ANALYTICAL STUDY ON SEISMIC RESPONSE CONTROL OF MULTISTORY RC BUILDING FRAME USING VARIOUS TYPES OF BRACING SYSTEMS

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ABSTRACT

Seismic design relies on inelastic deformation through hysteretic behaviour. 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 will be structured in a reinforced concrete G+7 storied moment resisting frame building which will be modeled using (Software for Analysis and Design) SAP-2000. The building will be modeled in accordance with the provisions prescribed by IS:1893 2016 part I. Three patterns of bracing will be fabricated on the peripheral frame of erection, where pattern being X, V and Inverted V. Both types of non linear analysis i.e. dynamic time history (NTH) and non linear static (pushover) analysis will be carried out to investigate the performance of building structure due to induced dynamic forces by ground excitation. Scrutinizing framework through pushover analysis structural elements will be provided with hinges in accordance with Federal Emergency and Management Agency (FEMA) 356 and NTH is conducted using accelerogram of different earthquake.
Results for NTH will described in the form of storey displacement, storey drift, shear force, bending moment and energy dissipated by frame and bracing. Whereas pushover analysis results will be quantified through different parameters like yield shear, yield displacement, target displacement and ductility ratio.

KEYWORDS: FEMA, accelerogram, behavior, Storey displaement

1. INTRODUCTION

1.1 General

The primary requirement of humans on planet earth is food, clothing and shelter. Prehistoric men and women used to live on trees but steadily they started developing the shelters for protection against natural calamities like rains, cold etc. and also from attack against wild animals. Soon humans grew in knowledge and they started living together, forming communities to ensure additional security and man became a social animal. Now these communities developed and started exploding forming villages which later on transformed into cities and became the commercial centers of a region. Soon within these commercial centers, land for horizontal expansion became extinct. The social animal started expanding vertically constructing multi-storied structures. These multi-storied edifice were susceptible against natural hazards like earthquake which was life threatening for the residents. With the advancement in engineering practices, researchers developed systems which reduced the effects of seismicity on the engineered structures. One such evolution which is added to the buildings is bracing system.

1.2 Modern Structural Protective System

The modern structural protective system is categorized into three major categories: Seismic Isolation System, Passive Energy Dissipation Devices and Semi Active and Active Energy Dissipation Devices. These energy dissipation devices When gets installed inside any structure curtails response due to the seismicity of earthquake ground motion. All these devices have their advantages and disadvantages but prove to be effective in improving response of structure.

1.2.1 Passive Energy Dissipation Devices

While all these technologies are likely to have an increasingly important role in structural design, the scope of the present monograph is limited to a discussion of passive energy dissipation systems. Research and development of passive energy dissipation devices for structural applications have roughly a 25-year history. In recent years, serious efforts have been undertaken to develop the concept of energy dissipation or supplemental damping into a workable technology, and a number of these devices have been installed in structures throughout the world. Because of the added damping force that passive device provides, their distribution over the height of the building is critical towards reducing vibration and preventing large structural damage.

1.2.1.1 Metallic Damper

One such passive energy dissipation device is a Metallic Damper. Metallic dampers are one of the most effective mechanisms available for the dissipation of energy, input to a structure during an earthquake, is through the inelastic deformation of metallic substances. This metallic damper is also called as a metallic fuse or structural fuse. The concept behind this device comes from the fuse of an electric circuit. What happens in an electric circuit is that excess of electric current flows through a circuit the electric fuse wire break down by self-sacrificing itself thereby protecting the electric appliances. Examples of metallic dampers that have received significant attention in recent years include the X-shaped and triangular plate dampers. Force-deformation characteristics. Since this overall response is intimately linked with the cyclic stress-strain behavior of the metal, it is beneficial at this point to briefly review the typical inelastic stress-strain response of structural steel.

1.2.3.2 Bracing as Passive Energy Dissipation Devices

Besides these devices different type of bracing system could be thought upon to dissipate the seismic energy through the structure functioning unlike the metallic damper. These bracings are essentially made of mild steel. These bracings also dissipate energy through their inelastic yielding capabilities. There are mainly two type of bracing system that exist they are concentric type and eccentric type of bracing system. Different type of bracing system that attained the focus of the structural designers includes X bracing system, V bracing system, Inverted V bracing system and K bracing system which are a part of concentric bracing system.

2. Modeling and Analysis of Frame

2.1 Introduction

From literature surveyed it is concluded that using bracing element is very economical way to reduce seismic weight of any type of building structure. Shear wall also help in curtailing the lateral force effect due to ground motion but it add on to a greater seismic weight. So using bracing element improves the performance of building during earthquake thereby reducing the seismic weight. So in the present work for evaluating the concept of metallic fuse a G+7 storey reinforced concrete (RC) moment resisting frame situated in zone IV is modeled. Concentric type bracing imparted to structure are modeled as fuse element. Concentric bracing includes four different pattern of bracing. Non Linear Dynamic Time history Analysis is carried out using SAP-2000 programming software.

2.2 Modeling of Building Frame

2.2.1General

Metallic braces is the easiest and simplest way of reducing response of building which gave rise to five models for the analysis

1. Model In - G7RCFWOBS : G+7 storey Reinforced Concrete Frame Without Bracing System
2. Model II - G7RCFWIVBS : G+ 7 storey Reinforced Concrete Frame with IV Bracing System.
3. Model III - G7RCFWXBS : G+ 7 storey Reinforced Concrete Frame with X Bracing System.
4. Model IV - G7RCFWVBS : G+ 7 storey Reinforced Concrete Frame with V Bracing System.
5. Model V- G7RCFWEBS : G+ 7 storey Reinforced Concrete Frame with Eccentric Bracing System

Model I is bare frame model. Model II, III and IV include inverted V (IV), X, V and Eccentric Braced Frame configuration of concentric bracing system. This system of bracing is used because eccentric bracing systems consist of a link element that undergoes inelastic deformation for energy dissipation. This link is possibly beam element of frame structure which is more suitable for steel structures and not for reinforced concrete structures.. 3-D and elevation view seven models created are depicted in Figure 3.1 to 3.5.

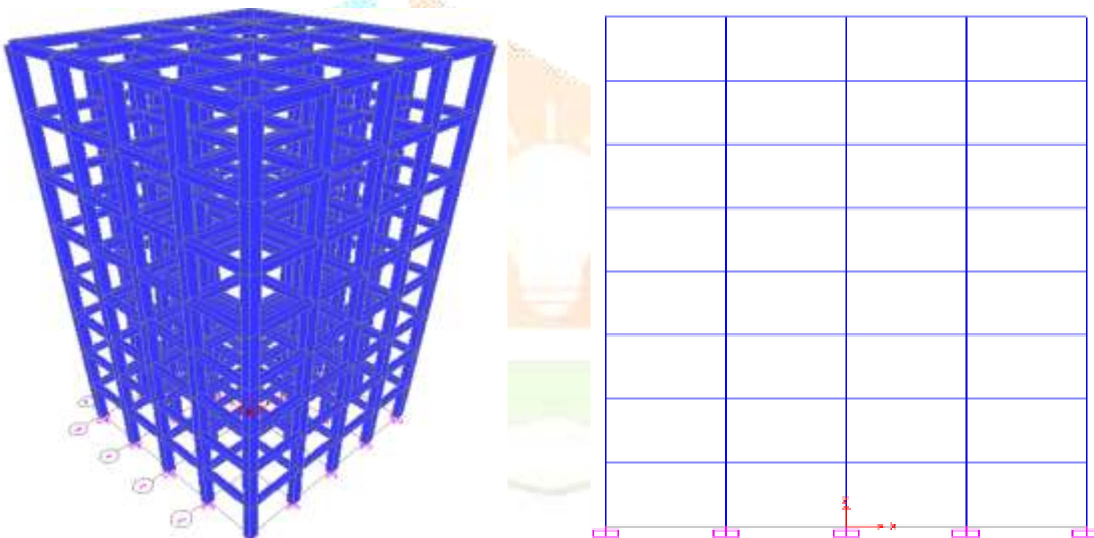


Figure 2.1: 3-D and Elevation View of Bare Frame Structure

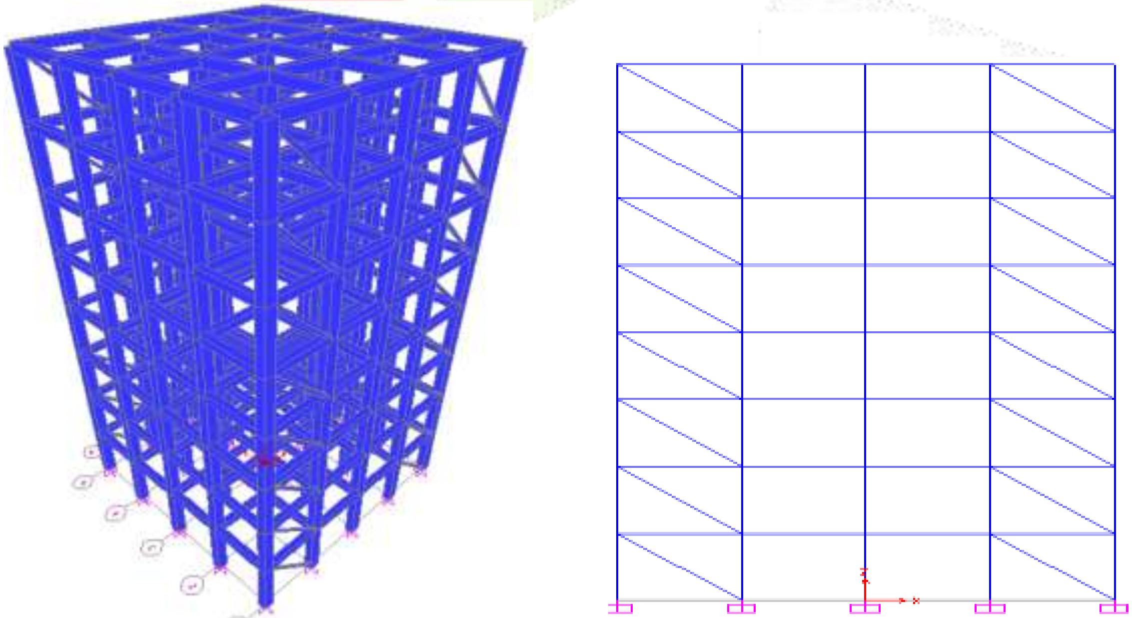
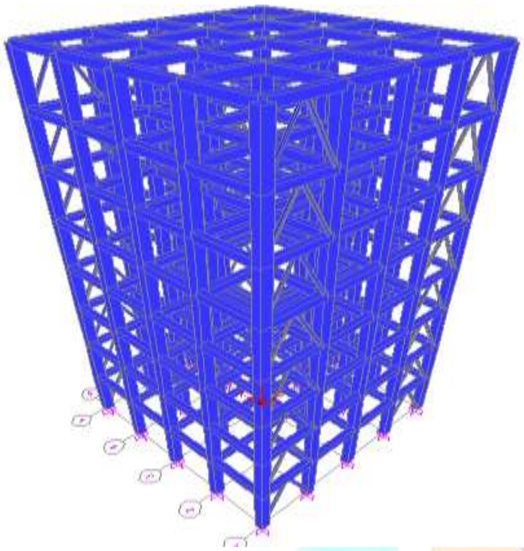


Figure 2.2: 3-D and Elevation View of Eccentric braced Frame Structure



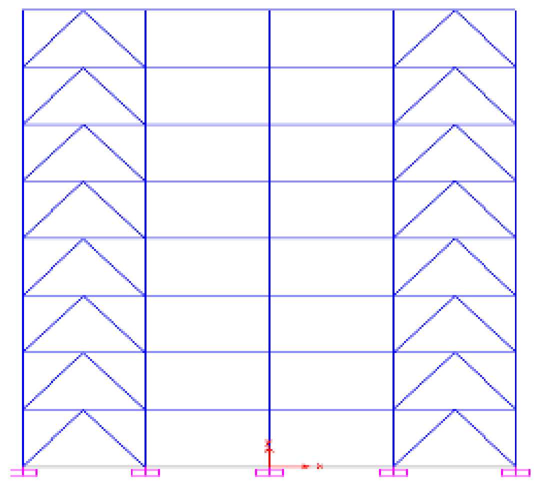
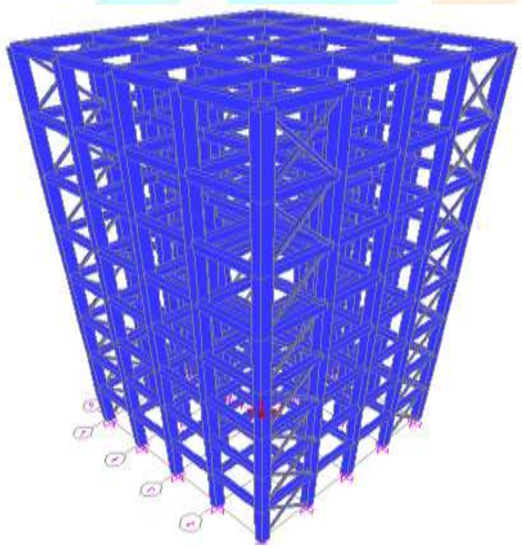


Figure 3.3: 3-D and Elevation View of Inverted V (Chevron) Braced Frame Structure



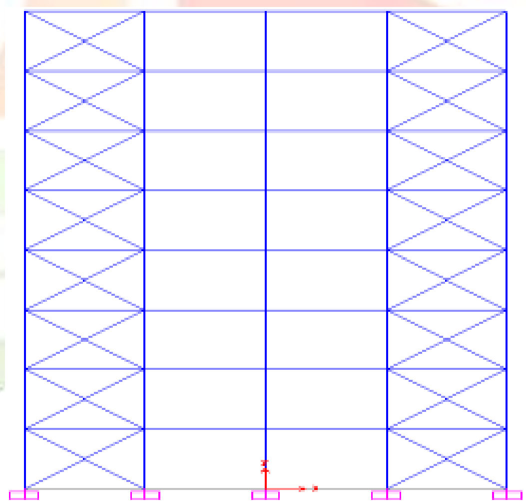


Figure 2.4: 3-D and Elevation View of X Braced Frame Structure

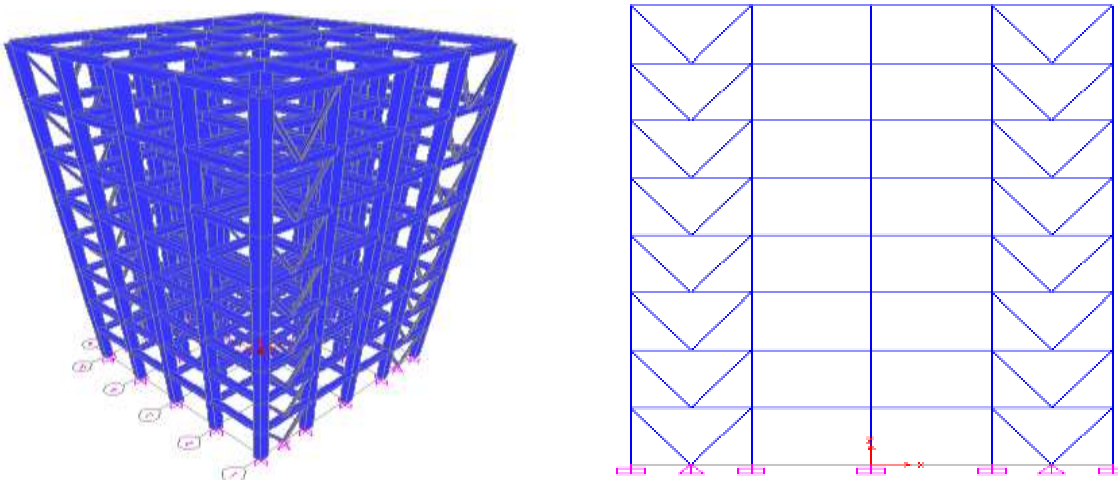


Figure 2.5: 3-D and Elevation View of V Braced Frame Structure

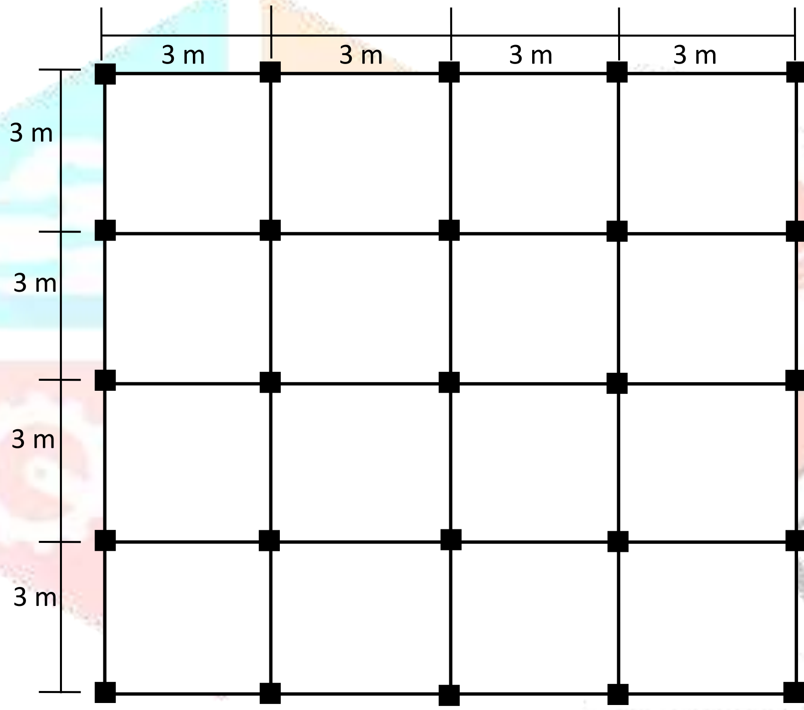


Figure 2.6: Typical Plan of Modelled Building

2.3 Details of the Models

2.3.1 Column and Beam Sizes for Modeling of Building

Table 2.1 Column and Beam Sizes for Modelling of Building

Sr. No.	Element	Notation	Size (mm)
1	Column	C1	400 X 500
2	Beam	B1	300 X 400

2.3.2 Assumed Data for Models

Building	=	G + 7 Storey
Slab Thickness	=	120 mm
Live Load	=	3 kN/m^2
Floor Finish	=	1 kN/m^2
Concrete Grade	=	M20
Concrete Density	=	25 kN/m^3
Steel Grade	=	Fe415
Steel Density	=	7850 kN/m^3
Earthquake Used	=	North Ridge, Imperial Valley, Kern & North Ridge

2.4 Description of Bracing

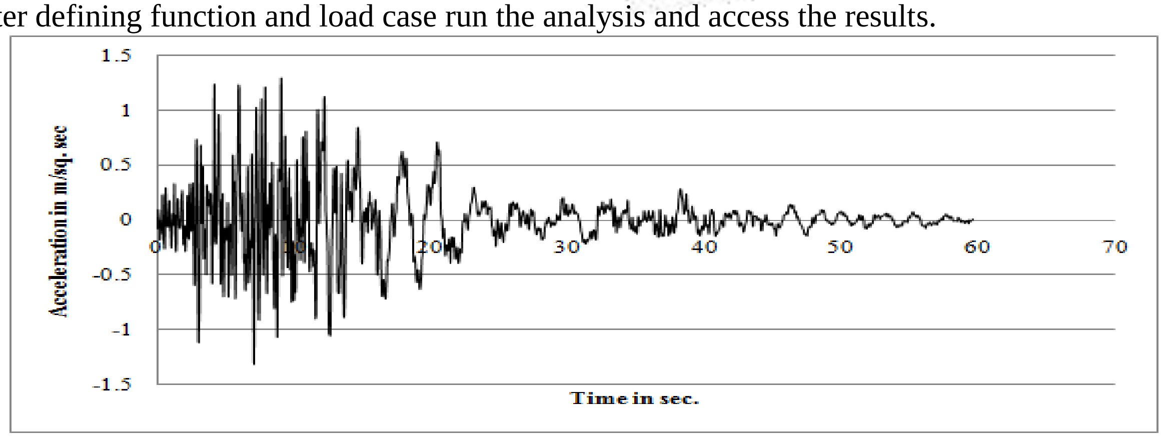
Section Used	=	ISMB125
Material Used	=	Mild Steel

2.5 Non Linear Time History Analysis

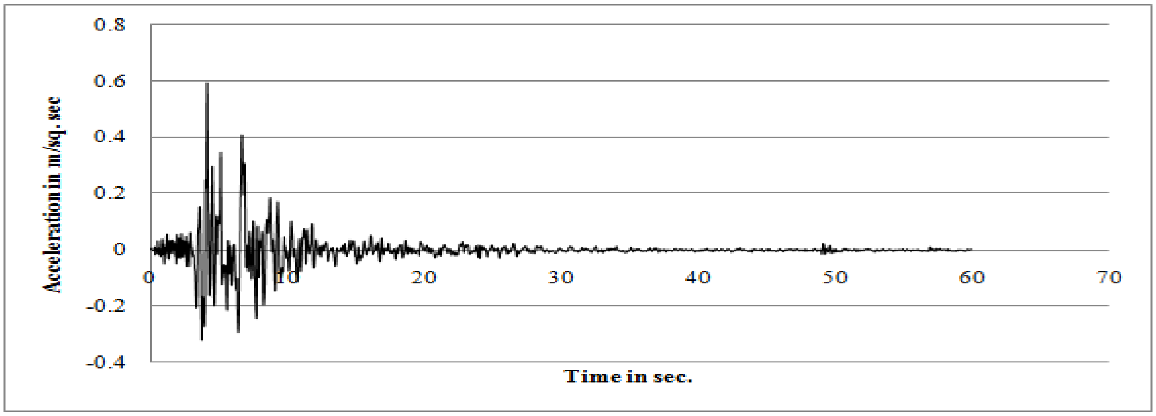
In this method of dynamic analysis, the earthquake motion is directly applied to the base of a given structure with the help of the computer program. Instantaneous stresses throughout the structure are calculated at small intervals of time for the full duration of the earthquake or the significant portion of it. The maximum stresses in any member that occurs during the earthquake can then be found by scanning the output record and the design reviewed. The actual plot of three ground motion record considered for study is shown in Figure 3.7.

2.5.1 Procedure for Non Linear Time History Analysis

1. Define time history function for applying time histories on the models.
2. Then define a new load case of time history function.
3. Write the function name and define the load case as time history from the dropdown menu.
4. Then select the analysis type as nonlinear and time history type as modal.
5. Load is applied to the modal in form of acceleration in X direction with predefined time history function and scale factor as one.
6. The whole procedure includes only material non linearity.
7. After defining function and load case run the analysis and access the results.



(a)



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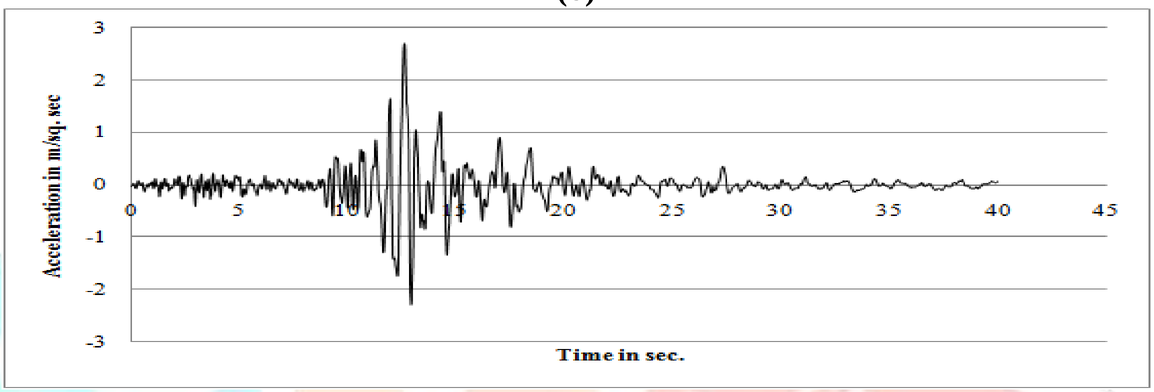

(c)

Figure 2.7 Input Acceleration Time History (a) Imperial Valley (b) North ridge (c) Loma Prieta Earthquake.

3. RESULTS AND DISCUSSION

3.1 Introduction

This chapter presents the results of the analytical work carried out using nonlinear time history analysis. At the preliminary stage a dynamic time history analysis of bare frame structure is carried out by imposing four time histories on to the modelled structure and various resulting entities like storey displacement, drift, shear force and moment are accessed. The technique used for analyzing the structural model is Hilber - Huges - Taylor method. The time interval of accelerogram is 0.02 sec.

3.2 Non Linear Dynamic Time History Analysis

The main purpose of applying nonlinear dynamic time history analysis is to examine the response of modelled building structure under real earthquake ground motions. The analysis exhibits actual behaviour caused due to seismic disturbances. The resulting response found from such an evaluation is very realistic in nature. Therefore the consequences of installing PED's in structure could be investigated on a factual basis. NTH is carried out by imposing three time histories on to the modelled structure which are applied in the horizontal direction and their outcomes are discussed in following points.

3.2.1 Effect of Bracing on Storey Displacement

Presents storey displacement occurred at various stories for different pattern of bracing. Table compares the effect of bracing on displacement of each storey with bare frame for earthquake of four different intensities.

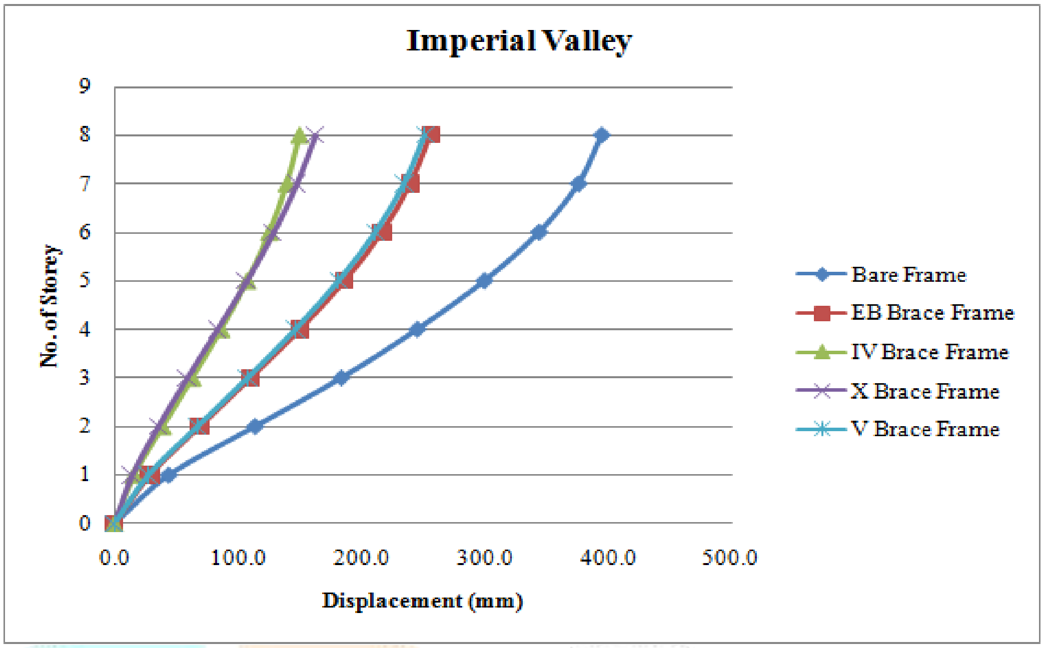

Figure 3.1: Displacement comparison for bare frame and braced frame model for Imperial Valley earthquake

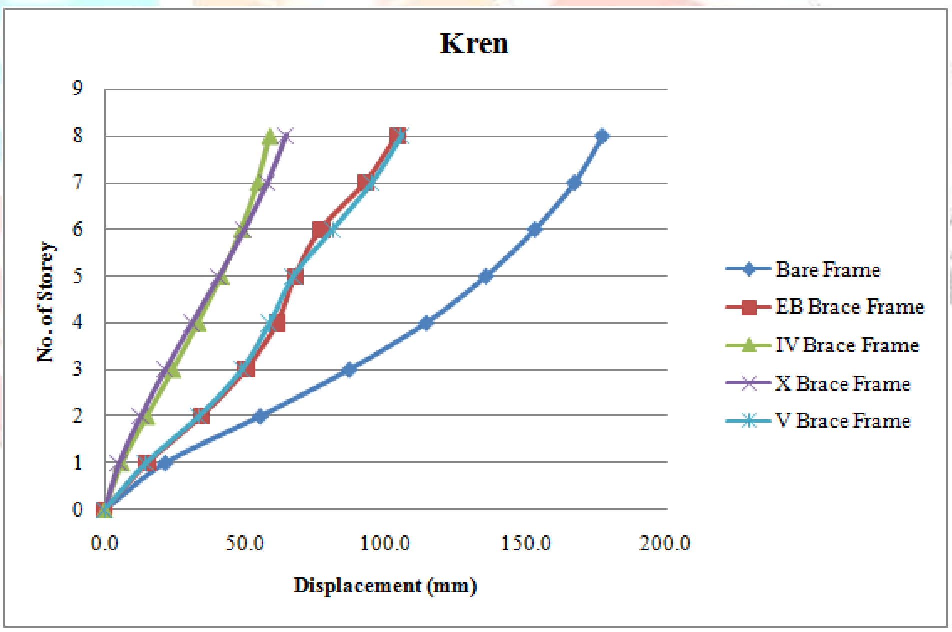

Figure 3.2: Displacement comparison for bare frame and braced frame model for Kern earthquake

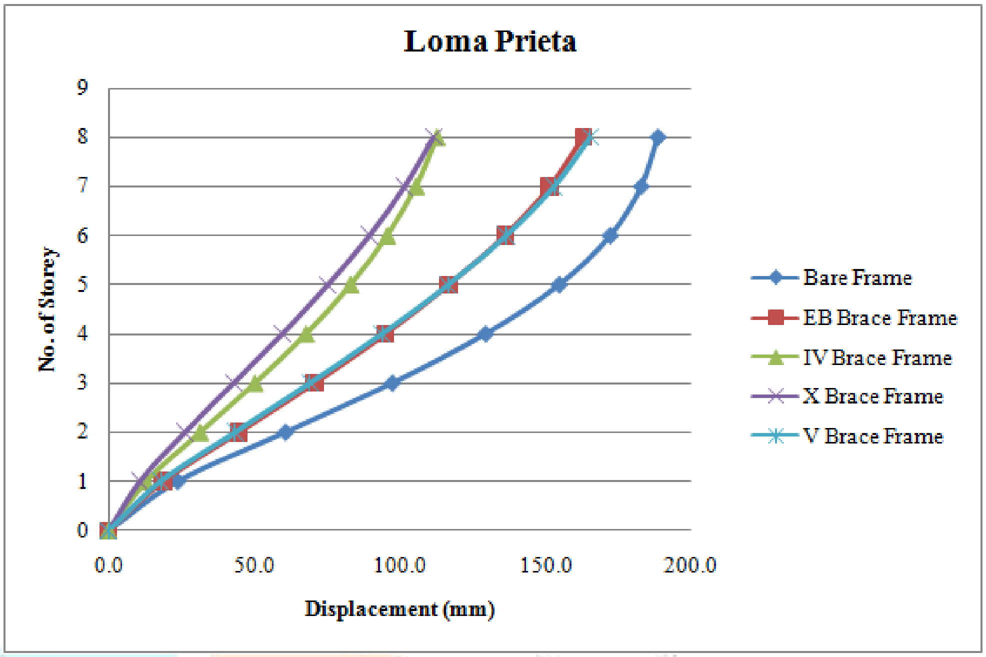

Figure 3.3: Displacement comparison for bare frame and braced frame model for Loma Prieta earthquake

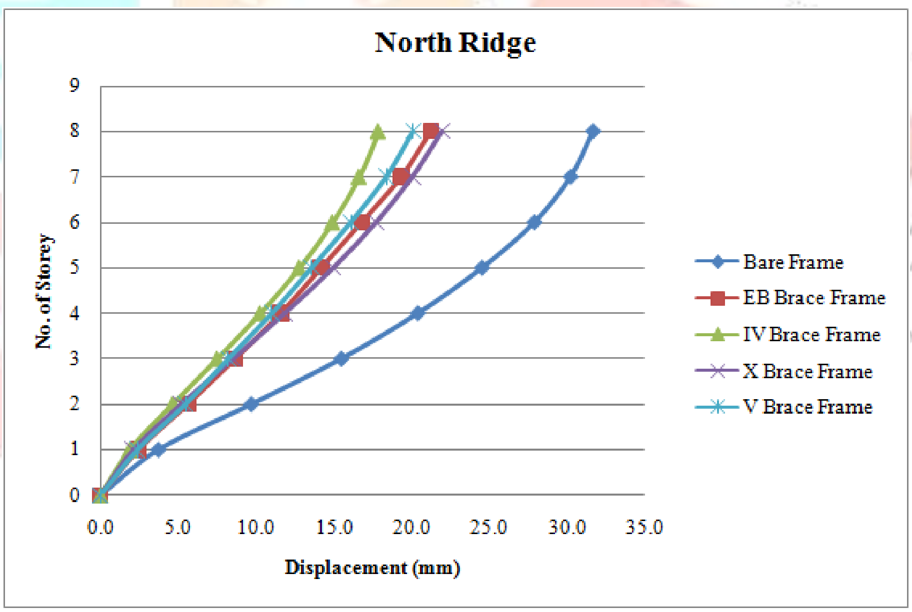

Figure 3.4: Displacement comparison for bare frame and braced frame model for North Ridge earthquake

The effect of bracings could be studied form tables and figures of storey displacement. It is observed that imparting different bracing patterns to the bare frame structure reduces the displacements at each storey level thereby reducing the top storey displacement substantially. It followed from the table that modelling Eccentrically brace frame reduces displacement of top storey by 36.43%, 44.49%, 17.26% and 36.09% for Imperial Valley, Kern, Loma Prieta and North Ridge earthquake respectively. Similarly for Chevron braced frame top storey displacement lowers by 62.48%, 67.46%, 42.45% and 45.03% for the same series of earthquake as above respectively. X braces curtails the top storey displacement to 60.89%, 65.49% , 44.42%, 33.44% and V brace lowers it to 37.66%, 43.18%, 16.48% and 39.07% for same series of earthquake respectively. Results also show that IV brace and X brace are the most effective in curtailing the top storey displacement than V and eccentric braces. Imparting braces to the bare frame structure adds on to the lateral stiffness of structure thereby reducing the displacement at each storey.

3.2.2 Effect of Bracing on Storey Drift

P-δ effect due to storey drift affects building. Therefore depicts storey drift at each storey level for different pattern of bracing with varying intensities of earthquake.

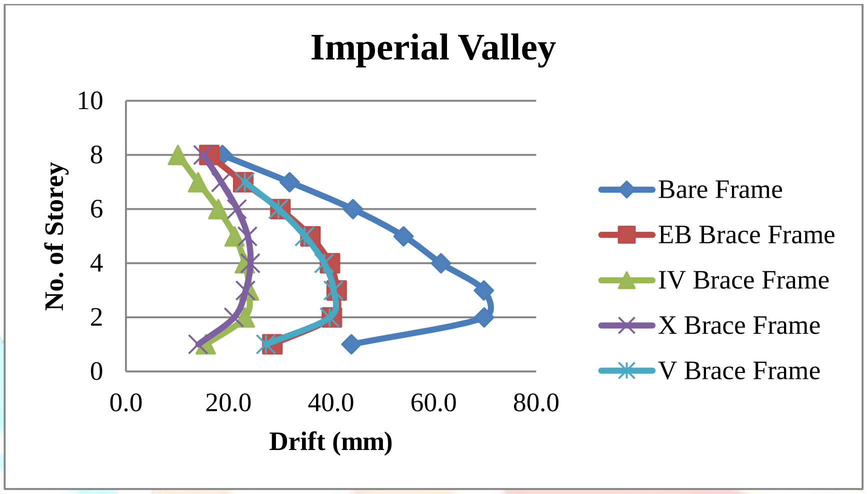

Figure 3.5: Storey Drift comparison for bare frame and braced frame model for Imperial Valley earthquake

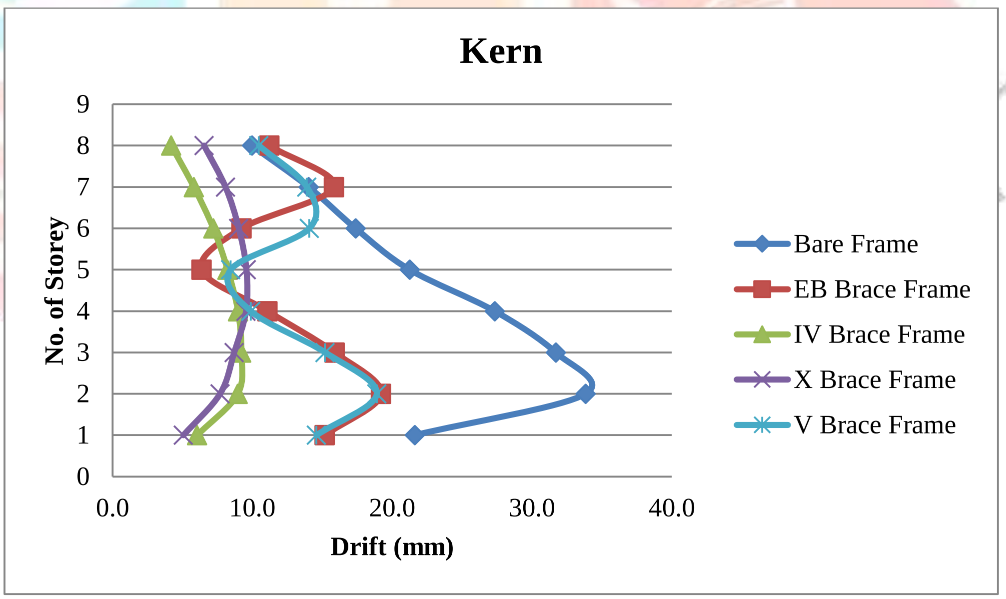

Figure 3.6: Storey Drift comparison for bare frame and braced frame model for Kern earthquake

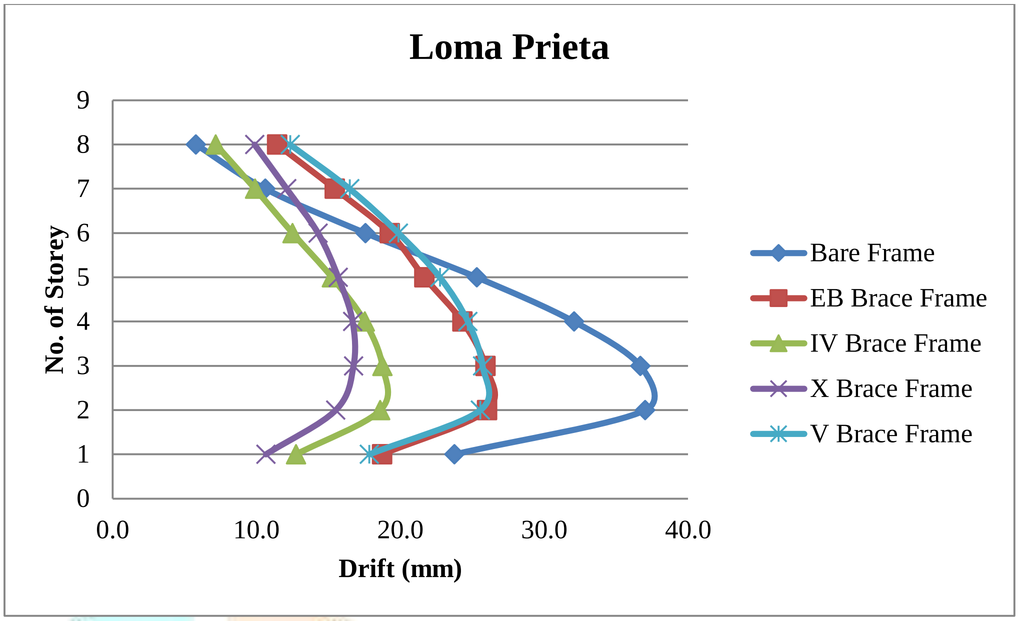

Figure 3.7: Storey Drift comparison for bare frame and braced frame model for Loma Prieta earthquake

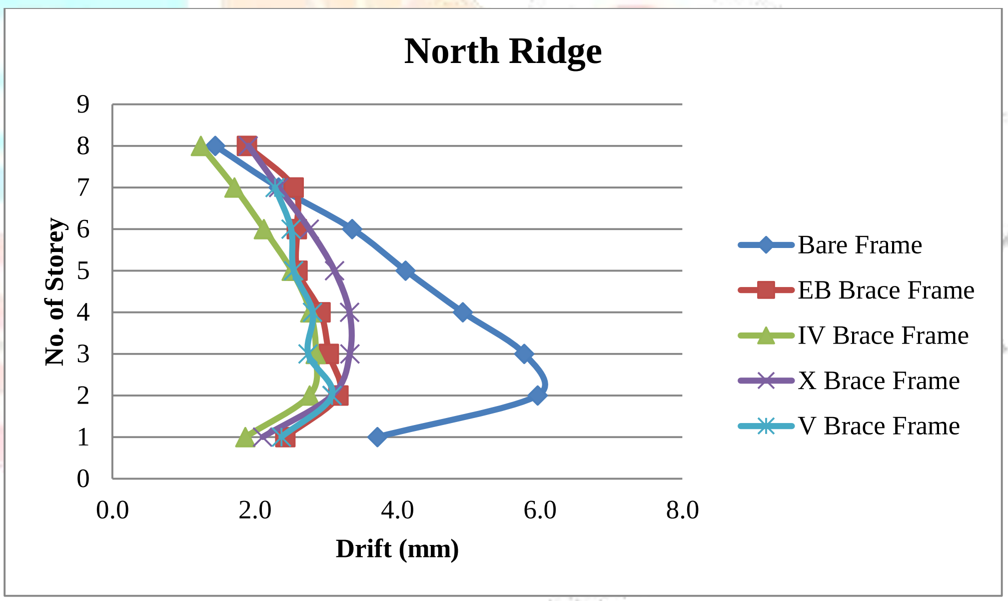

Figure 3.8: Storey Drift comparison for bare frame and braced frame model for North Ridge earthquake

Results and graphs of storey drift reveal reduced values of drift and increased performance of building structure. A drastic reduction in storey drift was observed at each storey for all earthquake time histories. 28.43% of reduction of drift was found in eccentric brace frame structure and increases again for chevron braced and X braced structure to 55.93% and 41.67% respectively for Imperial Valley time history. Kern earthquake outcome percentage reduction is 12.85%, 58.57%, 42.14% and 1% for eccentric brace frame, chevron brace frame, x brace and v brace frame. Though for Loma Prieta and North Ridge time histories top storey drift is greater than bare frame but for rest of the stories it is lesser. The increased lateral stiffness of the bare frame structure due bracings reduces the storey displacements thereby reducing drifts at each storey.

4. CONCLUSION

Nonlinear dynamic time history analysis gives accurate results due to earthquake ground motions. Three time histories of different earthquakes are imposed on models. Based on the time history analysis of various models, following conclusions are drawn.

1. A significant reduction in the top storey displacement and storey drift have been observed for X, V and Inverted V bracing models II, III and IV as compared to bare frame model-I.
2. The maximum shear in bottom storey column and biaxial moment in columns have been reduced significantly for X, V and Inverted V bracing models as compared to bare frame model.
3. Reduction in the top storey displacement and storey drift is not so significant between models V, VI and VII as compared to bare frame model-I.
4. A minor variations in the maximum shear in bottom storey column and biaxial moment in columns have been observed in models V, VI and VII as compared to bare frame model-I.
5. The input energy dissipated through hysteretic behavior of metallic damper in models V, VI and VII is not significant.
6. X bracing system proved to the most effective system in curtailing response due to ground motions.
7. All the plates in X-Plate Damper have yielded well and dissipated considerable amount of energy.

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