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Seismic performance of RC frame retrofitted using steel bracing.

Rendimiento sísmico de la estructura de RC reacondicionada utilizando refuerzos de acero.

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ABSTRACT

High rise buildings which are very common nowadays are subjected to problems due to lateral loads. Due to lateral loads like wind, earthquake etc. the structural stability of the structure is reduced. The lateral loads produce sway moment and induce high stresses in the structure. In order to reduce these effects of lateral loads bracings are efficient and effective. Bracings can be used for seismic retrofitting due to their high stiffness. Retrofitting approaches can be used to improve the seismic performance of the existing structures, before that are subjected to an earthquake. There are two retrofitting approaches, first is to add a new structural element like steel braces or shear wall and second is to provide concrete or steel jacketing. In this work steel bracings are used to retrofit the structure and they are provided in both concentric and eccentric manner. The main aim of the work is to analyze the performance of the building when the bracings are provided in eccentric manner. This study also focuses on performance of building with mega braced frame. Braced frames reduce lateral displacement and the bending moment in columns. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. Different types of bracing such as V bracing, X bracing and diagonal bracing are provided. Seismic analysis is done using ETABS software.

Keywords— Steel bracing, ETABS, Seismic analysis.

RESUMEN

Los edificios de gran altura, muy habituales en la actualidad, están sujetos a problemas debido a cargas laterales. Debido a cargas laterales como viento, terremoto, etc., se reduce la estabilidad estructural de la estructura. Las cargas laterales producen

momentos de balanceo e inducen grandes esfuerzos en la estructura. Para reducir estos efectos de las cargas laterales, los arriostramientos son eficientes y eficaces. Los arriostramientos se pueden utilizar para reacondicionamiento sísmico debido a su alta rigidez. Los enfoques de reacondicionamiento se pueden utilizar para mejorar el rendimiento sísmico de las estructuras existentes, antes de que estén sujetas a un terremoto. Hay dos enfoques de reacondicionamiento, el primero es agregar un nuevo elemento estructural como tirantes de acero o un muro de corte y el segundo es proporcionar revestimiento de concreto o acero. En este trabajo se utilizan arriostramientos de acero para modernizar la estructura y se proporcionan tanto de manera concéntrica como excéntrica. El objetivo principal del trabajo es analizar el comportamiento del edificio cuando los arriostramientos se proporcionan de forma excéntrica. Este estudio también se centra en el rendimiento de la construcción con un marco mega arriostrado. Los marcos arriostrados reducen el desplazamiento lateral y el momento de flexión en las columnas. El arriostramiento de acero es económico, fácil de montar, ocupa menos espacio y tiene un diseño flexible para cumplir con la resistencia y rigidez requeridas. Se proporcionan diferentes tipos de arriostramientos tales como arriostramientos en V, arriostramientos en X y arriostramientos diagonales. El análisis sísmico se realiza mediante el software ETABS.
Palabras clave: arriostramiento de acero, ETABS, análisis sísmico.

INTRODUCTION

Steel-braced frames are cost-effective structural system for structures that are subjected to lateral loads like, seismic or wind loads. As a result, upgrading reinforced concrete frames with insufficient lateral resistance with steel-bracing systems is appealing. The lateral loads cause the structure to shake and cause severe stresses. Bracing is an excellent choice for upgrading multi-storey frames that require lateral reinforcement or stiffening. The structure may be braced as a precaution or as part of the restoration process after seismic damage. The advantage of bracing over other retrofitting approaches, such as interior shear walls, is the relatively minor increase in mass. As a result, the cost of the foundation and building may be reduced. External bracing and internal bracing are the two most common bracing systems. Existing structures can be seismically upgraded with internal bracing. The main aim of this work is to look at how a building performs when the bracings are installed in an eccentric manner. The performance of buildings with mega braced frames is also a subject of this research. Mega braces are braces which are used to connect multiple floors. Different types of bracing such as V bracing, inverted Vbracing and diagonal bracing are provided. Drift and displacement are the parameters considered for analysis. Seismic analysis is carried out by using response spectrum analysis as per code IS: 1893-2002. The seismic assessment is executed by using ETABS software.

Naik and Annigeri [1] investigated a nine-storey structure in North Goa located in Zone III. Pushover analysis is carried out using ETABS software to analyze the seismic performance of the building. The safety ratio is used to assess the safety of the building. The base shear to design base shear ratio is known as the safety ratio. The structure is secure, with a safety ratio of greater than one. Balappa and Malagavelli [2] carried out study on G+10 storey structure with and without bracings using SAP 2000 software. Four models were analyzed. Various characteristics such as time duration, hinge placement, and pushover curve were studied. Structures with bracings in the middle have outperformed those with different bracing configurations. Bhojkar and Bagade [3] carried out seismic analysis of reinforced concrete building with different types of bracing. STAAD Pro software is used to examine a G+9 building in seismic zone III. Various aspects were taken into account, including lateral displacement, storey drift, axial force, and base shear. Steel bracing of the X type contributes to structural stiffness and minimizes the maximum inter-storey drift of the frame. Jagadeesh and Prakash [8] conducted study on a 15 storey steel moment resisting frame and is analyzed for all zones. Vertical irregular model and vertical irregular model with mega bracing were the two structural configurations evaluated. Mega braced frames are most effective in resisting earthquake. The usage of a mega bracing system reduces the storey displacement.

MATERIAL AND METHODS

Models with different types of bracings are analyzed. Different types of bracings like V, inverted V and diagonal bracings are used. The bracings are placed in concentric and eccentric manner. Bracings are provided at an eccentricity of 10%. Mega V, mega inverted V and mega diagonal braces are also analyzed. Nine models are analyzed.

Different types of models considered for the analysis

Model 1: Building with concentric V bracings (CV)

Model 2: Building with inverted V bracings (CIV)

Model 3: Building with concentric diagonal bracing (CD)

Model 4: Building with V bracing with 10% eccentricity (V10E)

Model 5: Building with inverted V bracing with 10% eccentricity (IV10E)

Model 6: Building with diagonal bracing with 10% eccentricity (D10E)

Model 7: Building with mega V bracing (MV)

Model 8: Building with mega inverted V bracing (MIV)

Model 9: Building with mega diagonal bracing (MD)

Table 1 Structural data

Building type	RC building
Number of storey	G+8
Plan size	12m × 12m
Floor height	3.2m
Height of ground floor	4.5m
Concrete grade	M25
Grade of steel (Reinforcement)	Fe 415
Grade of steel (Bracing)	Fe 415
Column size	0.45m × 0.45m
Beam size	0.25m × 0.50m
Slab thickness	0.15m
Bracing	ISA 110 × 110 × 10
Support	Fixed

Table 2 Loads and seismic zone details

Loads	
Live load	On floor – 3kN/m^2 On roof – 1.5kN/m^2 (IS 875 (part II)-1987)
Floor finish	1.5kN/m^2 (IS 875 (part II)-1987)
Weathering course	3kN/m^2 (IS 875 (part II)-1987)
Seismic zone details	
Seismic zone	III
Importance factor (I)	1
Response reduction factor (R)	5
Soil type	II (Medium)

The elevations of the various models are shown below.

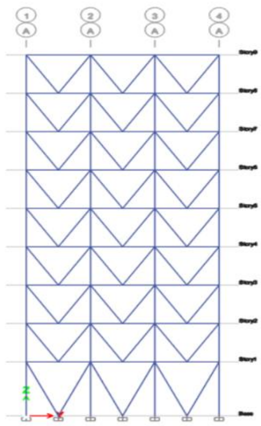

Fig.1 Model 1:

Concentric V bracings

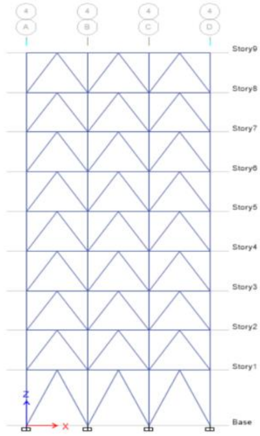

Fig.2 Model 2:
centric

Inverted V bracings

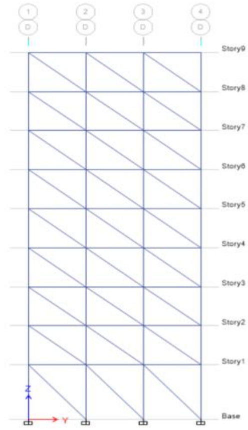

Fig.3 Model 3: Con-

diagonal bracings

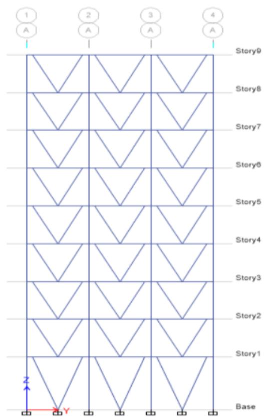

Fig.4 Model 4: V bracing
Diagonal with 10% eccentricity
10%

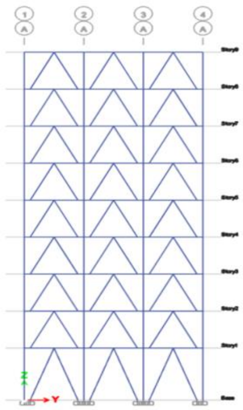

Fig.5 Model 5: Inverted
V bracing with 10%
eccentricity

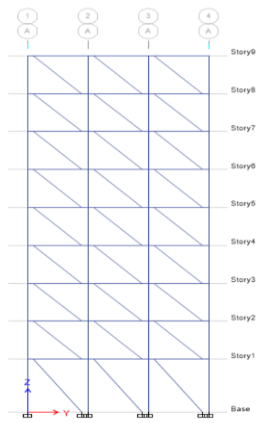

Fig.6 Model 6:
bracing with
eccentricity

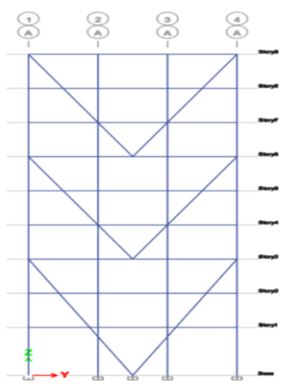

Fig.7 Model 7: Concentric
mega V bracing

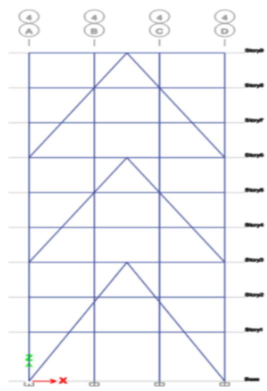

Fig.8 Model 8: Concentric
mega inverted V bracing

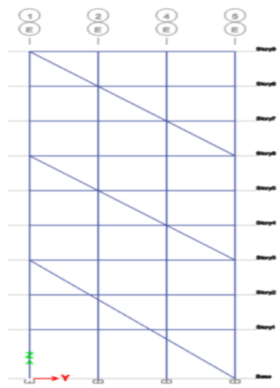

Fig.9 Model 9: Concentric
mega diagonal bracing

RESULTS AND DISCUSSION

From the graph it is clear that storey drift is decreasing with increase in height of the building. V, inverted V and diagonal bracings placed at an eccentricity of 10% shows minimum drift values as compared to the other models. Building with inverted V bracings with 10% eccentricity shows the minimum drift value in X direction. Building with inverted V bracings with 10% eccentricity shows the minimum drift value in Y direction. For inverted V braced model with 10% eccentricity the value of drift is reduced by 20.43% in X direction and 20.4% in Y direction.

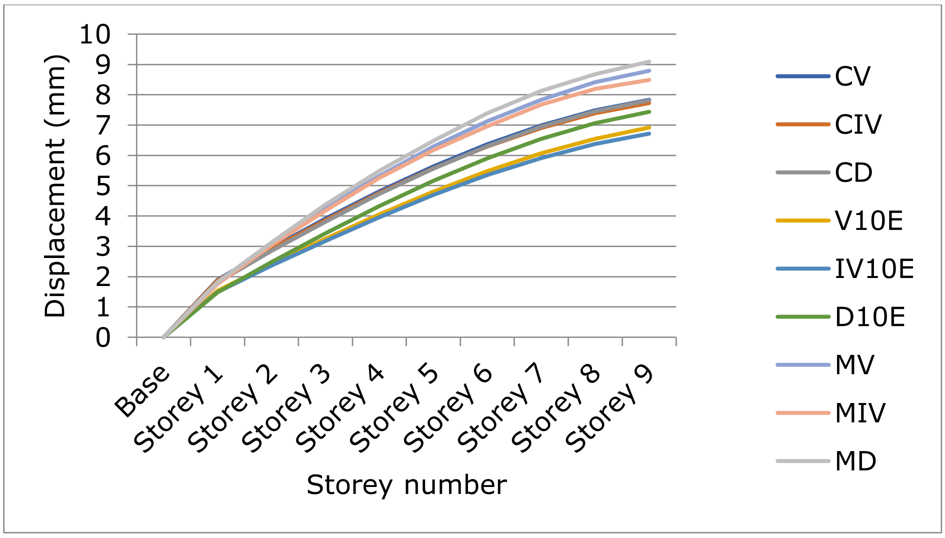

Fig.10 Comparison of displacement values in X direction

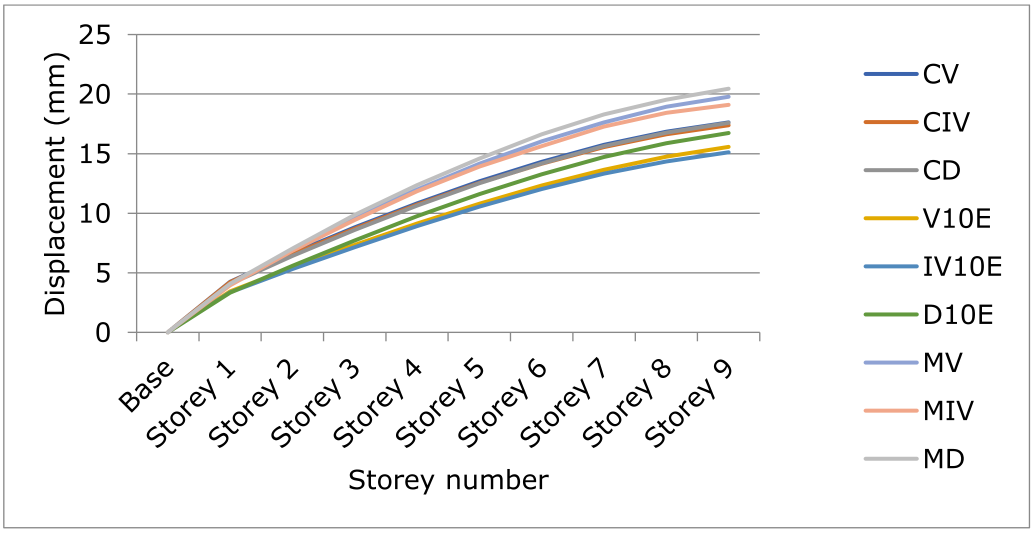

Fig.11 Comparison of displacement values in Y direction

Storey displacement is defined as the total displacement of each storey with respect to ground. The value of storey displacement for all models and a comparison between them are shown in the graph. The graph shows the variation of storey displacements in X direction with storey number. From the graph it is clear that storey displacement is increasing with increase in height of the building. Model with inverted V bracings with 10% eccentricity shows the minimum value of displacement in X direction. Model with inverted V bracings with 10% eccentricity shows the minimum value of displacement in Y direction. For inverted V braced model with 10% eccentricity the value of displacement is reduced by 20.4% in X direction and 20.41% in Y direction.

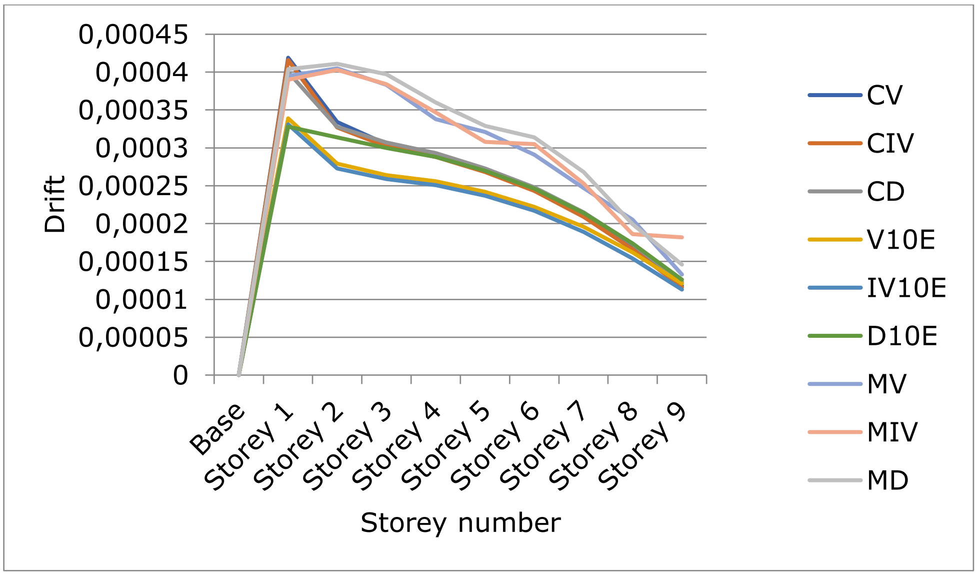

Fig.12 Comparison of drift values in X direction

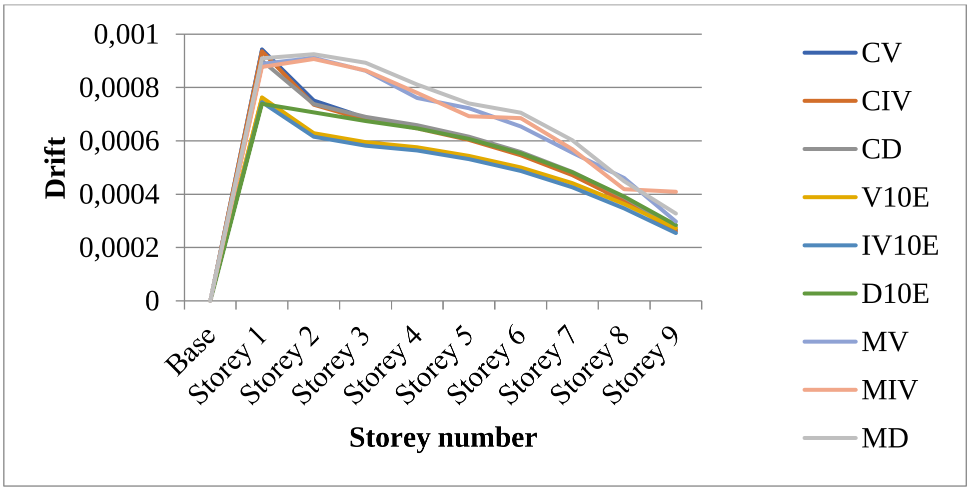

Fig.13 Comparison of drift values in Y direction

As conclusion, when bracings are provided with eccentricity, drift and displacement of the building decreases and shear and stiffness increases. For V, inverted V and diagonal bracings the minimum value of drift and displacement and maximum value of shear and stiffness are shown for model with 10% eccentricity. Minimum drift and displacement in X and Y direction and maximum shear and stiffness in both the direction are shown by inverted V braced building with 10% eccentricity. Mega braced frames shows higher values of drift and displacement and lower values of shear and stiffness as compared to concentrically braced frames. By providing eccentrically braced frames the performance of the building can be improved.

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