PERFORMANCE OF DIFFERENT TYPES OF BUILDINGS IN SEISMIC ZONES OF INDIA

A DISSERTATION

SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

STRUCTURAL ENGINEERING

Submitted by

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Candidate's Declaration

I hereby certify that the work which is presented in the Major Project- II entitled "Performance of Different Types of Buildings in Seismic Zones of India" in fulfilment of the requirement for the award of the Degree of Master of Technology in Structural Engineering and submitted to the Department of Civil Engineering, Delhi Technological University, Delhi is an authentic record of my own, carried out during a period from August 2019 to August 2020, under the supervision of Dr. Shilpa Pal. The matter presented in this report has not been submitted by me for the award of any other degree of this or any other University.

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Certificate

I hereby certify that the Project Dissertation titled "Performance of Different Types of Building in Seismic Zones of India", which is submitted by Sonya Singh, Roll no. 2K18/STE/21 Civil Engineering Department, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Shilpa Pal

Place: Delhi
Date: 03/09/2020

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Acknowledgement

Every project work requires the motivation and assistance of fellow colleagues. Unexceptionally For this case also. I would like to extend my sincere obligation and gratitude towards all my fellow people who directly or indirectly help me in completing this work. I would not have come so long without their active guidance, encouragement, and cooperation in this project. I am deeply grateful to **Dr. Shilpa Pal** for diligent guidance and motivation to complete this thesis. I take the privilege to extend my hearty thanks to the Head of Department of Civil Engineering, **Dr. Nirendra Dev** for his support and encouragement towards the project. Also I am deeply indebted to my parents, who act as fuel power in supporting us in every situation in physical as well as in mental way they made it possible to complete this research work. I also expresses my regards to Ministry of Human Resources and Development (MHRD), Govt. of India who have provided me post graduate scholarship through the academic session to carry out this assignment. I extend my gratitude to **Delhi Technological University** for giving me this opportunity. Last but not the least I want to thanks my friends who had helped me directly or indirectly in completing my thesis. Any inadvertence in this brief acknowledgement does not mean lack of gratitude.

SONYA SINGH

Abstract

Nonlinear analysis is mostly used for the predicting accurate result in case of moderate to extreme earthquake conditions. In this report, Seismic analysis of a building, located in different zones, is done to predict the behaviour with infill wall, bracing and shear wall. The building is located in different Indian zones from zone II to zone V and they are all identical in geometric properties. Evaluation is being carried out using Etabs. The performance and capacity of nine storeyed building model under seismic loading in all zones, is evaluated in medium stiff soil. The load displacement relationship, formation of sequential hinges, and the inelastic response of the structure are being evaluated. The actual behaviour of the structure out by the plastic hinge formation. Analysis shows that when zone changes from II to V, the time period, displacement and base shear increases gradually which indicates the sternness of the seismic activity. The first hinges were seen in beams and then in columns at the lower floor portions. It then finally goes from ground floors to middle floor and then to the upper floor columns. The hinge propagation from ground storey to upper stories leads to structure collapse. This analysis gives an estimate that higher magnitude seismic loading can cause damage much beyond the elastic limit and ultimately lead to failure of the structural frame model. Conclusion is that destruction is limited in a building and after analysing the structure the suitable retrofitting measures can be adopted based on the requirement of building.

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List of Abbreviations

SDOF	Single degree of freedom
MDOF	Multi degree of freedom
LS	Life Safety
IO	Immediate Occupancy
CP	Collapse prevention
IS	Indian standard
RC	Reinforced Concrete
Fy	Yield strength of steel
Fck	Characteristic strength of concrete
ADRS	Acceleration displacement response spectrum
Z	Seismic Zone factor
Sa	Spectral acceleration
G	Acceleration due to gravity
Ah	Seismic coefficient
I	Importance factor
R	Response reduction factor
Sd	Spectral displacement

CHAPTER 1-INTRODUCTION

1.1 General

The concept of seismic analysis need a brief explanation. In this static non-linear analysis shows the deformation pattern when the structure is subjected to incremental lateral load and fixed vertical loads. The Critical points or premature failure is denoted by means of graph between base shear and displacement (generally roof top). This analysis helps to identify the members that reaches yield or else has undergone minor cracks or damage. The graph between base shear and the inter storey drift is also produced. The analysis procedure is done for the structure subjected to incremental lateral loads monotonically which enables all the inertia force that the structure experiences under the earthquake. Most of the structures experiences sequential yielding when they are subjected to this incremental increased load. Thus, at every point, the reduction in stiffness is encountered by the structure. Pushover analysis enables the user to obtain the force displacement behaviour.

1.2 The Background

For the last two decades, pushover analysis is gaining significant amount of attention for the design of building and evaluation of seismic performance due to its simplicity and the statistics consideration of post elastic stage. There are also some approximations as well as simplifications in this technique which leads to exist certain probable amount of variations in the pushover analysis prediction seismic demand. By this analysis, response characteristics are determined but, but accuracy and reliability have been the most talked topic and also improved pushover analysis procedures have been recommended to get improvement over conventional pushover methods limits. Though, usage of these improved techniques in engineering profession, it is absolutely impractical because they are theoretically complex and computationally hard.

Hence, for the design and estimation of seismic behaviour, traditional method of pushover analysis is used and hence estimation is made for predicting accuracy, limitations and weakness and the limitations in the routine procedure by studying all the factors predicted by pushover analysis prediction. To be precise, this analysis application for seismic demands calculations is especially studied for the low rise, mid-rise and the high-rise building with recognition of some concerns such as nonlinear member behaviour modelling, differences in prediction of various lateral load patterns mainly in conventional method, efficiency in demonstrating higher mode effects of these invariant lateral load patterns, Computational scheme of the technique and accurate assessment of the target displacement wherever the prediction for seismic demand of structure by pushover analysis implemented.

1.3 Seismic analysis: The concept

Earthquake resistance building and earthquake proof building is practically not possible reason being a building is design and constructed and built, the magnitude of earthquake considered while designing is 5.9, and building can be resisted up-to magnitude of 5.9. But the concept of earthquake proof building states that zero damage will occur up-to when the design value is reached, but practically it is not possible. There present some minor damages that happen in the building so the concept is not practically acceptable. Coming to the earthquake resisting building, the buildings constructed in earthquake prone zones are earthquake resisting building. Efforts are made to provide provisions to maximize the resistivity due to which minimum damage is seen to the life as well as property.

The provisions, criteria, fulfilment for earthquake resisting building are given in IS Code. The new 6th revised edition is IS 1893:2016.This include the earthquake design procedure, regulations, Guidelines.

As per Indian standard code, Earthquake is divided into five zones. There are specific reasons and basis for the categorization of these zones. Zone 1 includes minor damages or reparable damage.

Zone 2 include severe damages to that of in zone 1.Zone 3 include moderate damage and zone 4 include high damage and zone 5 include highest damage. These zone are statewise.

Pushover calculates the structural deformation when the seismic activity occurs. It checks the capacity of the building, how much resistant it can offered in the prevailing conditions. And the vital thing is that how much it will be able to regain the displacement, if it does not comes to the original position, it will create problem, building gets deformed. To sustain its ductility, Pushover analysis is done. In Pushover analysis, hinges are provided as a precautionary measures. Plastic Hinges are provided at the corners overcoming the direct influence of earthquake in the horizontal and vertical frame elements i.e. beams and columns. It helps in the reduction of the chances of deformation as well as it helps in recovering the existed deformation by suitable methods such as retrofitting method.

These all analysis are done in order to make buildings safe since it is the only cause which comes suddenly and its very important to keep building safe from this activity and very difficult also.

The map describes the location of each zones. The building design should be according to this map only. There is a requirement of the location in which the building is to be located or existed. According to which, the design procedure is followed.

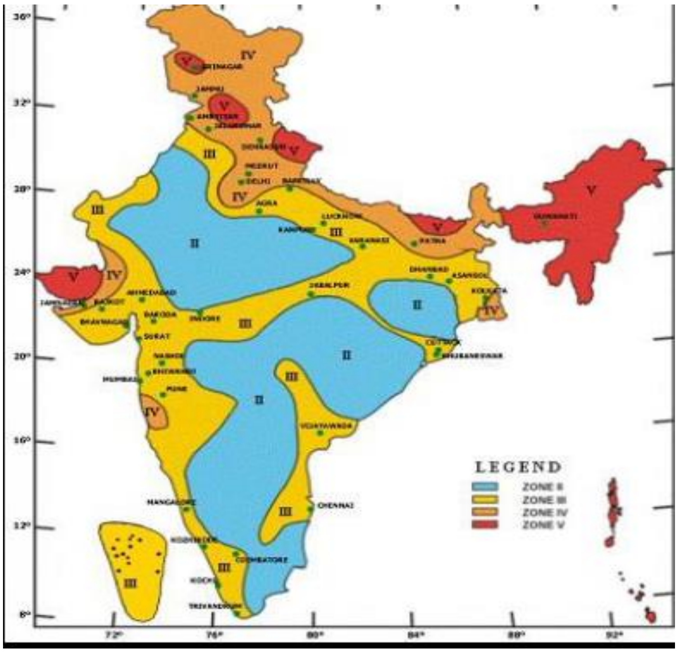

Figure 1.1 Seismic Zones of India

1.3.1 Methods available for seismic analysis

Analysis is done by two method static analysis and dynamic analysis. Deformation in both the direction is checked in static analysis while in dynamic analysis damage is checked in modes.

The effects of twisting on the building which is given term as modes. Number of modes depend on the size of the building.

Background history of the structure are required for the evaluation of qualitative techniques along with the availability of construction site, that implies certain physical requirements of site investigation report, structural drawing along with the behaviour in the past, of the same building under earthquake with some test results non-destructive mainly. Analytical or Systematic methods aimed at the predictions are centred for concern for the strength and ductility of the building on the basis of drawings available at the present.

It’s basically an estimated analysis procedure in which building is subjected to varying incremental increased lateral forces, with respect to the building height until we get our sequential yielding or target displacement. This method determines the accurate damage sequence of the building, all these parameters are superimposed for the generation of force-displacement plot of building.

The plotting of force displacement curve of the horizontal forces is done for the two or three dimension model along with the application of gravity loads. Now the application of increased force with varying height is done. Before the yielding of members take place, lateral forces has to be altered accounting deterioration in the stiffness of the generated structural elements. Horizontal force is made to increase again until yielding of additional members take place. These steps are been on repeating mode until the maximum target displacement is surpassed, the roof of the building attains a particular deformation until structure is finally unstable. Now obtained graph between storey shear and displacement for getting the demand and capacity curve is ready.

The displacement controlled and force controlled are the two ways to do the pushover analysis. When the load is predetermined or well-known, force controlled is used, it also includes some minor errors that disturbs the preciseness of results as this target displacement can be linked to minor on other hand an unwanted lateral stiffness due to the formation of hinges and subsequent P-delta effects. This method is recommended by various major rehabilitations owing to its simplification procedure.

Detection of yielding sequence of each members and the member failure on structural level and the generation of the capacity curves of the Building. This static process is mostly useful in seismic design of building with low to medium-rise height. Also, estimation of design forces by elastic spectrum obtained by means of a particular response modification factor which indicates the in-elastic behaviour of the model with specifying unknown strength and ductility of the structures in the inelastic analysis. The coefficient of ductility indicates the inelastic deformation capacity of the structures. Energy absorption follows the direct relationship with the ductility coefficient, the increase in the value of which leads to extension of plastic joints. Accordingly, it is important to get accurate elastic points determination with ultimate displacements. Seismic demands of the structure are evaluated using some failure gauges. The target displacement is defined as the max drift of the structure without undue collapsing by the seismic activity. In case this pushover analysis method is adopted, a mathematical model shall be imperilled to monotonically increased lateral loads which directly integrates the nonlinear force displacement behaviour of discrete elements and components of the building till target displacement is reached. This concept of target displacement helps in predicting max displacement experienced under seismic ground motion. This mathematical model incorporates the effects of response of material inelastic behaviour, calculation of internal forces are the reasonable estimates of those expected under the design earthquake.

Since it is the method of analysis which gives the results as a force displacement characteristics of every elements by acquiring a mathematical model and then the structural elements are being subjected to a incremental lateral load under seismic phenomenon until target displacement surpasses. The inelastic displacement and elastic displacement are combinedly called the maximum displacement and in the pushover analysis, structure is pushed to this maximum displacement at the top level under specified ground motion of earthquake. This method mainly focus on the force displacement patterns and the generation of demand and capacity curve incorporating static non-linear analysis algorithm. Performance criterias includes the storey displacement, storey drifts, base shear or forces along with subsequent component forces and deformation. The analysis accounts for the redistribution of internal forces, material inelasticity, and geometrical non linearity. Summing up all the advantages and response characteristics from this non-linear static analysis are as under:

a) The consideration of the failure modes of the buildings under the seismic activity and the displacement demand and the inter storey drifts.

b) The damage pattern of the structure along with its consequent effect on the stability of the building can be observed.

c) By doing the pushover, the estimation of the collapse pattern i.e. yielding is known with the hinge formation sequence. This leads to the development of capacity curve and also the force-displacement capabilities of the structure are estimated.

d) For ductile elements a deformation demand is acquired, and for Brittle ones, force demand are estimated.

e) It estimates the horizontal as well as vertical irregularities along with the weak points of the individual elements, in case of large inelastic displacement.

1.3.2 Procedure of Pushover Analysis

The structure behaviour encountered and load cases involved in the analysis, there are two ways the force controlled and displacement controlled to implement this pushover analysis. In case of already known forces and the capability of structures to resist the certain loads force controlled method is implemented generally in gravity loads cases whereas the later analysis is used when the unknown and uncertain forces such as earthquakes are there making the structure unstable and unsteady with its magnitude.

The followings steps are involved in implementing the Displacement controlled method:

1. Based on the physical nature of the building, two or three dimension modelling is done.

2. Taking note of the effects of lateral response, force displacement graph is plotted which can be bi linear or tri- linear.

3. In the starting load combinations of dead loads, specified live loads and gravity loads are applied to model.

4. Load pattern is defined and implemented accordingly to the structural model along its height.

5. The yielding of the member is done by application of incremental lateral loads accounting the load combination of lateral as well as gravity loads.

6. When the yielding occurs, roof top displacement and the storey shear is noted.

7. If the yielded member shows the change in stiffness, then the alteration is done to increase the stiffness.

8. The structure is modified by application of increasing lateral load and gravity load removal, to make sure that the yielding of additional structural model takes place. Modified structure is analysed to perform again with initial conditions as zero.

Every element forces after the revised analysis in the end get sum up from previous results. The obtained results are superimposed after each load perforations.

9. Similarly the values of roof top displacement and storey shear are obtained by summing up the displacement increment and force increment to the subsequent values obtained earlier for the consecutive addition of results.

10. The previous three steps are repeated to get the target displacement which will make the structure unsteady

11. The static curve of the structure is observed with plot of base shear versus displacement.

1.3.3 Use of Pushover Results

The Non-linear static Pushover analysis method emerges out to be the best method for earthquake analysis and design of the building owing to the ease and computational procedure involved. It is recommended under rehabilitation guidelines. It helps in getting the yielding pattern of the structural elements failures and the determination of the capacity and demand curve of the structure. One of the main advantage of this analysis is the critical response performance estimation of the structure along with its elements as close as conceivable to those predicted with dynamic analysis method. It became useful when the dynamic analysis is unable to provide response characteristics behaviour of the structure. Some of the response characteristics are given below:

- The evaluation of height wise distribution of inter-storey drifts of the structural model.
- The force demand are estimated for the brittle members which are actually the longitudinal force demand of column.
- The estimation of moment demands which include the connections of column-beam.
- The estimation of weak points which leads to collapsing of the structural model.
- The deterioration of structural strength behaviour of each elements.
- The estimation of vertical and structural irregularities which can cause the dynamic behaviour of the model in inelastic range.

- The accurate knowledge of the load path adequacy and the Authentication of completeness. It also helps in identifying the weakness of bad design which were unable to determine in the elastic analysis method. The parameters includes the strength irregularities, mechanisms of storey forces, surpluses on potentially brittle members and undue deformation demands.

The Pushover analysis are implemented in the computer software called ETABS. The performance of the structural model takes the form of discrete user defined hinges. The introduction of hinges is on the horizontal as well as vertical members i.e. bream and columns. The assignment of hinges can be on any location on the member but it is recommended to restrict the hinge assignment to mid height for the walls. The parameters easily available for analysis are torsion, story force, moments and the shear hinges. Usually the coupled P-M2-M3 hinge is taken into account yielding of which is based on axial force and bending moments interaction at the specified hinge location. There can be many hinges at a particular specified location like moment as well as shear hinge at the same location of beam or column.

Both lateral as well as longitudinal load cases are taken into account in this analysis. The individual load defined as pushover can follow a variety of load dispersion or distribution. Suppose under pushover analysis three types of load cases are defined, in the order as gravity, two lateral load along the building height.

Different outputs obtained after analysis form the pushover procedure are as follows:

1. The plotting of graph between the displacement and base shear at particular control point.

2. The above stated steps of graph plotting can also be made in another format which is called ADRS in which the spectral acceleration and spectral displacement are the taken as vertical and horizontal axis respectively. The Superimposing of the demand and capacity spectrum takes place on this graph.
3. The Hinge formation appear as a different color code for every hinge, it appears on the main screen, which can be viewed as steps or graphically.
4. Every steps post the analysis is viewable in tabular, graphical or as step wise process.
5. The Output of the result data at every point alongside the static pushover curve can be accessible in the tabular format with all number of hinges in table form outside definite control points by clicking on the hinge property, the plot of force-displacement can be viewable, printable, or can be saved as a particular file.
6. The values of the capacity spectrum which include capacity and demand curves, the natural time period, and the damping values are also accessible for viewing, printing and saving to computer.

1.3.4 Different stages of plastic hinges

For getting performance points and the hinges locations in different regions pushover curve is utilized. Explaining the different regions of curve, elastic range is the phase AB, range of instant occupancy is from B to IO, range of life safety is from IO to LS and the ultimate range collapse prevention from LS to CP.

If in the force-displacement graph hinge reaches C, then this hinge will initially start descent load. This procedure of releasing the load from the hinge is the base shear. It keep on decreasing until the hinge force is fixed with force at point D.

On releasing of all force, reduced displacement is obtained and also all of the elements unload. The degree of pushover force is enhanced again when yielded hinge reaches point D, with the increase displacement.

Building is considered safe when all hinges are within this given CP limit. Although, the hinges after Intermediate Occupancy level is prerequisite to be retrofitted as per structure's importance.

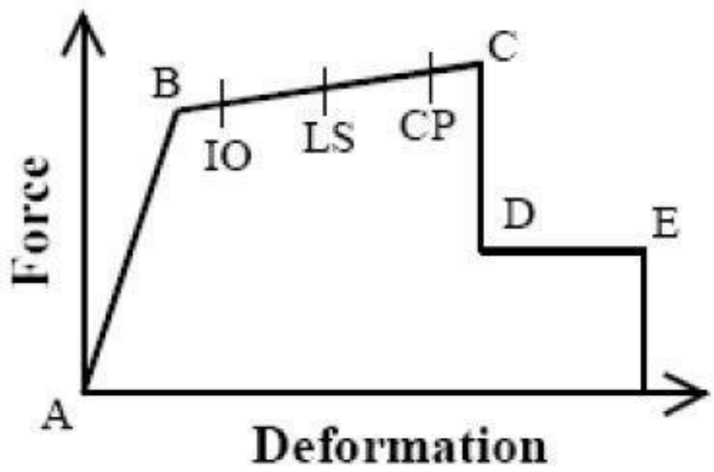

Figure 1.2 The Plastic hinge stages

The following are the main performance parameters which are analysed in the pushover analyses:

(i)Strength

(ii)Ductility

(iii)Stiffness

There some points of weakness when after analysing a usual RC Frame Building:

(i). There is an observed irregular load path

(ii). Most of the structural members lacks the deformation capabilities.

(iii).There is a doubt on the material quality and workmanship.

1.3.5 Different types of Buildings

i)Bare frame Building

In Bare frame Building, design is done neglecting the masonry loads. Masonry is the most commonly used material in the buildings. Masonry infill are used to partition walls. This building is modelled as beam and column structure with slab at the floors. The effect of masonry wall is neglected in this case.

Fig 1.3 Bare Frame of a Building

ii) Shear wall Building

Basically this type of system is used in a building for lateral forces resistant design. This structural member is needed to encounter the effects of seismic and wind forces.

They are built at different locations of the building as per requirement mostly in case of high rise structures as the wind forces increases as the height of the structures. The limits are imposed on the horizontal movement or sway.

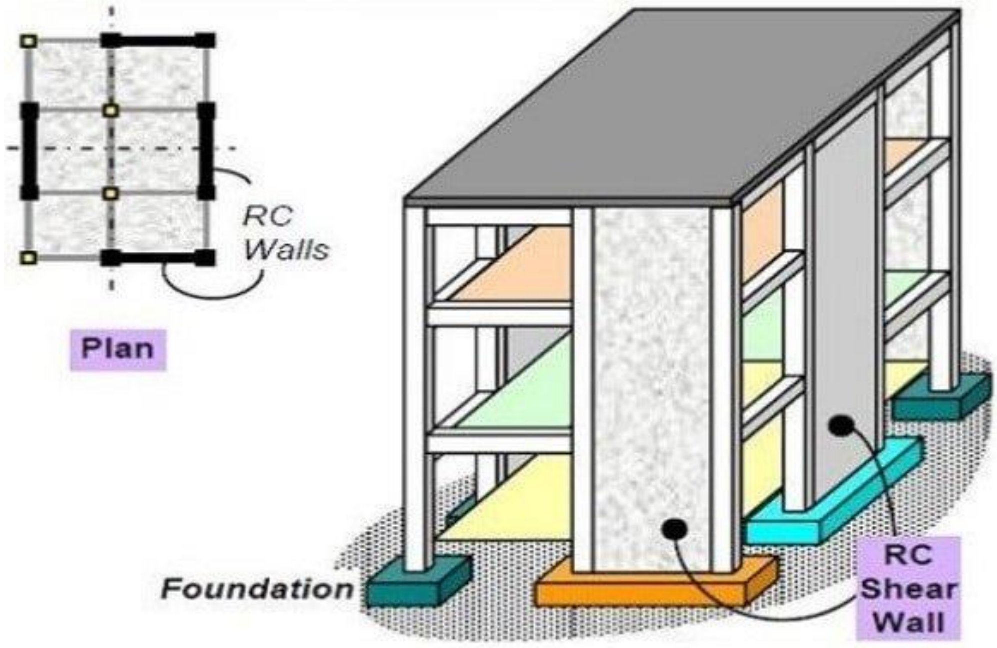

Figure 1.4 Plan and Elevation of RC Shear wall

The lateral deflection limits are there to restrict

- The building use is restricted with many limitations,
- The non-load bearing elements also undergoes adverse effects,
- The aesthetic appearance of building gets deteriorated.
- Ultimately it causes the discomforts.

It is recommended that the storey should not have relative lateral deflection more than its height/500.

iii) Masonry Infill wall

In Multi story buildings, the vertical loads do not have much effects as compared to the lateral loads which are experienced by the seismic activity or wind forces. They need special attention while designing a structure. The earthquake and wind forces can generate the regions of critical stress along with the shaking of ground which ultimately leads to displacement of the edifice which can create discomfort and harm to the people present in the structure at that time. Usually the most of the countries follows the basic concept in which the concrete structures are supported with partial or full infilled wall with openings as per requirement.

The infill wall improve overall strength of the structure but the involvement of these part is not accounted due to the non-existence of composite behaviour characteristics of the infills and frame elements which further leads to an unsafe design.

The infill walls generally comprises of concrete blocks or bricks which are constructed in between the frame elements. These masonry walls are used in multi storied building, industrial buildings as well as for commercial building in the earthquake prone regions.

The stiffness, lateral resistance, strength and energy dissipation can be enhanced by use of masonry infill walls, if proper designing is done. The chances of collapsing of building is also reduced as construction of masonry infill walls minimises the bending moment and the lateral deflection.

Overall it is observed that construction of infill makes the construction economical with the formation of slender frame member. The distribution of seismic force is dependent on the building mass and the stiffness.

The masonry infill walls makes structure more durable and stiffer which in turn have story drift reduced. Taking into consideration all these points, a good structural designer would rely on these infill walls more realistically in the seismic design.

Limitations of infill walls

The damage caused by infill walls include the

1. The effect of Soft storey, it comes into effect if a story has relatively lesser or no infill walls than the adjacent storys.

2. short column effect when infills are constructed up to partial column height.

3. If there is unsymmetrical location of infill walls in plan, plan torsion effects comes into play.

These 3 effects can results can greatly influence the collapse mechanism with excessive ductility demands of the elements with another great life threatening phenomenon of the out of plane collapse of infills.

There is no adequate separation that the frame does not come in contact with these infills, even when they are separated structurally from the wall member, the formation of struts and increased stiffness can be observed even after experiencing lateral displacement.

1.4 Need of the study

For estimation of a structure performance, Non-linear static Pushover analysis is one of the best technique available. Appropriate retrofitting techniques are predicted if the building indicates signs of failure.

1.5 Limitations of the method used

While it gives various benefits as compared to that elastic analysis methods, which underline several assumptions, the accuracy as well as limitations of existing pushover analysis techniques should be acknowledged.

In design earthquake, Target displacement is taken as the global displacement. The target displacement estimation, prediction of failure mechanisms due to higher modes of oscillation and lateral load pattern selection are some issues that affects the accuracy of pushover analysis result. Target displacement is affected by semi-rigid diaphragms, torsional effects, as well as the upliftment of foundations.

1.6 Objective of the study

- A Comparative analysis of the RC Building with and without Infill walls in all seismic zones of India.

1.7 Scope of Study

The work emphasises on reinforced concrete residential building with different types and varied zones. The study focuses on the non-linear static pushover analysis of the structure. . It will help to predict the Performance and Capacity of the structure in the seismic zones adopted.

1.8 Organisation of Thesis

The Thesis is organised into five Chapters. The Chapter outline are as follows:

Chapter 1: It contains a brief concept of the pushover analysis, its background and the need of the analysis. The scope of the study and the objectives of the work is included. It summarises the Organisation of the thesis.

Chapter 2: This chapter comprises the detailed literature review of the Reinforced concrete buildings and the analysis methods used for analysing them which establishes the present need of the study.

Chapter 3: This chapter deals with discussion of the methodology adopted for the study and the steps involved in modelling of the different models.

Chapter 4: It contains the result analysis of the Etabs software. Comparison has been done with different analytical results obtained. The base shear, displacement, spectral acceleration and displacement etc. have been included for comparison of the building model.

Chapter 5: It deals with the summary of the conclusion obtained from the work.

CHAPTER 2-LITERATURE REVIEW

2.1 General

This chapter gives a description of the earlier investigations in analysis and design of the structure under earthquake conditions.The various parameters influences the behaviour pattern of the structure such as loads, seismic zones, reinforcement arrangement thickness of slab allowable stresses in the material etc. Many methods are in trend in analysing the building for earthquake conditions such as static and dynamic methods. For a long time, the static methods were found useful but with the improvement in the analysis field, dynamic methods were found adequate and less time consuming. Below are some studies from the past.

2.2 Literature Review

Griffith and Pinto (2000) in their investigation carried out on a G+3 Building using masonry infills. The effect of seismic loading is accounted for the behaviour of reinforced concrete frame structure. The reinforced concrete structure analysed was having poor performance due to the weak columns and strong beams characteristics. Without infill walls, the structure was prone to get lateral deformation twice of the lateral drift. The application of masonry infills had shown that the minor cracks start developing at lesser lateral drifts which is less than half percent. The conclusion carried out was the load bearing capacity was completely lost by the drifts.

Otani (2000) highlighted the importance of the seismic analysis. With the advancement of technology, earthquake resistant building is gaining popularity. The estimation of response and the acceleration was initiated in the early years. He pointed out the chronology of the performance parameters which developed with the time. Nonlinear static analysis and capacity spectrum method was noticeable after the design response spectrum analysis. A structure was taken as an example and seismic analysis was done by past and the latest developed design approach. Old design approach lacks the improvement as compared to the recent procedure. Parameters for a safe earthquake resistant design of the structure was acquired.

Sasaki et al (2001) in multimode pushover procedure to identify the effects of higher modes in a pushover analysis, observed the limitations of static non-linear analysis for tall buildings with higher time period. It cannot identify the failure patterns observed in buildings with relatively high natural frequency. In the mmp, presented it helps in identification of damage patterns occurred due to the higher modes mostly in case of tall buildings. multimode analysis method involves the capacity spectrum method in which comparison of pushover curve is plotted on a graphical form is done with respect to seismic demand., it follows procedure based on higher modes and capacity spectrum method (csm) is used to compare the capacity vs demand. The results of mmp and csm , which indicated locations of beam hinging were compared to locations of observed weld cracking.

Huang et al (2006) in Non-linear pushover evaluation of in-filled concrete frames, constructed six rc frames without or with masonry infill and tested below horizontal cyclic hundreds. Non-linear pushover analysis, force deformation relationships of each elements have been advanced based on unique models and compared. Both failure mechanisms and impact of infill on behaviours of those frames have been tested. The outcomes presents the structural engineers with valuable data for assessment and layout of infilled concrete frame building systems.

Rehman (2009) in a world conference delivered a paper titled nonlinear static pushover analysis of an 8 story Reinforced Concrete structure with shear wall in Saudi Arabia.3d pushover analysis by using sap2000 combining inelastic fabric behaviour for concrete and steel is executed and shear wall became modelled the use of mid pier method which is a sort of shear wall. Damage modes consists of series of yielding and failure of participants and structural tiers have been developed for the goal displacement expected beneath layout earthquake and retrofitting strategies. The static non-linear curve for constructing in x direction, tale flow ratio, and plastic hinge formations are analysed.

D'Ambrisi (2009) in "Use of Pushover Analysis for Predicting Seismic Response of Irregular Buildings" performed the pushover analysis on an existing school building representing plan irregularities as well as vertical irregularities.it carries out the importance of pushover analysis in distribution of plastic hinges at ultimate load, estimation of inter-storey drifts and height wise distribution, in force demands, and to assess structural performance etc. the performance results showed that under moderate shaking, demand, the intersection of demand and capacity curve, minor cracking plastic hinge formation warn us for the deflection pattern by which the structure retains its strength and rigidness and under strong earthquakes demand curve intersects the capacity curve at life safety, formation of plastic hinges , collapsing of the building and subsequent strength reduction structure can be repaired but not possible for economic reasons.

Sattar & Siamak (2010) the performance of a building with masonry infill wall was evaluated under the effect of sudden ground activity which leads to structural damage of the building. The building was supported with only compressive column elements. The strut are strong non-linear members. The building was subjected to the lateral dynamic loads. The bare frame and infill frame performance was executed which shows that the infill wall performs better under the earthquake .increased capacity with less displacement and more stiffness and base shear was observed in infilled frame walls as compared to the bare frame structure. Non-linear dynamic analysis implemented the use of infill strut elements over the simple bare frame structure. The collapse mechanism of infilled frames have better Durability and strong resistant behaviour having high ductility and energy dissipation of the structure.

Belejo & Bento (2012) evaluated the seismic analysis by means of different software available for pushover analysis. A tall building was considered for the pushover analysis and performance was analysed using sap. The sap software was used to analyse the pushover results including the hinge formation and various means of lumped plasticity model. After analysis, the comparison was made between the distributed plasticity modal to that of lumped plasticity model. The comparison provide the user to choose the best software program for pushover analysis.

Bhatti (2012) analysed a building for pushover analysis by using demand spectra ATC 40 Technique, the comparison was made with spectra based on real site conditions. The comparison was made with and without strengthening and plotting of plastic hinges. Time history analysis comes out to be the best analysis for prediction of force displacement demand at different elements of the structure. It was also analysed that this method have some limitations due to use due to the fact dynamic behaviour may be very touchy to modelling and individual of ground movement. Conclusion comes out in favour of pushover analysis due it its simplicity and easiness.

Naveed (2016) pushover analysis using Etabs and Sap2000, a presentation at association of structural engineers, highlighted the basic theory and procedure of earthquake analysis using pushover analysis through Etabs and sap2000.comparison of software and the importance and limitation of the methods were included. The details of performance based design were also introduced which can be done using pushover analysis method.

2.3 Research Gap

Many experimental and analytical works has been done by researchers in the field of static and dynamic analysis of RC frame Buildings under the influence of seismic activities. The analysis contain modelling of the structure to the design and analysis by taking into account a number of variable factors. The static analysis is limited to some extent but the dynamic analysis has a number of benefits. Many researcher has adopted the dynamic analysis of a particular building in a particular zone but the pushover analysis of building analysed with varied seismic zone and varied support system has not been conducted. It will help to predict the Performance and Capacity of the structure in the seismic zone adopted.

2.4 Summary of Review

The methods for earthquake resistant design of structures differ from size of the structure to the location of the structure. Out of the static and dynamic analysis methods pushover is considered the accurate one because of the simplicity and prediction of approximate damage behaviour .The performance parameters are quite more and it is recommended for low to medium rise tall structures. Plastic hinge formation, demand and capacity curve generation, the force displacement curve all leads us to analyse the behaviour pattern more accurately. Also the application of supporting structures like shear wall, bracing or unreinforced masonry infill walls in the building creates more insight about the selection of construction of suitable concrete frame.

CHAPTER 3-WORK METHODOLOGY AND STRUCTURE MODELLING

3.1 General

This chapter deals with the methodology of the work presented and the modelling of all the structure selected. Selection of material and defining of load pattern is presented. It also deals with the modelling procedures of different types of building. An overview of the adopted technique is also explained.

3.2 Methodology

A Comparative analysis of the RC frame building is taken for analysis for the evaluation of strength and the performance under seismic activity. Etabs software version 2018 is used for the analysis of the Structural frame models. The Seismic analysis has been done for the Residential building models for evaluation of performance under earthquake. The basic steps involved are the modelling, analysis and the study of response parameters.

- ❖ To carry out literature review to define the thesis objective.
- ❖ To enquire about different methods available under dynamic analysis along with the advantages and disadvantages.
- ❖ Modelling of the structures selected along with the load and support condition assignment.
- ❖ Analysis of the selected models by non-linear static technique.
- ❖ Result with Comparative analysis of each model with respect to displacement and base shear in each zones.

The methodology chart of the study is depicted as follows:

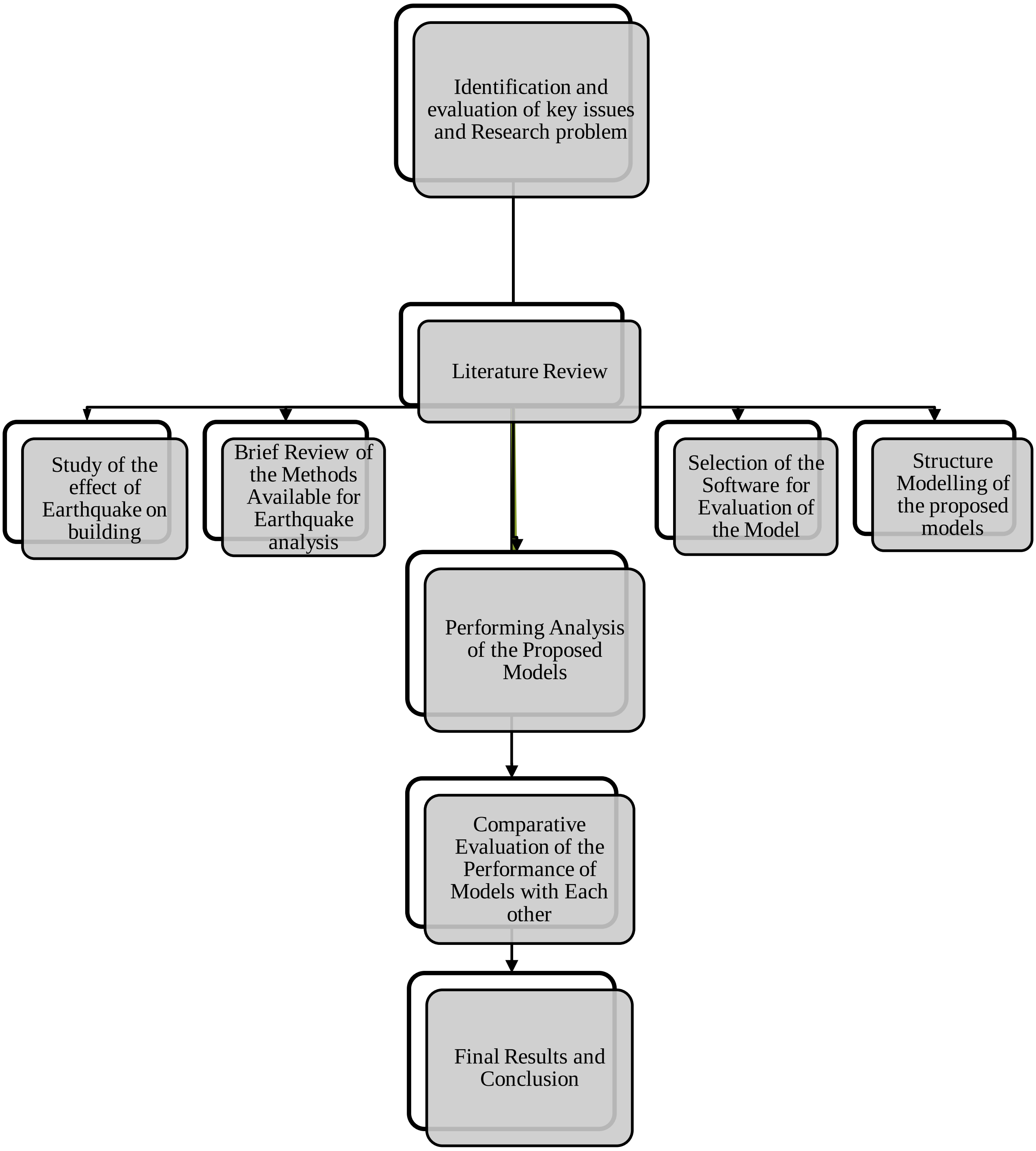

Figure 3.1 Work Methodology

In Non-linear analysis, it is very important to do accurate modelling of elements of the structure. Structure modelling and assemblage of different load carrying members involves a great care. It should be capable of representing strength, mass distribution, deformation and stiffness. The Pushover analysis reduces the long program hours to get good results. This method mainly focus on the force displacement patterns and the generation of demand and capacity curve incorporating static non-linear analysis algorithm. Performance criteria's includes the storey displacement, storey drifts, base shear or forces along with subsequent component forces and deformation. The analysis accounts for the redistribution of internal forces, material inelasticity, and geometrical non linearity.

The Models considered are Bare frame, Shear wall at the corners and infill wall model. The Building is a Reinforced Concrete frame structure with 31m height, soil configuration is medium soil. The zones are varied for evaluation, keeping geometrical configuration and loading condition constant.

3.4 Structural data

The data needed for the modelling and designing purpose are shown in the table. The plan size, the overall height, height of the floor are given below in table 1 along with seismic zone, type of soil as per the requirement of seismic design code. The IS 1893 (Part 1): 2002 is used for the values of response reduction factor, importance factor values. The section and material properties of the structure are shown in Table 3.2 while the details of loading in Table 3.3 respectively.

Table 3.1 General building and location details

Plan size	20x20
Building height	31m
Structure type	Reinforced Concrete Frame
Seismic Zone	All seismic zones of India(i.e. II,III,IV,V)
Soil type	Medium soil(Type II)
The Damping ratio	0.05
Height of storey	4m ground floor, others 3m
Bay width	4m
Bays in X and Y directions	5
Support conditions	Fixed
Importance factor, I	1
Response reduction factor,R	5(SMRF)

Table 3.2 Section properties and Materials

Column	600mmx600mm
Beam	300mm×600mm
Slab	125mm
Brick	Density=20kN/m3
Steel	fy= 415 MPa
Concrete	fck= 25 MPa, Density = 25 kN/m3

Table 3.3 loading details for the design

Wall load on beams	18.5 kN/m
Floor finishes load	1.0kN/m2
Equivalent lateral loads	According to IS 1893 (Part I):2002 [12]
Imposed load	3.0 kN/m2

3.5 Steps involved in Modelling the Building:

- Select-File-New Model
- Click Use Built in settings
- Display Units as Metric SI
- Enter the values in New Model Quick Template window for the Uniform Grids Spacing and simple story data
- Grid spacing is 4m and number of grids is 5 in both x and y directions
- Story height is taken as 3m except for base as 4m.No. of storey is 9.
- Defining the slab and structural properties.
- Model will appear in the main window.
- Define the material property for concrete by selecting define-material properties-add new material-add new material-concrete-click ok
- Defining column section properties
- Next step is to define frame section property.
- Steps are done for column and beam sections.

For shear wall definition,

- Go to Define- section properties-wall sections
- Select- Add New property-wall properties.
- Define the width of shear wall as 150 mm at the first and second stories.
- Go to wall property data-write wall for the property name, select wall material-enter thickness as 150mm
- Modelling type should be –Shell thin for shear walls.
- Click on modify/show in same window.
- Click ok.

- In order to define slab, select-define section properties-slab sections-choose slab 1
- Select modify property in slab properties window. click ok
- Done with defining beam and column sections.
- Now we can draw shear walls at the corner of the building by removing columns.
- Same steps of replicate is repeated for all corners.
- When all four shear wall is drawn 3d model will appear in the right panel.
- Click on Edit similar stories to apply wall load on roof.
- Assign the loads. Click on assign –frame –section properties-beam/column/slabs. Click ok after assigning.
- Assign support by clicking on assign-joints-restraints
- Defining the Load patterns. Click on define-load patterns-assign al the loads. Then click on define-mass source and ok.
- Assign the loads by selecting assign-shell loads-uniform-live loads/dead loads. Close the window.
- Wall loads by selecting all beam but changing similarities because terrace will not contain same load.
- Assign-frame loads-distributed-uniform loads
- Finally select the load combination by clicking on define-load combination-add new combo
- Final steps to check the design for any warning. if there are no warning then model is ok.
- Click on analyse-Run analysis
- Detailed summary report will be generated which includes all the results of the parameters needed.

3.5 Plan and Elevation view of Models

The first step of modelling is the building of its frame elements. The plan of the building shows the number of grid lines in x and y direction with spacing of 4m each. Height of story is taken as 3m above the ground with base height as 4m.

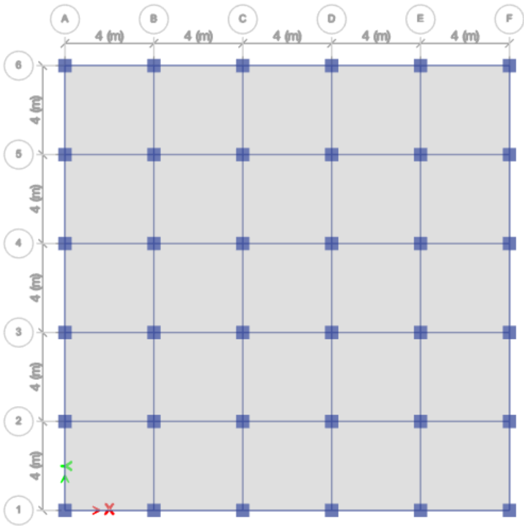

Figure 3.2 Buildings Plan view

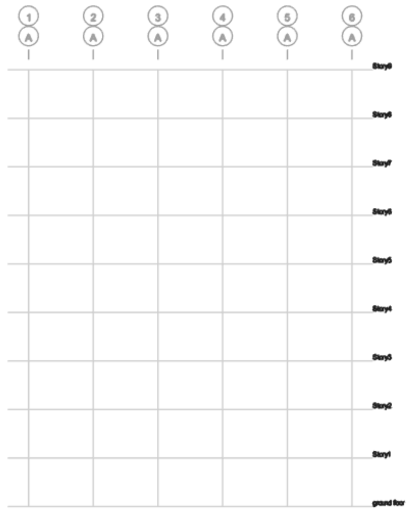

Figure 3.3 Elevation View of Building

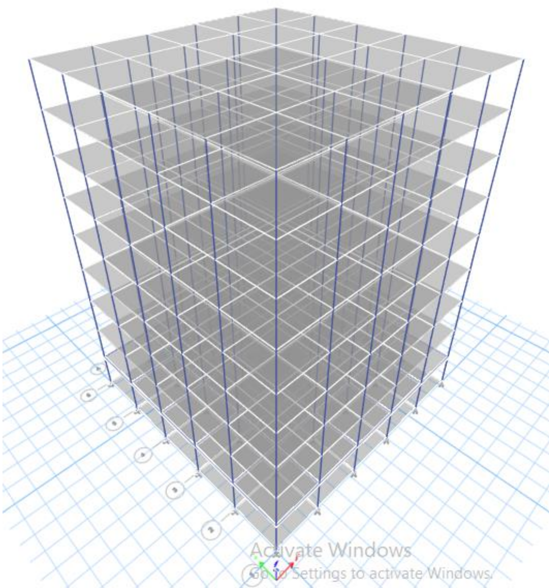

Figure 3.4 3-D Isometric view of the Bare Frame Building

Figure 3.4 represents the implication of shear walls at the corner of the model. The thickness is taken as 230mm. The drawing of shear wall is done through the quick draw tool bar. The modelling of infill wall is also shown below. After creation of model, load definition and patterns takes place.

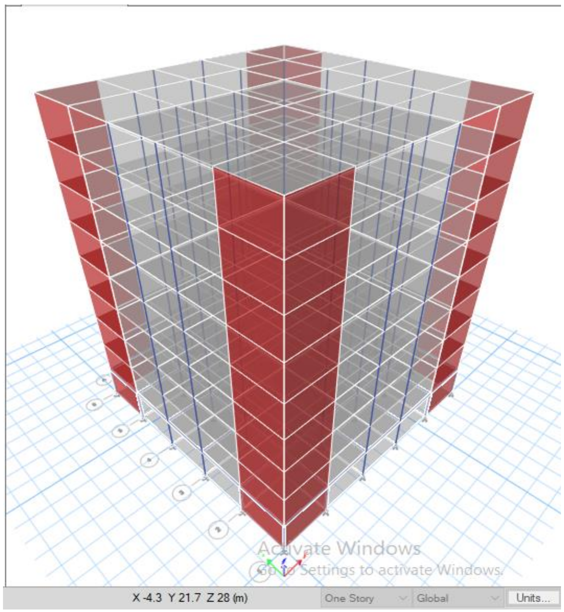

Figure 3.5: Shear wall Building

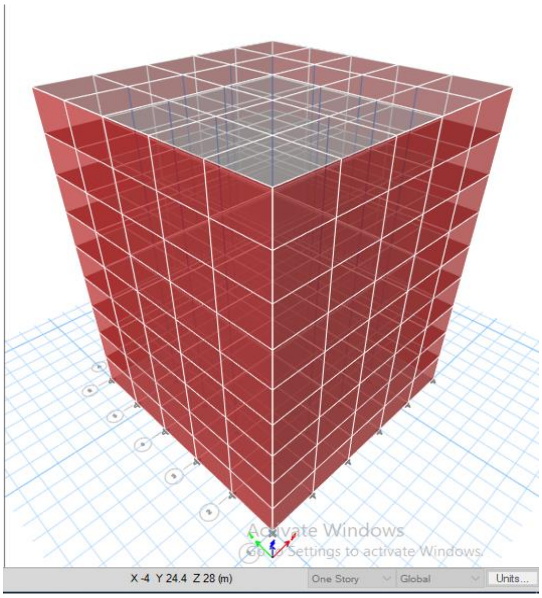

Figure 3.6: Building with Infill wall

3.6 Loads Considered

For analysis and design of the models, different types of loads are considered as in practical scenario. As per the code of Indian recommendation, the loads are defined according to the requirement of the analysis. In this dead load, live load, seismic loads and the pushover load in x as well as in y direction are taken for consideration. The software automatically generates the loading condition on the building with necessary multipliers. Table 3.5 represents all the loads considered for the evaluation.

Table 3.4 Loading Patterns

Name	IS Auto Load	Type	Self-Weight Multiplier	Auto load
Dead	No	Dead	1	
Live	No	Live	1	
Push x	No	Other	0	
Push y	No	Other	0	
Seismic	No	Seismic	1	IS 1893:2016

3.7 Auto Seismic Loading

The India standard code of Earthquake recommends certain guidelines to use various factors, ratios and the seismic coefficients which are important for the calculation of earthquake analysis. The values of these are presented below.

IS 1893:2016 Auto Seismic Load Calculation

This Calculation presents the automatically generated lateral seismic loads for load pattern seismic according to IS 1893:2016, as calculated by ETABS.

Direction and Eccentricity for the calculation of forces and displacement:

Direction = Multiple

Eccentricity Ratio = 5% for all diaphragms

Structural Period:

Period Calculation Method = Program Calculated

Factors and Coefficients:

Seismic Zone Factor, Z=1, R=5, I=1

Seismic Response calculation:

Spectral Acceleration Coefficient, S_a /g $\frac{S_a}{g} = \frac{1.36}{T}$ $\frac{S_a}{g} = 0.995646$

Equivalent Lateral Forces:

Seismic Coefficient, A_h $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

The structures has been modelled and their results are presented in the next chapters along with the comparative study of each models.

CHAPTER 4- RESULTS AND DISCUSSION

4.1 General

This chapter deals with the performance results of different types of models analysed by the software. In this study, the three building models are analysed for pushover analysis in four seismic zones of India, the models are similar in geometric configurations but different in terms of support system like shear wall, infill wall and simple bare frame system. Therefore this work study will help to demonstrate a reliable, accurate and convenient methodology for analysing the reinforced concrete building models with emphasis on strength and the seismic zones. The results have been compared with respect to elastic and pushover base shear, collapse displacement, roof displacement, spectral displacement and spectral acceleration.

4.2 Discussion of Results

The Important part of the analysis is the result discussion. The different values obtained are compiled to get an overview of the performance behaviour of the models. The results are compared with each other and on the basis of different zones. Different parameters are taken into account such as performance point of the structure, the base shear values, collapse displacement and roof displacement for the evaluation of performance and capacity of the structure. Description of different parameters is given below for each cases.

4.2.1 Performance Points and Shear values

The performance point is the point where demand and capacity curve intersects in the pushover curve developed by the software, it describes the performance level of the structure along with the base shear capacity. The summary of the data values are as under.

Table 1.1 Performance Point and Base shear values of infill wall, shear wall and bare frame wall in zone-II

Building Model	Collapse Disp.(KN)	Elastic Base shear(KN)	Pushover Base shear(KN)	Performance point			
				Sa(g)	Sd(m)	Roof Disp(m)	Base shear(KN)
Model 1 (Infill)	0.0988	449.38	1614.491	0.109	0.077	0.086	1443.845
Model 2(Shear wall)	0.109	605.06	1261.318	0.078	0.109	0.105	1236.545
Model 3 (Bare frame)	0.1340	760.70	1181.933	0.062	0.144	0.104	945.807

Table 4.1 shows the comparison of all the three models in zone II. The reserve strength which is not utilised is represented by the pushover and elastic base shear ratio. This ratio is more for first type of building which is the infill wall frame building. The ratio is lowest for bare frame building i.e. Model 3.

Table 4.2 Performance Point and base shear values of bare frame, shear wall and infill wall in zone III

Building Model	Collapse Disp.	Elastic Base shear	Pushover Base Shear(KN)	Performance point			
				Sa(g)	*Sd(m)*	*Roof disp*	*Base shear(KN)*
Model 1	0.0988	717.32	1614.4962	0.109	0.077	0.086	1443.872
Model 2	0.109	968.10	1261.6912	0.078	0.109	0.105	1236.760
Model 3	0.134	1214.48	1181.8341	0.063	0.147	0.108	966.627

Table 4.2 shows the ratio values of the ratio in the zone III comes out to be 2.32, 1.30 and 0.873. Highest for bare frame building and lowest for the infill wall building.

Table 4.3 Performance Point and base shear values of bare frame, shear wall and infill wall in zone IV

Building Model	**Collapse Disp.(m)**	**Elastic base shear(KN)**	**Pushover Base shear(KN)**	**Performance point**			
				Sa(g)	***Sd(m)***	***Roof disp(m)***	***Base shear(KN)***
Model 1	0.0988	1078.31	1614.5029	0.109	0.077	0.086	1443.862
Model 2	0.109	1449.00	1261.6947	0.081	0.111	0.108	1257.729
Model 3	0.1340	1825.67	1181.9885	0.062	0.144	0.104	945.814

Table 4.3 shows the value of the ratios as 0.647, 0.871 and 1.497 for infill, shear wall and bare frame building respectively. Here it can be seen that there is only slight difference in the values.

Table 4.4 Performance Point and base shear values of bare frame, shear wall and infill wall in zone V

Building model	**Collapse Disp.(m)**	**Elastic base shear(KN)**	**Pushover base shear(KN)**	**Performance point**			
				Sa(g)	***Sd(m)***	***Roof Disp(m)***	***Base shear(KN)***
Model 1	0.0988	1614.5043	1614.8123	0.109	0.077	0.086	1443.880
Model 2	0.1090	2178.2213	1261.6962	0.077	0.109	0.107	1242.140
Model 3	0.1340	2732.5832	1181.9892	0.063	0.147	0.108	966.624

Table 4.4 shows ratio of pushover and elastic base shear as 1, .58 and 0.533.The value of this ratio is keep decreasing with the increase in height for all building model in their respective zones. The Structure performance is found to be better if the spectral acceleration value is more and the spectral displacement value is less.

4.3 Performance point Variation

The Figures 4.1, 4.2, 4.3 and 4.4 summarises the performance point of all models for each zones. Basically when demand spectrum is superimposed on capacity curve into spectral coordinate, then the Performance point is obtained.

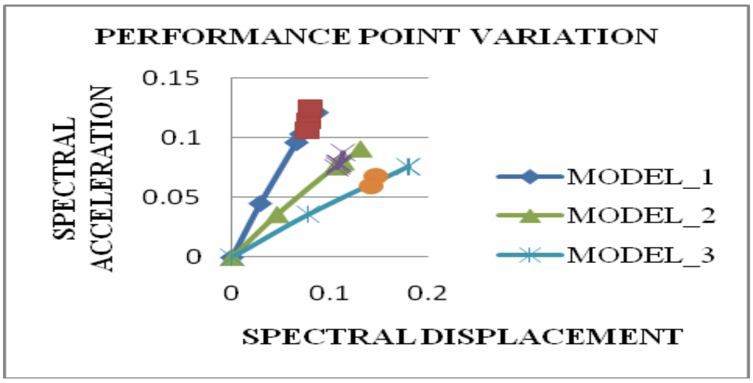

Figure 4.1 Variation of Performance Point of models with combination of combining demand curve and capacity curve in zone-II

Figure 4.1 shows the pattern of the models in zone II. At performance point, the demand curve intersects the capacity curve. The three models are Bare-frame, shear wall at the corner and the infill wall building model. Here the seismic zone and strength support system both influence the building performance point.

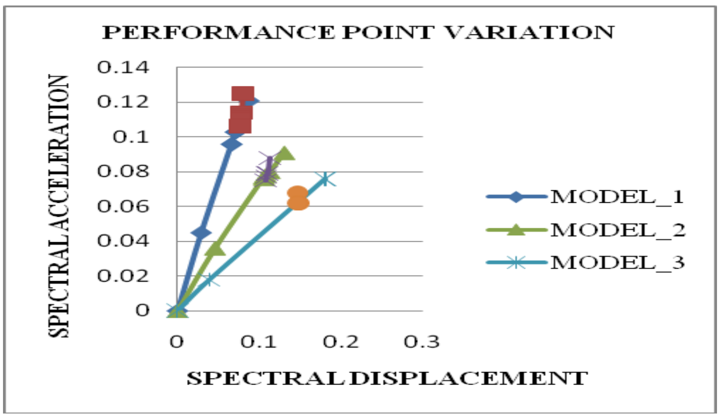

Figure 4.2 Variation of Performance Point of models with combination of combining demand curve and capacity curve in zone-III

Figure 4.2 indicates that there is a slight change in the performance point for bare frame and shear wall building in this zone as compared to the zone II, but it can be seen that for model 1 i.e. simple bare frame building, seismic zone variation do not have much impact on the performance point variation.

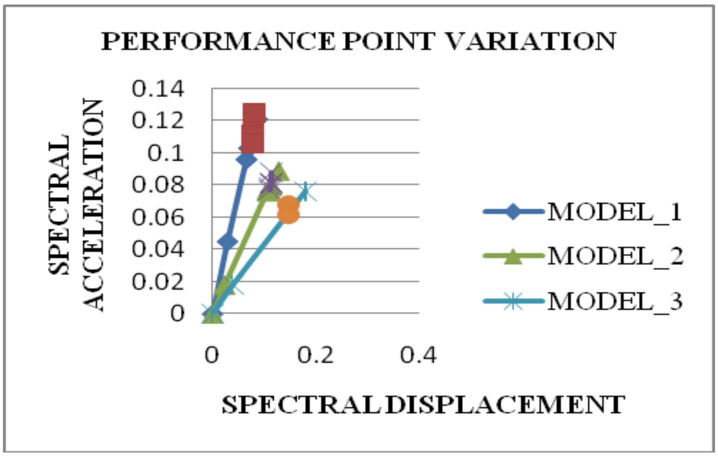

Figure 4.3 Variation of Performance Point of models with combination of combining demand curve and capacity curve in zone-IV

In Figure 4.3, model 2 and model 3 are depicting variation in the performance point with respect to the variation in the seismic zones.

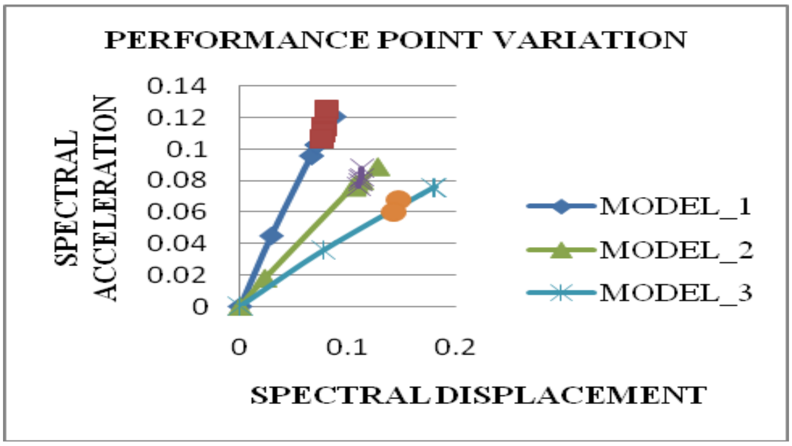

Figure 4.4 Variation of Performance Point of models with combination of combining demand curve and capacity curve in zone-V

From Figure 4.4 it is predicted that point of performance gets shifted to model 3 with the change in the seismic zones. With the margin of safety against collapse being sufficient, the interaction of demand curve and capacity curve takes place in the elastic range. The displacement and strength reserves in these structures seems sufficient with little decrease from bare frame wall towards infill wall model.

4.4 Variation of Pushover Curves

The pushover curve depicts the overall pattern in terms of ductility and strength. When the load is increased monotonically in lateral direction, the sequential yielding is obtained. With each step, there is stiffness loss in the structure. Because of this, pushover curve slope is found to be gradually decreasing. These below Figures are the summary of all the pushover curve obtained in every zone. The Pushover in x direction will have more stiffness as compared to the vertical direction.

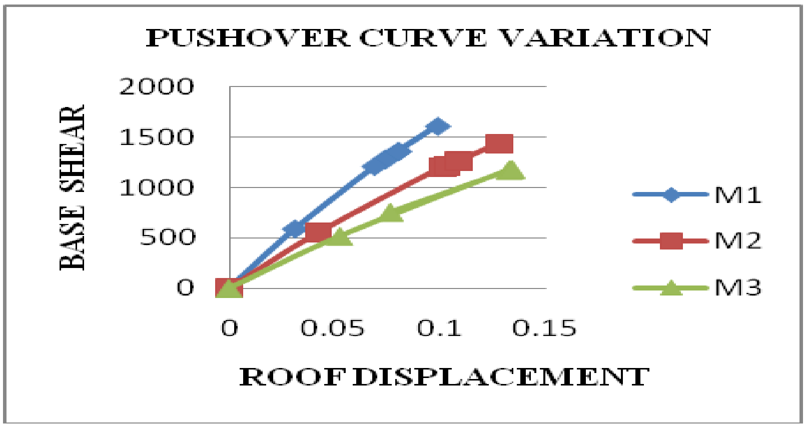

Figure 4.5 Variation of Pushover Curve in Zone II

Figure 4.5 shows variation in the pushover curve for three buildings in two seismic zones. The curves can be estimated with the bi linear relationship approach.

In Figure 4.6, there is slight percentage change in model 2.

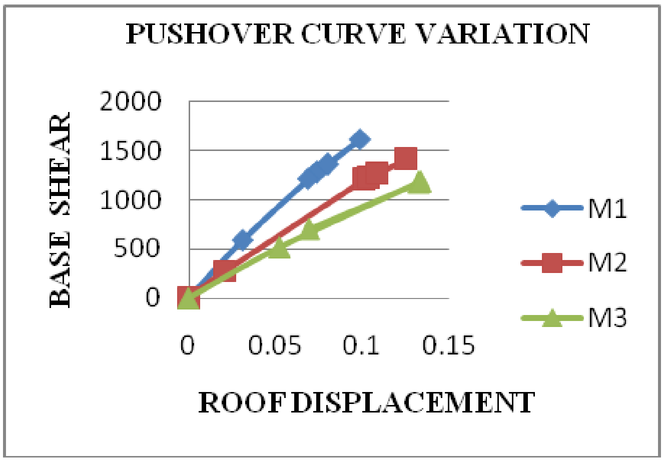

Figure 4.6 Variation of Pushover Curve in Zone III

Figure 4.7 clearly indicates that these variation for zone IV implies that the bare frame model is showing the higher value as compared to the other two models.

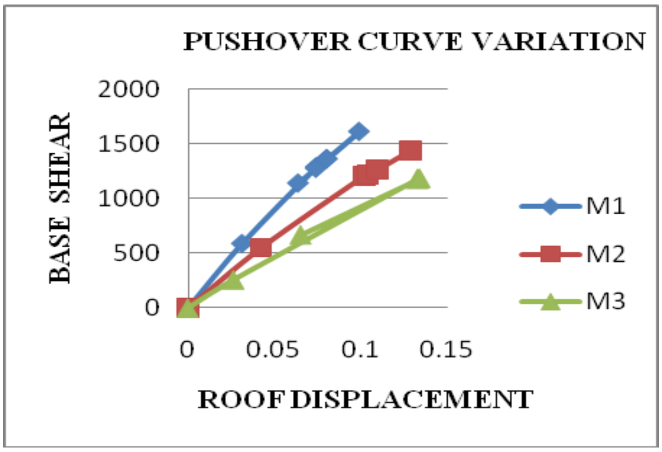

Figure 4.7 Variation of Pushover Curve in Zone IV

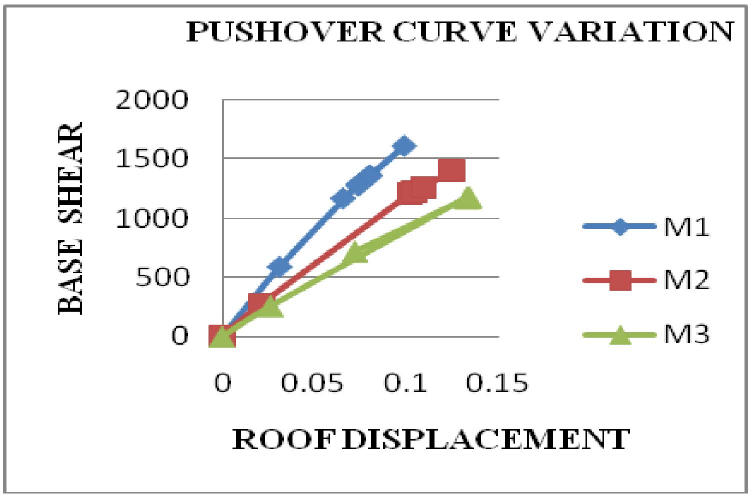

Figure 4.8 Variation of Pushover Curve in Zone V

In Figure 4.8, when models are analysed in Zone 5, there is a change in the pushover curves. The collapse displacement is the same in all zones. The displacement at the roof is same for model 1 i.e. bare frame model in all zones whereas it is increasing for the other two models in all zones. The pushover curve of bare frame and shear wall is linear in all zones. But Infill wall model is having non-linear pattern in every zone.

It is depicted that the pushover curve of all the models are linear initially but from bare frame to infill wall, they start to deviate from this linearity in every zone. This due to the inelastic behaviour changes in the columns and beams.

4.5 Modal Mass participation ratio

Modal participation factors are scalars that measure the interaction between the modes and the directional excitation in a given reference frame. Therefore a mode with a large effective mass will be a significant contributor to the structures response in the given excitation direction. Modal load participation ratio and mass participation ratio are presented in the following tables.

Table 4.5 represents the modal load participation ratios which indicates that 99.99% loads are actively participating in the static analysis and 97.25 for dynamic analysis in horizontal and vertical direction negligence in the z direction.

Table 4.5 Modal Load Participation Ratios

Case	ItemType	Item	Static %	Dynamic %
Modal	Acceleration	UX	99.99	97.25
Modal	Acceleration	UY	99.99	97.22
Modal	Acceleration	UZ	0	0

Table 4.6 represents the modal mass participation ratios for all the models. Along with the time period values and the different forces.

Table 4.6 Modal Participating Mass Ratios

Case	Mode	Period sec	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX
Modal	1	1.395	0	0.7807	0	0	0.7807	0	0.1488	0	0.0835	0.1488
Modal	2	1.366	0.8499	0	0	0.8499	0.7807	0	0	0.1753	0	0.1488
Modal	3	1.208	0	0.0717	0	0.8499	0.8524	0	0.0241	0	0.7672	0.1729
Modal	4	0.447	0	0.078	0	0.8499	0.9304	0	0.6025	0	0.0037	0.7753
Modal	5	0.441	0.0879	0	0	0.9378	0.9304	0	0	0.6332	0	0.7753
Modal	6	0.391	0	0.0078	0	0.9378	0.9381	0	0.0349	0	0.0814	0.8102
Modal	7	0.248	0	0.0216	0	0.9378	0.9597	0	0.0448	0	0.0002	0.855
Modal	8	0.246	0.0246	0	0	0.9624	0.9597	0	0	0.0501	0	0.855
Modal	9	0.222	0	0.0024	0	0.9624	0.9621	0	0.0036	0	0.026	0.8587
Modal	10	0.165	0	0.0092	0	0.9624	0.9713	0	0.0484	0	5.555E-07	0.9071
Modal	11	0.164	0.0101	0	0	0.9725	0.9713	0	0	0.0518	0	0.9071
Modal	12	0.149	0	0.0009	0	0.9725	0.9722	0	0.0029	0	0.0115	0.91

4.6 Base Shear Results

The structure experiences a lateral force at the base of the building when there is a seismic activity, its maximum value is known as the base shear. It is the product of a factor called horizontal seismic coefficient and the net vertical force at the base. The value of seismic coefficient is based on factors like seismic zone etc. In simple language when earthquake occurs, for each lump mass there is an inertial force which opposes the building movement. Hence these inertial forces are the structure's lateral force. On adding these lateral forces at the base, base shear is produced. This base shear is must to be generated to resist induced inertial force. Below are the results of base shear of all models in push x and push y direction.

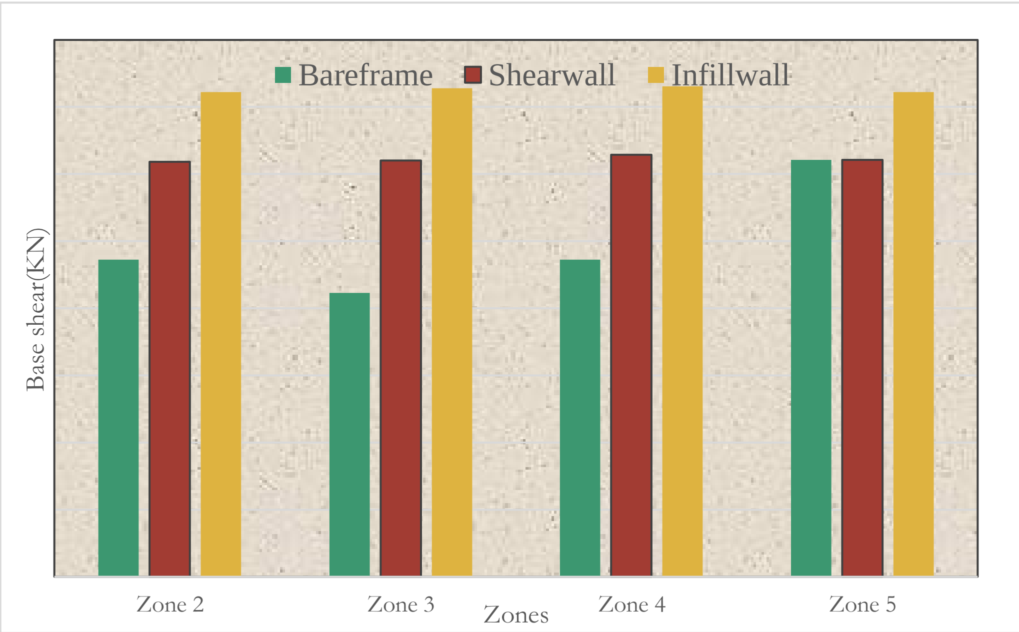

Figure 4.9 Base shear results

Figure 4.9 shows the summary of the base shear results for all models in each zones. The comparison shows the amount of variation in the structure.

The Bare frame model is getting more value in the y direction and less value in the push x direction in the zone 2. It is the same for model 2 in zone 2, higher value of push y and lesser value of push x which implies that the displacement is more in y direction. For Model 3, the value is quite less and somewhat good when considering the building design because of the infill wall. The both values are quite similar means they are getting equal displacement in both the direction. When the zone is changed to 3, the pattern of model 1 is quite same to as seen in the zone2.The displacement in the y direction comes out to be 1875.44 kN greater than push x displacement. For Model 2, when the shear wall is applied at the corners of the wall, there is change in the displacement value. It shows less displacement of the structural building as it the structures resisting tendency increases due to the support walls at the corners.

The overall deflection value is coming minimum on the application of infill wall to the structure. It can be depicted from the Figure that the model 3 comes out to be better than the other two models. This system is suitable for these zones.

Zone four has a higher level structure prone activities than 2 and 3.But in this case, base shear is same as it was coming in zone 2.Not much effect of the zone change is seen. For the Model 2 in zone 4, change in the value of base shear is observed. The base shear value in push y direction is 1441.17 whereas in push x it is 1261.69. It is noted here also that the base shear value is coming out to be less than other models. The value of base shear is minimum of all the zones for push x direction, only minor change in the bash shear in push y direction.

Base shear of the Shear wall model is showing minute changes on the shifting to this zone. Model strength is of moderate level that it is able to resist the forces and holding the same amount of base shear value.

The pattern of the chart is showing little change in the decimal values. It is concluded that as the zone changes there is change in the values of base shear and also when different type of building is analysed we get different results. It helps us to decide which one is better and economical for a good building design.

4.7 Number of Plastic hinges

The deformation of beam section where plastic bending takes place is predicted by the plastic hinge. When the applied load is increased until yielding, then there is an elasto plastic deformation which leads to a fully plastic condition. At this point, sufficient no. of plastic hnges can be seen which ultimately transform the building into a mechanism. The structure becomes unstable geometrically.

Table 4.7 Plastic hinges of building model in zone-II

Hinge stages	Model I (Infill wall)	Model II (Shear wall)	Model III (Bare frame)
A-B	3748	5043	6366
B-IO	92	114	107
IO-LS	2	0	1
LS-CP	1	1	1
CP-C	1	0	1
C-D	1	1	0
D-E	1	0	0
>E	5	5	5
Hinges formed	3849	5164	6480

Table 4.7 shows the number of plastic hinges for all the models in each zones. The different stages considered in the analysis are immediate occupancy, operational, to occupancy, reduced hazard, non-structural damage and life safety. These are influenced by the ground motion severity.

Table 4.8 Plastic hinges in zone-III

Hinge stages	Model 1 (Infill wall)	Model 2 (Shear wall)	Model 3 (Bare frame)
A-B	3748	5043	6366
B-IO	92	114	107
IO-LS	2	0	1
LS-CP	0	0	0
CP-C	0	0	0
C-D	0	1	0
D-E	0	0	0
>E	4	4	4
Hinges formed	3847	5163	6477

Table 4.8 shows the number of plastic hinges are almost same as that of in zone 2. The focus was on that total number of hinges are not supposed to exceed the limit of elasticity. Considering Model 1, it was predicted the seismic zone change do not influences the plastic hinges status. But in case of Shear wall and Bare frame model, there is an influence of seismic zone variation on the plastic hinges status.

Table 4.9 Number of plastic hinges of Buildings in Zone-IV

Hinge stages	Model I (Infill wall)	Model II (Shear wall)	Model III (Bare frame)
A-B	3748	5043	6367
B-IO	92	110	106
IO-LS	2	1	2
LS-CP	0	0	1
CP-C	0	0	1
C-D	0	1	1
D-E	0	0	0
>E	4	4	4
Hinges formed	3850	5163	6479

Table 4.9 and 4.10 shows that the hinges are more in case of model 3 and less for model 1.

Table 4.10 Number of plastic hinges of Buildings in Zone-V

Hinge stages	Model 1 (Infill wall)	Model 2 (Shear wall)	Model 3 (Bare frame)
A-B	3748	5043	6367
B-IO	92	114	105
IO-LS	2	0	1
LS-CP	0	0	1
CP-C	0	0	0
C-D	0	1	0
D-E	0	0	0
>E	4	4	4
Hinges formed	3846	5162	6479

4.8 Maximum story Displacement

The Maximum storey Displacement is the Displacement by which a building can get deflect or displace when any seismic activity takes place. Results shows the displacement of various building under the varying seismic zones of India. It may be notes that the as the graph follows, the displacement goes on increasing with the story height. Hence max deflection is found at the topmost storey. In this case bare frame in zone II, it comes out to be 10.4 mm. When zone is changed from II to zone III. The displacement values of the story comes out to be 10.8 mm which is little higher from the previous one. For the case when the displacement of the building when the zone is changed a level higher. There has not been much change in the displacement value. It is more or less the same as got in the previous zone.

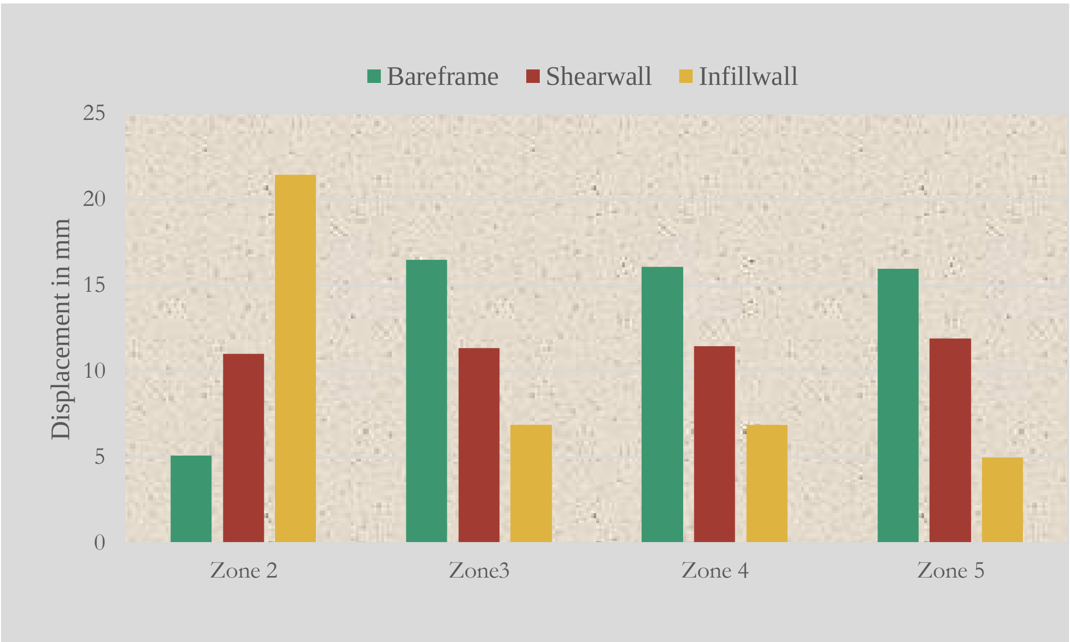

Figure 4.10 Displacement comparison of the models

Figure 4.10 briefs about the response of the building when bare framed in zone V. It shows no increment in the displacement as compared to the previous zone IV. Displacement values comes out here 10.80 mm. The response of the shear wall building to the displacement in seismic zone II. Here also the displacement is max at the top with a value of 10.50 mm. It is not of great concern for such a high rise building. The plot of displacement of the shear wall building when zone changed one degree up. There is no significant amount of change seen here. This is acceptable value which do not creates much trouble in the practical scenario. The displacement value of the shear wall building in zone 5 which is nearby 10.70 mm. There is a decrease in the displacement value with infill wall building. It shows the value around 8.6 mm which is quite less as others.

4.9 **Natural time period**

The Building vibrates back and forth under the influence of earthquake, the vibration period is called the time period. Higher the time period less stable the structure is. Higher seismic zones indicates high displacement and high period of oscillation. The time period obtained from the analysis are shown below for different models in the form of chart.

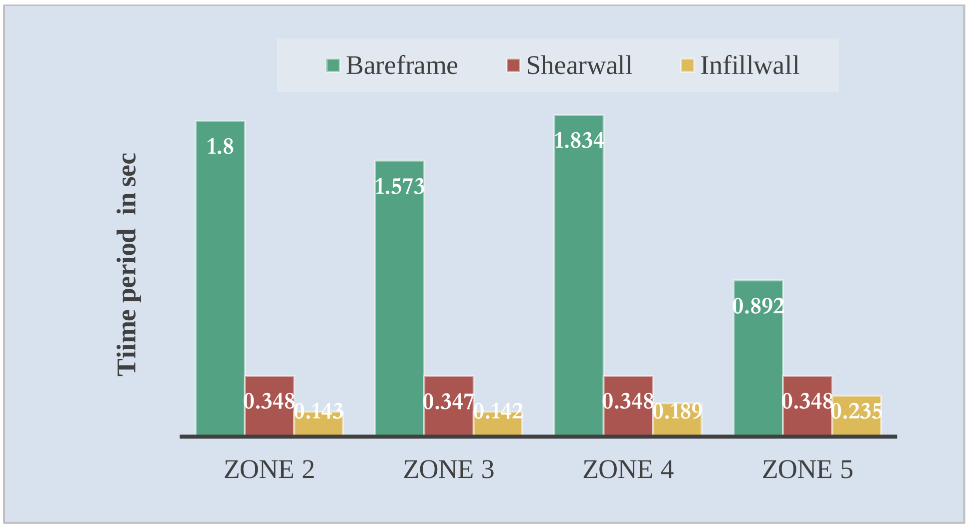

Figure 4.11 Natural time period comparison

4.10 **Performance Summary**

The Analysis of the models in each zones will help us to have a clear picture of the performance and strength behaviour. Important parameters are taken into consideration for evaluation purpose.

Table 4.11 Percentage change in Base shear values of models

Model	Base shear in Zone 2(kN)	Base shear in Zone 3(kN)	Base shear in Zone4(kN)	Base shear in Zone 5(kN)	Avg % change in the Model
Model 1	1443.845	1455.271	1460.861	1443.884	+0.788%
Model 2	1236.545	1236.762	1257.724	1242.141	+1.71%
Model 3	945.807	845.241	945.814	966.227	+2.15%

Table 4.11 shows the comparison in terms of base shear in al zones for all models with percentage change in the values. It shows that Model 1 is showing less percentage change means it is less affected by the prevailing conditions, however when building is simple structure as bare frame, it gets affected due to the seismic activity, the average seen was about 2.15%. Shear wall model is showing changes in value between these two only due to its strength support provided at the corners.

Table 4.12 shows the percentage change in the values of roof displacement in between all models in all zones. Supports provide strength and rigidity to the building, which will in terms reduces the displacement or deformation in the structure.

Table 4.12 Percentage change in roof displacement values

Model	Disp in Zone 2(m)	Disp in Zone 3(m)	Disp in Zone4(m)	Disp in Zone 5(m)	Avg % change in the Model
Model 1	0.086	0.099	0.101	0.120	+3.4%
Model 2	0.105	0.107	0.108	0.109	+3.8%
Model 3	0.104	0.213	0.225	0.232	+55.17%

Table 4.12 clearly indicates that the simple bare frame structure can get displacement change on a large scale, which can be reduce by implication of shear wall or infill wall which is having only minor change in comparison to the simple structural model. In this case infill wall model is found to be better than bare frame model and shear wall model.

Table 4.13 Percentage change in Natural time period

Model	Time period in Zone 2 sec	Time period in Zone 3 in sec	Time period in Zone 4 in sec	Time period in Zone 5 in sec	Avg % change in the Model
Model 1	1.801	1.573	1.834	0.892	+2.65%
Model 2	0.348	0.355	0.348	0.388	+4.28%
Model 3	0.143	0.142	0.189	0.235	+4.40%

Table 4.13, shows the change of Natural time period accordingly in the zones and with models. Time period of the model 1 is showing a minimum value change in terms of average percentage change also it is showing a satisfactory change in higher level zone. Variation of Time period vibration is coming out to be more for bare frame, which makes it not a good choice for adopting it. Preference will be given to infill wall and shear wall models.

CHAPTER 5-CONCLUSION

5.1 General

In this study of the seismic analysis, evaluation of performance parameters was carried out help of the software considering the various factors which in long term will help in designing a better structure.

The result of the work can greatly help in designing a building, this seismic analysis predicts the behaviour pattern of relatively tall building subjected to a monotonically increased lateral load.

5.2 Conclusion

- ❖ A Carefully performed Seismic analysis of the structures by Etabs software shows that the Building with Infill walls performs better than the Building without Infill walls in all Seismic zones of India.
- ❖ Under the influence of seismic activity, the percentage change in displacement for Infill wall model, Shear wall model and Bare frame Model was found to be 3.4%, 3.8% and 5.17% respectively when going from Zone II to Zone V. It means that displacement in bare frame structure increases upto 5.17% when going from zone II to zone V.
- ❖ On the other hand, the findings shows that there is only 0.788% decrease in the base shear value of Infill wall model while the shear wall and bare frame undergoes a change of 1.71% and 2.15% respectively.

- ❖ For the case of natural time period, a change of 2.65%, 4.28% and 4.40% was seen in Infill wall model, shear wall model and bare frame model respectively which indicate that the time period of bare frame model increase with the level of zone, shows it was much influenced by the seismic activity as compared to the other two.
- ❖ It concludes that the performance parameters of infill wall model was found better than the other two models. However the shear wall model also performs well so it can be a good option for low level seismic zones.

  Although the Infill wall model comes out to be costly but on the other side, it provides a greater level of performance with required strength and durability. In this respect, without compromising on the cost of structure Building with infill wall model is recommended for construction in high seismic prone areas.

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