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Seismic Performance Analysis of RC Frame Building Using Different Types of Steel Bracing

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Abstract
In this research, the seismic performance of reinforced concrete RC frame retrofitted with different types of steel bracing has been studied using dynamic response spectrum method. Three models which represents moment resisting RC frame of 7, 12 and 18 stories as low, mid-rise and high-rise buildings respectively were selected as a case study and are designed for gravity loads and seismic forces according to Indian standard code with the help of Finite Element Software SAP2000. Efficacy of using different types of steel bracing such as X, V, Inverted V, K, and diagonal as retrofitting measure on those models has been studied. At least 25 percent of the design base shear should be resisted by Moment resisting frame independently. The response of the buildings in terms of Base shear, storey drift, storey displacement were studied for both original building as well as retrofitted building. The seismic performance enhancement of buildings using different types of steel bracing has been studied by comparing those responses of the buildings. Results shows that steel bracing can be effectively used as a retrofitting measure in order to increase the structural stiffness and decrease interstorey drift as well as storey displacement of RC frame structure. Among different types of steel bracing X- type and Inverted V bracing showed significant decrease in storey displacement as well as storey drift of the buildings.

Keywords
Reinforced concrete frame, Steel braces, Retrofitting, Response spectrum, Storey displacement, Storey drift ratio, SAP2000

1. Introduction

Nepal is located at the boundary between Indian and Tibetan tectonic plates and therefore lies in a seismically active region. A large number of existing RC frame building which are located in seismically active region like Nepal especially in Kathmandu Valley after many destructive earthquake including Gorkha Earthquake are considered to be inadequate in terms of ductility and stiffness according to the current seismic code. The use of steel bracing in RC frame structure enhance the stiffness of the structure and reduce storey displacement and storey drift. Use of steel bracing in RC frame structure in place of shear wall for resting lateral load has great advantage in increasing architectural flexibility, reducing the weight of the structure, ease and speed of construction and has great flexibility in choosing the ductile system. Two system of bracing that are generally used in construction practice over a long time are internal bracing system and external bracing system. Steel trusses or frames are attached either as a global external support to the building exterior or, more locally, to the face of the individual building frames in external bracing system. The main drawback of external bracing system is that there is difficulty in providing appropriate connections between RC frames and there is concern about Architectural which is very dull in appearance. Steel bracing members are inserted in the empty space enclosed by columns and beams of RC frames in case of internal bracing system. Many researchers had worked on improving seismic performances of the RC framed building subjected to seismic loading using different types of steel bracing. Some models have different irregular floor plan, some models have different levels of stories, some of them try with different configuration of bracing, some has studied about efficacy of bracing over the height of building, some of them had studied about connection of steel braces to RC frame etc.

Although many researchers had worked on upliftment of performance of RC structure with different types of steel bracing, some models have different irregular floor plan, some models have different levels of stories, some of them try with different configuration of bracing, some has studied about efficacy of bracing over the height of building, some of them had studied about connection of steel braces to RC frame etc.

In this paper Nepal which lies in highly seismically active region has been considered for the study. Since many low, medium and high rise building are being constructed in Nepal in current scenario. So the upliftment of performance of those buildings is very important. In this paper 7, 12 and 18 storey building has been considered to represent the low, mid and high rise building respectively which are common practices in Nepal. Many structures that lacks the seismic capacity located in highly active seismic zone like Nepal can effectively use steel bracing to improve the performance of buildings. The seismic analysis of reinforced concrete building with different types of bracing such as Diagonal, V-type and Inverted V- type shows that X-type of steel bracing significantly contributes to the structural stiffness and reduces the maximum inter story drift of RCC building than other bracing system [1], [2]. When V- bracing is used with 10 percent eccentricity it is more reliable under seismic activity than other arrangements [3]. On comparison to double and I section braces tube section braces shows better performance in seismic activity [4]. The load carrying capacity, ductility and stiffness of the retrofitted structure is greatly influenced by distribution of bracing over the height of building [4]. Use of steel bracing in RC frame structure is a great challenge since the special care should be taken in the connection between RC frame and steel bracing [5], [6].

2. Objective of the study

The main objective of this research is to evaluate the seismic response of RC frame structure braced with different types of steel bracing such as V, K, X, Diagonal and inverted V subjected to seismic loading. Specific objectives of this research are to compare the different responses of building such as story drift, Story displacement, time period of structure and base shear for different types of steel braced RC structure subjected to earthquake loading and to reduce the global displacement of RC frame to a desired level using different types of bracing system.

3. Methodology

A finite element analytical model representing the real building has been prepared in SAP2000. The data collected from the preliminary design for the beam, column and slab sizes were used for different story building. At first building is analyzed and compare the global displacement of building with the maximum permissible value given by the code. Up to six story the global displacement of the building was within the permissible limit when designed with the preliminary sizes of beams and columns. When the building designed with preliminary sizes of beams and column were made upto 7 story, the global displacement of the building was not within permissible value so that the building is braced with different types of steel bracing and the global displacement of the building was compared for these types. Same procedure was adopted for the 12 and 18 story building. While comparing the global displacement of the building other parameter such as storey drift, base shear and time period, shear force on column and axial force on bracing was also compared.

4. Building configuration

The Reinforced concrete buildings used in this study are 7, 12 and 18 story as low, mid-rise and high-rise buildings respectively located in Zone V having same floor plan with 4 bays in longitudinal direction with spacing of 6.248m, 6.4m, 4.2m and 4.2m respectively and 3 bays in transverse direction with spacing of 6.55m, 6.55m, and 6.55m respectively. The story height is kept 3.35m for all the floors. In this study the preliminary sizing of beam was taken as 300mm*500mm, column was taken as 400mm*400mm.The size of steel bracing used in this study was ISA 150x150x18.The live load was taken as 3.5kN/m2 and floor finish was taken as 1.5 kN/m2.

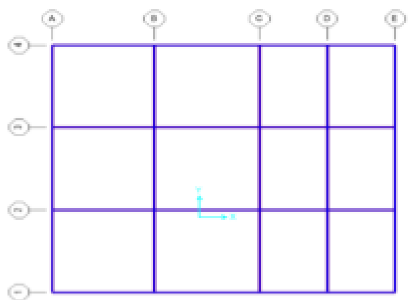

Figure 1: plan of building

The beam and column are modelled as frame element with centreline dimension and the slab is modelled as thin element. Supports at the base of column are assumed to be fixed. The effective length of bracing is taken as unity. The buildings are designed as Special Moment Resisting Frame.

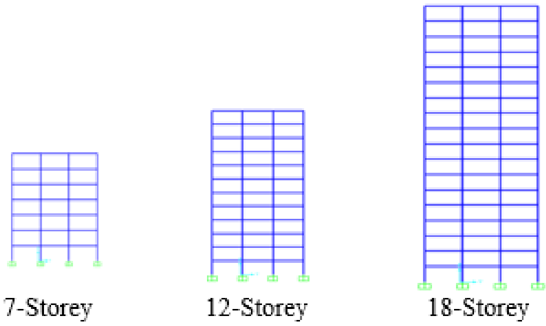

Figure 2: Elevation of Buildings

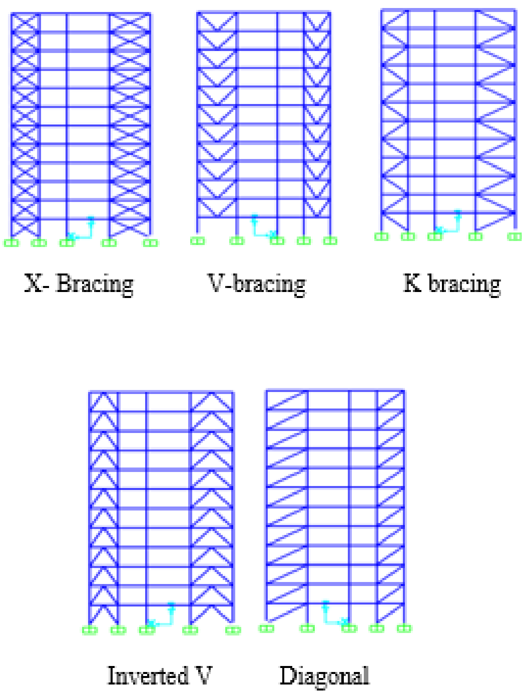

Figure 3: Different types of steel bracing

5. Analysis and results

In this study the frame have been modelled and analyzed using finite element software SAP2000. FEM modeling gives the basic mathematical formulation of the given structure behavior. Beams and columns are modelled as frame elements with centerline dimension. The slab is considered as thin element. Since the buildings are located in high seismic zone V and soil condition is very weak so linear dynamic analysis has been performed to obtain the design lateral force. In place of a time history analysis response spectrum analysis can be used to determine the response of structure subjected to earthquake loading. A curve between maximum responses of SDOF system subjected to specified earthquake ground motion and its time period are plotted in order to obtain response spectra. For a given damping ratio response spectrum can be interpreted as locus of maximum response of a SDOF system. Linear response spectrum analysis is carried out as per Indian Standard Code 1893:2016 part I for soil type III, zone V, importance factor 1.2 and response reduction factor 5. Interpretation of responses of buildings both for bare frame and frame retrofitted with different types of bracing in terms of storey displacement, storey drift, time period variation, shear force on column and axial force on bracing has been done graphically as shown below:-

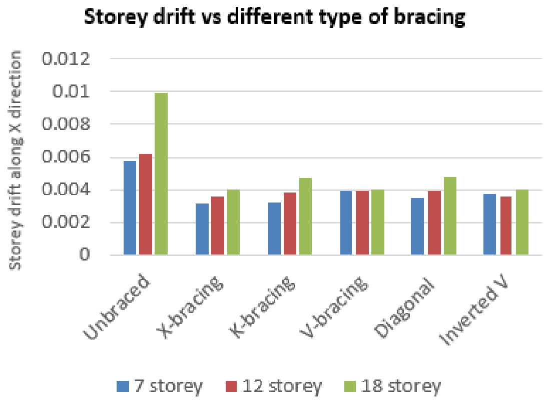

Figure 4: Variation of storey drift along X direction for different types of bracing

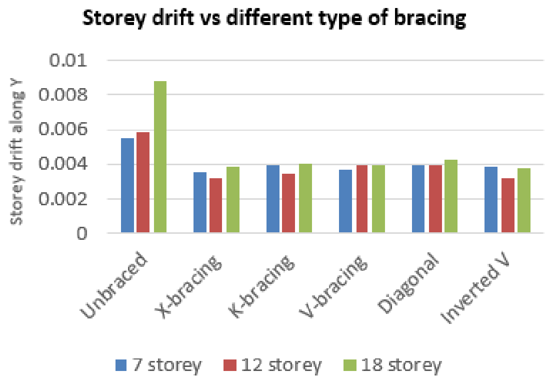

Figure 5: Variation of storey drift along Y direction for different types of bracing

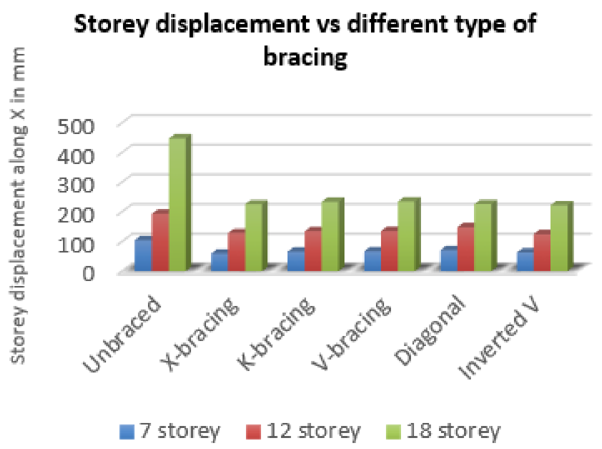

Figure 6: Variation of storey displacement along X direction for different types of bracing

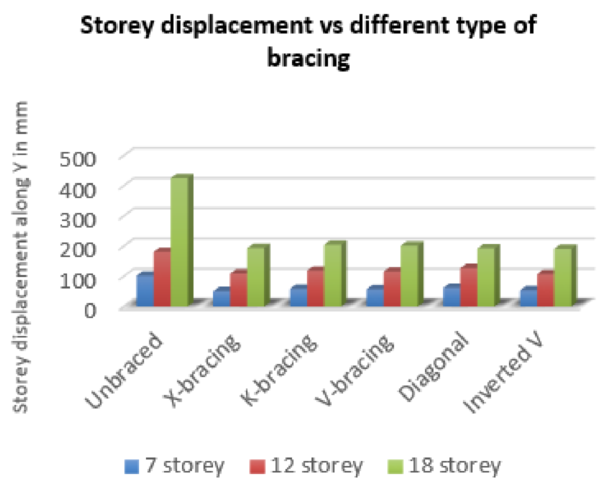

Figure 7: Variation of storey displacement along Y direction for different types of bracing

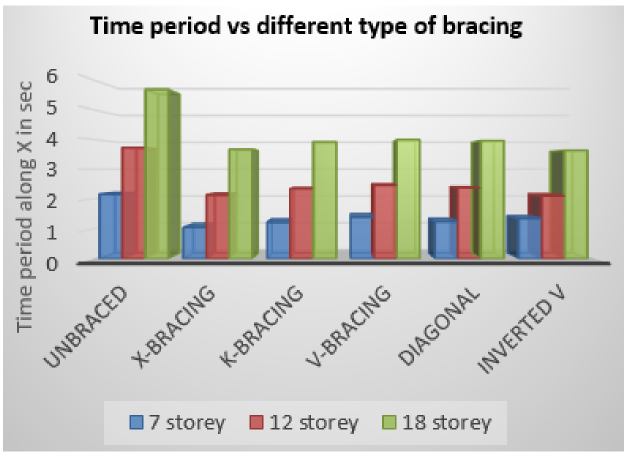

Figure 8: Variation of time period along X direction for different types of bracing

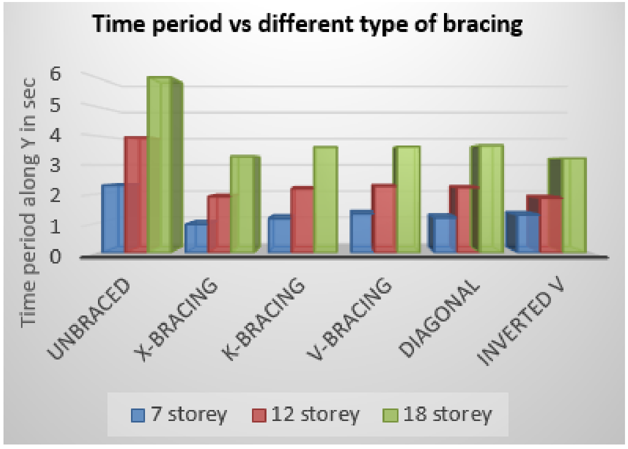

Figure 9: Variation of time period along Y direction for different types of bracing

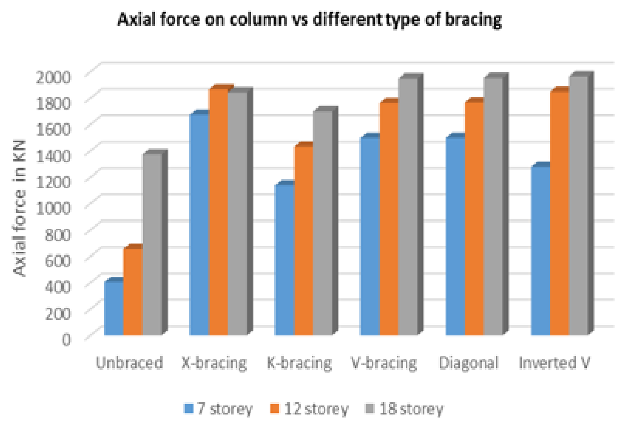

Figure 10: Variation of axial force on column retrofitted with different types of bracing

6. Conclusion

From the above study we can conclude that the steel bracing can be effectively used as an alternative to other lateral resisting system over the low, medium and high rise building in order to improve the seismic performance of the buildings in terms of drift, displacement and stiffness. Following conclusions are drawn:

1. Among different types of steel bracing X type of bracing and Inverted V bracing shows significant decrease in displacement of the building. The X-bracing and inverted V types of steel bracing has reduced displacement up to 55% whereas V-bracing, K bracing, and diagonal bracing has reduced displacement upto 53%, 52% and 54% respectively.

2. There is reduction in time period of the structure

upto 58% when X- bracing types of steel bracing system was used. Other types of steel bracing such as Inverted, diagonal, K and V type has reduced time period up to 46%, 48%, 49%, and 42% respectively.

3. Target Storey drift ratio of the structure as specified by the code can be achived through the use of steel bracing in RC moment frame. X-bracing, inverted V and V bracing are capable of reducing drift ratio upto 60%, 57% and 55%. Diagonal and K bracing has failed to meet the target drift ratio for high rise building.
4. Axial force on retrofitted column has increased due to the addition of different types of steel bracing.
5. X bracing reduced displacement, time period significantly for low rise building and on progression to other medium and high rise building inverted V bracing reduced displacement, time period more significantly than other types of bracing.
6. X- Bracing supports compression and tension forces coming on structure where one brace will be subjected to tension while the other will be subjected to compression which helps in making structures stand sturdier and resist lateral forces.

7. References

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