Seismic Analysis of Braced Steel Frames in Multistory Buildings with Mass Irregularity

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***Abstract*—— Nowadays, the necessity and demand of the new generation and growing population have created the architects and engineers inevitable towards the planning of irregular configurations. Therefore, it is necessary to understand the role of building configurations, as well as the seismic response of structures with mass irregularity Braced frames are a very common type of construction, being economic to construct and straightforward to research. In the present paper, the seismic behavior of multistoried building with mass irregular having different braced steel frames is investigated. The study comprises of comparison of concentric braced frames and eccentric braced frames in the earthquake zones. The seismic analysis of different bracings is analyzed for 40 storey height building with mass irregularity. The response of each steel braced frame considered in terms of storey displacement, storey drift, base shear, and time history response is studied by time history analysis using ETABS Software.**

Keywords— seismic behavior, braced frame, mass irregularity, non-linear analysis, time history analysis, ETABS Software

I. INTRODUCTION

Structural systems for tall buildings have undergone a dramatic evolution throughout the previous years. Developments in structural form have traditionally been accomplished as a response to rising subject trends in high-rise buildings. Earthquakes are the foremost unpredictable and harmful of all natural disasters, that is very difficult to save the engineering properties and life, against and life, against it. Thus so as to overcome these problems, we want to identify the unstable performance of the designed atmosphere through the event of assorted analytical procedures. It ensures the structures to resist throughout frequent minor earthquakes and turn out enough caution whenever subjected to major earthquake events so it will save as several lives as possible.

In the past years, various major earthquakes have exposed the defects in the structures which are caused by damage or collapse. According to many researches, it has been established that the regular shaped structures is likely to not collapse during earthquakes [1].The buildings with regular geometry and uniformly distributed mass and stiffness in the plan as well as in elevation suffer much less damage compared to irregular configurations [2]. In the various members of the structures, non-uniform load distribution is caused by structural irregularities. It is necessary to develop the understanding about the role of building configurations as well as to acquire better understanding about the seismic response of structures with mass irregularity.

The effects of seismic response on structures with horizontal and vertical irregularities were investigated by many researchers. Guevara et al. studied about the effects of floor plan on the seismic performance of the buildings. It has been suggested that the H and L shaped building plan should be divided into rectangular blocks separated by seismic joints [3]. Ahmed et al. observed that the effect of seismic response of L shape plan is higher than regular frames due to torsion [4]. Patil et al. have analysed that the increase in height of L and T shaped plan buildings increases the displacement response in the multi-storey buildings [5]. It has been reported that the torsional irregularity is increased when the number of storey in the structure decreases by Ozmen et al. [6]. Valmundsson and Nauhave also studied about the seismic behaviour having vertical structural irregularities of multi-storied buildings [7]. The study of dynamic behaviour of multi-storied buildings with mass irregularity was studied by Tremblay and Poncethave. It was reported that the static and dynamic analysis methods are not effective in analysing the seismic response of multi-storied building with mass irregularity [8]. Therefore in this study, time history analysis is carried out for seismic analysis of multi-storied building with mass irregularity.

II. BACKGROUND THEORY

This section comprises of the theory of bracings and its two types which is used in the study. Also, the non-linear analysis and methodology of time history analysis is presented.

A. Bracings

When the buildings are constructed over seismic active zones, they have to bear lateral earthquake forces as well as their own gravity loads. Stiffness of building is necessary for high rise buildings and bracings are commonly used to increase the stiffness of the building. Braced frames offer resistance to lateral force functioning on a structure. In high rise structures, braced frames are generally adopted than Moment Resisting Frame [9]. Mainly, bracings are of two types: concentric bracings and eccentric bracings.

a. Concentric Braced Frame

Concentric Braced Frames exhibit their seismic performance when each yield in elastic buckling in compression of their diagonal members contributes to the hysteretic energy dissipation. The energy absorption capability of braces in compression depends within the slenderness ratio and resistance to local buckling during repeated cycle of inelastic deformation**.** Nouri et al. had studied the constraints of concentric braced frames and he suggested zipper bracings [10]. Several concentric braced frames are adopted by structural engineers: X-Bracing, diagonal Bracing, V-Bracing, K-Bracing, Chevron Bracing.

b. Eccentric Braced Frame

An eccentrically braced frame could be a frame system during which the axial force induced within the brace is transferred to the columns or another bracing in small section of the beam. The critical beam section is called link and designed by e link in EBFs act as structural component which uses to dissipate earthquake energy in building inelastic manners.

B. Non-Linear Analysis

In the recent years, simplified non-linear analysis methods were introduced for the analysis of the inelastic performance of the structures under the seismic excitations. Static pushover analysis and dynamic pushover analysis has become an applicable tool for the design of earthquake resistant buildings and seismic rehabilitation of existing buildings [7]. Equivalent Lateral Force (ELF) approach is used to establish design force in most of the earthquake design codes for irregular structures with mass discontinuity [7]. In non-linear dynamic analysis, Time History analysis is one of the effective methods to study the seismic response of the structure. Non-linear analysis is generally carried out by using ETABS Software.

- Time History Analysis

Time history analysis is an effective method to study the seismic response of the structure; it is based on the dynamic response at each time increment when the base of the structure is subjected to ground motion. The recorded ground motion of the Bhuj earthquake in 2001 was done by time history analysis. The approach that has been taken into consideration is the variation in time of ground motion intensity as well as the distribution of energy content among frequencies.

3 steps of time history analysis:

1) The period of the record to be simulated is divided into many sections, the intensity of the ground motion and frequency is acquired.

2) The unit-intensity segments of the Gaussian method with the related spectral densities are designed for each portion which is characterized in the first step.

3) The simulated segments are assembled, and each result is altered by a deterministic time function.[11]

Though the method is based on the analytical procedure, going past the existing codes, it does not represent the code approaches that relate to the extent of ductile detailing which is used in the design of the structure. The detailed provisions in the codes are acquired in the present phase of the development of time history analysis and it should be revised to accomplish a better economy in the future developments. [12]

In the present study, the efficiency of applying steel braces to multistoried building will be investigated. To achieve this, nonlinear dynamic analysis with X-bracing, Y-bracing, K-bracing and chevron concentric and eccentric bracing systems is modelled using Time History Analysis for 40-storey structures in ETABS software.

III. STRUCTURAL MODELLING: EARTHQUAKE EXCITATION

To investigate the non-linear dynamic behavior of the concentric and eccentric braced frame and to estimate the seismic behaviour, 40 storey building is modeled based on time history analysis as per Indian Codes. In this study, nine structural models were modelled as per the details shown in Fig 1. The models taken into consideration is studied in all four zones of storey displacement, storey drift, base shear, and time history response for all bracings.

MODELS	REGULAR FRAME	IRREGULAR FRAME	CONCENTRIC BRACE			ECCENTRIC BRACE
			XBs	IVBs	KBs	YBs
MODEL 1	☑					
MODEL 2		☑				
MODEL 3		☑	☑			
MODEL 4		☑		☑		
MODEL 5		☑			☑	
MODEL 6		☑				☑
MODEL 7		☑	☑			☑
MODEL 8		☑		☑		☑
MODEL 9		☑			☑	☑

XBs - X Braced Frames, IVBs - Inverted V Braced Frames(Chevron Braced Frames), KBs - K Braced Frames, Ybs - Diagonal Braced Frames (Y Braced Frames)

Fig 1 Model Details

A. Design Parameters

The following are the salient features adopted to study the seismic behavior of multi-story structure:

Steel frame data:

Dead Load – 2 kN/m

Live Load – 2 kN/m

Wall/Frame Load – 7 kN/m (glass frame)
Width of the Building – 64 m
Length of the Building – 64 m
Bay Spacing – 8 m
Floor Height – 4.2 m

Earthquake Load:
Zone – V
Response Reduction Factor – 5 (For Steel Frames with concentric bracing)
Soil Type – II
Importance Factor I – 1.0
Damping Ratio – 5

Mass Irregular Storey Data:
Number of Irregular stories – 10th, 20th & 30th storey
Dead load – 3 KN/m
Live load – 2 KN/m
Slab thickness- 200 mm

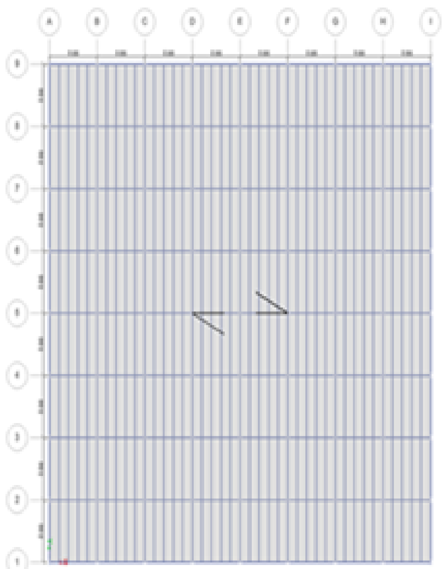
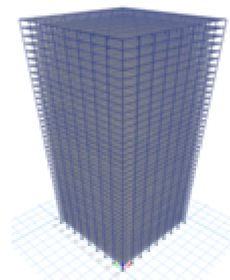


Fig 2 Plan view of Steel Frames

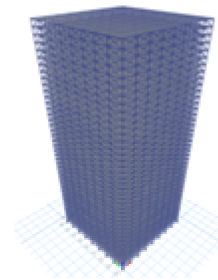
B. 3D Models:

The following are the 3D view of 40 storey steel frames with different bracings:

(a) Mass Irregular Frame
(b) Mass Irregular Frame with X Bracing
(c) Mass Irregular Frame with Inverted V (IV) Bracing
(d) Mass Irregular Frame with K Bracing
(e) Mass Irregular Frame with Diagonal(Y) Bracing
(f) Mass Irregular Frame with X &Y Bracing
(g) Mass Irregular Frame with IV & Y Bracing
(h) Mass Irregular Frame with K & Y Bracing



(a)



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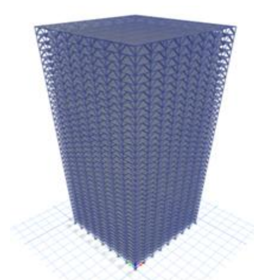

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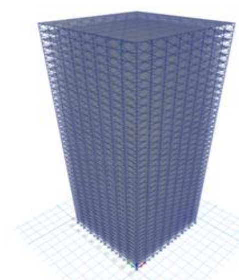

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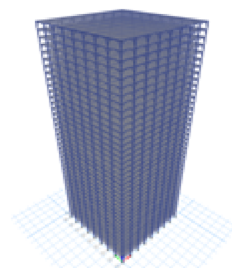

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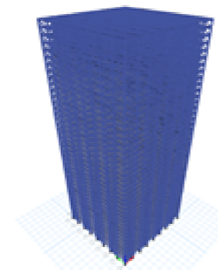

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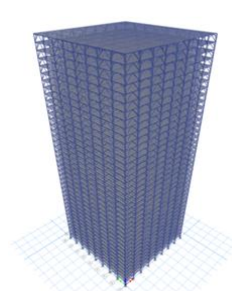
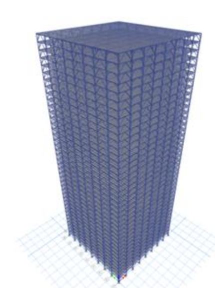


(g)



(h)

Fig 3 3D view of 40 storey steel frames with different bracings

C. Time History Analysis

For the Time History Analysis, define time history function & response spectrum function.

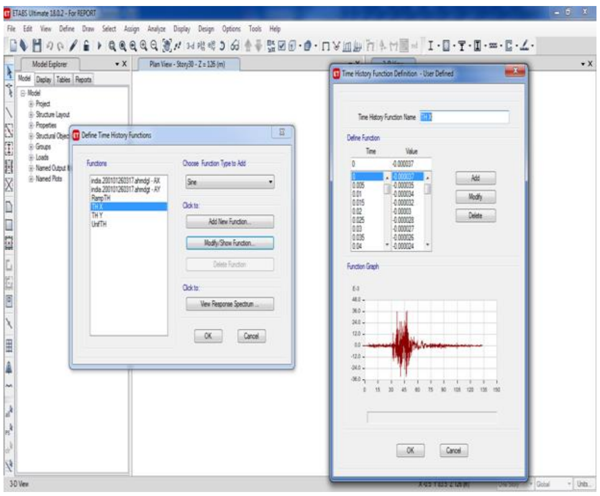
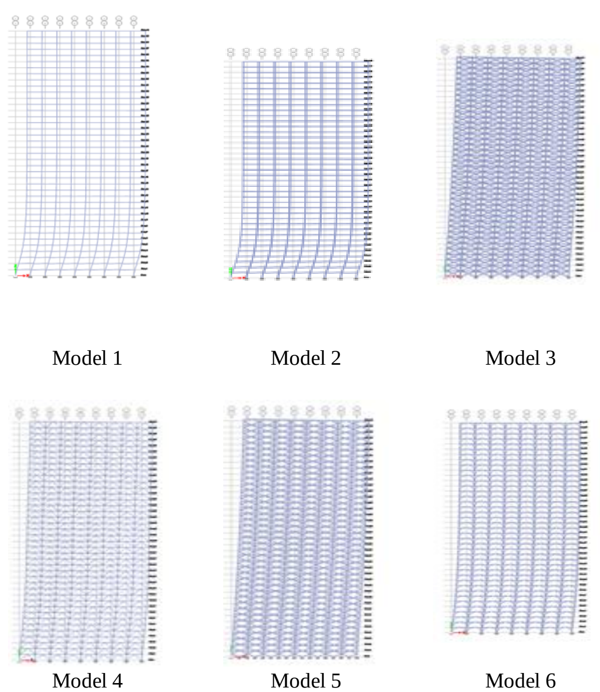


Fig 4 Time History Function Defination

IV. RESULTS AND DISCUSSION

A. Deformed Shapes due to Time History Function



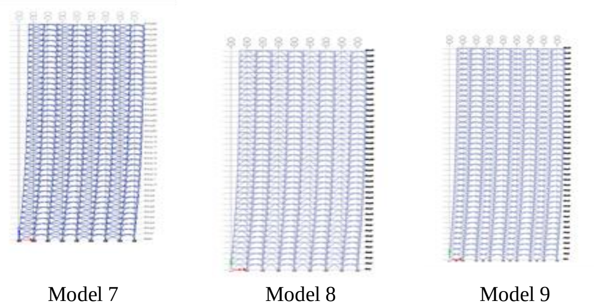


Fig 5 Deformed Shapes of Steel frames with different braced frames models

B. Storey Displacement due to Time History Function

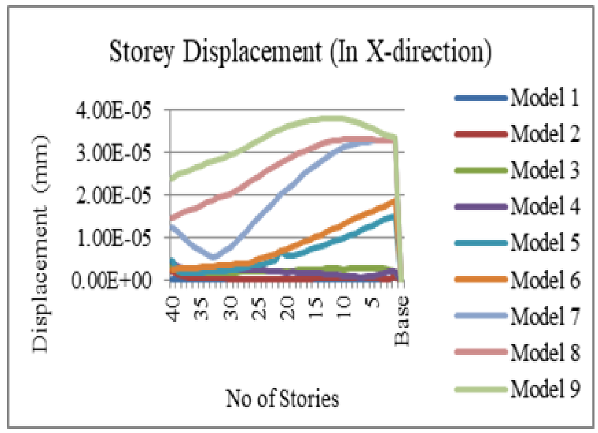


Fig 6 Storey Displacement in X-direction

Fig 7 Storey Displacement in Y-direction

By observing the results from the graph, it can be analyzed that the frames with different bracing systems have less storey displacement compared to without bracing frames. The storey displacement of the eccentric bracing frame and combine bracing frames is more in both directions compared to the concentric bracing frame.

C. Storey Displacement due to Time History Function

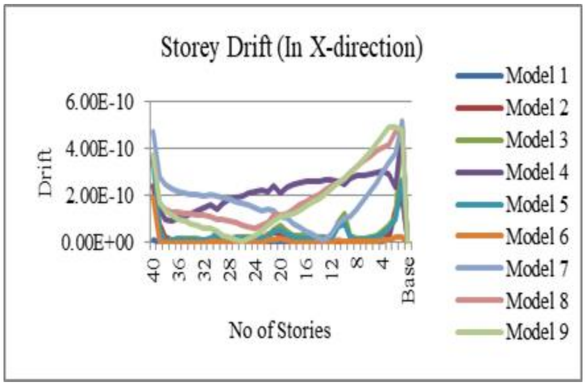


Fig 8 Storey Drift in X-direction

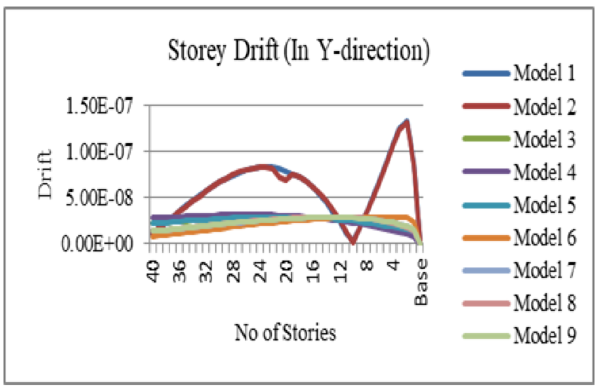


Fig 9 Storey Drift in Y-direction

From the results of the graph, it has been observed that the steel frames having different bracing systems have less storey drift compared to without bracing frames. Whereas Concentric bracing frames show less storey drift in X direction compared to Eccentric braced frames. Story Drift of diagonal braced frame is less in top stories in both directions compared to other frames.

D. Total Base Shear of Steel frames with different bracing systems

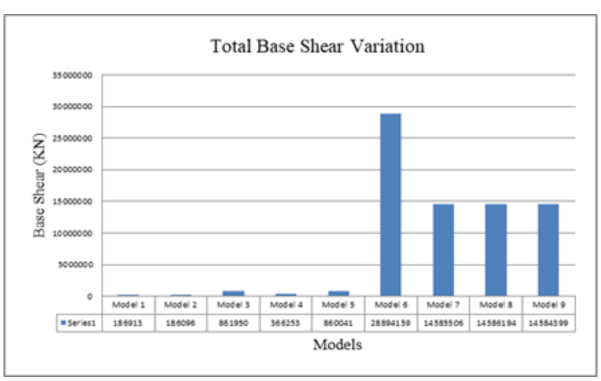


Fig 10 Total Base Shear Variation of Different Braced Frames

By observing the results from the graph, the structure with Diagonal bracing (YBs) provides more base shear for the hard soil condition compared to inverted V (IVBs), X bracing, K bracings and combination of each bracing with diagonal bracing respectively. From the graph, it is also observed that the base shear of concentric braced frames is less compared to the eccentric and combined braced frames.

E. Time History Plot

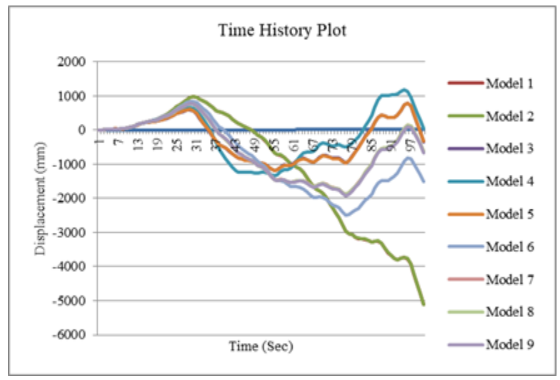


Fig 11 Time History Plot

From the graph, it has been found that the frames without bracing show more displacement compared to the braced framed. By observing the results from the time history plot, it shows that the concentric braced frames have less displacement compared to eccentric and combine braced frames.

V. CONCLUSION

The structural behavior of multi-storey frames with single and combinations of different bracing systems with mass irregularity is studied. The results indicate that by using different bracing systems considerably affects the structural response. The present study indicates that the presence of irregularities does not amplify the response. Certain combinations of different bracing systems increase the structural response when compared to the regular configuration under seismic loads. The following are the main conclusions that can be drawn from the study:

- The storey displacement of the eccentric bracing frame and combine bracing frames is more in both X and Y directions compared to the concentric bracing frame.
- The concentric bracing frames show less storey drift in X direction compared to eccentric braced frames.
- From the analysis, it can be observed that the base shear of concentric braced frames is less compared to the eccentric and combined braced frames.
- From the time history plot, it shows that the concentric braced frames have less displacement compared to eccentric and combine braced frames.

Here X-Bracings & K-Bracings have the minimum displacement while comparing with that of the other braced frames Inverted bracings hold, the priority. From all the results, it can be concluded that the Concentric Braced Frames holds the priority for the frequent earthquake-prone zones.

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