# Seismic Response Control using Metallic Fuses

Manoj A. Sadafale, ,
M.E. Student,
Government College of Engineering,
Aurangabad.

Dr. R.S. Londhe
Associate Professor,
Government College of Engineering,
Aurangabad.

***Abstract*:- The present study reveals the seismic performance of moment resisting RC frames with different patterns of bracing system. The three different configuration of bracings utilized, X - bracing system, V - bracing system and Inverted V - bracing system. This arrangement helped in reducing the structural response (i.e. displacement and interstorey drift etc.) of the designed building structure. An eight storey building was modeled and designed as per the code provisions of IS-1893:2002. Four different time histories of various earthquakes records were imposed on the building to carry out the inelastic time history analysis. The analysis was conducted with a view of accessing the seismic performance of the building structure. For the purpose of modelling and carrying out inelastic time history analysis SAP - 2000 software was used. Interstorey drift was considered as the primary parameters in comparison between a bare frame building and building with various bracing system. The results show that the building retrofitted with different bracing system was superior to the bare frame building with a reduction in storey drift. And amongst the various type of bracing used, X - bracing system was best in reducing the structural response. Axial forces were found to be least for bare frame and increased with installation of braces. Shear forces and bending moment valued high for bare frame and reduced on installing braces and were found to be least for X bracing system.**

***Keywords: X-bracing, V-Bracing, Inverted V-Bracing, Inelastic Time History Analysis.***

## 1. INTRODUCTION

Seismic design of a structure has been based upon a combination of strength and ductility. For small and frequent seismic excitations, the traditional structure ensures its safety for the stress are well below the yield level. but for a major earthquake it is not so, since the structure do not respond elastically. In such a case the design engineer relies upon the inherent ductility and strength of the building structure to prevent catastrophic failure. This philosophy has led to the development of design codes and various energy dissipation devices. By considering the actual nature of dynamic disturbances various innovative research have propagated with a view of increasing the dissipative energy within a structure.

Modern research have led to development of very innovative energy dissipating devices. The energy dissipative system is categorized into three major groups namely Seismic Isolation System, Semi-active & Active Energy Dissipation Devices and Passive Energy Dissipating Devices. Some of the Seismic Isolation Devices are Elastometric Bearings, Lead Rubber Bearings, Combined Elastometric and Sliding Bearings, Sliding Friction and Pendulum System and Sliding Bearing with Restoring Forces. Active Bracing System, Active Mass Damper, Variable Stiffness & Damping System and Smart Materials are categorized under Semi-active & Active Energy Dissipation Devices. Passive Energy Dissipation Devises consist of Metallic Dampers, Friction Dampers, Viscoelastic Solid Dampers, Viscoelastic or Viscous Fluid Damper, Tuned Mass Damper and Tuned Liquid Damper.

From past 10 to 15 years Passive Energy Dissipating Devices have gained importance and attention of researchers and design Engineers. The research and development of these devices have a history of about 20 to 25 years. The basic function of such devices is to dissipate out the energy induced due to the seismic excitations when they get installed within a structure. One such PED Device is a Metallic Damper. These are the most effective mechanisms available to dissipate the induced earthquake energy through the structure. The concept of metallic damper have evolved from Yield Deformation Theory. According to this theory when this damper is installed within a building it will yield due to the seismic excitations crossing the elastic limit of the structure. This yielding of Metallic Damper takes place well before the structural components of the building reach the inelastic range. So this Metallic Damper is a self sacrificable component of the parent building structure. Here this concept reflects the functioning of an electric fuse. In case of a electrical system, when there is an excess flow of an electric current through the circuit the circuit breaks down. this phenomenon occurs in the electric fuse wire which is designed for a stipulated flow of electric current thereby restricting the flow of excess current and saving the electric appliances from damage. On such similar lines a Metallic Damper works and therefore it can also be called as a "Metallic Fuse".

Some examples of Metallic Dampers that have trapped attention are X-shaped and Triangular Plate Metallic Damper. They are typically parallel plate devices installed within a frame bay between chevron braces and the overlying beam. As a result, the damper primarily resist horizontal deformation via flexural deformation of individual plate element. Beyond a certain level of forces the plates yield and thus provides a supplemental amount of energy dissipation. Besides these plate dampers bracing system is also becoming popular Metallic Damper.

### *1.1 Bracing System*

Any structures which is to be constructed in earthquake prone areas must be designed to resist lateral forces due to wind, seismic and crane lateral forces. The lateral force resisting systems employed to resist these forces include rigid frames, steel plate shear walls and bracing systems. Conventional bracing systems are simple to design and provide effective and economical lateral force resisting systems. Bracing systems can be constructed in many different configurations, often established by specific clearance constraints or to behave in predetermined fashion. Bracing configurations include tension compression cross braces, chevron and inverted chevron tension compression braces. These systems may be designed and detailed as concentrically or eccentrically braced frames. Sizing of the brace member is normally a simple task as the section is designed only to resist an axial tension or a compressive force. Braced members may be oversized in order to limit its axial deformation in order to control interstory drift.

## 2. DYNAMIC ANALYSIS

The time history analysis determines the response of a structure due to forces, displacements, velocities or accelerations that vary with time. There are two versions of this method, first is direct integration and the second, modal superposition. Modal superposition is only suitable for linear analysis, whereas direct integration can be used also for nonlinear analysis. The direct integration utilizes a step-by-step solution of Equation of motion, which is generally described as:

$$M\ddot{U} + C\dot{U} + KU = F(t)$$

Where, *M,C,K* are the mass, the damping, and the stiffness matrices, respectively

For this purpose ground acceleration records, Imperial Valley, Kern, Loma Prieta and North Ridge earthquake are used as the disturbing ground motion.

## 3. METHODOLOGY OF RESEARCH WORK

This study comprehensively investigates the seismic response of 8 storey RC structures with bracing system. Considering the imposition any one earthquake record on the building structure, the effects of the three bracing system used were investigated.

## 4. DESCRIPTION OF THE INVESTIGATED STRUCTURES

The data assumed for the problem to be analyzed in SAP 2000 is as follows

Columns and Beams**:**

| Columns Notation | Size (mm) | Beams Notation | Size (mm) |
|---|---|---|---|
| C1 | 450 X 500 | B1 | 300 X 350 |
| C2 | 450 X 450 | B2 | 230 X 300 |
| C3 | 400 X 450 | | |

Building = (G + 7) storey
Slab thickness = 150 mm
Live Load = 3 KN/m$^2$. (no live load at roof)
Floor Finish = 1 KN/m$^2$
Software Used = SAP 2000.4.2
Method of Analysis = Nonlinear Time History Analysis
Earthquake used = Imperial Valley, Kern, San Fransisco and North Ridge

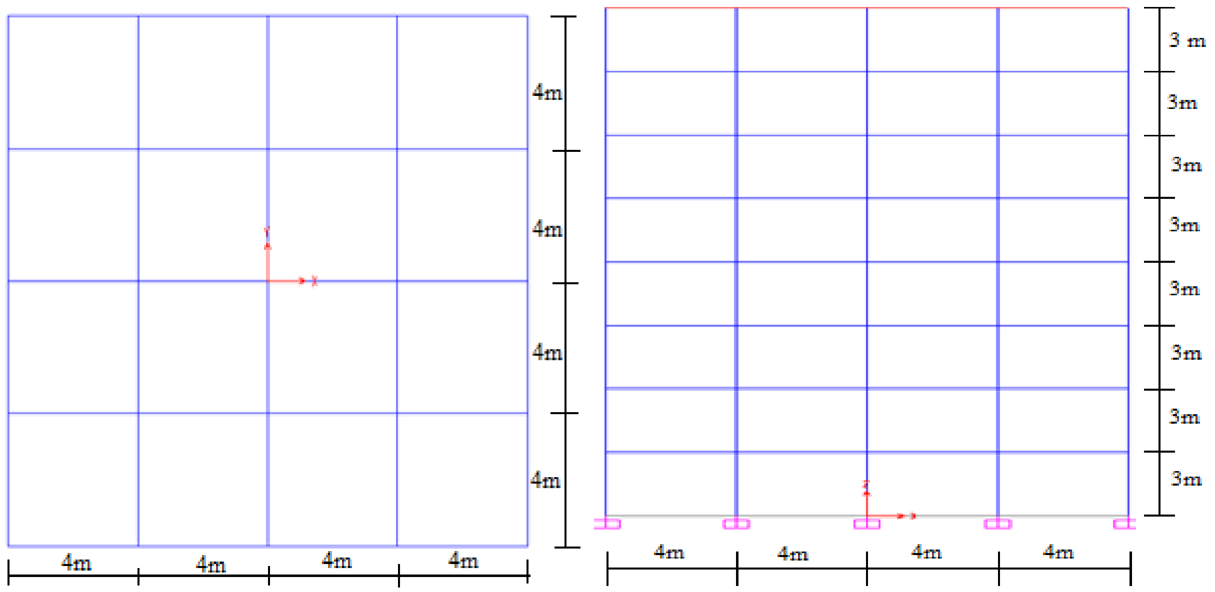



Figure 4.1: Plan and Elevation of RC Building

***Properties and Material of Bracing***

Section Used = ISMC100
Material Used = MILD STEEL (Fe250).

## 5. RESULT AND OBSERVATION

Table 5.1 Displacements and Inter-Storey Drift comparison between bare frame and Bracings for Imperial valley, San Fransisco, Kern, and North Ridge Earthquake

**IMPERIAL VALLEY EARTHQUAKE**

| Floor level | Displacement (mm) | | | | Drift (mm) | | | | % Disp. Reduction | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bare frame | X brace | V brace | IV brace | Bare frame | X brace | V brace | IV brace | X brace | V brace | IV brace |
| 1 | 44.3 | 39.01 | 43.05 | 40.85 | 44.3 | 39.01 | 43.05 | 40.85 | 11.94 | 2.82 | 7.78 |
| 2 | 123.5 | 100.66 | 121.47 | 115.92 | 79.2 | 61.65 | 78.42 | 75.07 | 18.49 | 1.64 | 6.13 |
| 3 | 200.7 | 163.16 | 190.58 | 182.66 | 77.2 | 62.5 | 69.11 | 66.74 | 18.70 | 5.04 | 8.98 |
| 4 | 264.3 | 222.48 | 250.45 | 246.1 | 63.6 | 59.32 | 59.87 | 63.44 | 15.82 | 5.24 | 6.88 |
| 5 | 311.6 | 274.49 | 305.26 | 298.21 | 47.3 | 52.01 | 54.81 | 52.11 | 11.90 | 2.03 | 4.29 |
| 6 | 369.2 | 316.15 | 355.96 | 337.45 | 57.6 | 41.66 | 50.7 | 39.24 | 14.36 | 3.58 | 8.59 |
| 7 | 410.7 | 348.28 | 409.8 | 365.29 | 41.5 | 32.13 | 53.84 | 27.84 | 15.19 | 0.21 | 11.05 |
| 8 | 434.3 | 372.1 | 434.1 | 385.59 | 23.6 | 23.82 | 24.3 | 20.3 | 14.32 | 0.04 | 11.21 |

**KERN EARTHQUAKE**

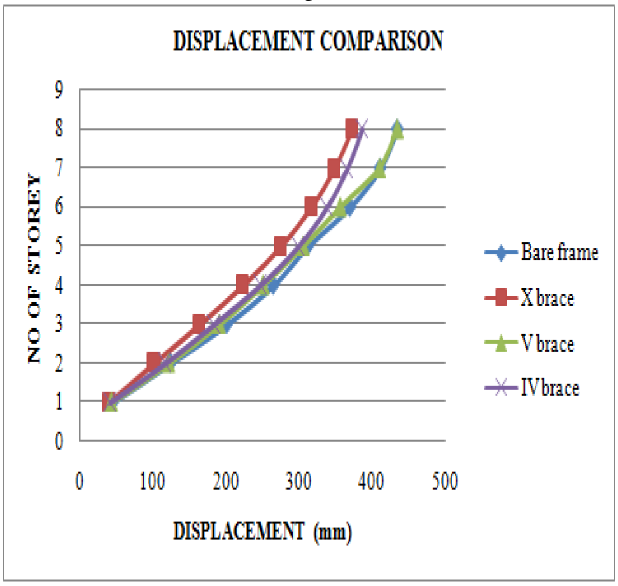
| Floor level | Displacement (mm) | | | | Drift (mm) | | | | % Disp. Reduction | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bare frame | X brace | V brace | IV brace | Bare frame | X brace | V brace | IV brace | X brace | V brace | IV brace |
| 1 | 25.7 | 11.82 | 21.12 | 19.98 | 25.7 | 11.82 | 21.12 | 19.98 | 54.00 | 17.82 | 22.25 |
| 2 | 68.5 | 28.48 | 66.78 | 51.37 | 42.8 | 16.66 | 45.66 | 31.39 | 58.42 | 2.51 | 25.00 |
| 3 | 109.4 | 44.1 | 100.28 | 81.87 | 40.9 | 15.62 | 33.5 | 30.5 | 59.68 | 8.33 | 25.16 |
| 4 | 140.8 | 58.16 | 130.02 | 109.03 | 31.4 | 14.06 | 29.74 | 27.16 | 58.69 | 7.65 | 22.56 |
| 5 | 158.7 | 70.49 | 154.3 | 133.9 | 17.9 | 12.33 | 24.28 | 24.87 | 55.58 | 2.77 | 15.62 |
| 6 | 168.2 | 80.93 | 163.59 | 158.95 | 9.5 | 10.44 | 9.29 | 25.05 | 51.88 | 2.74 | 5.49 |
| 7 | 185.6 | 89.73 | 178.67 | 177.52 | 17.4 | 8.8 | 15.08 | 18.57 | 51.65 | 3.73 | 4.35 |
| 8 | 211.6 | 96.58 | 195.23 | 190.29 | 26 | 6.85 | 16.56 | 12.77 | 54.35 | 7.73 | 10.07 |

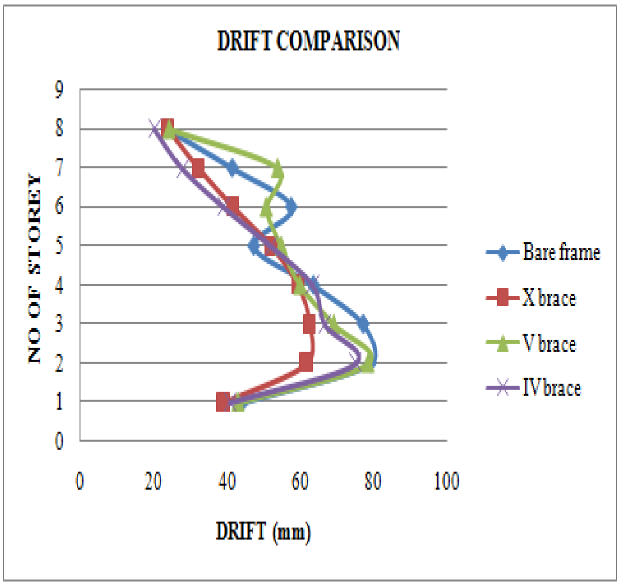
**NORTH RIDGE EARTHQUAKE**

| Floor level | Displacement (mm) | | | | Drift (mm) | | | | % Disp. Reduction | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bare frame | X brace | V brace | IV brace | Bare frame | X brace | V brace | IV brace | X brace | V brace | IV brace |
| 1 | 9.2 | 6.6 | 6.71 | 6.622 | 9.2 | 6.6 | 6.71 | 6.62 | 29.26 | 28.26 | 28.02 |
| 2 | 26.2 | 16.22 | 14.86 | 15.58 | 17 | 9.62 | 8.15 | 8.95 | 38.09 | 38.09 | 40.53 |
| 3 | 42.9 | 24.84 | 21.93 | 23.71 | 16.7 | 8.62 | 7.07 | 8.13 | 42.09 | 42.09 | 44.73 |
| 4 | 56.4 | 34.12 | 28.51 | 31.42 | 13.5 | 9.28 | 6.58 | 7.71 | 39.50 | 39.50 | 44.29 |
| 5 | 66.9 | 41.79 | 34.45 | 38.62 | 10.5 | 7.67 | 5.94 | 7.2 | 37.53 | 37.53 | 42.27 |
| 6 | 74.8 | 47.6 | 39.11 | 43.82 | 7.9 | 5.81 | 4.66 | 5.2 | 36.36 | 36.36 | 41.41 |
| 7 | 84 | 52.27 | 43.25 | 47.31 | 9.2 | 4.67 | 4.14 | 3.49 | 37.73 | 37.73 | 43.67 |
| 8 | 89.9 | 55.55 | 46.24 | 49.76 | 5.9 | 3.28 | 2.99 | 2.45 | 38.20 | 38.0 | 44.64 |

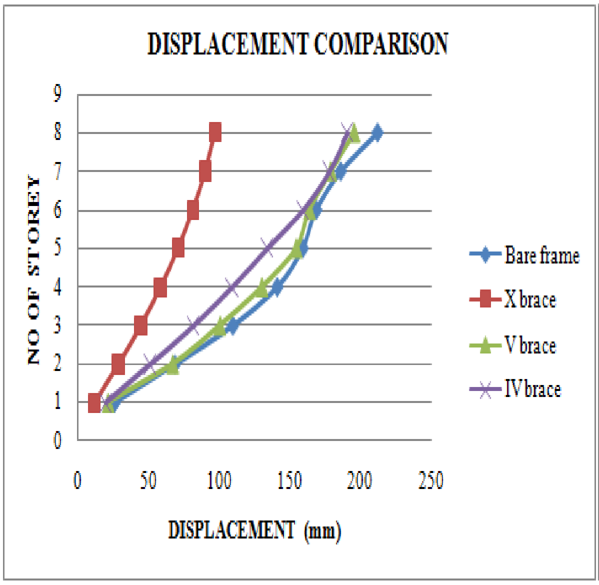
Figure 5.1 Displacements and Inter-Storey Drift comparison between bare frame and Bracings for Imperial valley, San Fransisco, Kern, and North Ridge Earthquake

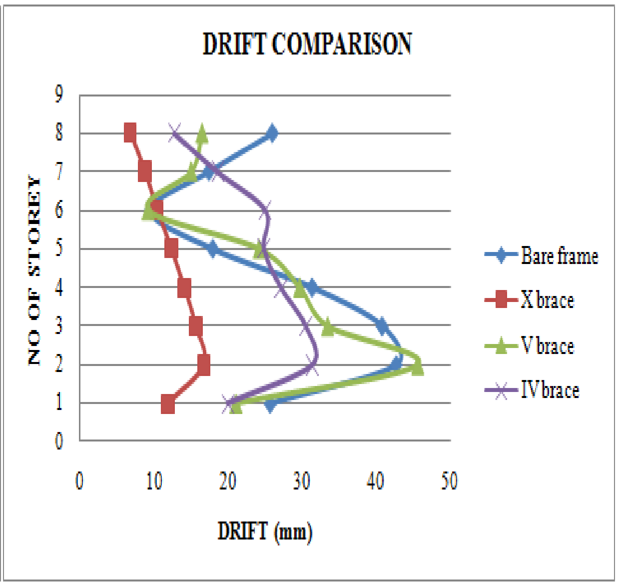
***1. IMPERIAL VALLEY EARTHQUAKE***



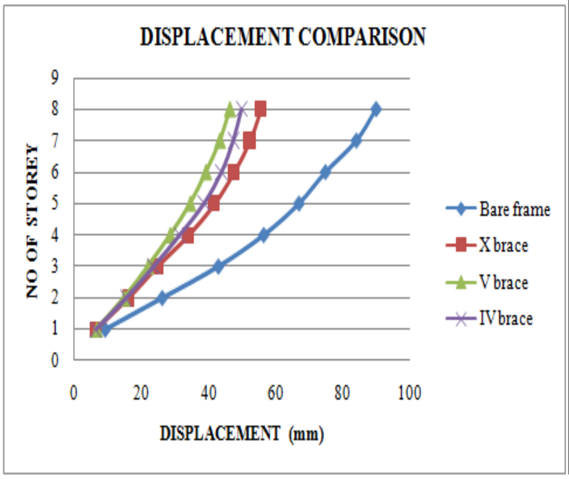



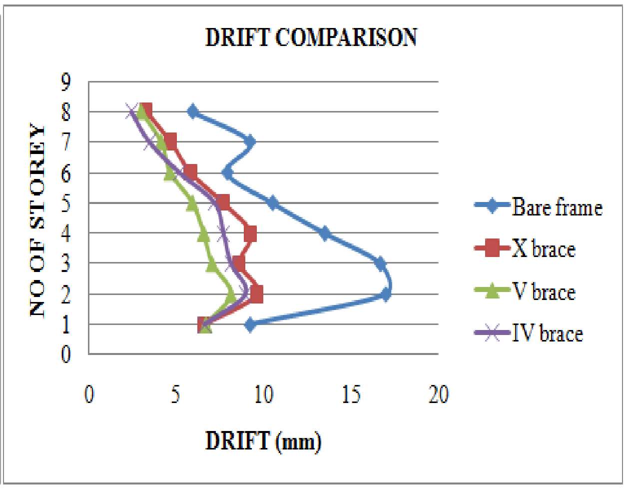

*2. KERN EARTHQUAKE*




***4. NORTH RIDGE EARTHQUAKE***



## 6. CONCLUSION

With the installation of bracings in the building structure the displacements and interstorey drift at various floor level show a significant reduction. Amongst the various types of bracing system X-bracing and inverted V-bracing were the most effective in controlling the displacement and interstorey. They brought about 50% - 60% reduction in drift values. And X-bracing system proved to be the most effective one. This bracing system also reduced the Shear Force and Bending Moment. A reduction of about 55% - 60% was observed in Shear Force and Bending Moment in comparison to the bare frame with the introduction of bracing system in skeletal building structure.

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