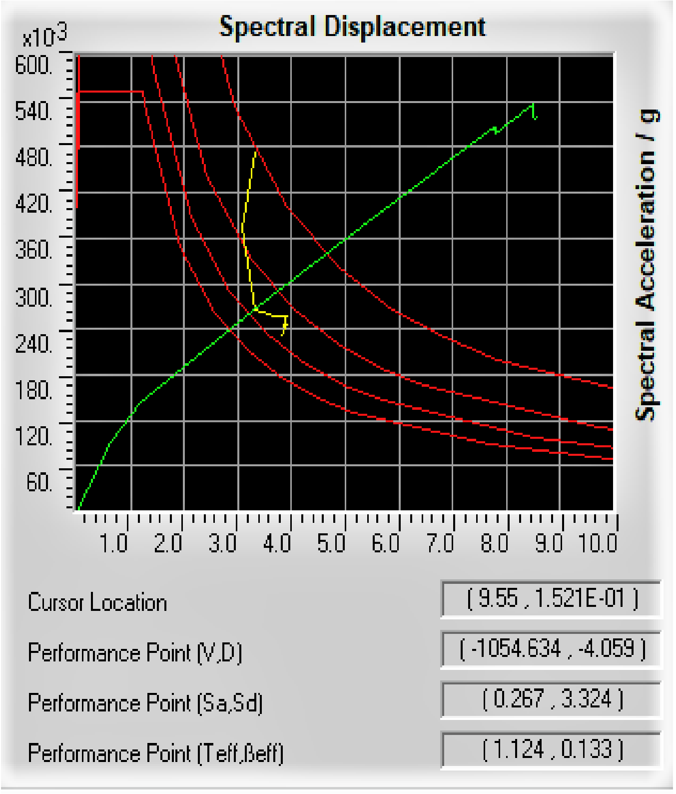
Figure 5.3.4: Capacity Spectrum of 5 Storied RCC Building in Zone-0.15(push-y)

Table 5.3.5: Performance Point of 5 Storied RCC Building

Base Shear, V (kip)	1054.634
Displacement, D (inch)	4.059

For push –y in zone 0.20

It is seen that the base shear at (zone- 0.20) the performance point is 1054.634 kip and the structure can deflect up to 4.059inch without any damage



Cursor Location (9.55 , 1.521E-01)

Performance Point (V,D) (-1054.634 , -4.059)

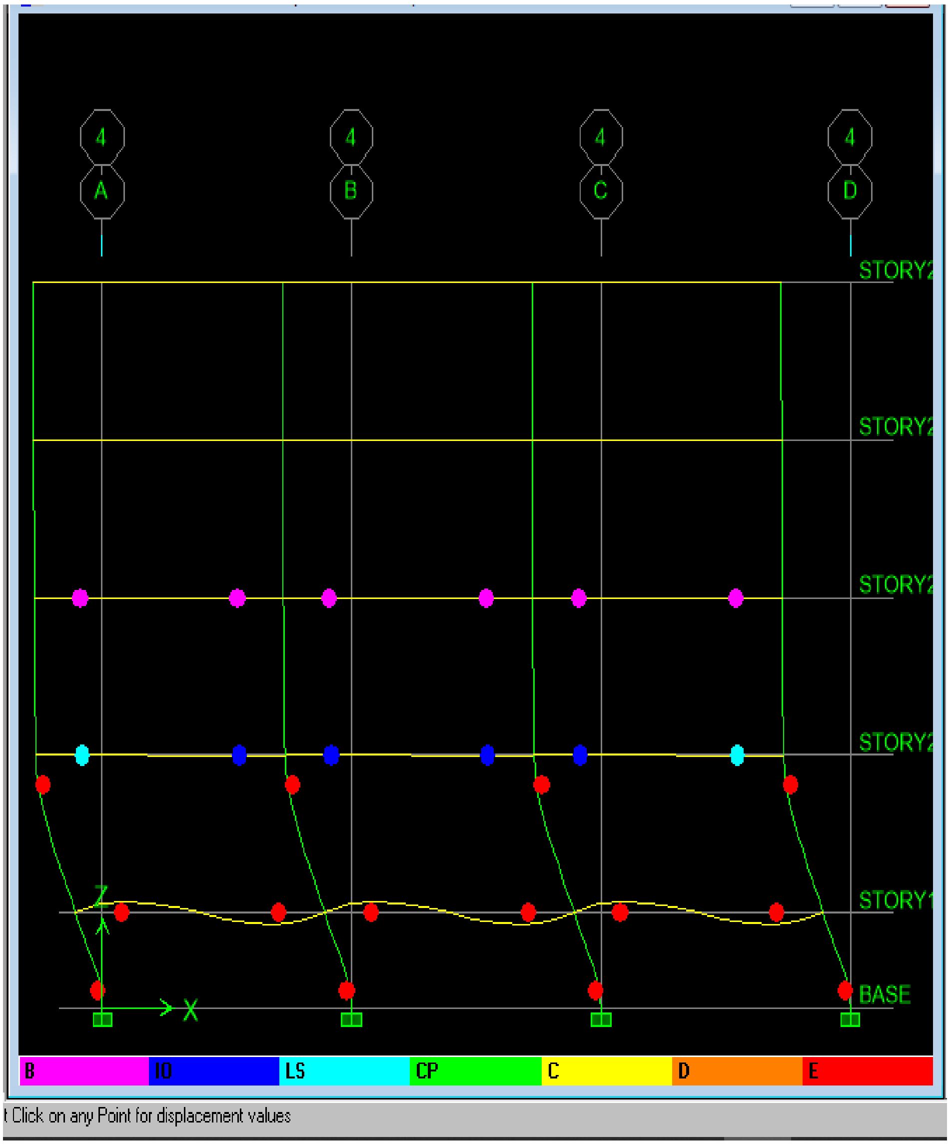
Performance Point (Sa,Sd) (0.267 , 3.324)

Performance Point (Teff,ßeff) (1.124 , 0.133)

Figure 5.3.5: Capacity Spectrum of 5 Storied RCC Building in Zone-0.20(push-y)

5.3 Plastic Hinge Mechanism

Plastic hinge formations for 3, 4, 5 storied building have been obtained at different displacements levels in different seismic zone by pushover analysis. We can see that there are some hinge found for CP (collapse prevention level) limits in push X. Therefore it has been said that one of these three storied buildings fulfills the performances at local level for serviceability earthquake, design earthquake and maximum earthquake and some are not. So the deform shapes of 3, 4, and 5 storied buildings are given bellow:



Click on any Point for displacement values

Figure 5.4: Deformation Shape of 3 Storied RCC Building in zone-0.075

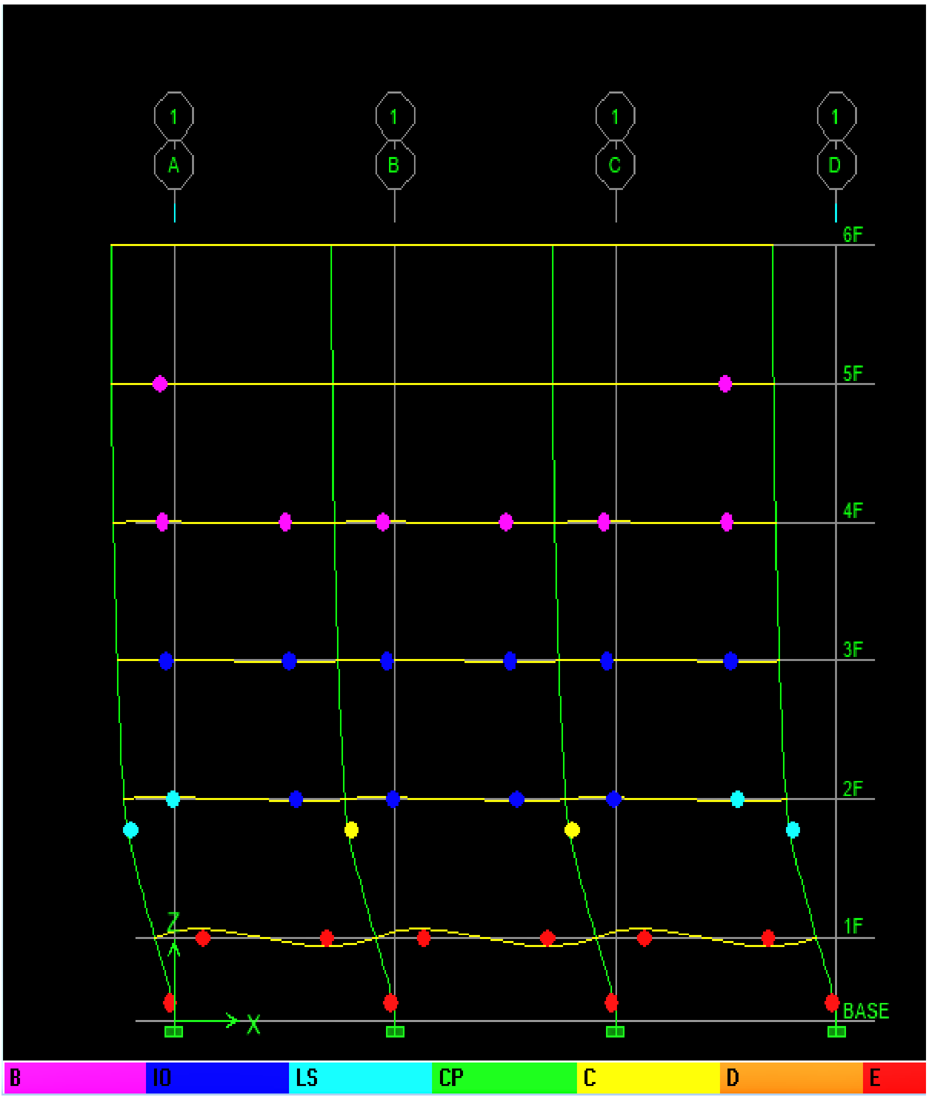


Figure 5.4.1: Deformation Shape of 3 Storied RCC Building in zone-0.15

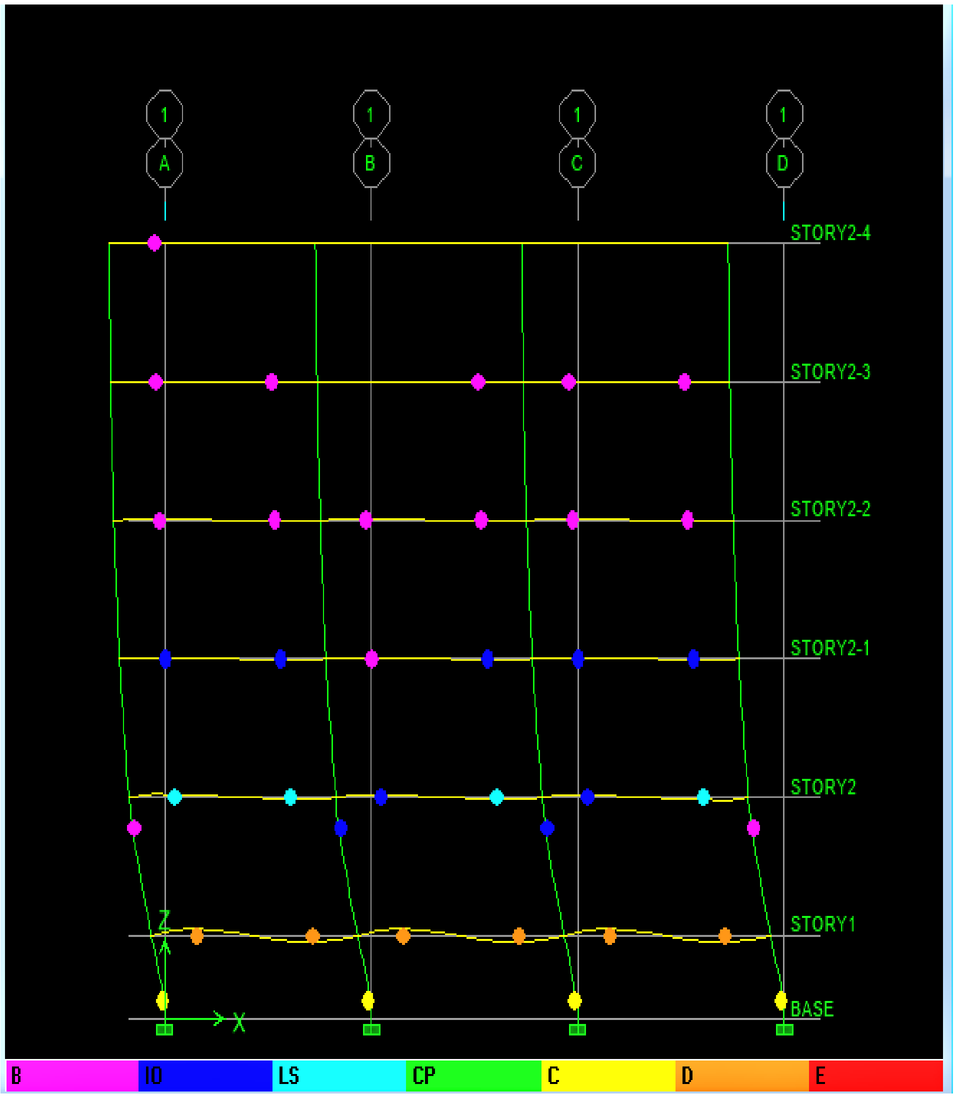


Figure 5.4.2: Deformation Shape of 3 Storied RCC Building in zone-0.20

After analyzing the deformation shape of building 3 we got that in zone-0.20 the cp level has barely crossed so in real life we can consider it pretty safe and the other two zones (0.075 and 0.15) should considered as not much safe so they should analyzed again in proper manner and necessary steps should be taken to make it alright.

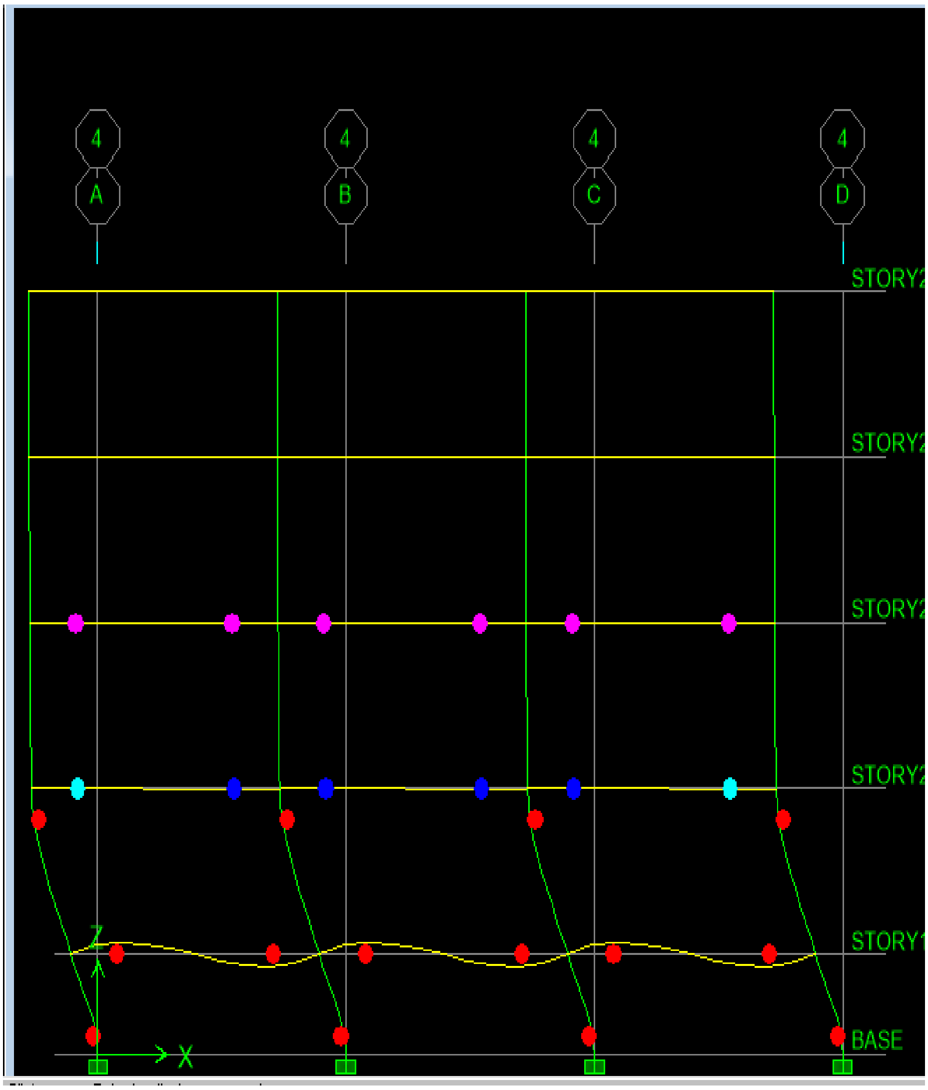


Figure 5.5: Deformation Shape of 4 Storied RCC Building in zone-0.075

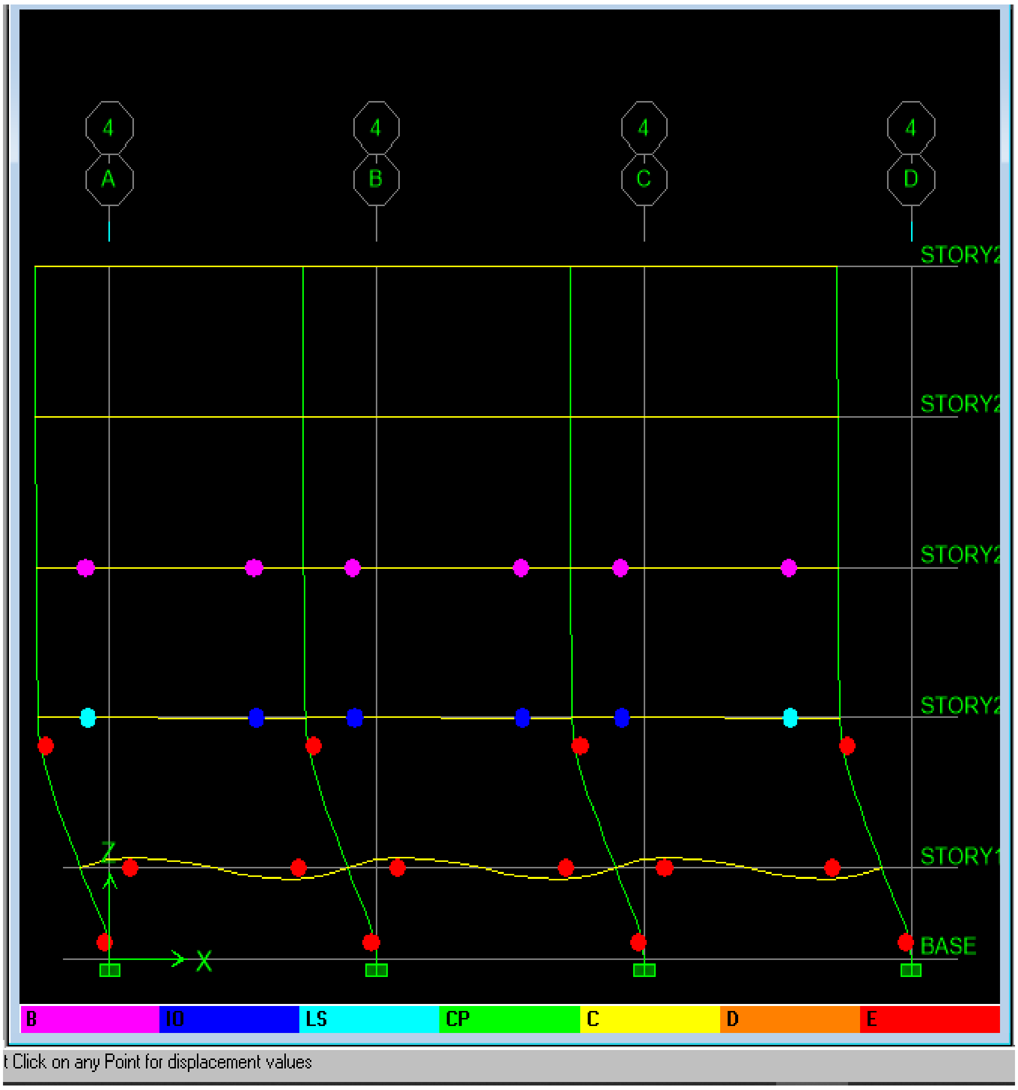


Figure 5.5.1: Deformation Shape of 4 Storied RCC Building in zone-0.15

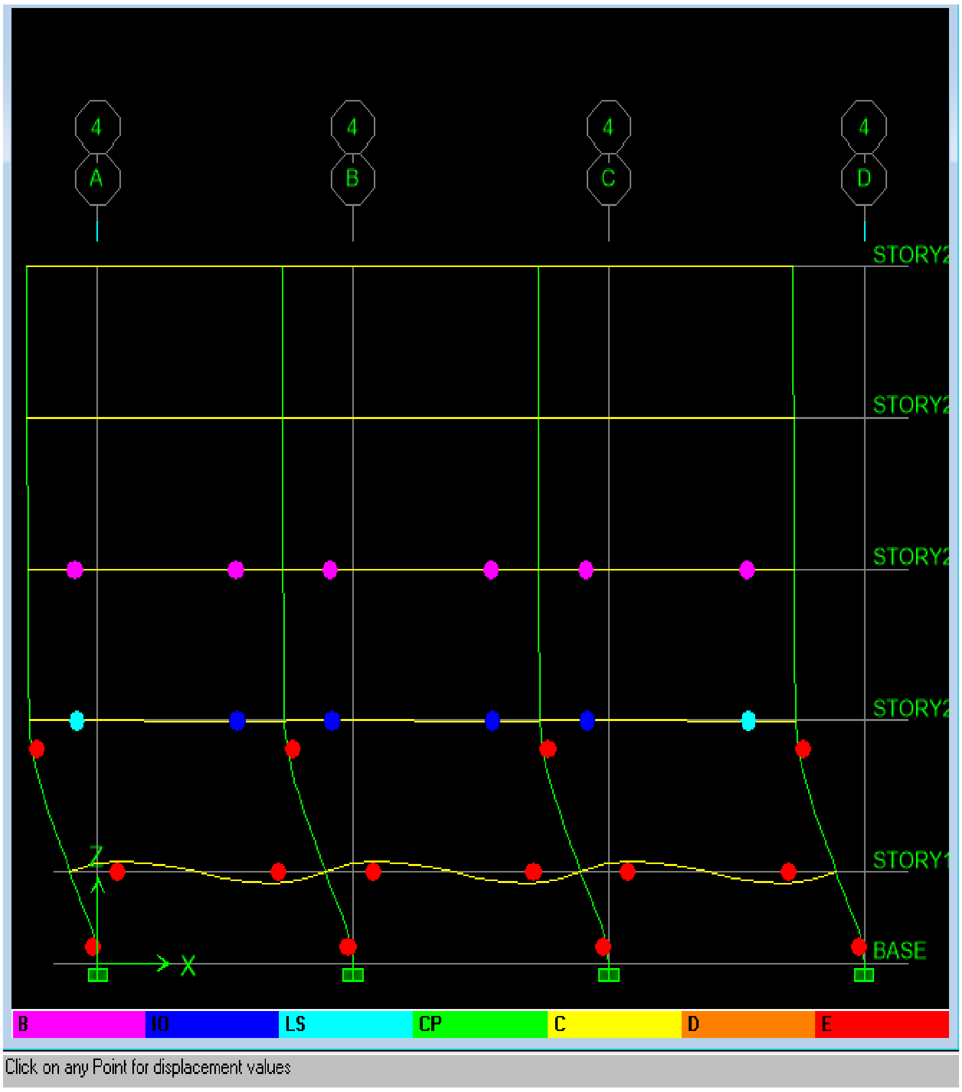


Figure 5.5.2: Deformation Shape of 4 Storied RCC Building in zone-0.20

After analyzing the deformation shape of building 4 we got that all three zones has crossed cp level so the structure will be considered as in danger zone . So necessary steps should be taken to make it alright

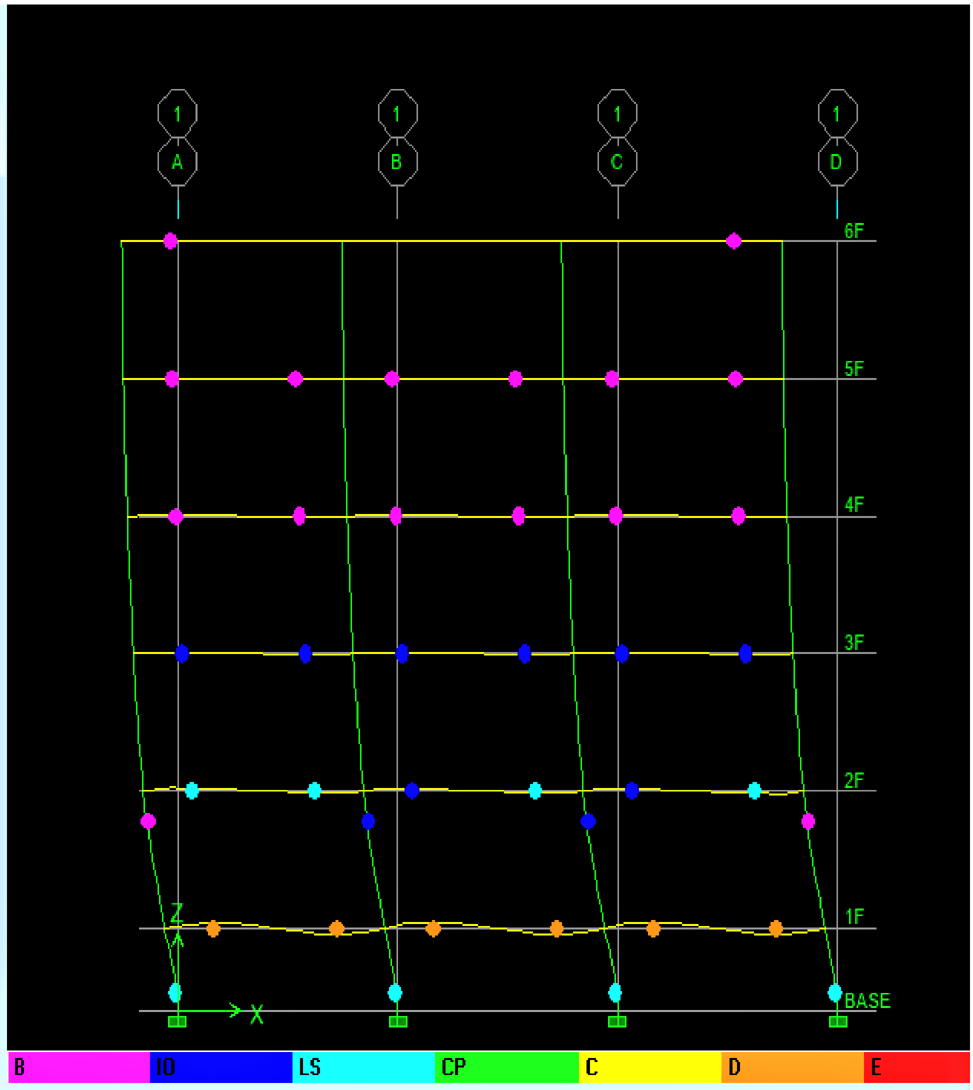


Figure 5.6: Deformation Shape of 5 Storied RCC Building in zone-0.075

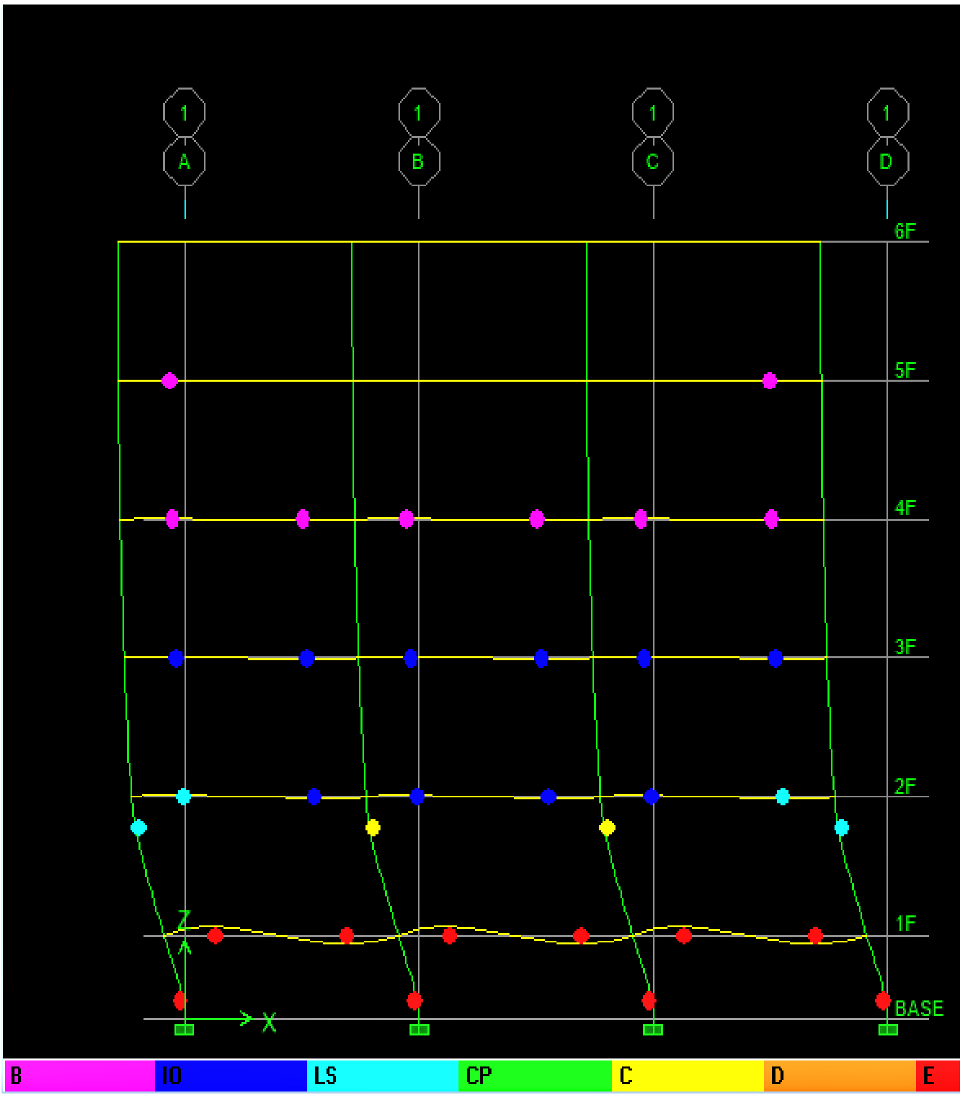


Figure 5.6.1: Deformation Shape of 5 Storied RCC Building in zone-0.15

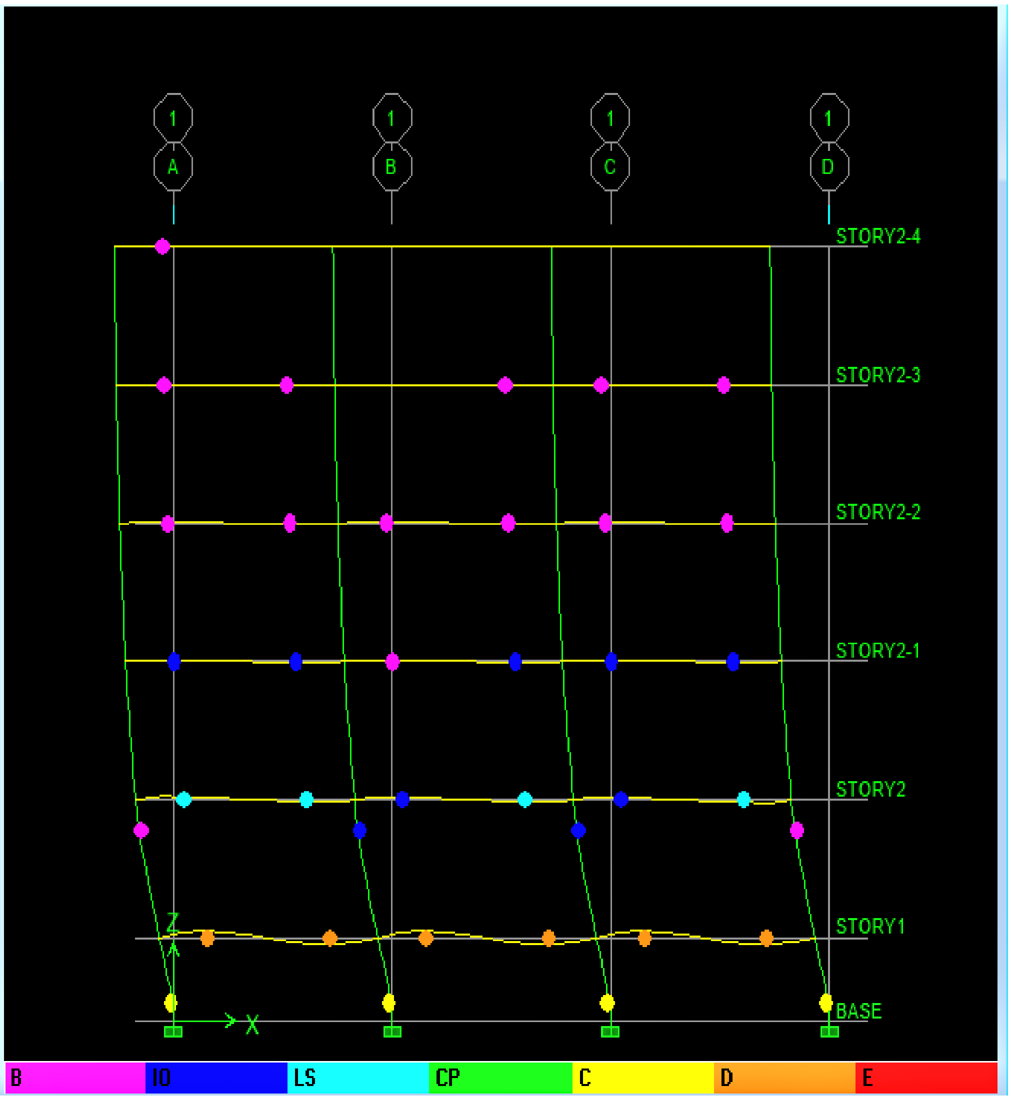


Figure 5.6.2: Deformation Shape of 5 Storied RCC Building in zone-0.20

After analyzing the deformation shape of building 5 we got that zone – 0.075 has not crossed the Cp level, zone-0.15 crossed the Cp level and zone-0.20 just barely crossed Cp level. So the structures in zone-0.075, 0.20 should be just fine but in the case of zone-0.15 necessary steps should be taken to make things alright.

CHAPTER-6

CONCLUSIONS

6.1 Conclusions

Nonlinear pushover analysis has now been considered as an effective tool for understanding the performance of structure under different condition. When the structure is subjected to specific levels of seismic motion, there are some desired levels of seismic performance. Acceptable performance is measured by the level of structural and non-structural damage expected from the earthquake shaking.

In this study the main goal was to present the performance base analysis of RCC structures of 3, 4, and 5 storied buildings and their seismic performance was evaluated in a detail way.

The result of the nonlinear static pushover analysis quantitatively establish that the seismic performance of a masonry infill R/C adversely and significantly affected if the infill panels were discontinued in the ground story resulting in the structural configuration with an open story, commonly termed as 'weak' story , at the ground levels.

Hinges formation in the beam is more than column and demonstrates rational nonlinear displacement-based analysis methods for a more objective performance-based seismic evaluation of the masonry in filled R/C frames with seismically undesirable (and preferred) distribution of masonry infill panels over the frame elevation.

6.2 Limitations of the Work

Although pushover analysis has advantages over elastic analysis procedures, underlying assumptions, the accuracy of pushover predictions and limitations of current pushover procedures must be identified. The estimate of target displacement, selection of lateral load patterns and identification of failure mechanisms due to higher modes of vibration are important issues that affect the accuracy of pushover results. Target displacement is the global displacement expected in a design earthquake. The roof displacement at mass center of the structure is used as target displacement. The accurate estimation of target displacement associated with specific performance objective affect the accuracy of seismic demand predictions of pushover analysis.

6.3 Future Scopes of the Work

- This study employed a few number of reinforced concrete moment resisting frames. An extensive study containing a larger number of frames would enhance the result.
- In the thesis from two to five storied building analysis. Performance another high rise buildings can be studied further.
- Further studies can be performed on composite structures.
- Further studies can be performed with stair and shear wall.
- Only static analysis in building design is not enough.
- Hinge should not be CP level.
- For more accuracy in seismic analysis "Time History Analysis" can be done.

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