Study of Bracing Systems for RC Frame Structure

Thesis

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By

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Pantnagar
July, 2019

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Author

CERTIFICATE

This is to certify that the thesis entitled **"Study of Bracing Systems for RC Frame Structure"**, submitted in partial fulfillment of the requirements for the degree of **Master of Technology (Civil Engineering)** with major in **Structural Engineering** of the College of Post Graduate Studies, G. B. Pant University of Agriculture & Technology, Pantnagar, is a record of bona fide work carried out by **Ashish Rauthan,** Id. No. **52720** under my supervision and no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been acknowledged.

Pantnagar
July, 2019

(Dr. Vaneeta Devi)
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of **Ashish Rauthan,** Id. No. **52720**, a candidate for the degree of **Master of Technology (Civil Engineering)** with major in **Structural Engineering** agree that the thesis entitled **"Study of Bracing Systems for RC Frame Structure"** may be submitted in partial fulfillment of the requirements for the degree.

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Member

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS AND SYMBOLS

RC	Reinforced concrete
CBF	concentric braced frame
EBF	Eccentric braced frame
STADD PRO	Structural Analysis and Design Program
IS	Indian standard
G	Ground
3D	3 Dimension
ETAB	Extended to Three-Dimensional Analysis of Building System
m	Meter
RCC	Reinforced cement concrete
MBF	Mega-Braces
SMRF	Special moment Resisting frame
2D	2 Dimension
Fig.	Figure
ZBF	zipper braced frame
XBF	X bracing frame
VBF	V braced frame
DBS	Diagonal bracing system
DL	Dead Load
LL	Live Load
IL	Imposed Load
WL	Wind Load
EL	Earthquake Load
kN/m^2	Kilo Newton/meter square
N/m^2	Newton/meter square

m/sec	Meter/Second
N-S	North-South
E-W	East-West
Cl	clause
Z	Zone Factor
T_a	Natural time period
Sa/g	Design acceleration spectrum
RSA	Response-spectrum analysis
MDOF	Multi-degree-of-freedom
SDOF	Single-degree-of-freedom
I	Importance Factor
BM	Bending Moment
SF	Shear Force

Introduction

1.1 GENERAL

The present expanded requirement for housing in urban areas prompts the development of tall structures. The main role of all wide range of structure is to transmit gravity loads effectively. The most widely recognized loads coming about because of the impact of gravity are dead load, live load and snow load. Other than these vertical loads, a structure is additionally exposed to lateral loads caused by wind, earthquake, and blasting. The lateral loads reduce the stability of structure by producing sway moment and induce high stresses. In such a case, the stiffness of the structure is more important than the strength of the structure to resist the lateral load.

Disturbance at some depth below the earth surface causes the vibration of the ground surface is called an earthquake. These vibrations are absolutely uncertain and happen in all direction. Earthquake cause ground to shake and support of the structure is subjected to vibration. Because of the earthquake, it causes both financial and living losses. A large portion of these losses is a result of harm of structure or fall of the building. Thus it is important to plan the structure to protect against such a rigorous earthquake.

In the course of recent decades, India has encountered a number of earthquakes made vast harm to the structure. Today, over 60% of Indian land territories lies in higher three seismic zones III, IV and V according to Indian seismic code [IS 1893 (Part-1):2016]. However, just about 3% of the built environment is correctly engineered. India has the potential for powerful seismic shaking with a vast supply of powerless structures. A large portion of these losses is a result of harm of structure or fall of the building. Thus it is important to plan the structure to protect against such a rigerous earthquake. As the tallness of structure expands, the influences of sway increases to diminish this sway bracing are provided.

1.2 MOMENT RESISTING FRAMES

The frames obtain their lateral load resistance from the rigidity of connections among beams and columns as shown in Fig 1.1 that is, by the developments of bending moment and shear force in the frame members and joints. The behavior of frames is straight forward and their computer modeling is uncomplicated. The frames are infilled by masonry panels for the reason of partition. These partitions are considered non structural and their lateral load resistance is usually ignored. The behavior of these panels is complex. These act as diagonal bracing members before failing and falling separately from the frame. In many cases, under brutal shaking these fail and fall away from each other before the frame is subjected to ultimate load and that is why their contribution to lateral load resistance is not measured.

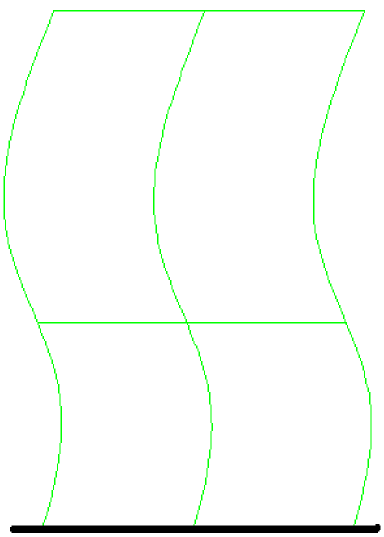


Fig. 1.1 Behaviour of Moment Resisting Frames

1.3 STRENGTHENING OF RCC BUILDINGS WITH STEEL BRACING

Steel bracing is a very effective and efficient strategy for resisting horizontal forces in a structure. Bracing has been utilized to stabilize laterally most of the world tallest structure as well as major retrofit measures. A bracing system enhances the seismic execution of the building by expanding its lateral stiffnesss and capacity. The various researcher has explored a different technique, for example, infilling walls, adding walls to an existing column, encasing columns and adding steel bracing to enhance the quality as well as ductility of the existing structure. With the help of bracing system load transfer from frame to the bracing, bypassing the weak beam and columns while increasing strength. It is one of the main components of the structure to prevent it from seismic and wind load. Therefore, the utilization of steel bracing frame work for retrofitting the RC frame is attractive as shown in Fig.1.2 and 1.3. Exicting RC framed structure planned without seismic criteria can cause a considerable hazard during earthquake motion.

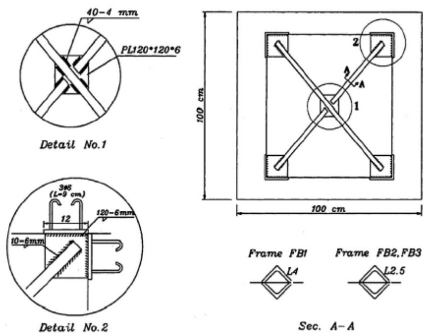


Fig.1.2 Connection of Steel Brace to Concrete Member [Rahimi and Maheri, 2018]

Fig.1.3 RC Building with Exterior a Bracing System [Dash, 2015]

1.4 STRUCTURAL MECHANISM OF BRACING SYSTEM

The different bracing framework performs differently under lateral and gravity loads. The mechanism of each kind of bracing framework against the two loading cases (gravity and lateral) is clarified below:

1.4.1 BEHAVIOR OF STEEL BRACING UNDER LATERAL LOADS

The design of a tall building is governed by the lateral forces induced due to the earthquake. Braced frames are viewed as the most effective to oppose these lateral forces in either direction. The main role of the brace is to oppose horizontal shear induced due to lateral forces. These process to resist horizontal shear can be understood by following the way of the horizontal shear along the frame. It can be understood by taking four different types of bracings which are subjected to lateral loads as shown in Fig.1.4.

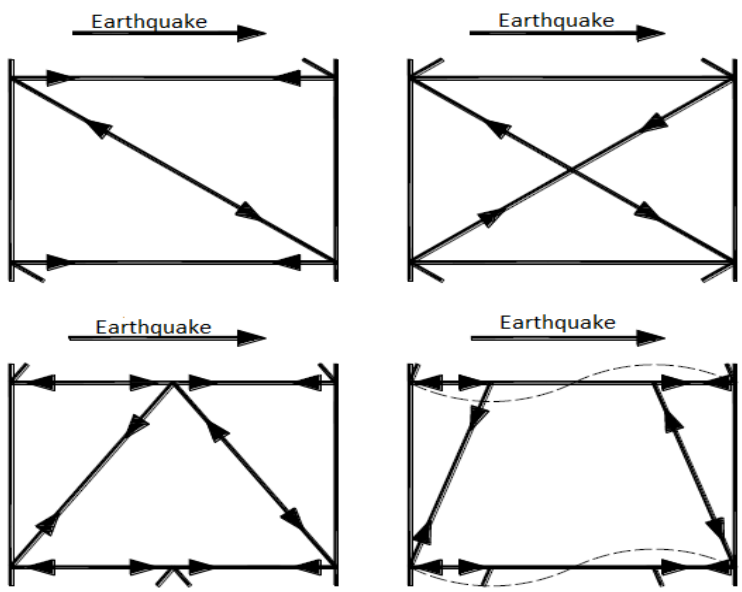


Fig.1.4 Latral Load Transfer Path in Bracing [Siddiqi *et.al*, 2014]

It clear from Fig.1.4 that when the diagonal member is placed to compression, the horizontal web member will undergo axial tension for equilibrium in the lateral direction. Forces and deformation in each member of braced will be reversed as the building is subjected to lateral loading in the opposite direction.

1.4.2 BEHAVIOR OF STEEL BRACING UNDER GRAVITY LOADS

When gravity load acts on a column, it gets shorten axially because of the compressive loads. As a result, the diagonal members are exposed to compression and beam will experience axial tension due to the tying action as shown in Fig.1.5. In the situation, where diagonal members are not connected at the ends of the beams, the diagonal members would not convey any force because no restraint is provided by the beams to develop force. In this way, such bracing would not take any part in opposing the gravity loads.

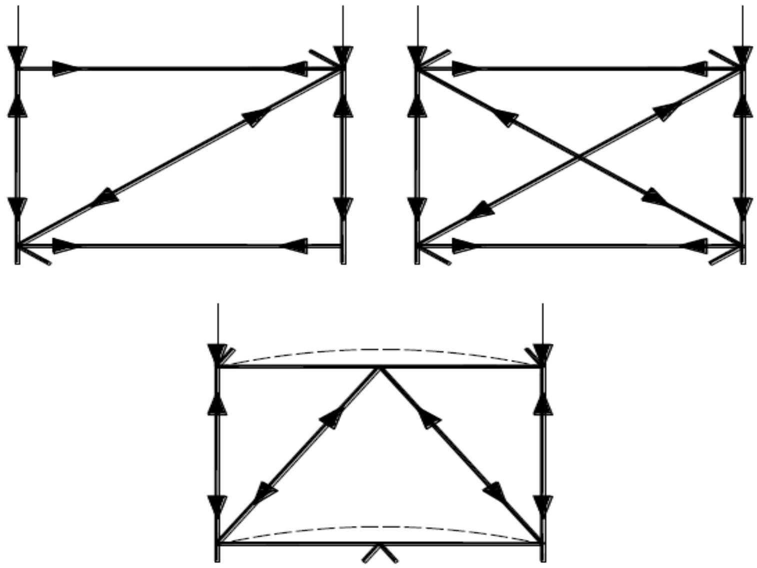


Fig.1.5 Path of Gravity Load [Siddiqi et.al, 2014]

1.5 ADVANTAGES AND DISADVANTAGES OF BRACING SYSTEM

1. The combination of gravity and lateral stability system provide efficiency in the design.
2. Braced frames resist the wind and seismic forces, much more than non-braced buildings.
3. Structures are more robust due to the redundancy of the diagonal members, as they can easily transfer the load from the failed portion to other parts of the structure.
4. The reduction in the requirement of the columns results in a more flexible design of space for the client.
5. K and chevron bracing are favoured over diagonal bracing because there is a space to give opening to entry and window opening etc.
6. When we provide the eccentric bracing it is able to reduce the structural repairing cost.
7. Steel bracing is economical, easy to erect, occupies less space and has the flexibility to design for meeting the required strength and stiffness.
8. As all the diagonal members intersect into nodes, the design of the nodes becomes especially essential for this type of structures.

9. Diagonal bracing is obstructive in nature as it blocks the area of an opening which eventually influences the aesthetic of the building elevation.
10. For buildings over 70 stories, this system becomes uneconomical, mainly due to its complicated joints.
11. K bracing causes yielding in the columns during severe seismic loading.
12. Damage due to earthquake cause difficulties in replacing and repairing the horizontal link in the eccentric bracing system.

1.6 MOTIVATION OF PRESENT WORK

An earthquake shows extraordinary destruction due to unpredicted seismic movement cause broad damage to countless structures of varying degree i.e either full or partial. This damage to the structure directly affects the living and non living property as shown in Fig.1.6. To avoid this huge destruction and to minimize the construction cost, preplanned seismic evaluation and strengthening of the structure show a better option rather than the replacement of buildings.

Seismic strengthening and retrofitting are mainly carried out in two ways either global retrofit methods or local retrofit methods. In global retrofit methods, a convential method based on increasing seismic resistance of the existing structure and non-convential methods based on the reduction of seismic demands is used. Steel bracing is a greatly efficient and economical method for resisting horizontal forces in a frame structure as shown in Fig.1.7. Bracings have been used to stabilize laterally the majority of the world's tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, the load could be transferred out of the frame and into the braces, bypassing the weak columns while increasing strength. Steel-braced frames are efficient structural systems for buildings subjected to lateral (seismic or wind) loadings. Therefore, the use of steel-bracing systems for reinforced-concrete frames has been more attractive.

Fig.1.6 A Site where Buildings Collapsed is Seen in this Aerial Picture taken after a Powerful Earthquake Hit Tainan, Southern Taiwan, February 6, 2016.

Fig.1.7 People's Daily New Headquarters' by Architects and Engineers of the Southeast University, a Beijing, China

1.7 OBJECTIVE OF PRESENT STUDY

1. To analyze the building model with a different arrangement of steel bracing system namely Concentric Braced Frame (CBF's) and Eccentric Braced Frame (EBF's) by response spectrum method using STADD PRO V8i Software.
2. Comparative study of various parameters of concentrically braced frames CBF's in seismic zones III, IV and V.
3. Comparative study of various parameters of the unbraced RC frame model and braced RC frame model in seismic zones III, IV and V.
4. To study the most efficient bracing System for RC frame building model structure in different seismic zones.

1.8 THESIS ORGANIZTION

The work in this thesis has been presented in six chapters. These chapters are briefly described here.

Chapter One	This chapter gives a brief introduction of the study work and objective of the present study.
Chapter Two	This chapter contains previous research carried out by a different author on the topic, to identify what has been done and what still needs to be done for a more comprehensive understanding of the seismic performance of the multistorey building.
Chapter Three	This chapter includes different methodology.
Chapter Four	This chapter includes model configuration, dimension and various parameter of the proposed model, different cases are considered in the study. Analysis of G+13 RC multistoried framed building is carried out using STADD Pro Software.
Chapter Five	In this chapter tables, graph and result of the analyzed multistoried structure are presented.
Chapter Six	General conclusions from the present investigation and suggestion for future work are presented in the last chapter.

Review of Literature

CHAPTER 2 REVIEW OF LITERATURE

2.1 INTRODUCTION

This chapter deals with a brief review of the past and a recent study performed by researchers on seismic analysis of braced frames. Considering the recent trend in building design high importance has given to seismic design and retrofitting. The raising danger in building due to earthquake, made compulsory to provide lateral supporting system for earthquake resistant design of structure. For this purpose, the steel bracing and braced frame were used abundantly and many types of research have been carried out. The researcher results show that bracings have been an effective strategy for improving the stiffness and deformation in RCC buildings. Therefore, this chapter comprises the review of literature and various types of bracing systems with their basic characteristics viz., strength, stability and ductility and bracing mechanism involved.

2.2 REVIEW OF RESEARCH WORKS

Following paragraphs describing the research works and its finding carried by various researchers.

Adithya *et al.* (2004) examined the effectiveness of utilizing different types of bracings and with various steel profiles for bracing members for multi-storey steel frames. ETABS software was utilized to get the design of frames and bracing systems with the least weight and suitable steel section selection for beams, columns and bracing members from the standard arrangement of steel sections. A 3D structure was taken with 4 horizontal bays of width 4 meters, and 20 stories were taken with storey tallness of 3m. The beams and columns were intended 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 utilized in a storey for economic purposes. In this examination, an effort has been made to contemplate the impacts of different types of bracing systems, its location in the building and cost of the bracing system by means of respect to minimum drift index and inter storey drift.

Kevadkar and Kodag (2009) explored that the structure in high seismic areas might be vulnerable to extreme harm. Alongside gravity, load structure needs to withstand to lateral load which can develop high stresses. Presently shear wall in R.C. structure and steel bracing in steel structure is a most famous framework to oppose lateral load due to earthquake, wind, blast etc. The shear wall was one of the most excellent lateral load resisting systems which are broadly used in construction world however use of steel supporting will be the practical answer for upgrading the steel bracing will be the viable solution for enhancing earthquake resistance. In this study R.C.C. building is demonstrated and investigated in three Parts, Model with Different bracing and shear wall, Model with different shear wall system, Model with Different bracing system. The computer aided analysis was done by utilizing ETABS to discover the effective lateral load system during an earthquake in a high seismic region. The execution of the building is assessed in terms of Lateral Displacement, Storey Shear and Storey Drifts, Base shear and Demand Capacity (Performance point). It was discovered that the X Type of steel bracing system considerably contribute to the structural stiffness and reduce the maximum inter storey drift, lateral displacement and demand capacity (Performance Point) of R.C.C building than the shear wall system

Eghtesadi *et al.* (2011) this paper are gone for researching and comparing different types of bracing system. For this purpose, 4 different types of bracing has been used including X bracing, Diagonal bracing, inverted chevron (CBF) and inverted chevron (EBF) in four different storey height are modeled with the help of computer program SAP 2000 version 11 used to anticipate the response of frame and analyzed by static equivalent method considering P-delta effect. In this study, three kinds of steel braced frames and one eccentric braced frames and one eccentric braced frame with a different height of 3,6,9 and 12 stories. During this methodology, the model is analyzed in various aspect for example weight of the structure, the maximum top stories displacement, and energy absorption. For this reason, plate girder of I shaped section is used for the bracing system. Result demonstrate that in spit of the fact that diagonal bracing increase the energy absorption capacity but because of less rigidity it increases the weight of the structure. So, the best arrangement is to apply the inverted chevron (CBF) bracing in steel fames building.

Sangle *et al.* (2012) have done research work on the sesimic performance of high rise steel frame with and without bracing. For this analysis work, six models of high rise steel frame builsing(G+40) floors are models to get the realastic behaviour of the building during an earthquake. The length and width of the building were 10x22m and each storey height is 3.5m. the different bracing pattern has been used such as diagonal bracing-A, X brace, K brace, Knee brace, and diagonal barce- B. The parameter which has used for analysis for analysis was base shear, interstorey drift, total lateral displacement, and stress level with in acceptable limit. Linear dynamic analysis i.e time historey analysis was used according to the rule given in IS 1893(part1). Northridge earthquake time historey is utilized and maximium acceleration is applied at the base of the building. The consequence of the present investigation demonstrates that the bracing element will have a critical impact on structure behaviour under earthquake effect. Iit was found that because of bracing in both direction base shear increament upto 38% and displacement of building reduce upto 43% to 60%. The modal time period was reduced by upto 65%. The result shows the digonal brace-B indicate the effective and economical design of bracing style.

Takey and Vidhale (2012) studied the behaviour of a linear bracing system of steel building under seismic response using software approach. As associated with Reinforced cement concrete(RCC) the steel has got some important physical properties like the high strength per unit weight and ductility. The analysis of unsymmetrical building with the bracing system to resist the seismic lateral load using SAP and also compared the braced and unbraced building which was subject to seismic load has carried out in G+9 stories in zone III using response spectrum analysis with or without steel bracing. The bracing which was used the X bracing system and inverted v bracing system. In this paper, the parameter which was considerd to compare the seismic performance of the building i.e bending moment, shear force, storey drift, and axial force. The conclusion which has come out that braced building of storey drift and displacement as compared to unbraced building decrease the storey drift and displacement. it was concluded that X bracing performanve better than another different type of braces.

Bajoria *et al.* (2012) studied the seismic examination of steel outline structure with or without bracing. The examination had done in steel outline building (G+40) to check the behavior of an alternate kind of bracing (X bracing, Diagonal bracing A and B and k bracing) in steel outline building, bracing surround the building because of which it enlarges the lateral resisting capability of the building during an earthquake. In this paper, the procedure was utilized to characterize seismic examination i.e dynamic investigation (time historey investigation) has been completed according to IS 1893 (part1). The building which had taken was symmetric in x and y-course having length 40m and width 22m having storey stature 3.5 m. The parameter which has been utilized to gauge the seismic investigation of the building is natural frequency, base shear, inter-storey drift, and mode shape. It was observed through their research that with the aid of different bracing the displacement of the top roof is reduced up to 65% and base shear is increased up to 38%. The final conclusion which came out is that diagonal brace shows the highly effective and economical design of bracing style.

Tafheem and Khusru (2013) had studied the behavior of steel building by using eccentric and concentric bracing. In the present study, a steel building with 6 storeys has been modeled and then analyzed due to seismic loading, wind loading, dead and live load. The same steel building has been performed with a different type of bracing systems such as concentric bracing and eccentric bracing. The bracing which have been used in the frame was HSS section. Different parameter has been used for determining the performance of the building in terms of storey drift, storey displacement, the axial and bending moment at the different storey of the structure. The study also carried out to find effective bracing among concentric and eccentric bracing. From the study, it was found out that concentric bracing (X bracing) reduce the lateral displacement comparatively more than the other type of bracing.

Viswanath and Prakash (2013) detailed steel braced frame as one of the structure reinforced concrete building which requires retrofit to expect retrofit to defeat insufficiency to oppose seismic loads. The utilize of steel bracing systems for strengthening or retrofitting of seismically inadequate reinforced concrete frames was a practical answer for improving earthquake resistance. Steel bracing is economical, affordable; simple to erect possesses less space and has the adaptability to plan for meeting the required quality and firmness. In this investigation, the seismic execution of strengthened RC building restored utilizing concentric steel bracing. The bracing was accommodated in peripheral columns. A 4-storey building was analyzed for seismic zone IV as per IS 1893; 2002 utilizing STAAD Pro software. The impact of the restored building was studied. The examination was reached out to eight storied, twelve storied building. The percentage reduction during lateral displacement was found and reductions of the maximum inter storey drift of the frames.

Sheikhand Massumi (2014) had studied the impact of bracing arrangement on seismic behavior of tall steel structure subjected to seismic ground motion. For this reason, steel frame with 18 to 30 storey having a bracing framework with the various design was studied utilizing PERFORM-3D software. Four bracing systems were used: concentrically brace (CBF) and three types of mega-braces (MBF). In one frame, bracing was just built in a single bay however in the other, bracing was placed over five storeys. The four braced frame model of 30 storeys considered. Nonlinear time historey investigations were directed to evaluate the structural performance under seismic ground motion. The parameter which has been used for analysis was roof displacement; inter storey drift and energy absorption. The result of the analysis showed that roof drift in MBF is 12 to 70% lower than CBF. The reduction of inter storey drift was equal to 35%. The energy absorption increases for the mega structural bracing system.

Tanaji and Shaikh (2015) reported steel braced and the concrete braced frame was used to resist seismic load in the multistoried building. In this study, the basic concept was to use a distinct type of bracing (Diagonal, Inverted V type, X type, V type, K type and combine V type). The bracing was provided on all periphery and two parallel sides of the building. The 13 storey SMRF (Special moment Resisting frame) was analyzed for seismic zone III as per IS 1893 using Etab software. The different parameter has been used to carry out the comparative study of base shear, top floor displacement compared with bare framed. It presumed that X bracing is most effective for reducing storey overturning moments. The provision of concrete and steel X bracing on all periphery and two inverse sides of the building increment the base shear by 60 to 65% as a measure to another sort. So, it finalized that from all another diverse type of bracing X bracing gave effective resistance from seismic load in R.C.C building.

Patel and Sangle (2015) studied the seismic behaviour of high rise 2D steel building with a different bracing system. For this reason, the different braced structure was examined for various storeys; and the performance is compared. Pushover analysis have been done to assess the structural performance of the different bracing system in high rise 2D steel building of 15,20,25,30 and 35 storey. The bracing system which has been used was moment resisting frame(MRF), V bracing system, X bracing system, zipper braced frame system and chevron braced frame(CBF). The different parameter had considered determining the seismic performance of structure which was storey displacement, inter storey drift ratio, base shear and etc.these parameter affecting the seismic performance of building with a different type of bracing system and with the different storey height and lateral load pattern were investigated. This study shows that chevron braced frame and V braced frame has lower storey displacement and storey drift ratio which indicate that these bracing have higher stiffness and strength compared to other bracing systems. ZBF shows nearly the same storey displacement and storey drift. They concluded that seismic performnce of zipper braced frame building as compared to another type of bracing have higher capacity where as moment resisiting frame has a minimum capacity.

Jagadish and Tejas (2015) had studied the effect of wind on the different bracing system on high rise steel structures compared to the unbraced steel structure and select the proper bracing model and to choose the appropriate connection type. The bracing system was utilized in structures so as to resist lateral forces. This paper presented the impact of various kind of bracing system in the multistoried steel structure. For this reason, the G+15 stories steel building model is utilized with the same design and different bracing system such as single diagonal, X bracing, double X bracing, K bracing, V bracing were utilized. The STADD PRO software has been used for the analysis of steel building and different parameters were compared these are displacement, base shear, storey drift, maximum axial forces and maximum weight for different types of braces. The conclusion shows that all bracings were good to reduce the displacement, weight of structure are more in different types of bracing as compared to the unbraced frame.

Khan *et al.* (2016) studied the efficiency of the different bracing system on Reinforced concrete building frame for strengthening and retrofitting of the seismic inadequate RC building frame. In their research G+15 building frame is taken into consideration with different bracing and analysis was done on different seismic zone III, IV, V which was used as per IS code 1893. Both equivalent static and Response spectrum method was being utilized for the investigation, which had finished with the utilization of ETAB Software. In this study, Researcher found that different type of bracing had to use in order to control storey drift, lateral displacement and member forces in the frame. Bracing lessens storey drift and lateral displacement as compared with bare frame and X bracing contributes least lateral displacement as compared to other bracing.

Patel *et al.* (2017) had carried out the investigation to study the behavior of seismic load in RCC building. Research fundamentally completed to locate the best bracing system which can be provided in structure these are moment resisting frame (MRF), X bracing frame (XBF), V braced frame(VBF) for G+10 storey working in various seismic tremor zone II and III. The structure was analyzed by response spectrum investigation as per IS 1893 with the aid of Stadd pro and Etab software. The diverse parameter has been chosen to check the efficiency of structure for seismic analysis were base shear and displacement. In this paper, it was observed that X bracing provide more stiffness and provide resistance to storey displacement about 55 to 60%. The author observed through this research that there was a significant increment in base shear of the braced frame compared to the bare frame structure.

Nassani *et al.* (2017) studied that in tall building strength is less significant than the stiffness. Braced and moment resisting frame had used as lateral load resisting structural elements in steel frame building. In this paper, the researcher exhibits a correlation of the seismic response of different bracing in steel frames under seismic effect. The different bracing system has been used are X, V, inverted V, knee, and zipper braced frame. The frame consists of 3 bays and a steel brace which is inserted in the middle bay. The structure was modeled and analyzed at four different height level and was performed with the help of dynamic analysis and nonlinear static analysis. The different constraint has been used for determining the stiffness of structure are drift ratio, base shear, storey displacement, roof displacement time historey. The outcomes demonstrated a decent enhancement in the seismic resistance with different bracing. The outcomes uncovered that the bracing components were exceptionally successful in decreasing drift since the reduction of inter-storey drift concerning unbraced frames were on the normal 58%. These bracing system also show lower storey displacement and representing that these systems contain strength and stiffness.

Abhishek and Rajeeva (2017) had done research on the effect of the bracing system in R.C tall building on seismic lateral load. The bracing system is one of the viable structural systems which assumes an indispensable job in the structural behaviour during an earthquake. The study was done on G+19 stories building analyzed at seismic zone V utilizing CYPE-CAD software to check the lateral load resisting behaviour of the structural system. This analysis has been conveyed utilizing the parameters storey displacement, storey drift, base shear, and column force. The structural configuration of tall building i.e bare frame, Diagonal bracing system, X bracing system, eccentric bracing system, inverted V bracing system, K bracing, V bracing and the combination of X bracing and DBS. The conclusion has found out that from all the bracing system COMB and XBS was found to gave the best performance annd bringing about considerable decreases of lateral displacement 32 to 54%, inter storey drift 58 to 59%, column bending moment and shear force 69% compared to the bare frame.

Mapari and Ghugal (2017) had studied the seismic evaluation of high rise steel structure with and without bracing. Bracing systems are mainly categorized into two systems 1. Concentrically brace frames CBF consisting of columns, beams, trusses joined with pin connection. Lateral load in this system is resisted by truss action and columns. 2. Eccentric Brace system in this system lateral load is resisted by both frame and truss action. It is simply defined as a braced member is attached to the isolated member. In this paper, dynamic analysis by the response spectrum method is carried out with a high rise steel building with a different pattern of the bracing system. The aim of the study was to investigate and compare different results of the seismic analysis for different types of bracing system and without bracing. For this purpose, 25 stories steel building model is used with the same configuration and different bracing systems such as X brace, V brace, inverted V brace and K brace. A commercial package Etabs 2013 is used for analysis purpose. The different parameter has been used to study the seismic behavior of building are Base shear, displacement and modal time period comparison. From the analysis, it was found that due to bracing in both direction base shear of the structure increases up to 30.63%. Modal time period reduced up to 14.52 %. The displacement of the roof level of the building decreases up to 20.2 % due to the bracing system. It is suggested that X bracing is highly effective bracing system.

Ghule *et al.* (2017) had carried out the investigation on the study of different types of bracing system on a steel frame by placing at different seismic zone. Bracing in steel structure are mostly used in the structure because it can withstand the lateral load due to earthquake, wind and etc. In this research paper 25 storey steel frame was analyzed for the rectangular plan of 25x15m in a different zone (II and IV) for medium soil type. ETAB software had use for analysis of the structure. In this paper, different types of bracing such as X bracing, inverted V bracing and single diagonal bracing in different location of the building like inner, outer and at the center edge in X and Y direction. The bracing of 130X130X8 had used in the analysis. The parameter has been used like storey displacement, storey drift and storey shears. The conclusion of research shows that bracing system reduces the lateral displacement and drift compared to the other bracing system in steel structure.

Rahimi and Maheri (2018) had studied the effect of retrofitting on RC frames by X bracing on the seismic performance of the column. There are a number of retrofitting techniques which can be utilized. Using different types of steel bracing increases the seismic capacity of RC frames. In this paper, analysis has been done through time historey analysis, the behavior of RC column has been checked before and after retrofitting with steel X bracing and examining possible complication, increased demand and symptoms of such retrofitting strategy. The different parameter has been done are column shear and axial forces, as well as, column performance level and low cycle fatigue life is investigated. The conclusion found that retrofitting of low rise RC frame with X bracing gave better performance in almost all aspect and for mid to high rise frames, the bracing which are connected to the column should be taken into consideration and if needed the local strengthening of the column should be done.

Haque *et al.* (2018) had studied the impact of the bracing system on the structural performance of steel building. In this research, a steel building of ten storied building has been designed and analyzed under seismic (lateral) loading. The performance of structure has carried out using various types of the bracing system these are X bracing, diagonal bracing and eccentric bracing. The different parameter has been selected for a comparative study these are storey displacement, storey drift, moment on beam at a different level between braced and un-braced system. ETAB software has been used for the comparative study of 10 storied steel building. From the study it was found out that, X bracing reduced the lateral displacement of the structure by 41% and provide greater structural stiffness to the structure. The researcher concluded that X bracing gives better performance than another type of bracing under similar circumstances.

2.3 TYPES OF BRACINGS

There are different types of bracing system commonly used in multistorey structure between orthogonally arranged beams and column to transfer horizontal forces imposed on the structure. There are two types of bracing system, namely Concentrically braced system, and eccentrically braced system. These are explianed in the following sections:

2.3.1 CONCENTRICALLY BRACED FRAMES (CBF)

These are comprised of diagonal brace situated in the plane of the frame. Both ends of braces join towards the end point of other framing members to form a truss, making a stiff frame. The concentric bracing increment the lateral stiffness of the frame, in this way, expanding the natural frequency and further more normally diminishing the lateral drift. However, the increment in the stiffness may draw a large inertia force because of the earthquake. Further, while bracing decline the bending moments and shear forces in the column, they increment the axial compression in the column to which they are connected. Since RC column is strong in compression, it may not represent an issue to retrofit in RC frame utilizing concentric steel bracing. Concentrically braced frames don't have broad requirement with respect to members and connection and are often times utilized in the area of low seismic hazard. It means that, where a member meets at a node, the centroid of every part goes through a similar node. Concentric bracing might be arranged in several unique arrangements such as X, K or one-directional diagonal bracing as shown in Fig.2.1 and the bracing members might be intended to act in tension or compression or both. Balance diagonal bracing is the most widely recognized for medium-rise structure. Since it gives the same strength in both directions.

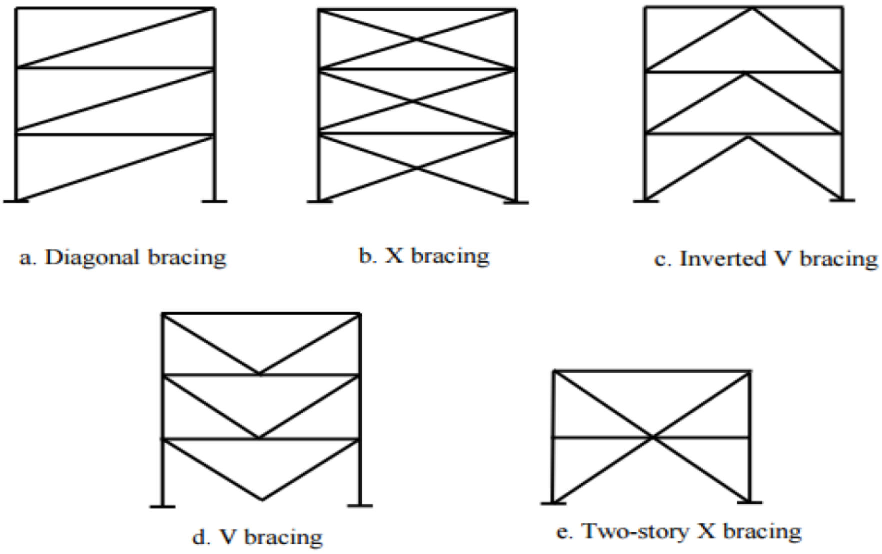


Fig.2.1 Concentrically Braced Frames (CBFs) System [C. V. R. Murty et.al]

2.3.1.1 Diagonal Bracing

These members resist both tension and compression. The diagonal bracings are working together with an interior core which gives additional stiffness. Therefore, the entire structure can accomplish more heights. There are many other methods such as outriggers system as shown in Fig.2.2 which can be replaced by the diagonal bracing shown in Fig.2.3.This is because the most effective approach to resist lateral loads is to give the resisting elements with maximum stiffness at the building. Therefore, reduces the need for another system like outriggers. The lateral and gravity load resist by diagonal members which help to increase the lateral and torsional stiffness of the tower.

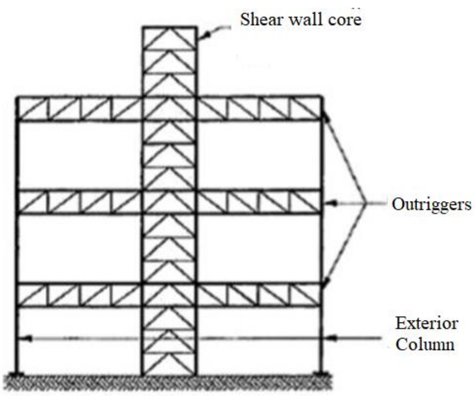


Fig.2.2 Outriggers System
[Shah and George, 2017]

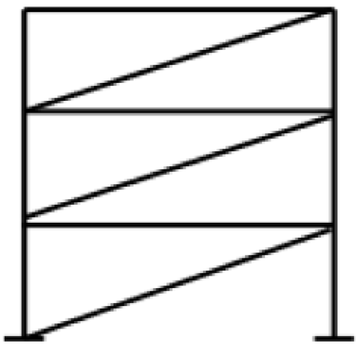


Fig.2.3 Diagonal Bracing
[Seyedbabak Momenzadeh, 2017]

2.3.1.2 Chevron Bracing

Chevron bracing can be classified as V and Inverted V bracing, two diagonal members are extended from top two corners of horizontal members of a frame to downward and connected at the mid point on the lower horizontal members of the same frame and turn in V shape bracing as shown in Fig.2.4.a. This can be used as invetred V shape in which diagonal member is extended upward from the bottom two corners of horizontal members and jointed at the mid point of the upper horizontal members as shown in Fig.2.4.b.

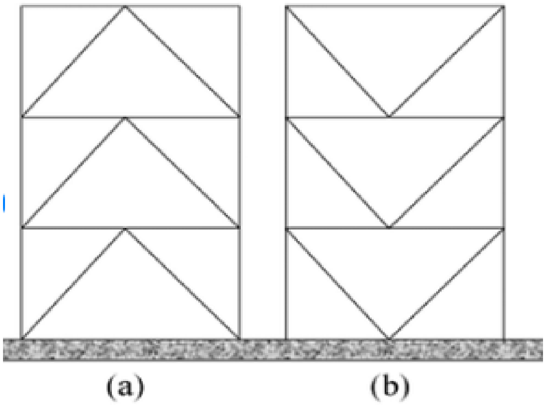


Fig. 2.4 Chevron Bracing[Azad, 2017]

2.3.1.3 K- Bracing

K bracing connect to the column at its mid height from the adjacent top and bottom corner of the column as shown in Fig.2.5. The chances of column failure are more, therefore K- bracing is not provided in the seismic region. However, This frame provides more opening space for doors, windows and ventilaters opening in the structures.

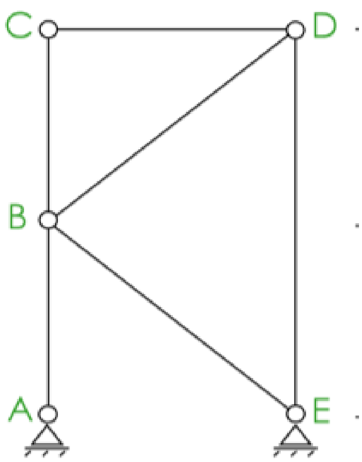


Fig.2.5 K Bracing [wong, 2003]

2.3.2 ECCENTRIC BRACED SYSTEM (EBS)

Eccentric bracing consists of diagonal braces located in the plane of the frame where one or both ends of the brace do not join at the end points of other framing members as shown in Fig.2.6. Eccentrically braced frames are prepared of two small diagonal braces linking the column to the middle span of the beam with a small segment of the beam, to enlarge the lateral load resistance in terms of the seismic performance. The system basically combines the features of a moment frame and a concentrically braced frame, though minimizing the disadvantage of each system. The eccentric connection to the frame implies an eccentric brace transfers lateral forces via shear either to a further brace or to a vertical column. In the structural frame, the horizontal short segment in between the two braces member connection is called links. The major purpose of the link beam is used to absorb the energy dissipation resulting from the lateral disturbance. This is because the links are utilized to manage plastic deformation and keep structural stability from the seismic disturbance. Moreover, the resistance of lateral movement in the eccentric braces is throughout the bending of the column and beam. Therefore, the links provide the ductility behaviour to oppose the impact of seismic force from the lateral excitation. The strength, stability, and ductility of the eccentrically braced frame are influenced by the length of the horizontal links. Since the links indicate the capability of energy dissipation inside the system. The previous researcher indicated that the short links have greater strength and ductility when it subjected several cyclic loads. Even through the longer links is able to provide the architecture freedom especially in the placement of the window and door opening [Azad and Topkaya, 2017].

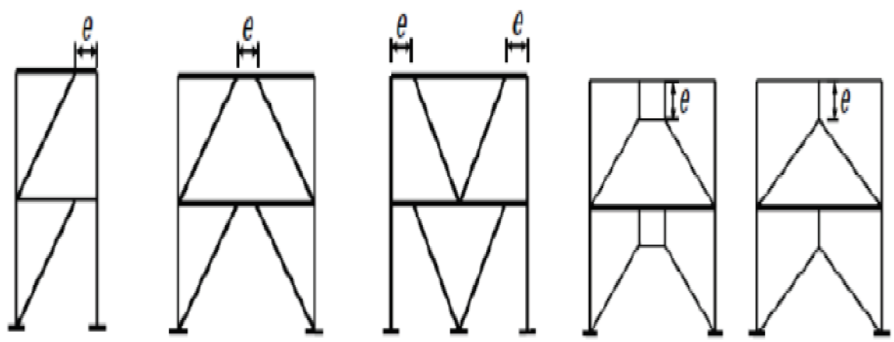


Fig.2.6 Types of Eccentrically Braced Frame [Razak et.al 2018]

2.4 COMPARETIVE STUDY

Different bracing has different characteristics, mechanism and latest improvement, among the different types of the bracing system being used in the reseach studies and construction works. On the bases of dynamic properties of frame, diagonal brace has high natural than chevron bracing. The capacity of energy absortion is also affected by the slenderness ratio because slenderness ratio has a high capacity of energy absorption. The braces with small slenderness ratio decrease the ductility behaviour (Kangilmaz,2017). The lateral stiffness of eccentric braces is lower than the concentrated braces frame especially the diagonal bracing because eccentrically braced frame has more ductile characterisitic (Ozcelik et.al, 2016).

Struts replace the deap beam this arrangement is called zipper braced frame. The strut lessens the vertical load and caused to the adjacent storey braces and keep their axial load capacity after compression braces buckle.

The main function of the link beam is used to absorb the energy dissipation resulting from the lateral excitation. This is because the links are used to control plastic deformation and maintain structural stability.Therefore, the links provide the ductility behaviour to counter the impact of seismic force from the lateral excitation.

Table 2.1 Comparison of Different Types of Bracing System

Properties	**Diagonal Braced Frames**	**Chevron Braced Frames**	**Eccentrically Braced Frames**
Characteristic *(Strenght, stiffness andductility)*	➢ High natural frequency ➢ Smaller slenderness ➢ High Capacity energy absorption ➢ Decreasing the ductility ➢ Deterioration of energy dissipation becomes faster for X-bracing	➢ Low natural frequency ➢ High elastic stiffness and strength	➢ Absorb energy dissipation ➢ Control plastic deformation ➢ Maintain structural stability ➢ Links provide ductility behaviour ➢ Strength, stability, and ductility influenced by the length of horizontal links

Bracing Mechanism	➢ Bracing acts as the compression member while the horizontal web member (beam) acts as a tension member in the single diagonal braced frame ➢ Both bracing in the X-bracing acts as the tensionand compression member respectivily	➢ Compression and tension exerted on each side of braces respectively ➢ Unbalances forces created in braces beam ➢ Compression braces are deformed ➢ Tension braces sustain tension ➢ Cause elastic deformation ➢ Poor performance ➢ Both braces distribute the lateral load equally before buckling ➢ Compression lost axial load capacity after buckling ➢ Contribute unbalanced distributed load capacity after buckling ➢ Large bending moment on the intersection of	➢ The resistance of lateral movement through bending of column and beam ➢ Shorter horizontal links lead to high shear yielding efficiency ➢ Longer horizontal links contribute flexural yielding ➢ Intermediate links will lead to a combination of shear and flexural yielding experiences ➢ Short links show better performances in terms of rotation capacities ➢ Lateral stiffness lower than CBF especially diagonally bracing due to the eccentrical braces have more ductile ➢ Time consuming and expensive in replacement horizontal links

		beam and braces	➢ Difficulties of replacing or repairing since it is the primary component of despite high capacity of energy dissipation.
Latest Improvement	**Mega X-Bracing (Diagrid)** ➢ Reduced in a lateral drift with appro. 50% (zeng et.al,2015) ➢ 25% of material saving in term of less steel bracing is used ➢ Minimizing shear deformation ➢ Provide maximum resistance against torsion ➢ Possess greater structural flexibility than a bracing system ➢ Diagrid can be configured, with some adjustment in modules and angle(s) of diagonals, to meet	**Strong beam** ➢ Deep and heavy beam to provide adequate strength and prevent undesirable deterioration of frame **Strut** ➢ Replace deep beam and heavy beam due to expensive ➢ Mitigate vertical load induced to adjacent storey braces and keep their axial load capacity after compression braces buckled	**Vertical links** ➢ No rotational restraint at the lower end ➢ Does not lead to significant damage to beam since internal energy dissipation and intensive elastic deformation accumulate in the link ➢ Replacement more efficient and easier

	architectural and structural requirements.		

2.5 SUMMARY

By studying the various literature regarding different types of bracing system for the multistoried steel frame and RC frame in a high seismic area. The following details present a breif summary of the lietrature.

- By studying various research paper, the bracing system is not only capable of controlling displacement but also plays an important role in reducing interstorey drift.
- The performance of structure has been carried out using various types of the bracing system these are X bracing, diagonal bracing and eccentric bracing. From the study, it was found out that, X bracing reduced the lateral displacement of the structure by 41% and provide greater structural stiffness to the structure.
- Concrete bracing and steel bracing have been used as an alternative to the other for strengthning. It was found that X type of concrete bracing for reducing storey displacement and V types of steel bracing is most efficient for reducing storey displacement. In concrete X bracing system and steel frame, V bracing system on all the side of the building as well as on any two sides of the building increases base shear by 60 to 65%.
- There was a significant increment in base shear of the braced frame compared to the bare frame structure.
- For different types of bracing system weight of the structure are more when compared to the unbraced structure with the same configuration of the stucture.

Materials

and

Methods

CHAPTER 3 MATERIALS AND METHODS

3.1 GENERAL

Special bracing systems like Eccentric braced frame (EBS) and concentric braced frame (CBFs) are widely used globally in earthquake resisting systems because of their simplicity in construction and design. The main objectives of present study are mentioned in chapter 1 and relative literature has been discussed in chapter 2.Since the present study is to compare the seismic effect on high rise multistorey RC building by using different types of bracing systems in different seismic zones, this chapter illustrates the various load and their combinations as per IS codes, details of frame being analyzed and methodology to be used in the study.

3.2 TYPES OF LOADS

The structure should be design in such a way that it should be sufficiently strong to tolerate any kind of load at any time which is likely to occur in its lifespan. Different types of loads can cause stress, displacement and displacement on a structure which causes a problem in the structure and may increase the chances of failure of the structure. So, the estimation of the total load that likely to occur in structure is calculated accurately and structural elements should be designed properly. The types of load that occur in the structure are Dead Load (DL), Live Load/ imposed load (LL/IL), Wind Load (WL) and Earthquake Load (EL). Indian Standard (IS) codes provide the information of all types of loads for the design of structures and discussed in the subsequent section.

3.2.1 DEAD LOAD

Dead load also called as permanent load are mainly associated with the weight of the structure and are always at rest and always constant with time. Dead loads include the self-weight of any structural element i.e. partition wall, beam column, slab, etc. and any types of floor/ roof finishing as shown in Fig.3.1.It is calculated by finding the quantity of each material and then multiplied it with the unit weight of that specific material. The unit weight of Reinforced concrete is 25kN/m^2. Dead loads for various materials being considered in analysis and design to have taken from the IS 875:1987 (part1). In the present analysis, a dead load of 3 kN/m^2 on floor/ roof is used.

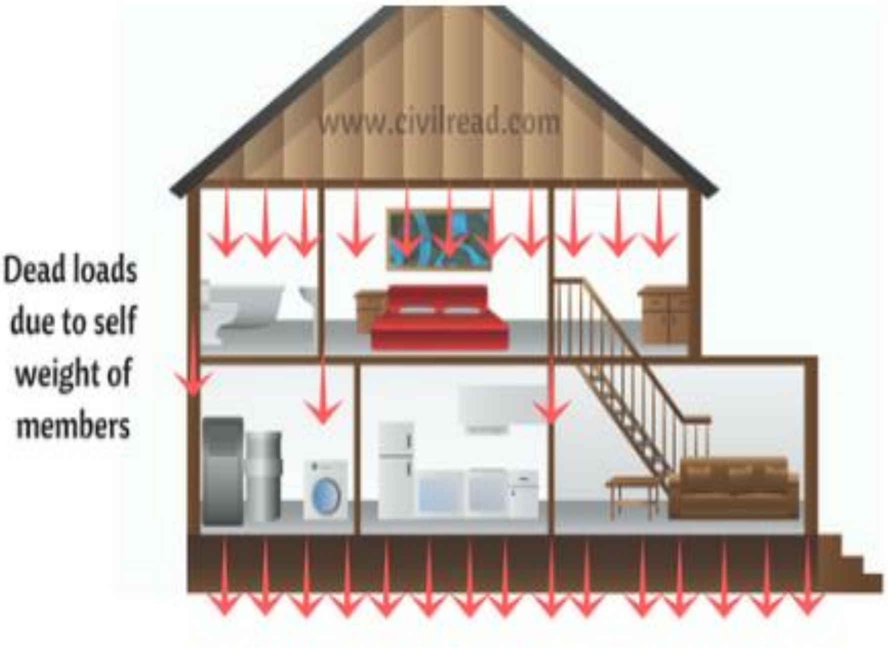


Fig.3.1 Dead Load on the Structure

3.2.2 LIVE LOAD

Live load is also called as imposed loads are usually temporary and changeable. Its intensity depends on the time of the day at one time room may be empty that time the live load is zero. Another example of an office building which experience increased live load during the weak hour and less live load during the weekend. These include loads such as furniture; occupants and other equipment as shown in Fig.3.2. Live loads may be concentrated or distributed.

In the present analysis live load used as 4kN/m^2. The codal provision which has been used for live load is given in IS 875(part 2) 1987. Imposed floor loads for different occupancies have been given in table 1(clauses 3.1, 3.1.1 and 4.1.1) of IS 875(part 2) 1987. Live load to be considered in the calculation of the seismic weight of building as per IS 1893-2016 load up to and including 3kN/m^2 percentage of imposed load is 25% and above 3kN/m^2 percentage of imposed load 50%.

Fig.3.2 Live Load on the Structure

3.2.3 WIND LOAD

Wind load is basically horizontal load caused by the development of air in respect to earth as shown in Fig.3.3. Wind load is required to be considered in the tall building because as the height of structure increase than it is exposed to wind surface.

For low rise building up to 4 to 5 floors the wind load is not critical. Further, in limit state method, the factor for design load is reduced to 1.2(DL+LL+WL) when the wind is considered as against the factor of 1.5(DL+LL).

During the designing of building horizontal forces developed by wind should be kept in mind, loads depend on the two factors height of the building and wind velocity. The code given for calculating wind load on the structure is given in IS 875(part3) 1987. To get the design wind velocity $V_z$the following expression shall be used.

$$V_z = K_1 K_2 K_3 V_b$$

V_b= Basic wind pressure

K_1= Risk coefficient

K_2= Coefficient based on terrain, height and structure size

K_3= Topography factor

The design wind pressure is given by

$$P_z = 0.6V_z$$

Where P_z is in N/m^2 at height z and V_z is in m/sec. Up to a height of 30 m, the wind pressure is considered to act uniformly. Above 30 m height, the wind pressure increases.

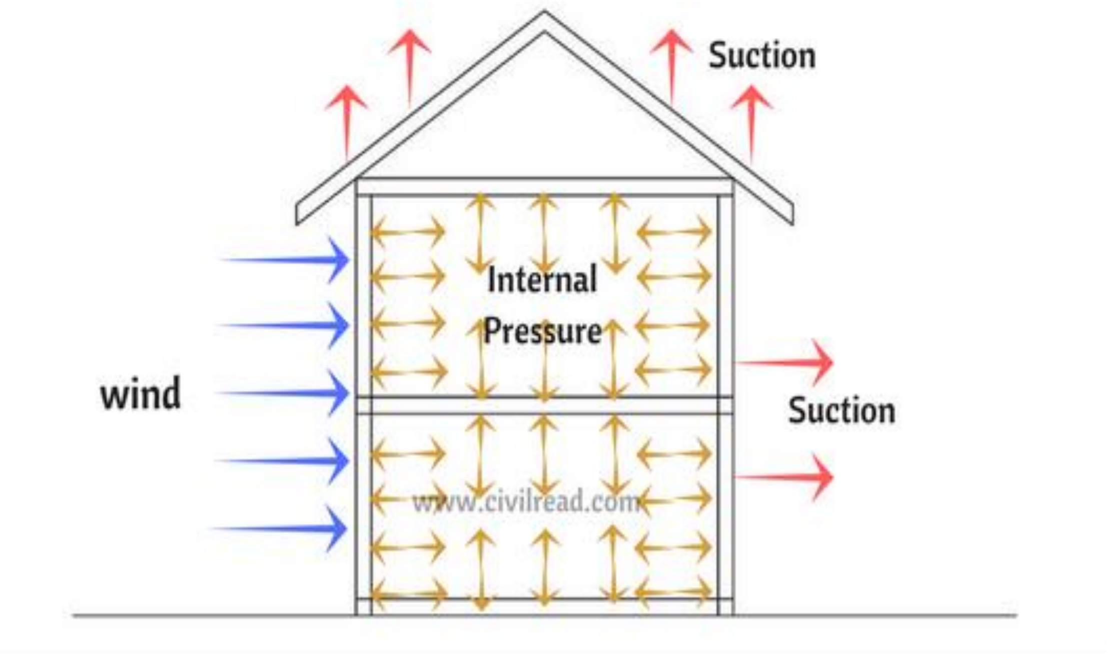


Fig.3.3 Wind Load on the Structure

3.2.4 EARTHQUAKE LOAD

Earthquake force comprises both vertical and horizontal forces in the building. The total vibration brought by an earthquake is recorded into three mutually perpendicular directions normally taken as vertical and two horizontal directions viz., N-S and E-W as shown in Fig.3.4. The vertical direction earthquake forces do not cause any significant damages to structures while the effect of horizontal earthquake forces on structures is devastating if not considered in the analysis of structures. The structural stability due to ground vibration depends on the nature of foundation soil, size of the foundation, mode of construction and intensity of ground motion. IS 1893 (part1) 2016 has been used for calculation of earthquake forces.

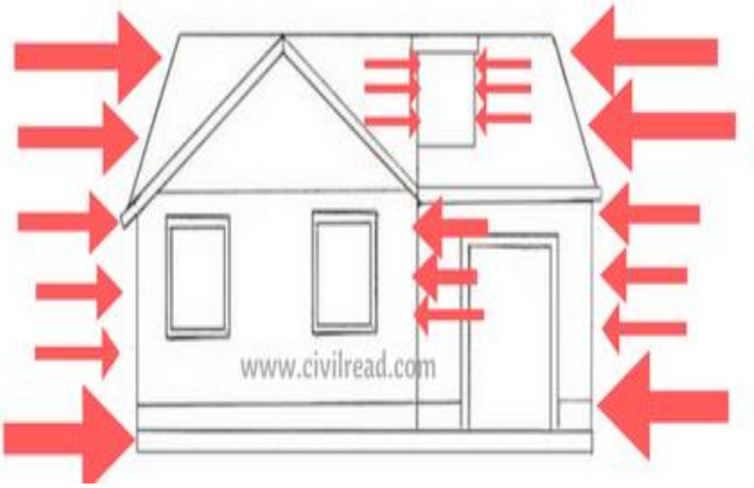


Fig.3.4 Earthquake Load on the Structure

3.3 LOAD COMBINATION

A load combination is provided when more than one load types act on the structure. Building codes usually indicate a variety of load combination together with load factors for each load types in order to ensure the safety of the structure under different maximum loading situation. The combination of different loads which produce an adverse effect in the structure may be adopted for the analysis.

As per IS 1893(part 1):2016 clause no. 6.3.2.2 the following load cases have tobe considered for analysis.

1.5(DL+IL)

1.2(DL+IL+EL)

1.2(DL+IL-EL)

1.5(DL+ EL)

1.5(DL- EL)

0.9DL+ 1.5EL

0.9DL- 1.5EL

DL = Dead load, IL = Imposed load / Live load, & EL = Earthquake load

3.4 FRAME DETAILS

Table 3.1 gives the details of frame elements and material used in the analysis. Steel sections for the bracing system have been chosen as per specifications are given in the IS 800-2007 and IS 800 steel table, whereas reinforced concrete elements are selected to meet the basic requirement as per IS 456-2000and IS13920 – 2016.

Table 3.1 Frame Detail

Number of storey	G+13
Seismic Zone	III, IV, V
Typical storey height	3.0m
Bottom storey height	3.0m
Size of Beams	450x450
Size of column	600x600mm
Bracing	200x200x25
Type of support	Fixed
Response reduction factor	5
Importance factor	1
Damping ratio	5%
Soil type	Medium
Structure Type	SMRF building

3.5 METHOD OF SEISMIC ANALYSIS

In general, the methods of seismic analysis can be classified as (i) Static analysis and (ii) Dynamic analysis. In Static approach Equivalent, static analysis method is used and for Dynamic approach Response spectrum, modal time history method and Time History analysis are used. IS 1893 part 1-2016 is the principle code that gives an outline for computing seismic design forces on buildings. Depending on the buildings height and seismic zone to which it belongs, different analysis methodology (static and dynamic) can be taken for seismic analysis of RCC frames. A brief overview of static analysis and dynamic analysis methods are explained in the following section.

3.5.1 STATIC ANALYSIS

3.5.1.1 Seismic Coefficient Method/Equivalent Static Analysis/IS Code Method

The equivalent lateral force (static force) for an earthquake is a unique concept used in earthquake engineering. The concept is attractive because it converts a dynamic analysis into partly dynamic and partly static analyses for finding the maximum displacement (or stresses) induced in the structure due to the earthquake. The equivalent lateral force for an earthquake is defined as a set of lateral static forces which will produce the same peak response of the structure as that obtained by the dynamic analysis of the structure under the same earthquake. This equivalence is restricted only to a single mode of vibration of the structure inherently.

Equivalent static lateral force analysis is based on the following assumptions,

1) Assume that structure is rigid.
2) Assume perfect fixity between structure and foundation.
3) During ground motion every point on the structure experience same accelerations.
4) The dominant effect of an earthquake is equivalent to the horizontal force of varying magnitude over the height.
5) Approximately determines the total horizontal force (Base shear) on the structure.

Step by step procedure for Equivalent static force analysis

Step 1: Select the location of the building and depending on the location identify the seismic zone and assign zone factor (Z). Use Annex of IS-1893 (2016) Part I.

Step 2: Seismic weight W of the structure will be calculated as per IS1893:2016. Seismic weight of a structure is the total dead load plus appropriate amounts of the imposed(live) load as given in clause 7.3.1 and Table 10 of IS 1893:2016, guides for taking the appropriate amounts of Imposed(live) Load.

Step 3: Calculate fundamental natural time period (T_a) of the structure as per Clause 7.6.2, IS-1893 (2016) Part I.

For without brick infill panel, will be calculated using the using the formula,

$T_a = 0.075h^{0.75}$, (For moment resisting RC frame building)

$T_a = 0.080h^{0.75}$, (for RC Steel composite MRF Building)

$T_a = 0.085h^{0.75}$, (For moment resisting steel frame building)

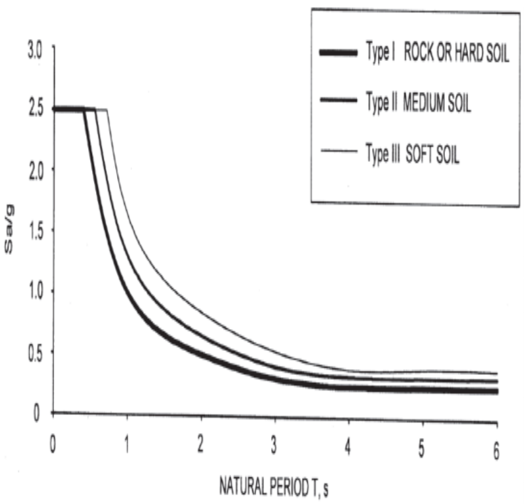
For with brick infill panel

$T_a = 0.09h/\sqrt{d}$, (For all other building including moment resisting RC frame building).

Where, h= height of building in m

d = Base dimension of building at the plinth level (meter) along lateral force direction.

Step 4: Depending on the type of soil (I, II and III) and the fundamental natural time period T_a, the design acceleration spectrum (Sa/g) will be calculated as per clause 6.4.2 of IS1893:2016 and shown in Fig 3.5, and this will be multiplied by the multiplying factor as per Table 3 of IS: 1893:2016, for damping coefficient other than 5 % of critical damping. In our case damping coefficient has been taken as 5% of critical damping as suggested by Clause 7.8.2.1 of IS 1893 (part1):2016.



$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} \begin{cases} 2.5 & 0 < T < 0.40 \text{ s} \\ \frac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 4.00 \text{ s} \end{cases} \\ \text{For medium stiff soil sites} \begin{cases} 2.5 & 0 < T < 0.55 \text{ s} \\ \frac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 4.00 \text{ s} \end{cases} \\ \text{For soft soil sites} \begin{cases} 2.5 & 0 < T < 0.67 \text{ s} \\ \frac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.42 & T > 4.00 \text{ s} \end{cases} \end{cases}$$

Fig.3.5 Design Acceleration Coefficient for Different Soil Sites for 5% Damping (IS-1893 2016)

Step 5: Horizontal seismic coefficient A_h will be calculated by using formula

$$A_h = \left(\frac{S_a}{g} \text{x} \frac{Z}{2}\right) / \left(\frac{R}{I}\right)$$

Where,

Z = Zone factor as per Table 3 of IS1893:2016

I = Importance factor as per Table 8 of IS1893:2016

R = Response reduction factor as per Table 9 of IS1893:2016

Sa/g = Average response acceleration coefficient

Step 6: The design seismic base shear V_b will be calculated using formula

$V_b = A_h$ * W, as per Clause 7.6 of IS1893:2016

Step7: The design base shear (V_b) computed in step 6, will be distributed along with the height of the buildings as per the following expression as suggested by IS: 1893:2016 Clause 7.6.3

$$Q_i = V_b \{(W_i h_i^2) / (\sum W_j h_j^2)\}$$

Where,

Q_i = Design lateral force at floor i

W_i = Seismic weight of floor i

h_i = Height of floor i measured from the base, and

n = Number of the storey in the building is the number of levels which masses are located.

Advantages of static analysis

1. Calculations are very simple and handy.
2. This is less time consuming.

Disadvantages of static analysis

1. This method does not represent the correct picture of seismic load distribution, which is more logical in Response spectrum method.
2. First, the design base shear is computed for the whole building. It is then distributed along with the height of the building.

   Static analysis approach should only be used for regular, symmetrical buildings up to around 15 m height and where the primary mode of the structure governs the structural dynamics. This is not suitable for other buildings which are having irregularities in their plan and elevation.

3.5.2 RESPONSE SPECTRUM ANALYSIS

Response-spectrum analysis (RSA) is a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration to indicate the likely maximum seismic response of an essentially elastic structure.

In this method the response of multi-degree-of-freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single-degree-of-freedom (SDOF) system, which is then combined to compute the total response.

Response spectrum can then be used to pick off the response of any linear system, given its natural frequency of oscillation. One such use is in assessing the peak response of buildings to earthquakes. Dynamic analysis of the system gives the mode shapes and frequencies of the structure and has to solve an Eigen value problem. The provisions of codes per IS: 1893 (Part 1)-2016 for response spectrum analysis of the multi-storey building.

Step by step procedure for Response spectrum method

Step 1: Select the location of the building and depending on the location identify the seismic zone and assign zone factor (Z). Use Annex of IS-1893 (2016) Part I.

Step 2: Calculate the seismic weight of the structure (W).

As per clause 7.4.2, IS 1893(2016) - Seismic weight of floor (W_i)

Step 3: determination of the fundamental natural period of vibration (T_a) as per IS 1893(part 1) 2016 clause number 7.6.2 then design the seismic coefficient A_h as per clause 6.4.2 of IS 1893:2016 (part 1).

$$A_h = \left[\frac{S_a}{g} \text{ x } \frac{Z}{2}\right] / \left[\frac{R}{I}\right]$$

Where,

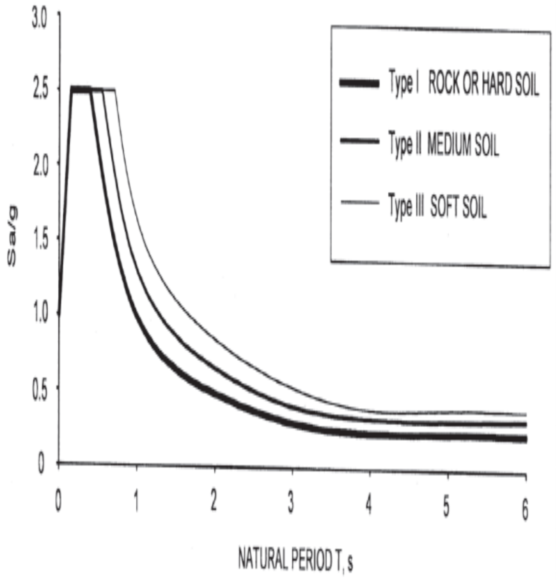
Z = Zone factor as per Table 3 of IS1893:2016

I = Importance factor as per Table 8 of IS1893:2016

R = Response reduction factor as per Table 9 of IS1893:2016

Sa/g = Average response acceleration coefficient as shown in Fig. 3.6

Then calculate the design base shear $V_b = A_h \times W$ as per clause 7.6.1 of IS 1893(part 1) 2016.



$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} \begin{cases} 1+15T & T < 0.10 \text{ s} \\ 2.5 & 0.10 \text{ s} < T < 0.40 \text{ s} \\ \dfrac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 4.00 \text{ s} \end{cases} \\ \text{For medium stiff soil sites} \begin{cases} 1+15T & T < 0.10 \text{ s} \\ 2.5 & 0.10 \text{ s} < T < 0.55 \text{ s} \\ \dfrac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 4.00 \text{ s} \end{cases} \\ \text{For soft soil sites} \begin{cases} 1+15T & T < 0.10 \text{ s} \\ 2.5 & 0.10 \text{ s} < T < 0.67 \text{ s} \\ \dfrac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.42 & T > 4.00 \text{ s} \end{cases} \end{cases}$$

Fig.3.6 Design Acceleration Coefficient for Different Soil Sites for 5% Damping (IS-1893 2016)

Step 4: The design base shear (V_b) computed in step 3, will be distributed along the height of the buildings as per the following expression as suggested by IS: 1893:2016 Clause 7.6.3

$$Q_i = V_b \{(W_i h_i^2) / (\sum W_j h_j^2)\}$$

Step 5: Establish mass [M] and stiffness [K] matrices of the structure using system of masses lumped at the floor levels with each mass having one degree of freedom.

Step 6: Using step 3 and operate the principles of dynamics calculate the modal frequency $\{w\}$ and corresponding mode shape $\{\phi\}$.

Step 7: we can find the modal mass M_K of mode k using the following relationship where n is the number of modes.

$$M_K = \frac{[\sum_{i=1}^{n} W_i \Phi_{ik}]2}{[g \sum_{i=1}^{n} W_i \Phi_{ik}^2]}$$ as per clause 7.7.5.4a of IS 1893 part 1 2016

Where,

g = acceleration due to gravity

Φ_{ik}= Mode shape coefficient at floor i in mode k.

W_i= Seismic weight of floor i of the structure.

Step 8: Calculate modal participation factor P_k of mode k using the following relation where n is a number of modes. Considered,

$$P_K = \frac{\sum_{i=1}^{n} W_i \Phi_{ik}}{\sum_{i=1}^{n} W_i \Phi_{ik}^2}$$ as per clause 7.7.5.4b of IS 1893 part 1 2016

Step 9: Compute design lateral force (Q_{ik}) at each floor in each mode (i.e. for i^{th} the floor in mode k) using the following relationship.

$$Q_{ik} = A_{h(K)} \Phi_{ik} P_k W_i$$ as per clause 7.7.5.4c of IS 1893 part 1 2016

Step 10: Calculate storey shear forces due to all modes considered, V_i in the storey I, by combining shear forces due to each mode in accordance with clause 7.7.5.3 of IS 1893 (2016) i.e. either CQC or SRSS modal combination method are used.

Step 11: Finally compute design lateral forces at each storey as

$F_{roof} = V_{roof}$ and

$F_i = V_i - V_{i+1}$

Advantages

1. This method represents the correct picture of seismic load distribution up to an elastic limit, which is more logical in Response spectrum method
2. This method can be applied for high rise buildings with irregular plans.

Disadvantages

1. Calculations are tedious,

2. This method is more time consuming.

3.6 PROCEDURE OF ANALYSIS IN STADD PRO

For analyzing and to study the behavior of RC frame with or without bracing system under the effect of seismic forces in different seismic zone i.e. III, IV and V, the following procedure is adopted.

Modeling procedure of braced frame RC building using Stadd pro

Step 1: Select the structure type

a) Select the new project
b) The space structure has to select, which is a 3D framed structure with loads applied in any plane.
c) Give the file name and its location.
d) Length should be in meter and force unit in kilo Newton.
e) Click next and select the add beam option.
f) Click finish.

Step 2: Geometrical Modelling of RC frame

a) Click on geometry option on the tool and select run structure wizard.
b) Select the model type as frame models.
c) Double click on the bay frame.
d) Describe the length, width and height of frames and respectively provide bay along the length, width and height.
e) Click apply and transfer this frame into the stadd pro and click yes.
f) Give coordinate 0, 0, and 0 in X, Y and Z direction and select ok.
g) In snap node/beam in right hand side unselect the default grid.
   Continue the step until the frame profile will be obtained.

Step 3: Selection of properties of various sections

a) Go to general tap and define section from the property.
b) Select the define option from the property and select the rectangular option and specify the value of beam and column.
c) For steel bracing select section database in that select the Indian code and select the material and close it.

d) Don't forget to select the material for beam and column will be concrete and for bracing it will be steel.
e) Go to select beam and click on beam parallel to and select the respective direction.
f) Click on assign to edit the list and click on assign.

Step 4: Assign of supports conditions

a) In general tab select support option.
b) Click creates an option in the dialogue box.
c) From all the support select fixed support and then add.
d) Select the fixed support from the dialogue box and now select the node where fixed support has to provide.
e) Click on assign to the selected node and click on apply.

Step 5: Assign different loads and their combination

a) In general tab select load and definition.
b) Click on the definition and select seismic definition.
c) Select code IS 1893-2002/2005 and give the parameter like zone, response reduction factor, importance factor, type of soil and damping ratio.
d) Assign the self-weight and floor weight and then close it.
e) Then select load case detail and assign seismic load, dead load and live load.
f) In seismic load give self-weight, floor weight in all direction (X, Y and Z)
g) Select the seismic load and click the add option after that one dialogue box will open in that select code and type of soil.
h) After that give the load combination by selecting add option in load case detail, a dialogue box will open select auto load combination after that select auto load combination.
i) Generate the loads and click on add.

Step 6: Analysis of the frame

a) Click on the analysis/Print tab
b) In analysis/print command select print option all and select add.
c) Select the post print option.
d) Click defines command.
e) Select storey drifts value and click add.
f) Click analysis in the task bar.
g) Click save then click done.

Step 7: Exploration of analyzed results

a) To view the output results, choose view output file.
b) Member forces due to different load combinations for each and every member can be seen through member forces all option.
c) Click on Results option and view results by selecting Eigen solution, Mass Participation Factors, Analysis Results and Storey Drift option in STAAD Output Viewer.
d) Mode shape, time v/s acceleration graph, time v/s velocity graph and time v/s displacement graph can be seen through a dynamic tab.
e) To determine the deflection, bending, shear and axial force in any beam. Select the beam then go to the post processing section.
f) Select the load case and then click ok.
g) Go to result on the task bar, and then click view value and then select beam result after that annotate the value.

3.7 SUMMARY

This chapter compresses the various approaches for analysis of the structure under seismic load these approaches are static analysis and dynamic analysis. Detail description of the load that occurs in the structure and their load combination are given in this chapter. The step by step analysis of the RC structure with the help of STADD PRO Software has been detailed explained in this chapter.

Model Description

CHAPTER 4 MODEL DESCRIPTION

4.1 GENERAL

The various types of methodology used in the analysis have been described in chapter 3. This chapter describes the details of un-braced RC frame and braced RC frame model in which geometry of the structure is explained in brief and shown through the elevation and 3 D view of RC frame with and without bracing system**.**

4.2 DETAIL OF UNBRACED RC FRAME AND BRACED RC FRAME MODEL

A G+13 storey RC frame building is selected to study the behavior of the structure under seismic force and it has compared with different bracing systems with the same configuration. A G+13 storey building is modeled and analyzed using STADD PRO software. The Plan and elevation of the bare (un-braced) RC frame of a building are shown in Fig. 4.1 and Fig. 4.2 respectively. In the structural plan of RC frame model of the structure, there are total 6 grid lines in both X and Y direction and having 5 bays in both X and Y direction at a spacing of 3m i.e. it is a square plan building having plan dimension 15 m x 15m. The total height of the building is 42 m and the height of each floor is 3m. The foundation of the structure is 3m below the ground level.

The structural Models of RC frames with different bracing systems are also shown in Fig.4.3 to Fig.4.6. Figure 4.3 represents the elevation and 3D view of RC frame structure with X Bracing, Fig.4.4 for elevation and 3D view of RC frame structure with V Bracing, Fig.4.4 for elevation and 3D view of RC frame structure with inverted V Bracing and Fig.4.6 for elevation and 3D view of RC frame structure with X Bracing. All the selected bracing systems namely, X bracing, diagonal bracing, V bracing, eccentric bracing and inverted V bracing have been provided in all the periphery/side of the selected RC frame of a building. The basic data details of the selected building frame for analysis are listed in Table 4.1. To study the seismic analysis of frames, the basic values are selected form IS 1893:2016 (part 1) to meet the basic requirement of the structure. Moreover, various IS code has been used to calculate the DL, LL, etc. and all are explained in detail in chapter 3. The base shear obtained in the analysis of frames with and without bracing is distributed along with the height of the frame as per IS 1893:2016. One of the examples of base shear distribution has demonstrated in Fig 4.8.

Table 4.1 RC Frame Data Details Considered for the Analysis

The geometry of the structure	Detail/ value
Number of Grid in X direction	6
Number of Grid in Y direction	6
Spacing of Grid line in X direction	3m
Spacing of Grid line in Y direction	3m
Number of Storey	G+13
Typical Storey height	3m
Ground Floor height	3m
Size of Beam	450 x 450mm
Size of column	600 x 600mm
Bracing size	200 x 200 x 25
Types of Soil	Medium
Types of support	Fixed
Zones	III, IV and V
Dead Load	$3kN/m^2$
Live Load	$4kN/m^2$
Combination Method	SRSS
Response Reduction Factor	5
Importance Factor(I)	1
Damping Ratio	5%

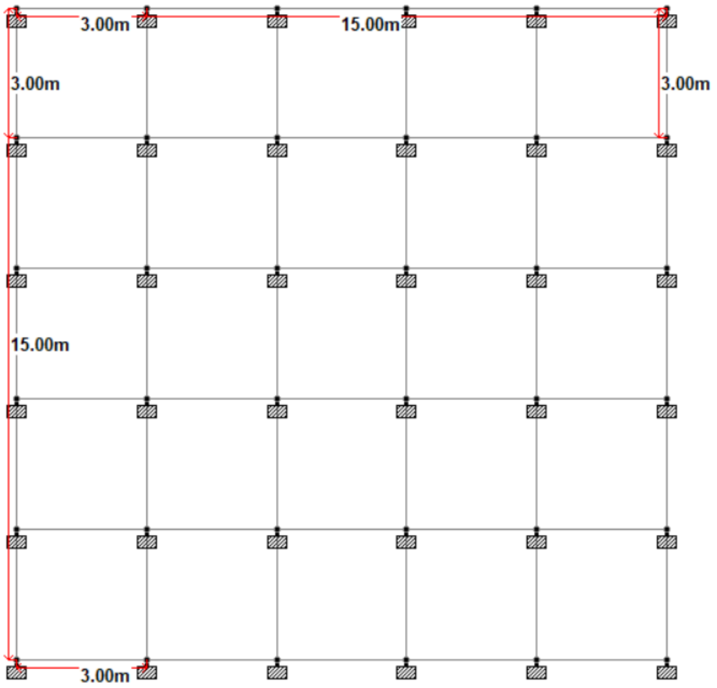


Fig.4.1 Structural Plan/Layout of RC Frame Model

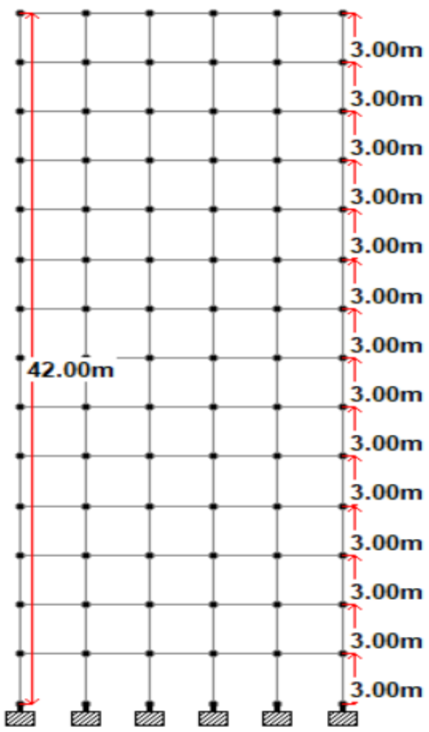


Fig.4.2 Structural Elevation of RC Frame Model

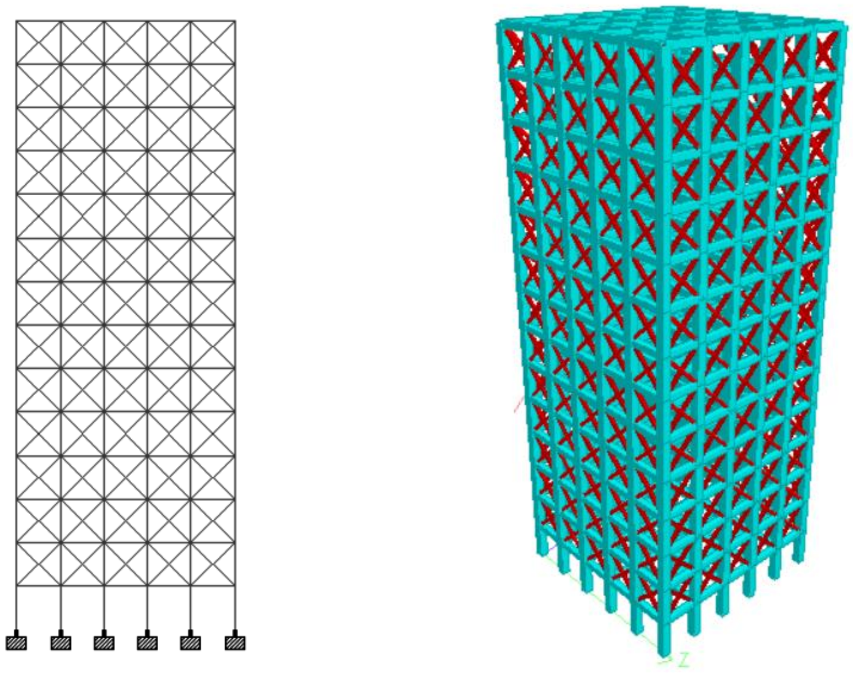


Fig.4.3 Elevation and 3D View of RC Frame Structure with X Bracing

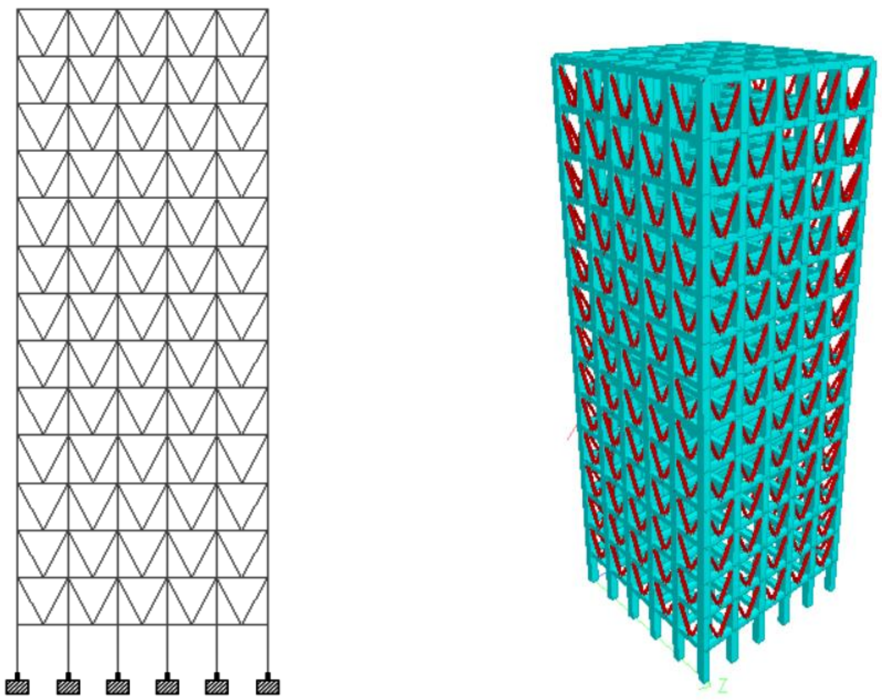


Fig.4.4 Elevation and 3D view of RC Frame Structure with V Bracing

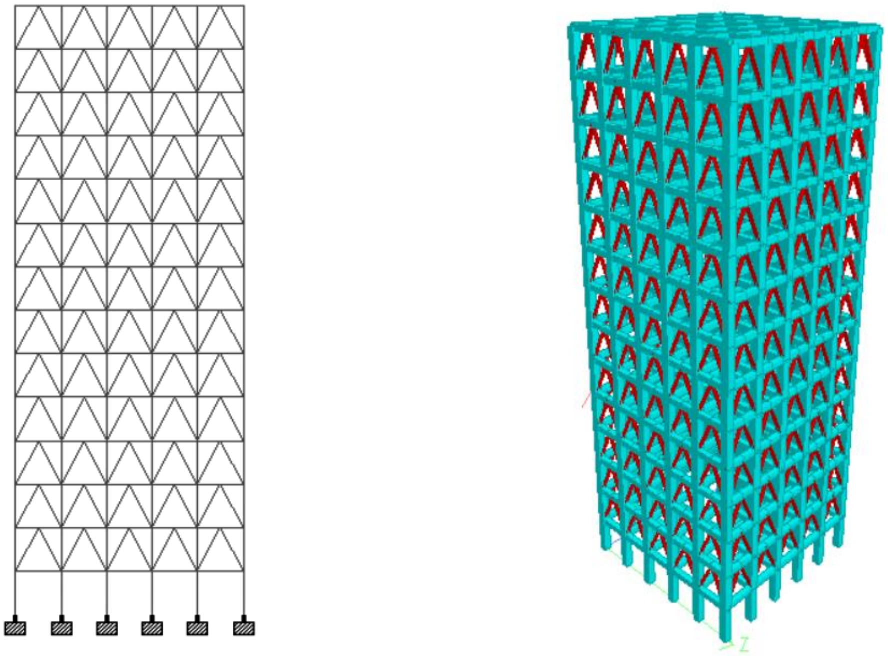


Fig.4.5 Elevation and 3D view of RC Frame Structure with Inverted V Bracing

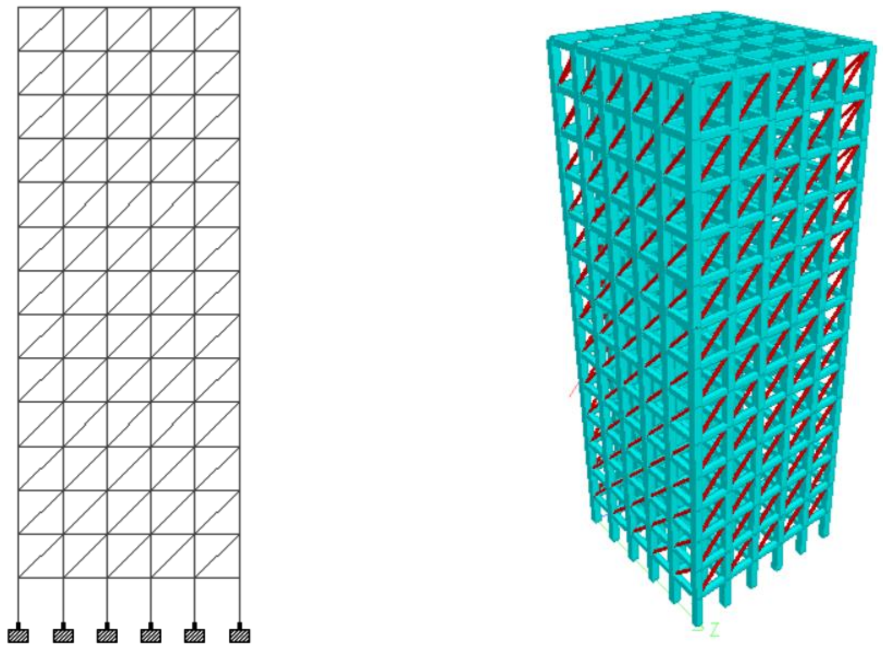


Fig.4.6 Elevation and 3D View of RC Frame Structure with Diagonal Bracing

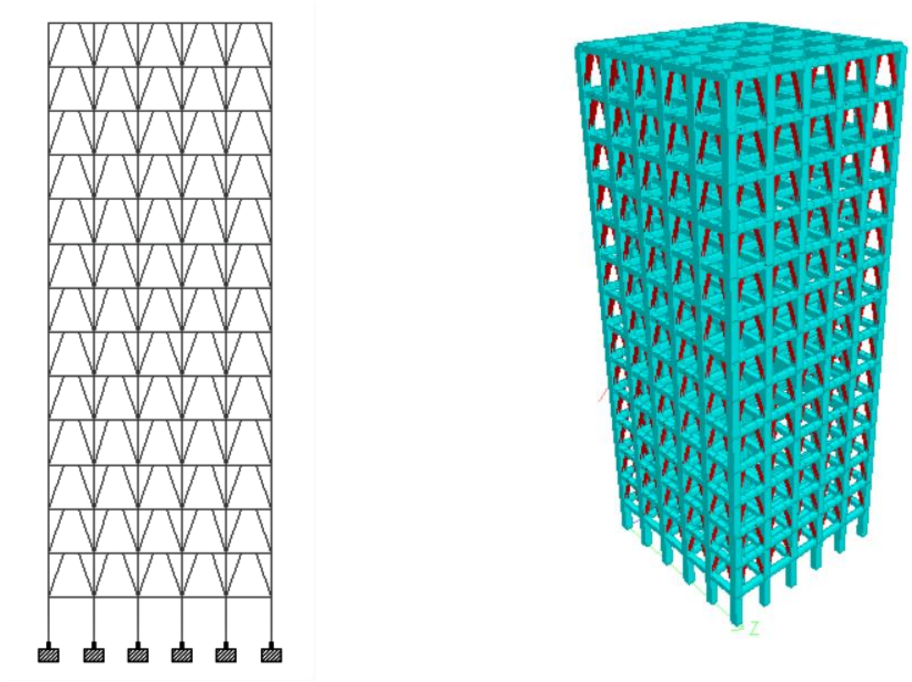


Fig.4.7 Elevation and 3D View of RC Frame Structure with Eccentric Bracing

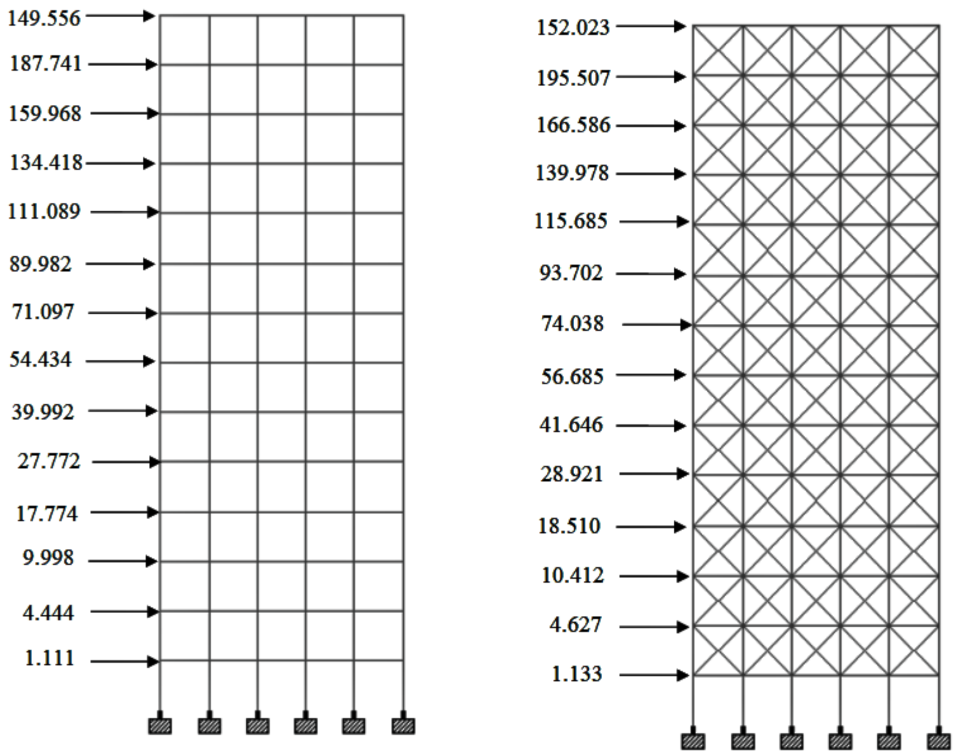


Fig.4.8 Lateral Load Distribution of Structure with Height

4.3 ANALYSIS OF FRAMES

The main objective of the present study is to compare the seismic behavior of un-braced and braced RC frame in three seismic zones viz., zone III, zone IV and zone V. To achieve the objectives, following parameters have considered in the analysis.

1. Storey Displacement
2. Storey drift
3. Base Shear for different types of bracing system
4. Maximum weight for different types of bracing system
5. Maximum axial force
6. Maximum Bending Moment

1. Storey Displacement

Displacement or deflection refers to the deviation of the whole structural element from its original position by the action of lateral forces (earthquake/seismic forces) on the buildings. Figure 4.9 illustrates the storey displacement at different storey height by Δ_1 and Δ_2 at storey height H_1 and H_2 respectively.

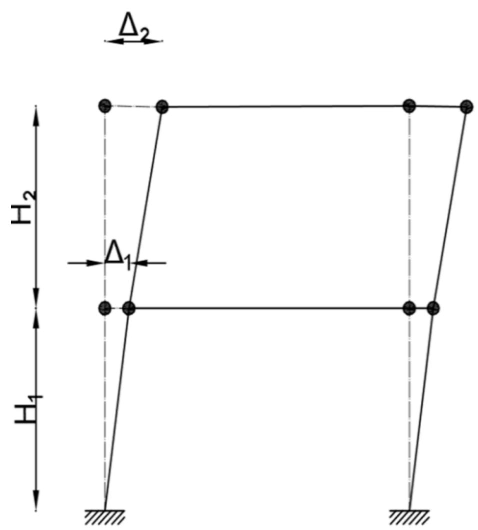


Fig.4.9 Lateral Displacement of the Frame

2. **Storey Drift**

Storey drift or inter storey displacement is the relative displacement between floors above or below the storey under consideration as indicated in Fig 4.10.

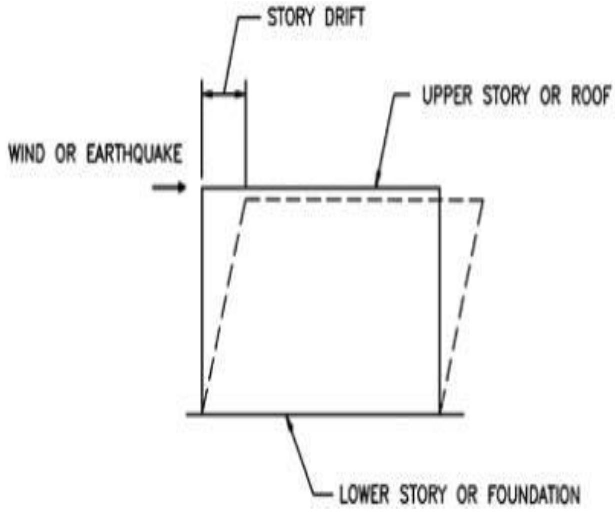


Fig. 4.10 Storey Drift of the Frame

3. **Base Shear**

Base shear is the maximum lateral force generated at the base of the structure. For analysis purpose, the structure has fixed at the base i.e. at the foundation level. During the earthquake, structures do not remain stiff, it deflects, and thus base shear is distributed all along with the height of the building. The base shear calculation relies upon the soil condition of the site. Total base shear distribution on each storey height has illustrated in Fig 4.11.

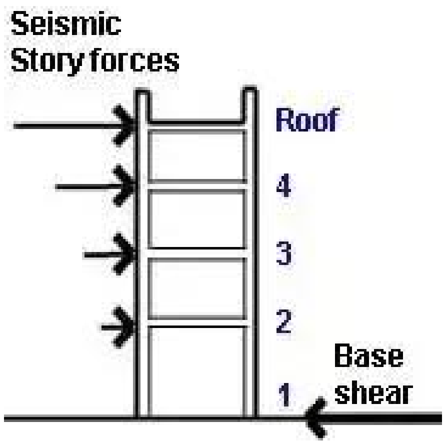


Fig.4.11 Base Shear at the Base of the Structure

4. **Maximum Weight**

Maximum weight of the structure depends upon the dead weight of the structure like the weight of beam, column and weight of different bracing in different structure model.

5. **Maximum Axial Force**

Axial load is along the axis of the structural members and passes through the centroid of the cross-section and being perpendicular the plane of the section of the member. An axial force is compression or tension force in the member. If the axial force passes through the centroid of the member is called concentric loading. If the force is not passing through the centroid is called eccentric loading.

6. **Maximum Bending Moment**

When the external/transverse force applied to the beams or columns causing the element to bend from its original axis which induces bending moment in the element. The maximum bending moment occurs in the beam when a shear force is zero at that section or changes the sign.

4.4 SUMMARY

This chapter compresses the detail of plan and elevation of unbraced RC frame and elevations with a 3D view of the different braced system. Total plane area of the building is 15m x 15m and the total height of the building is 42m. In the structural plan of RC frame model of the structure, there are total of 6 numbers grid lines in both X and Y direction and 5 bays at a rate of 3m each. This chapter also includes the description of various parameters of the objects that have used in the analysis of the building frames.

Results and Discussion

CHAPTER 5 RESULTS AND DISCUSSION

5.1 GENERAL

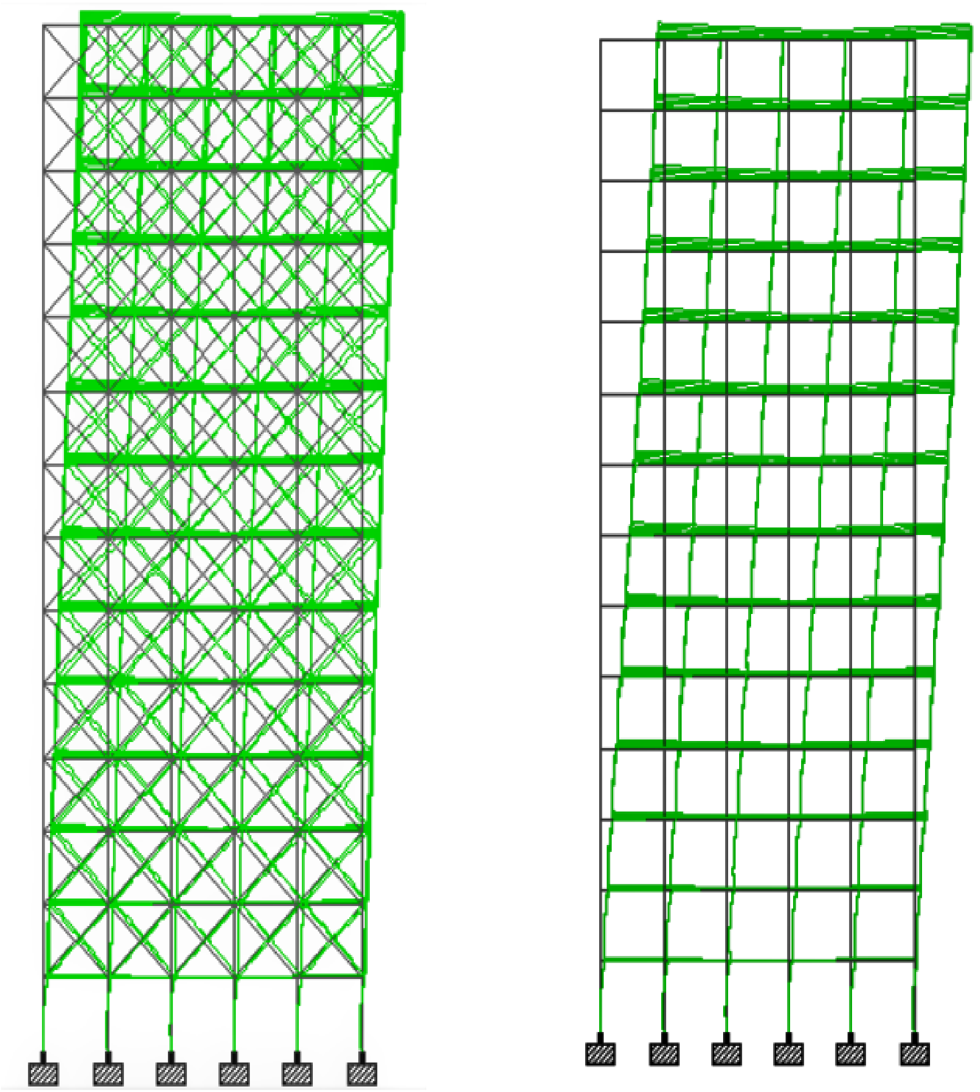
The various types of model and parameters used in the analysis have been described in chapter 4 in detail. In order to study the behavior and performance of the un-braced and braced system in RC structure, Equivalent static analysis, and Dynamic analysis has carried out and has discussed in chapter 3. In this chapter, the results obtained from analysis of different types of frame have been discussed. For this purpose, five different types of bracing system viz. X bracing, diagonal bracing, V bracing, inverted V bracing and eccentric bracing were analyzed in three seismic zones III, IV, and V using STAAD PRO and their results are compared with un-braced frame. The soil strata condition are kept same throughout the analysis of the structure.

To interpret the behavior and performance of the bracing system in the RC frame Structure, six different parameters, as given in chapter 4 (i.e. Storey Displacement, Base shear, Storey Drift, Maximum Axial Force, Maximum Bending Moment and Weight of the structure) has considered and their results are explained in the following section of this chapter.

5.2 STOREY DISPLACEMENT

Displacement or deflection refers to the deviation of the whole structural element from its original position by the action of lateral forces (earthquake/seismic forces) on the buildings.

An RC building frame with and without bracing has been studied for lateral displacement in three seismic zones III, IV, and V. For demonstration, an example of the maximum lateral displacement for selected building frame with and without bracing is shown in Fig.5.1 (a) and Fig. 5.1(b) respectively. The maximum lateral displacement values obtained from analysis at each storey level are given in Table 5.1 to 5.3. Table 5.1 provides the maximum lateral displacement values in zone III, Table 5.2 in zone IV and Table 5.3 in zone V. Further, the maximum lateral displacement values, which have been listed in Tables, are plotted against the storey height to understand the effectiveness of different bracing system and these plots are shown in Fig 5.2 to 5.4. Fig.5.2 shows maximum displacement behavior at each storey height as per values given in Table 5.1 in zone III. Fig.5.3 depicts maximum displacement behavior at each storey height as per values given in Table 5.2 in for zone IV and Fig.5.4 as per Table 5.3 in zone V.



(a) (b)

Fig.5.1 Lateral Displacement of Building (A) with Bracing Systems (B) without Bracing

Table 5.1 Maximum Lateral Displacement (mm) for Different Bracing System in Zone III

Storey Height	Maximum Lateral Displacement (mm)					
	Without Bracing	With Bracing				
		X Bracing	V Bracing	Diagonal Bracing	Inverted V Bracing	Eccentric Bracing
0	0	0	0	0	0	0
3	0.822	0.798	0.806	0.798	0.811	0.989
6	1.722	1.232	1.376	1.54	1.36	1.68
9	2.681	1.724	1.993	2.326	1.955	2.462
12	3.684	2.262	2.646	3.145	2.588	3.345
15	4.715	2.838	3.325	3.984	3.246	4.101
18	5.757	3.443	4.02	4.833	3.92	4.966
21	6.798	4.067	4.72	5.682	4.6	5.826
24	7.821	4.7	5.4117	6.518	5.277	6.718
27	8.813	5.335	6.1	7.333	5.94	7.484
30	9.761	5.96	6.761	8.116	6.583	8.346
33	10.652	6.538	7.431	8.959	7.216	9.201
36	11.473	7.158	8.131	9.786	7.884	9.989
39	12.213	7.755	8.762	10.508	8.491	10.709
42	12.862	8.325	9.332	11.149	9.032	11.357

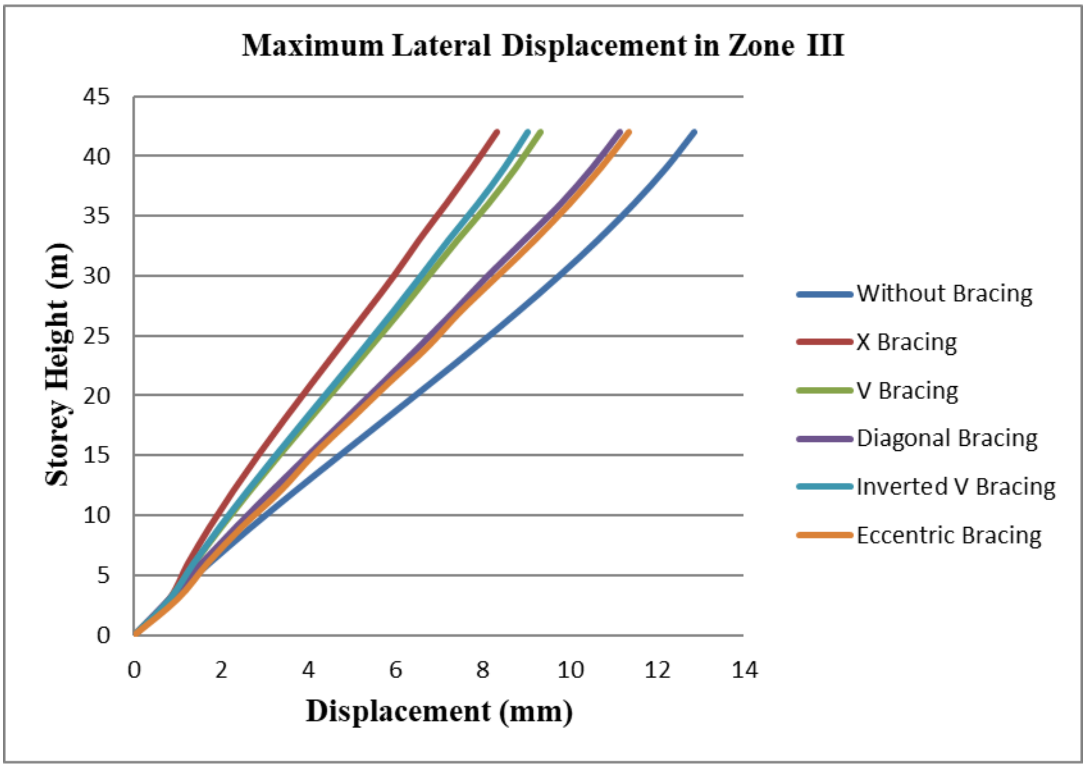


Fig.5.2 Maximum Lateral Displacement (mm) for Different Bracing System in Zone III

Table 5.2 Maximum Lateral Displacement (mm) for Different Bracing Systems in Zone IV

Storey Height	Maximum Lateral Displacement					
	Without Bracing	With Bracing				
		X Bracing	V Bracing	Diagonal Bracing	Inverted V Bracing	Eccentric Bracing
0	0	0	0	0	0	0
3	1.249	1.257	1.539	1.263	1.101	1.296
6	2.608	1.953	2.652	2.339	2.194	2.322
9	4.054	2.737	3.796	3.495	3.156	3.417
12	5.562	3.596	4.96	4.712	4.179	4.563
15	7.11	4.516	6.134	5.973	5.246	5.742

18	8.675	5.483	7.32	7.263	6.341	6.936
21	10.234	6.484	8.474	8.562	7.45	8.129
24	11.766	7.504	9.628	9.855	8.556	9.305
27	13.252	8.531	10.729	11.124	9.645	10.447
30	14.671	9.551	11.795	12.355	10.702	11.54
33	16.003	10.551	12.806	13.532	11.713	12.57
36	17.232	11.518	13.752	14.641	12.666	13.523
39	18.34	12.443	14.622	15.667	13.549	14.386
42	19.312	13.314	15.408	16.601	14.35	15.149

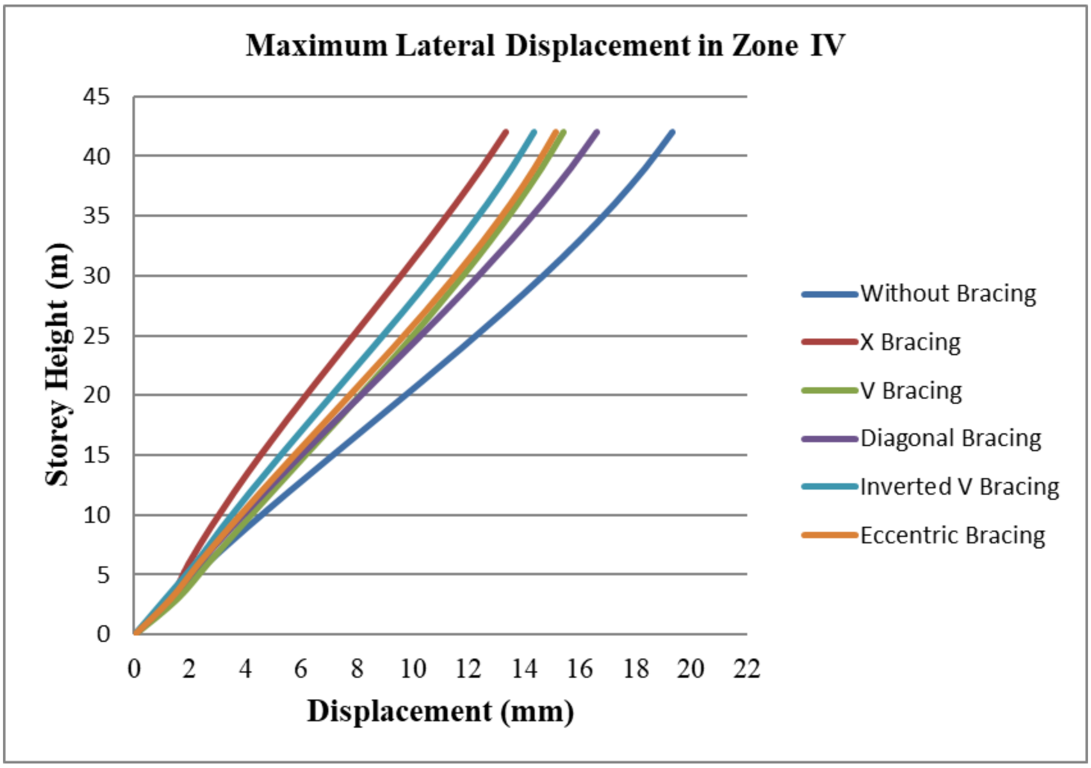


Fig.5.3 Maximum Lateral Displacement (mm) for Different Bracing System in Zone IV

Table 5.3 Maximum Lateral Displacement (mm) for Different Bracing System in Zone V

Storey Height	Maximum Lateral Displacement					
	Without Bracing	With Bracing				
		X Bracing	V Bracing	Diagonal Bracing	Inverted V Bracing	Eccentric Bracing
0	0	0	0	0	0	0
3	1.905	1.838	1.855	1.839	1.868	1.977
6	3.968	2.856	3.165	3.323	3.126	3.535
9	6.154	3.989	4.569	4.91	4.479	5.19
12	8.43	5.215	6.047	6.579	5.906	6.917
15	10.759	6.516	7.576	8.304	7.386	8.69
18	13.111	7.874	9.136	10.063	8.897	10.484
21	15.452	9.268	10.704	11.832	10.418	12.274
24	17.751	10.68	12.262	13.59	11.93	14.036
27	19.978	12.091	13.788	15.312	13.411	15.747
30	22.103	13.484	15.264	16.978	14.842	17.384
33	24.098	14.828	16.784	18.799	16.284	19.13
36	25.937	16.212	18.35	20.575	17.785	20.989
39	27.595	17.529	19.762	22.141	19.138	22.484
42	29.049	18.776	21.021	23.538	20.332	23.87

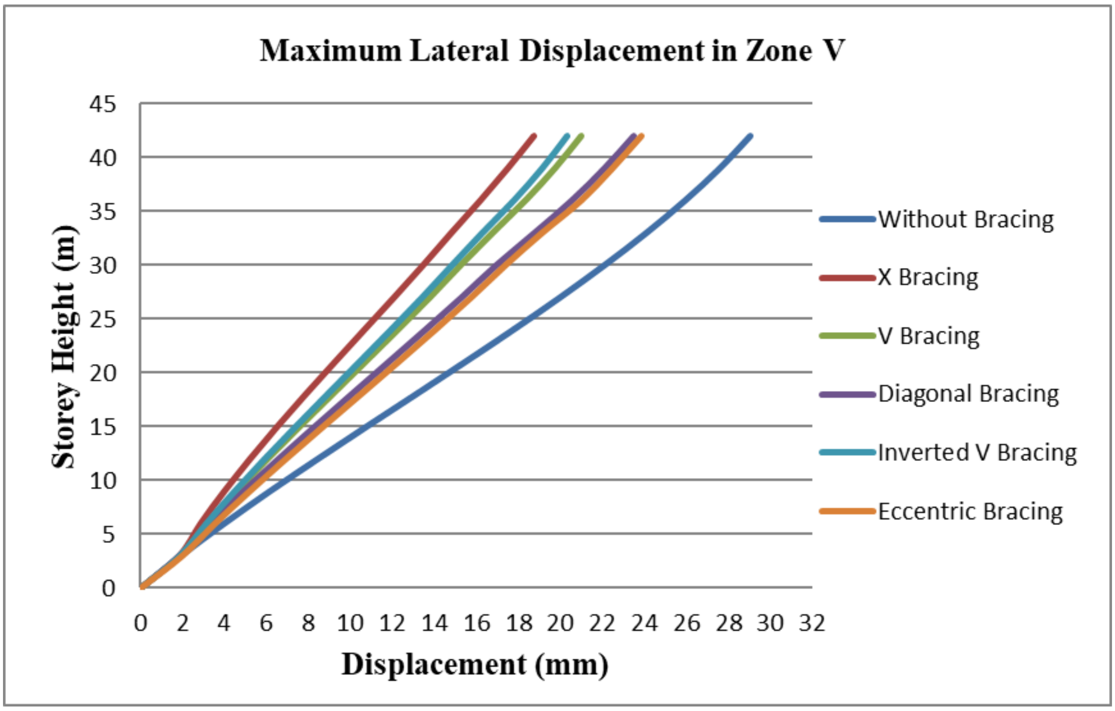


Fig.5.4 Maximum Lateral Displacement (mm) for Different Bracing System in Zone V

It has been observed that the values given in the Tables and their plots, the lateral displacement of braced system decreases with increase in the height of the building. This decrease is gradual from base to top of the frame. Moreover, lateral deflection behavior of different braced system is also deviated whenever compared among themselves. All the graphs portray that the lateral displacement in case of X bracing system reduces very high as compared to other bracing and bare frame. It has been found that the percentage reduction in the lateral displacement increases with increase in the storey height. Since, the soil medium is kept same in analysis, the percentage reduction in the lateral displacement at storey height 12m for different braced structure in zone III, IV and V in comparison to unbraced structure is given in Table 5.3

Table 5.4 Percentage Reduction in the Lateral Displacement at Storey Height 12m

Zone	Types of bracing system				
	X bracing	V bracing	Inverted V bracing	Diagonal bracing	Eccentric bracing
III	54.23%	39.23%	42.34%	5.44%	10.13%
IV	54.67%	12.13%	33.67%	18.03%	21.89%
V	61.64%	39.47%	42.75%	30.56%	23.80%

The percentage reduction in the lateral displacement at storey height 42m for different braced structure in zone III, IV and V in comparison to un-braced structure is given in Table.5.5.

Table 5.5 Percentage Reduction in the Lateral Displacement at Storey Height 42m

Zone	Types of bracing structure				
	X bracing	V bracing	Inverted V bracing	Diagonal bracing	Eccentric bracing
III	54.39%	37.82%	42.40%	15%	13.357%
IV	45.05%	25.46%	34.57%	16.33%	27.48%
V	54.71%	38.19%	42.87%	23.538%	21.68%

Moreover, in case of X bracing system, the percentage reduction of displacement is very high in all zones. This reduction in displacement in X bracing is high because of the high shear stiffness, high ductility and high energy absorption capacity.

5.3 BASE SHEAR

Base shear is the maximum lateral force generated at the base of the structure. For analysis, the structure has been fixed at the base that is at the foundation level.

An RC building frame with and without bracing has been studied for base shear in three seismic zones III, IV, and V. The base shear values obtained from analysis are given in Table 5.4 to 5.6. Table 5.4 provides the base shear values in zone III, Table 5.5 in zone IV and Table 5.6 in zone V. Further, the base shear values, which have been listed in Tables, are plotted to understand the effectiveness of different bracing system and these plots are shown in fig 5.5 to 5.7. Fig.5.5 shows the plot of magnitude of the base shear for different structure systems which have been mentioned in Table 5.4 in zone III. Similarly, Fig.5.6 is the plot as per Table 5.5 in zone IV and Fig.5.4 as per Table 5.3 in zone V.

Table 5.4 Base Shear (kN) for Different Bracing System in Zone III

Structure Type	Base Shear(kN)
Bare Frame	706.61
X Bracing	734.68
V Bracing	728.80
Inverted V Bracing	728.80
Diagonal Bracing	720.60
Eccentric Bracing	727.53

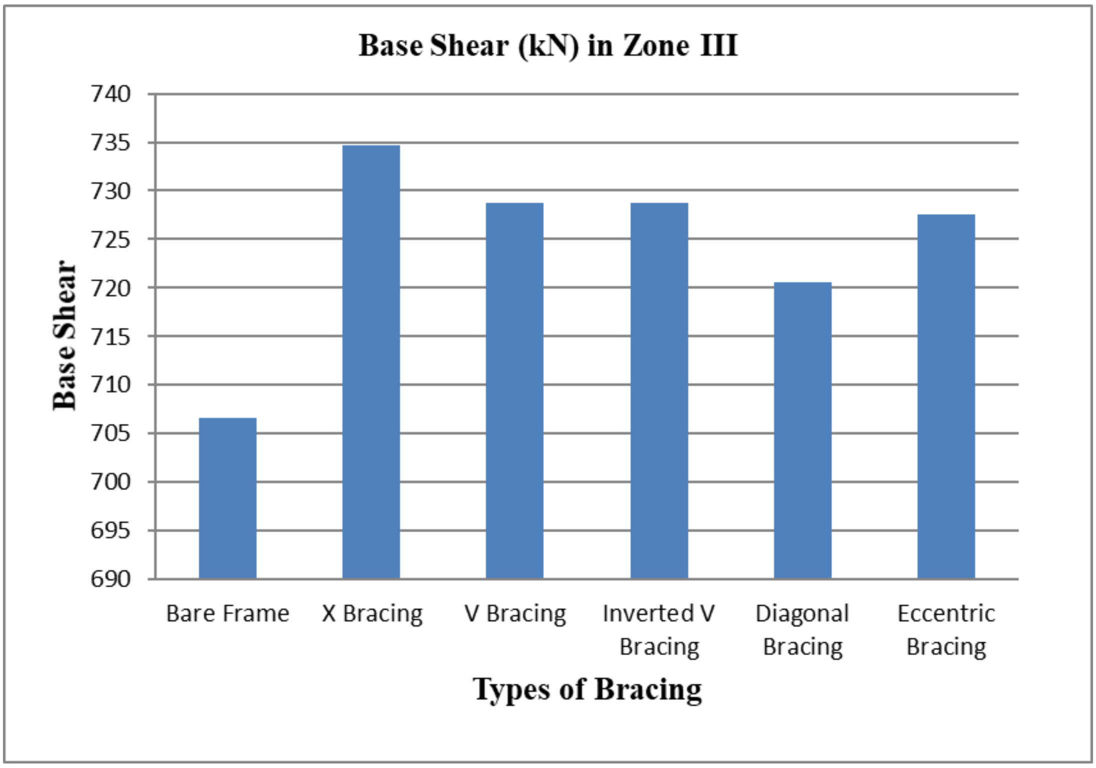


Fig.5.5 Base Shear (kN) for Different Bracing Systemic in Zone III

Table 5.5: Base Shear (kN) for Different Bracing System in Zone IV

Structure Type	Base Shear(kN)
Bare Frame	1059.9
X Bracing	1102.02
V Bracing	1093.2
Inverted V Bracing	1093.2
Diagonal Bracing	1080
Eccentric Bracing	1091.3

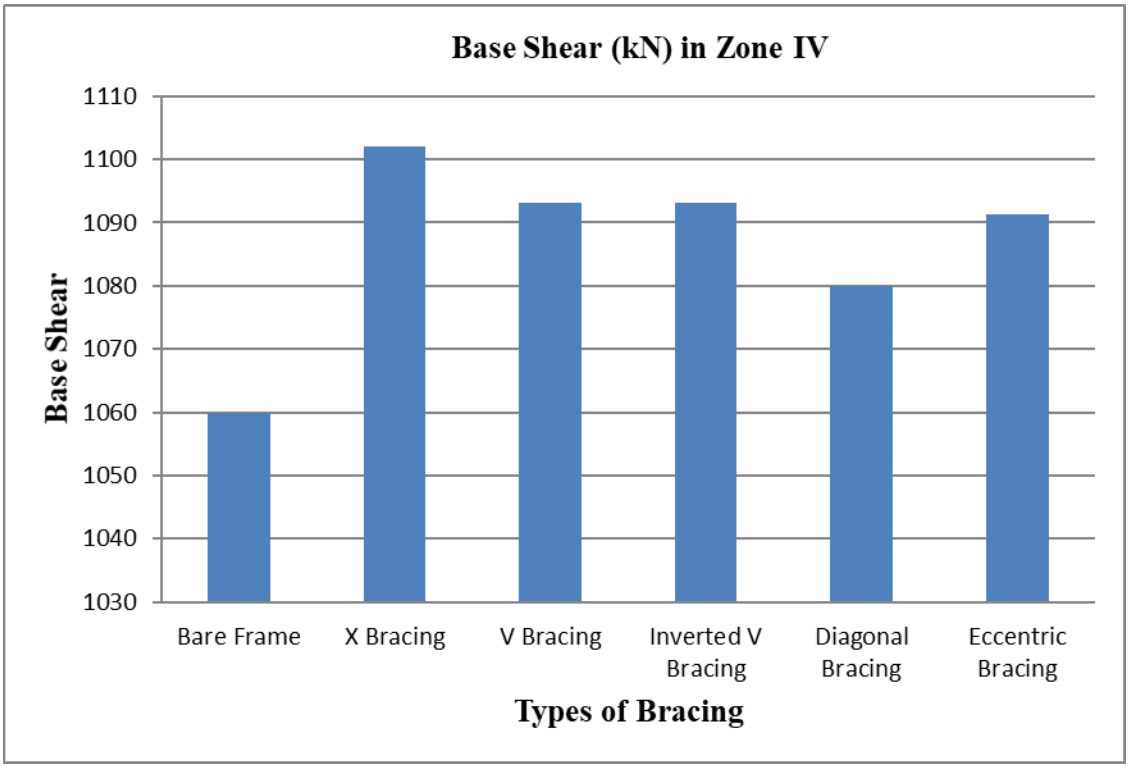


Fig 5.6 Base Shear (kN) for Different Bracing System in Zone IV

Table 5.6: Base Shear (kN) for Different Bracing System in Zone V

Structure Type	Base Shear(kN)
Bare Frame	1589.88
X Bracing	1653.03
V Bracing	1639.8
Inverted V Bracing	1639.8
Diagonal Bracing	1621.4
Eccentric Bracing	1636.9

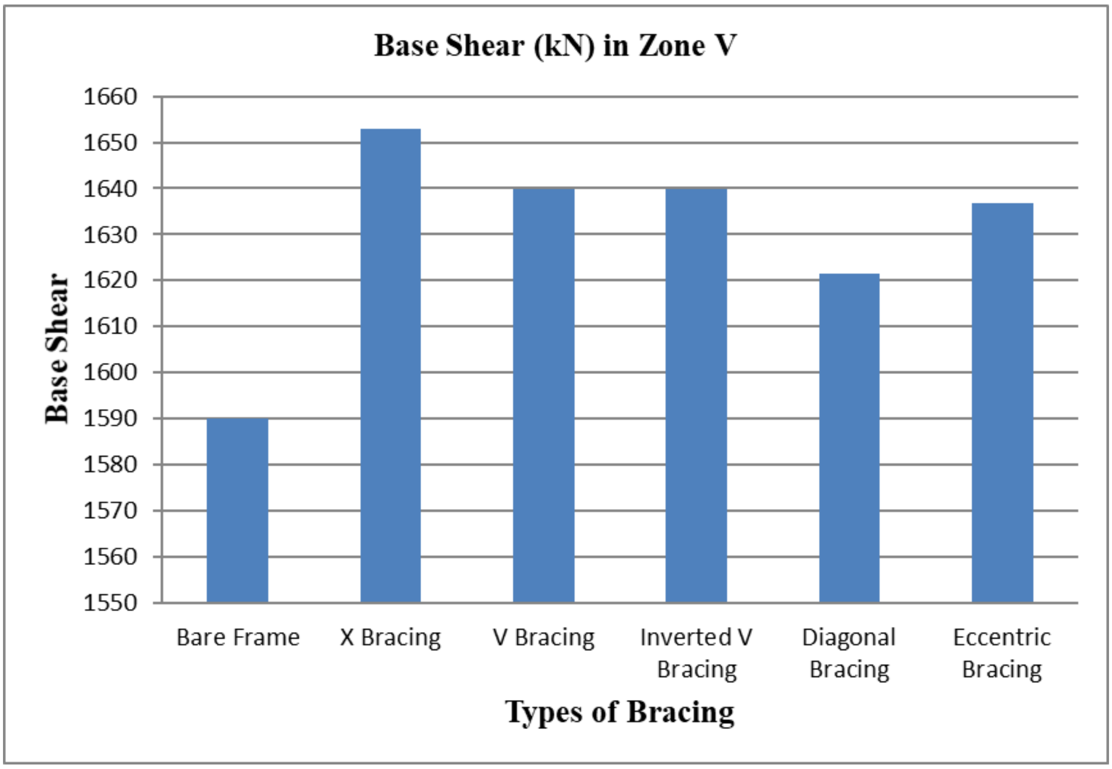


Fig 5.7 Base Shear (kN) for Different Bracing System in Zone V

It has been observed that the values given in the Tables and their plots, the magnitude of the base shear of braced system increase in the structure. All the graphs depict that magnitude of base shear in case V bracing and inverted V bracing is same. Overall comparison of base shear shows that the magnitude of the base shear in case of X bracing system is large as compared to other bracing and bare frame. Lateral stiffness as well as weight of structure of X bracing system in high as compared other thus, having high value of base shear and this has depicted in the graphs.

5.4 STOREY DRIFT

Storey drift or inter storey displacement is the relative displacement between floor above or below the storey under consideration. An RC building frame with and without bracing has been studied for storey drift in three seismic zones III, IV, and V. The storey drift values obtained from analysis at each storey level are given in Table 5.7 to 5.9. Table 5.7 provides the storey drift values in zone III, Table 5.8 in zone IV and Table 5.9 in zone V. Further, the storey drift values, which have been listed in Tables, are plotted against the storey height to understand the effectiveness of different bracing system and these plots are shown in Fig.5.8 to 5.10. Fig.5.8 shows maximum storey drift behavior at each storey height as per values given in Table 5.7 in zone III. Fig.5.9 depicts storey drift behavior at each storey height as per values given in Table 5.8 for zone IV and Fig.5.10 as per Table 5.9 for zone V.

Table 5.7 Maximum Storey Drift for Different Bracing System in Zone III

Storey Number	Maximum Storey Drift					
	Without Bracing	With Bracing				
		X Bracing	Inverted V Bracing	V Bracing	Diagonal Bracing	Eccentric Bracing
0	0	0	0	0	0	0
1	0.0794	0.0575	0.0601	0.0654	0.0647	0.0678
2	0.139	0.046	0.0602	0.0585	0.0774	0.0913
3	0.154	0.0433	0.0547	0.0575	0.0781	0.0916
4	0.1585	0.0428	0.0556	0.0585	0.0781	0.0939

5	0.1595	0.0431	0.0565	0.0593	0.0777	0.095
6	0.1582	0.0438	0.0573	0.06	0.077	0.095
7	0.1546	0.0448	0.0575	0.0602	0.0758	0.0938
8	0.1486	0.0445	0.057	0.0597	0.0737	0.091
9	0.1399	0.0445	0.0556	0.0587	0.0706	0.08666
10	0.1281	0.0434	0.0537	0.0553	0.0663	0.0804
11	0.1132	0.0414	0.0495	0.052	0.0607	0.0722
12	0.0949	0.0383	0.0444	0.0469	0.0535	0.0619
13	0.0737	0.0338	0.0377	0.0402	0.0448	0.0495
14	0.0525	0.0288	0.0308	0.0379	0.0358	0.03838

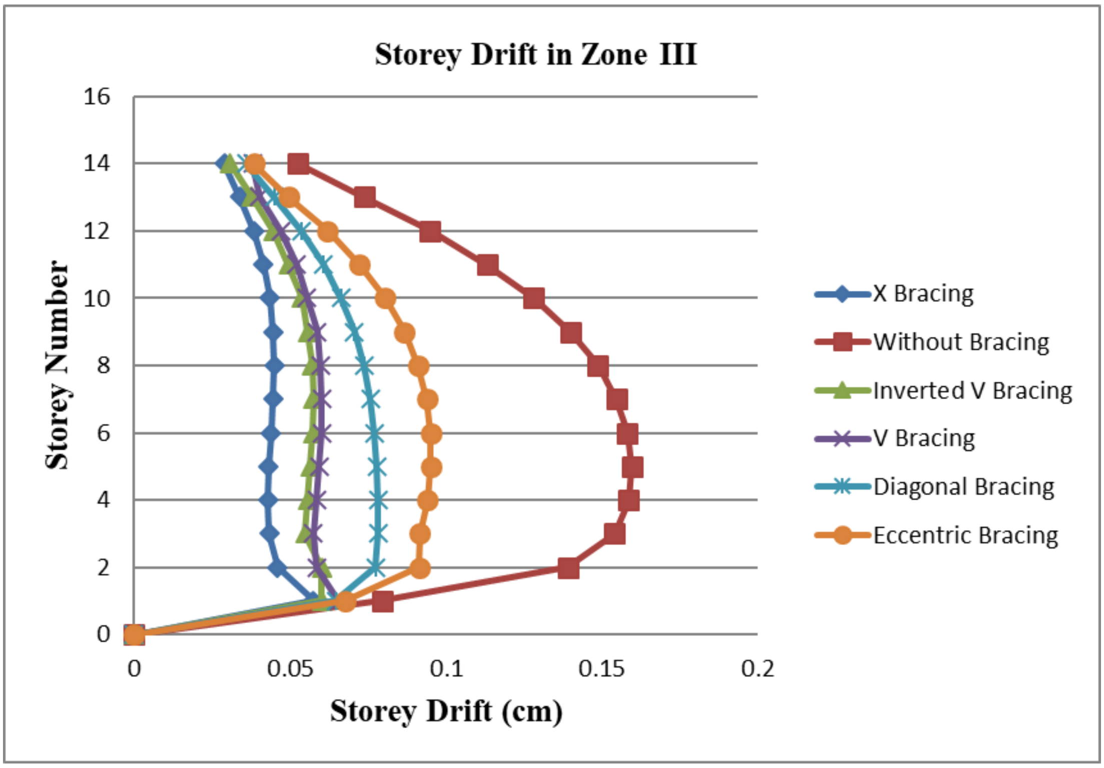


Fig.5.8 Maximum Storey Drift for Different Types of Bracing System in Zone III

Table 5.8 Maximum Storey Drift for Different Types of Bracing System in Zone IV

Storey Number	Maximum Storey Drift					
	Without Bracing	With Bracing				
		X Bracing	Inverted V Bracing	V Bracing	Diagonal Bracing	Eccentric Bracing
0	0	0	0	0	0	0
1	0.119	0.0862	0.0902	0.0981	0.0867	0.1017
2	0.2084	0.0696	0.082	0.0877	0.0765	0.1369
3	0.231	0.065	0.0834	0.0863	0.0743	0.1374
4	0.2378	0.0642	0.0847	0.0877	0.076	0.1408
5	0.2392	0.0646	0.0859	0.0889	0.0783	0.1425
6	0.2373	0.0658	0.0863	0.09	0.0808	0.1425
7	0.232	0.0668	0.0856	0.0903	0.0826	0.1407
8	0.2229	0.0672	0.0856	0.0895	0.0832	0.1366
9	0.209	0.0668	0.0834	0.088	0.0824	0.13
10	0.1922	0.0652	0.0806	0.0829	0.0794	0.1206
11	0.1697	0.0621	0.0742	0.078	0.0754	0.1083
12	0.1423	0.0574	0.0665	0.0703	0.0686	0.0928
13	0.1103	0.0507	0.0566	0.0604	0.0593	0.0743
14	0.0787	0.0432	0.0461	0.0569	0.049	0.057

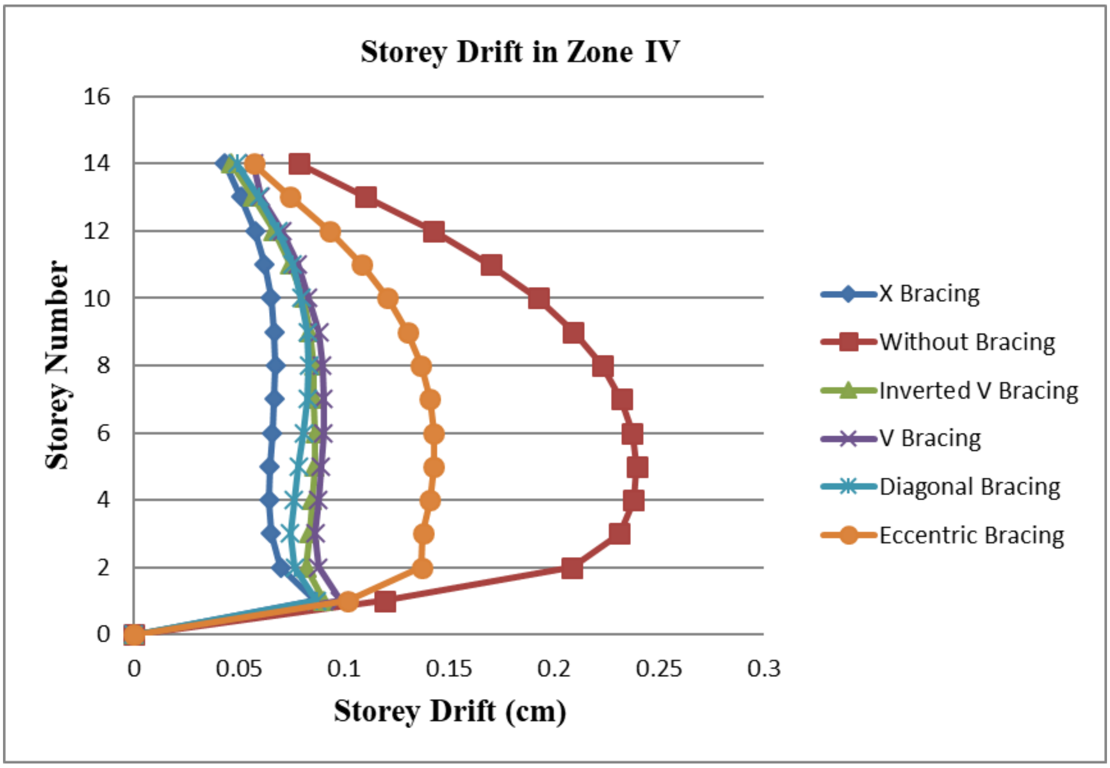


Fig.5.9 Maximum Storey Drift for Different Bracing System in Zone IV

Table 5.9: Maximum Storey Drift for Different Bracing System in Zone V

Storey Number	Maximum Storey Drift					
	Without Bracing	With Bracing				
		X Bracing	Inverted V Bracing	V Bracing	Diagonal Bracing	Eccentric Bracing
0	0	0	0	0	0	0
1	0.1786	0.1293	0.1353	0.1471	0.1405	0.1525
2	0.3127	0.1035	0.1355	0.1316	0.1543	0.2054
3	0.3464	0.0974	0.123	0.1295	0.1543	0.2061
4	0.3566	0.0963	0.1251	0.1315	0.1551	0.2113
5	0.3589	0.097	0.1271	0.1334	0.1557	0.2138

6	0.3559	0.0986	0.1289	0.135	0.1559	0.2138
7	0.3479	0.1002	0.1295	0.1355	0.1549	0.211
8	0.3344	0.1008	0.1284	0.1343	0.1521	0.2048
9	0.3147	0.1002	0.1252	0.132	0.147	0.1949
10	0.2883	0.0977	0.1208	0.1244	0.1394	0.1809
11	0.2546	0.0932	0.1114	0.117	0.1287	0.1624
12	0.2135	0.0861	0.0998	0.1054	0.1146	0.1392
13	0.1658	0.076	0.0849	0.0905	0.0969	0.1115
14	0.1181	0.0648	0.069	0.0853	0.0781	0.0855

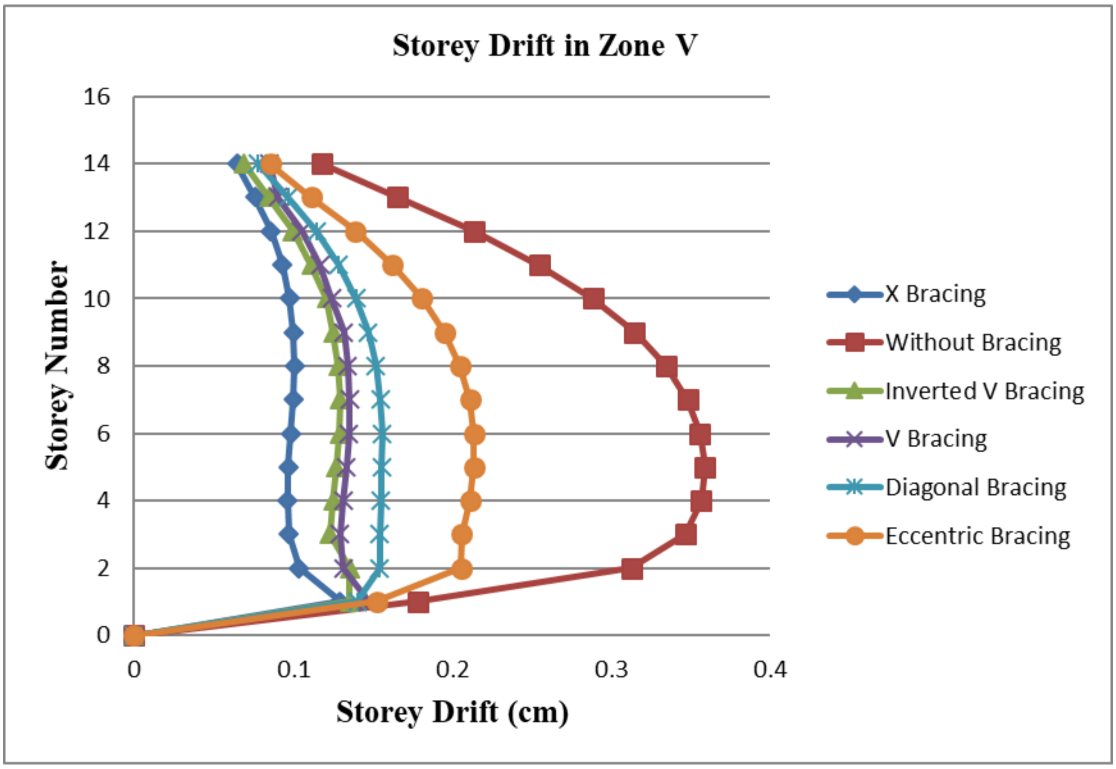


Fig.5.10 Maximum Storey Drift for Different Bracing System in Zone V

It has been observed that all graphs show the similar pattern for the reduction in the storey drift value with storey height. Initial up to 2-3 storey height level, the storey drift reduction rate has been observed very low in all braced systems. In general, it has been found that the storey drift reduction increases sharply up to 6-7th storey height level. After that, there is again a decrease in storey drift values. However, different bracing systems provided maximum storey drift value at different storey height level. In case of X braced structure, the percentage reduction in storey drift is very high as compared with other braced and un-braced structures and manifested in the all graphs (Fig.5.8 to Fig.5.10) in different seismic zone.

The reduction in storey drift values for X braced structure in zone III is 82.29% while compared to un-braced braced structure followed by 70.4% for inverted V bracing, 38.52% for V bracing, 46.64% for diagonal bracing and 36.78% for eccentric bracing. Similarly, for zone IV the reduction in storey drift values for X braced structure is 82.17% while compared to un-braced braced structure followed by 70.72% for inverted V bracing, 38.12% for V bracing, 60.64% for diagonal bracing and 38.07% for eccentric bracing and for zone V the reduction in storey drift values for X braced structure is 82.22% while compared to un-braced structure followed by 71.15% for inverted V bracing, 38.45% for V bracing, 51.21% for diagonal bracing and 38.12% for eccentric bracing.

5.5 Maximum Weight (kN)

An RC building frame with and without bracing has been studied for maximum weight in all three seismic zones. The maximum weights obtained from analysis of the structure are given in Table 5.10. Table 5.10 provides the maximum weight of structure in zone III, IV and V. The maximum weight of different structures have used in the analysis are listed in Table 5.10. The maximum weights of different bracing system are represented by bar chart in different seismic zones (i.e. III, IV and V) and have shown in Fig 5.11.

Table 5.10 Maximum Weight (kN) for Different Bracing System

Structure Type	Weight(kN)
Bare Frame	40148.54
X Bracing	41743.32
V Bracing	41409.30
Inverted V Bracing	41409.30
Diagonal Bracing	40945.94
Eccentric Bracing	41337.28

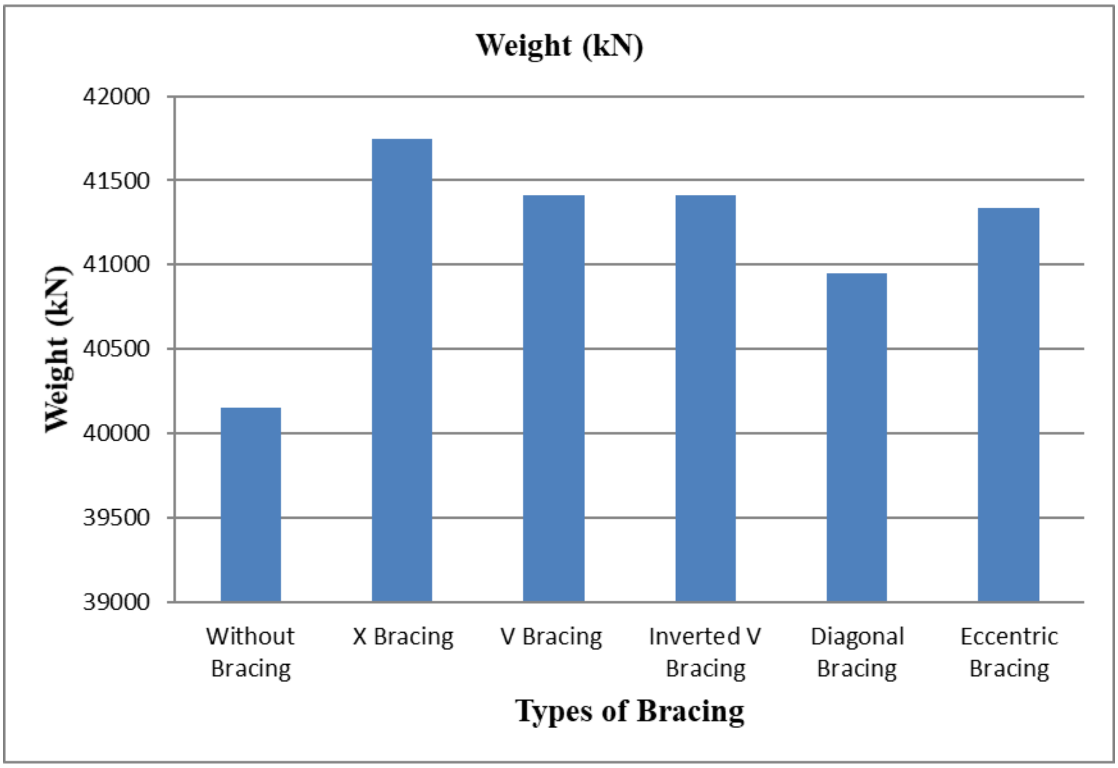


Fig.5.11 Maximum Weight (kN) for Different Bracing System

It has been observed from the values given in Tables 5.10 and bar chart in fig 5.11, the increase in maximum weight in the bracing system depends on the types of bracing system. All the graphs portray that the maximum weight in case of X bracing system increases as compared to other bracing system and bare frame. It is quite obvious that the X bracing system has the maximum weight and thus attracts a high magnitude of base shear.

5.7 Maximum Axial Forces

An RC building frame with and without bracing has been studied for maximum axial force in three seismic zones III, IV, and V. The maximum axial force values obtained from the analysis are given in Table 5.11, Table 5.12 and Table 5.13 in seismic zone III, IV and V respectively. Further, the maximum axial force values for different systems have represented by the bar charts and have shown in Fig 5.12 for zone III, Fig 5.13 for zone IV and Fig 5.13 for zone V.

Table 5.11 Maximum Axial Force for Different Bracing System for Zone III

Structure Type	Axial Force (kN)
Without Bracing	2333.54
X Bracing	2432
V Bracing	2420.975
Inverted V Bracing	2425.8
Eccentric Bracing	2417.478
Diagonal Bracing	2397.967

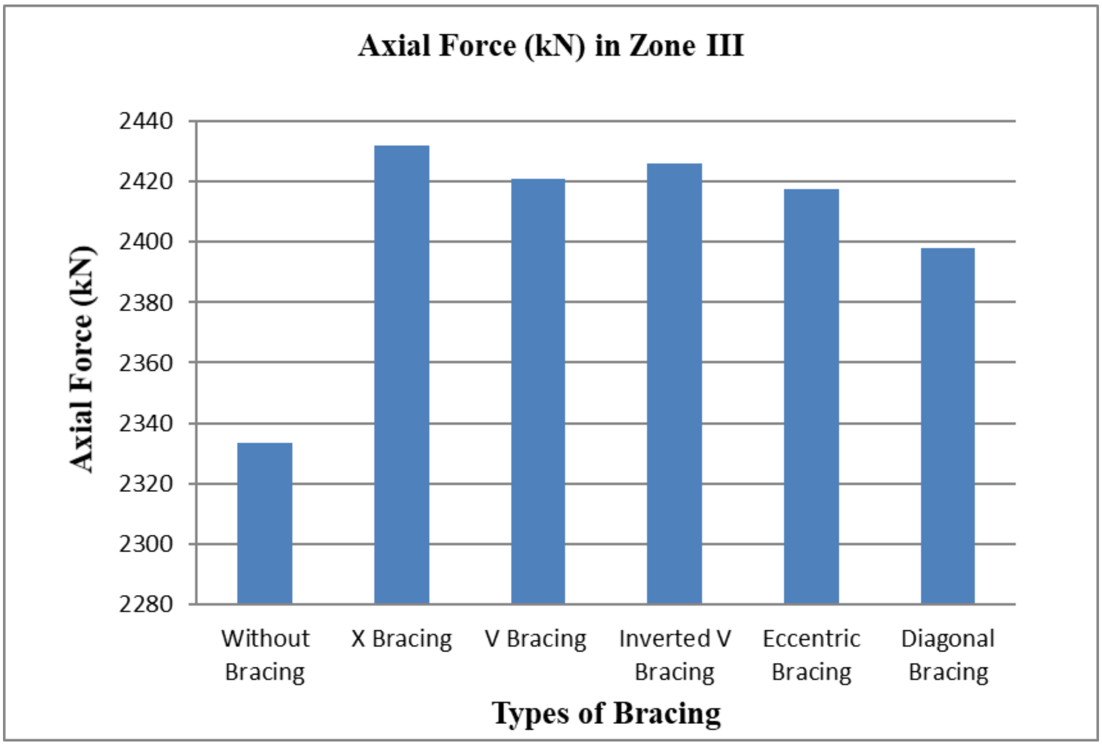


Fig.5.12 Maximum Axial Force for Different Bracing System for Zone III

Table 5.12 Maximum Axial Force for Different Bracing System for Zone IV

Structure Type	**Axial Force (kN)**
Without Bracing	2785.757
X Bracing	2901.69
V Bracing	2890.646
Inverted V Bracing	2897
Eccentric Bracing	2886.899
Diagonal Bracing	2862.302

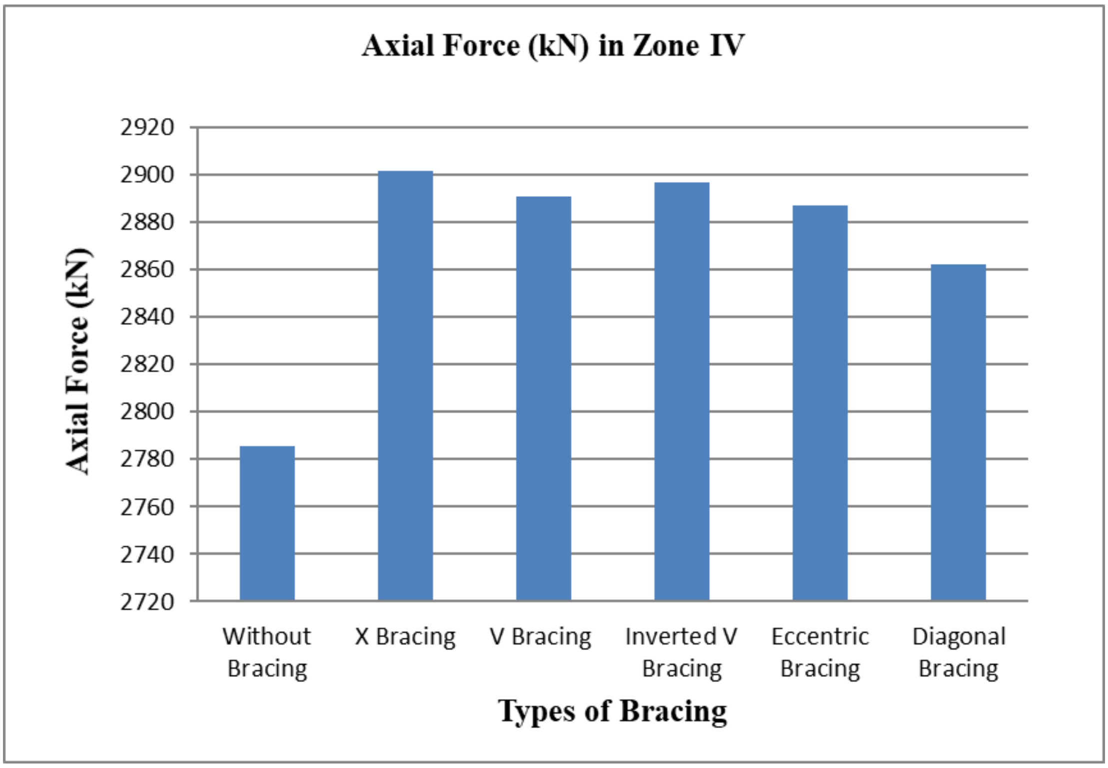


Fig.5.13 Maximum Axial force for Different Bracing System for Zone IV

Table 5.13 Maximum Axial Force for Different Bracing System for Zone V

Structure Type	**Axial Force (kN)**
Without Bracing	3464.083
X Bracing	3615.75
V Bracing	3595.645
Inverted V Bracing	3600.48
Eccentric Bracing	3591.632
Diagonal Bracing	3562.408

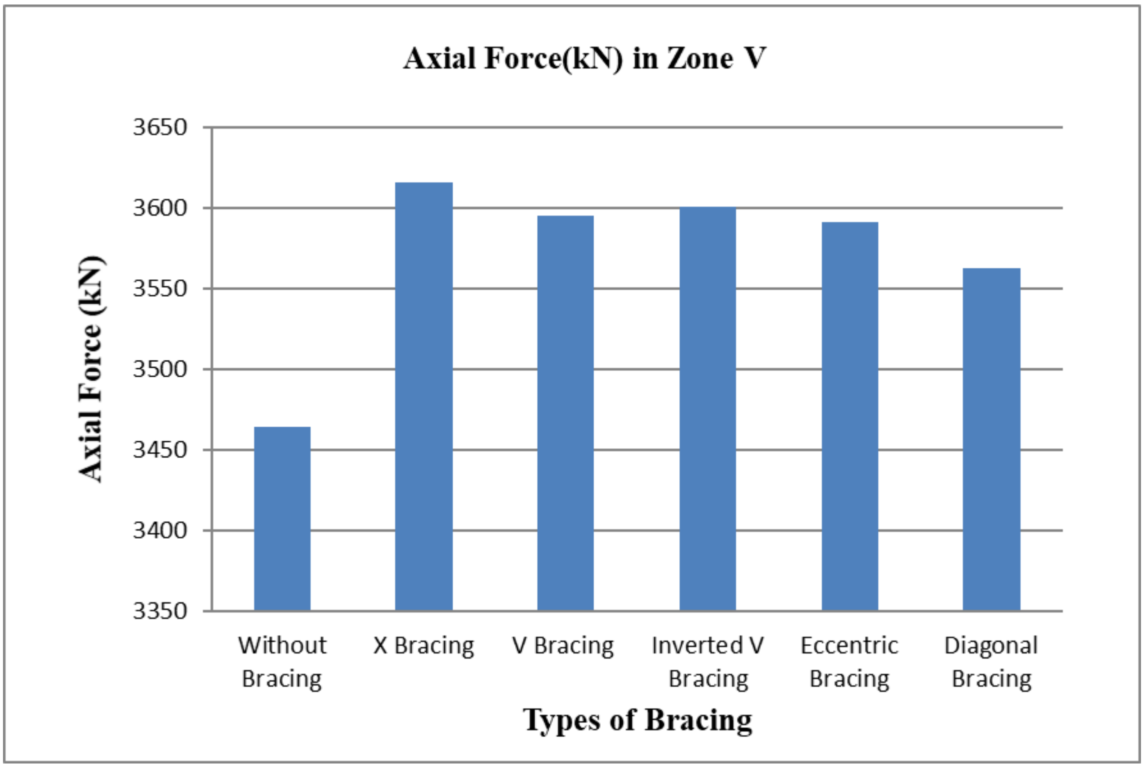


Fig.5.14 Maximum Axial Force for Different Bracing System for Zone V

It has been observed that axial forces increased in the bracing structures as compared to un-braced structures. The maximum increase in axial force has been found in X bracing as compared with other bracing systems i.e. V bracing, inverted V bracing, diagonal bracing and eccentric bracing.

5.6 BENDING MOMENT

The analysis has been carried out to study the occurrence of maximum bending moment in bracing and un-braced frame structures in three seismic zones III, IV, and V. The bending moment values obtained from analysis are given in Table 5.14 in zone III, Table 5.15 in zone IV and Table 5.16 for zone V. To study the effect of bracing in RC bared structures, obtained resulting values of bending moment are represented by the bar chart and have shown in fig 5.15 for zone III, fig 5.16 for zone IV and Fig 5.17 for zone V.

Table 5.14 Maximum Bending Moment for Different Bracing System for Zone III

Structure Type	Bending Moment (kN.m)
Without Bracing	82.01
X Bracing	75.46
V Bracing	77.546
Inverted V Bracing	78.051
Eccentric Bracing	79.072
Diagonal Bracing	76.186

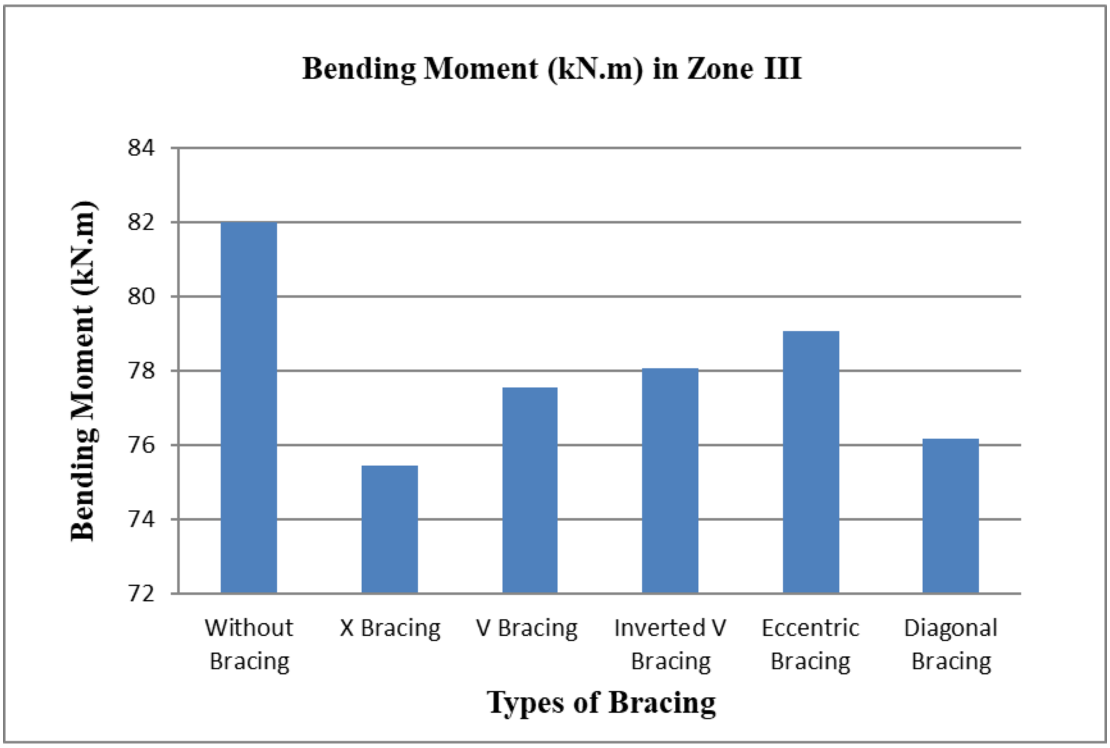


Fig.5.15 Maximum Bending Moment for Different Bracing System for Zone III

Table 5.15 Maximum Bending Moment for Different Bracing System for Zone IV

Structure Type	Bending Moment (kN.m)
Without Bracing	128.016
X Bracing	116.78
V Bracing	121.592
Inverted V Bracing	122.017
Eccentric Bracing	123.016
Diagonal Bracing	119.762

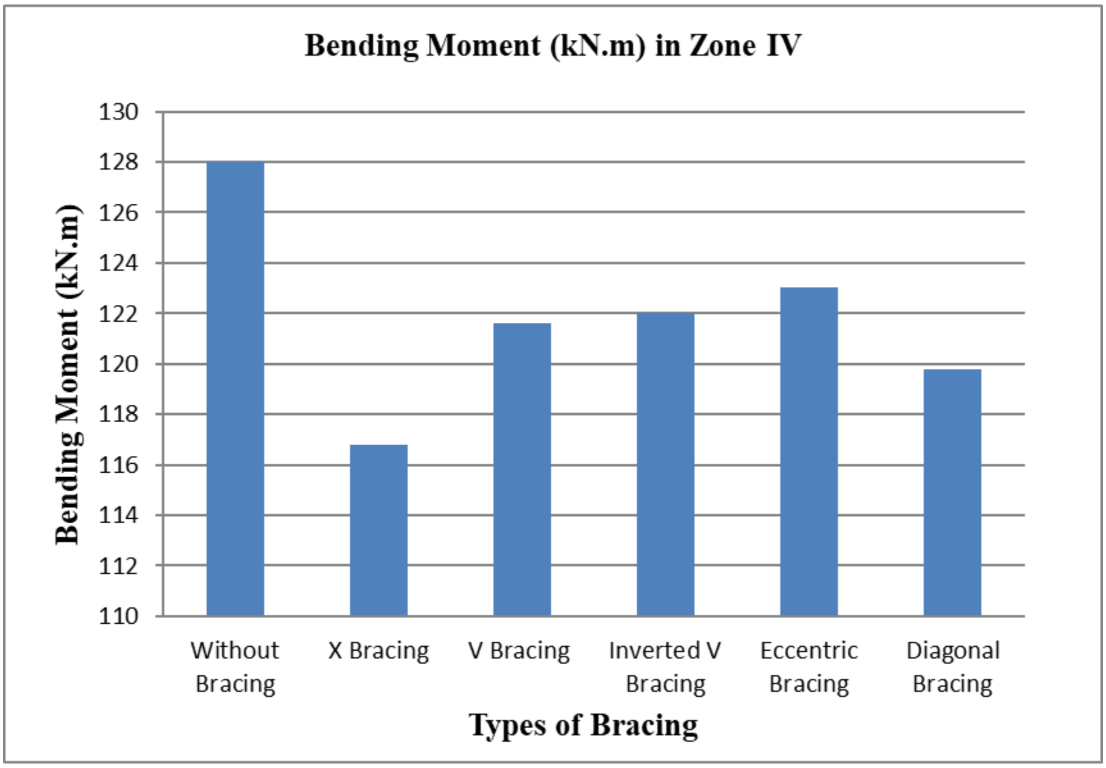


Fig.5.16 Maximum Bending Moment for Different Bracing System for Zone IV

Table 5.16 Maximum Bending Moment for Different Bracing System for Zone V

Structure Type	Bending Moment (kN.m)
Without Bracing	189.825
X Bracing	172.708
V Bracing	179.478
Inverted V Bracing	178.615
Eccentric Bracing	180.615
Diagonal Bracing	176.768

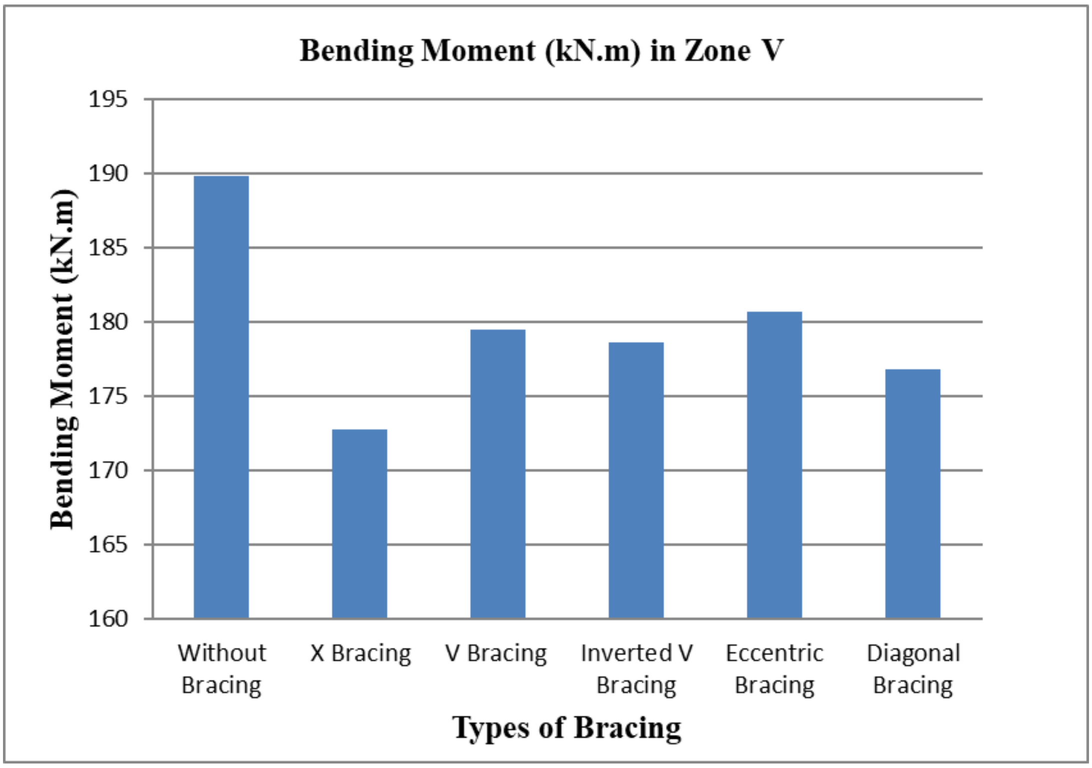


Fig.5.17 Maximum Bending Moment for Different Bracing System for Zone V

It has been observed that bending moment gets reduce when the bracing system is added and it is advantageous for the structure. The building structure with X bracing system will have the least possible bending moment as compared to other types of bracing system.

Conclusion

CHAPTER 6 CONCLUSION

6.1 GENERAL

The present work is clearly focused on the study of the seismic response of G+13 storey building. The main objective of the study is to compare the effect of bracing frames over unbraced frame in a structure in different seismic zone i.e. III, IV and V. To achieve the objective the various parameters have been considered includes storey displacement, storey drift, Base shear, a maximum weight of the structure, maximum axial force and maximum bending moment and has described in chapter 4. Mainly two types of bracing system namely, concentric bracing system (CBS) and Eccentric bracing system (EBS) have been analyzed for lateral loads by response spectrum analysis and static analysis using software STADD PRO. The result values of parameters (storey displacement, storey drift, Base shear, a maximum weight of the structure, maximum axial force and maximum bending moment) obtained from the analysis are have been compared with unbraced frame model and has discussed in chapter 5. The conclusions of the study work are concluded in the following section.

6.2 CONCLUSIONS

All the bracing frame models have been analyzed by response spectrum analysis and static analysis using software STADD PRO for all selected parameters namely, storey displacement, storey drift, Base shear, a maximum weight of the structure, maximum axial force and maximum bending moment. From the analysis of bracing models, it has been observed that the braced frame modeled structure has shown better seismic resistance than an unbraced structure in all seismic zone i.e. III, IV and V. Furthermore, it has been observed that among all models considered, X-Braced frame model is a comparatively best selection from the structural point of view. Therefore, only values of X braced frame model are shown in the following conclusions.

1. The lateral displacement of the bracing system decreases with an increase in the height of the building as compared to the bare frame. Structure model with X bracing shows less lateral displacement as compared to the structure model with other bracing (diagonal bracing, chevron bracing and eccentric bracing) and un-braced system in all

three zones (III, IV and V). The reduction in lateral displacement values for X braced model in zone III is 54.23%, in zone IV is 54.49% and in zone V is 54.71%.

2. Overall comparison of base shear shows that the base shear value in case of X bracing system is large as compared to other bracing. However, the base shear of the braced building increases as compared to un-braced RC frame model. The base shear value increases with an increase in seismic zones.
3. The Story drift of the structure is reducing by using different types of bracing system in the model. A structural model with X bracing shows less storey drift as compared to the structure with other braced and un-braced system in all three seismic zones. The reduction in storey drift values for X braced model in zone III is 82.29%, in zone IV is 82.17% and in zone V is 82.22%.
4. The weight of the different braced structural model is more as compared to an un-braced structure model with the same structural configuration. All the results show that the weight in case of X bracing system is more as compared to another frame model.
5. Bending moment values in braced frame model get reduced as compared to unbraced frame model. The building frame model with X bracing has the least possible bending moment as compared to other types of bracing system. Therefore, it is advantageous to provide X bracing in structures.
6. Axial force values in the braced frame model increased as expected as compared to unbraced frame model. The building frame model with X bracing has a maximum possible axial force as compared to other types of bracing system. Therefore, it is advantageous to provide X bracing in structures.

6.3 FUTURE SCOPE

This research area has a vast research experiment for future studies. The following options can be used in research experiment work for further studies:

1. In further research, we can use the time history method for analysis.
2. In a further study, we can consider building with rectangular and offsets plan.
3. The performance of a building can also be studied by using concrete bracing instead of steel bracing and we would do an experimental study on actual modal.

4. We can also examine the building with mega braces which is huge X braces and diagrid in the structure instead of Concentrically braced frames (CBF's) and Eccentrically braced frame (EBF's)
5. We can also provide a different dead load on different stories levels of the building.
6. We can provide bracing in different location of the column, two parallel sides/phase of the building and in the single bay at a particular phase of the building to carry out the analysis.

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ABSTRACT

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When a tall building is subjected to earthquake under the action of lateral loads. Providing a suitable lateral force resisting system has a significant effect on the performance of the RC frame structure. The present study focuses on the study of bracing systems for RC frame structure. The effectiveness of different types of bracing on the RC frame structure has been carrying out. For this study, a G+13 storied RC frame structure has been considered and structural behavior has been studied at three seismic zones (III, IV and V). The RC frame structure models are analyze by Response spectrum and equivalent static as per IS 1893:2016(part1) using STADD Pro software. The structural behavior has been studied using different types of bracing system such as X bracing, Diagonal bracing, Chevron bracing and Eccentric bracing. A comparative study has been done on parameters story displacement, story drift, base shear, axial force, Bending moment and weight of the structure between braced and un-braced RC frame model. From the study, it has been observed that the lateral displacement and story drift of the braced system decrease in the structure as compared to the un-braced frame in all seismic zones (III, IV and V). Base shear value and weight of the structure are increases in the braced system as compared to un-braced system. Bending moment values in braced frame model get reduced and axial force value in the braced frame model increase as compared to unbraced frame model. It is concluded that the X bracing significantly contribute to structure stiffness as compared to the other bracing system.

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प्रमुख	: संरचनात्मक अभियांत्रिकी	विभाग	:	जनपद अभियांत्रिकी
शोध का शीर्षक	: आरसी फ्रेम संरचना के लिए ब्रेसिंग सिस्टम का अध्ययन			
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जब पार्श्व भार की कार्रवाई के तहत एक ऊंची □मारत को भूकंप के अधीन किया जाता ह□एक उपयुक्त पार्श्व बल प्रतिरोध प्रणाली प्रदान करने से आरसी फ्रेम संरचना के प्रदर्शन पर महत्वपूर्ण प्रभाव पड़ता ह□वर्तमान अध्ययन आरसी फ्रेम संरचना के लिए ब्रेसिंग सिस्टम के अध्ययन पर ध्यान केंद्रित करता ह□आरसी फ्रेम संरचना पर विभिन्न प्रकार के ब्रेसिंग की प्रभावशीलता को आगे बढ़ाया गया ह□□स अध्ययन के लिए, एक जी + 13 मंजिला आरसी फ्रेम संरचना पर विचार किया गया ह□ और तीन भूकंपीय क्षेत्र (III, IV और V) पर संरचनात्मक व्यवहार का अध्ययन किया गया ह□RC फ्रेमवर्क मॉडल का विश्लेषण STADD प्रो सॉफ्टवेयर का उपयोग करके IS 1893: 2016 (part1) के अनुसार रिस्पांस स्पेक्ट्रम और समकक्ष स्थ□तिक द्वारा किया जाता ह□विभिन्न प्रकार के ब्रेसिंग सिस्टम का उपयोग करके संरचनात्मक व्यवहार का अध्ययन किया गया ह□जै□से एक्स ब्रेसिंग, विकर्ण ब्रेसिंग, शेवरॉन ब्रेसिंग और सनकी ब्रेसिंग। पर□मीटर कहानी विस्थापन, कहानी बहाव, आधार कतरनी, अक्षीय बल, झुकने का क्षण और लट और बिना लटके आरसी फ्रेम मॉडल के बीच संरचना का वजन पर एक तुलनात्मक अध्ययन किया गया ह□अध्ययन से, यह देखा गया ह□कि सभी सिस्मिक ज़ोन (III, IV और V) में अन-ब्रेस्ड फ्रेम की तुलना में ब्रेस्टेड सिस्टम का लेटरल डिसप्लेसमेंट और स्टोरी बहाव कम हो जाता ह□आधार-कतरनी मूल्य और संरचना का वजन अनियंत्रित प्रणाली की तुलना में लट प्रणाली में बढ़ जाता ह□ब्रेडेड फ्रेम मॉडल में झुकने वाले मूल्य कम हो जाते हैं और बिना फ्रेम वाले मॉडल की तुलना में ब्रेस्ड फ्रेम मॉडल में अक्षीय बल मूल्य बढ़ जाता ह□यह निष्कर्ष निकाला गया ह□कि एक्स ब्रेसिंग अन्य ब्रेसिंग सिस्टम की तुलना में संरचना की कठोरता में महत्वपूर्ण योगदान देता ह□

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