Seismic Performance of RC Buildings with Different Geometry and Structural Variation

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Abstract: To make any building more functional for natural light and the fresh air, and the best architectural view we have to make it in geometrical irregular shapes like L-shape or U-shape in the plan[3]. Most of the hospitals, offices, schools, and commercial buildings are make an irregular shape in Nepal. According to our building code it is mandatory to make the seismic joint in L-shape and U-shape building [1]. However, in this research work, the study was made for the effectiveness of shear walls and bracing systems in corners in comparison with bare frame systems [9], [3]. Static analysis were performed using ETABS software based on IS code for this study [1]. An earthquake load was applied to eleven different models (Rectangular, L-shape, and U-shape having floor area constant and all models located in seismic zone V for different cases of bare frame, shear wall, and bracing system. Lateral displacement, story drift, Story stiffness, overturning moment, and base shear were calculated in all the cases [7]. The result showed that L-shape and U-shape buildings with shear wall and bracing system at corners have less displacement and drift than rectangular bare frame building structure. L-shape and U-shape building with shear wall and bracing system at corner have more story stiffness, story shear, over toning moment than rectangular bare frame building structure. Among various models studied, it is concluded that U-shape having a shear wall at the corner has better seismic performance than other model building. L-Shape and U-shape building having a Shear wall or bracing system at the corner has better seismic performance than the bare frame rectangular building.

Keywords: Seismic performance, Shear wall, Bracing, Geometry Irregular buildings.

1. INTRODUCTION

The population is increasing at an alarming rate everywhere; a large population from remote areas is migrating towards main cities and commercial centers to grab the different types of opportunities. The available space in such centers is limited and also land values are high. In some cases to make a building more functional to use natural light and fresh air and the best architectural view we should make a building irregular in shape likewise L-shape plan or U-shape plan[7]. Most of the hospitals, offices, schools, and commercial buildings are made in an irregular shape in Nepal. According to our Indian stander building code it is mandatory to make the seismic join in L-shape and U-shape block [1]. To overcome this problem this study is most important.

1.1Statement of the problem

RC building development is rapidly increasing worldwide. Nowadays in the case of Nepal, it is also starting to construct RC buildings. The growth of population like Kathmandu, Pokhara, and The available space in such areas is limited, and land values are high. In some cases to make a building more functional, use natural light, fresh air, and the best architectural view we have to make a building irregular in shape likewise L-shape plan or U-shape plan. Most of the hospitals, offices, school buildings, and commercial buildings are made in an irregular shape in Nepal. According to building IS code [1], it is mandatory to make a seismic join in L-shape and U-shape building. To overcome this problem this study is most important.

1.2 Objective of the Study

The main aim of this Research is to investigate the seismic preference in the response of geometrical configuration and the structural variation. Further, some of its specific objectives are as follows:

1. To determine seismic performance of reinforced concrete framed building with a regular plan (rectangular) and irregular plan (according to IS 1893-2002) such as L, U-Shape building by using FEM based software.
2. To determine the most effective system to resist seismic load in between bare frame, shear wall system, and bracing system.

1.3 Scope of the study

This study focuses on the comparison of seismic analysis for the RC frame regular and irregular structure with introducing the bracing system, and shear wall at the corner. In this analysis four-story, RC buildings were taken. The performance of the building was analyzed in seismic zone-v. Modeling and analysis of the structure were carried out with FEM based software. The model of the building with RC frame structure, bracing system, and shear wall structures system was analyzed for static analysis method. The time period of the structures was retrieved from the software and as per IS code [1]; and then, a seismic analysis was done for story displacements, the story drifts for the comparison. Some special scopes of the study were as follows.

- This study focuses on the identification of seismic performance of RC frame regular and irregular structure with introducing the bracing system, and shear wall at the corner which is beast structure.
- This study helps to construct RC irregular buildings like L-shape and U-shape without seismic join.

2. MODELING OF THE BUILDING

Rectangular, L-shape, and U-shape building have a plan area, beam, column size, and story height constant model were taken for analysis. Such a model has a shear lock and bracing at a corner. The size of the building was 30m X 25m having a total height 13.5m model was analyzed. In this analysis four stories building was taken it represents the most of the building which are construct in Nepal. ETABS 2017 version 17.0.1 is used for the analysis of the model.

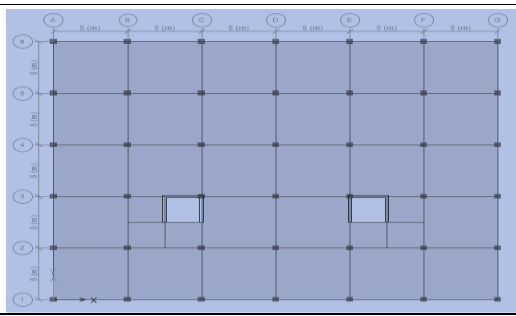

Fig. 1 Plan of a bare frame only in a rectangular building

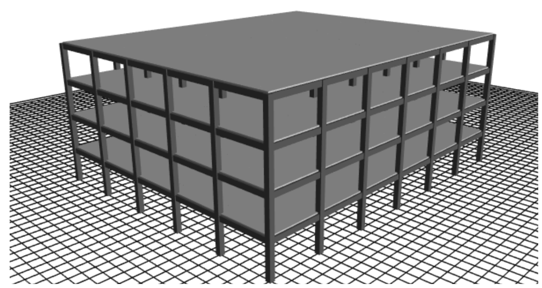

Fig. 2 3-D modeling of the bare frame only in a rectangular building

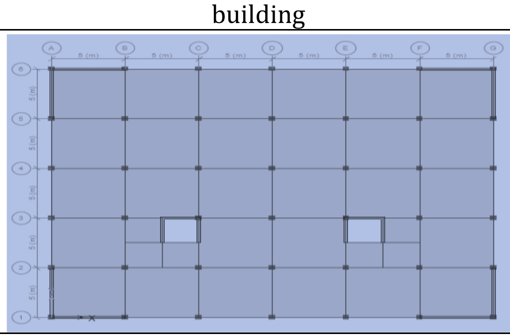

Fig. 3 Plan of a rectangular building with a corner shear wall

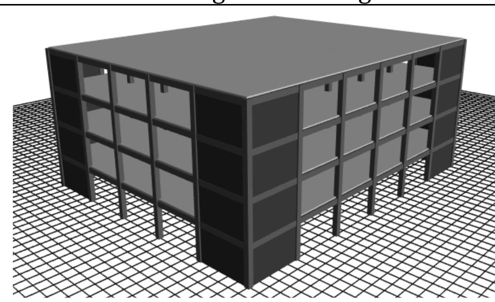

Fig. 4 Modeling of a rectangular building with a corner shear wall

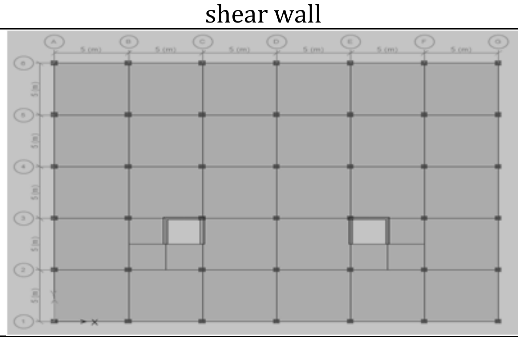

Fig. 5 Plan of a rectangular building with corner

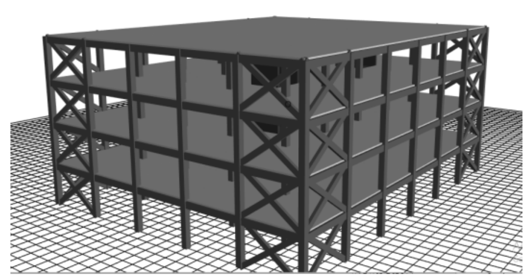

Fig. 6 3-D modeling of a rectangular building

RC bracing	with corner RC bracing
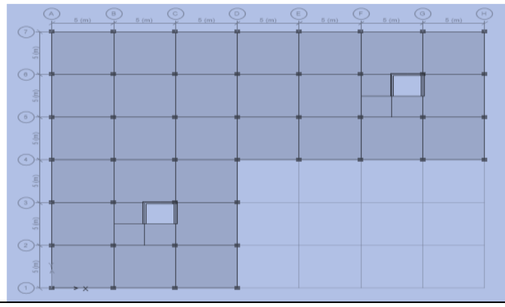	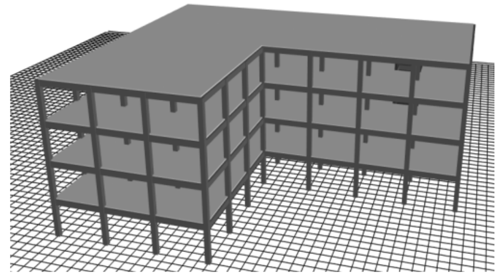
Fig. 7 Plan of L-shape bare frame only building	Fig. 8 3-D modeling of L-shape bare frame only building
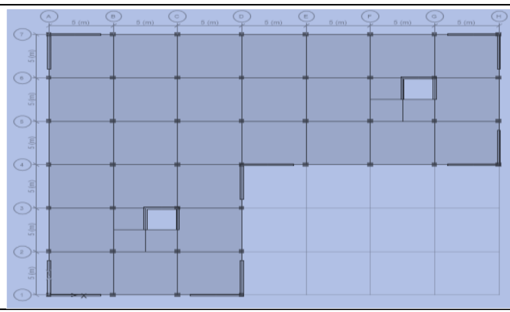	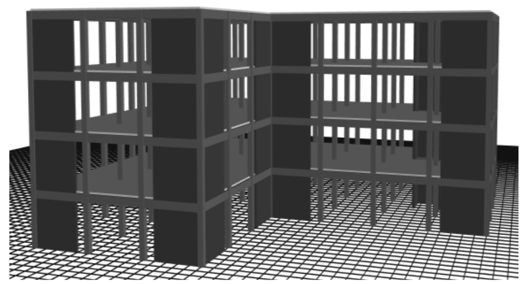
Fig. 9 Plan of L-shape building with the constant corner shear wall	Fig. 10 3-D modeling of L-shape building with the constant corner shear wall
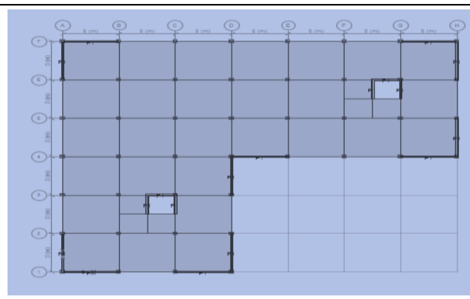	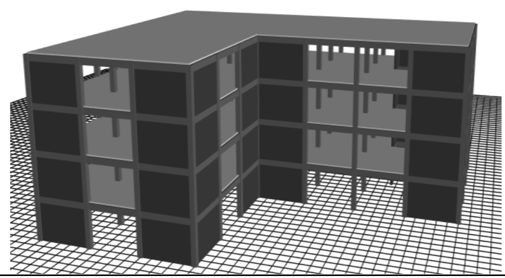
Fig. 11 Plan of L-shape building with the corner shear wall	Fig. 12 Plan of L-shape building with the corner shear wall
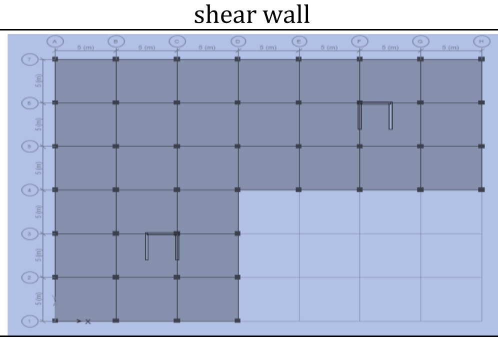	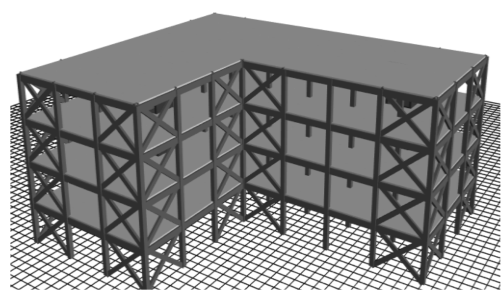
Fig. 13 Plan of L-shape building with bracing at the corner	Fig. 14 3-D modeling of L-shape building with bracing at the corner

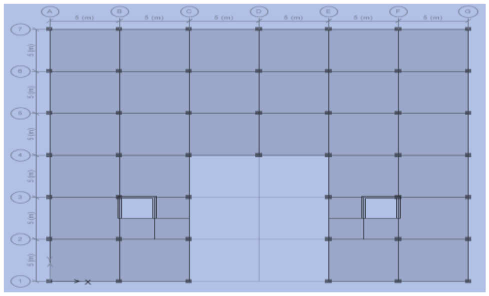	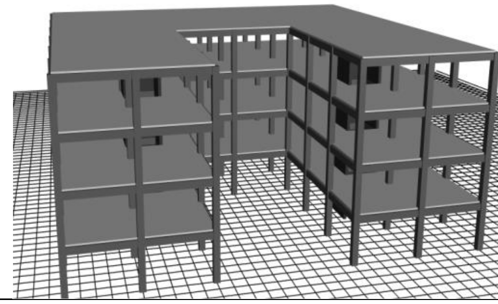
Fig. 15 Plan of U-shape building only bare	Fig. 16 3-D modeling of U-shape building only bare
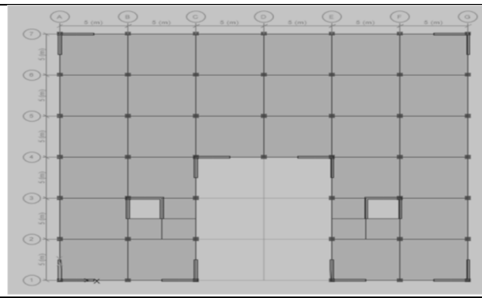	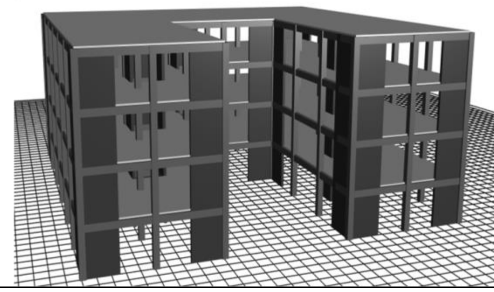
Fig. 17 Plan of U-shape building with constant shear lock	Fig. 18 3-D modeling of U-shape building with constant shear lock
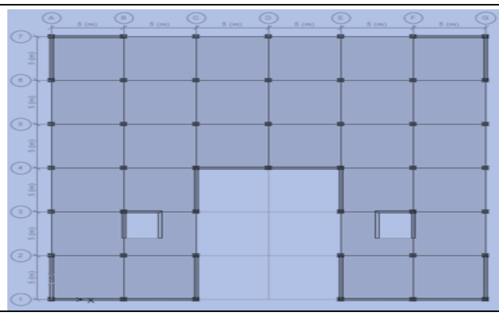	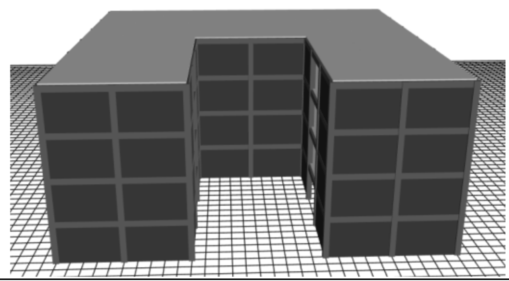
Fig. 19 Plan of U-shape building with shear	Fig. 20 3-D modeling of U-shape building with shear
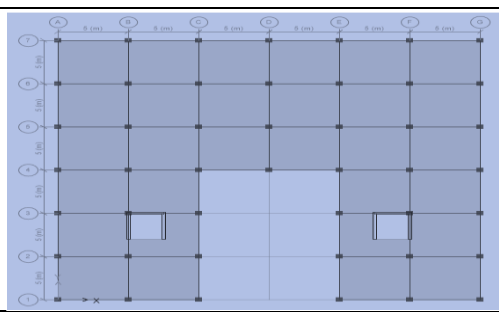	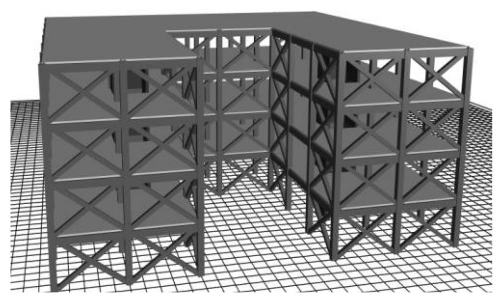
Fig. 21 Plan of U-shape building with bracing at the corner	Fig. 22 3-D model of U-shape building with bracing at the corner

2.1 Assumptions of building design criteria

Assumptions

For the transparency in results the study considered some important assumptions as mentioned below:

- Important Factor (I): 1.5

- Zone V, (Z): 0.36
- Response Reduction Factor (R) =5
- Damping = 0.05
- The structure was a special RC moment-resting frame (SMRF)
- IS code 1893-2002 considered, Limit state

In all cases, only a double lift was provided which was placed in two different locations of the structures. Rectangular, L-shape, and U-shape building having a plan area, beam, column size, story height constant different shear lock at a corner, and bracing at corner model were taken for the static and dynamic study. Design Loads Considered (IS: 875 (Part 1) -1987, IS: 875 (Part 2) -1987, IS: 875 (Part 3) -1987).

3. METHOD OF ANALYSIS

A structure was analyzed and designed for an earthquake that the structure was expected to experience so that the weaker portion can be identified before the structure was built. Seismic analysis was related to the calculation of the response of buildings under earthquake. Different types of analysis methods are developed for the safety assessment of the structure. In this study, the analysis of the building structure ware carried out for lateral loads using Equivalent Static Method, Response spectrum method and Time History analysis method.

4. RESULT

4.1 Maximum story Displacement.

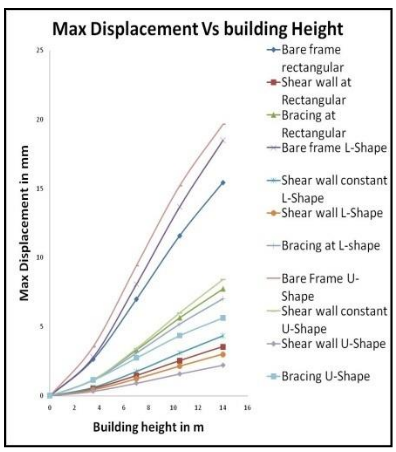

Figure 23 Sturdy of the maximum displacement due to static analysis

The max values of lateral displacement for all models were plotted in fig 23. By analyzing these values, the result obtained that RC bare frame U-shape had maximum lateral displacement and shear wall at the corner had minimum lateral displacement. Besides, shear wall or bracing at the corner in different geometry had less displacement than rectangular bare frame building.

4.2 Maximum story Drift.

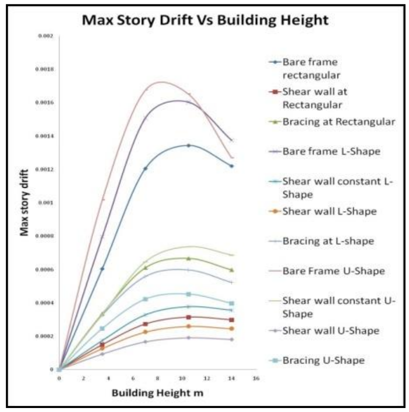

Figure 24 Study of maximum story drift due to static analysis.

The max values of maximum story drift for all models were plotted in fig. 24. By analyzing these values, the result obtained that RC bare frame U-shape had maximum drift, and shear wall at the corner had minimum story drift. Shear wall or bracing at the corner in different geometry also had less story drift than a rectangular bare frame building.

4.3 Maximum story stiffness

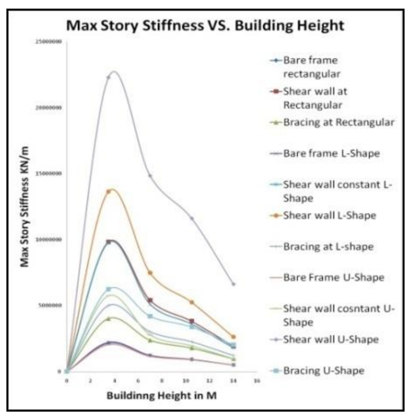

Figure 25 Study of maximum story drift due to Static Analysis

The maximum values of story stiffness for all models were plotted in fig. 25. By analyzing these values, the result obtained was RC bare frame U-shape had minimum story stiffness and Shear wall at the corner had maximum story stiffness. Shear wall or bracing at the corner in different geometry had more story stiffness than rectangular bare frame building.

4.4 Maximum Base Shear

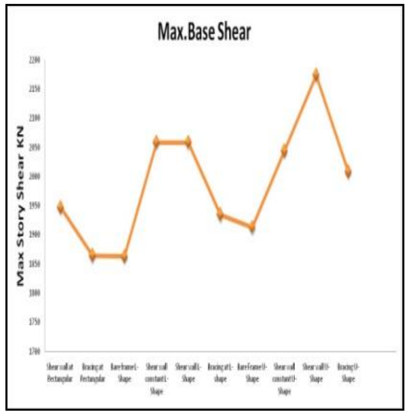

Figure 26 Study of maximum story shear due to static analysis.

The max values of base shear for all models were plotted in fig.26. By analyzing these values, the result obtained RC shear wall at corner U-shape had maximum base shear and rectangular bare frame had minimum base shear. Shear wall or bracing at the corner in different geometry building had increased story shear.

4.5 Maximum Story Overturning Moment

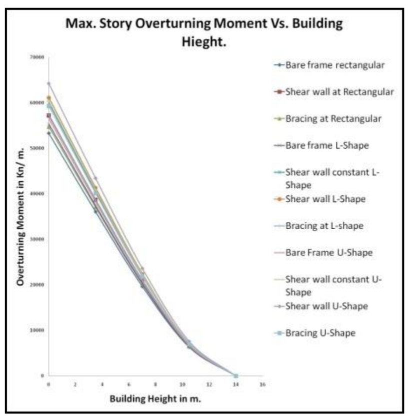

Figure 27 Study of maximum story overturning moment due to static analysis.

The max values of the overturning moment for all models were plotted in fig. 27 By analyzing these values, the result obtained was the shear wall at the corner U-shape building had maximum story overstoring moment and RC rectangular bare frame building had minimum lateral displacement. Shear wall or bracing at the corner in differential geometry also had more overturning moment than a rectangular bare frame building. While increasing the height of a building overturning moment is an increase in a building base. In actual the moment in the base is negative sing but according to the engineering point of view, it is taken as an absolute value.

4.6 Comparison of all building model

Table 5.4 Comparisons of all Rectangular, L-shape and U-shape Building Models

Analysis	BFR	SWR	X-BR	BFL	SWCL	SWL	X-BL	BFU	SWCU	SWU	X-BU
Displacement Comparisons with Rectangular Bare Frame Building.											
Static Analysis	1	0.23	0.50	1.19	0.28	0.19	0.45	1.27	0.54	0.14	0.36

Drift Comparisons with Rectangular Bare Frame building.											
Static Analysis	1	0.24	0.48	1.12	0.29	0.20	0.42	1.04	0.56	0.14	0.32
Stiffness Comparisons with Bare frame Rectangular Building											
Static Analysis	1	3.81	1.92	1.01	3.50	5.10	2.42	1.01	1.96	6.06	3.99
Base Shear Comparisons with rectangular Bare Frame Building											
Static Analysis	1	1.07	1.02	1.03	1.13	1.13	1.06	1.05	1.12	1.19	1.10
Overturning Moment Comparisons with Bare frame Building											
Static Analysis	1	1.07	1.02	1.03	1.25	1.14	1.07	1.05	1.13	1.20	1.11

5. CONCLUSIONS

Static analysis, response spectrum analysis, and time history analyses of the earthquake-resistant structure were performed satisfactorily. The study was conducted for different geometrical regular (i.e. rectangular) and irregular (i.e. L-shape and U-shape) models with various structural parameters like bare frame, shear wall, and bracing system building.

From the above analysis, it was observed that the shear wall placed at the corner shows a better response with less displacement than that of bare frame, constant shear wall, and bracing system building. The displacement is less in such a model due to box action where all the walls at the corner are interconnected and resist the force by each other.

- While placing the shear wall or bracing at the corner in different geometry buildings, the displacement was 0.14 times less than that of a rectangular bare frame building.
- An irregular building of different geometry with the shear wall or bracing at the corner also has 0.14 times less drift than that of a rectangular bare frame building.
- Irregular buildings of different geometry with the shear wall or bracing at the corner also have 6.06 times more story stiffness than rectangular bare frame building.
- Irregular buildings of different geometry with the shear wall or bracing at the corner have 1.19 times increased story shear and 1.2 times increased overturning Moment than rectangular bare frame building. However, overall seismic performances of irregular buildings of different geometry with the shear wall or bracing at the corner have better than that of rectangular bare frame buildings.

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