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Effectiveness of Bracing on RC Moment Resisting Frame Building

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Abstract

After Gorkha Earthquakes most of the concrete structures have been slightly damaged, severely damaged or collapsed. Many existing reinforced concrete buildings need retrofit to overcome deficiencies to resist seismic loads. The use of steel bracing systems for strengthening seismically inadequate reinforced concrete frames is a viable solution for enhancing earthquake resistance. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. In this study, the seismic behavior of reinforced concrete (RC) buildings with different types of bracing X-braced, inverted V braced, Diagonal braced is studied. From Static nonlinear pushover analysis Response reduction factor and ductility factor has been calculated and comparison has been made. It is found that adding braces enhances the global capacity of the buildings in terms of strength, deformation and ductility compared to the case with no bracing, and the X and V bracing systems performed better depending on the type and size of the cross section.

Keywords

RC frame Bracing – pushover analysis – R-factor – Steel Braced RC Structures

1. Introduction

The recent 25th April 2015 (Mw = 7.8) earthquake that affected the central region of Nepal showed that numerous existing low to- medium rise reinforced concrete (RC) framed buildings located in areas with high seismic risk exhibit inadequate lateral stiffness, strength and ductility to prevent either non-structural damage or structural failure. Therefore, it is necessary to provide special mechanism or mechanisms that improve lateral stability of the structure by installing a steel braces to upgrade the seismic performance of structures using concentric and eccentric steel bracing techniques [1]. The bracing methods adopted fall into two main categories, (i) external bracing and (ii) internal bracing. In the external bracing system, existing buildings are retrofitted by attaching a local or global bracing system to the exterior. In the internal bracing method, the buildings are retrofitted by incorporating a bracing system inside the individual units or panels of the RC frames [2].

Response reduction factor is the factor by which the actual base shear force should be reduced, to obtain the design lateral force during design basic earthquake (DBE) shaking. The response reduction factor (R) depends on Overstrength , Ductility , Redundancy [3]. The R factor and lateral strength of RC frames are considerably affected by the types and arrangement of the bracing system[4].

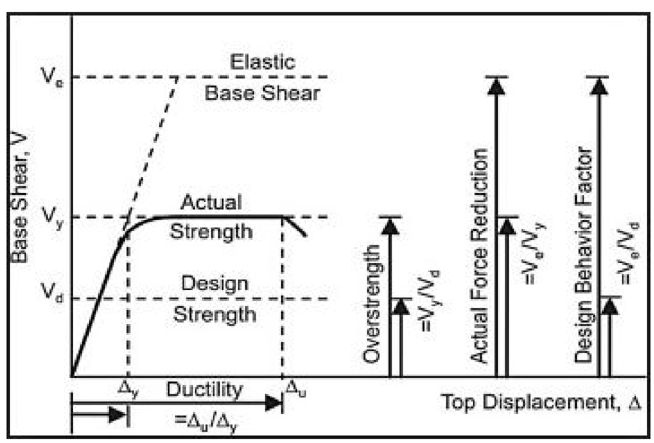

Figure 1: Concept of Response Reduction factor

2. Objective and Methodology

Objectives of this study is conducting pushover analysis and comparing its performance with bare frame and braced frame of X-braced, Inverted V type and Diagonal Braced by calculating R-factor. The effect of distribution of braces over height of storey and the effect of change in hinge formation on braced frame is also studied. Two to six storey 3D buildings are used for study with different type of bracing configuration of bracing systems are used in this investigation as shown below.

3. Building Description

The RC buildings used in this study is from three storey to six storey storied. All ten building models have different irregular in floor plan with different number of bays. The model taken for the analysis is as shown in figure 2 and 3:

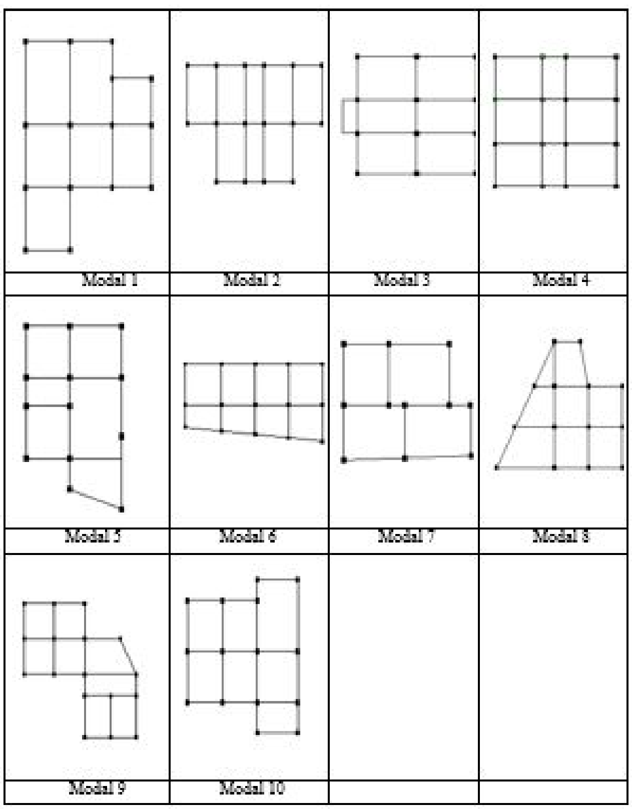

Figure 2: Plan of study Building

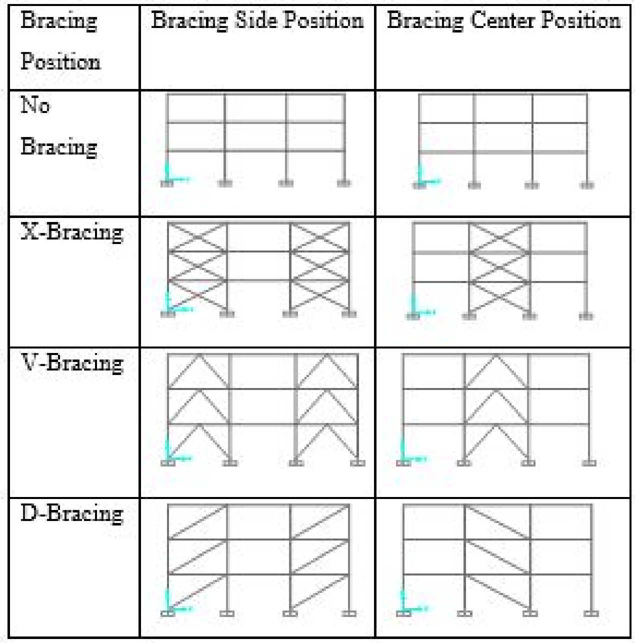

Figure 3: Position of Different Types of Bracing in Building Model

4. Analysis and Result

Nonlinear version of SAP2000 can model nonlinear behavior and perform pushover analysis directly to obtain capacity curve for three dimensional models of the structure. Displacement-controlled Pushover analysis is performed depending on the physical nature of the load and the behavior expected from the structure [5].After Pushover analysis hinges formation in each stage of a building are calculated, also from it is obvious that the demand curve tend to intersect the capacity curve near the event point, which means an elastic response and the security margin is greatly enhanced. Therefore, it can be Concluded that the margin safety against collapse is high and there are sufficient strength and displacement reserves. The calculation for evaluation of response reduction factor as per ATC-19 for bare RC frame in seismic zone-V is shown in Figure 6. From the capacity spectrum curve the existence of performance point and response reduction factor, ductility factor, Overstrength factor can be noted [6]. The comparison of ductility factor and 'R' factor for bare frames and frame with different types of bracing X-Bracing,V-bracing,D-Bracing are shown in Graphical form as follow:

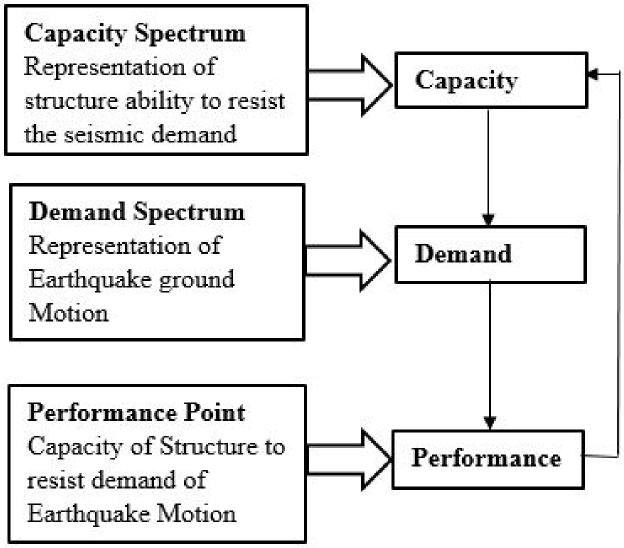

Figure 4: Procedure of Non-Linear Analysis (ATC 40)

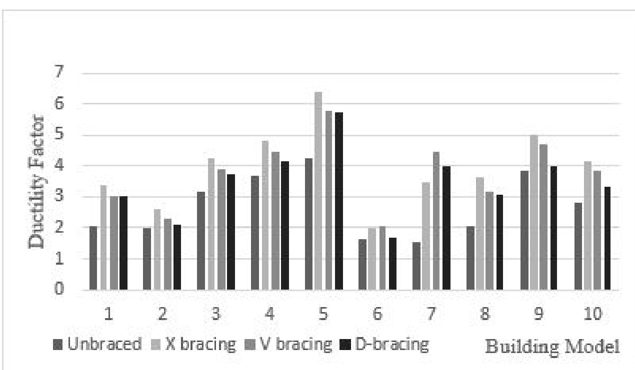

Figure 5: Variation of Ductility factor for different types of Bracing

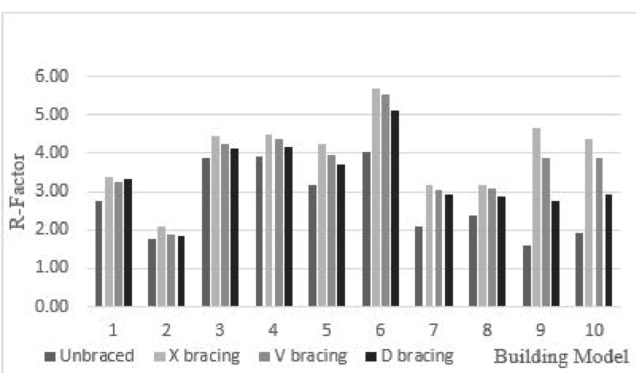

Figure 6: Variation of R- factor for different types of Bracing

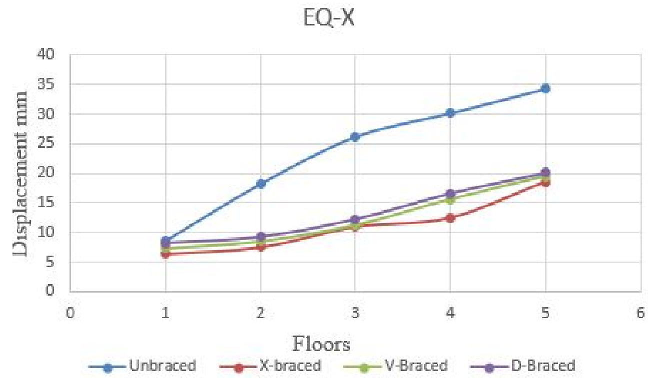

Figure 7: Variation Displacement for different types of Bracing EQ-X

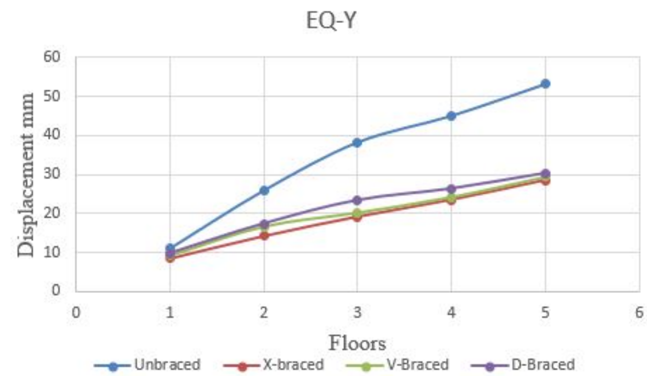

Figure 8: Variation Displacement for different types of Bracing EQ-Y

5. Conclusions

Based on the analysis the following conclusion are drawn,

i. From above data and graph we can conclude that the average increase in ductility When bracing are placed at corners with use of X-Bracing is about 55%, V-bracing is about 40% and D-Bracing is about 35%.When bracing are placed at center with use of X-Bracing is about 39.24%, V-bracing is about 26.54% and D-Bracing is about 20.57%.

ii. From above data and graph we can conclude that the average increase in R-Factor .When bracing are placed at corners with use of X-Bracing is about 62%, V-bracing is about 53.8% and D-Bracing is about 36%. When bracing are placed at center with use of X-Bracing is about 48.58%, V-bracing is about 37.30% and D-Bracing is about 27.26%.

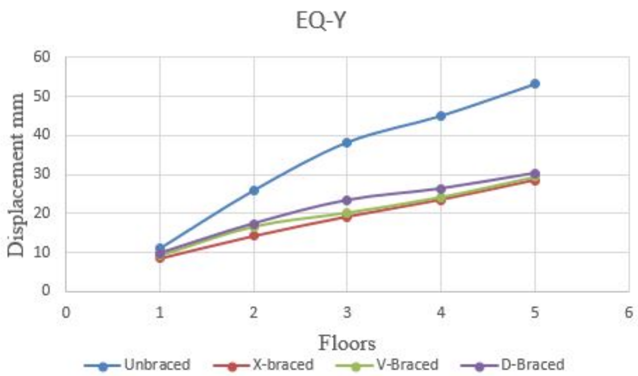

Figure 9: Variation Displacement for different types of Bracing EQ-Y

iii. The position of bracing is found to best when bracing are placed at corners.
iv. Bracing have effect on Displacement control as well as inter storey drift. From above graph we found that X-Bracing are more efficient than other type of bracing in controlling the displacement of the building.
v. By providing lateral systems in the framed structures the reduction in displacement, drift, storey shear, thereby increasing the stiffness of the structure for resisting loads due to earthquake.

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