A

PROJECT REPORT

ON

“PUSHOVER ANALYSIS OF (G+10) BUILDING USING ETABS”

SUBMMITED BY

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UNDER THE GUIDANCE OF

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DEPARTMENT OF CIVIL ENGINEERING

NAGESH KARAJAGI ***ORCHID*** COLLEGE OF ENGINEERING AND

TECHNOLOGY, SOLAPUR-413002.

(AFFILIATED TO DBATU, LONERE)

2022 – 2023

CERTIFICATE

This is to certify that Project Entitled **"**PUSHOVER ANALYSIS OF (G+10) BUILDING USING ETABS**"** is completed by the following students of B.Tech (Civil) class in satisfactory manner under my guidance.

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The project is found to be complete in partial fulfilment for the award for Degree of Bachelor Technology in Civil Engineering from Dr. Babasaheb Ambedkar Technological University, Lonere.

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PROJECT APPROVAL SHEET

The project entitled "PUSHOVER ANALYSIS OF (G+10) BUILDING USING ETABS" submitted by following students-

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Is hereby approved in partial fulfilment for the award of Degree of Bachelor of Technology in Civil Engineering of DBATU University, Lonere.

EXAMINERS

1). **Prof. R. A. Patil** (INTERNAL)

2). ________________(EXTERNAL)

DEPARTMENT OF CIVIL ENGINEERING

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ABSTRACT

Over the past several years, seismic design codes which have consequently been updated for the seismic rehabilitation of buildings have become more stringent for the implementation of Performance Based Design principles, especially for existing structures. Performance-Based Design requires rigorous nonlinear analysis. Nonlinear static analysis (pushover analysis) under constant gravity loads and monotonically increasing lateral forces during an earthquake until a target displacement is reached it generally carried out as an effective tool for performance-based design. The major outcome of a pushover analysis is the capacity curve which shows the base shear vs. the roof displacement relationship and represents the overall performance of the building. Therefore, the numerical modeling technique used for reflecting the physical behavior of structural elements such as frame and shear walls, becomes most important issue in design process. For nonlinear analysis, the nonlinear material model of mid-pier frame element is generally based on plastic hinge concept located at plastic zones towards the ends of structural elements or distributed along the member span length. The nonlinear behavior of shells is generally modeled using multi-layer shell element with layered material model. In this approach, the concrete and the reinforcement contained in the structural elements are modeled using different layers respectively. This project evaluates and comments on the consistency of different approaches for nonlinear shear wall modeling that are used in practice. For this purpose, 10 story reinforcement concrete (RC) frames with shear walls are analyzed using nonlinear two-dimensional nonlinear finite element method under constant gravity loads and incrementally increased lateral loads. The analysis results for these models are compared in terms of overall behavior of the structural systems. Besides, definition of the plastic hinge properties which strongly affects the prediction of the capacity curve of RC wall in the pushover analysis is also discussed.

Keywords: Seismic design, Pushover analysis, RC Shear wall, Plastic hinge, Storey Drift, Storey Shear, Spectral Acceleration.

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INTRODUCTION

1.1 BACKGROUND:

Tall buildings are the most complex built structures since there are many conflicting requirements and complex building systems to integrate. Today's tall buildings are becoming more and more slender, leading to the possibility of more sway in comparison with earlier high-rise buildings. Thus, the impact of wind and seismic forces acting on them becomes an important aspect for the design. Reinforced concrete framed buildings are adequate for resisting both vertical and horizontal loads acting on them. Lateral forces like wind and seismic forces can be resisted by the use of a shear wall system which is one of the most efficient methods of ensuring the lateral stability of tall buildings.

Generally, shear wall can be defined as structural vertical member that is able to resist combination of shear, moment and axial load induced by lateral load and gravity load transfer to the wall from another structural member. An introduction of shear wall represents a structurally efficient solution to stiffen a structural system because the main function of a shear wall is to increase the rigidity against lateral load.

When a building has a story without shear wall, or with poorly placed shear walls, it is known as a soft story building. Shear walls of varying cross sections i.e. rectangular shapes to more irregular cores such as channel, T, L, barbell shape, box etc. can be used. The size and location may vary from architectural and functional point of view. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. When shear walls are situated in advantageous positions in the building, they can form an efficient lateral force resisting system by reducing lateral displacements under earthquake loads. Therefore, it is very necessary to determine effective, efficient and ideal location of shear wall. In this paper effort has been made to investigate the effect of Shear Wall position on lateral displacement and Base Shear in RCC Frames.

1.2 REINFORCED CONCRETE (RC) SHEAR WALL:

Reinforced concrete (RC) shear walls are specially designed structural walls included in the buildings to resist horizontal forces which are induced in the plane of the wall due to wind, earthquake and other forces. Shear walls have very high in-plane stiffness and strength, which can be used to simultaneously resist large horizontal loads and support gravity loads. Reinforced concrete wall thickness varies from 150 mm to 500 mm, depending on horizontal forces due to wind, earthquake etc., building age, and thermal insulation requirements. In general, these walls are continuous throughout the building height; however, some walls are discontinued at the street front or basement level to allow for commercial or parking spaces shown in figure 1.1. Usually the wall layout is symmetrical with respect to at least one axis of symmetry in the plan. Shear walls provide lateral load resistance by transferring the wind or earthquake load to foundation. Besides, they impart lateral stiffness to the system and also carry gravity loads. When shear walls are situated in advantageous positions in the building, they can form an efficient lateral force resisting system.

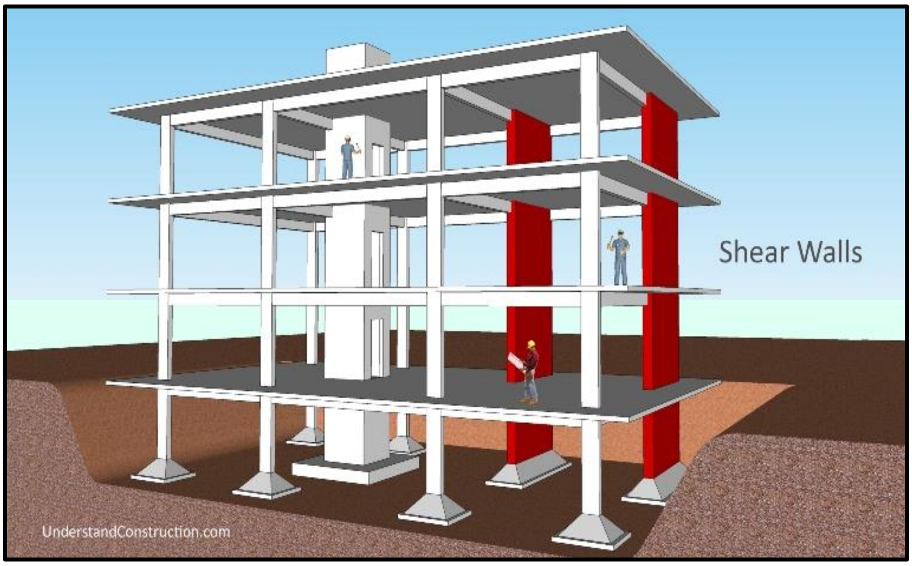


Figure 1.1: General Configuration of a Shear Wall

(Courtesy: http://www.nicee.org)

1.3 FUNCTIONS OF A SHEAR WALL:

Shear wall are one of the excellent means of providing earthquake resistance to multistoried reinforced concrete buildings. When RC Multi-Storey building is designed without shear walls then column sizes are quite heavy and steel required is large. So, there is lot of congestion at these joints and it is difficult to place and vibrate concrete at these places and displacement is quite heavy which induces heavy forces in member. Shear walls may become essential from the point of view of economy and control of horizontal displacement. The structure is still damaged due to some or the other reason during earthquakes. Behavior of structure during earthquake motion depends on distribution of weight, lateral stiffness and strength in both horizontal and planes of building. To reduce the effect of earthquake, reinforced concrete shear walls are used in the building. These can be used for improving seismic response of buildings. Structural design of buildings for seismic loading is primarily concerned with structural safety during major Earthquakes. In tall buildings, it is very important to ensure adequate lateral stiffness to resist lateral load. The provision of shear walls in building to achieve lateral stiffness has been found to be effective and economical.

Properly designed and detailed buildings with shear walls have shown very good performance in past earthquakes. The overwhelming success of buildings with shear walls in resisting strong earthquakes is summarized in the quote: "We cannot afford to build concrete buildings meant to resist severe earthquakes without shear walls." Mark Fintel, a noted consulting engineer in USA. Shear walls in high seismic regions require special detailing. However, in past earthquakes, even buildings with sufficient number of walls that were not specially detailed for seismic performance (but had enough well-distributed reinforcement) were saved from collapse. Shear wall buildings are a popular choice in many earthquake prone countries, like Chile, New Zealand and USA. Shear walls are easy to construct, because reinforcement detailing of walls is relatively straight-forward and therefore easily implemented at site. Shear walls are efficient, both in terms of construction cost and effectiveness in minimizing earthquake damage in structural and non-structural elements (like glass windows and building contents).

1.4 CONVENTIONAL STUDY OF SHEAR WALL WITH RESPECT TO LOAD BEARING WALL:

Load bearing masonry wall is very brittle in nature. Due to different kinds of stresses such as shear, tension, torsion etc. caused by the earthquake, the conventional unreinforced brick masonry wall may collapse instantly during the sudden earthquake. The RCC frame structures are slender, when compared to shear wall concept of box like three-dimensional structure. Though, it is possible to design earthquake resistant RCC frame, it requires extra ordinary skills in design, detailing and construction, which cannot be anticipated in all types of construction project. On the other hand, even moderately designed shear wall structure is not only more stable, but also comparatively more ductile. In safety terms, it means that during high intensity of earthquake they will not suddenly collapse, causing the major damage of human and property. They give enough indicative warnings such as widening structural cracks, yielding rods, etc., offering most precious moments/warning the people to evacuate the structure before totally collapse.

1.5 EXTERNAL FORCES ACTING ON SHEAR WALL:

Shear walls resist two types of forces: shear forces and uplift forces. Shear forces are generated in stationary buildings by accelerations resulting from ground motion and by external forces like wind and P-waves. This action creates shear forces throughout the height of the wall and the top and bottom shear wall connections. Uplift forces exist on shear walls because the horizontal forces are also applied to the top of the wall. These uplift forces try to lift up one end of the wall and push the other end down. In some cases, the uplift force is large enough to topple the wall over. Uplift forces are greater on tall short walls and less on low long walls. Bearing walls have less uplift than non-bearing walls/shear walls because gravity loads on shear walls help them to resist the uplift. Shear walls should be located on each level of the structure including the crawl space. To form an effective box structure, equal length shear walls should be placed symmetrically on all four exterior walls of the building. Shear walls should be added to the building internally when the exterior walls cannot provide sufficient strength and lateral stiffness. Shear walls are most efficient when tile is aligned vertically and are supported on foundation walls or footing. When exterior shear walls do not provide sufficient strength, other parts of the building need additional strength. The figure 1.2 shows forces acting on a shear wall.

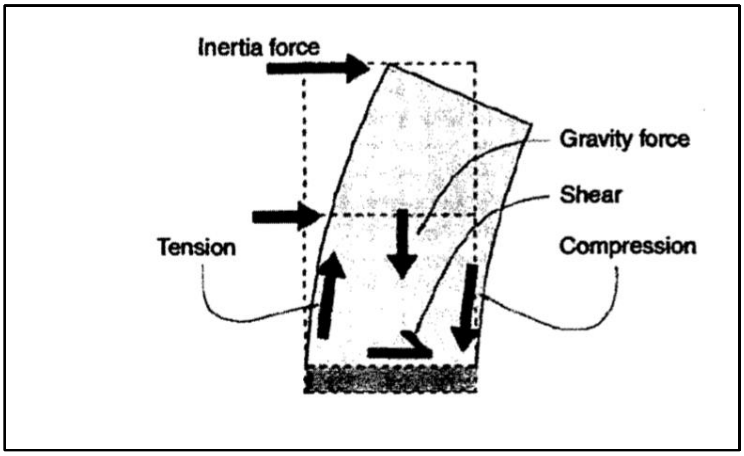


Figure 1.2: Forces Acting on a Shear Wall
(Courtesy: https://civildigital.com**)**

1.6 ARCHITECTURAL ASPECTS OF SHEAR WALL:

Shear walls are usually provided between column lines, in stair wells, lift wells, in shafts that house other utilities. Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads (i.e. those due to self-weight and contents of building). Shear walls provide large strength and lateral stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. Since shear walls carry large horizontal earthquake forces, the overturning effects on them are large. Thus, design of their foundations requires special attention. Shear walls should be provided along preferably both length and width. However, if they are provided along only one direction, a proper grid of beams and columns in the vertical plane (called a moment resistant frame) must be provided along the other direction to resist strong earthquake effects.

Door or window openings can be provided in shear walls, but their size must be small to ensure least interruption to force flow through walls. Moreover, openings should be symmetrically located. Special design checks are required to ensure that the net cross- sectional area of a wall at an opening is sufficient to carry the horizontal earthquake force. Shear walls in buildings must be symmetrically located in plan to reduce ill-effects of twist in buildings. They could be placed symmetrically along one or both directions in plan. In asymmetric buildings, shear walls are more effective when located along exterior perimeter of the building - such a layout increases resistance of the building to twisting.

1.7 SEISMIC DESIGN PHILOSOPHY:

The philosophy of a particular document indicates the general level of protection that it can be expected to provide. Code documents clearly state that their standards are minimum requirements that are meant to provide for high safety but not to insure against damage.

The philosophy of seismic design can be summarized as:

i) The design philosophy adopted in the code IS: 1893 (Part l)-2002, is to ensure that structures possess at least a minimum strength to

a) Withstand minor earthquake (< DBE), which may occur frequently, without damage.

b) Resist moderate earthquake (DBE), without significant structural damage though some non-structural damage may occur.

c) Withstand major earthquake (MCE), without collapse.

Design Basis Earthquake (DBE) is defined as the maximum earthquake that responsibly can be expected to experience at site once during lifetime of the structure. The earthquake corresponding to the ultimate safety requirements is often called as Maximum Considered Earthquake (MCE). Generally, the DBE is half of MCE.

ii) Actual forces that appear on structure during earthquake are much higher than the design forces specified in the codes. The basic criteria of earthquake resistant design should be based on lateral strength as well as deformability and ductility capacity of structure with limited damage but no collapse.

iii) Earthquake generated vertical inertia forces are to be considered in design unless it is not significant. Special attention should be paid to the effect of vertical component of the ground motion on pre-stressed or cantilevered beams, girders and slab.

iv) The response of a structure to ground vibration is a function of the nature of foundation soils; materials, form, size and mode of construction of structures; and duration and characteristics of ground motion. The codes specify design forces for structures standing on rock or firm soils, which do not liquefy or slide due to loss of strength during ground vibrations.

v) The design lateral forces specified in the code IS: 1893 (Part l)-2016, shall be considered in each of the two orthogonal directions of the structure.

1.8 DUCTILE DESIGN OF SHEAR WALLS:

Although this study does not deal with the design of shear wall but reference to the basic code guidelines helps in better understanding the concepts. Just like reinforced concrete (RC) beams and columns, RC shear walls also perform much better if designed to be ductile. Overall geometric proportions of the wall, types and amount of reinforcement, and connection with remaining elements in the building help in improving the ductility of walls. The Indian Standard Ductile Detailing Code for RC members (IS: 13920-1993) provides special design guidelines for ductile detailing of shear walls. Steel reinforcing bars are to be provided in walls in regularly spaced vertical and horizontal grids. The vertical and horizontal reinforcement.in the wall can be placed in one or two parallel layers called curtains. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This reinforcement should be distributed uniformly across the wall cross-section.

1.9 OVERALL GEOMETRY OF SHEAR WALLS:

Shear walls are oblong in cross-section, i.e. one dimension of the cross-section is much larger than the other. While rectangular cross-section is common. L- and C-shape sections are also used figure 1.3. Thin-walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces.

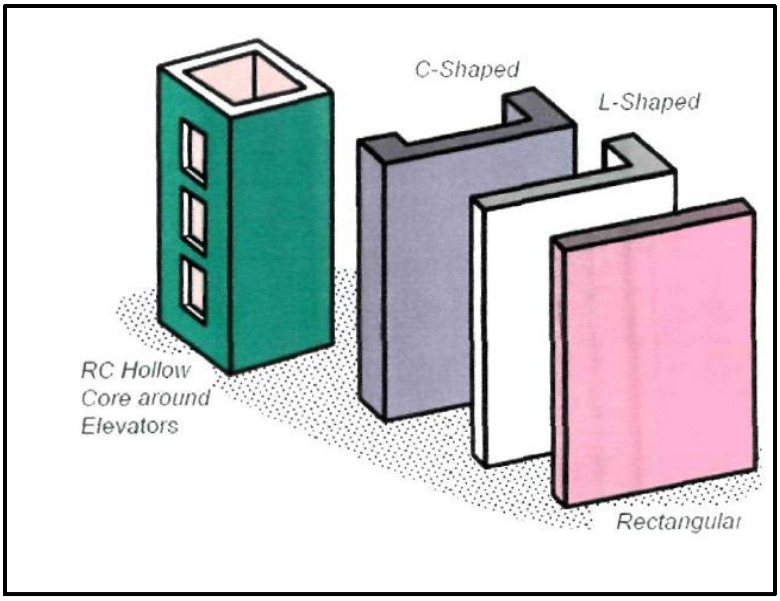


Figure 1.3: Different Geometries of Shear Wall
(Courtesy: https://civildigital.com**)**

CHAPTER TWO
LITERATURE REVIEW

2.1 REVIEW OF LITERATURE:

Abhijeet A. Maske, Nikhil A. Maske, Preeti P. Shiras (2014), Recent earthquakes in which many concrete structures have been severely damaged or collapsed, have indicated the need for evaluating the seismic adequacy of existing buildings. About 60% of the land area of our country is susceptible to damaging levels of seismic hazard. We can't avoid future earthquakes, but preparedness and safe building construction practices can certainly reduce the extent of damage and loss. In order to strengthen and resist the buildings for future earthquakes, some procedures have to be adopted. One of the procedures is the nonlinear static pushover analysis which is becoming a popular tool for seismic performance evaluation of existing and new structures. By conducting this push over analysis, we can know the weak zones in the structure and then we will decide whether the particular part is to be retrofitted or rehabilitated according to the requirement. In the present study the push over analysis is performed on multistoried frame structures by using most common software ETABS (version 14). To achieve this objective, two framed buildings with 5 and 12 stories respectively were analyzed. The results obtained from this study show that properly designed frames will perform well under seismic loads.

E. Pavan Kumar, A. Naresh, M. Nagajyothi, M. Rajasekhar (2014), Earthquake occurred in multistoried building shows that if the structures are not well designed and constructed with and adequate strength it leads to the complete collapse of the structures. To ensure safety against seismic forces of multi-storied building hence, there is need to study of seismic analysis to design earthquake resistance structures. In seismic analysis the response reduction was considered for two cases both Ordinary moments resisting frame and Special moment resisting frame. The main objective this paper is to study the seismic analysis of structure for static and dynamic analysis in ordinary moment resisting frame and special moment resisting frame. Equivalent static analysis and response spectrum analysis are the methods used in structural seismic analysis. We considered the residential building of G+ 15 storied structure for the seismic analysis and it is located in zone II. The total structure was analyzed by computer with using STAAD.PRO software. We observed the response reduction of cases ordinary moment resisting frame and special moment resisting frame values with deflection diagrams in static and dynamic analysis. The special moment of resisting frame structured is good in resisting the seismic loads.

Anil Baral, Dr. SK.Yajdani (2015), Shear walls are incorporated in building to resist lateral Forces and support the gravity loads. RC shear wall has high in plane stiffness. Positioning of shear wall has influence on the overall behavior of the building. For effective and efficient performance of building it is essential to position shear wall in an ideal location. This paper presents the response of building with different positioning of shear wall using both Equivalent Static Method (Seismic Coefficient Method) and Response spectrum Analysis. Five different Model of RCC building, one with no shear wall and other four models with different position of shear wall which is subjected to earthquake load in zone V has been studied .This study also incorporates how the bending moment, shear force for beam and axial Force for column vary with change in positioning of RC shear wall. Building are modeled and analysed using standard package ETABS 2013.

Mr. K. Lova Raju, Dr. K. V. G. D. Balaji (2015), this paper deals with the non-linear analysis of frame for various positions of shear wall in a building frame. In this present study, the focus is to identify effective location of shear wall in multi-storey building. Considering model one is bare frame structural system and other three models are dual type structural system. An earthquake load is applied to a building of eight storey is located in zone II, zone III, zone IV and zone V as per Code Provision IS1893-2002. The analysis has been carried out using ETABS software. Pushover curves have been developed and compared for various models. It has been observed that structure with shear wall at appropriate location is more significant in case of displacement and base shear.

Kasliwal N. A, Rajguru R. S (2016), Tall buildings are the demand of present situation. As the height of structure increases, lateral forces due to wind or seismic become predominant. The major portion of these shall be resisted by the structural elements. Out of different structural systems, moment resisting frames and shear wall frames are two principal structural systems used in reinforced concrete buildings to resist wind and earthquake forces. This paper deals with the Dynamic linear Response spectra method on multi-storey shear wall building with variation in number and position of shear wall. Dynamic responses under prominent earthquake, this paper highlight the accuracy and exactness of shear wall.

Ms. Medini Deshpande, Dr. M.G.Kalyanshetti and Dr. S.A.Halkude (2016), Earthquakes are natural hazards under which disasters are mainly caused by devastating damage due to sudden collapse of buildings mainly occurring due to dynamic actions. A systematic investigation has shown that shear wall structures have performed remarkably well in the most severe earthquakes around the world. Location of the shear wall plays an important role in multistoried building. Therefore, in the present work parametric study has been carried out to study the seismic parameters like roof displacement, storey drift and time period by providing shear walls at various locations in a building frame by changing percentage length of shear walls and by changing number of stories. The study shows that when shear walls are placed equally in both X & in Y-direction, seismic performance is observed to be better than shear walls placed in either X or Y-direction individually. When shear walls are provided in only one direction, structure resist lateral forces in that direction only. Therefore, geometry of the shear wall in both directions should be maintained.

Pardeshi sameer, Prof. N. G. Gore (2016), the current version of the IS: 1893-2002 requires that practically all multi storied buildings be analyzed as three-dimensional systems. Buildings may be considered as asymmetric in plan, in mass and stiffness along storey, of the buildings. Most of the hilly regions of India are highly seismic. In this study, 3D analytical model of G+15 storied buildings have been generated for symmetric and asymmetric building models and analyzed using structural analysis tool ETABS software. Mass and stiffness are two basic parameters to evaluate the dynamic response of a structural system. Multi-storied buildings are behaved differently depending upon the various parameters like mass-stiffness distribution, foundation types and soil conditions. 2001 Bhuj earthquake in Gujrat, India demonstrated the damage and collapse of the buildings due to the irregularities in structural stiffness and floor mass. This paper is concerned with the effects of various vertical irregularities on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) of regular and irregular RC building frames and Time history Analysis (THA) of regular RC building frames and carry out the ductility-based design using IS 13920 corresponding to response spectrum analysis. Comparison of the results of analysis of irregular structures with regular structure is done.

Gaikwad Ujwala Vithal (2017), Shear wall is used in tall buildings as supporting element to resist earthquake loading. In order to enhance the ductility of the structural system the walls are connected together with lateral beams. Many researchers have investigated the behavior of shear walls using different methods. Analytical methods are one of the early techniques used in analysis of shear walls. During an earthquake, damage to building is largely caused by dynamic loads. Therefore, in order to design buildings resistant to earthquake, dynamic characteristics of building must be known. Generally asymmetric tall buildings may consist of any combination of structural forms, such as frames, shear walls, structural cores, and coupled shear walls. Lateral forces caused by wind, earthquake, and uneven settlement loads, in addition to the weight of structure and people living; create torsion in structure. In this study Response Spectrum method is used to analyze horizontally unsymmetrical structure. Aim of this study to decrease torsion using shear wall in structure.

J Tariganetal (2018), Shear wall is one of lateral resisting structure which is used commonly. Shear wall gives high stiffness to the structure so as the structure will be stable. Applying shear wall can effectively reduce the displacement and story-drift of the structure. This will reduce the destruction comes from lateral loads such as an earthquake. Earlier studies showed that shear wall gives different performance based on its position in structures. In this paper, seismic analysis has been performed using response spectrum method for different Model of structures; they are the open frame, the shear wall at core symmetrically, the shear wall at periphery symmetrically, and the shear wall at periphery asymmetrically. The results are observed by comparing the displacement and story-drift. Based on the analysis, the placement of shear wall at the core of structure symmetrically gives the best performance to reduce the displacement and story-drift.

Mr. Madhu sudhan rao.kondapalli (2018), Shear walls are commonly used as vertical structural element for resisting the lateral loads that may be induced by the loads due to wind and earthquake. Besides that, they also carry gravity loads. A well-designed system of shear wall in building frame improves seismic performance significantly. This study aims at comparing various parameters such as storey drift, storey shear and storey displacement of a building under lateral loads based on strategic positioning of shear walls. Linear static analysis has been adopted in this paper.

Moghadam (2019), proposed a procedure to quantify the effects of higher mode responses in tall buildings. A series of pushover analysis is performed on the buildings using elastic mode shapes as load pattern. Maximum seismic responses are estimated by combining the responses from the individual pushover analyses. The proposed combination rule is that response for each mode is multiplied by mass participating factor for the mode considered and contribution of each mode is summed. The procedure was applied to a 20-story steel moment resisting frame to assess the accuracy of the procedure. The frame was subjected to six earthquake ground motions and mean of maximum displacements and inter-story drift ratios of each story of the frame in six analyses were calculated. Also, pushover analyses for first three modes were performed on the frame and the responses for each mode were combined to estimate the final response. Comparison of estimated displacements and inter-story drifts with the mean of maximum responses resulted from six nonlinear dynamic analysis indicated a good correlation.

Dhileep. M (2020), explained the practical difficulties associated with the nonlinear direct numerical integration of the equations of motion leads to the use of nonlinear static pushover analysis of structures. Pushover analysis is getting popular due to its simplicity. High frequency modes and nonlinear effects may play an important role in stiff and irregular structures. The contribution of higher modes in pushover analysis is not fully developed. The behavior of high frequency model responses in nonlinear seismic analysis of structures is not known. In their paper an attempt is made to study the behavior of high frequency model responses in nonlinear seismic analysis of structures. Nonlinear static pushover analysis used as an approximation to nonlinear time history analysis is becoming a standard tool among the engineers, researches and professionals worldwide. High frequency modes may contribute 21 significantly in the seismic analysis of irregular and stiff structures. In order to take the contribution of higher modes structural engineers may include high frequency modes in the nonlinear static pushover analysis. The behavior of high frequency modes in nonlinear static pushover analysis of irregular structures is studied. At high frequencies, the responses of nonlinear dynamic analysis converge to the nonlinear static pushover analysis. Therefore, nonlinear response of high frequency modes can be evaluated using a nonlinear static push over analysis with an implemental force pattern given by their modal mass contribution times zero period acceleration. The higher modes with rigid content as a major contributing factor exhibit a better accuracy in nonlinear pushover analysis of structures when compared to the damped periodic modes.

2.2 OBJECTIVES:

The Major objective of the project is to study the performance of building for different location of shear walls in multiple models. Different models are being made in this study and the decision of selecting a best model is based on the seismic parameters like base shear, storey drift, storey displacement and formation of plastic hinges.

Pushover analysis is commonly used to evaluate the seismic capacity of existing structures and appears in several recent guidelines for retrofit seismic design. It can also be useful for performance-based design of new buildings that rely on ductility or redundancies to resist earthquake forces.

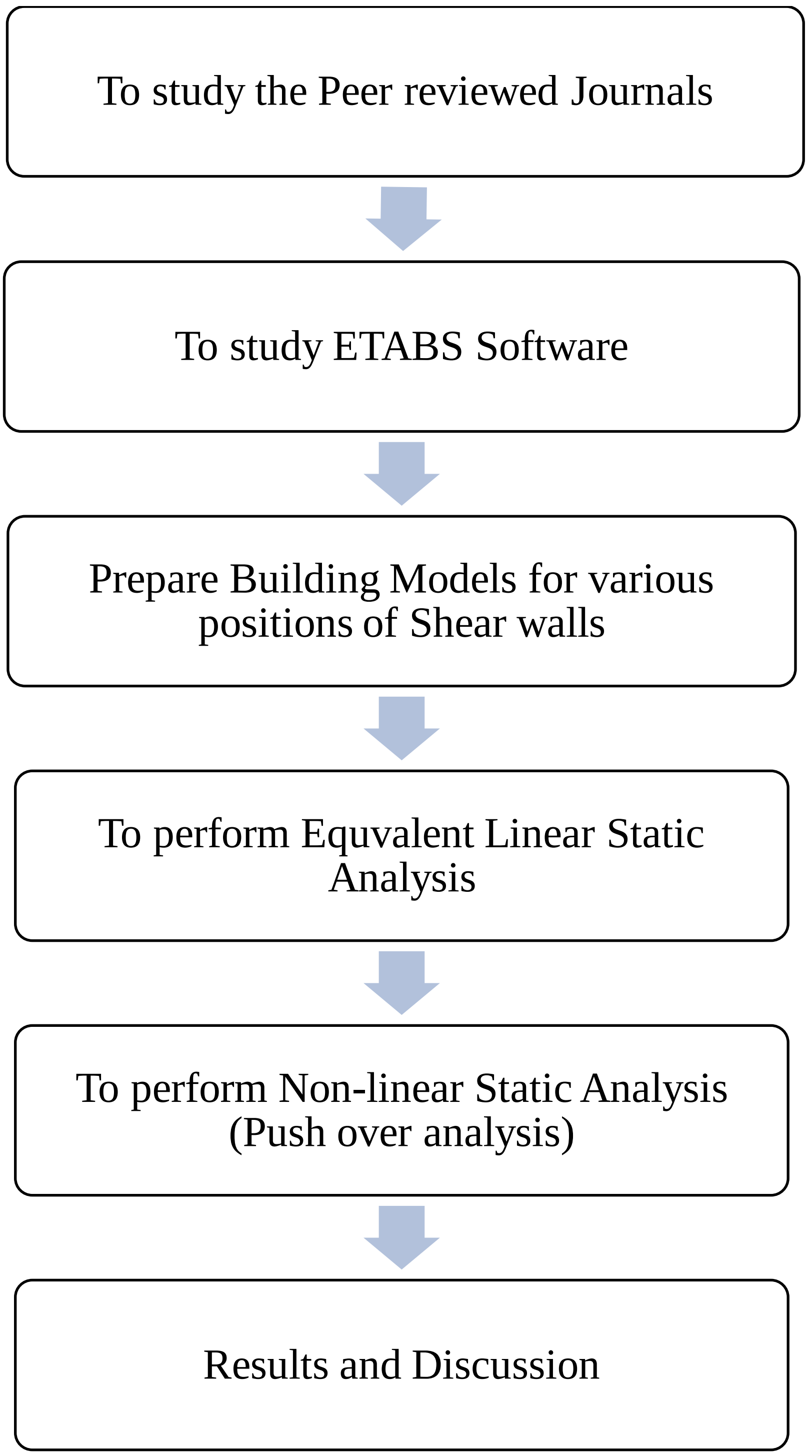
CHAPTER THREE

METHODOLOGY

3.1 PROJECT FLOW CHART

Pushover analysis is a static procedure that uses a simplified nonlinear technique to estimate seismic structural deformations. The table 3.1 shows project flow chart.

Table 3.1: Project Flow Chart



3.1.1 General:

This chapter covers the methodology adopted in the study for the present research work. The present study was carried out to check parameters like lateral displacement, storey drift to find out the effect of location of shear walls on performance of building. Following four types of models have been prepared in the present study and equivalent linear static and non-linear static analysis (push over analysis) has been done on the same.

Model 1: Building without Shear Wall

Model 2: Shear Wall at 3 periphery sides of lift

Model 3: Shear Wall at middle along periphery of structure

Model 4: Shear Wall at Corner along periphery of structure in L shape

3.1.2 Equivalent Linear Static Analysis:

All design against earthquake effects must consider the dynamic nature of the load. However, for simple regular structures analysis by equivalent linear static methods is often sufficient. This is permitted in most codes of practice for regular, low- to medium rise buildings.

In this method of analyzing multi storey buildings recommended in the code, the structure is treated as discrete system having concentrated masses at floor levels which include that weight of columns and walls in any storey should be equally distributed to the floors above and below the storey. In addition, the appropriate amount of imposed load at the floor is also lumped with it. First, the design base shear is computed for the whole building, and then it is distributed along the height of the building. The lateral forces at each floor thus obtained are distributed to individual lateral load resisting elements. It assumes that the building responds in its fundamental mode. For this to be true, the building must be low-rise and must not twist significantly when the around moves. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). The Linear Static Procedure ignores the non-linearity of the structure and the dynamic effect.

3.1.2.1 Seismic Base Shear -

According to IS: 1893 (Part l)-2016, the base shear (V_B) is given by the following formula:

$$V_B = A_h \text{ x } W \text{ (Clause 7.6.1, IS: 1893 (Part l)-2002)}$$

Where,

A_h = Design horizontal acceleration spectrum value using the fundamental natural period T_a in the considered direction of vibration

W = seismic weight of the building

The A_h shall be determined by the following expression

$$A_h = Z\ I\ S_a / 2\ R\ g \quad \text{(Clause 6.4.2, IS: 1893 (Part l)-2002)}$$

where,

Z = Zone factor as per Table 2 of IS: 1893

R = Response Reduction factor

I = Importance factor as per Table 6 of IS: 1893

S_a / g = Average response acceleration coefficient as per Clause 6.4.5 of the Indian standard IS: 1893 (Part l)-2016.

3.1.2.2 Seismic Weight -

The seismic weight of the whole building is the sum of the seismic weights of all the floors. As per (Clause 7.4.1, IS: 1893 (Part l)-2002) the seismic weight of each floor is sum of its full dead load and the appropriate amount of imposed load, the latter being that part of the imposed loads that may reasonably be expected to be attached to the structure at the time of earthquake shaking. It includes the weight of permanent and movable partitions, permanent equipment, a part of the live load, etc. While computing the seismic weight of each floor, the weight of columns and walls in any storey should be equally distributed to the floors above and below the storey. Any weight supported in between storeys should be distributed to the floors above and below in inverse proportion to its distance from the floors. As per IS: 1893 (Part l)-2016, the percentage of imposed load as given in code should be used. For calculating the design seismic forces of the structure, the imposed load on the roof need not be considered.

3.1.2.3 Distribution of Design Force -

Buildings and their elements should be designed and constructed to resist the effects of design lateral force. The design lateral force is first computed for the building as a whole and then distributed to various floor levels. The overall design seismic force thus obtained at each floor level is then distributed to individual lateral load-resisting elements, depending on the floor diaphragm action. Vertical distribution of base shear to different floor levels, the design base shear (V_B) is distributed along the height of the building as per the following expression:

$$\mathrm{Qi} = \mathrm{VB}\ \frac{\mathrm{Wihi2}}{\sum_{j=1}^{n} \mathrm{Wj\ hj2}} \qquad \text{(Clause 7.6.3(a), IS: 1893 (Part 1)-2016)}$$

Where,

Q_i is the design lateral force at floor i,

W_i is the seismic weight of floor i,

h_i, is the height of floor i measured above the base, and

n is the number of storeys in the building i.e., the number of levels at which the masses are located.

3.1.3 Loading Pattern:

Apart from the self-weight, the building is subjected to various type of loading. The major loads acting on the building are:

1. Dead Load (DL): - The dead load, include self-weight of the structure itself, and immovable fixtures such as infill walls, plasterboard or carpet. Dead loads are also known as permanent loads. The dead load of the beams and columns are automatically considered by the model. The loads from the slabs are distributed as triangular or trapezoidal line loads on the supporting beam as per IS 456:2000.

2. Live Load (LL) or Imposed Load (IL): - Live loads, or imposed loads are temporary, of short duration, or moving. These dynamic loads involve considerations such as impact, momentum, vibration, fatigue, etc. Apart from the self-weight, the building is subjected to live loads. The load distribution pattern of the live load from the slabs to the supporting beams is similar as that in case of the DL.

3. Seismic Loading: -Seismic loading is one of the basic concepts of earthquake engineering which means application of an earthquake-generated agitation to the structure. It happens at contact surfaces of a structure either with the ground, or with adjacent structures, or with gravity waves from tsunami. The seismic load is calculated as per the provisions given in IS: 1893 (Part l)-2016.

3.1.4 Load Combinations:

The following Load Combinations have been considered for the design:

1) 1.5(DL±LL)

2) 1.5(DL±EQX)

3) 1.5(DL±EQY)

4) 1.2(DL + LL±EQX)

5) 1.2(DL + LL±EQY)

6) (0.9DL±1.5EQX)

7) (0.9DL±1.5EQY)

Where: -

DL - Dead Load

LL - Live Load

EQX-Earthquake load in X direction

EQY-Earthquake load in Y direction

So, all the responses in the analysis are taken by considering this load combinations.

3.1.5 Computer Software ETABS:

The linear static and non-linear static behavior of the multi-story buildings is the main focus of the study reported in this work. Therefore, computer program with the ability of 00program ETABS has been chosen as the base computer software in performing the analyses. The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. ETABS follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modelling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, ETABS has proven to be the most integrated, productive and practical general-purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of ETABS for all of your analysis and design tasks, including small day-to-day problems.

Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

Advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, catenary cable analysis, material nonlinear analysis with fibre hinges, multi-layered nonlinear shell element, buckling analysis, progressive collapse analysis, energy methods for drift control, velocity-dependent dampers, base isolators, support plasticity and nonlinear segmental construction analysis. Nonlinear analyses can be static and/or time history, with options for FNA nonlinear time history dynamic analysis and direct integration.

From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, ETABS is the easiest, most productive solution for your structural analysis and design needs.

The linear static, linear dynamic and non-linear static behavior of the multi-story buildings is the main focus of the study reported in this work. Therefore, computer program with the ability of performing 3-D linear static, linear dynamic and non-linear static analysis was necessary. The program ETABS 2016 has been chosen as the base computer software in performing the analyses.

The innovative and revolutionary new ETABS is the ultimate integrated software package for the structural analysis and design of buildings. Incorporating 40 years of continuous research and development, this latest ETABS offers unmatched 3D object based modeling and visualization tools, blazingly fast linear and nonlinear analytical power, sophisticated and comprehensive design capabilities for a wide-range of materials, and insightful graphic displays, reports, and schematic drawings that allow users to quickly and easily decipher and understand analysis and design results.

From the start of design conception through the production of schematic drawings, ETABS integrates every aspect of the engineering design process.

3.1.6 Basic Assumptions in Modeling:

The following are the main modeling assumptions used in this study.

Hinged Base: The columns of buildings are assumed to be hinged at their base on rigid foundation. No soil-structure interaction effect is considered in present study.

One Directional Earthquake Input: Only one direction of response values are applied at the junction of columns and floor diaphragms. Due to the fixed base assumption, all supports are assumed to move in phase. No vertical translation is applied to the buildings.

Lumped Mass at Floor Level: The masses and the mass rotational moments of inertia of the building are assumed to be lumped at the floor levels.

Rigid Diaphragm: Each floor has been assigned as rigid diaphragm.

3.2 PUSHOVER ANALYSIS

3.2.1 Pushover Methodology:

A pushover analysis is performed by subjecting a structure to a monotonically increasing pattern of lateral loads, representing the inertial forces which would be experienced by the structure when subjected to ground shaking. Under incrementally increasing loads various structural elements may yield sequentially. Consequently, at each event, the structure experiences a loss in stiffness. Using a pushover analysis, a characteristic non-linear force displacement relationship can be determined. It is necessary for the following considerations:

- Pushover analysis is a nonlinear static analysis used mainly for seismic evaluation of framed building.
- Seismic demands are computed by nonlinear static analysis of the structure, which is subjected to monotonically increasing lateral forces with an invariant height-wise distribution until a target displacement is reached.
- It is also necessary for evaluating the seismic adequacy of existing buildings.

Nonlinear static pushover analysis can provide an insight into the structural aspects, which control performance during severe earthquakes. The analysis provides data on the strength and ductility of the structure, which cannot be obtained by elastic analysis. By pushover analysis, the base shear versus top displacement curve of the structure, usually called capacity curve, is obtained. Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined. The extent of damage experienced by the structure at this target displacement is considered representative of the damage experienced by the building when subjected to design level ground shaking.

3.2.2 General –

The Seismic vulnerability assessment of multistoried buildings will be carried out using pushover analysis. The different methods to be used are as follows:

i. Standard pushover analysis method (FEMA 356)

ii. Capacity spectrum Method (ATC 40)

iii. Modal pushover analysis method.

iv. Non-linear Time history analysis method.

3.2.3 Standard Pushover Analysis -

The pushover analysis consists of the application of gravity loads and a representative lateral load pattern. The lateral loads were applied monotonically in a step-by-step nonlinear static analysis. The applied lateral loads were accelerations in the x direction representing the forces that would be experienced by the structures when subjected to ground shaking. A two- or three-dimensional model diagrams of all lateral force and gravity forces are first created and gravity loads are applied initially. A predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield. The capacity of the structure is represented by the base shear versus roof- displacement graph as shown in Figure 3.1.

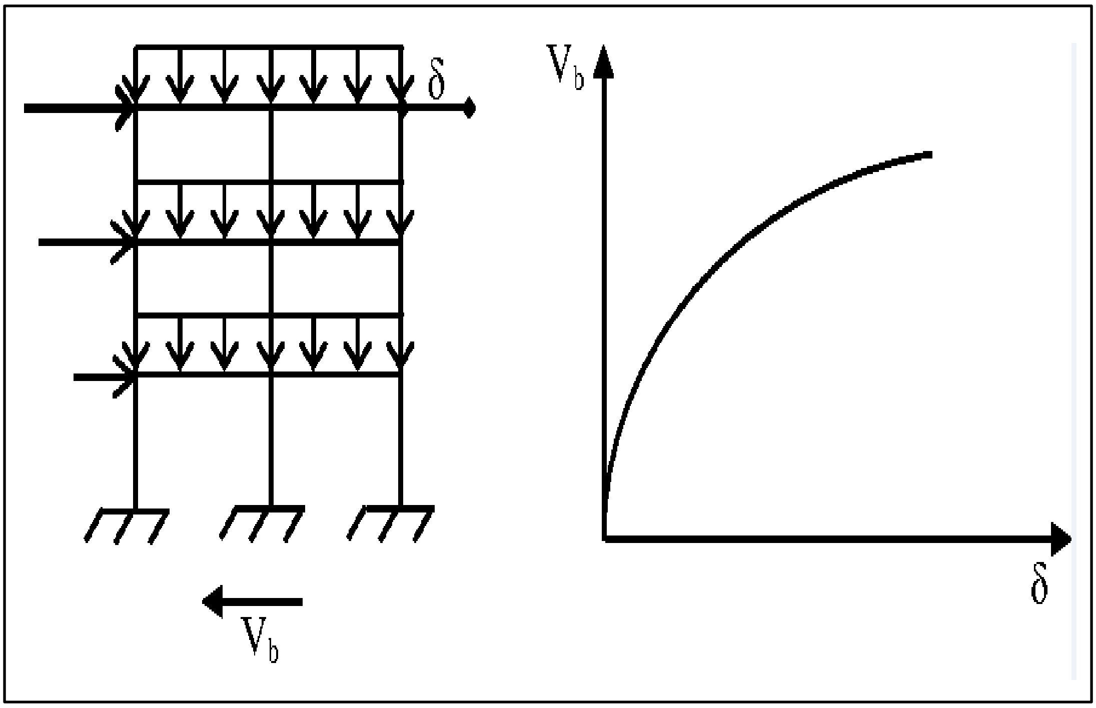


Figure 3.1: Construction of Pushover Curve

3.2.4 Key Elements of Pushover Analysis -

1. Definition of plastic hinges: In ETABS, nonlinear behavior is assumed to occur within a structure at concentrated plastic hinges. The default types include an uncoupled moment hinges, an uncoupled axial hinge, an uncoupled shear hinges and a coupled axial force and biaxial bending moment hinges.

2. 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.

3. 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.

4. Estimation of the displacement demand: This is a difficult step when using pushover analysis. The control is pushed to reach the demand displacement which represents the maximum expected displacement resulting from the earthquake intensity under consideration, which is calculated in Response spectrum analysis.

The main output of a pushover analysis is in terms of response demand versus capacity. If the demand curve intersects the capacity envelope near the elastic range, Fig.3.2 (a), then the structure has a good resistance. If the demand curve intersects the capacity curve with little reserve of strength and deformation capacity, Fig.3.2 (b), then it can be concluded that the structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse. Depending on the weak zones that are obtained in the pushover analysis, we have to decide whether to do perform seismic retrofitting or rehabilitation.

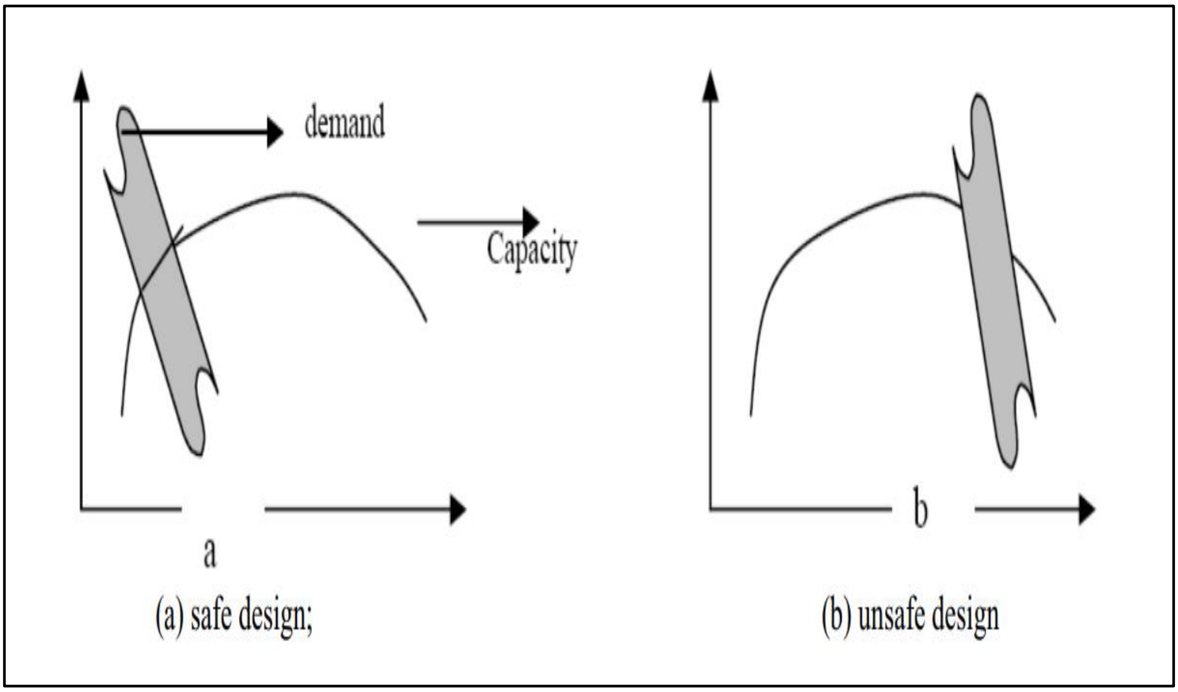


Figure 3.2: Typical seismic demand versus capacity

Under incrementally increasing loads some elements may yield sequentially. Consequently, at each event, the structures experience a stiffness change as shown in Figure 3.3, where IO, LS and CP stand for immediate occupancy, life safety and collapse prevention respectively

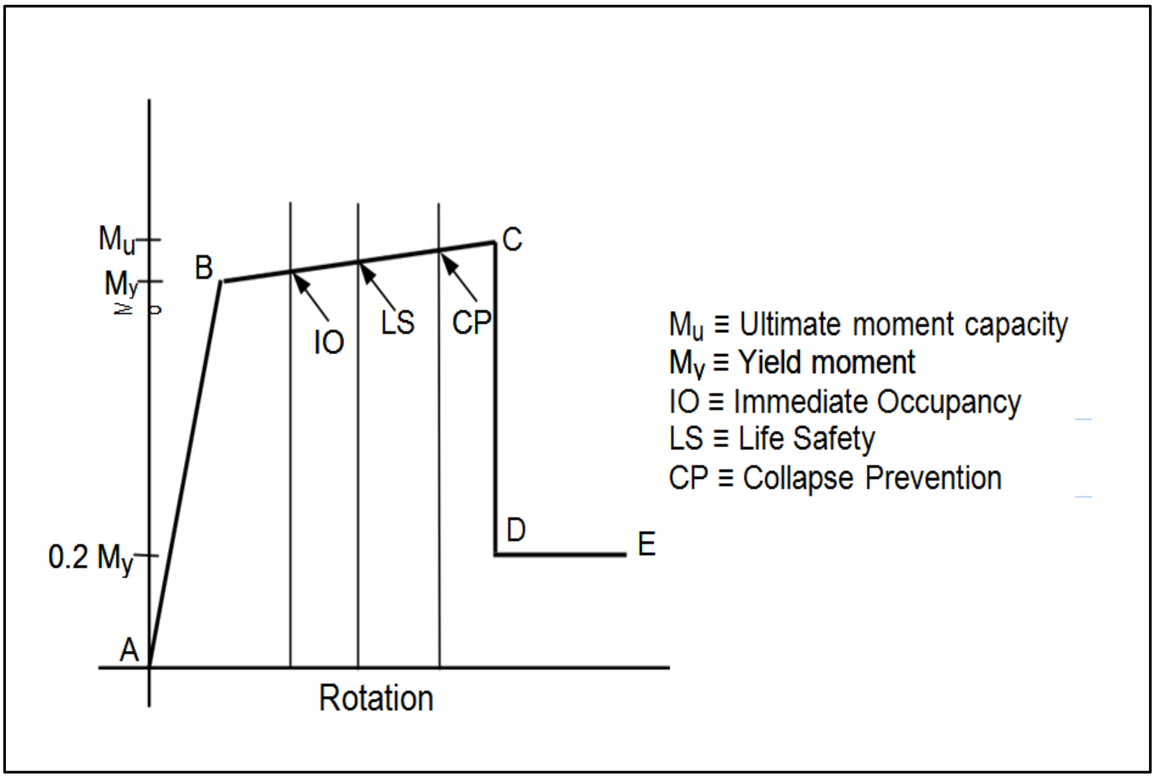


Figure 3.3: Typical moment-rotation relations for plastic hinges

Immediate occupancy IO: damage is relatively limited; the structure retains a significant portion of its original stiffness.

Life safety level LS: substantial damage has occurred to the structure, and it may have lost a significant amount of its original stiffness. However, a substantial margin remains for additional lateral deformation before collapse would occur.

Collapse prevention CP: at this level the building has experienced extreme damage, if laterally deformed beyond this point; the structure can experience instability and collapse

3.3 STRUCTURAL MODELLING

The buildings are modeled and analyzed for static and pushover analyses, using the finite element package ETABS. The analytical models of the buildings include all components that influence the mass, strength and stiffness. The non-structural elements and components that do not significantly influence the building behavior were not modeled. The floor slabs are assumed to act as diaphragms, which ensure integral action of all the vertical lateral load-resisting elements. Beams and columns were modeled as frame elements with the centerlines joined at nodes. Rigid offsets were provided from the nodes to the faces of the columns or beams.

The weight of the slab was distributed to the surrounding beams as per IS 456: 2000, Clause 24.5. The mass of the slab was lumped at the center of mass location at each floor level. This was located at the design eccentricity (based on IS 1893:2002) from the calculated center of stiffness. Design lateral forces at each storey level were applied at the center of mass locations independently in two horizontal directions (*X*- and *Y*- directions).

Staircases and water tanks were not modeled for their stiffness but their masses were considered in the static and dynamic analyses. The design spectrum for medium soil as specified in IS 1893:2002 was used for the analyses. The effect of soil-structure interaction was ignored in the analyses. The columns were assumed to be hinged at the level of the bottom of the base slabs of respective isolated footings the figure 3.4 shows the plan of building used for analysis.

3.3.1 Building Description:

Number of storeys: 10

Type of frame: Special RC moment resisting frame hinged at base.

Floor height: 3.0 m

Slab: S1 (150 mm thick)

Beam: B1 (300 x 550) mm

Cover = 25mm

Column: A) C1 (300 x 600) mm

Cover = 40mm

Longitudinal steel = 12 no's 25mm of Fe500

Transverse steel = 3 legged stirrups of 8mm @ 150mm

B) C2 (300 x 300) mm

Cover = 40mm

Longitudinal steel = 8 no's 25mm of Fe500

Transverse steel = 3 legged stirrups of 8mm @ 150mm

Thickness of masonry wall: 230 mm

Thickness of shear wall: 300 mm

Materials: Slab M 25, Beam and Shear Wall M30, Column M40 concrete,

Rebar: Fe 500 steel Material

Area: 22.57X11.5 = 259.55m^2

Density of concrete: 25 KN/m^3

Density of masonry: 20 KN/m^3

Live load on each floor: 3 KN/m^3

Floor finish: 1.0 KN/m^3

Wall load: 12.42 KN/m^3

Seismic zone: III

Type of soil: Medium

Importance factor: 1

Response reduction factor: 5

Damping of structure: 5 percent

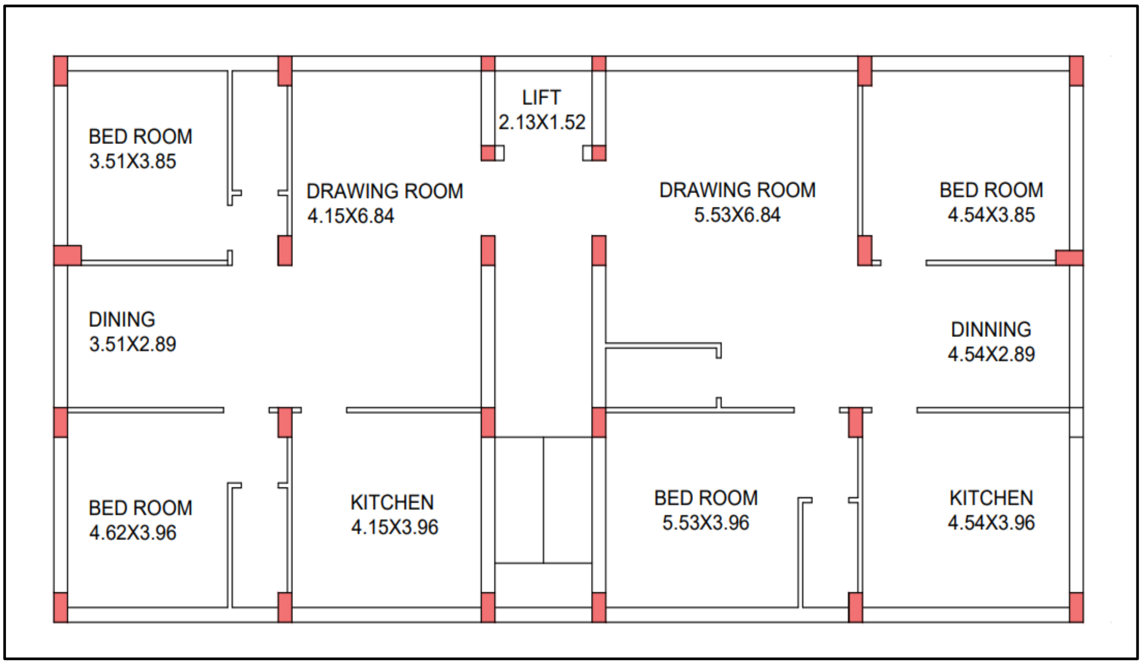


Figure 3.4: Plan of Building

3.3.2 Gravity load calculation

Dead load of members

C1 = 0.6 x 0.3 x 25 = 4.5 KN/m

C2 = 0.3 x 0.3 x 25 = 2.25 KN/m

B = 0.3 x 0.55 x 25 = 4.12 KN/m

Slab (150mm thick) = 25 x 0.150 = 3.75 KN/m^2

Brick wall (230mm thick) = 0.23 x 2.45(wall height) x 20 = 11.27 KN/m

Parapet wall (230 mm thick) = 0.23 x 1 x 20 = 4.6 KN/m

Dead floor finish = 1 KN/m^2

Live Load = 3 KN/m^2

Case 1: Building Without Shear Wall

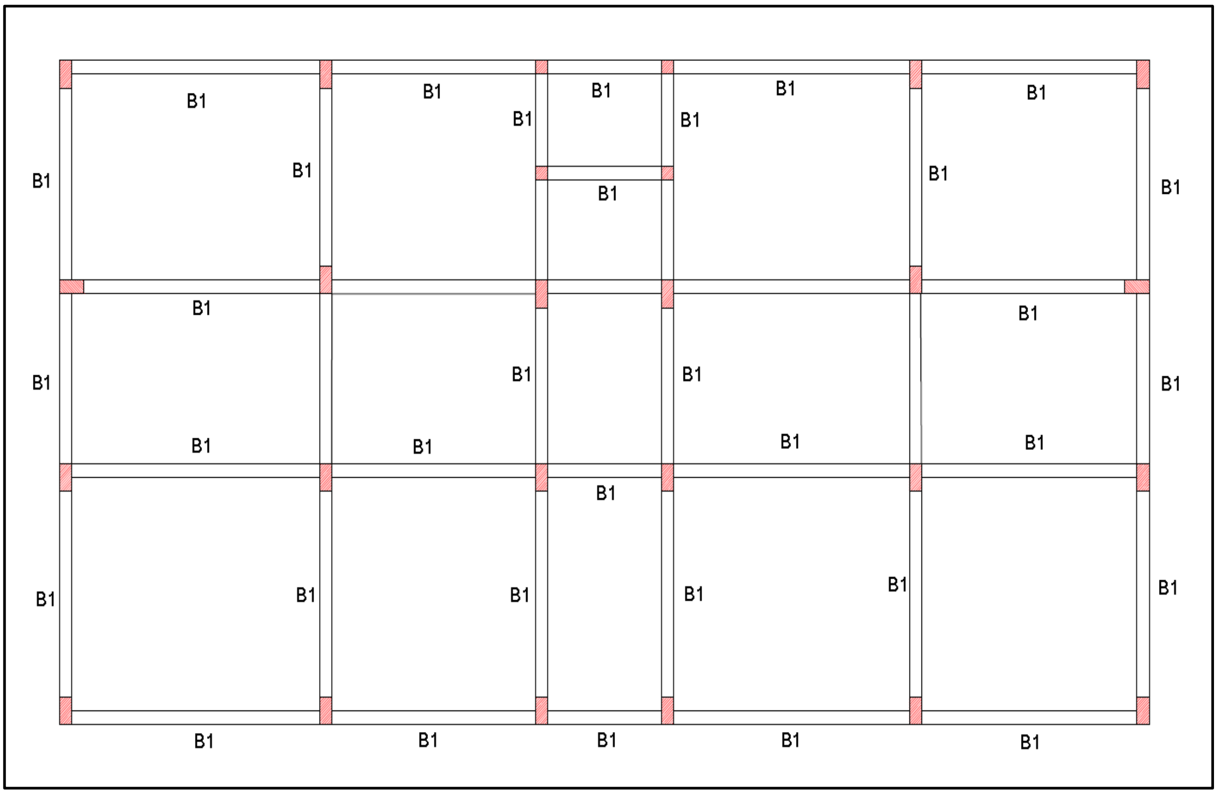


Figure 3.5: Building without Shear Wall in AutoCAD Plan

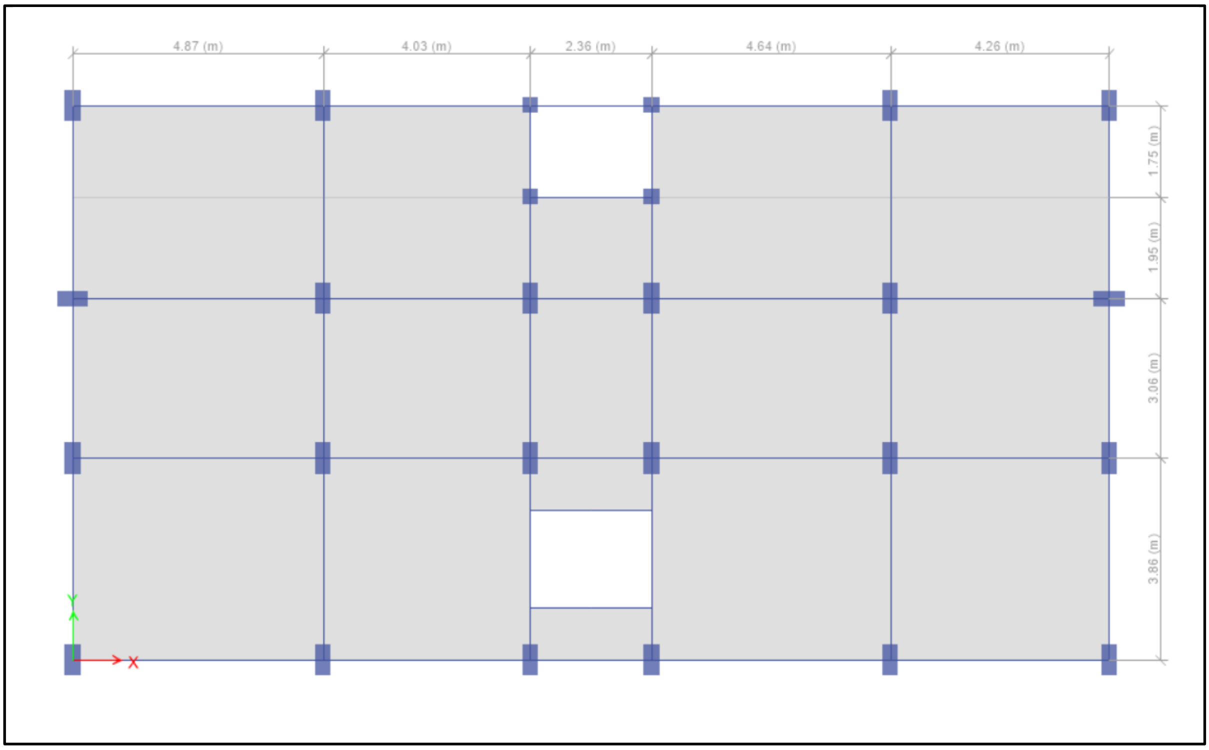


Figure 3.6: Building Without Shear Wall plan in ETABS

Case 2: Shear Wall at 3 periphery sides of lift

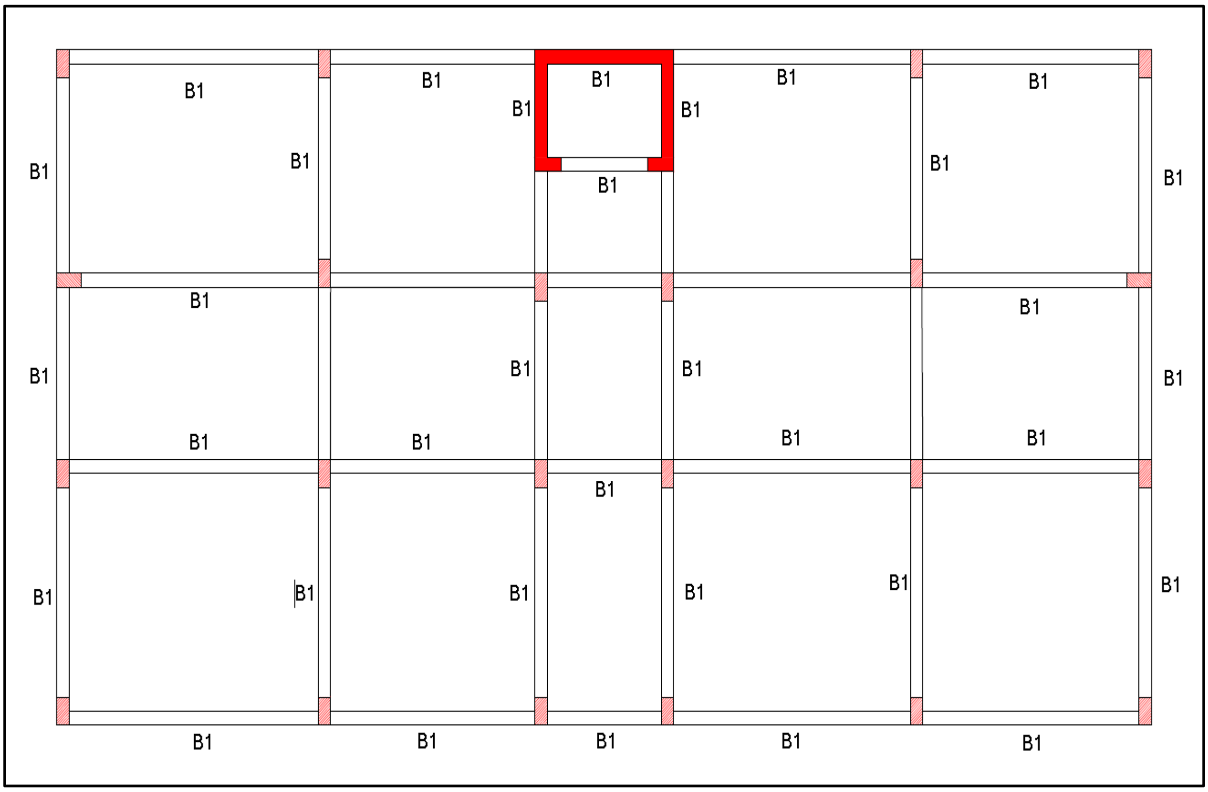


Figure 3.7: Shear Wall at Three periphery sides of lift AutoCAD Plan

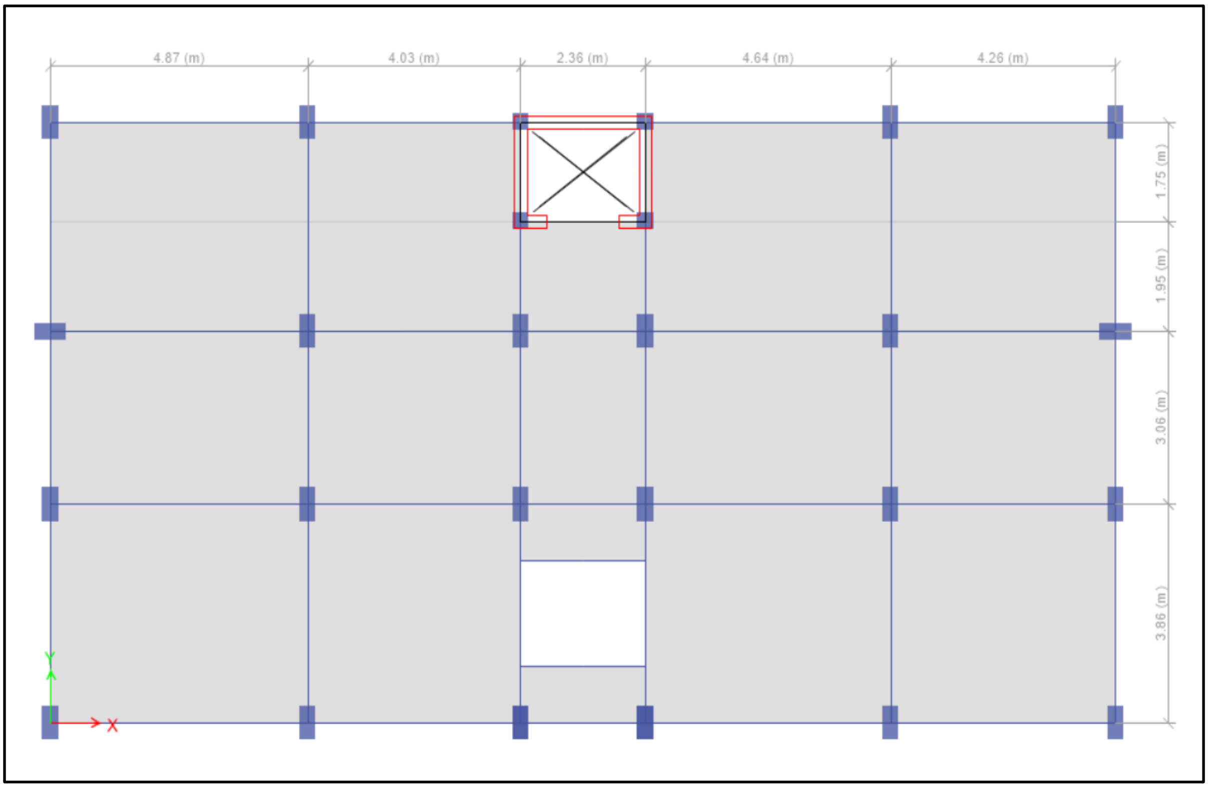


Figure 3.8: Shear Wall at Three periphery sides of lift plan in ETABS

Case 3: Shear Wall at middle along periphery of structure

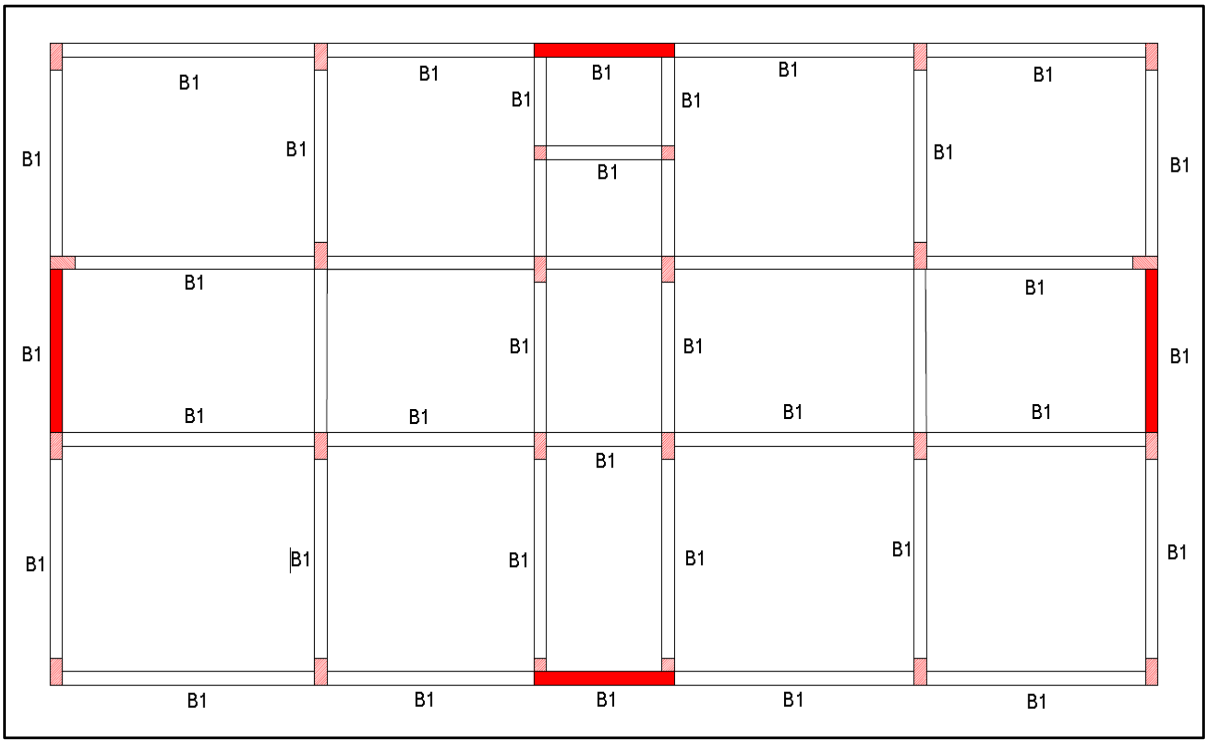


Figure 3.9: Shear Wall at middle along periphery of structure AutoCAD Plan

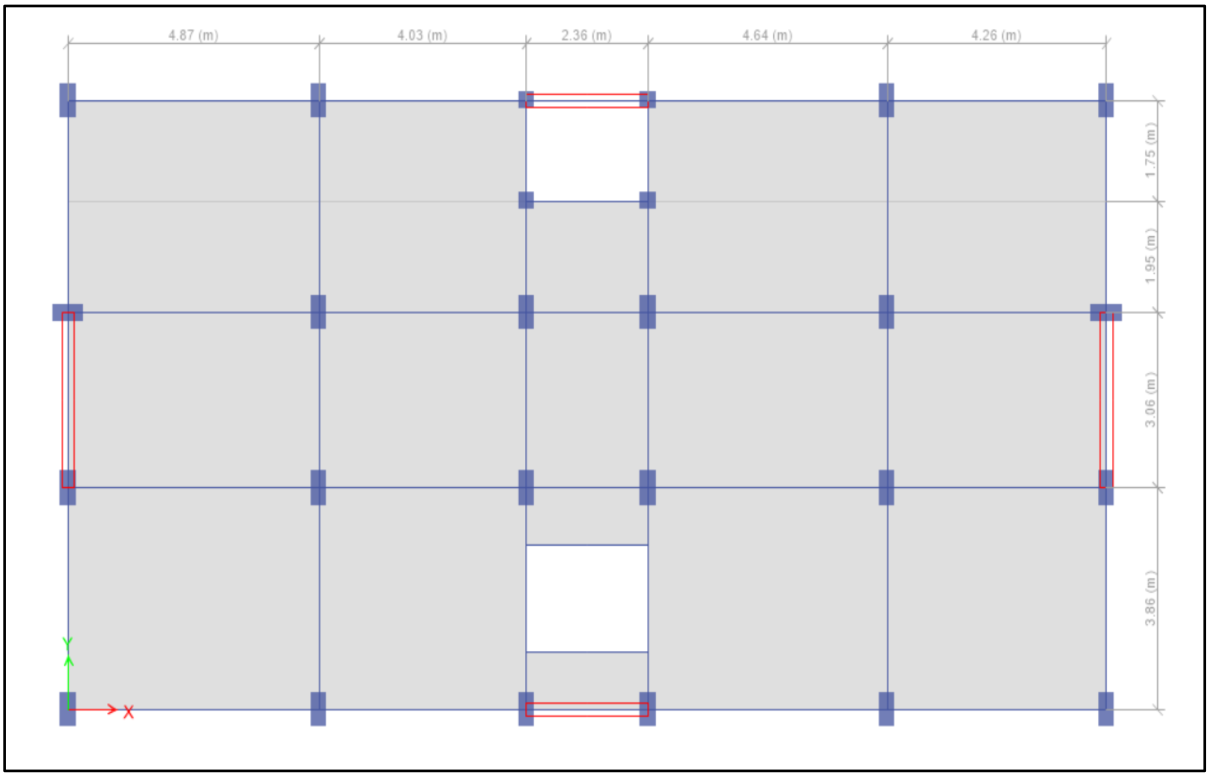


Figure 3.10: Shear Wall at middle along periphery of structure plan in ETABS

Case 4: Shear Wall at Corner along Periphery of Structure in L Shape

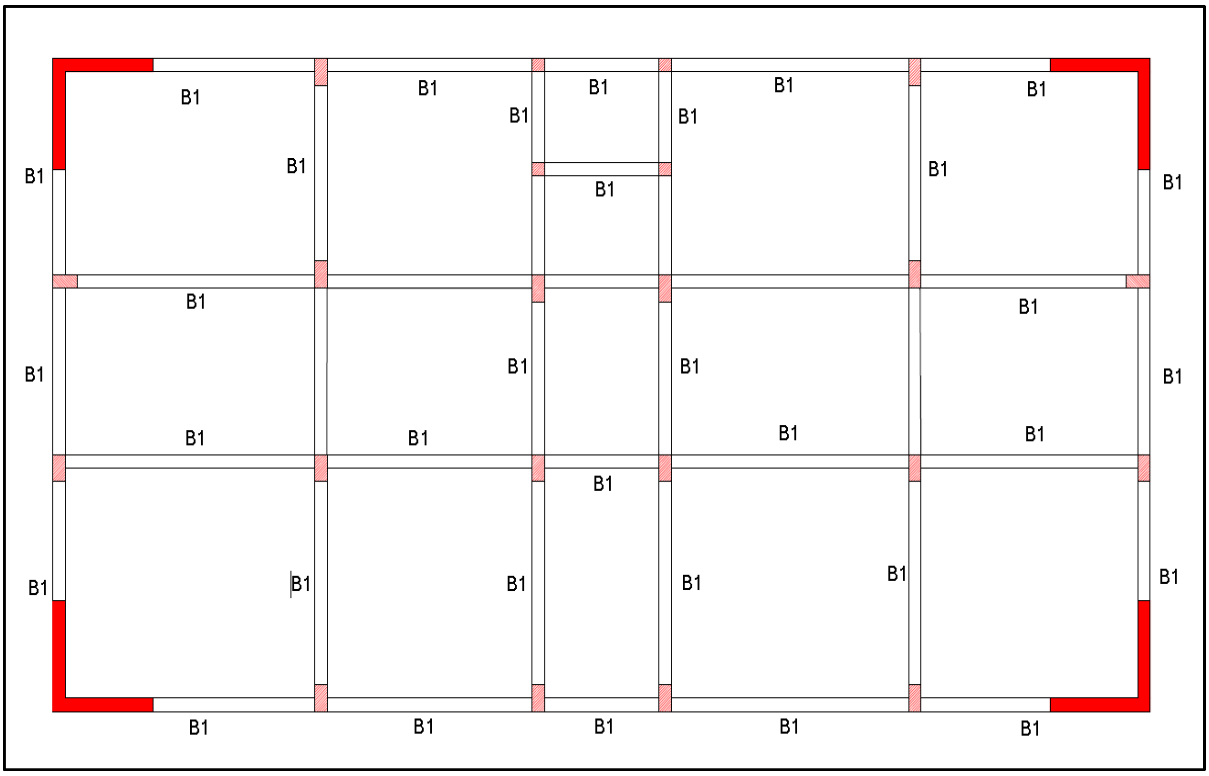


Figure 3.11: Shear Wall at Corner along Periphery of Structure in L Shape plan in AutoCAD

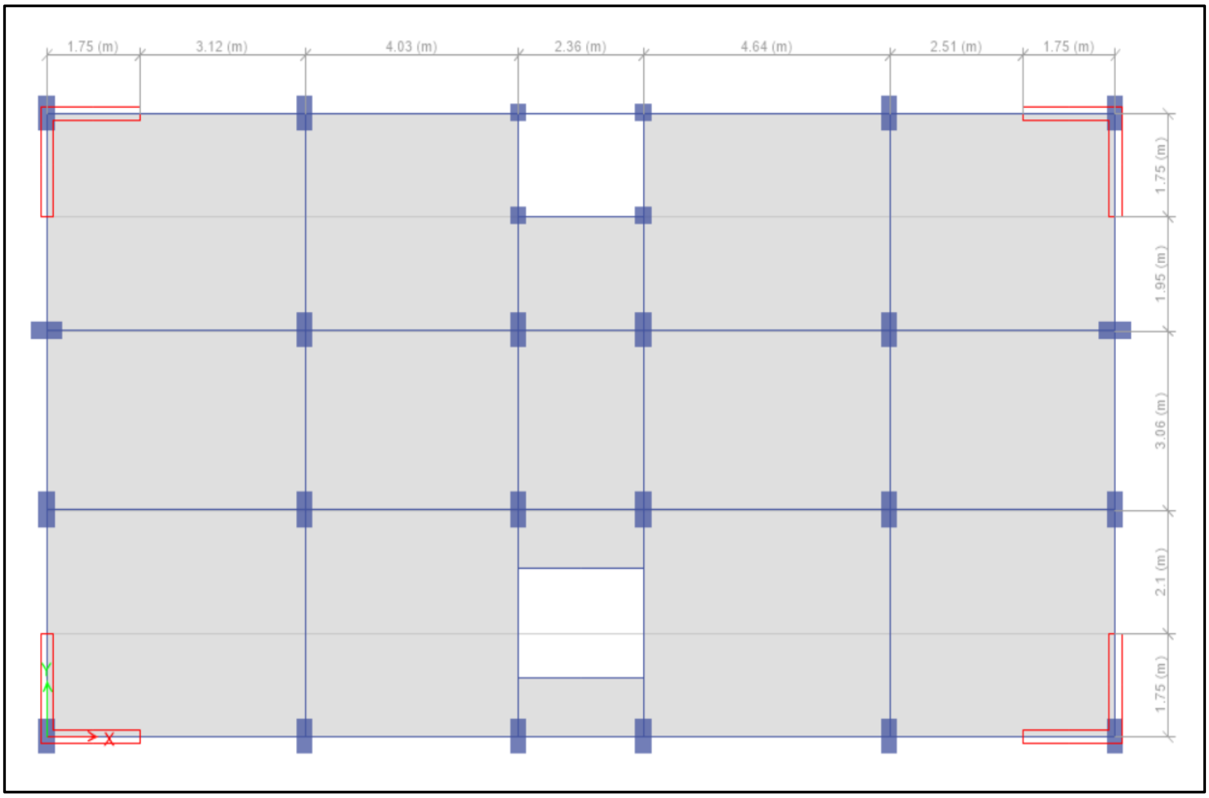


Figure 3.12: Shear Wall at Corner along Periphery of Structure in L Shape plan in ETABS

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 EQUIVALENT STATIC METHOD:

The equivalent static lateral force method is a simplified technique to substitute the effect of dynamic loading of an expected earthquake by a static force distributed laterally on a structure for design purposes. Table 4.1 & 4.2 shows the lateral displacement along X-Direction & Y-Direction.

Table 4.1: Lateral Displacement along X-Direction

Storey No.	Elevation	Lateral Displacement (mm)			
	(m)	CASE 1	CASE 2	CASE 3	CASE 4
10	30	16	16.7	11.5	12.7
9	27	14.9	15.2	10.3	11.5
8	24	13.7	13.5	9.1	10.2
7	21	12.3	11.7	7.7	8.8
6	18	10.9	9.9	6.3	7.2
5	15	9.4	8.1	4.9	5.7
4	12	7.8	6.2	3.5	4.1
3	9	6.2	4.4	2.2	2.7
2	6	4.5	2.8	1.1	1.4
1	3	2.6	1.3	0.4	0.5
Base	0	0	0	0	0

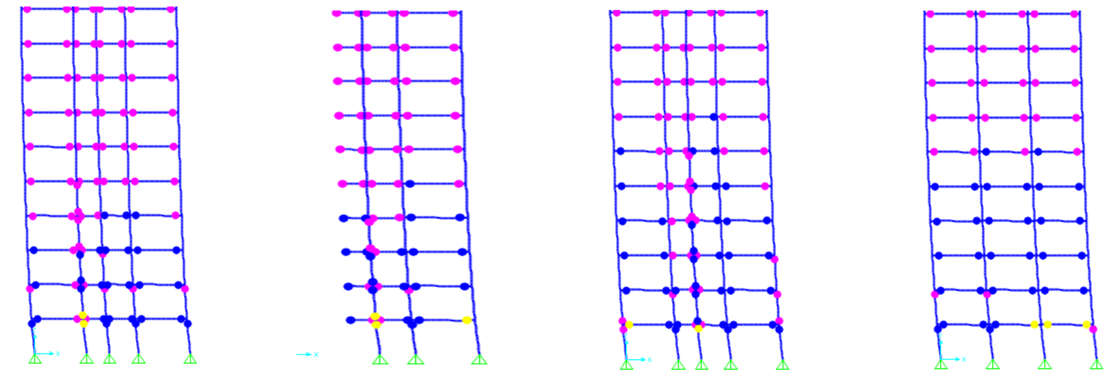
Table 4.2: Lateral Displacement along Y-Direction

Storey No.	Elevation	Lateral Displacement (mm)			
	(m)	CASE 1	CASE 2	CASE 3	CASE 4
10	30	15.6	12.6	12.1	12.5
9	27	14.5	11.2	10.8	11.3
8	24	13.3	9.8	9.5	10.0
7	21	11.9	8.3	8.0	8.6
6	18	10.5	6.8	6.6	7.1
5	15	9.1	5.3	5.1	5.6
4	12	7.5	3.9	3.6	4.1
3	9	6.0	2.6	2.3	2.6
2	6	4.4	1.4	1.2	1.4
1	3	2.6	0.6	0.4	0.4
Base	0	0	0	0	0

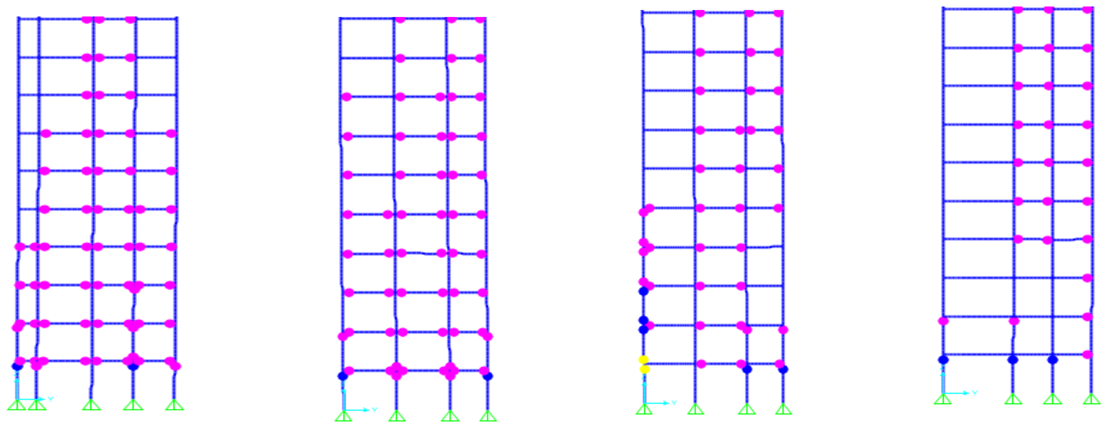
4.2 PUSH OVER ANALYSIS METHOD:

4.2.1 Hinging Mechanism

Two objects connected by an ideal hinge rotate relative to each other about a fixed axis of rotation, with all other translations or rotations prevented; thus, a hinge has one degree of freedom. Hinges may be made of flexible material or moving components. The figure 4.1 shows elevation at different levels or distance.



@ 0m @ 3.85m @ 6.91m @ 10.61m



@ 0m @ 4.87m @ 15.9m @ 20.16m

Figure 4.1: Elevation at different levels or distance

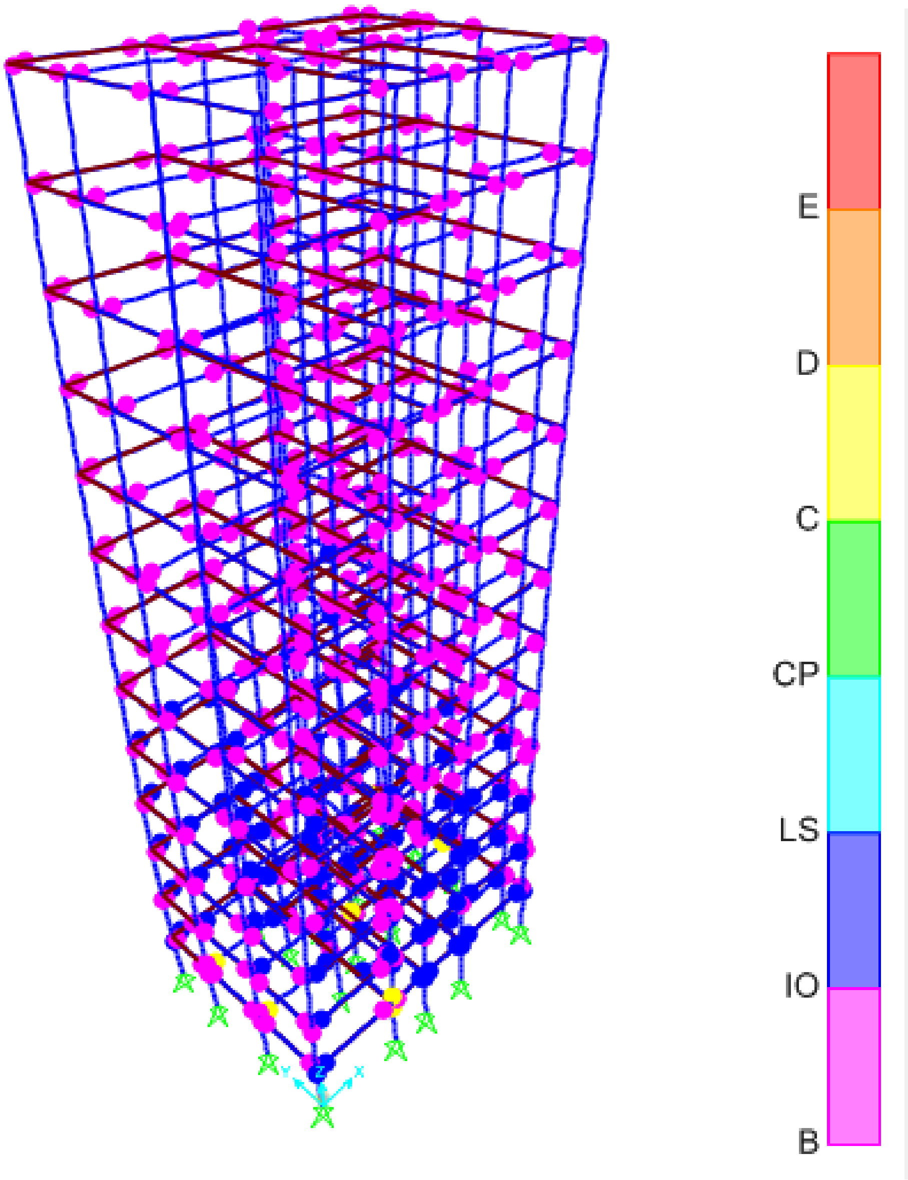


Figure 4.2: Hinges in formation for whole building

It allows structure to move which reduces the reactive stresses. It is sometimes provided to solve the problems created by the additional stresses i.e. by settlement or temperature stresses etc. as shown in figure 4.2.

The Capacity Curve or Pushover Curve represents the nonlinear behavior of the structure and is a load-deformation curve of the base shear force versus the horizontal roof displacement of the building. The table 4.3 & 4.4 shows push-over capacity curve in x-direction & y-direction for case-1

Table No. 4.3: Push-Over Capacity Curve in X-Direction for Case-1

LoadCase	Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUX	0	-0.0012	0	2704	0	0	0	0	0	0	0	2704
PUX	1	-0.0206	269.926	2702	2	0	0	0	0	0	0	2704
PUX	2	-0.2318	1776.51	1864	840	0	0	0	0	0	0	2704
PUX	3	-0.5017	3050.21	1378	1138	184	2	0	2	0	0	2704
PUX	4	-0.6057	3418.02	1278	1148	268	0	0	10	0	0	2704
PUX	5	-0.6071	3420.23	1278	1148	268	0	0	10	0	0	2704
PUX	6	-0.6128	3438.03	1274	1150	264	0	0	16	0	0	2704
PUX	7	-0.6135	3438.22	1274	1150	262	0	0	18	0	0	2704
PUX	8	-0.6208	3460.59	1272	1150	264	0	0	18	0	0	2704
PUX	9	-0.6236	3460.88	1272	1146	268	0	0	18	0	0	2704
PUX	10	-0.6366	3503.9	1260	1150	272	0	0	22	0	0	2704
PUX	11	-0.6381	3497.43	1258	1152	272	0	0	22	0	0	2704
PUX	12	-0.6451	3523.46	1256	1148	272	0	0	28	0	0	2704
PUX	13	-0.6464	3516.91	1256	1148	272	0	0	28	0	0	2704
PUX	14	-0.6528	3539.86	1248	1148	280	0	0	28	0	0	2704

Table No. 4.4: Push-Over Capacity Curve In Y-Direction for Case-1

LoadCase	Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUY	0	0.001291	0	2704	0	0	0	0	0	0	0	2704
PUY	1	-0.019332	233.851	2700	4	0	0	0	0	0	0	2704
PUY	2	-0.069676	591.549	2426	278	0	0	0	0	0	0	2704
PUY	3	-0.250495	1224.341	2056	648	0	0	0	0	0	0	2704
PUY	4	-0.430483	1722.352	1844	804	56	0	0	0	0	0	2704
PUY	5	-0.745479	2403.782	1610	830	264	0	0	0	0	0	2704
PUY	6	-0.914239	2720.526	1522	832	322	0	0	28	0	0	2704
PUY	7	-0.917051	2722.25	1522	832	320	0	0	30	0	0	2704

The Capacity Curve or Pushover Curve represents the nonlinear behavior of the structure and is a load-deformation curve of the base shear force versus the horizontal roof displacement of the building. The table 4.5 & 4.6 shows push-over capacity curve in x-direction & y-direction for case-2

Table No. 4.5: Push-Over Capacity Curve in X-Direction for Case – 2

LoadCase	**Step**	**Displacement**	**BaseForce**	**AtoB**	**BtoIO**	**IOtoLS**	**LStoCP**	**CPtoC**	**CtoD**	**DtoE**	**BeyondE**	**Total**
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUX	0	-0.002393	0	2548	0	0	0	0	0	0	0	2548
PUX	1	-0.019123	362.931	2546	2	0	0	0	0	0	0	2548
PUX	2	-0.055794	1068.971	2360	188	0	0	0	0	0	0	2548
PUX	3	-0.092632	1638.107	2132	416	0	0	0	0	0	0	2548
PUX	4	-0.129646	2132.955	1914	634	0	0	0	0	0	0	2548
PUX	5	-0.177755	2695.811	1746	802	0	0	0	0	0	0	2548
PUX	6	-0.248661	3453.438	1532	1014	2	0	0	0	0	0	2548
PUX	7	-0.291874	3882.258	1434	1104	10	0	0	0	0	0	2548
PUX	8	-0.344241	4358.581	1366	1136	46	0	0	0	0	0	2548
PUX	9	-0.386879	4718.115	1292	1190	66	0	0	0	0	0	2548
PUX	10	-0.436002	5100.1	1252	1182	114	0	0	0	0	0	2548
PUX	11	-0.47863	5405.488	1214	1206	124	0	0	4	0	0	2548
PUX	12	-0.516224	5650.519	1192	1190	160	0	0	6	0	0	2548
PUX	13	-0.542415	5811.424	1170	1192	180	0	0	6	0	0	2548
PUX	14	-0.543431	5814.592	1170	1192	180	0	0	6	0	0	2548

Table No. 4.6: Push-Over Capacity Curve in Y-Direction for case-2

LoadCase	Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUY	0	-0.002431	0	2548	0	0	0	0	0	0	0	2548
PUY	1	-0.018713	336.054	2546	2	0	0	0	0	0	0	2548
PUY	2	-0.056246	918.35	2332	216	0	0	0	0	0	0	2548
PUY	3	-0.093795	1373.128	2216	332	0	0	0	0	0	0	2548
PUY	4	-0.130457	1784.052	2108	440	0	0	0	0	0	0	2548
PUY	5	-0.200248	2484.814	1932	616	0	0	0	0	0	0	2548
PUY	6	-0.271328	3164.26	1750	760	38	0	0	0	0	0	2548
PUY	7	-0.333651	3734.025	1632	832	84	0	0	0	0	0	2548
PUY	8	-0.403948	4353.648	1504	902	142	0	0	0	0	0	2548
PUY	9	-0.473543	4954.097	1396	972	180	0	0	0	0	0	2548
PUY	10	-0.524737	5382.949	1346	988	202	0	0	12	0	0	2548
PUY	11	-0.559316	5665.632	1306	1016	206	0	0	20	0	0	2548

The Capacity Curve or Pushover Curve represents the nonlinear behavior of the structure and is a load-deformation curve of the base shear force versus the horizontal roof displacement of the building. The table 4.7 & 4.8 shows push-over capacity curve in x-direction & y-direction for case-3

Table No. 4.7: Push-Over Capacity Curve in X-Direction for Case - 3

LoadCase	**Step**	**Displacement**	**BaseForce**	**AtoB**	**BtoIO**	**IOtoLS**	**LStoCP**	**CPtoC**	**CtoD**	**DtoE**	**BeyondE**	**Total**
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUX	0	-0.004538	0	2592	0	0	0	0	0	0	0	2592
PUX	1	-0.021602	396.245	2590	2	0	0	0	0	0	0	2592
PUX	2	-0.058442	1101.377	2266	326	0	0	0	0	0	0	2592
PUX	3	-0.096041	1639.082	2046	546	0	0	0	0	0	0	2592
PUX	4	-0.112779	1845.479	1990	602	0	0	0	0	0	0	2592
PUX	5	-0.11341	1847.469	1986	606	0	0	0	0	0	0	2592
PUX	6	-0.150679	2293.827	1856	736	0	0	0	0	0	0	2592
PUX	7	-0.186736	2703.154	1736	852	4	0	0	0	0	0	2592
PUX	8	-0.240319	3291.722	1582	994	16	0	0	0	0	0	2592
PUX	9	-0.2938	3820.128	1486	1038	68	0	0	0	0	0	2592
PUX	10	-0.295038	3819.184	1486	1038	68	0	0	0	0	0	2592
PUX	11	-0.296241	3824.184	1484	1040	68	0	0	0	0	0	2592
PUX	12	-0.305287	3908.27	1474	1042	76	0	0	0	0	0	2592

sTable No. 4.8: Push-Over Capacity Curve in Y-Direction for Case - 3

LoadCase	Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUY	0	0.010291	0	2592	0	0	0	0	0	0	0	2592
PUY	1	-0.008088	319.498	2588	4	0	0	0	0	0	0	2592
PUY	2	-0.044283	830.905	2426	166	0	0	0	0	0	0	2592
PUY	3	-0.080761	1214.776	2292	300	0	0	0	0	0	0	2592
PUY	4	-0.117365	1558.042	2204	388	0	0	0	0	0	0	2592
PUY	5	-0.153879	1867.402	2118	474	0	0	0	0	0	0	2592
PUY	6	-0.209417	2304.436	1994	598	0	0	0	0	0	0	2592
PUY	7	-0.280857	2840.413	1906	666	20	0	0	0	0	0	2592
PUY	8	-0.326834	3173.234	1828	728	36	0	0	0	0	0	2592
PUY	9	-0.366347	3435.447	1782	748	62	0	0	0	0	0	2592
PUY	10	-0.39057	3593.705	1748	766	78	0	0	0	0	0	2592
PUY	11	-0.393072	3603.404	1740	770	82	0	0	0	0	0	2592

The Capacity Curve or Pushover Curve represents the nonlinear behavior of the structure and is a load-deformation curve of the base shear force versus the horizontal roof displacement of the building. The table 4.9 & 4.10 shows push-over capacity curve in x-direction & y-direction for case-4

Table No. 4.9: Push-Over Capacity Curve in X-Direction for Case - 4

LoadCase	**Step**	**Displacement**	**BaseForce**	**AtoB**	**BtoIO**	**IOtoLS**	**LStoCP**	**CPtoC**	**CtoD**	**DtoE**	**BeyondE**	**Total**
Text	Unitless	m	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUX	0	0	0	2640	0	0	0	0	0	0	0	2640
PUX	1	-0.018795	306.975	2638	2	0	0	0	0	0	0	2640
PUX	2	-0.055147	804.313	2426	214	0	0	0	0	0	0	2640
PUX	3	-0.091889	1166.833	2274	366	0	0	0	0	0	0	2640
PUX	4	-0.128731	1494.266	2182	458	0	0	0	0	0	0	2640
PUX	5	-0.174607	1882.814	2084	556	0	0	0	0	0	0	2640
PUX	6	-0.2106	2172.574	2010	622	8	0	0	0	0	0	2640
PUX	7	-0.263461	2573.175	1926	706	8	0	0	0	0	0	2640
PUX	8	-0.333457	3068.993	1816	798	26	0	0	0	0	0	2640
PUX	9	-0.372406	3322.982	1748	830	62	0	0	0	0	0	2640
PUX	10	-0.419612	3607.344	1700	834	106	0	0	0	0	0	2640
PUX	11	-0.453548	3794.61	1662	850	128	0	0	0	0	0	2640

Table No. 4.10: Push-Over Capacity Curve in Y-Direction for Case - 4

LoadCase	Step	Displacement	BaseForce	AtoB	BtoIO	IOtoLS	LStoCP	CPtoC	CtoD	DtoE	BeyondE	Total
Text	Unitless	M	KN	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless	Unitless
PUY	0	0.00158	0	2640	0	0	0	0	0	0	0	2640
PUY	1	0.003176	271.308	2638	2	0	0	0	0	0	0	2640
PUY	2	0.005783	655.14	2454	186	0	0	0	0	0	0	2640
PUY	3	0.031384	3010.288	1914	612	112	0	0	2	0	0	2640
PUY	4	0.032822	3091.01	1902	600	136	0	0	2	0	0	2640
PUY	5	0.033237	3167.473	1896	594	148	0	0	2	0	0	2640
PUY	6	0.036338	3423.982	1860	580	198	0	0	2	0	0	2640
PUY	7	0.036341	3427.597	1858	580	200	0	0	2	0	0	2640
PUY	8	0.039368	3611.26	1820	592	224	0	0	4	0	0	2640
PUY	9	0.039848	3666.608	1808	600	228	0	0	4	0	0	2640
PUY	10	0.03987	3667.702	1808	598	230	0	0	4	0	0	2640
PUY	11	0.039877	3678.861	1806	598	232	0	0	4	0	0	2640
PUY	12	0.048044	4129.415	1732	624	278	0	0	6	0	0	2640

CHAPTER FIVE

CONCLUSION

- The performance of reinforced concrete frames was investigated using the pushover Analysis. Based on the above results and observations the following conclusions are drawn.

1. The frame is modeled with default and user-defined hinges properties to study the possible differences in the results of pushover analysis.

2. From table 4.1 and 4.2, the lateral displacement in X- and Y-Direction for different cases we get, a significant variation is observed. Case 3 gives minimum lateral displacements in both X and Y direction.

3. Comparison of all four cases with respect to hinge formation from table no. 4.3 to 4.10, were as follows.

Case-1	The number of hinges formed in C to D region in X-Direction are 220 & Y- Direction are 58.
Case-2	The number of hinges formed in C to D region are in X-Direction are 22 & Y- Direction are 32.
Case-3	There are no hinges formed after life safety level.
Case-4	The number of hinges formed in C to D region are in X-Direction no hinges formed & Y- Direction are 32.

4. In above comparison the case 3 were no hinges are formed after life safety level. So, case 3 is more safe structure as compared to other three cases.

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Course Outcomes (COs)	
Students will able to:	
BTCEP803.1	Understand the fundamental principles of concrete: Students should develop a solid understanding of the basic properties, composition, and behavior of concrete, including its strength, durability, and workability.
BTCEP803.2	Demonstrate proficiency in concrete testing and quality control: Students should be able to perform various tests on fresh and hardened concrete to assess its quality, including slump tests, compressive strength tests, and air content tests. They should understand the significance of these tests and be able to interpret the results to ensure the concrete meets the specified standards.
BTCEP803.3	Apply design principles to structural concrete elements: Students should learn how to analyze and design structural concrete elements such as beams, columns, and slabs. They should be able to calculate the required reinforcement, consider loadings and design criteria, and apply relevant design codes and standards to ensure the structural integrity and safety of the concrete elements.
BTCEP803.4	Execute concrete construction techniques and practices: Students should gain hands-on experience in executing concrete construction techniques, including formwork assembly, concrete placement, compaction, and finishing. They should understand the importance of proper construction practices, such as curing and temperature control, to achieve desired concrete performance and minimize potential defects.
BTCEP803.5	Identify and mitigate common concrete-related challenges: Students should be able to identify and troubleshoot common issues that can arise during concrete construction, such as cracking, segregation, and inadequate curing. They should develop problem-solving skills to propose appropriate solutions and preventive measures to address these challenges effectively.
BTCEP803.6	Demonstrate the Knowledge, Skills and Attitudes of a professional engineer.

Sr. No.	Program Outcomes (POs)
1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Course Outcomes (COs)	Program Outcomes POS)											
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
BTCEP803.1												
BTCEP803.2												
BTCEO803.3	3	3	3	3	3	3	2		1	2	2	2
BTCEP803.4	3	3	2	3	3	3	2		2	2	1	2
BTCEP803.5	2	3	3	2	3	3	3		2	1	2	2
BTCEP803.6	3	2	3	3	2	3	3		1	2	1	2