SEISMIC ANALYSIS OF A MULTI-STOREY BUILDING USING STEEL BRACED FRAMES

A Thesis Submitted
in Partial Fulfillment of the Requirements
for the Degree
of

MASTER OF TECHNOLOGY

In

Structural Engineering

By

Mohd Atif khan
(University Roll No. 1170444007)

Under the Guidance of

Mr. Faheem Ahmad Khan
(Assistant Prof.)

BABU BANARASI DAS UNIVERSITY
LUCKNOW

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CERTIFICATE

Certified that **MOHD ATIF KHAN** (1170444007) has carried out the research work presented in this Thesis entitled **"SEISMIC ANALYSIS OF A MULTI-STOREY BUILDING USING STEEL BRACED FRAMES"** for the award of **MASTER OF TECHNOLOGY (Structural Engineering)** from BABU BANARASI DAS UNIVERSITY, LUCKNOW under my supervision. The Thesis embodies results of original work, and studies are carried out by the student himself and the contents of the Thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

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DECLARATION

I hereby declare that the Thesis entitled **"SEISMIC ANALYSIS OF A MULTI-STOREY BUILDING USING STEEL BRACED FRAMES"** in the partial fulfillment of the requirements for the award of the degree of Master of Technology (Structural Engineering) of **BABU BANARASI DAS UNIVERSITY**, is record of the own work carried under the supervision and guidance of **Mr. FAHEEM AHMAD KHAN** to the best of my knowledge this Thesis has not been submitted to **BABU BANARASI DAS UNIVERSITY** or any other University or Institute for the award of any degree.

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[1170444007]

ABSTRACT

The main concern in the high rise building is their lateral stability i.e. they provide stability during seismic activity without any major destruction .Bracing is one of the horizontal force resisting system. An attempt is made to analyze the response of G+14 storied RC multi-storey building due to the application of different bracing system such as X, V, inverted V bracing and to find the best bracing system during earthquake. ETABs software is used for modeling and analyzing the building. The building is taken in Zone III and analyzed with Time History analysis method. Various parameters such as storey drift, storey displacement, fundamental time period and storey stiffness are studied. From the study it was concluded that building with bracing perform better during seismic activity as compared with building without bracing. Among all the different bracing, X bracing is the best bracing system to reduce the responses during seismic activity.

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I wish to express my deepest gratitude and indebtedness to my supervisors, **Mr. Faheem Ahmad Khan** and to the Head of Department **Mr. Anupam Mehrotra** for their stimulating ideas, numerous constructive suggestions and guidance, continuous encouragement and invaluable support throughout this study. Without their advice, encouragement and support, this thesis would not be completed.

Finally, I would like to dedicate this research work to my family and friends (**Shariqa Ali**) whose continuous love and support guided me through difficult times.

Mohd Atif Khan

(M-Tech. Structural Engineering)

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CHAPTER 1

INTRODUCTION

1.1 General

At present India is developing at a very fast rate which requires increased demand of infrastructure facilities with the growth in population. Due to increase in population the demand of housing is also increasing, so to full fill the need for construction of housing and commercial buildings the use multi-storey building is highly in demand now days. These types of development require safety both for life and property because multi storey buildings are highly susceptible to additional lateral load due to earthquake and wind.

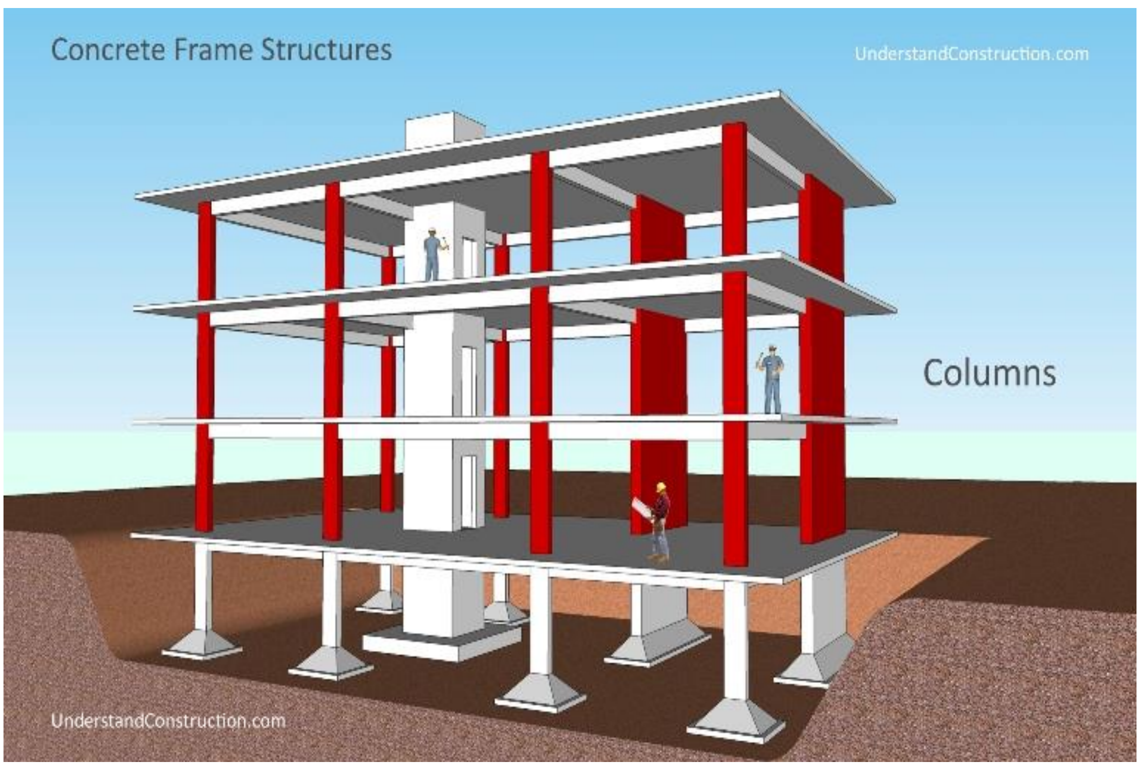


Figure 1.1- Concrete frame structure

Concrete has become universal building material and more appropriate structural forms such as shear wall and tube structures. The high dead load characteristics are no limited on the height of concrete building. Otherwise, the dead load from the concrete tends to be more significant in minimizing the sway deflection and floor vibration as well as instability problem.

Tall building cannot be defined in specific terms related to height or number of floor. Building to be considered as tall when the structural analyses and design are affected by the lateral loads. The lateral loads begin to dominate the structural system and take on increasing importance in the overall building system when the building heights increase.

Vertical load, lateral load effects on building are quite variable and increase rapidly with increase in height. The strength, rigidity and stability were three major factors to consider in design of such structures. Basically there are two ways to satisfy these requirements that may be by increasing the size of the member beyond to achieve the strength requirement or change the form of the structure into something more rigid and stable.

Reinforced Concrete frames are the most common construction practices in India, with increasing numbers of high-rise structures adding up to the landscape. There are many important Indian cities that fall in highly active seismic zones. Such high-rise structures, constructed especially in highly prone seismic zones, should be analyzed and designed for ductility and should be designed with extra lateral stiffening system to improve their seismic performance and reduce damages.

Generally, it is recognized that seismic design of buildings should satisfy at least two fundamental requirements. First, the structure must behave elastically and protect relatively brittle non-structural components against minor earthquake ground shaking. Therefore, a structure should have sufficient strength and elastic stiffness to limit structural displacements, such as inter story drift. Second, the structure must not collapse in a major earthquake. For this case, significant damage of the structure and non-structural components is acceptable. In order for a structure not to collapse and thereby minimize the loss of life, it must have large energy dissipation capacity during large inelastic deformations. In general, structural systems which exhibit stable hysteretic loops perform well under the large inelastic cyclic loadings characteristics of major earthquakes. Such stable hysteretic characteristics of a structure can be obtained provided that the structural members and joints are designed to posses sufficient ductility.

Earthquakes are the most life damaging and destructive phenomenon; these are generated due to sudden release of energy in the earth crust that creates the seismic waves which appears at different instances with different intensity level. When earthquake occurs, the building collapse and damage due to earthquake. Ground motion which is radiated in all direction from epicenter. Due to the effect of earthquake, the building encounters supreme level of displacements, the inertial force which is caused due to tendency of a building to remain at rest. All though, the lateral instability is the major issue while designing a multistory building and seismic zones are also considered while designing a multi-storey building.

The word ‘earthquake’ is used to express any seismic occurrence whether natural or caused by humans that can produce seismic influence around any particular area. Earthquakes are caused generally by rupture of geological faults inside the earth, but also by other events such as volcanic movement, landslides, mine blasts, and atomic tests.

In Seismic Analysis, we come to know that earthquakes are the most volatile, disturbing and unpredictable of all natural disasters, in which it is very difficult to save life and engineering properties. Care has to take for each step of construction of a building from foundation part. When earthquakes take place, a building undergoes dynamic motion. Because of subjected to inertia forces that may act in the opposite direction to speeding up of earthquake excitations. These inertia forces normally called seismic loads dealt by assuming forces external to the building.

To overcome these problems, we need to identify the seismic performance of various buildings through various analytical procedures. This is because to make sure that the various buildings withstand during earthquake events. Hence, can save as many lives as possible. During earthquake the performance of a structure depends on many factors such as stiffness, adequate lateral strength, simple and regular configurations etc.

SEISMIC ZONE:- The earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5). According to the present zoning map, zone 5 expects the highest level of seismicity whereas zone 2 is associated with the lowest level of seismically.

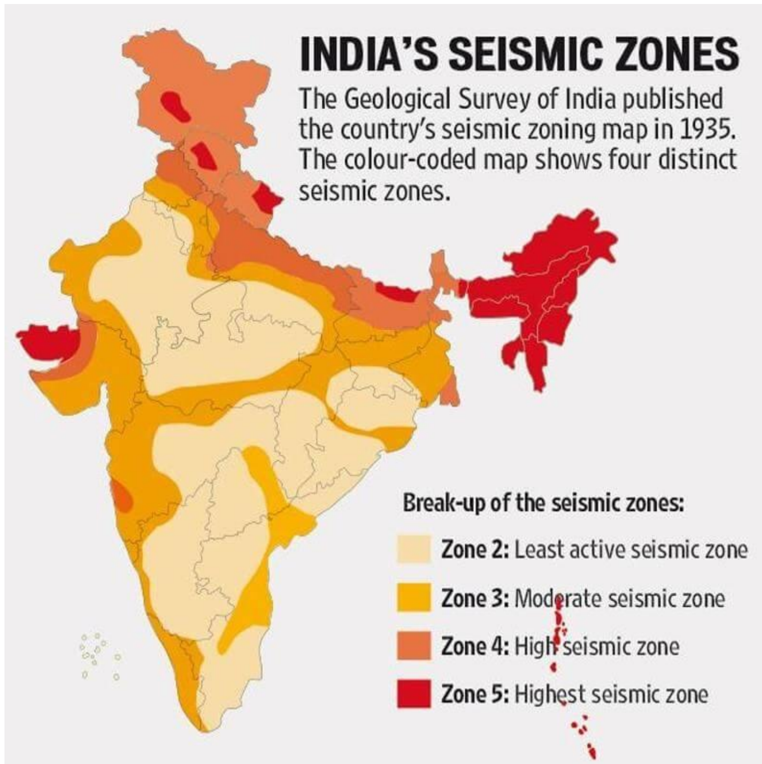


Figure 1.2- Seismic zones in India

During earthquake motions, deformations takes place across the elements of all loads bearing system. Due to theses deformations internal forces develop across the ;load bearing system and results in displacement of the building. To make the stable and free from displacement the seismic analysis of the building must be done. In general steel is used as a construction material to increase ductility. Steel allows less time of construction and can be constructed in any season. these are light weight and can be easily modify according to the need of the architecture. The one from the two horizontal force resisting system is bracing system.

The use of steel bracing system is a viable option for retrofitting a reinforced concrete frame for improved seismic performances. Steel braces provide required strength and stiffness, takes up less space, easy to handle during construction, can also be used as architectural element and is economic. Steel braces are effective as they take up axial stresses and due to their stiffness, reduce deflection along the direction of their orientation.

Figure 1.3- RC Residential Building with bracing

1.2 OBJECTIVES

The objective of this research is focused on various techniques used to study the seismic behaviour of R.C buildings with seismic zone III of India using bracing system. The whole design was carried out in ETABs which covers all aspects of structural engineering. More specifically, the salient objectives of this research are:

1) To perform a comparative study of the various seismic parameters.

2) Comparison among building with X, inverted V bracing and without bracing on the basis of story displacement, storey drift, Storey Stiffness & fundamental time period etc.
3) To propose the best suitable technique for seismic analysis.

In this report, a multi-storey residential building is studied for earthquake and wind load using Time history method and ETABs. This analysis is carried out by considering seismic zone III, and for this zone, the behaviour assesses by taking the medium soil. A different response for displacements, storey drift, storey stiffness and fundamental time period is plotted for zone III for medium type of soil.

1.3 SCOPE OF THE PRESENT STUDY

In the present study, modeling of the RCC frame under the time history analysis by taking four models i.e. without bracing ,with X. V and inverted V bracing using ETABs software and the results so obtained are compared.

1.4 ORGANIZATION OF THE THESIS

The thesis is organized as per detail given below:

Chapter 1: Introduces to the topic of thesis in brief.

Chapter 2 : Discusses the literature review i.e. the work done by various researchers.

Chapter 3 : Work methodology for the analysis

Chapter 4 : Analysis and Result

Chapter 5 : Conclusions

1.4.1 Bracing System

A braced frame is a structural system commonly used in structures subject to lateral loads such as wind and seismic pressure. The members in a braced frame are generally made of structural steel, which can work effectively both in tension and compression.

The beams and columns that form the frame carry vertical loads, and the bracing system carries the lateral loads. The positioning of braces, however, can be problematic as they can interfere with the design of the façade and the position of openings. Buildings adopting high-tech or post-modernist styles have responded to this by expressing bracing as an internal or external design feature.

Braced frames are often the most economical method of resisting wind and earthquake load in multistory building. Members in a braced frame are not allowed to sway laterally (which can be done using shear wall or a diagonal steel sections, similar to truss).there are two types of bracing system. concentrically and eccentrically braced frame.
Structures which are subjected to a lateral load must have adequate stiffness and strength which helps in controlling the deflection and also prevents any damage which may occur. Steel framed construction is a new concept in which lateral loads are better resisted by bracings. Steel braced frame models are effective means to transverse lateral forces caused by earthquake and wind forces in multi-story buildings. Bracings hold the structure stable by distributing the loads. Braced frames are less in weight than shear wall so it attracts less seismic forces. There are various types of Braced Frames such as concentrically braced frames and eccentrically braced frames. These Bracings are arranged in different configuration like X Bracing, V bracing, Inverted V bracing, Single diagonal Bracing.

The resistance to horizontal forces is provided by two bracing systems:

Vertical bracing -Bracing between column lines (in vertical planes) provides load paths for the transference of horizontal forces to ground level. Framed buildings require at least three planes of vertical bracing to brace both directions in plan and to resist torsion about a vertical axis.

Horizontal bracing -The bracing at each floor (in horizontal planes) provides load paths for the transference of horizontal forces to the planes of vertical bracing. Horizontal bracing is needed at each floor level, however, the floor system itself may provide sufficient resistance. Roofs may require bracing.

1.4.1.1 Types of bracing

a) **Concentrically Braced Frames (CBFs):-** CBFs increases the lateral stiffness of the frame and usually decrease the lateral drift. CBFs are conventionally designed braced frames in which the centre lines of the bracing members cross at the main joints in the structure, thus minimizing residual moments in the frame. The pros and cons of braced frames are essentially the opposite of moment frames; they provide strength and stiffness at low cost but ductility is likely to be limited and the bracing may restrict architectural planning.

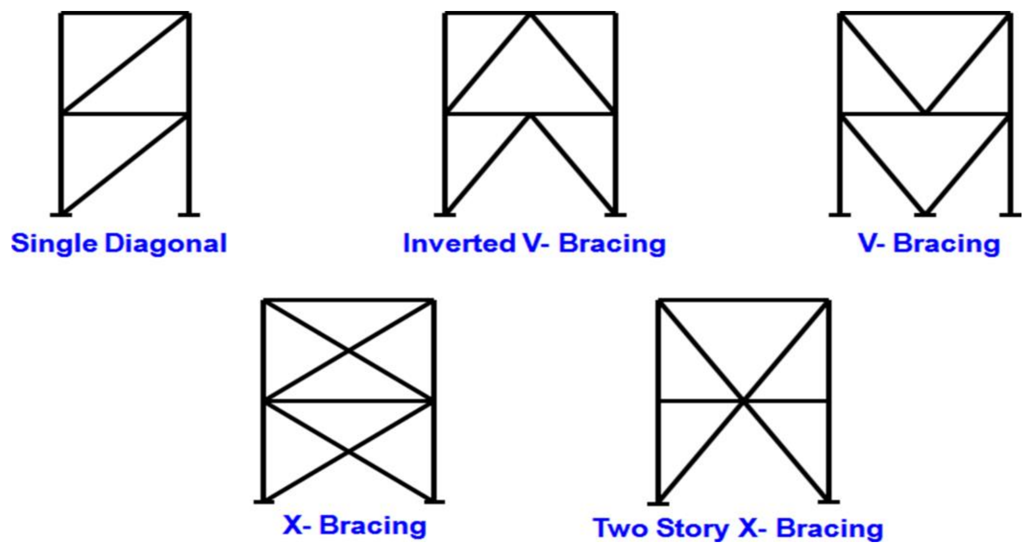


Figure 1.4 - Concentric Bracings

X- bracing

Cross-bracing (or X-bracing) uses two diagonal members crossing each other. These only need to be resistant to tension, one brace at a time acting to resist sideways forces, depending on the direction of loading. As a result, steel cables can also be used for cross-bracing. However, cross bracing on the outside face of a building can interfere with the positioning and functioning of window openings. It also results in greater bending in floor beams.

V-bracing

The V-braced arrangements suffer from the fact that the buckling capacity of the compression brace is likely to be significantly less than the tension yield capacity of the tension brace. Thus there is inevitably an out-of balance load on the horizontal beam when the braces reach their capacity, which must be resisted in bending of the horizontal member. This restricts the amount of yielding that the braces can develop, and hence the overall ductility. Where the horizontal brace has a large bending strength which can resist the out-of-balance load, the hysteretic performance of V-braced systems is improved.

Diagonal braces:

Single bays of diagonal braces respond differently according to the direction of loading. Configuration may be much weaker and flexible in the direction causing compression in the braces, while configuration will be weaker and more flexible in the storey with compression braces, leading to the possibility of soft-storey formation. This is clearly not satisfactory. With more than one diagonally braced bay, the performance can revert to that of X-bracing if a suitable arrangement of bracing direction is chosen.

b) **Eccentrically Braced Frames (EBFs):-** Eccentrically bracing reduces the Lateral stiffness of the system and improve the Energy Dissipation capacity. In EBFs, some of the bracing members are arranged so that their ends do not meet concentrically on a main member, but are separated to meet eccentrically The eccentric link element between the ends of the braces is designed as a weak but ductile link which yields before any of the other frame members. It therefore provides a dependable source of ductility and, by using capacity design principles, it can prevent the shear in the structure from reaching the level at which buckling occurs in any of the members. The link element is relatively short and so the elastic response of the frame is similar to that of the equivalent CBF.

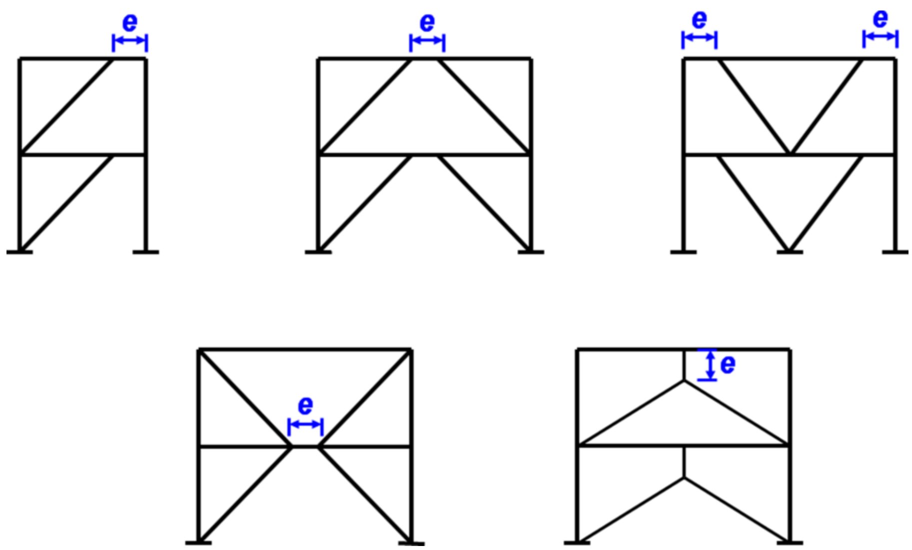


Figure 1.5- Eccentric bracing

The eccentric link element between the ends of the braces is designed as a weak but ductile link which yields before any of the other frame members. It therefore provides a dependable source of ductility and, by using capacity design principles, it can prevent the shear in the structure from
reaching the level at which buckling occurs in any of the members.

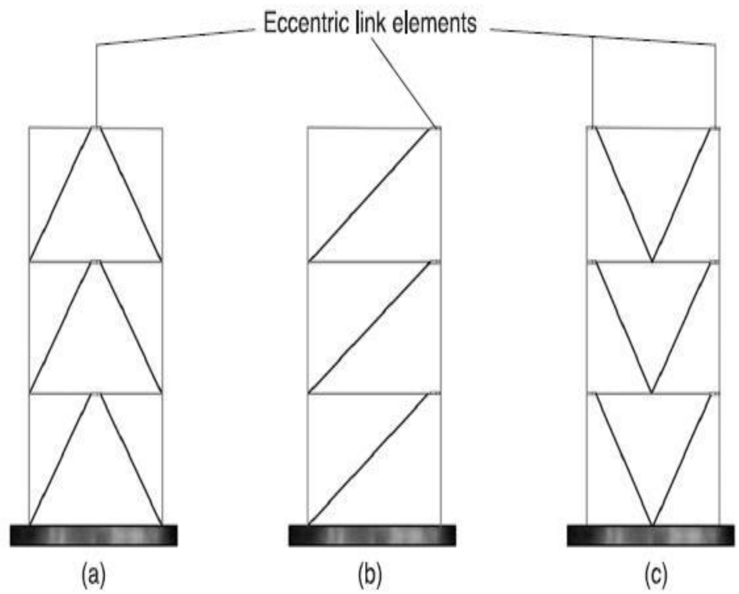


Figure 1.6- Eccentric links

The eccentric link element between the ends of the braces is designed as a weak but ductile link which yields before any of the other frame members. It therefore provides a dependable source of ductility and, by using capacity design principles, it can prevent the shear in the structure from

reaching the level at which buckling occurs in any of the members.

The link element is relatively short and so the elastic response of the frame is similar to that of the equivalent CBF. The arrangement thus combines the advantageous stiffness of CBFs in its elastic response, while providing much greater ductility and avoiding problems of buckling and irreversible yielding which affect CBFs in their post-yield phase. Arrangements such as (a) and (b) in Fig above also have architectural advantages in allowing more space for circulation between bracing members than their concentrically braced equivalent.

An alternative arrangement with similar characteristics is the knee-braced frame.

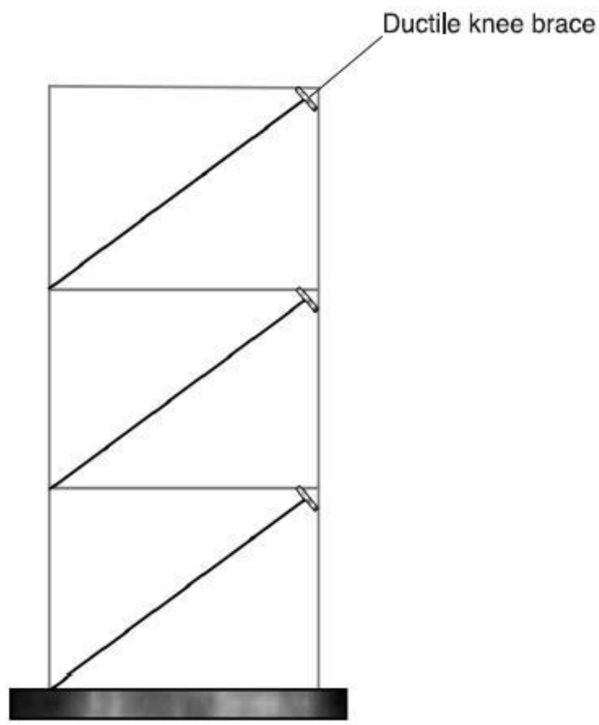


Figure 1.7- Knee-braced frame

There is an another important bracing system which is now readily used by structural engineers for seismic analysis as discussed below:

1.4.1.2 K-braced systems:

These are not permitted, because buckling of the compression brace imposes an out-of-balance force not on the horizontal beam (as in the case of V-braced systems) but on the column, and this is clearly unacceptable. The design procedure for EBFs in both Eurocode 8 and AISC is similar. For an elastic analysis, the links are sized from the actions obtained from the seismic analysis, using the specified q or R factor. They can then be classified on the basis of their length e, shear strength Vp and flexural strength Mp as follows.

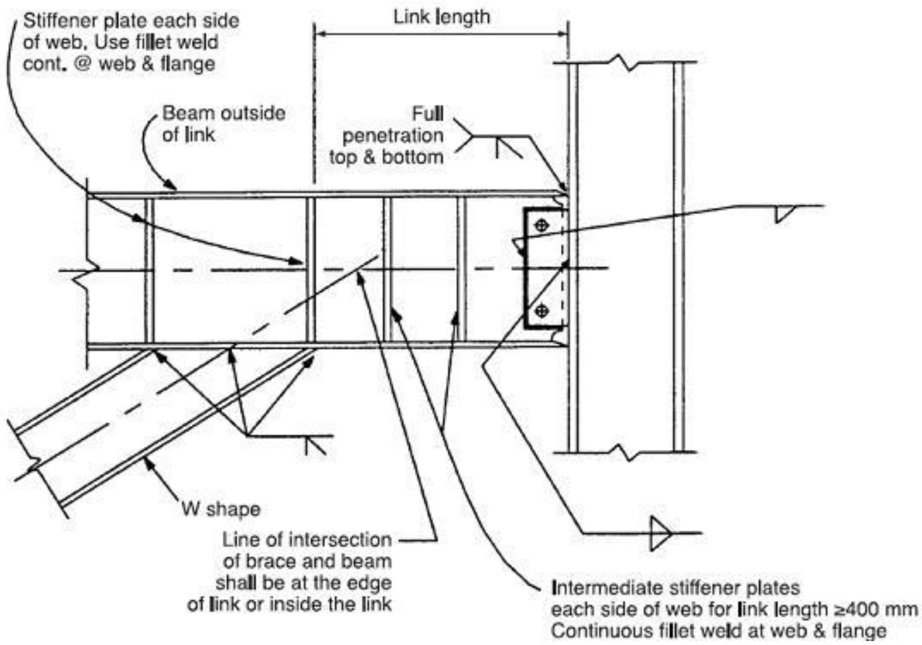


Figure 1.8- Knee bracing system

Short links	$e \leq (1.6\boldsymbol{M}_{\mathrm{p}})/\boldsymbol{V}_{\mathrm{p}}$
Intermediate links	$(1.6\boldsymbol{M}_{\mathrm{p}})/\boldsymbol{V}_{\mathrm{p}} < e < (2.5\boldsymbol{M}_{\mathrm{p}})/\boldsymbol{V}_{\mathrm{p}}$
Long links	$e \geq (2.5\boldsymbol{M}_{\mathrm{p}})/\boldsymbol{V}_{\mathrm{p}}$

Typical details of a short link (from AISC)

1.4.1.3 Arrangement of Tension and Compression Braces

Within any plane of bracing, the compression diagonal braces should balance the tension diagonal braces at each bracing level, in order to avoid tension braces contributing most to lateral resistance in one direction and compression braces in the other. This is to satisfy the general principle that the diagonal elements of bracings should be placed in such a way that the load deflection characteristics of the structure are the same for both positive and negative phases of the loading cycle.

1.4.1.4 Distribution of Ductility Demand in Braces:

It is important to ensure a reasonably uniform distribution of ductility demand in the braces over the height of the structure. If this is not achieved, and the braces at one level yield well before the others, a weak storey might form, concentrating most of the ductility demand at that level. To avoid this, Euro code 8 places a restriction on the ratio of bracing member strength to strength required from the seismic design. The ratio between maximum and minimum values of this ratio must not exceed 125%. There is no similar requirement in AISC.

CHAPTER -2

LITERATURE REVIEW

2.1 General

A brief review of previous studies which focuses on recent contributions related to seismic analysis of multi-storey building using braced frame by various analysis method and past efforts most closely related to the needs of the present work.

Dawn LEHMAN[1] (2004)

In this paper it was concluded that the researcher proposed an innovative design methods based on balancing the control yield mechanism, secondary yield mechanism and critical failure mode to improve seismic performance of gusset plate connection used in concentrically braced frame system. Recommendations were examine for modeling the inelastic and post buckling behaviour of the brace for pushover and dynamic time history performance.

Shawn Johnson[2] (2004)

In this paper it was concluded that Seismic response of braced frames largely depended on the response of braces. In high seismic zones in the United States, two systems were being used at that time; special concentrically braced frames (SCBF) and concentrically braced frames with buckling restrained braces (BRCBF). Braces in SCBF systems develop their inelastic action through compressive buckling and tension yielding. Buckling restrained braces (BRB) were encased in an un bonded, stiff material that restricts brace buckling and they develop their ductility through compression and tension yielding. In both types of systems gusset plate connections were used to connect the brace to the framing elements. These different systems place different demands on the connection by the brace depended on the brace type. Braces in SCBF systems place large axial and out-of plane rotational demands on the brace as a result of brace buckling. The stiffness of BRB can result in large in-plane moment and axial force demands. The connection design must account for these different demands.

A.H. Salmanpour[3] (2008)

In this paper it was concluded that the buckling Restrained braced frames (BRBFs) could more readily satisfy the collapse prevention criteria than the special concentrically braced frames (SCBFs) because the collapse prevention probability of BRBF model was less than 2% and the immediate occupancy probability of BRBF model was 66% where as the collapse prevention probability was about 43%, a value much higher than 2%.

N.Ozhendekci[4] (2008)

In this paper it was concluded that the researcher studied nine eccentrically braced steel frames with various geometries with static pushover analysis. The rotation of load pattern and maximum link rotations pattern were similar and not similar respectively in pushover and inelastic dynamic analysis for EBFs with shear link.

S. Sabouri-Ghomi[5] (2008)

In this paper it was concluded that researcher introduced and applied a method called easy going steel (EGS) theory for improvement of behavior of X bracing system. The lateral stiffness ductility and energy absorption capacity of the system increased and lateral drift decreased with EGS. Stability of the system increases**.**

E. M. Hines[6] (2010)

In this paper it was concluded that the discussions related to the seismic performance of low-ductility steel systems designed for moderate seismic regions had generated new interest in the cost effective design of ductile systems for such regions. Although eccentrically braced frames (EBFs) had a well-established reputation as high-ductility systems and had the potential to offer cost-effective solutions in moderate seismic regions, their system performance had not been widely discussed. This paper discussed the historical development of EBFs and their provisions, highlighting previous studies on EBF system performance. New performance assessment results for EBFs in moderate seismic regions were compared to previous system studies with the intention of clarifying the nature of EBF system performance including: story drift Capacity, response to higher mode effects, and frame overturning forces.

Jonathan Rozon[7] (2012)

In this paper it was concluded that the global seismic response of 3-and 8 story eccentrically braced frames (EBFs), designed for western and eastern North American locations, was studied using nonlinear time history analysis. Analytical models were built in three computer programs. Similar maximum forces were obtained, but the inelastic deformation predictions at the element and global structural levels showed sensitivity to the modeling employed. This feature should be considered in seismic performance assessment or design. Current design methods failed to predict interstory drifts and plastic link rotations, but the study confirmed the strong correlation between the two parameters associated with rigid-plastic behavior.

The influence of yielding and flexural buckling of frame members, other than the links on the global frame performance, was evaluated using the Open Sees model. It was confirmed that the flexural yielding of outer beams is acceptable for EBFs with short and intermediate links, if the combined flexural strength of the braces and beams was at least equal to the expected end-link moments and the braces can resist the associated axial force-bending moment demand. Inelastic response of braces and columns in such frames did not negatively impact the overall frame behavior.

Sanda KoboevicI[8] (2012)

In this paper it was concluded that the researcher performed the global seismic response of 3- and 8- story eccentrically braced frames EBFs using non linear time history analysis. It was found that modeling had limited impact on force response but large influence on deformation response. Peak inter storey drift and plastic link rotation had a strong correlation.

P.SAIRAJ[9] (2014)

In this paper it was concluded that an economic aspects of G+4 multi-storey building designed by using braced frame composite construction. For the ductile performance over all displacement and inter story drift can be effectively controlled by adopting braced frame model. This concept was very usefull for retrofitting of and seismic up gradation of existing multi-storied building.

R. Snehaneela[10] (2015)

In this paper it was concluded that Outrigger braced structures had efficient structural form consist of a central core, comprising braced frames with horizontal cantilever ”outrigger” trusses or girders connecting the core to the outer column. When the structure was loaded horizontally, vertical plane rotation of the core was restrained by the outriggers through tension in windward column and compression in leeward column. The effective structural depth of the building was greatly increased, thus augmenting the lateral stiffness of the building and reducing the lateral deflections and moments in core. In effect, the outriggers join the columns to the core to make the structure behave as a partly composite cantilever. By providing eccentrically braced system in outrigger frame by varying the size of links and analyzing it. Push over analysis was carried out by varying the link size using computer programs, Sap 2007 to understand their seismic performance.

The ductile behavior of eccentrically braced frame was highly desirable for structures subjected to strong ground motion. Maximum stiffness, strength, ductility and energy dissipation capacity are provided by eccentrically braced frame. Studies were conducted on the use of outrigger frame for the high steel building subjected to earthquake load. Braces were designed not to buckle, regardless of the severity of lateral loading on the frame. Thus eccentrically braced frame ensured safety against seismic activity.

Adithya.M[11] (2015)

In this paper it was concluded that the resistance to the lateral loads from wind or from an earthquake was the reason for the evolution of various structural systems. Bracing system was one such structural system which forms an integral part of the frame. Such a structure had to be analyzed before arriving at the best type or effective arrangement of bracing. This project was about the efficiency of using different types of bracings and with different steel profiles for bracing members for multi-storey steel frames. ETABS software was used to obtain the design of frames and bracing systems with the least weight and appropriate steel section selection for beams, columns and bracing members from the standard set of steel sections.

A three dimensional structure was taken with 4 horizontal bays of width 4 meters, and 20 stories was taken with storey height of 3m. The beams and columns were designed to withstand dead and live load only. Wind load and Earthquake loads were taken by bracings. The bracings were provided only on the peripheral columns. Maximum of 4 bracings were used in a storey for economic purposes. In this study, an attempt had been made to study the effects of various types of bracing systems, its position in the building and cost of the bracing system with respect to minimum drift index and inter storey drift.

Shachindra Kumar Chadhar[12] (2015)

In this paper it was concluded that Steel bracing system was one of the effective measures for resisting the horizontal forces like seismic and wind forces in reinforced concrete multistory buildings. Bracing member’s were subjected to tension and compression; subsequently they were provided to take these forces. Steel bracing framework expanded the stiffness and strength of the RC multistory building and reduced their deformation. Present study was based on seismic analysis of RC building frames with V type bracing and inverted V type bracing. Seismic coefficient method (linear static analysis) had been conducted to evaluate the effect of different arrangements of bracing members in the building frame and influence of the different steel cross-section.

For this study, a fifteen story building had assumed to be situated at seismic zone IV as per the seismic zone map of India. Three steel profiles ISA, ISMC and ISMB were utilized as bracing members by considering same cross- sectional area. For modeling and analysis work computer software StaadproV8i was used. Result of this study revealed that inverted

V bracing reduces the bending moment, shear force, storey drift and node displacement significantly. It was also found that the various arrangements of bracing systems had great influence on seismic performance of the building frame and double angle section give better result as compared to ISMB and ISMC section.

Anitha M.[13] (2015)

In this paper it was concluded that Steel had become the predominate material for the construction of bridges, buildings, towers and other structures. Its great strength, uniformity, light weight and many other desirable properties make it the material of choice for numerous structures such as steel bridges, high rise buildings, towers and other structures. The advantages in general credited to steel as a structural design material were high strength/weight ratio ductility, predictable material properties, speed of erection structures, quality of construction, ease of repair, adaptation of prefabrication, repetitive use, expanding existing structures and fatigue strength. Steel structures in areas prone to high seismic activity should satisfy two main conditions. It should be stiff enough to control the drift to prevent structural damage, and also must have sufficient ductility to prevent collapse caused by dramatic deformation.

Bracing element in structural system played vital role in structural behavior during earthquake. Steel bracing was an effective and economical solution for resisting lateral forces in a framed structure. Knee braced steel frame was that which had got excellent ductility and lateral stiffness. Since the knee element was properly fused, yielding occurs only to the knee element and no damage to major elements. Compared to other type of bracings it performed better during a seismic activity. In this study the seismic effect of different types of steel bracings was studied. A comparison of knee braced steel frame with other types of bracings had been done. Performance of each frame had been studied using non-linear static analysis and non linear time history analysis. Various parameters such as displacement and stiffness were studied.

Shengfang Qiao[14] (2016)

In this paper it was concluded that seismic analysis for steel frame structure with brace configuration using topology optimization based on truss-like material model was studied. The initial design domain for topology optimization was determined according to original steel frame structure and filled with truss-like members. Hence the initial truss-like continuum was established. The densities and orientation of truss-like members at any point were taken as design variables in finite element analysis.

The topology optimization problem of least-weight truss-like continuum with stress constraints was solved. The orientations and densities of members in truss-like continuum were optimized and updated by fully-stressed criterion in every iteration. The optimized truss-like continuum was founded after finite element analysis was finished. The optimal bracing system was established based on optimized truss-like continuum without numerical instability. Seismic performance for steel frame structures was derived using dynamic time-history analysis. A numerical example showed the advantage for frame structures with brace configuration using topology optimization in seismic performance.

Muhammed Tahir Khaleel[15] (2016)

In this paper it was concluded that Lateral stability was important for the steel structures in the seismic zones. Effective way to increase the lateral strength was by means of bracing system. An attempt was made to analyze the effect of seismic force on Regular and Irregular Steel framed high rise building with different bracing system and also to found the best bracing system. The building was modeled and analyzed using ETABS and sections were selected based on their capability to control the maximum lateral storey displacements. The Zone V as per IS 1893-2002 was selected for the study. Analysis was carried out by Equivalent Static Method and Response Spectrum Method. Various parameters such as, displacement and base shear were studied. From the study it could be concluded that for both regular and irregular building, cross bracings are the best bracing system for reducing the storey displacement. It was also observed that base Shear is high in cross bracing system because of the increased stiffness.

Sara Raphael[16] (2016)

In this paper it was concluded that steel structures tend to be more economical than concrete structures for tall buildings and large span buildings and bridges due to its large strength to weight ratio. The steel structures in the areas of high seismic activity should be stiff enough to prevent structural damage and have sufficient ductility to prevent collapse. Bracing was the technique for resisting the lateral forces in a framed structure in an effective and economical way. Knee braced steel frame was that which had good ductility and lateral stiffness compared with other types of bracings. In knee braced steel frame, yielding occur only to the knee element and no damage to major elements. In this study the seismic effect of knee braced steel frames was studied. A comparison of double knee braced steel frame with single knee braced frame had been done through pushover analysis. An angle study of knee member was conducted to study the effect of knee angle through a non-linear analysis. The parameters such as displacement and stiffness were investigated.

Mrutyunjay.S.Hasarani[17] (2016)

In this paper it was concluded that in past decades, the steel structures had played an important role in growing construction industry. It was essential to design a structure to perform well under earthquake loads, especially in seismic prone areas. The seismic design of a multi-story steel frame building was carried as per IS 800: 2007. By introducing steel bracings in a structure, its shear capacity could be increased. They could be also used as strengthening an existing building. In various patterns steel bracings could be arranged. A 15-story steel frame building was designed for eccentric K- and V- bracings as per the IS 800: 2007. Eccentric K and V type bracings in a steel frame having different configurations were selected for this study. Performance of the each frame was studied under Response Spectrum and Time History analysis. The results of analysis had shown that, performance of the eccentric V-bracing system was better than eccentric K-bracing system.

Sreehma.k.k[18] (2016)

In this paper it was concluded that steel structures were exhibit ductile behaviour when subjected to transient lateral loading, caused by wind or earthquake action. Steel bracings were lateral load resisting system used in seismic region. In eccentrically braced frames, a distance was either created between the two ends of the bracing members, or between the bracing member and the column, or between the bracing member and the beam. The created distance was called link. The main function of the link was to provide a weak section in the frame which provides plastic deformation capacity and the energy released by the earthquake.

EBF configuration was similar to traditional braced frames with the exception that at least one end of each brace must be eccentrically connected to the frame. The energy dissipation was achieved through the yielding of a beam segment called the link, while the other frame members, including outer beam segments, braces, and columns, should remain essentially elastic. This study dealt with eccentrically braced frames with short link. Assessed the performance of different types of eccentrically braced frames by performing seismic analysis over the structure. The variation of performance with change in link length, height of the building was also considered in this study**.**

Pooja. B. Suryawanshi[19] (2016)

In this paper it was concluded that from last few decades steel structures played an important role in construction industry. Steel was most essential material for building construction. Steel structure were ductile in nature also they had good strength and stability. Steel structures give sufficient warning prior to the failure by means of excessive deformations. The design of structure should be such that it could sustain in seismic load. This paper emphasis on a analysis of nonlinear and static pushover for the G+5 storey steel frame building with braced and without braced systems. A variation of the lateral shear force with respect to the lateral deformation of steel frame building was calculated by pushover analysis. Shear capacity of any structure was enhanced with the application of the steel bracing. The G+5 storey industrial steel frame building was designed for crossed X bracing and V bracing and comparison was made between the bare frame and frame with bracing and performance point of structure was carried out through nonlinear static pushover analysis. Analysis was done by using the ETABS -2015 software.

Swetha Sunil[20] (2017)

In this paper it was concluded that previous earthquakes showed that not only non-engineered structures, but also engineered structures needed to be designed in such a way that they perform better under seismic loading. Structures situated in high seismic risk areas might be susceptible to severe damage in a major earthquake. Shear wall and steel bracings were the most popular system to resist lateral load due to earthquake. Bracing system was one of the retrofitting techniques and it provided strength and stiffness to existing building against lateral forces. Bracing could be applied as eccentric bracing or concentric bracing. There were different possibilities to arrange steel bracings such as Diagonal, X, V, Inverted V. Bracing increased lateral stiffness and they increased the natural frequency and usually decreased the lateral drift. This study concentrated on seismic studies of reinforced concrete building with different bracing system. From the study it was found that X bracing was more effective bracing system compared to other bracings. Further study was carried out with X bracing with different aspect ratio by changing the height of the building. Different heights selected for the study were 6m, 9m, 12m. ETABS 2016 software was used for the study. Response spectrum analysis was carried out. The results such as storey drift and displacements were compared.

M.K.Alam[21] (2017)

In this paper it was concluded that the researcher investigated and compared the behavior of steel braced structures with the help of time history analysis with the purpose of designing the most effective steel structure for resisting the lateral loads caused by earthquakes. In this study, a ten-storied building comprising of 2800 sq ft plan area was first designed with sophisticated finite element software called SAP 2000 V14 by incorporating gravity load as per BNBC. The building was optimally redesigned with concentric and eccentric bracing system. Earthquake data of Imperial Valley for four different magnitudes such as 5.0, 5.5, 5.6 and 6.95 had been selected for time history analysis.

The parameters for the study were column bending moment, shear force and joint displacement. It was concluded from observing the results of dynamic analysis that the cross braced structure carries higher bending moment and shear force at base of corner column than the other two cases. The cross braced structure gave small displacement than without braced type of structure which is 0.21 inch. Concentrically braced structure was 1.05 times and unbraced structure is 1.15 times of the weight of the eccentrically braced structure. So the study concludes that eccentric braced was more economic than cross braced system but the cross braced system was considered safer due to the displacement, moment and shear being more than that of eccentric braced structure.

Sachin Metre[22] (2017)

In this paper it was concluded that bracings in steel structure were commonly used because it could withstand lateral loads due to earthquake, wind, etc. It was one of the best method for lateral load resisting systems. This system provided to minimize the lateral deflection of structure. In this thesis 25 storey steel frame was analyzed for the rectangular plan of 25x15 m by considering Z-II and Z-V for soil type-II. The analyses were done by using the ETABS 2016 software. In this paper models were compared for different types of bracing such as X, inverted V and Single diagonal bracing by placing in different locations like Outer Edge, Inner Edge and at centre in X and Y-directions for the bracing angle ISA 130x130x8. Results were obtained by considering the parameters like storey displacement, storey drift and storey shear.

Arathi Thamarakshan[23] (2017)

In this paper it was concluded that Steel braced frame was one of the structural systems used to resist earthquake loads in structures. Steel bracing was economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. Bracing could be used as retrofit as well. There were various types of steel bracings available. In the present study, steel frame with various configurations were analyzed by ETABS software. The results of time history analysis were then compared with the results of the pushover analysis. The study also involving the analysis for suggesting the best configurations.

Safvana p[24] (2018)

In this paper it was concluded that the steel braced frame was one of the structural systems used to resist earthquake loads in multistoried buildings. Many existing reinforced concrete buildings need retrofit to overcome deficiencies to resist seismic loads. The use of steel bracing systems for strengthening or retrofitting seismically inadequate reinforced concrete frames was a viable solution for enhancing earthquake resistance. Steel bracing was economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In this study, the seismic study of conventional x brace, zipper brace and SBS in composite structures using ETABS software was investigated.

The bracing was provided at each corner. a G+6, G+12 and G+18 story with 6 bay in x direction and 3 bay in y direction was analyzed using ETABS.. The effectiveness of various types of steel bracing was examined. The effect of the distribution of the steel bracing along the height of the composite structure on the seismic performance of the rehabilitated building is studied. Provision of conventional x braced, zipper braced and SBS was provided in each stories. The percentage reduction in lateral displacement was found out. It was found that the zipper of steel bracing significantly contributes to the reduction in displacement and SBS contributes in the reduction of story shear compared to conventional x bracings.

CHAPTER 3

WORK METHODOLOGY

3.1 General

The research methodology was started with problem identification in RC multi-storey buildings under seismic activity and setting up the objectives and scope of study. Then all the related background information were collected and studied for the literature review for knowledge updating. The major part of this study was structural modeling and computational analysis using time history analysis method in ETABs. The results thus obtained then being assessed, interpreted and compared.

The work methodology can be briefly divided into following:

1) Literature review and problem identification
2) Description of building plan
3) Problem formulation
4) Method of analysis
5) Structural modelling
6) Analysis and results using ETABs software
7) Conclusions and suggestions

A RC Multi-storey building of G+14 storey was analyzed to resist the gravity loads and earthquake loads using ETABs software. Seismic parameters such as storey drift, storey displacement, storey stiffness and fundamental time period were computed in the analysis phase using ETABs. The result obtained from the analysis was compared among different bracing system.

The time history analysis was used which was most suited to the present problem and was used in the analysis and conclusions were made on the basis of analysis performed. This is the summary of the work methodology adopted in achieving the target objectives defined.

3.2 Description of Building Plan

For analysis a 15 storied high rise building is modelled in ETABs software. The building does not represent any real existing building. RC framed (G+14) multi-storey building have same floor plan with 6 bays of 3m each along longitudinal direction and along transverse direction. The building is 45.5m high .The building is analyzed by Time history Analysis, which is a linear dynamic analysis. Dynamic Analysis is adopted since it gives better results than static analysis.

The dead load is taken as wall load and parapet wall load which depend upon the wall thickness and the height of wall. the thickness of wall is taken as 250 mm and the unit weight of brick is 20KN/m^3. The live load and the roof load are taken as 3 KN/m^2 and 2.5 KN/m^2 according to IS 875:1987 (part 2). All the specifications of the frame are given in Table 1.

Table 3.1

1.	Building type	Residential building
2.	No. of storeys	G+14
3.	Bottom storey height	3.5m
4.	Total height	45.5m
5.	Floor height	3m
6.	Size of column	300mm*400mm
7.	Size of beam	230mm*300mm
8.	Thickness of slab	150mm
9.	Masonry wall thickness	250mm

10.	Seismic zone	III
11.	Importance factor	1
12.	Response reduction factor	5
13.	Soil type	II
14.	Grade of concrete	M20
15.	Grade of steel	Fe250
16.	Unit weight of concrete	$25kN/m^3$
17.	Unit weight of PCC	$24\ kN/m^3$
18.	Unit weight of brick	$20\ kN/m^3$
19.	Unit weight of plaster	$21\ kN/m^3$
20.	Damping	5%
21.	Live load	$3KN/m^2$
22.	Roof	$2.5KN/m^2$
23.	IS Code for concrete	IS 456:2000
24.	IS Code for earthquake	IS 1893:2002 (part I)
25.	Self weight factor	1
26.	Bracing member	Steel I section
27.	Wall load	13.5 KN/m
28.	Parapet wall load	7KN/m

Dimension of Bracing Members

We have taken steel I- section of Fe250 Whose Top depth is 250mm. the width of Top & bottom both flanges in I- section is taken as 150mm. The thickness of the Top and bottom flanges taken as 10mm and the thickness of the web in the I -section is taken as 8mm.

Load combination-

Building is analyzed on the basis of Various load combinations in the limit state of design for reinforced concrete structures as per IS 1893:2002(part1).these all are given below:

1) 1.5(DL+IL)

2) 1.2 $(DL+IL+EL_x)$

3) 1.2 $(DL+LL+EL_Y)$

4) 1.2$(DL+IL-EL_X)$

5) 1.2$(DL+IL-EL_Y)$

6) 1.5$(DL+EL_X)$

7) 1.5$(DL+EL_Y)$

8) 1.5$(DL-EL_X)$

9) 1.5$(DL-EL_Y)$

10) 0.9DL+1.5EL_X

11) 0.9DL+1.5EL_Y

12) 0.9DL-1.5EL_X

13) 0.9DL-1.5EL_Y

As we know that 1.5(DL+IL) is not the Earthquake load combo. It is purely the gravity load combination. But when we are designing a structure, we need to consider all the different load combinations as specified by the respective design code . So, 1.5 (DL+LL) has nothing to do with the earthquake loading. 1.5(DL+LL) as defined in the IS-1893 code is one of the load combination as specified in IS 456 for the RCC structure. See below the factors these factors are same as IS 456:2000.

Load Combination	Limit State of Collapse			Limit States of Serviceability		
	DL	*IL*	*WL*	*DL*	*IL*	*WL*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
DL + IL	1.5		1.0	1.0	1.0	-
DL + WL	1.5 or 0.9[1)]	-	1.5	1.0	-	1.0
DL + IL + WL	1.2			1.0	0.8	0.8

Showing Load combination

3.3 Problem Formulation

The study was focused on the behaviour of the multi-storey building with and without bracing under seismic activity. As it is clear from the previous studies that multi-storey buildings are unstable for seismic forces. The analysis was done as per IS Code provision using ETABs software. In this comparison is done for G+14 multi storey residential building.

The seismic data is taken according to the IS 1893(Part 1):2002 for the Zone III as given below in table 2.

Table 3.2 Seismic Data

Serial No	Model Description	
1	Zone	III
2	Zone Factor	0.16
3	Type of building	Residential
4	Importance Factor	1
5	Soil Type	II
6	Soil Condition	Medium
7	Damping Ratio	5%
8	Response Reduction Factors	5

3.4 Method of Analysis - Seismic analysis may be carried out by:

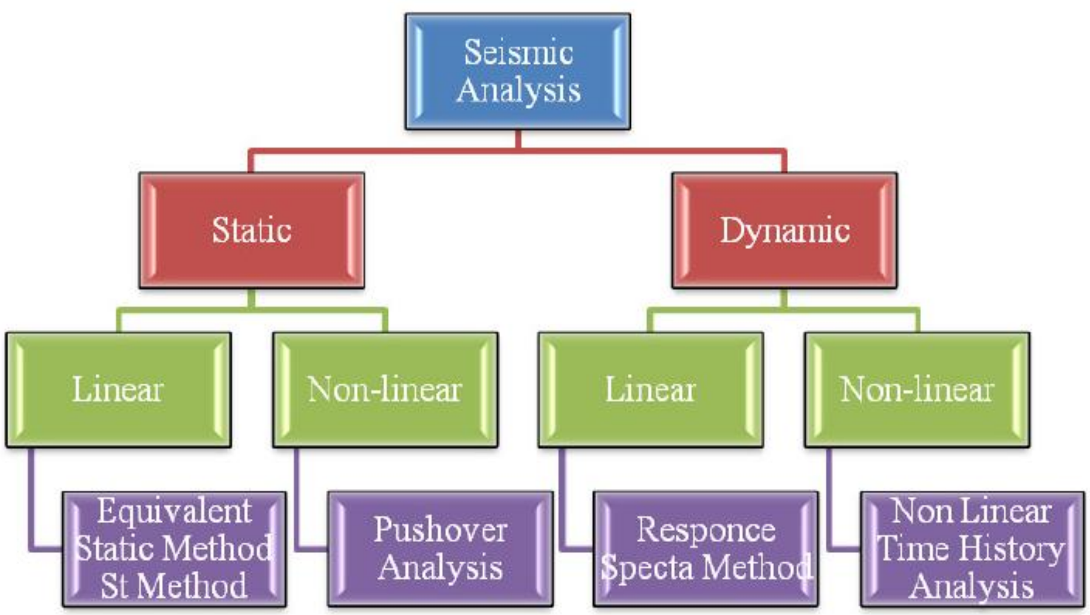


Fig.3.1- Method of Analysis

3.4.1 Static Method

The design base shear shall be computed as a whole, and then be distributed along the height of the building based on simple formulas appropriate for the building with regular distributin of mass and stiffness according to IS Code 1893 (part 1): 2002.

3.4.1.1 Equivalent static method

This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. 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 ground 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 applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting. To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).

For determination of seismic forces, the country is classified in four seismic zones:

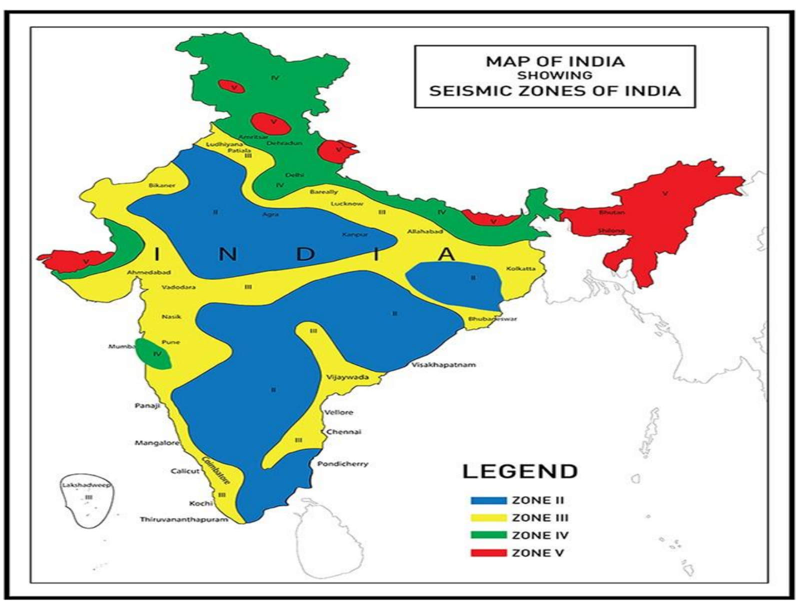


Fig 3.2- seismic zones of India

Each zone has their own zone factor value and as per IS 1893 (Part 1):2002 these values are given below:

Seismic Zone Factor (1)	II (2)	III (3)	IV (4)	V (5)
Z	0.10	0.16	0.24	0.36

As per IS Code 1893(part 1) :2002 the following were the major steps for determining the seismic forces:

3.4.1.1.1 Determination of base shear

The total design lateral force or design base shear along any principal dirction shall be determined by the following expression,(clause 7.6.1 of IS 1893 (part 1): 2002)

$$V_b = A_h * W$$

Where, A_h= Design horizontal seismic coefficient for structure

W= Seismic weight of the building

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{Sa}{g}\right)}{\left(\frac{R}{I}\right)}$$

Where, R=response reduction factor

Z= zone factor

I= importance factor

Sa/g is the average response acceleration coefficient for rock and soil sites as given in figure 2 of IS 1893:2002 (part 1).

The values are given for 5% damping of the structure for S_a/g.

For rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.40 \\ 1.00/T & 0.40 \leq T \leq 4.00 \end{cases}$$

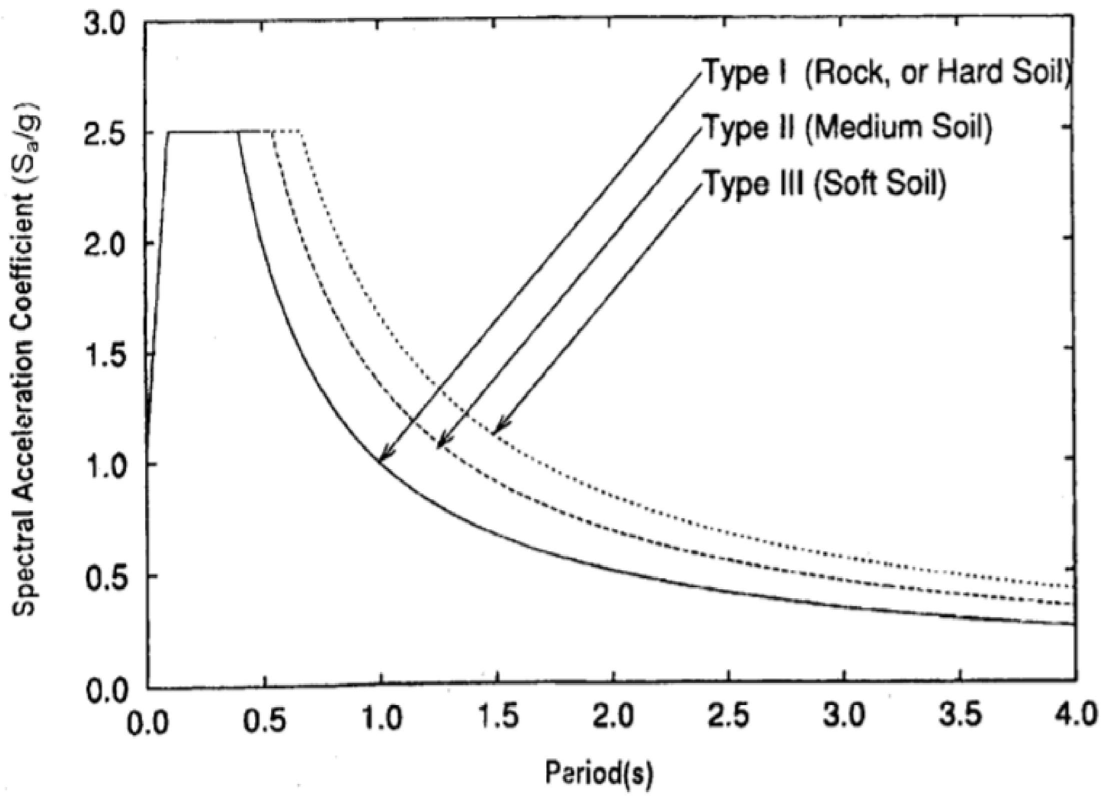
For medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.55 \\ 1.36/T & 0.55 \leq T \leq 4.00 \end{cases}$$

For soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.67 \\ 1.67/T & 0.67 \leq T \leq 4.00 \end{cases}$$

Where T is the fundamental natural period for buildings calculated as per clause 7.6 of IS 1893:2002 (part1) and shown further.



3.4.1.1.2 Lateral distribution of base shear

In equivalent lateral force procedure, the magnitude of lateral force is based on the fundamentals period of vibration, IS 1893 (part 1):2002 uses of parabolic distribution of the lateral force along the height of the building as per the following expression:

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B$$

Where,

Q_i= Design lateral force at floor i

W_i= seismic weight of the floor i

h_i= height of the floor i from the base

n= number of storeys of the building at which masses are located.

3.4.1.1.3 Fundamental natural time period

The approximate fundamental natural period of vibration (T), in seconds, of all other buildings, including moment resisting frame buildings with brick infill panels, maybe estimated by the empirical expression given in clause 7.6.2 of IS 1893(part 1):2002.

$T_a=0.075h^{0.75}$ for RC frame building without brick infill wall

$T_a= 0.085h^{0.75}$ for steel frame building without brick infill wall

$T_a=0.09h/\sqrt{d}$ all other buildings including moment resisting RC frame with brick infill

3.4.1.2 Nonlinear static analysis

In general, linear procedures are applicable when the structure is expected to remain nearly elastic for the level of ground motion or when the design results in nearly uniform distribution of nonlinear response throughout the structure. As the performance objective of the structure implies greater inelastic demands, the uncertainty with linear procedures increases to a point that requires a high level of conservatism in demand assumptions and acceptability criteria to avoid unintended performance. Therefore, procedures incorporating inelastic analysis can reduce the uncertainty and conservatism.

This approach is also known as "pushover" analysis. A pattern of forces is applied to a structural model that includes non-linear properties (such as steel yield), and the total force is plotted against a reference displacement to define a capacity curve. This can then be combined with a demand curve (typically in the form of an acceleration-displacement response spectrum (ADRS). This essentially reduces the problem to a single degree of freedom (SDOF) system. Nonlinear static procedures use equivalent SDOF structural models and represent seismic ground motion with response spectra. Story drifts and component actions are related subsequently to the global demand parameter by the pushover or capacity curves that are the basis of the non-linear static procedures.

3.4.2.1 Linear Dynamic Methods

Static procedures are appropriate when higher mode effects are not significant. This is generally true for short, regular buildings. Therefore, for tall buildings, buildings with torsion irregularities, or non-orthogonal systems, a dynamic procedure is required. In the linear dynamic procedure, the building is modeled as a multi-degree-of-freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled using either modal spectral analysis or time history analysis but in both cases, the corresponding internal forces and displacements are determined using linear elastic analysis. In linear dynamic analysis, the response of the structure to ground motion is calculated in the time domain, and all phase information is therefore maintained. Only linear properties are assumed. The analytical method can use modal decomposition as a means of reducing the degrees of freedom in the analysis.

The advantage of linear dynamic procedures with respect to linear static procedures is that higher modes can be considered. However, they are based on linear elastic response and hence the applicability decreases with increasing nonlinear behaviour, which is approximated by global force reduction factors. The type of linear dynamic methods is as follows-

3.4.2.1.1 Response Spectrum Analysis

Response spectrum analysis is a procedure for calculating the maximum response of a structure when applied with ground motion. Each of the vibration modes that are considered are assumed to respond independently as a single degree of freedom system. Design codes specify response spectra which determine the base acceleration applied to each mode according to its period (the number of seconds required for a cycle of vibration).Having determined the response of each vibration mode to the excitation, it is necessary to obtain the response of the structure by combining the effects of each vibration mode because the maximum response of each mode will not necessarily occur at the same instant, the statistical maximum response, where damping is zero, is taken as sum of squares (SRSS) of the individual responses.

The results of response spectrum are all absolute extreme values and so they need to be combined as they do not correspond to any equilibrium state nor they take place at the same time. There are several methods to execute this , one of them being the (SRSS) method, Square root of sum of squares method. In this method , the maximum response in terms of given parameter, G (displacement, acceleration, velocity) may be estimated through the square root of sum of m modal response squares, contributing to global response:

$$G = \Sigma mn=1 (Gn)2$$

3.4.2.2 Nonlinear dynamic analysis

Nonlinear dynamic analysis utilizes the combination of ground motion records with a detailed structural model, therefore is capable of producing results with relatively low uncertainty. In nonlinear dynamic analyses, the detailed structural model subjected to a ground-motion record produces estimates of component deformations for each degree of freedom in the model and the modal responses are combined using schemes such as the square-root-sum-of-squares.

In non-linear dynamic analysis, the non-linear properties of the structure are considered as part of a time domain analysis. This approach is the most rigorous, and is required by some building codes for buildings of unusual configuration or of special importance. However, the calculated response can be very sensitive to the characteristics of the individual ground motion used as seismic input; therefore, several analyses are required using different ground motion records to achieve a reliable estimation of the probabilistic distribution of structural response. Since the properties of the seismic response depend on the intensity, or severity, of the seismic shaking, a comprehensive assessment calls for numerous nonlinear dynamic analyses at various levels of intensity to represent different possible earthquake scenarios.

3.4.2.2.1 Time History Method

It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. Time history analysis is a step-by- step analysis of the dynamic response of a structure to a specified loading that may vary with time. A full time history will give the response of a structure over time during and after the application of a load. To find the full time history of a structure's response A linear time history analysis overcomes all the disadvantages of a modal response spectrum analysis provided non linear behaviour is not involving. This method requires greater computational efforts for calculating the response at discrete times. It is used to determine the dynamic response of a structureto arbitrary loading

3.4.3 Method chosen for analysis – "Time History Analysis Method"

Reason- Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed. In linear dynamic method, the structures is modeled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled utilizing time history analysis, the displacements and internal forces are found using linear elastic analysis. The playing point of linear dynamic procedure as for linear static procedure is that higher modes could be taken into account.

3.4.4 Parameters considered for analysis

1. Storey drift
2. Storey displacement
3. Fundamental time period
4. Storey stiffness

3.4.4.1 Stoey drift- It is the relative displacement of one level relative to other level above or below. According to IS 1893(Part 1):2002 (part 1), the storey drift should not exceed 0.004 times of relative storey height.

3.4.4.2 Storey displacement- It is the displacement of each storey with respect to ground level. According to IS 1893 (part1) :2002 the max value of displacement is 1/250 times of storey height with respect to ground.

3.4.4.3 Fundamental time period- According to IS 1893 (Part 1):2002 it is the first (longest) modal time period of vibration.

3.4.4.4 Storey stiffness- As per IS 1893(Part 1):2002 the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of average lateral stiffness of the three storey above.

3.5 Structural Modeling

Software ETABs is used for seismic analysis and to study the behaviour of multistorey building with and without bracing. Different models are made and compared with different parametres of analysis.Complete analysis including structural modeling is performed in this software.

For the purpose of this study, a RC framed (G+14) multistory building having same floor plan with 6 bays of 3m each along longitudinal direction and along transverse direction as shown in figure 3.3. Four models with different types of bracings were selected in order to determine the behavior of structural steel during seismic activity. The columns are fixed at the ground and are taken as restrains. The total height of the building is 45.5.The bottom storey height is 3.5m and rest are of 3m. All the values of loads and dimensions are given in table no.3.1.the figure 3.3 shows the plan of the building.

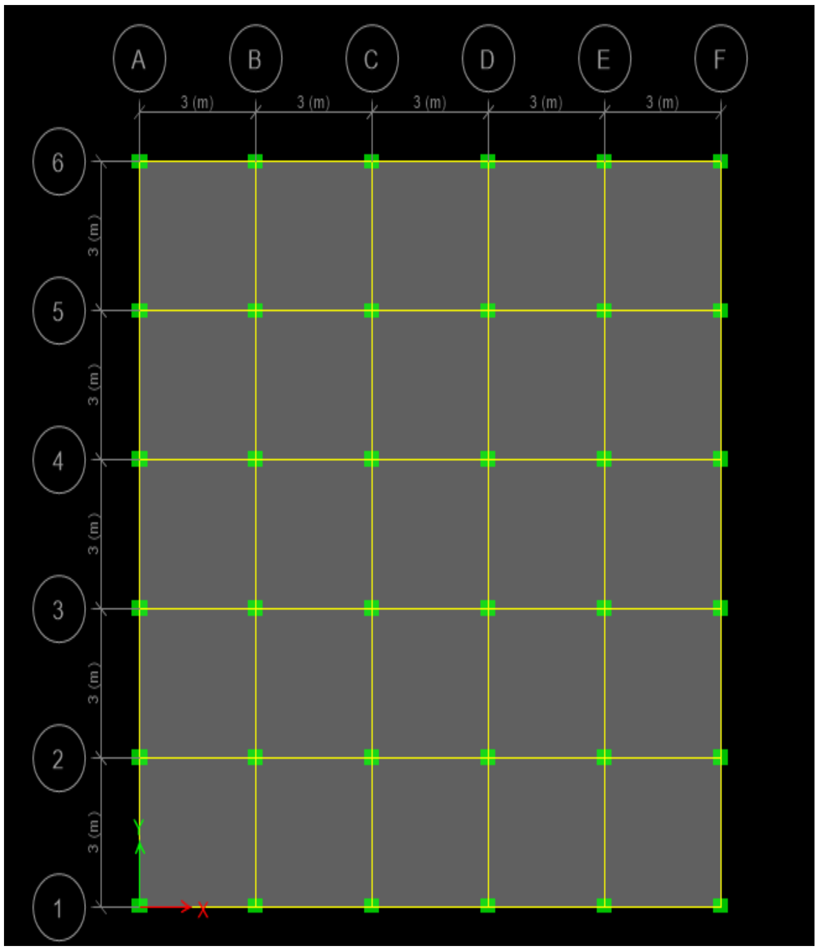


Fig.3.3- Plan of Building

The four models are selected for the study which are shown below. the figure 3.4 and 3.5 shows the 3D view and elevation of the building without bracing.

MODEL 1- BUILDING WITHOUT BRACING

In this model we have not provided any bracing. This is simple RC framed structure. The figure 2 and 3 shows the 3D view and elevation of the building without bracing.

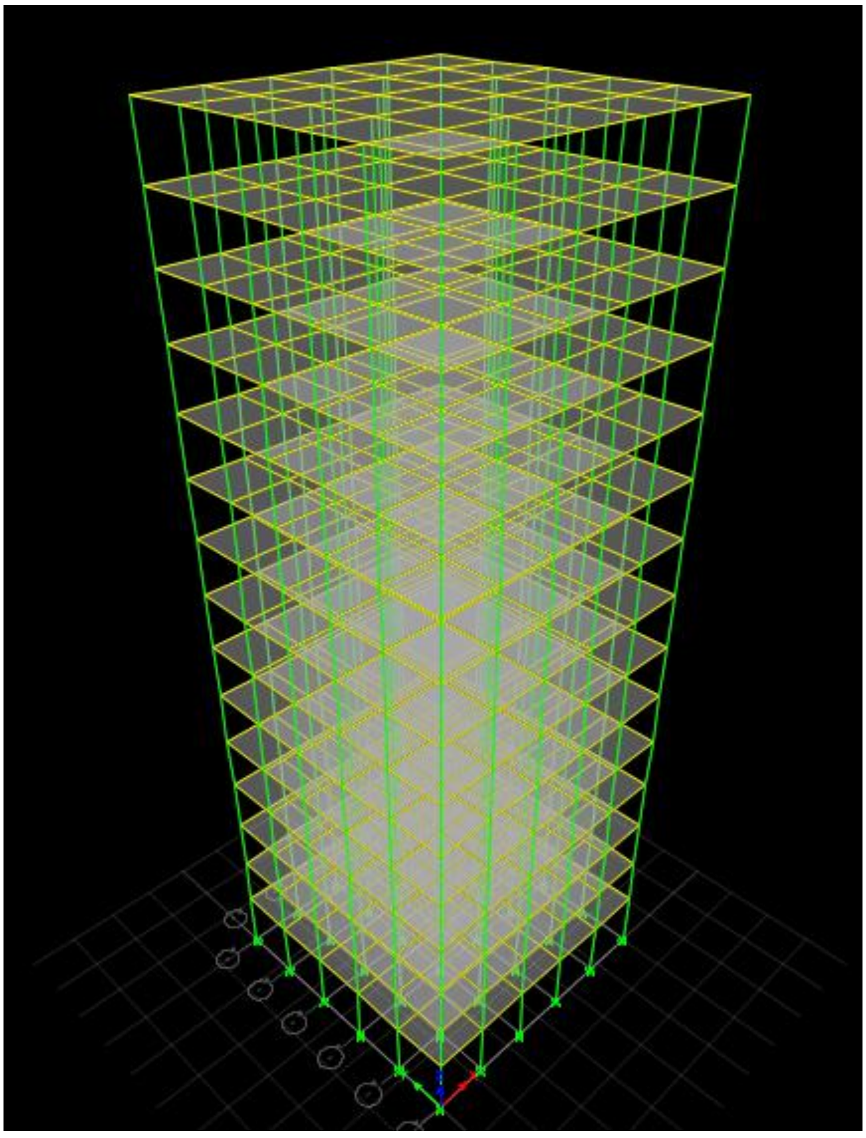


FIG.3.4- 3D View of Building Without Bracing

ELEVATION OF BUILDING WITHOUT BRACING

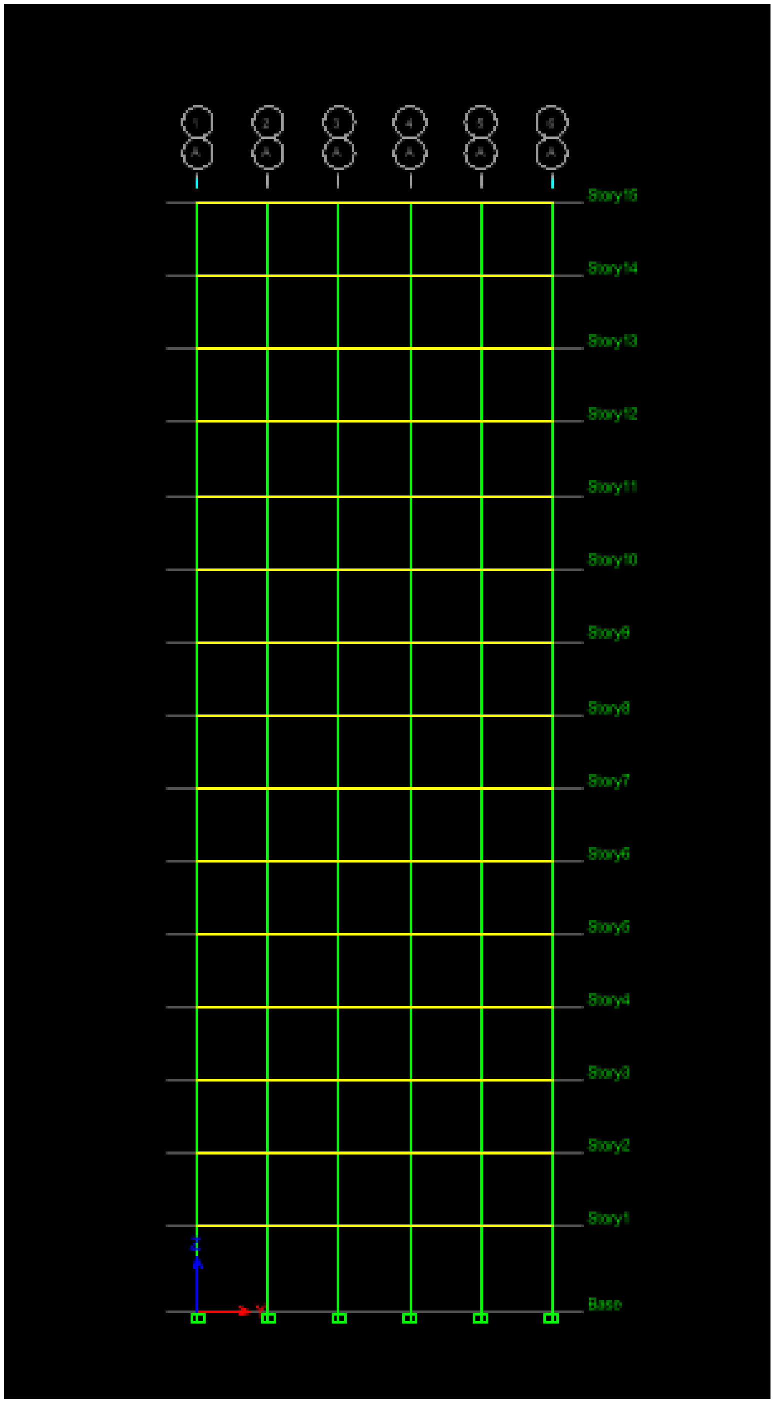


FIG.3.5- Elevation View of Building Without Bracing

MODEL 2- BUILDING WITH X- BRACING

In this model we have applied X bracing all over the four sides of the building.figure 3.6 and 3.7 shows the 3D view and elevation of the building with X bracing.

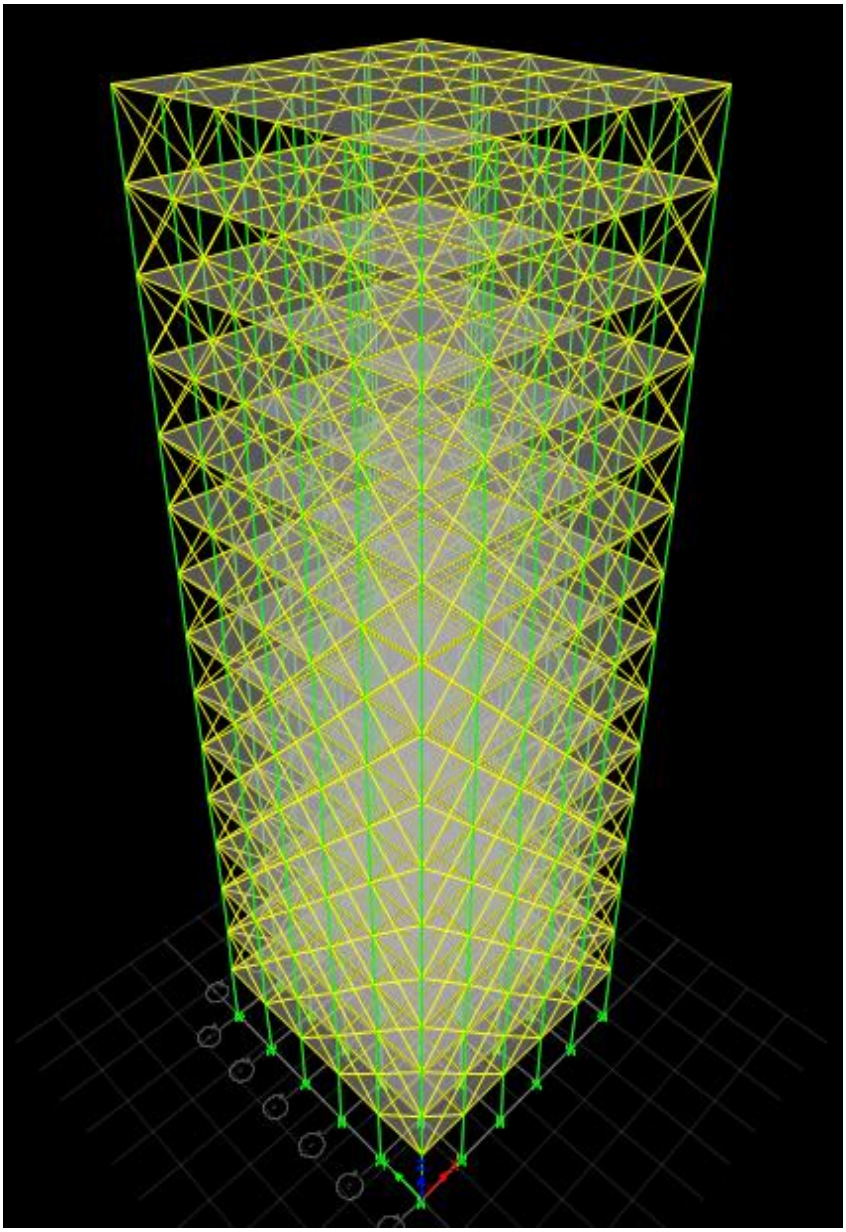


FIG.3.6- 3D View of Building With X- Bracing

ELEVATION OF BUILDING WITH X-BRACING

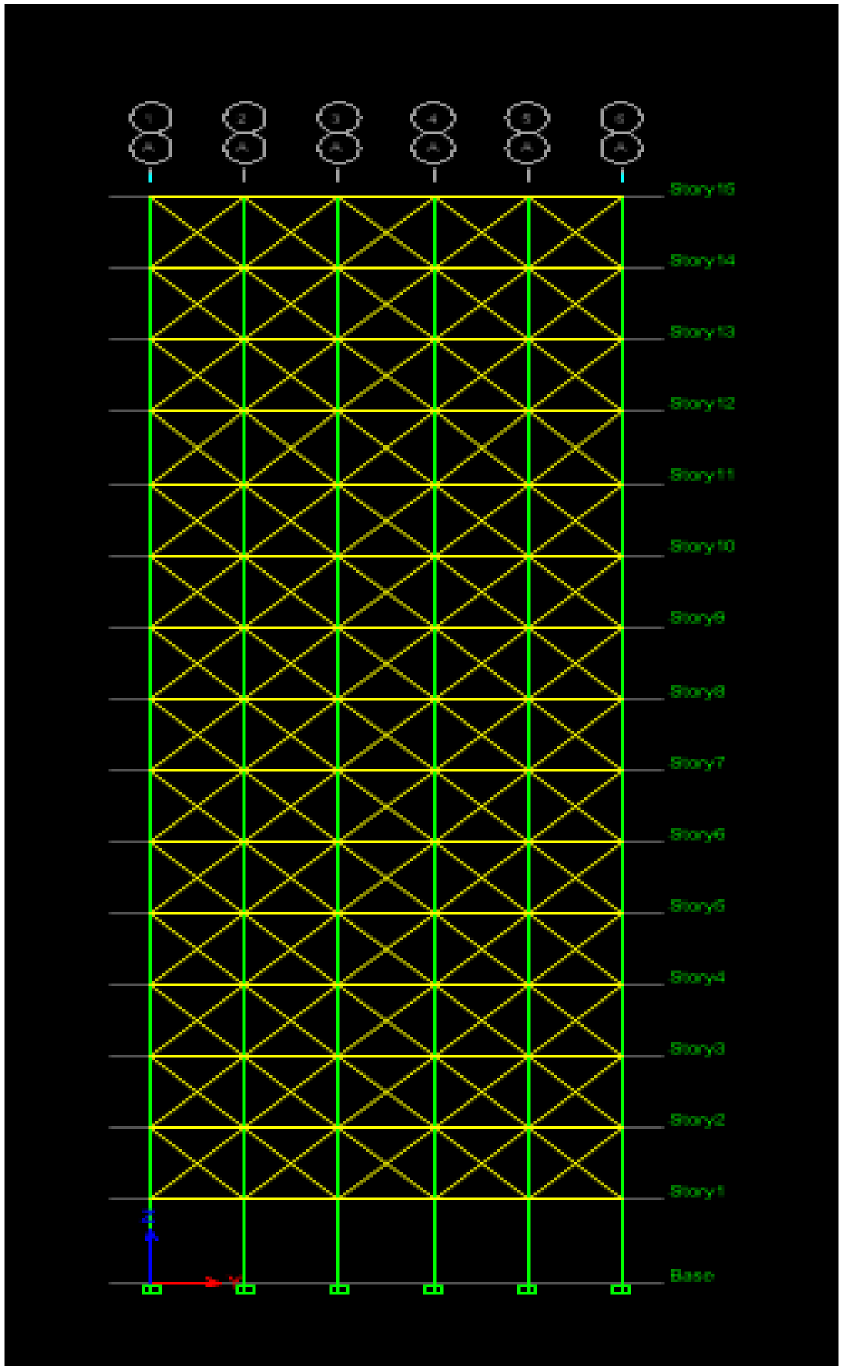


Fig. 3.7- Elevation View of Building With X-Bracing

MODEL 3-BUILDING WITH V-BRACING

In this model we have applied V bracing all over the four sides of the building. the figure 3.8 and 3.9 shows the 3D view and elevation of the building with V bracing.

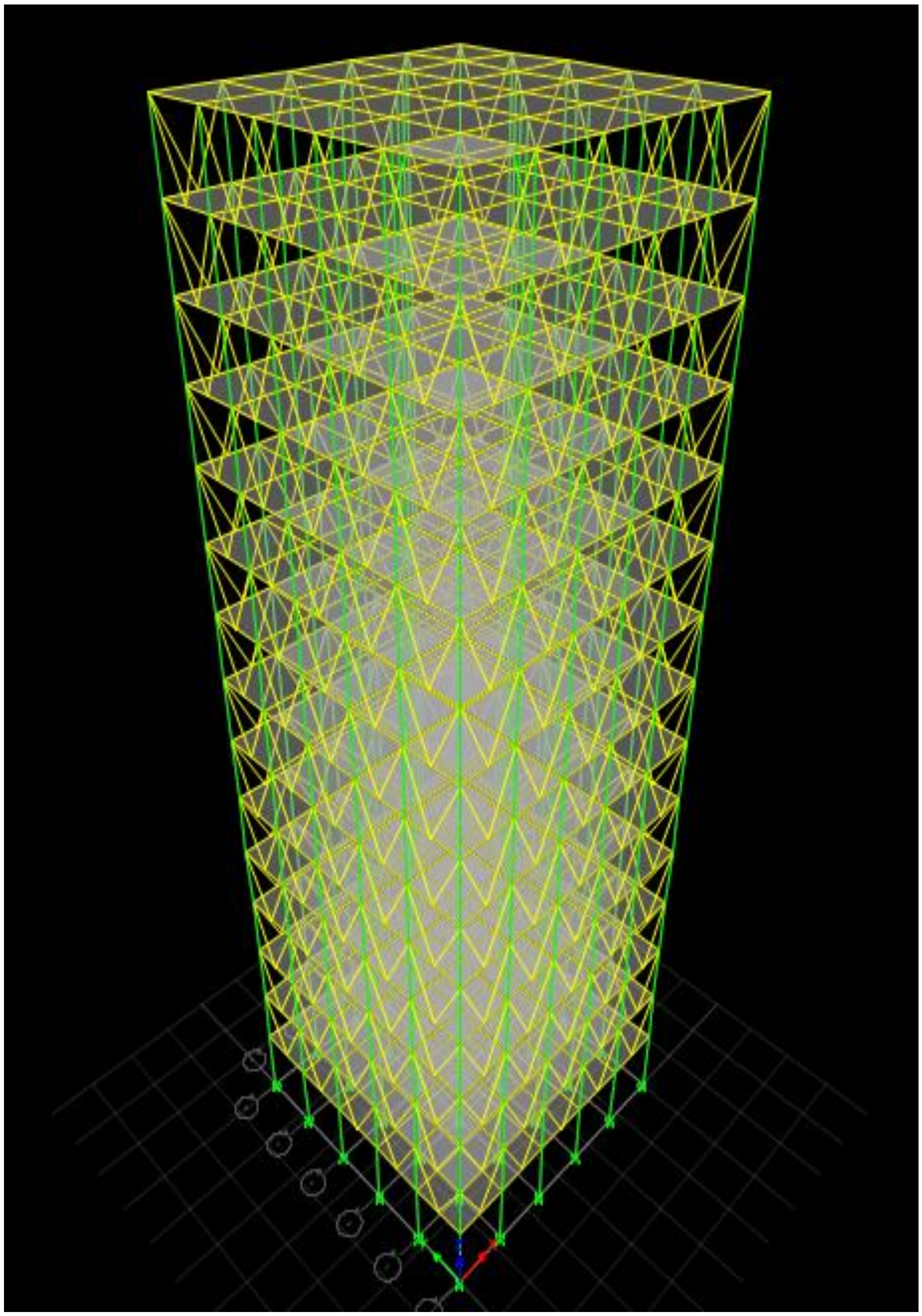


Fig.3.8- 3D View of Building With V- Bracing

ELEVATION OF BUILDING WITH V-BRACING

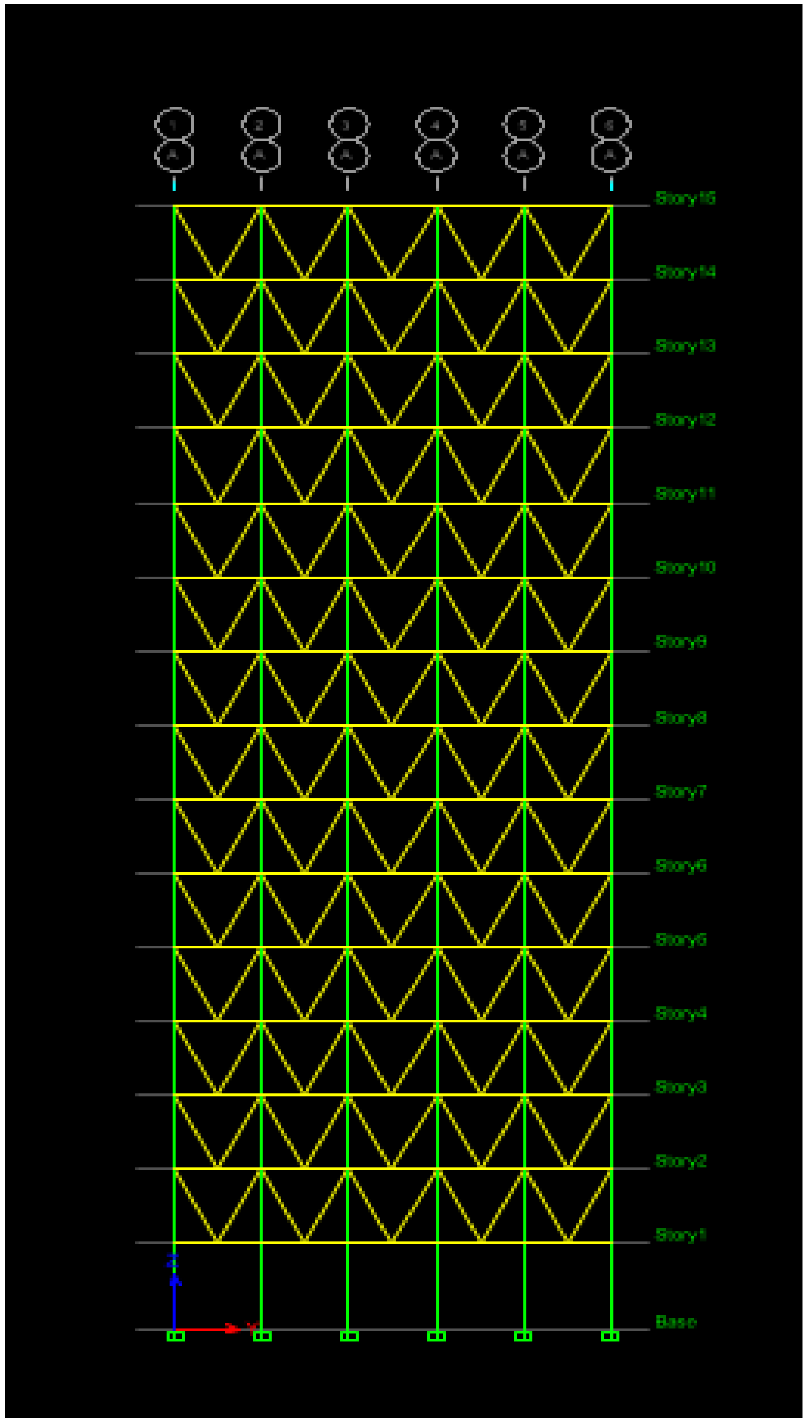


Fig.3.9- Elevation View of Building With V-Bracing

MODEL 4-BUILDING WITH INVERTED V-BRACING

In this model we have applied inverted V bracing all over the four sides of the building. The figure 3.10 and 3.11 shows the 3D view and elevation of the building with inverted V bracing.

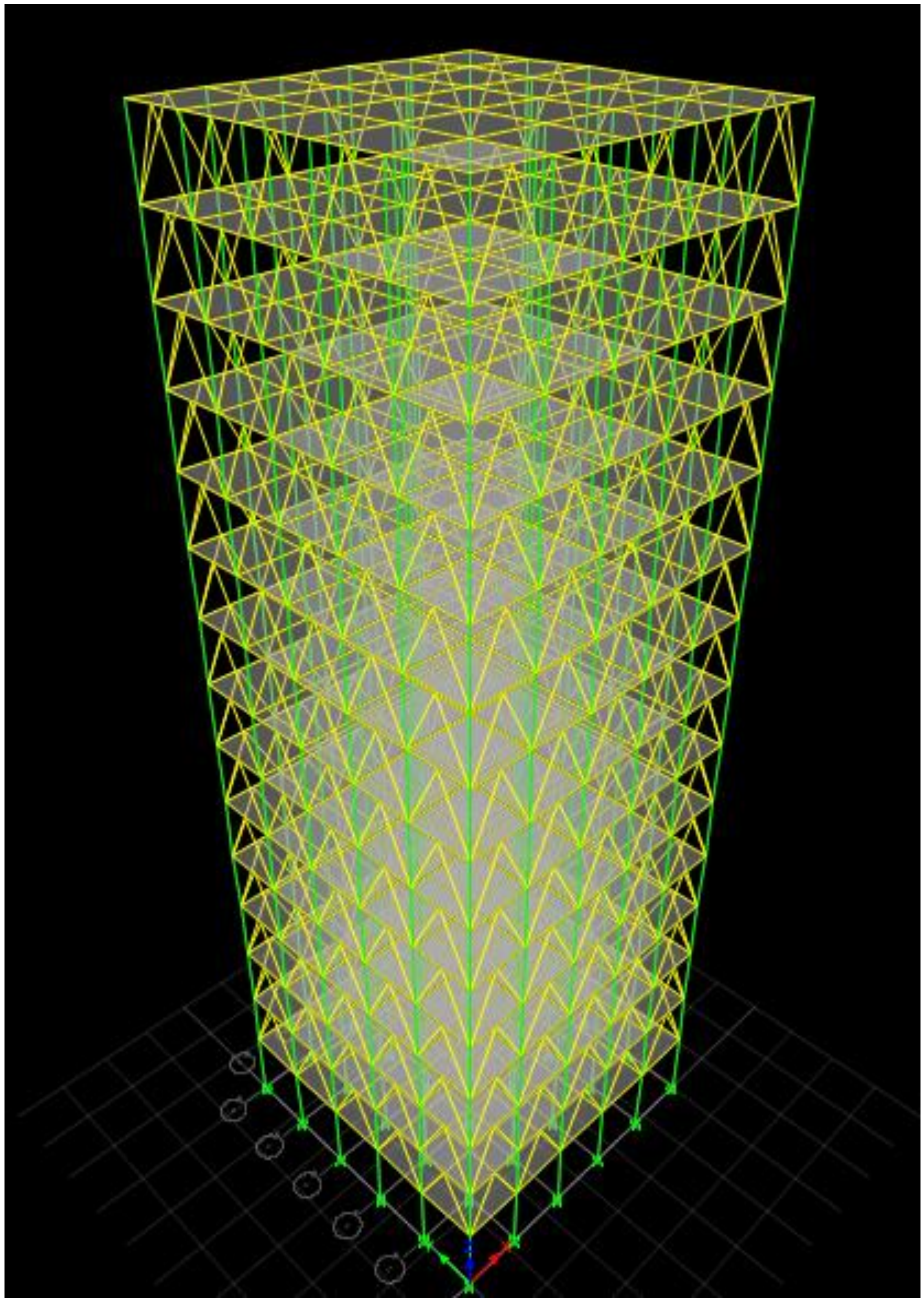


Fig.3.10- 3D View of Building With Inverted V- Bracing

ELEVATION OF BUILDING WITH INVERTED V-BRACING

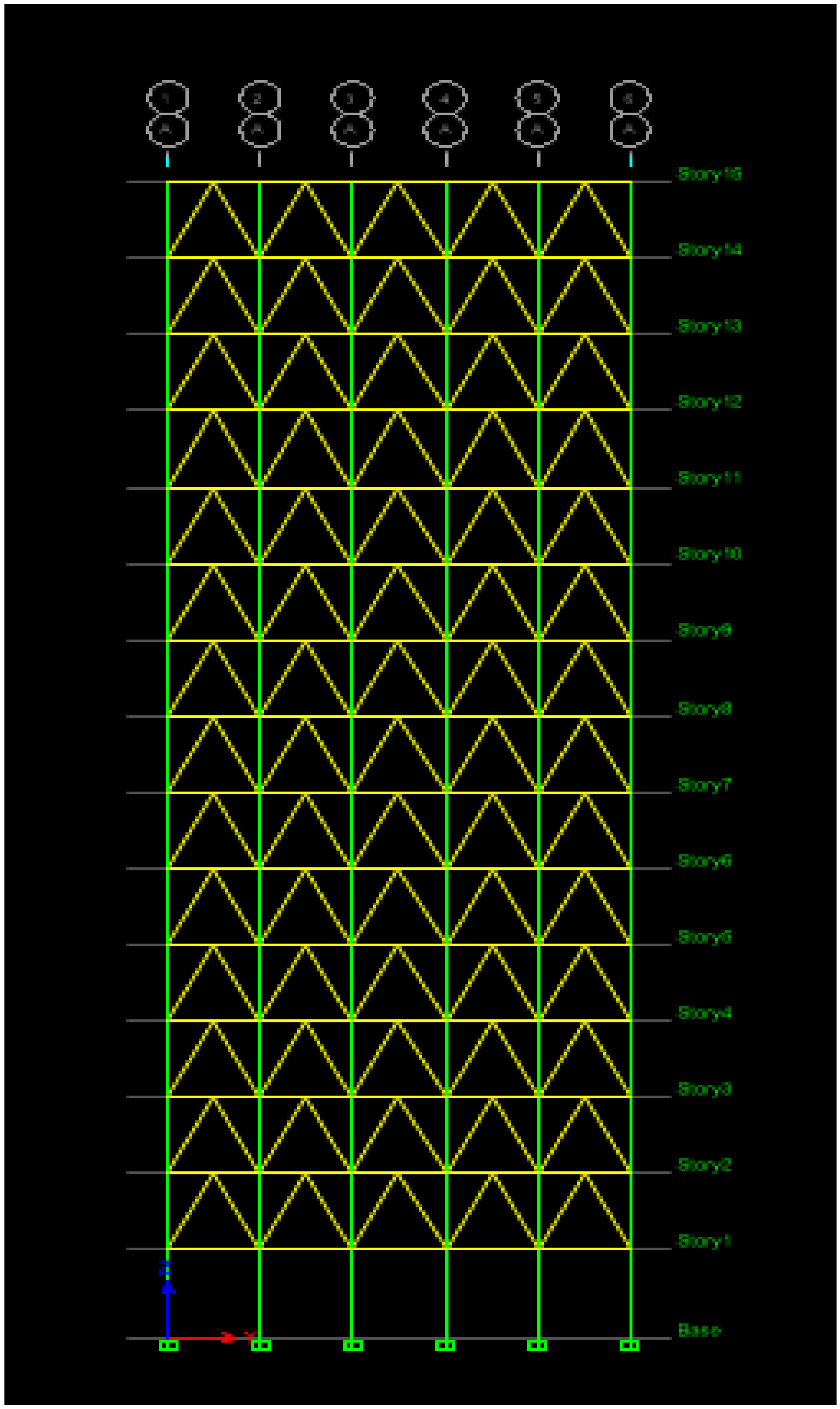


Fig.3.11- Elevation View of Building With Inverted V-Bracing

3.6 Analysis Using ETABs Software

The analysis has been done using ETABs software which involves following steps:-

1. Defining dimensions of the plan
2. Defining the members and material properties
3. Assigning loads and load combinations
4. Run and check model to find errors
5. Run analysis
6. Extract results and discuss

As we know,we are using the time historey method for seismic analysis of all four models of the structure.for that we need to define the the time history function in the ETABs .For time historey function we need to take a specific data on which our analysis is based. For this need we have taken Elcentro data which is the most accurate data of the earthquake in Maxico in 1940.

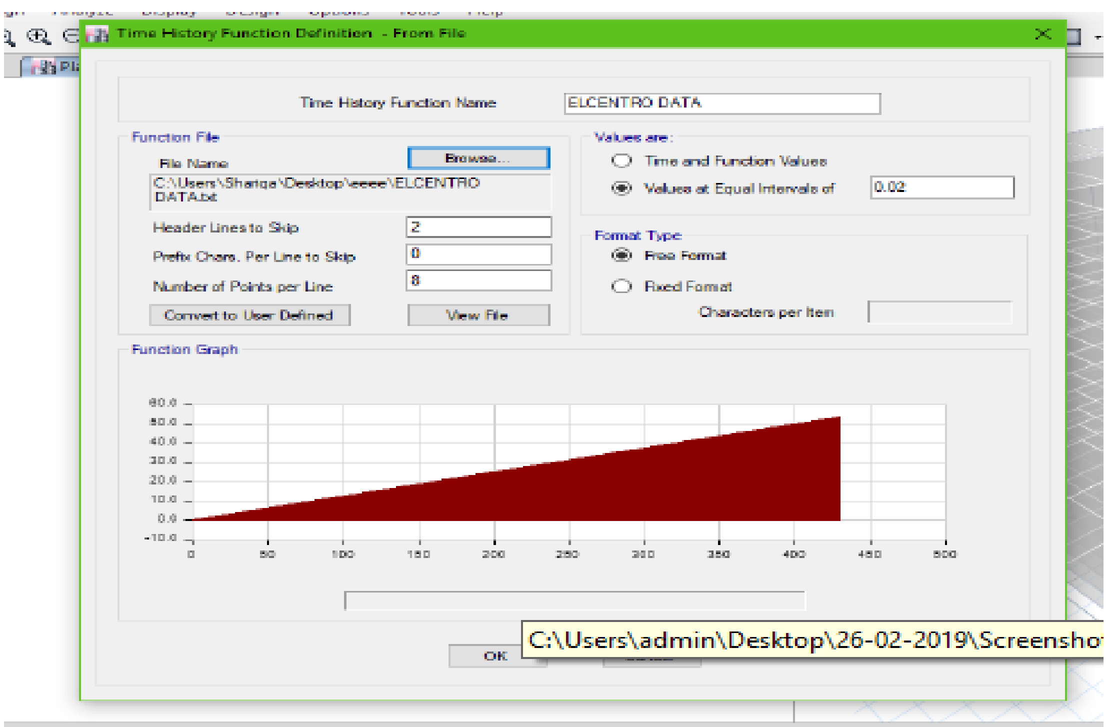


Fig.3.12- Defining Elcentro data

After defining the function,all the models are analysed and gives the result.the displaced shape of all four models are given in figure 21,22 23and 24 below.

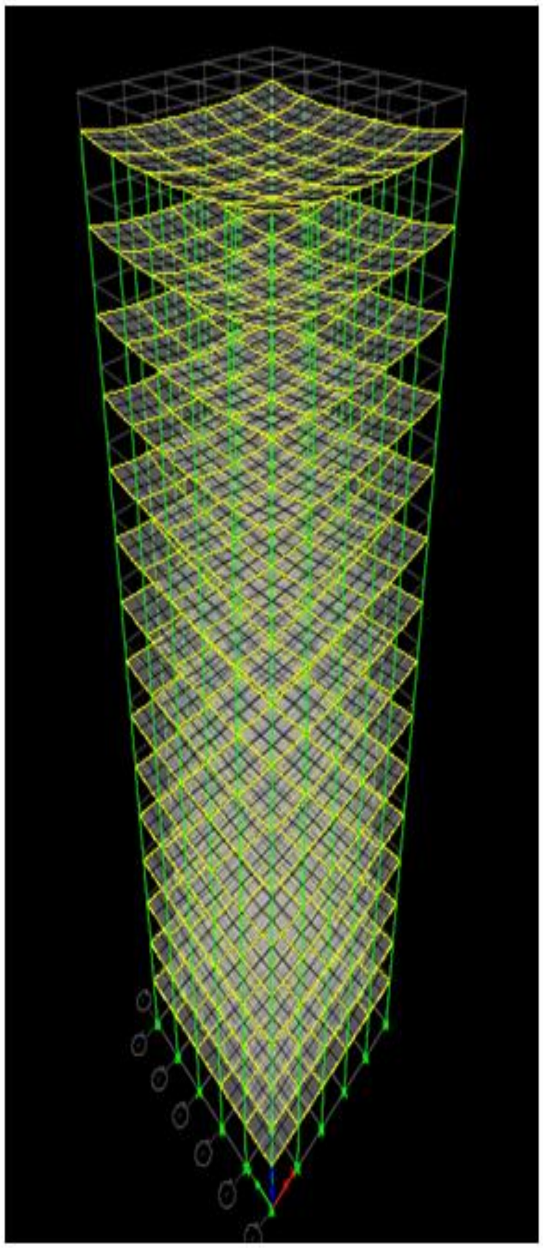


Fig. 3.13 View of Displacement without bracing

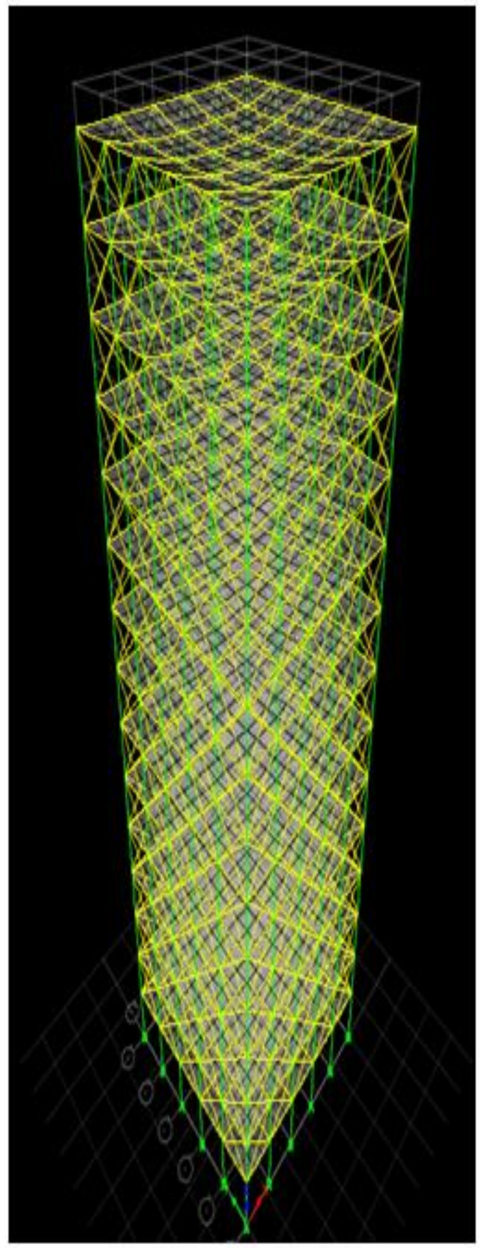


Fig.3.14 View of Displacement with X bracing

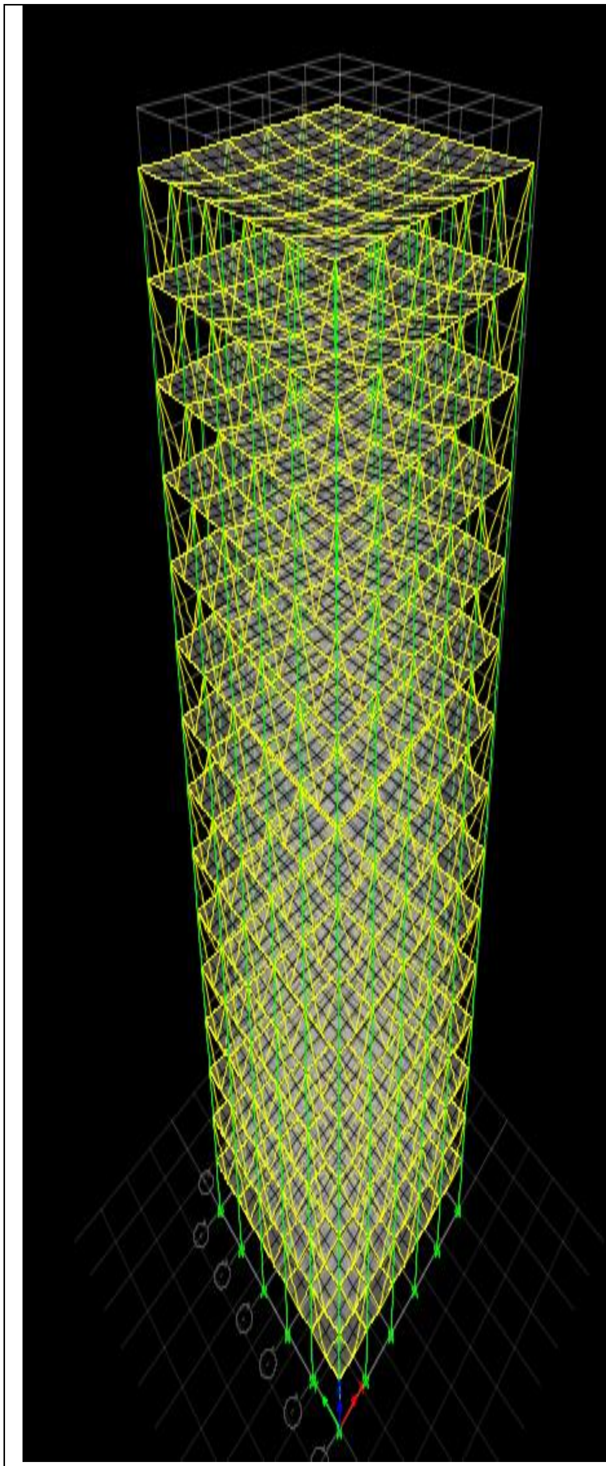


Fig.3.15 View of Displacement with V- bracing

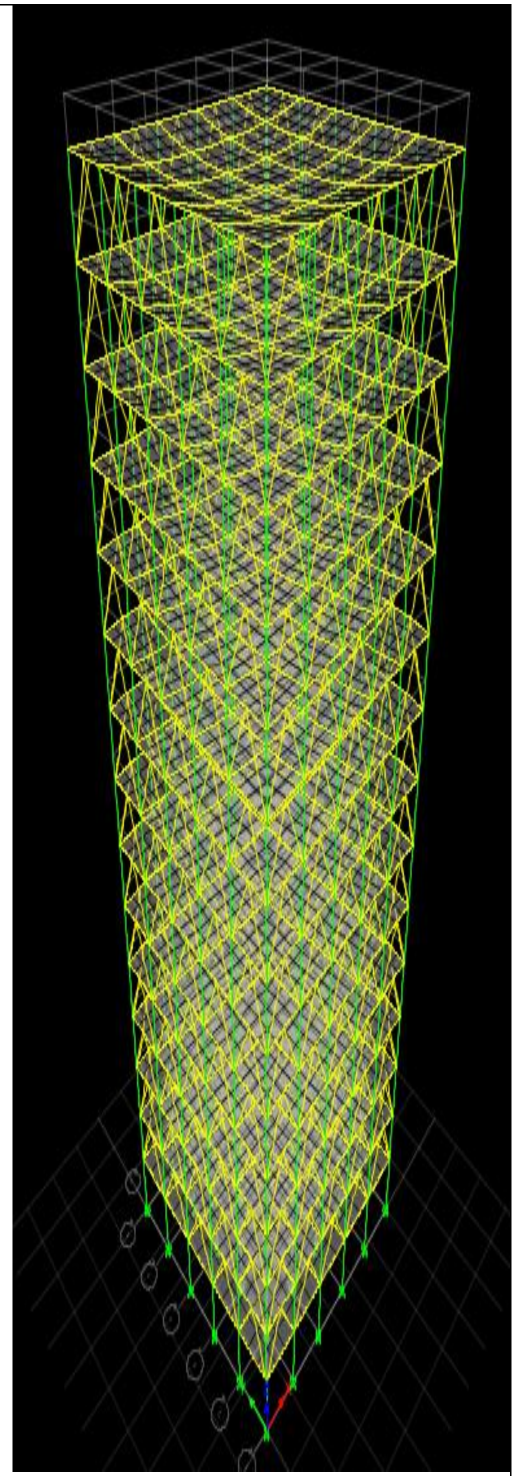


Fig.3.16 View of Displacement with Inverted V bracing

CHAPTER-4

RESULT

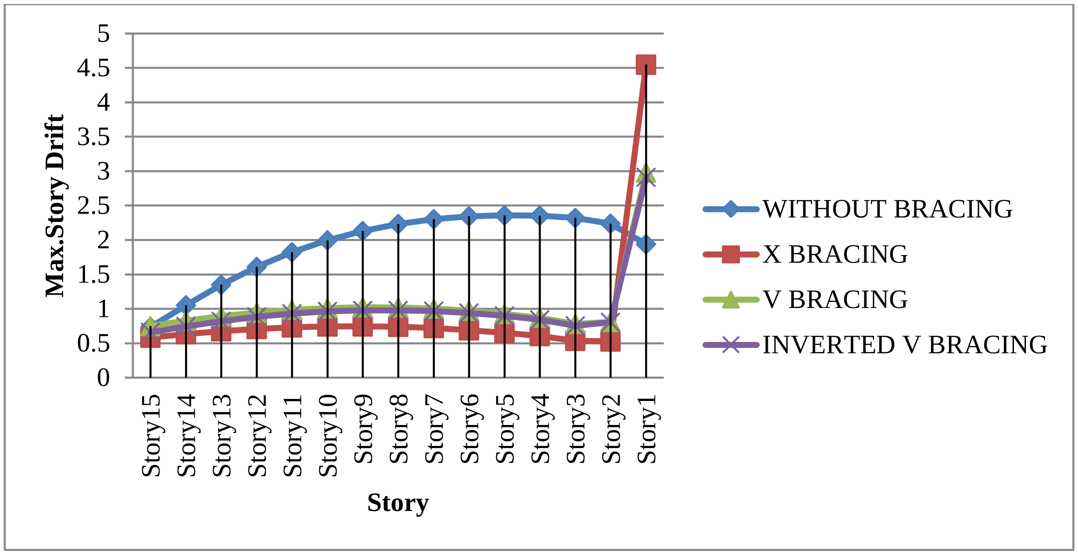
4. RESULT

4.1 Storey Drift It is the relative displacement of one level relative to other level above or below. According to IS 1893:2002 (part 1), the storey drift should not exceed 0.004 times of relative storey height.

4.1.1 Max. Storey drift (mm) comparison in X direction- The table 3 and the graph1 below shows the comparison of various bracing with bare frame in terms of storey drift in X direction.

No of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.734	0.584	0.751	0.659
Story14	1.051	0.632	0.826	0.745
Story13	1.351	0.673	0.892	0.82
Story12	1.608	0.706	0.945	0.882
Story11	1.822	0.729	0.985	0.929
Story10	1.995	0.743	1.011	0.961
Story9	2.131	0.746	1.023	0.977
Story8	2.232	0.738	1.021	0.979
Story7	2.302	0.72	1.004	0.966
Story6	2.343	0.691	0.973	0.938
Story5	2.359	0.652	0.928	0.896
Story4	2.352	0.603	0.87	0.84
Story3	2.321	0.536	0.784	0.755
Story2	2.238	0.528	0.81	0.806
Story1	1.94	4.55	2.981	2.91

Table 4.1 storey drift in X direction



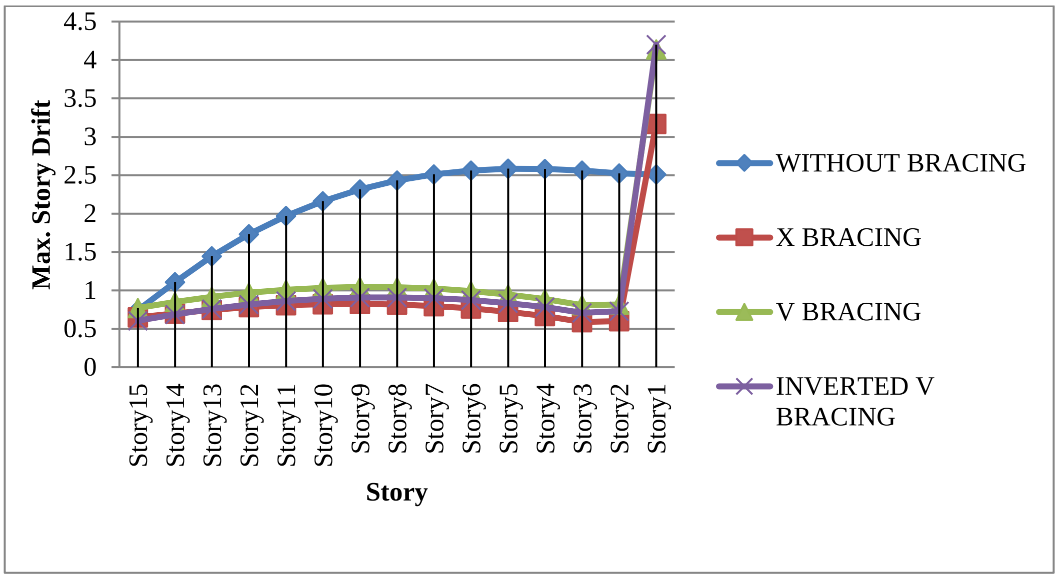
Graph- 4.1 storey drift in X direction

4.1.2 Max. Storey drift (mm) comparison in Y direction- The table 4 and graph 2 below shows the comparison of different bracing system with bare frame in terms of storey drift in Y direction.

No.of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.743	0.649	0.771	0.606
Story14	1.109	0.701	0.849	0.687
Story13	1.445	0.747	0.917	0.758
Story12	1.731	0.783	0.97	0.816
Story11	1.969	0.808	1.01	0.861
Story10	2.163	0.822	1.035	0.891
Story9	2.316	0.825	1.045	0.908
Story8	2.431	0.817	1.042	0.91
Story7	2.511	0.797	1.024	0.899
Story6	2.561	0.765	0.992	0.874
Story5	2.584	0.721	0.946	0.835
Story4	2.583	0.667	0.888	0.783
Story3	2.562	0.589	0.807	0.707

Story2	2.523	0.6	0.815	0.731
Story1	2.512	3.17	4.14	4.199

Table 4.2 storey drift in Y direction



Graph- 4.2 Storey Drift in Y direction

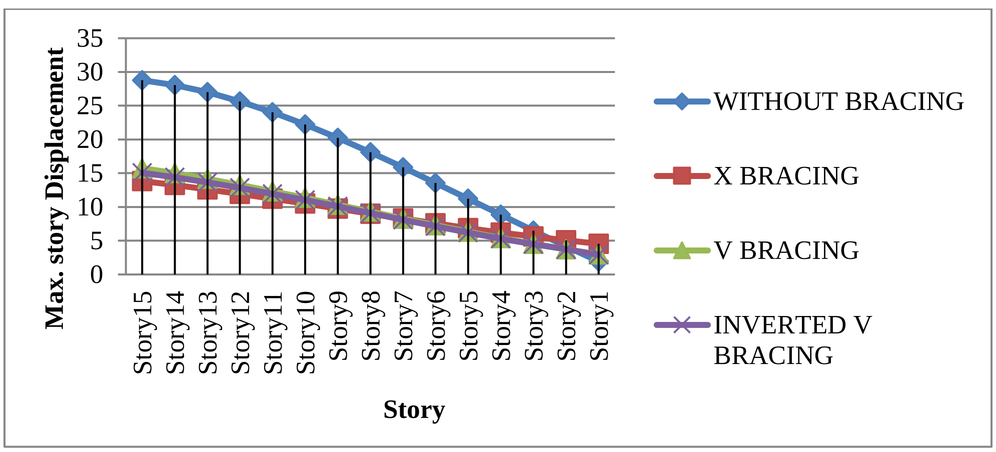
4.2 Storey Displacement

It is the diplascement of each storey with respect to ground level. According to IS 1893 (part1) :2002 the max value of diplacement is 1/250 times of storey height with respet to ground**.**

4.2.1 Max.Storey displacement (mm) comparison in x direction- The table and graph below shows the comparison of various bracing system with bare frame in terms of storey displacement in X direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	28.779	13.832	15.751	15.063
Story14	28.045	13.247	15	14.404
Story13	26.993	12.615	14.174	13.659
Story12	25.643	11.942	13.283	12.838
Story11	24.035	11.236	12.338	11.957
Story10	22.213	10.506	11.353	11.028
Story9	20.218	9.764	10.341	10.068
Story8	18.086	9.018	9.318	9.09
Story7	15.854	8.28	8.297	8.111
Story6	13.552	7.56	7.293	7.145
Story5	11.21	6.869	6.319	6.206
Story4	8.851	6.217	5.391	5.31
Story3	6.499	5.613	4.521	4.47
Story2	4.178	5.078	3.737	3.715
Story1	1.94	4.55	2.981	2.91

Table 4.3 Storey Displacement in X direction

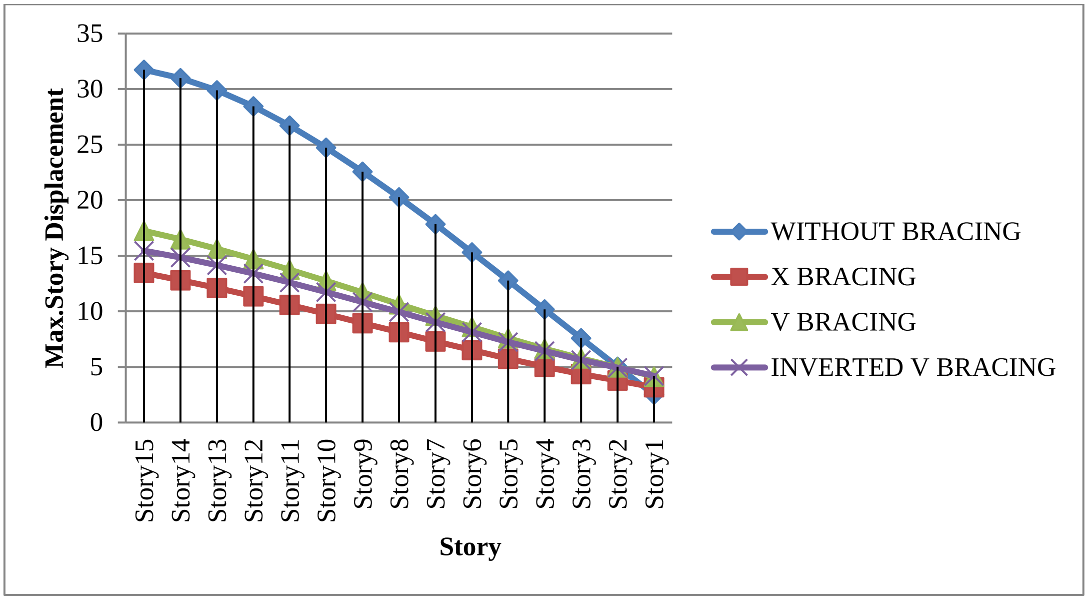


Graph 4.3 Storey Displacement in X direction

4.2.2 Max. Storey displacement (mm) comparison in Y direction- The table 6 and graph 4 below shows the comparison of various bracing system with bare frame in terms of storey displacement in Y direction.

NO OF STORYS	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	31.742	13.461	17.25	15.465
Story14	30.999	12.811	16.48	14.859
Story13	29.89	12.11	15.63	14.171
Story12	28.445	11.363	14.714	13.413
Story11	26.715	10.581	13.743	12.597
Story10	24.745	9.773	12.733	11.737
Story9	22.582	8.95	11.698	10.846
Story8	20.267	8.125	10.653	9.938
Story7	17.836	7.308	9.611	9.028
Story6	15.325	6.512	8.588	8.129
Story5	12.764	5.747	7.596	7.256
Story4	10.18	5.026	6.65	6.421
Story3	7.597	4.359	5.762	5.638
Story2	5.035	3.77	4.955	4.93
Story1	2.512	3.17	4.14	4.199

Table 4.4-storey Displacement in y direction



Graph 4.4 Storey Displacement in y direction

4.3 Fundamental time periods-

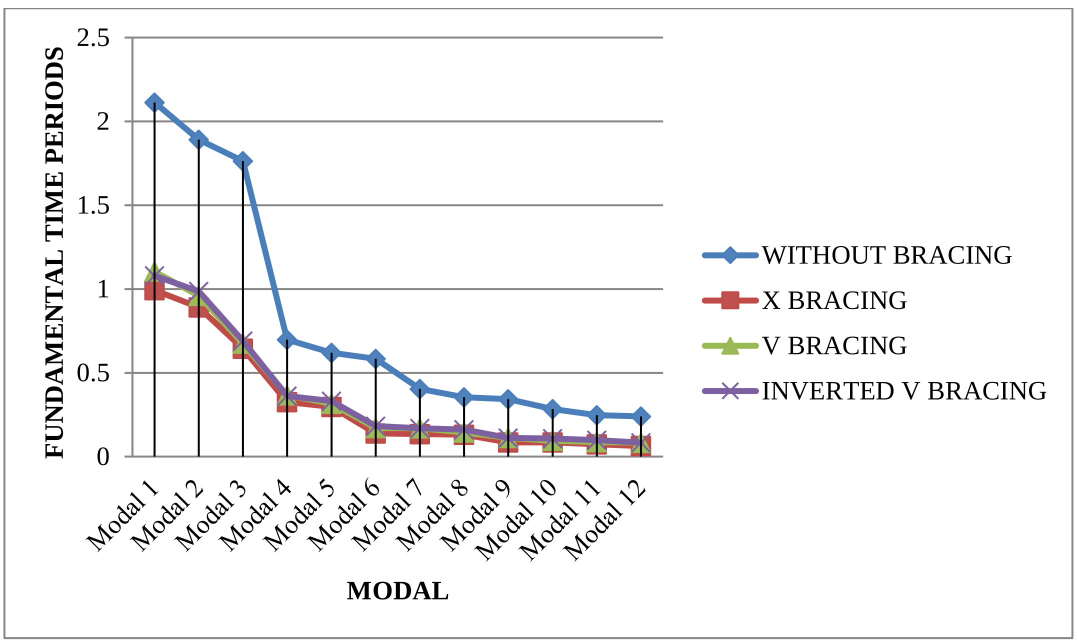
According to IS 1893(Part 1):2002 it is the first(longest) modal time period of vibration.

4.3.1Fundamental time period (S) comparison-The table and the graph below shows the comparison of various bracing system with bare frame in terms of fundamental time period.

MODAL	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Modal 1	2.113	0.993	1.104	1.079
Modal 2	1.891	0.89	0.959	0.986
Modal 3	1.764	0.644	0.675	0.691
Modal 4	0.697	0.326	0.366	0.362

Modal 5	0.619	0.297	0.316	0.332
Modal 6	0.583	0.139	0.17	0.182
Modal 7	0.404	0.134	0.169	0.169
Modal 8	0.355	0.13	0.145	0.162
Modal 9	0.343	0.085	0.112	0.111
Modal 10	0.284	0.084	0.095	0.108
Modal 11	0.247	0.073	0.086	0.098
Modal 12	0.24	0.063	0.083	0.083

Table 4.5 fundamental time period



Graph 4.5 Fundamental time period

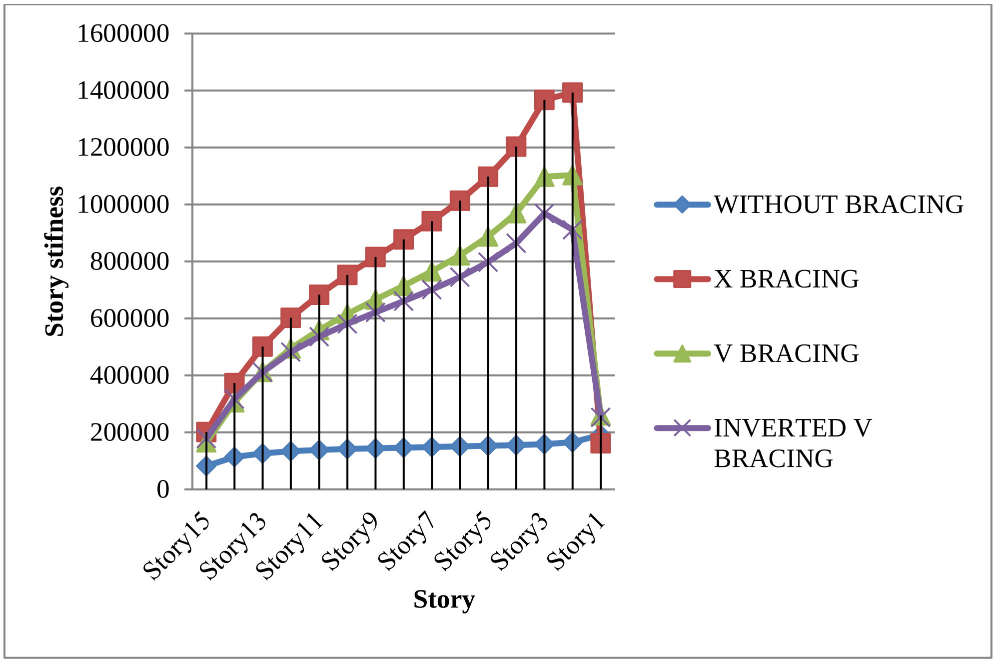
4.4 Storey stiffness

As per IS 1893:2002 the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of average lateral stiffness of the three storey above.

4.4.1Max.Storey stifness (kN/m) comparison in x direction-The table 8 and graph 6 below shows the comparison of various bracing system with bare frame in terms of storey stiffness in X direction.

NO OF STOREY	**WITHOUT BRACING**	**X BRACING**	**V BRACING**	**INVERTED V BRACING**
Story15	82225.893	201749.63	165111.89	179165.8
Story14	113846.64	373293.98	306364.7	316707.3
Story13	126534.47	501809.39	412105.18	411757.6
Story12	133531.57	601861.5	494022.47	481678
Story11	138074.29	683217.72	560090.31	536175.6
Story10	141383.28	752901	616125.72	581487.3
Story9	144031.15	816253.48	666559.5	621892.3
Story8	146339.62	877773.32	715104.71	660695.7
Story7	148514.22	941771.95	765284.54	700841.2
Story6	150703.98	1013015.1	820943.82	745401.4
Story5	153036.45	1097900.6	887210.06	798351.3
Story4	155659.05	1203792.2	969674.53	863782
Story3	159033.88	1366816.7	1098192.5	968549.9
Story2	165553.96	1392896.2	1102921.2	911152.3
Story1	191139.93	161702.39	259663.03	252550.7

Table 4.6 storey stiffness in x direction



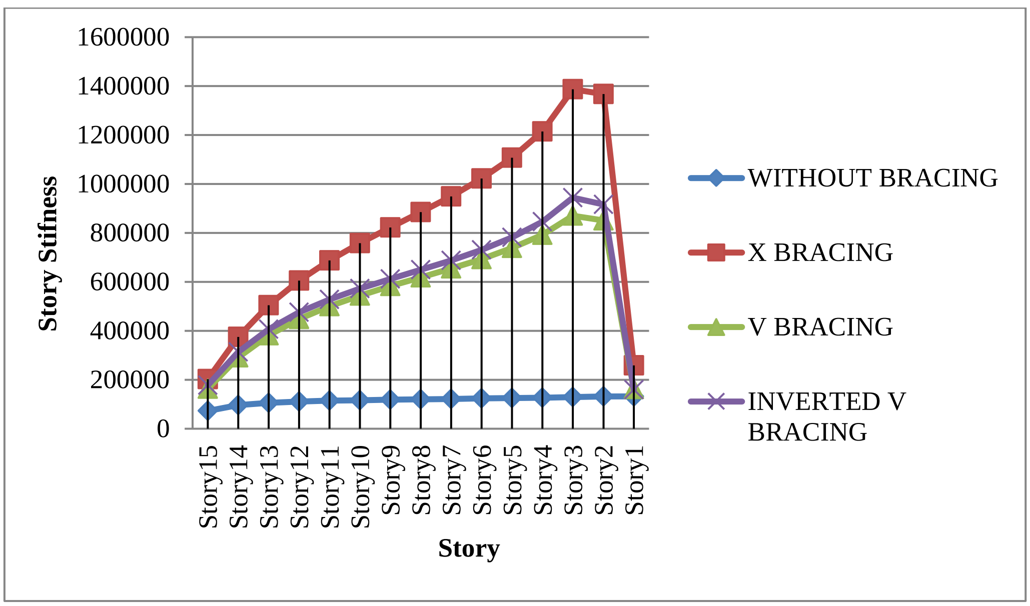
Graph 4.6 storey stiffness in X direction

4.4.2Max.Storey stifness (kN/m) comparison in Y direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey stiffness in Y direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	72684.213	202627.23	163480.93	177941.84
Story14	96586.265	375344.8	291989.22	313435.62
Story13	105880.63	504836.59	382069.79	406758.85
Story12	111006.47	605800.18	448897.84	475112.96
Story11	114314.96	687972.52	501129.39	528233.64
Story10	116709.24	758416.06	544362.17	572292.24
Story9	118614.25	822505.88	582445.61	611505.59
Story8	120267.07	884780.63	618311.46	649109.94
Story7	121817.56	949601.85	654481.54	687972.12

Story6	123372.44	1021775.5	693444.68	731076.42
Story5	125018.23	1107918.2	738182.25	782244.12
Story4	126826.98	1214374.3	791565.06	845682.99
Story3	128924.25	1386994.3	870299.17	944067.29
Story2	131374.3	1366867.2	850370.28	916639.61
Story1	132134.35	258920.79	161354.81	159764.65

Table 4.7 storey stiffness in Y direction



Graph 4.7 storey stiffness in Y direction

CHAPTER-5

CONCLUSION

5. CONCLUSIONS

From the above study and results several conclusions can be drawn such as:

1) Building with bracing is more earthquake resistance than building without bracing.
2) Steel bracing can be used to strengthen or retrofit the existing structures.
3) Displacements and Drifts are reduced in Building with bracing as compared to building without bracing.
4) Axial forces in columns increases from without braced to braced system.
5) X bracing is more effective as compared with other bracing for storey drift in x as well as y directions.
6) X bracing is also more effective in x and y direction as compared to other bracing for storey displacement.
7) The fundamental time period can be also reduced with bracing. Again the X bracing performed better in terms of fundamental time period it gives the lesser value of time period as compared with other bracing.
8) For storey stiffness X bracing is more effective in both x and y direction as compared with other bracing system.
9) Hence, in comparison to X, V and inverted V bracing, X bracing is the most effective bracing system of all.

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APPENDIX

Seismic Analysis of a Multi-Storey Building using Steel Braced Frames

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Abstract – *The main concern in the high rise building is their lateral stability i.e. they provide stability during seismic activity without any major destruction .Bracing is one of the horizontal force resisting system. An attempt is made to analyze the response of G+14 storied RC multi-storey building due to the application of different bracing system such as X, V, inverted V bracing and to find the best bracing system during earthquake. ETABs software is used for modeling and analyzing the building. The building is taken in Zone III and analyzed with Time History analysis method. Various parameters such as storey drift, storey displacement, fundamental time period and storey stiffness are studied. From the study it was concluded that building with bracing perform better during seismic activity as compared with building without bracing. Among all the different bracing, X bracing is the best bracing system to reduce the responses during seismic activity.*

Key Words: ***Time History Analysis, Storey drift, Storey displacement, Time period, Storey stiffness.***

1. INTRODUCTION

Generally, it is recognized that seismic design of buildings should satisfy at least two fundamental requirements. First, the structure must behave elastically and protect relatively brittle non-structural components against minor earthquake ground shaking. Therefore, a structure should have sufficient strength and elastic stiffness to limit structural displacements, such as interstorey drift. Second, the structure must not collapse in a major earthquake. For this case, significant damage of the structure and non-structural components is acceptable. In order for a structure not to collapse and thereby minimize the loss of life, it must have large energy dissipation capacity during large inelastic deformations. In general, structural systems which exhibit stable hysteretic loops perform well under the large inelastic cyclic loadings characteristics of major earthquakes. Such stable hysteretic characteristics of a structure can be obtained provided that the structural members and joints are designed to possess sufficient ductility.

In Seismic Analysis, we come to know that earthquakes are the most volatile, disturbing and unpredictable of all natural disasters, in which it is very difficult to save life and engineering properties. Care has to take for each step of construction of a building from foundation part. When earthquakes take place, a building undergoes dynamic motion. Because of subjected to inertia forces that may act in the opposite direction to speeding up of earthquake excitations. These inertia forces normally called seismic loads dealt by assuming forces external to the building. To overcome these problems, we need to identify the seismic performance of multi-storey buildings during various horizontal force resisting systems. This is because to make sure that the high rise buildings withstand during earthquake events. Hence, can save as many lives as possible. During earthquake the performance of a structure depends on many factors such as stiffness, adequate lateral strength, simple and regular configurations etc.

2. OBJECTIVE

The objective of this research is focused on the technique which are used to study the seismic behaviour of R.C buildings with seismic zone III of India using bracing system. The whole design was carried out in ETABs which covers all aspects of structural engineering. More specifically, the salient objectives of this research are:

1) To perform a comparative study of the various seismic parameters.
2) Comparison among building with X, V bracing, inverted V bracing and without bracing on the basis of storey displacement, storey drift, storey stiffness & fundamental time period.
3) To propose the best suitable technique for seismic analysis.

In this paper, an RC multi-storey residential building is studied for earthquake using Time history method in the ETABs software. This analysis is carried out by considering seismic zone III, and for this zone, the behaviour assesses by taking the medium soil. A different response for displacements, storey drift and other parameters are plotted for zone III for medium type of soil.

3. STRUCTURALMODELING

For the purpose of this study, a RC framed (G+14) multistory building having same floor plan with 6 bays of 3m each along longitudinal direction and along transverse direction as shown in figure 1. Four models with different types of bracings were selected in order to determine the behavior of structural steel during seismic activity. The columns are fixed at the ground and are taken as restrains. The bottom storey height is 3.5m and rest are of 3m. All the values of loads and dimensions are given in table no.1.The load cases considered in the seismic analysis are as per IS 1893:2002 (part 1). Figure 1 and 2 shows the geometrical configuration of the building. The model was prepared for bare frame and with different bracing systems. Table1 gives the material properties of the members.

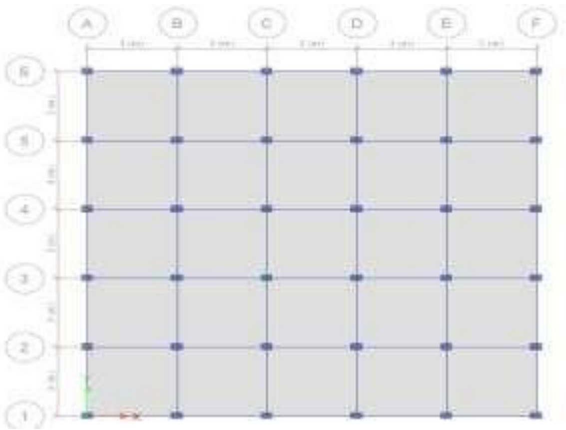


Figure 1: Plan of Building without Bracing.

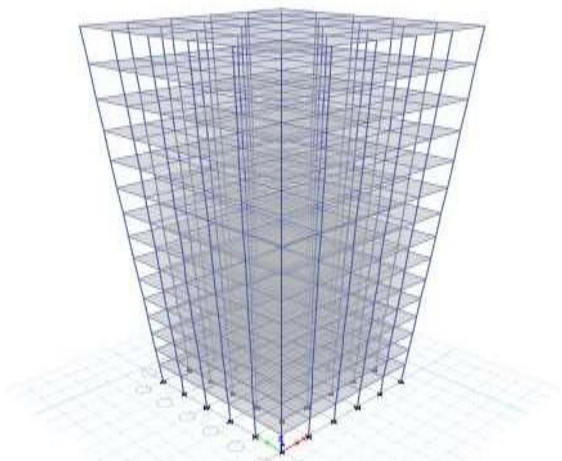


Figure 2: A 3D View of Building without Bracing.

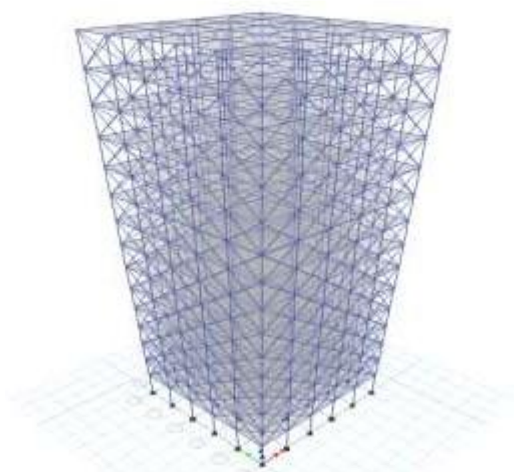


Figure 3:- 3D View of Building with X- Bracing.

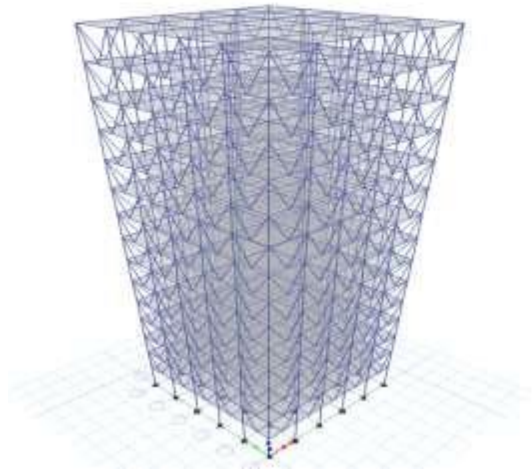


Figure 4:- 3D View of Building with V- Bracing

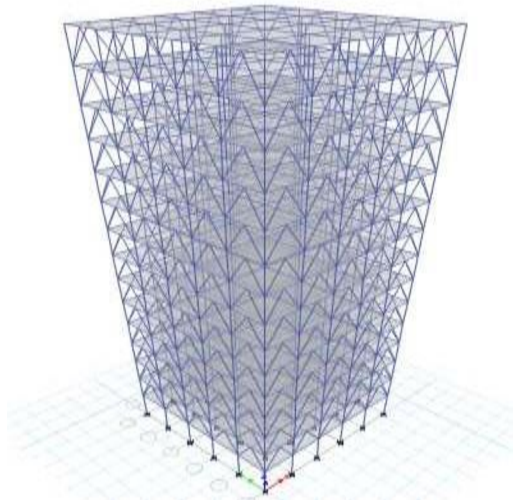


Figure 5:- 3D View of Building with Inverted V- Bracing.

Table 1: Material and Section Properties

1.	Building Type	Residential building
2.	No. of storey	G+14
3.	Bottom storey height	3.5m
4.	Total height	45.5m
5.	Floor height	3m
6.	Size of column	300mm*400mm
7.	Size of beam	230mm*300mm
8.	Thickness of slab	150mm
9.	Masonry wall thickness	250mm
10.	Seismic zone	III
11.	Grade of concrete	M20
12.	Grade of steel	Fe250
13.	Unit weight of concrete	25KN/m^3
14.	Unit weight of PCC	24 KN/m^3
15.	Unit weight of brick	20 KN/m^3
16.	Unit weight of plaster	21 KN/m^3
17.	Wall load	13.5 KN/m

18.	Parapet wall load	7KN/m
19.	Live load	3 KN/m^2
20.	Roof load	2.5 KN/m^2
21.	IS Code for concrete	IS 456:2000
22.	IS Code for earthquake	IS 1893:2002 (part I)

Building is analyzed on the basis of Various load combinations in the limit state of design for reinforced concrete structures as per IS 1893:2000(part1).

3.1 ETABs Overview

ETABs is used for seismic analysis and to study the behaviour of multi-storey building with and without bracing are compared with different parametres of analysis. Complete analysis including structural modeling is performed in this software.

The analysis has been done by using ETABs software which involves following steps:-

1. Defining dimensions of the plan
2. Defining the members and material properties
3. Assigning loads and load combinations
4. Run and check model to find errors
5. Run analysis
6. Extract results and discuss

4. METHOD OFANALYSIS

Time History Analysis

Time history analysis is the study of the dynamic response of the structure at every addition of time, when its base is exposed to a particular ground motion. Static techniques are applicable when higher mode effects are not important. This is for the most part valid for short, regular structures. Thus, for tall structures, structures with torsional asymmetries, or no orthogonal frameworks, a dynamic method is needed. In linear dynamic method, the structures is modeled as a multi degree of freedom (MDOF) system with a linear elastic stiffness matrix and an equivalent viscous damping matrix. The seismic input is modeled utilizing time history analysis, the displacements and internal forces are found using linear elastic analysis. The playing point of linear dynamic procedure as for linear static procedure is that higher modes could be taken into account.

In order to study the seismic behaviour of RC multi-storey building under lateral forces with or without bracing, dynamic analysis is required. The ETABs software is used to perform linear time history analysis.

Parameters considered for analysis

1. Storey drift
2. Storey displacement
3. Fundamental time period
4. Storey stiffness

The seismic data is taken according to the IS 1893:2002 for the Zone III.

Table 2:Seismic Data

Serial No	Model Description	
1	Zone	III
2	Zone Factor	0.16
3	Type of building	Residential
4	Importance Factor	1
5	Soil Type	II
6	Soil Condition	Medium
7	Damping Ratio	5%
8	Response Reduction Factors	5

5. RESULTS

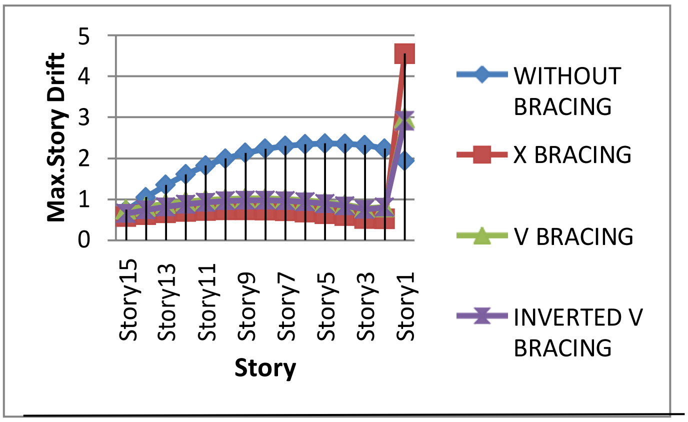
Storey drift

It is the relative displacement of one level relative to other level above or below. According to IS 1893:2002 (part 1),the storey drift should not exceed 0.004 times of relative storey height.

Max. Storey drift(mm) comparison in X direction the table and the graph below shows the comparison of various bracing with bare frame in terms of storey drift in X direction.

No of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.734	0.584	0.751	0.659
Story14	1.051	0.632	0.826	0.745
Story13	1.351	0.673	0.892	0.82
Story12	1.608	0.706	0.945	0.882
Story11	1.822	0.729	0.985	0.929
Story10	1.995	0.743	1.011	0.961
Story9	2.131	0.746	1.023	0.977
Story8	2.232	0.738	1.021	0.979
Story7	2.302	0.72	1.004	0.966
Story6	2.343	0.691	0.973	0.938
Story5	2.359	0.652	0.928	0.896
Story4	2.352	0.603	0.87	0.84
Story3	2.321	0.536	0.784	0.755
Story2	2.238	0.528	0.81	0.806
Story1	1.94	4.55	2.981	2.91

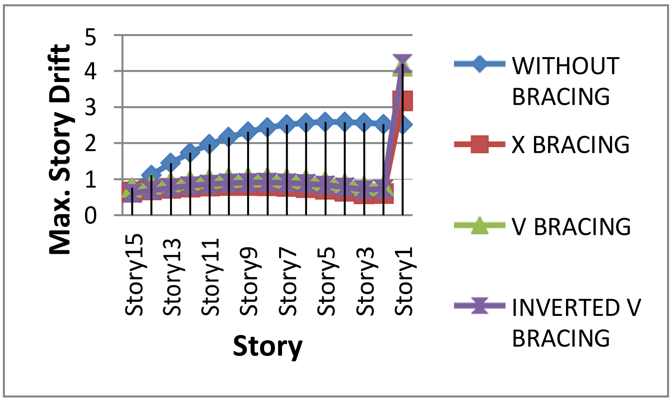
Max. Storey drift(mm) comparison in X direction-



Max. Storey drift (mm) comparison in Y direction- the table and graph below shows the comparison of different bracing system with bare frame in terms of storey drift in Y direction.

No.of story	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	0.743	0.649	0.771	0.606
Story14	1.109	0.701	0.849	0.687
Story13	1.445	0.747	0.917	0.758
Story12	1.731	0.783	0.97	0.816
Story11	1.969	0.808	1.01	0.861
Story10	2.163	0.822	1.035	0.891
Story9	2.316	0.825	1.045	0.908
Story8	2.431	0.817	1.042	0.91
Story7	2.511	0.797	1.024	0.899
Story6	2.561	0.765	0.992	0.874
Story5	2.584	0.721	0.946	0.835
Story4	2.583	0.667	0.888	0.783
Story3	2.562	0.589	0.807	0.707
Story2	2.523	0.6	0.815	0.731
Story1	2.512	3.17	4.14	4.199

Max. Storey drift(mm) comparison in Y-direction-



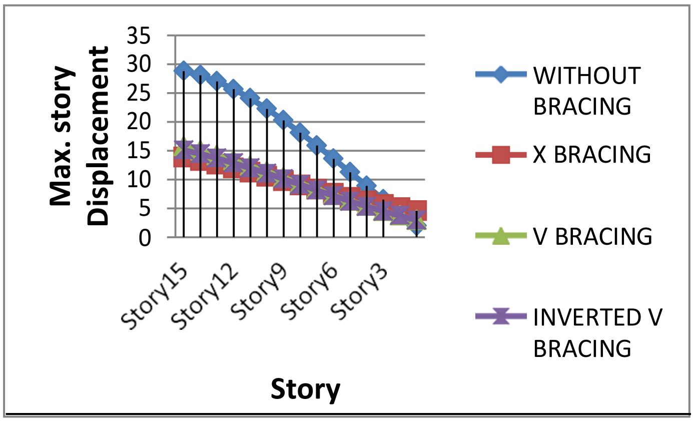
Storey Displacement

It is the displacement of each storey with respect to ground level. According to IS 1893 (part1) :2002 the max value of displacement is 1/250 times of storey height with respect to ground.

Max. Storey displacement (mm) comparison in x direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey displacement in X direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	28.779	13.832	15.751	15.063
Story14	28.045	13.247	15	14.404
Story13	26.993	12.615	14.174	13.659
Story12	25.643	11.942	13.283	12.838
Story11	24.035	11.236	12.338	11.957
Story10	22.213	10.506	11.353	11.028
Story9	20.218	9.764	10.341	10.068
Story8	18.086	9.018	9.318	9.09
Story7	15.854	8.28	8.297	8.111
Story6	13.552	7.56	7.293	7.145
Story5	11.21	6.869	6.319	6.206
Story4	8.851	6.217	5.391	5.31
Story3	6.499	5.613	4.521	4.47
Story2	4.178	5.078	3.737	3.715
Story1	1.94	4.55	2.981	2.91

Max. Storey displacement (mm) comparison in x direction-

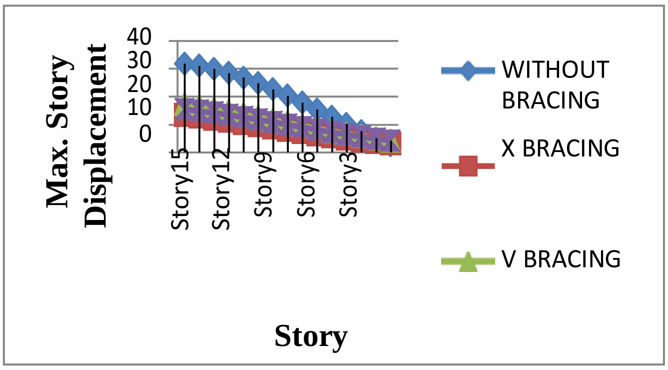


Max. Storey displacement (mm) comparison in Y direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey displacement in Y direction.

NO OF STORYS	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	31.742	13.461	17.25	15.465
Story14	30.999	12.811	16.48	14.859
Story13	29.89	12.11	15.63	14.171
Story12	28.445	11.363	14.714	13.413
Story11	26.715	10.581	13.743	12.597
Story10	24.745	9.773	12.733	11.737
Story9	22.582	8.95	11.698	10.846
Story8	20.267	8.125	10.653	9.938
Story7	17.836	7.308	9.611	9.028
Story6	15.325	6.512	8.588	8.129

Story5	12.764	5.747	7.596	7.256
Story4	10.18	5.026	6.65	6.421
Story3	7.597	4.359	5.762	5.638
Story2	5.035	3.77	4.955	4.93
Story1	2.512	3.17	4.14	4.199

Max. Storey displacement (mm) comparison in Y direction-



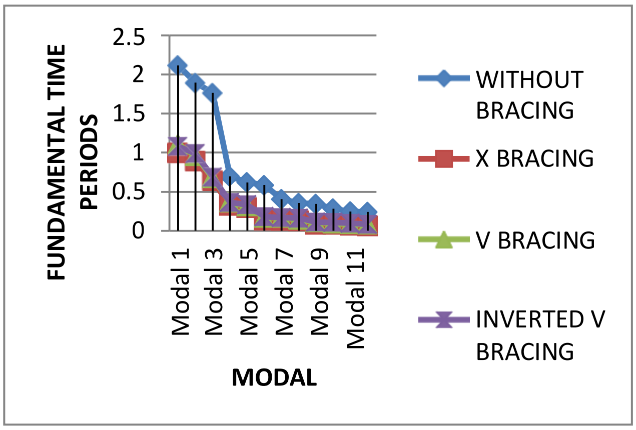
Fundamental time periods-

According to IS 1893:2002 it is the first (longest) modal time period of vibration.

Fundamental time period (S) comparison-The table and the graph below shows the comparison of various bracing system with bare frame in terms of fundamental time period.

MODAL	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Modal 1	2.113	0.993	1.104	1.079
Modal 2	1.891	0.89	0.959	0.986
Modal 3	1.764	0.644	0.675	0.691
Modal 4	0.697	0.326	0.366	0.362
Modal 5	0.619	0.297	0.316	0.332
Modal 6	0.583	0.139	0.17	0.182
Modal 7	0.404	0.134	0.169	0.169
Modal 8	0.355	0.13	0.145	0.162
Modal 9	0.343	0.085	0.112	0.111
Modal 10	0.284	0.084	0.095	0.108
Modal 11	0.247	0.073	0.086	0.098
Modal 12	0.24	0.063	0.083	0.083

Fundamental time period (S) comparison



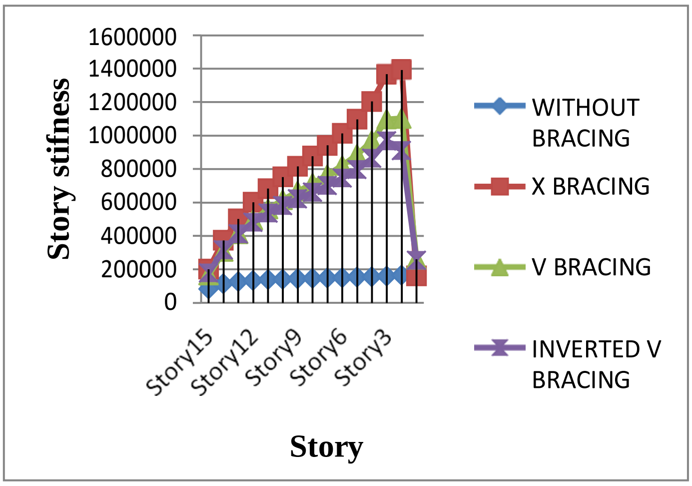
5.4 Storey stiffness

As per IS 1893:2002 the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of average lateral stiffness of the three storey above.

Max. Storey stiffness (kN/m) comparison in x direction-the table and graph below shows the comparison of various bracing system with bare frame in terms of storey stiffness in X direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	82225.893	201749.63	165111.89	179165.8
Story14	113846.64	373293.98	306364.7	316707.3
Story13	126534.47	501809.39	412105.18	411757.6
Story12	133531.57	601861.5	494022.47	481678
Story11	138074.29	683217.72	560090.31	536175.6
Story10	141383.28	752901	616125.72	581487.3
Story9	144031.15	816253.48	666559.5	621892.3
Story8	146339.62	877773.32	715104.71	660695.7
Story7	148514.22	941771.95	765284.54	700841.2
Story6	150703.98	1013015.1	820943.82	745401.4
Story5	153036.45	1097900.6	887210.06	798351.3
Story4	155659.05	1203792.2	969674.53	863782
Story3	159033.88	1366816.7	1098192.5	968549.9
Story2	165553.96	1392896.2	1102921.2	911152.3
Story1	191139.93	161702.39	259663.03	252550.7

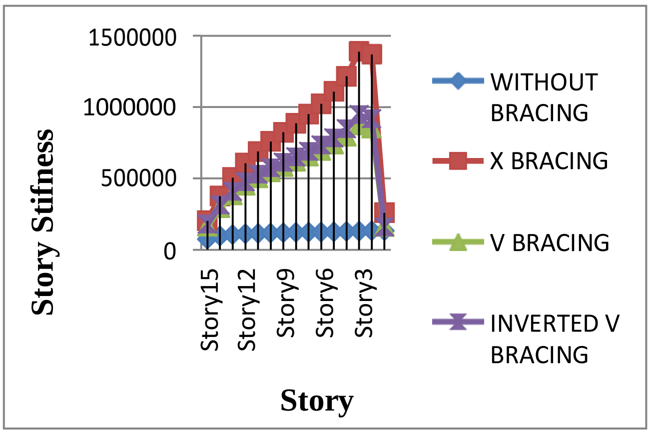
Max. Storey stiffness (kN/m) comparison in x direction-



Max. Storey stiffness (kN/m) comparison in Y direction- the table and graph below shows the comparison of various bracing system with bare frame in terms of storey stiffness in Y direction.

NO OF STOREY	WITHOUT BRACING	X BRACING	V BRACING	INVERTED V BRACING
Story15	72684.213	202627.23	163480.93	177941.84
Story14	96586.265	375344.8	291989.22	313435.62
Story13	105880.63	504836.59	382069.79	406758.85
Story12	111006.47	605800.18	448897.84	475112.96
Story11	114314.96	687972.52	501129.39	528233.64
Story10	116709.24	758416.06	544362.17	572292.24
Story9	118614.25	822505.88	582445.61	611505.59
Story8	120267.07	884780.63	618311.46	649109.94
Story7	121817.56	949601.85	654481.54	687972.12
Story6	123372.44	1021775.5	693444.68	731076.42
Story5	125018.23	1107918.2	738182.25	782244.12
Story4	126826.98	1214374.3	791565.06	845682.99
Story3	128924.25	1386994.3	870299.17	944067.29
Story2	131374.3	1366867.2	850370.28	916639.61
Story1	132134.35	258920.79	161354.81	159764.65

Max. Storey stiffness (kN/m) comparison in Y direction-



6. CONCLUSION

From the above study and results several conclusions can be drawn such as:

1) Building with bracing is more earthquake resistance than building without bracing.
2) Steel bracing can be used to strengthen or retrofit the existing structures.
3) Displacements and Drifts are reduced in Building with bracing as compared to building without bracing.
4) X bracing is more effective as compared with other bracing for storey drift in x as well as y directions.
5) X bracing is also more effective in x and y direction as compared to other bracing for storey displacement.
6) The fundamental time period can be also reduced with bracing. Again the X bracing performed better in terms of fundamental time period it gives the lesser value of time period as compared with other bracing.
7) For storey stiffness X bracing is more effective in both x and y direction as compared with other bracing system.
8) Hence, in comparison to X, V and inverted V bracing, X bracing is the most effective bracing system of all.

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BIOGRAPHY

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A STUDY ON THE EFFECT OF STEEL BRACED FRAMES ON THE SEISMIC BEHAVIOUR OF A MULTI-STOREY BUILDING

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Abstract - In multistory building there a lot of parameters of concern which need to be considered for the effect of earthquake and wind load. There are many ways by which the performance of a building during the seismic activity can be improved. Bracing is one of the best method for lateral load resisting system as it is economical and easy to apply. This paper compares the response of building with different types of bracing systems such as X, V, inverted V , Knee bracing and single diagonal bracing. It also compares the seismic behavior of structure under the concentrically and eccentrically braced frames using ETABs and different methods of analysis like Response spectrum, pushover and Time History analysis.

Keywords- Bracing, Storey displacement, storey drift, base shear, response spectrum, pushover and time history methods, analysis using ETABs.

1. INTRODUCTION

At present India is developing at a very fast rate which requires increased demand of infrastructure facilities with the growth in population. Due to increase in population the demand of housing is also increasing, so to full fill the need for construction of housing and commercial buildings the use multi-storey building is highly in demand now days. These types of development require safety both for life and property because multi storey buildings are highly susceptible to additional lateral load due to earthquake and wind. Earthquakes are the most life damaging and destructive phenomenon; these are generated due to sudden release of energy in the earth crust that creates the seismic waves which appears at different instances with different intensity level. When earthquake occurs, the building collapse and damage due to earthquake. Ground motion which is radiated in all direction from epicenter. Due to the effect of earthquake, the building encounters supreme level of displacements, the inertial force which is caused due to tendency of a building to remain at rest. All though, the lateral instability is the major issue while designing a multistory building and seismic zones are also considered while designing a multi-storey building.

SEISMIC ZONE:**-** The earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5). According to the present zoning map, zone 5 expects the highest level of seismicity whereas zone 2 is associated with the lowest level of seismicity.

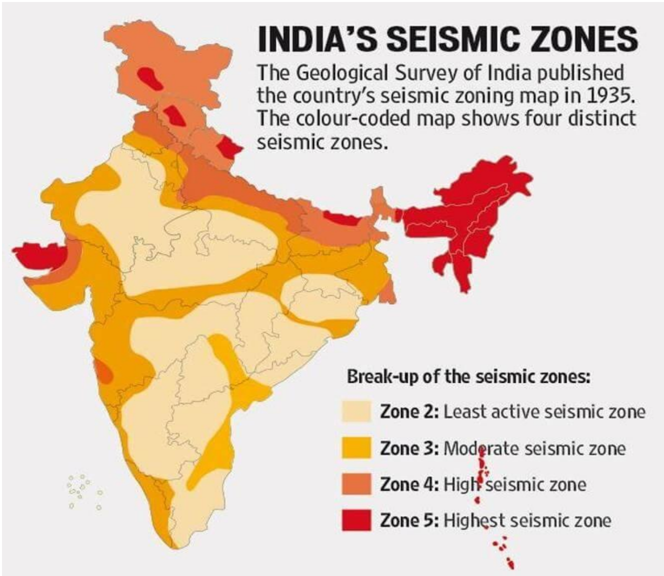

Figure showing the seismic zones in India

Structures which are subjected to a lateral load must have adequate stiffness and strength which helps in controlling the deflection and also prevents any damage which may occur. Steel framed construction is a new concept in which lateral loads are better resisted by bracings. Steel braced frame models are effective means to transverse lateral forces caused by earthquake and wind forces in multi-story buildings. Bracings hold the structure stable by distributing the loads. Braced frames are less in weight than shear wall so it attracts less seismic forces. There are various types of Braced Frames such as concentrically braced frames and eccentrically braced frames. These Bracings are arranged in different configuration like X Bracing, V bracing, Inverted V bracing, Single diagonal Bracing.

- ***Concentrically Braced Frames (CBFs)*:-** CBFs increases the lateral stiffness of the frame and usually decrease the lateral drift.

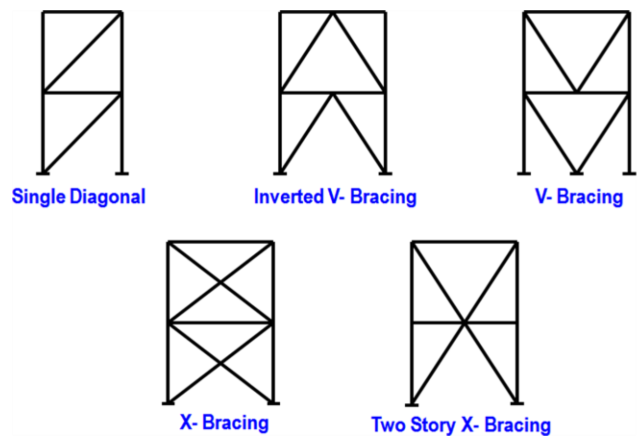

Figure showing concentric Bracings

- ***Eccentrically Braced Frames (EBFs):-*** Eccentrically bracing reduces the Lateral stiffness of the system and improve the Energy Dissipation capacity.
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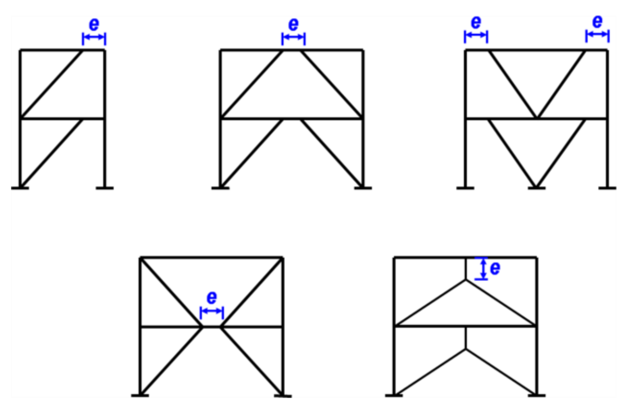

Figure showing eccentric bracing

2. LITERATURE REVIEW

Dawn LEHMAN[1] (2004) Proposed an innovative design methods based on balancing the control yield mechanism, secondary yield mechanism and critical failure mode to improve seismic performance of gusset plate connection used in concentrically braced frame system. Recommendation are examine for modeling the inelastic and post buckling behaviour of the brace for pushover and dynamic time history performance.

A.H. Salmanpour[2] (2008) Study shows that the buckling Restrained braced frames (BRBFs) can more readily satisfy the collapse prevention criteria than the special concentrically braced frames (SCBFs) because the collapse prevention probability of BRBF model is less than 2% and the immediate occupancy probability of BRBF model is 66% where as the collapse prevention probability is about 43%, a value much higher than 2%.

N.Ozhendekci[3] (2008) studied nine eccentrically braced steel frames with various geometries with static pushover analysis. The rotation of load pattern and maximum link rotations pattern are similar and not similar respectively in pushover and inelastic dynamic analysis for EBFs with shear link.

S. Sabouri-Ghomi[4] (2008) an introduction and application of easy going steel (EGS) theory for improvement of behavior of X bracing system is discussed. The lateral stiffness ductility and energy absorption capacity of the system increase and lateral drift decreases with EGS. Stability of the system increases**.**

E.M. Hines [5] (2010) Understood the need for further analysis determine the capacity design load on EBF column. A strong view should be given to design links as weak as possible. It discussed that longer, weaker links at the Top of the building experience problem due to higher mode effect. This paper advises to study the relationship bi/w EBF system ductility and column over strength demand with maximum link rotation capacity.

Sanda KoboevicI[6] (2012) This paper studied the global seismic response of 3**-** and 8**-** story eccentrically braced frames EBFs using non linear time history analysis. it was found that modeling has limited impact on force response but large influence on deformation response. Peak interstory drift and plastic link rotation have a strong correlation.

P.SAIRAJ[7] (2014) This paper is represent an economic aspects of G+4 multi-storey building design by using braced frame composite construction. For the ductile performance over all displacement and inter story drift can be effectively controlled by adopting braced frame model. This concept is very use full for retrofitting of and seismic up gradation of existing multi-storied building.

R. Snehaneela[8] (2015) Outrigger braced structures are studied using pushover analysis. 0.8m link is not sufficient but 1.5m link proved to be sufficient for 15 storey outrigger frame structure**.**

Shachindra Kumar chadhar[9] (2015)
The analysis is done on G+15 story building using seismic coefficient method. Inverted v bracing reduces the bending moment and shear force compared to V type bracing. Story drift and node displacement are minimum for inverted V braced frame. There is a considerable effect of arrangement of bracing on seismic performance of building.

Sreeshma.K.K[10] (2016) Using pushover analysis it was determine that MRF have lowest lateral strength and lateral stiffness and high deformation capacity.EBF came in b/w CBF and MRF in performance.

Pooja.B.Suryawanshi[11] (2016) This paper is based on analysis of Nonlinear and static pushover for the G+5 storey steel building with braced and un braced system. Braced system results enhanced level of performance not only in terms of displacement of roof but also sustaining capacity base shear.

Muhammed Tahir khaleel[12] (2016)
Analysis of G+9 story building with different bracing both regular and irregular building using response spectrum method. In both Regular and irregular building cross bracing gives less displacement and more base shear. Knee bracing gives least amount of base shear.

Sara Raphael[13] (2016) In this paper pushover analysis is used and comparative study of knee bracing is presented. Double knee bracing showed very good behavior during seismic activity with pushover analysis. The degree of inclination with 35^0 of the knee member shows maximum stiffness.

Mrutyunjay.S.Hasarani[14] (2016) A 15 storey building is analyzed for eccentric K and V Bracing under response spectrum and Time history analysis. maximum storey drift is reduced in K2, K15 and V2,V15models .Base shear is increased in K2, K25, V2 V25 and V35 models.

S.Khusru[15] (2017) Include analysis of 10 story building using Time history analysis and shows that un braced structures gives higher displacement than the braced structures. On considering the product of unit weight and displacement, X braced system is more economical and safer than eccentric braced system.

Swetha sunil[16] (2017) It focuses on seismic study of reinforced concrete building with different bracing system by changing the height of the system using response spectrum analysis .X bracing is more effective than other bracing, base shear increases but drift has no effect with increase in aspect ratio.

Safvana P[17] (2018) Analysis of +6 G+12,G+18 storey building with various types of steel bracing mainly X braced Zipper braced and SBS is provided in each storey. Zipper bracing contributes to the reduction displacement and SBS contribute to the reduction of storey drift as compared to X bracings.

3. CONCLUSION

This study came to a conclusion that bracing is the most economical, safe and easy method for providing lateral stiffness to the structure. Concentrically and eccentrically braced frame are analyzed both have their own advantages since EBFs provide more space than CBFs so it is more use for further study. The X and inverted V bracing are found to be most effective under seismic loading. A new concept of providing bracing system was introduced which is knee bracing also be used as a seismic retrofitting method. Mostly response spectrum and Time history analysis methods are used for analysis in ETABS.

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BIOGRAPHY

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