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SEISMIC ANALYSIS OF G+12 RCC BUILDING WITH AND WITHOUT BRACING SYSTEMS

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Abstract: *Seismic design relies on inelastic deformation through hysteretic behavior. During severe earthquakes the structural system undergoes extensive damage that result in high cost of repair. Research these days has elevated and surpassed common human instinct. One such research that backed structural systems to sustain tremors of earthquake is metallic braces. These components are predominantly the lateral force resisting system in any building structure. The installation of braces within a structure system will magnetize substantial part of destruction while the parent elements persist elastically with inferior inelastic deformation. Dissipation of seismic energy occurs through inelastic yielding and buckling of bracing member in tension and compression respectively. In the present work structured in a reinforced concrete G+12 storied frame building which modeled using (Extended Three dimensional Analysis of Building Systems) ETABS 2018. The building modeled in accordance with the provisions prescribed by IS:1893 2002 part I. Three patterns of bracing will be fabricated on the peripheral frame, where pattern being X, V and Inverted V. Results for Time History Analysis will described in the form of storey displacement, storey drift and storey shear by frame and bracing.*

***Key Words*: ETABs 2018, Bracing System, Time History Analysis, Seismic Analysis**

1. INTRODUCTION

1.1. General

Earthquakes are one of the most destructive natural hazards. They not only cause damage to the property but are responsible for the large number of lives. Earthquakes are perhaps the most unpredictable and devastating of all natural disasters. The word earthquake is self-explaining the earthquake that means the earth shakes and we feel the vibration caused by these motions. Earthquakes are caused due to many reasons but most commonly the term 'earthquake' is used when shaking of the earth's surface is caused due to some disturbances occurring inside the earth. Earthquake may be defined as a wave-like motion generated by forces in constant turmoil under the surface layer of the earth (the lithosphere), travelling through the earth's crust.

Whenever the earth is disturbed, vibrations are produced. These vibrations are set out in all directions from the place of their origin. Whenever these vibrations travel, an earthquake is said to have taken place. These vibrations are more intense near their source. But most of them are not of great concern for civil engineers, only a few of them, having high intensity, are a cause of major concern. Some earthquakes can be very destructive and result in collapse of the structures, thus, resulting in heavy loss of life and damage to the buildings. Thus, it is necessary to study the earthquakes in detail and take every precautionary measure and protection, to minimize the loss of life and property.

Earthquake is also defined as the vibration, sometimes violent, of the earth's surface as a result of a release of energy in the earth's crust. This release of energy can be caused by sudden dislocations of segments of the crust, volcanic eruptions, or even explosion created by humans. Dislocations of crust segments, however, lead to the most destructive earthquakes. In the process of dislocation, vibrations called seismic waves are generated.

The energy released during an earthquake is enormous. For example, the energy released during Bhuj earthquake (India 2001) was about 400 times more than the energy released by the 1945 atom bomb dropped in Hiroshima. The size and severity of an earthquake is estimated by two important parameters –intensity and magnitude. The magnitude is a measure of the amount of energy released, while the intensity is the apparent effect experienced at a specific location.

Earthquakes are a major cause of concern for civil engineers because the effect of this disaster is measured in terms of extent of damaged. This damage includes loss of lives and property both. Somebody has rightly said that ''Earthquakes do not kill people but it is the structures built by them that do so." Thus it is very necessary to make the structures earthquake resistant. So, the study of earthquake engineering is important for civil engineers to equip them with the basic knowledge of earthquakes, its effect on structures and various principles and techniques to be followed while designing and constructing earthquake resistant structures.

1.2 Causes of Earthquakes

Earthquakes are vibrations or oscillations of the ground surface caused by a transient disturbance of the elastic or gravitational equilibrium of the rocks at or beneath the surface of the earth. The disturbance and the consequent movements give rise to elastic impulses or waves.

Earthquakes are preliminary caused due to two reasons:

(1) Natural disturbances.
a) Volcanic causes
b) Tectonic causes
(2) Artificial disturbances.

(1) Natural Disturbances: The natural disturbances which causes earthquakes are following-

a) Volcanic causes: Volcanic activity keeps on taking place in several parts of the world. Very often, it produces sudden outburst or explosions. This impact is sometimes strong enough to produce vibrations in the nearby areas. People, living in Japan and Italy, have experience this type of earthquake frequently. These earthquakes are not very deep and of mild intensity. The damage caused due to this type of earthquake is confined within a few kilometers. All volcanic eruptions don't produce earthquake.

b) Tectonic Causes: Tectonic causes are those which occur inside the earth. According to the theory of plate tectonics, the Crust (outermost layer of earth) is made up of rocks and is divided into many plates. These plates are constantly in motion in different directions and with different speeds. These rocks or plates have strain energy stored in them.

(2) Artificial Disturbances: Sometimes the surface of the earth vibrates due to man-made or artificial disturbance. These vibrations are very mild and affect the surrounding area only. The earthquakes of mild intensity are caused due to these external man made agencies. Some of the artificial disturbances causing earthquakes are listed below :

a. Nuclear tests and explosions.
b. Mining blasts.
c. Large and deep excavations.
d. Vibration induced due to heavy machinery used in industries.
e. Movement of heavy vehicles.

1.3 Effects of Earthquakes

Earthquakes are major hazards and can cause catastrophic damage. They have two types of effects-direct and indirect. Direct effects cause damages directly and include ground motion and faulting. Indirect effects cause damages indirectly, as a result of the processes set in motion by an earthquake.

(1) Direct Effects– The direct effect of earthquakes are as follows:

a) Seismic waves, especially surface waves, through surface rock layers and regolith result in ground motion. Such motion can damage and, sometimes, completely destroy buildings. If a structure, such as a building or a road, straddles a fault, then the ground displacement that occurs during an earthquake will seriously damage or rip apart that structure.

b) In regions consisting of hills and steep slopes, earthquake vibration may cause landslides and mudslides and cliffs to collapse, which can damage building and lead to loss of life.

c) Soil vibration can either shake a building off its foundation, modify its supports, or cause its foundation to disintegrate.

d) Strong surface seismic waves make the ground heave and lurch and damage the structure.

(2) Indirect Effects- The following are indirect effects of an earthquake:

a) Since a tsunami occurs because of sudden displacement of a large body of water, this displacement may be caused by

- Undersea landslides whereby large amount of sediment is dislodged from the sea floor, displacing a water column and potentially generating a localized tsunami.
- Surface land sliding in to the ocean due to earthquake, resulting in local tsunami; and
- Volcanic eruption in or near the ocean which may cause the tsunami, but are not usual.

b) Earthquakes can cause fire by damaging gas lines and snapping electric wires.

c) Earthquakes can rupture dams and levees (raised river embankments), causing floods, resulting in damage to structures and considerable loss of life.

2. SEISMIC ZONES IN INDIA

2.1 Seismic Zoning

The seismicity or earthquake activity at a place is assessed by, its distance from the faulted rocks, and from the past records. It varies in different parts of a country or region. It is seen from the past records that earthquake activity (their severity, occurrence etc.) are more or less same in a particular area or zone. Therefore, a country can be divided into zones of similar seismic activity. Seismic zoning can be defined as dividing a country or region into smaller zones on the basis of their seismicity or earthquake activity (Intensity of damage).

The seismic zoning of a country mainly depends upon the following:

(a) The seismic history of a region. It means the detail study of the earthquakes that have occurred in past, their characteristics like magnitude, intensity and extend of damage etc.

(b) The tectonic features of the place which could cause an earthquake in future.

2.2 Use of Zoning Map

The zoning maps are very useful for design of earthquake resistant structures. We can easily come to know about the various design forces depending upon the place (site's location) because the forces for which structures are designed depend upon the seismicity of that place. However, for important structures, it is necessary to take geological and seismological observations for the site to get design forces caused by the earthquakes. These should be studied along with historical data of earthquakes and then various seismic factors for design could be determined. The zoning maps also provide information of expected earthquake effects in terms of maximum intensity of earthquake (MMI) or ground motion characteristics at a particular region.

2.3 Tectonic Features of India

India lies at the north-western end of the Indo-Australian plate. On this plate, India, Australia, a major part of the Indian Ocean and other smaller countries are located. This plate is colliding against other neighboring plates. The three major tectonic plates of India are following:

1. Northern Himalayas

2. Plains of the Ganges and other rivers.

3. The peninsular region.

1. Northern Himalayas: The Himalayan ranges comprises of highly seismic zone which is very unstable. All along the foothills of the Himalayas, stretching from Kashmir to Assam is a long thrust fault known as the Great Boundary fault. This fault is highly prone to earthquakes and is marked as highly seismic zone. India's earthquake history shows that most of the destructive earthquakes ranking as severe earthquakes of the world, took place in this zone, which were interplate earthquakes.

2. Plains of the Ganges and other rivers: Leaving aside the zones of Great Boundary Fault, other regions of Himalayan belt and Indo-Gangetic plains are moderately seismic areas. A study about the formation of Indo-Gangetic Plains indicates that this zone is made of the alluvial deposits which are laid into a great depression present in front of the Himalayan ranges. This zone is still in an unstable condition and moderate earthquakes are common in the region. Normal faults along Narmada, Godavari and Koyna rifts are also reactivated occasionally.

3. Peninsular India: The Peninsular part of India consists of ancient rocks. Erosion has exposed the roots of the old mountains. The rocks are hard but softened by weathering. It is a geological stable region. Though, there are several faults but these are quire inactive. Very small earthquakes occur in these areas which are mostly interplate.

Date	Location	Magnitude	Causalities
16-10-1819	Kutch, Gujrat	8.0	2000 dead
12-01-1897	Shillong plateau	8.7	1542 dead
04-04-1995	Kangra, Himachal Pradesh	8.0	20,000 dead
15-01-1934	Bihar-Nepal border	8.3	1000 dead, 9000 injured
15-08-1950	Assam	8.5	532 dead
21-08-1988	Indo-Nepal border	6.5	1000 dead
20-10-1991	Uttarkashi, Uttar Pradesh	6.6	760 dead, 5000 injured
30-09-1993	Latur-Osmanabad, Maharashtra	6.3	7601 dead, 15,846 injured
22-05-1997	Jabalpur, Madhya Pradesh	6.0	55 dead, 500 injured
29-03-1999	Chamoli district, Uttar Pradesh	6.8	1000 dead, 400 injured
26-01-2001	Bhuj, Gujrat	7.9	19,727 dead, 166,000 injured

Table 1.1 Some significant earthquakes in India

2.4. Zones of India

The different geology at different locations in the country implies that the possibility of damaging earthquakes taking place at different location is different. Thus a seismic zone map is required to identify these regions. Based on the levels of intensities during past earthquakes, the 1970 zone map divided India into five zones. I, II, III, IV and V. The maximum modified Mercalli (MMI) intensity of shaking expected in this zones were V or less, VI, VII, VIII and IX and higher, respectively. Parts of Himalayan boundary in the north and north east and Kutch area in the west were classified as zone V.

The seismic zone maps are revised from time to time as more knowledge is gained about earthquakes, the tectonics and seismic characteristics of the country. The Indian Standard published the first seismic zone map in 1962 which was later revised in 1967 and again in 1970. The map has been revised lastly in 2002 and it now has only four seismic zones- II, III, IV and V. The areas of zone I of the earlier 1970 map are merged with the seismic zone II. Also the zones in peninsular region has been modified and Chennai now comes in zone III (earlier it was in zone II).

3. SEISMIC ANALYSIS

Seismic analysis is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. Earthquake engineering has developed a lot since the early days, and some of the more complex designs now use special earthquake protective elements either just in the foundation (base isolation) or distributed throughout the structure.

Earthquakes are one of the most unpredictable and devastating natural disaster which cause extensive damage to the buildings structure. This damage results in loss of lives and property. Thus, it is very important on the part of the civil engineers to build structures with high seismic performance. It has been observed that majority of such structures may be safely reused if they are made seismically strong by using some method/techniques (retrofitting techniques). It is a better and economical choice as compared to demolition and reconstruction. Thus there is a need to restore or strengthen the old and weak or damaged buildings so that they can sustain future earthquakes. It is one of the most important aspect of mitigation especially in earthquake prone areas which will reduce the earthquake hazards/damages.

Two types of building need to be retrofitted:

(i) Earthquake Damaged Buildings: The buildings which are damaged or weakened by the earthquakes thus making them unfit or unsafe for future use.

(ii) Weak Buildings: Buildings which have not experienced severe earthquakes but are seismically weak and are vulnerable to earthquakes.

4. NEED OF RETROFITTING

In addition to this retrofitting or strengthening of a building is also required to be done in following cases:

(i) Up gradation of a Code: As the experience of the civil engineers is increasing, codes or standards are also being upgraded from time to time. Thus the buildings designed by the code, which has been revised or upgraded, need to be retrofitted to fulfil the latest codal provisions.

(ii) Change in use of Buildings: Whenever there are changes in the use of a building, for example, public buildings converted to an industrial building or residential building to office building etc., there is a need to retrofit or strengthen the building to satisfy the codal provisions as per the present class of the buildings.

(iii) Important Buildings: Important buildings such as hospitals, schools, historical monuments etc. need to be strengthened and restored from time to time to counter effects of ageing and weathering.

(iv) Retrofitting and Strengthening: Retrofitting and strengthening of a building is also needed in the case of extensions or expansion of the building, for example making more stories etc.

5. SEISMIC EVALUATION OF BUILDINGS

Seismic evaluation is a process of assessing the seismic resistance of a building. This evaluation is necessary for determining or planning the retrofitting scheme or techniques required for making the structure seismically safe. The estimation of seismic resistance of a building i.e., in terms of its strength and ductility is not a simple task and require a lot of effort and studies on the part of structural engineer. There is no well define procedure for the same. The methodologies available so far are based on the studies and examination of various parameters of the building, some of which are explained below:

1. Architectural and structural drawing of the building.
2. Comprehensive examination of the load bearing members of the building. It may require some non-destructive testing for assessing the strength of the material, location and amount of reinforcement and its condition (effect of rusting etc.).
3. Specification of materials, soil testing reports etc.
4. Past performance of similar type of building during the earthquake. The extent and type of damage in such buildings help a lot to decide about the selection of retrofitting technique.
5. Visual inspection of the building which should include all types of weakness and damage present in the building. The weakness include the unsymmetrical constructions, short columns, floating columns, soft stories, opening in the buildings and other points of distress like heavy floors, beam column joints etc. The damage part should include a detailed inspection of the type and extent of the damage like cracking, spalling of concrete, corrosion of bars, damaged structural elements etc.

The aim of these studies is to identify the weaknesses of the buildings which help in estimating the seismic resistance of the building which is also called as Available Seismic Resistance or ASR. The Available Seismic Resistance (ASR) of the building should be at least equal to the Minimum Seismic Resistance (MSR) specified by IS code, which is essentially required to withstand the effect of earthquake in the remaining life of the building. Thus seismic retrofitting or strengthening of a building is required to be planned and executed properly which will increase the ASR of the building to become equal to MSR. The minimum seismic resistance of any building estimated by design seismic coefficients given by IS 1893-2002 (Part-1) these coefficients depend upon the location of the building (zone), type of construction material of the building, importance of the building, its soil parameters.

6. STEEL BRACING

The idea of using steel bracings as lateral resisting elements in RC frames has received some attention in recent years. The earlier works concentrated either on external bracing of the RC frames or on indirect internal bracing through intermediary steel frames. Both methods have a number of shortcomings, particularly in terms of application and cost. There are various lateral resisting system and steel bracing is one of them. Although steel bracing of RC frames started as a measure for retrofitting existing buildings, it soon developed into a method for designing new buildings. Due to their high strength, stiffness and lateral load capacity, steel bracing are an ideal choice for lateral load resisting system in a reinforced concrete structures.

Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing has 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 number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and/or ductility of existing buildings. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, 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 seismic or wind lateral loadings. Therefore, the use of steel-bracing systems for retrofitting reinforced-concrete frames with inadequate lateral resistance is attractive. Strengthening of structures proves to be a better option catering to the economic considerations and immediate shelter problems rather than replacement of buildings.

7. SCOPE OF PRESENT WORK

The scope of the present work is to study the seismic analysis of RCC building with X-type bracing, V-type bracing, inverted V-type bracing and building without bracing:

- To study seismic analysis on software like ETABS
- To study modeling of building with X-type bracing, V-type bracing, inverted V-type bracing and building without bracing by time history analysis method.
- To find the effect of storey drift, storey shear, storey displacement and time history analysis on model with different types of bracing structure to the building.
- To evaluate and compare modeling with different types of bracing introduce to the building.
- To study the different analysis & result as compared to each modeling of different type of bracings.

8. DESIGN OF EXPERIMENTATION DESCRIPTION OF SELECTED STRUCTURE

The ETABS2018 software is utilized to create 3D model and carry out the time-history analysis. The buildings are modelled as a series of load resisting elements. The lateral loads to be applied on the buildings are based on the Indian standards. The study is performed for seismic zone V as per IS 1893:2002 for medium type of soil. The buildings adopted consist of reinforced concrete. The frames are assumed to be firmly fixed at the bottom and the soil–structure interaction is neglected.

- 12 storied building analyzed only for gravity loads.
- 12 storied building analyzed for seismic forces.
- 12 storied building analyzed with different types of bracing systems.

The G+12 storey building structure is analyzed for zone V on medium soil with structure without bracing, X-type bracing, V-type bracing and inverted V-type bracing.

The data of modelled buildings is given below in table 1

Member Properties	
Thickness of slab	0.125 m.
Beam size	0.50 x 0.50 m
Column size	0.60 x 0.60 m
Beam cover	0.025m
Column cover	0.04m
Bar size	16d
Corner bar size	16d
Dead Load Intensities	
Floor finishes	1.0 kN/m^2
Live Load Intensities	
Roof and Floor	3.0 kN/m^2
Wind load	Not considered

Table 9.1: Model data of the buildings

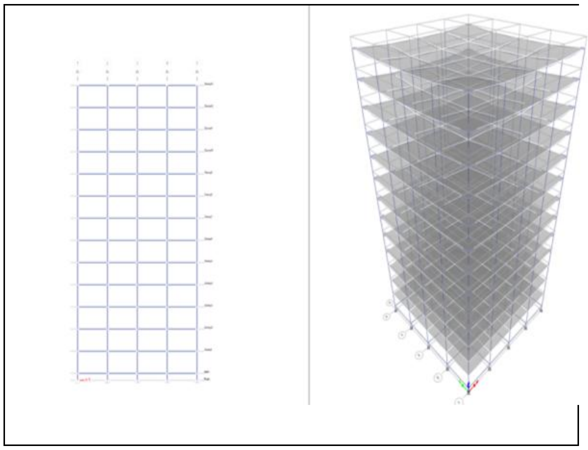
Seismic Zone=V

Zone factor, Z=0.36

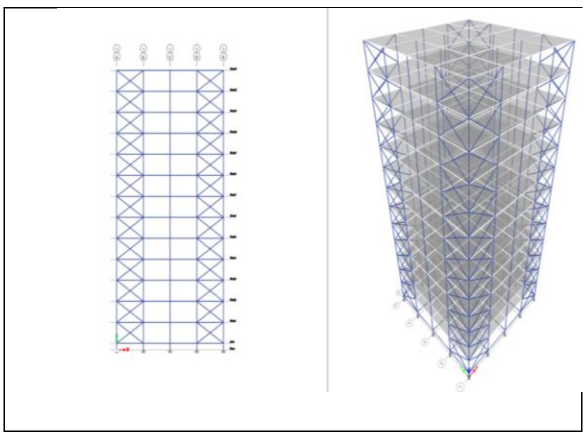
Importance factor, I=1.00

Response reduction factor, R=3.00

The load cases considered in the seismic analysis are as per IS 1893 – 2002.



a)



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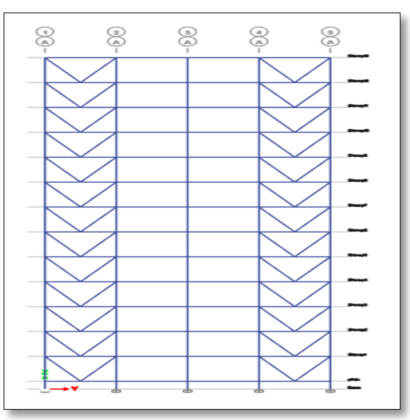

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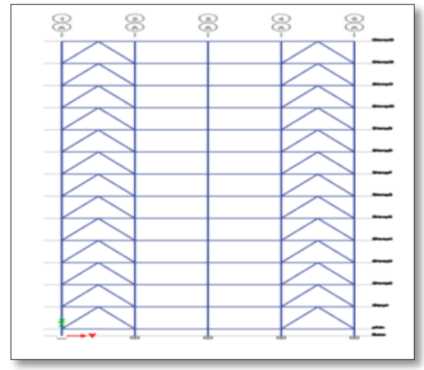

d)

Fig 8.1. Model in ETABS of building a) without bracings b) X bracings c) V bracings and d) Invt. V bracings.

9. ANALYSIS OF RESULTS

9.1 Introduction

The obtained results based on study performed are presented in current chapter. All the results are presented in graphical format. Present study is carried out on symmetric structure. Further every structure is analyzed with the help of ETAB software.

9.2 Comparative study for different types of bracing:

To access the seismic analysis performance of G+12 storey reinforced concrete structure a comparative study is done between structure without bracing and structure with different types of steel bracing such as X-type bracing, V-type bracing and inverted V-type bracing. For this study structure are analyzed with the help of ETABS software and result were compared on key parameters like storey displacement, storey drift, and storey shear.

In this section, three analyses were done for four different buildings i.e. (G+12) storey without bracing, (G+12) storey with X-type bracing, (G+12) storey with V-type bracing, (G+12) storey with inverted V-type bracing by using earthquake ground motion data.

9.3 Maximum Storey Displacement:-

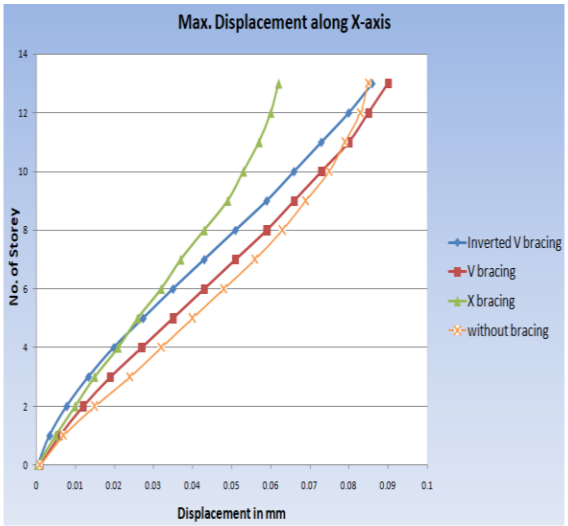

Fig 9.1 max. displacement along X-axis

From above figure 9.1, it is shown that the max. displacement along X-axis of G+12 building structure without bracing and G+12 building structure with V bracing as compared to other bracing system of building is more. The X bracing reduce the max. displacement by 55% as compared to the structure without bracing and 40% as compared to other bracing, hence the X bracing provides better result as compared to other bracing.

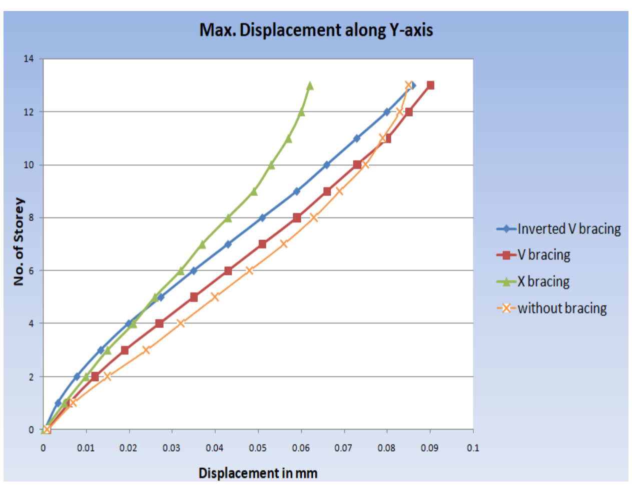

Fig 9.2 max. displacement along Y-axis

From above figure 9.2, it is shown that the max. displacement along Y-axis of G+12 building structure without bracing and G+12 building structure with V bracing as compared to other bracing system of building is more. The X bracing reduce the max. displacement by 55% as compared to the structure without bracing and 40% as compared to other bracing, hence the X bracing provides better result as compared to other bracing.

9.1.2) Storey Shear:-

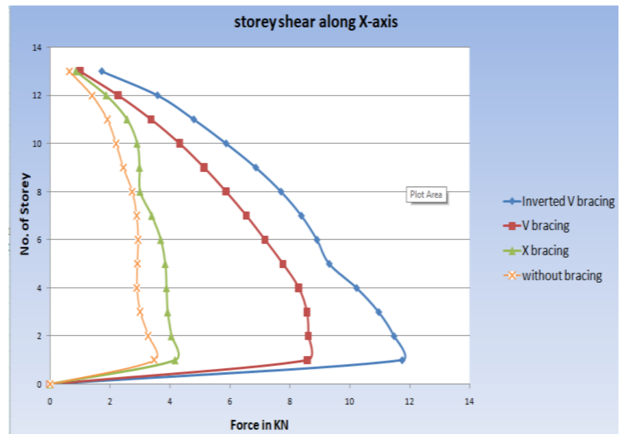

Fig 9.3 Storey shear along X-axis

From above figure 9.3, it is shown that the storey shear along X-axis of G+12 building structure without bracing as compared to other bracing system of building is less. The Invt. V bracing increase the storey shear by 25% as compared with the structure without bracing and 35% as compared to the other bracing, hence the Invt. V bracing provides better result as compared to other bracing.

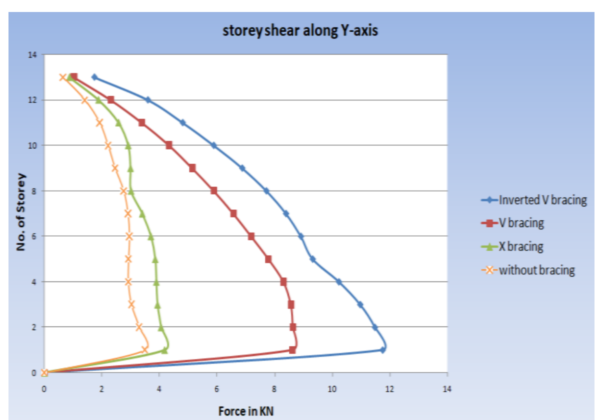

Fig 9.4 Storey shear along Y-axiS

From above figure 9.4, it is shown that the storey shear along Y-axis of G+12 building structure without bracing as compared to other bracing system of building is less. .The Invt. V bracing increase the storey shear by 25% as compared with the structure without bracing and 35% as compared to the other bracing, hence the Invt. V bracing provides better result as compared to other bracing.

9.1.3) Storey Drift:-

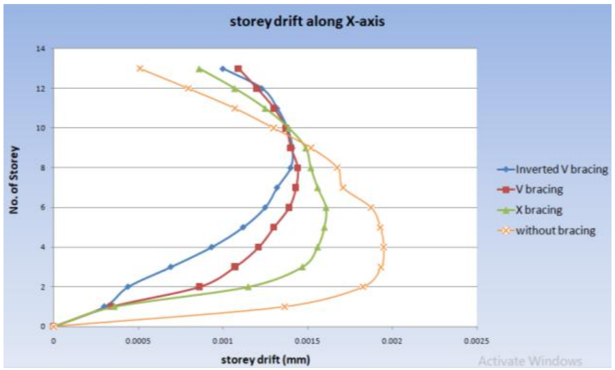

Fig 9.5 Storey drift along X-axis

From above figure 9.5, it is shown that the storey drift along X-axis of G+12 building structure without bracing and G+12 building structure with X bracing as compared to other bracing system of building is large. The Invt. V bracing reduce the storey drift by 55% as compared to the structure without bracing and 20% as compared to other bracing, hence the Invt. V bracing provides better result as compared to other bracing.

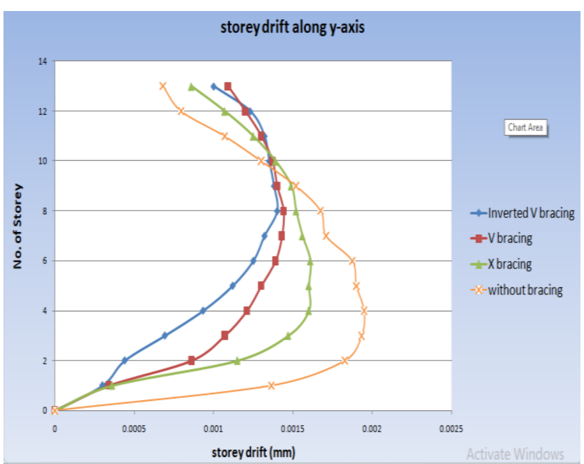

Fig 9.6 Storey drift along Y-axis

From above figure 9.6, it is shown that the storey drift along Y-axis of G+12 building structure without bracing and G+12 building structure with X bracing as compared to other bracing system of building is large. The Invt. V bracing reduce the storey drift by 50% as compared to the structure without bracing and 20% as compared to other bracing, hence the Invt. V bracing provides better result as compared to other bracing.

10. CONCLUSIONS

- Steel bracings can be used as an alternative to the other strengthening or retrofitting techniques available.
- The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures.
- The concept of using steel bracing is advantageous to resist the seismic forces and structural behavior of earthquake.
- Due to different behavior of structure the non-linear performance of the structure will get Invert-V bracing system proves as effective member to control storey drift (up to 60%) in structure as compare to without bracing system.
- Invert-V bracing system gives max. storey shear (up to 65%) of structure as compare to without bracing system.
- Invert-V bracing system gives more lateral support to the structure as compared to structure without bracing.
- Using steel bracing, the total weight on the existing building will not change significantly.

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