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The Study of Shear Wall in L Shape Reinforced Concrete Buildings under Lateral Loading

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Abstract: *Irregular buildings have considered more venerable as compared to regular buildings during earthquakes. To prevent the failure of irregular buildings, it is important to provide sufficient earthquake-resisting systems such as a shear wall, bracings, base isolations, etc. the study focused on the effect of shear wall in different positions in L-shaped irregular buildings. In the study number of models are prepared where the shear wall is placed in different positioned in L shape RC buildings and compared with and without a shear wall. The models are analyzed using static and dynamic (Response Spectrum) methods as per IS:1893 2016 in finite elements software ETABs V8. Time periods, torsional irregularity, base shear, maximum displacements, inter-story drifts response, buildings stiffness, overturning moments, torsional amplification factor and columns design parameters are analyzed for each building and compared in two cases. The study concluded that adding the shear wall in the L shape of buildings, earthquake load affects the inter-story drift, displacements of the structure, torsional irregularity etc. effectively. It is noticed that the configuration and the location of shear walls have a significant impact on the response of the structure. The location should be such that the shear wall should help in decreasing eccentricity and distributing gravity and lateral loads in the best way possible.*

Keywords: L shape Building, irregular, torsional irregularity, RC, Earthquake

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I. INTRODUCTION

In many parts of the globe, earthquakes pose a serious threat to human life. For locations close to the boundaries of significant tectonic plates, it presents engineering design issues for the majority of civil engineering structures, and the likelihood that any given structure will never be impacted by a major earthquake is very low. When there is moderate to powerful ground motion, buildings are prone to collapsing, which causes enormous economic and human-life losses. Using current design codes, seismic design of building structures is usually carried out to ensure life safety. The best engineering strategy for dealing with this possibility is to build the structure to resist collapsing in extreme weather, protect people from harm, and accept the chance of structural damage in proportion to the structure's significance. Building layouts and the size, shape, and placement of beam-columns all affect how seismically resistant a structure is.

Buildings that aren't normal may be vulnerable to earthquakes and have structural members collapse. The most prevalent irregularities found in buildings include irregularities of mass, stiffness, verticality, geometry, and plan. Horizontally irregular buildings are defined as those that have discontinuities in the horizontal plan, such as cut-outs, large openings, and asymmetrical plan shapes (T, E, F, H, L, etc.). Understanding how the seismic risk assessment of the structures is determined by relating the physical damage to irregular buildings to earthquake ground motion is crucial. Making the earthquake-resisting buildings shear wall is one of the best options and has shown very good performance for many earthquakes in the past. In high seismic regions, shear walls need special detailing. Because of the high plane stiffness and strength of the shear walls, the shear walls are strong to withstand lateral loads and they transfer lateral loads to the next member in the load direction below them. Therefore, shear walls prevent the floor and roof members from shifting out of the supports.

1.1 Research Needs

These days, buildings are often designed with irregular shapes rather than regular shapes because of the architectural aspect of a building. The lateral resistance of the structure to ground motion is typically torsionally unbalanced because of asymmetries in the mass, stiffness, or strength. This leads to large displacement amplification and high force concentrations within the resisting elements, which can result in severe damage and occasionally the collapse of the structures. So that it is important to take special attention while designing irregular buildings which is constructed in the highly seismic active zone like Nepal.

1.2 Objectives of Study

The major objectives of the study are to check and understand the behavior of shear walls in L shape Reinforced Concrete framed buildings under the action of seismic forces. To compare the performance of Reinforced concrete framed buildings with and without shear wall and observe the behavior of unsymmetrical buildings for story drift, story displacement,story stiffness, story shear forces, overturning moments, time period torsional effect and base shear forces under a different position of shear walls. The study also observes excessive torsional irregularity according to the code. Finally, to identify the best performing shear wall position in irregular L shape RC buildings with the help of seismic parameters.

II. LITERATURE REVIEW

The study of different research which is mainly related to the L shape of RC buildings, shear walls and its effects on buildings is an important parameter to understand the basic subject of concern. Several studies are performed in the field of RC buildings with shear walls and suggested that the shear walls improve the structural performance of the structures effectively. Due to the historical interaction of the Indian plate beneath the Eurasian plate, as shown in Figure 1, Nepal is situated in a seismically active region of the globe. Past earthquakes like those that struck Nepal (2015), Sikkim (2011), Kashmir (2005), and Uttarkashi (1990) resulted in severe human casualties, monetary losses, and structural damage, including some serious failures of structures. One illustration from the Sikkim earthquake is how a ground motion (earthquake) of low magnitude can have significant effects on a building's structural elements [1]. Research shows that in past earthquake activities show that many of the existing structures in Nepal exhibit inadequate earthquake performance [2]. In the study, it is also noticed that most of the buildings in Nepal fail due to both the construction aspect as well as structural aspects [3].

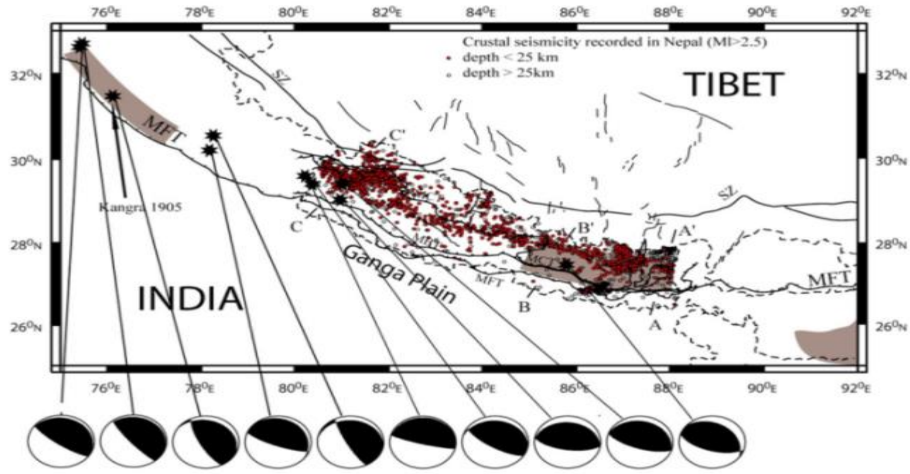


Figure 1. Seismicity in the Himalayas of Nepal. [4]

Numerous scholars investigated the seismic impact of both regular and irregular structures, both with and without various earthquake-resisting components like bracing, moment-resisting frames, and shear walls. Mohammad et al.(2017) [5] observed the vertical types of irregularity in the buildings by using ETABs software and analyzed seismic effects on it. Surana et al (2020) [6] investigated the seismic vulnerability of the hillside structure Himalayan region and focused on the vertical irregular structures. It is observed that the maximum probability get the structure failing during an earthquake is when the structure is irregular in shape. L-shaped structures are plan irregularities and they primarily have two kinds of issues. One is opening and shutting mode, which uses the high-frequency oscillatory mode. It is a result of the structures' thin projection. which, as illustrated in Figure 2, results in a high-stress concentration at the corners and the failure of structural elements. Another issue is caused by the L-shaped buildings' induced torsional impact, as shown in Figure 3. The primary focus of research has been on the seismic behaviors of the L-shaped building based on displacements, drift, and static linear analysis (RSA). Researchers are focused on the observation of comparative analysis on the regular and L shape buildings and torsional irregularity ratio [7]. Much other research such as [8], [9], [10] were observed in the investigation of the torsional effect of shear wall structures.

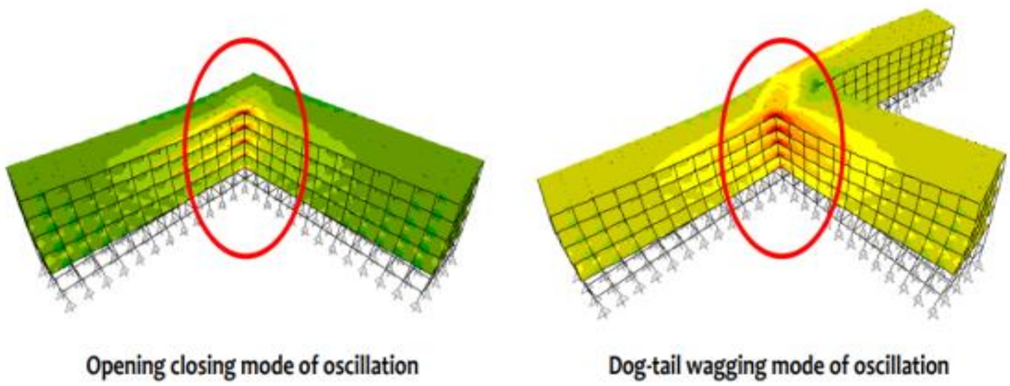


Figure 2. Irregular L shape buildings and positions of stress concentrations

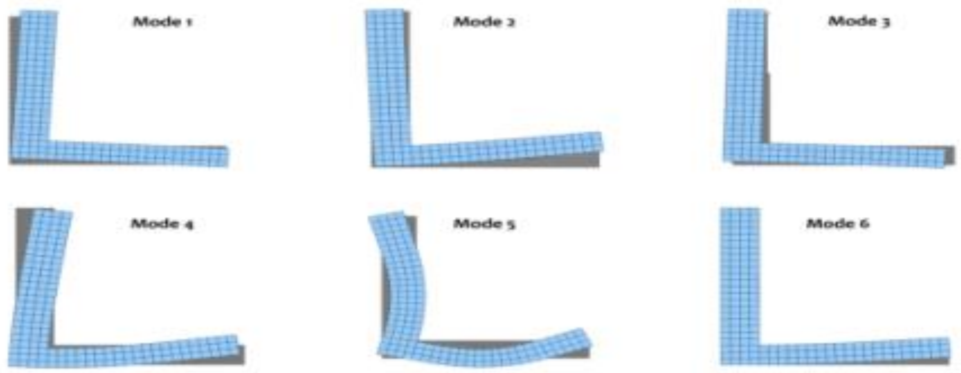


Figure 3. L shape buildings and their six modes of oscillation.

C. M. Ravikumaret al. (2012) [11] This study demonstrates how important it was to determine the built environment's seismic performance to reduce the risk caused by earthquakes. It was accomplished through the creation of various analytical techniques that guarantee the buildings will hold up during major earthquakes and generate enough caution whenever one occurs. A structure's behavior during an earthquake is influenced by several variables, including stiffness, sufficient lateral strength, ductility, and basic and regular configurations. So, when designing a structure to withstand earthquake ground shaking, the choice of building plan configuration is important. Investigations into the effects of earthquakes on buildings have shown that irregular buildings sustain more harm than regular structures. Abdel Raheem et al. (2018) [12] this study suggested that it is important to study the irregularity in buildings to avoid enormous changes in mass and stiffness. Prajwal, Parvez, and Kamath (2017) [13] investigate the buildings by using static nonlinear and dynamic analysis in regular and irregular buildings. They studied the L shape of buildings and made comparative analyses and results.

Because these vertical plate-like structural elements have significant in-plane stiffness and strength, they can be used to help decrease the overall displacement of buildings when lateral displacement in a building with moment frames alone is high. These walls are also known as shear walls. Structured walls withstand lateral pressures by combining axial, flexure, and shear forces. Farghaly (2016) [14] investigated and found that structures, where the shear wall was placed at the central part of the structure, are most effective for resisting lateral forces. Mukundan and Manivel (2015) [15] noticed that the torsional effect is only prevalent in irregular structures as the center of mass and rigidity are near to each other in a regular building. Monish and Karuna (2015)"[16]" examined irregular buildings by using the Indian standard. (Kodappana and Dilip (2017) [17] staggered opened shear walls have a better performance than regular opening shear walls. Venkatesh and Venkatdas (2017) [18] completed a study on the seismic performance of high-rise structures with and without a shear wall. The analytical study on the lateral behavior of structure examines how the orientation of the shear wall affects the responses in a high-rise building. Moreover, it finds that the story displacements are less for buildings with shear walls as compared to buildings without shear walls.

In irregular buildings to reduce the damage level, structural walls are used in the buildings. There are several research presents that describe the effects of shear walls in irregular buildings. Jereen, Anand, and Issac (2017) [19] conducted a seismic evaluation of buildings with plan irregularity in which it was found that variation in plan configuration affects the displacement and story drifts of the buildings. Singh (2015) [20] completed research that investigates the different frame configurations and different performance limits are examined. Wiyono et al. (1018) [21]"conducted research on "the effect of shear wall configuration on seismic performance in the hotel building and recommended the use of two-sided shear walls in both X and Y directions.". Saravanan and Kavitha (2020) [22] completed a study on optimal positions of shear walls in high-rise soft-story buildings subjected to seismic forces in which the researchers compared the responses, displacements, bending moments, torsional moment, shear force and story drifts in models with different models and similar research also conducted by Banerjee and Srivastava (2019) [23]**.**"

The effects of shear walls on high-rise structures have been the subject of numerous studies. The majority of the study is done on ordinary structures. The irregularity of the plan examined in this study, the building shaped "L," which is typically built as an irregularly plan-shaped building in Nepal, has been the subject of limited research despite the fact that research on irregular buildings has been done. Numerous studies only considered vertically irregular buildings with shear walls or standard RC buildings. The position of the shear wall in various positions and its impact on L-shaped irregular buildings with soft stories in the lower part of the structure is not well studied. Under the influence of dynamic loads, these irregularities cause structures' structural collapse. As a result, an in-depth study is needed to achieve the best performance even with a subpar configuration. As a result, the goal of this research is to better understand and evaluate seismic behavior for horizontal irregular buildings with various shear wall placements.

With the support of seismic parameters, the seismic behavior of L-shaped RC buildings with and without shear walls at various locations is examined in this research. Based on the seismic performance, a comparative study of variously positioned shear wall structures is given. Studies and comparisons are made regarding the seismic performance, including displacement, drift, shear force, basic time period, stiffness, torsional irregularity ratio, torsional amplification factor, the capacity ratio in columns, axial forces, and moment in the base columns. The level of torsional effects observed when the shear wall is provided in different positions is mainly focused of this study. Additionally, torsional effects may greatly amplify a building's seismic reaction. Therefore, it is important to take extra care when designing irregular structures and to increase component sizes where they are needed. In terms of displacement, story drift, and story shear demands, the plan configurations of the structure have a major effect on its seismic response.

III. METHODOLOGY

The research on L shape RC buildings with and without shear wall buildings in earthquake-prone areas was selected as the sub-domain. The need for shear walls on L-shaped buildings was determined through further analysis of the literature, and this became the subject under consideration for the study. The equivalent-static and response spectrum analyses are used in the research to evaluate the responses on an L-shaped irregular building subjected to earthquake loads with and without various shear wall positions.

With regard to the research and design of each model, ETABs software is used to examine the seismic behaviors of shear walls in RC frames and without shear wall RC frames. To comprehend and analyze each model's torsional impact, story drift, and story displacements, linear dynamic analysis (RSA) is used. Based on the shape of the vibration mode, the RSA, or linear dynamic analysis, is used to determine the seismic reaction. The approach offers a lateral force profile that is almost entirely accurate. After and before the shear wall is used, a comparative study is conducted. After the design, the girder and column are examined and created.

3.1 Design Requirements

Indian standard 1893: 2016 (part 1) [24] provides the design criteria for the earthquake design of the building. The IS 1893 and some other international codes (UBC-97, ACI 318- 08) are used to design ductile RC buildings. For ductile designing not only is 1893 part 1:2016 but also IS13920:2016 is used for ductile designing and ductile detailing. Even the different codes do not have the guideline for shear force balance in the moment-resisting frame and bracing frame to confirm that the outcome in the dual system should have satisfactory deformation capacity for the ductile property. For the basic ductile design philosophy i.e. failure mechanism of a weak beam-strong column generally available guidelines in IS 1893 and some other international codes as well. According to IS1893 (part 1):2016 [24] building with a dual system consists of an MR frame and a shear wall system. The involvement of shear force in the shear wall is limited, the code provides that the MR frames are designed such that at least 25% of base shear resists independently. Therefore it is important to know the effects of the structural behavior of RC, where the shear wall is used when the above code design requirement (at least 25% of seismic forces contributed by the moment-resisting frame.) is used.

The first story in this research, which is about common practices, presents the soft story [25]. The Indian standard defines a soft tale as having lateral stiffness that is less than the stiffness of the story above. The first story is 4 meters tall, while the remaining stories are 3.2 meters tall. According to the stiffness equation (K=12EI/L3), the height of the story decreased stiffness. Thus, the square of the ratio of the first story height to the second story height is known as the soft story ratio. The soft tale ratio is 1.95 according to the calculation.

3.2 Code provisions for torsional irregularity

A re-entrant corner is one where the projection exceeds 15% of the total plan dimension in that direction. [24]. In the study, the projection along the x-direction is 66% and along the y-direction is 57% and which is greater than the overall dimension of the plan in each direction. Drift is used to determine torsional irregularity at each 3D model corner. A similar provision for calculating the torsional irregularity of an L-shaped structure can be found in almost every seismic code (IS 1893:2016, UBC 97, ASCE 7–10). The accidental torsional effect and torsional amplification factor (A_x) [26] shall be observed. The Δ_{max}, Δ_{min} and Δ_{avg} are the maximum, minimum and average drift as shown in Fig 4 respectively. The torsional irregularity coefficient is defined as the ratio of the drift maximum and average drift ($\eta_t = \Delta_{max}/\Delta_{avg}$). Three conditions are described. when η_t is less than or equal to 1.2 then no torsional irregularity exists and A_x is equal to the 1. When η_t is between 1.2 to 2.083, the torsional irregularity exists and A_x is calculated. When the η_t is greater than 2.083 then η_t=2.083 and A_x is equal to 3.

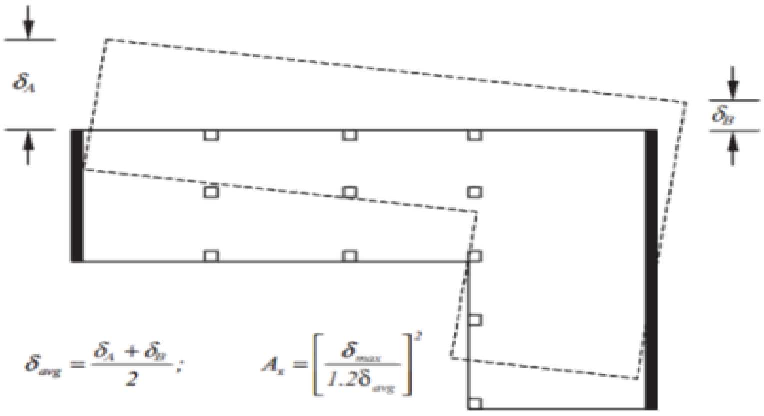
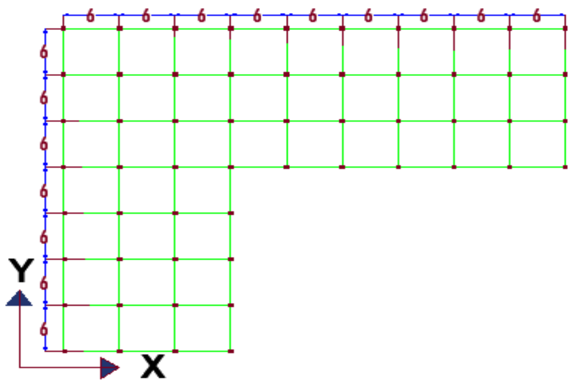
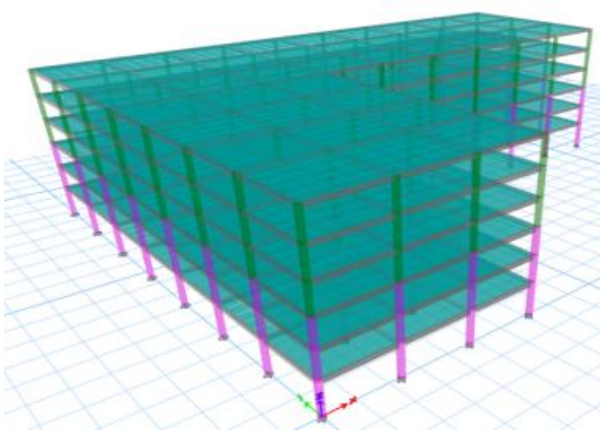


Figure 4. drift at the corners of the L shape structures for calculation of torsional irregularity [26].

3.3 Modeling of the Structure

The hypothetical L-shape of 6-story buildings is assumed in order to examine the efficacy of the shear wall in the actual L-shape RC building. The 6-story structures are made to act as a frame that resists moments. The L-shaped irregular structures' seismic performance is enhanced by the use of shear walls. The six-story structure has an irregular, L-shaped design, as seen in Fig. 5.





a) 2D plan L shape buildings (unit are in meters) **b) 3D view**

Figure 5. Plan and 3D view of L shape RC buildings

3.4 General Description

Due to lateral torsional coupling, plan asymmetric structures are particularly vulnerable to earthquake-induced damage, and the corners of these systems sustain significant damage. Investigating the seismic behavior of a structure with an asymmetrical plan is crucial. First, a reference model is created (Table 4 (L1)), after which several models with plan asymmetry are created (Table 4 (L2-L12)), by including specific building parts with shear walls in the reference model. (L1). The 6-story RC building in the L shape (see Table 4) is 3.2 meters tall overall, with the exception of the first story, which is typically considered to be 4 meters tall in Nepal. The structure is 20 m tall altogether. Each bay width is assumed to be 6 meters, or a column-to-column span of 6 meters, as shown in Fig. 4 for each model in both the x and y orientations. As shown in Table 1 below, the seismic measure and other geometric design parameters. In Tables 2 and 3, the material and ultimately chosen cross-sectional property are displayed, correspondingly. The columns section is changed every 3 stories of the building. The reference model was designed by assuming these above conditions.

Some presumptions, such as the P-effect being taken into account for each model for both RSA, are made for the seismic design of the building. SSRS (square root of the sum of squares) and CQC are taken into account for the RSA. According to IS 1893: 2016 part 1, a significant number of modes are taken into account in the analysis such that to obtain the total model mass for all modes, 90% of the total seismic mass was assumed. The building is intended to support a live load of 5 kN/m2, while the live load for the top level is 2 kN/m2. The seismic weight of the structure is taken as 100% of dead load, 50% of live load when the live load is greater than 3kN/m^2 and 25% of live load when the live load is less than 3kN/m^2. All parameters are the same for each model except for shear wall positions. For all (L2 to L12) same thickness of the shear wall (200mm) was provided the according to the positions in each model. The shear wall was provided in the reference models to form each model.

The observed models range from L1 to L12, with L1 being the initial model without a shear wall RC frame. Almost 12 models are observed. There are additional models from L2 to L12 where the various shear-walled designs are seen.

Table1. General parameter of the each models.

Parameters	General Description
Type of building	Commercial building
Location	V
Structure system	RCC frame structure; Special moment resistant frame
No. of story	6 (six) story
No. of Bays	9 in the X direction and 7 in the Y direction
Floor-to-floor height	4.0 m for the Ground floor & 3.2 m for the other’s
Types of Slab	120mm thick; Two-way Slab

Table 2.Specifications of beams, columns and shear wall used in the 6 story L-shape study buildings

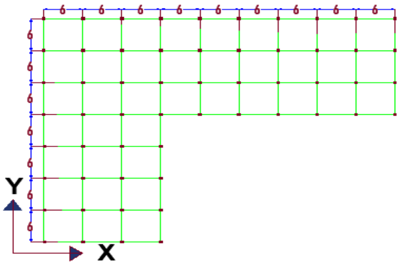
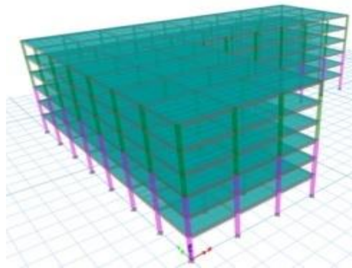
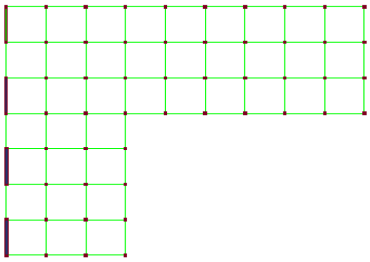
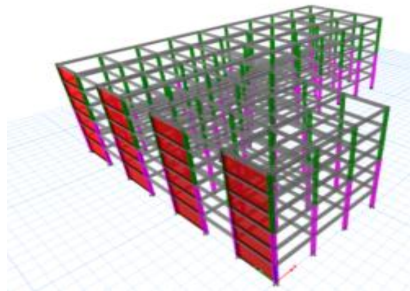
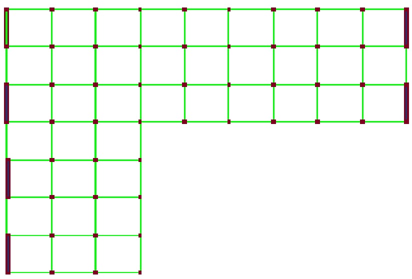
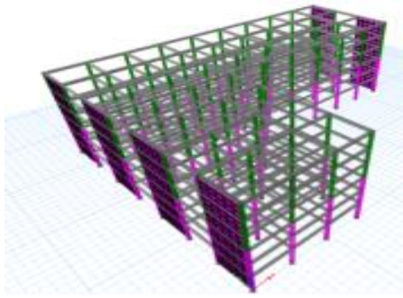
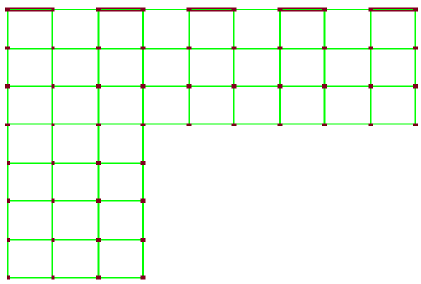
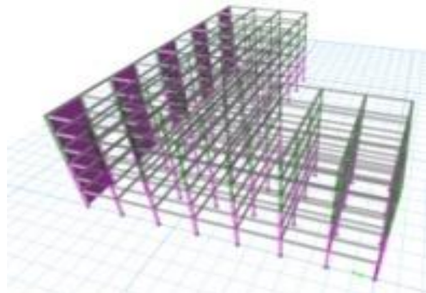
Structure	RC section Columns(mm)	Beam (mm)	Shear wall
6-story	400X400 (1-3 story) 350X350 (4-6 story)	300X400	200mm

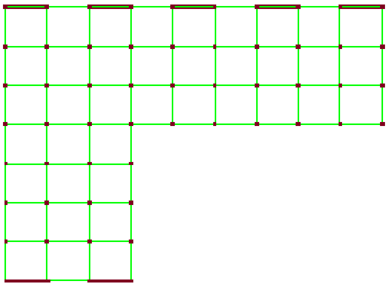
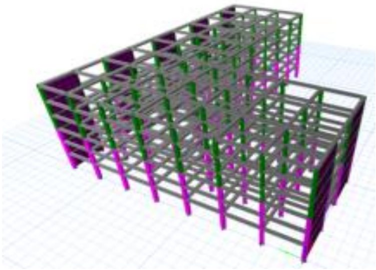
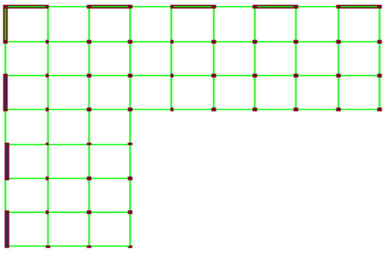
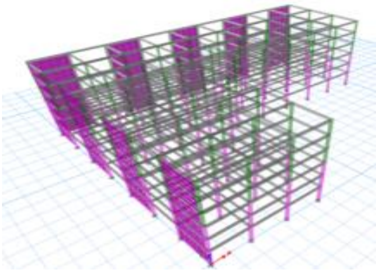
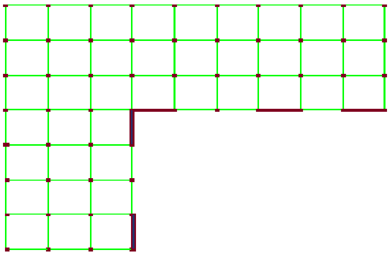
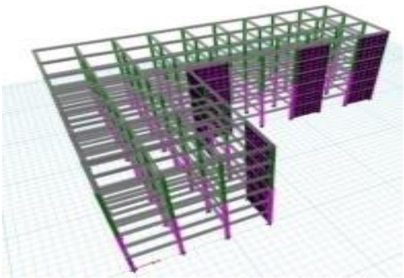
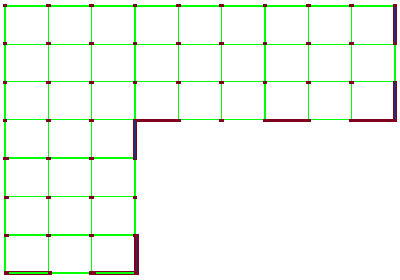
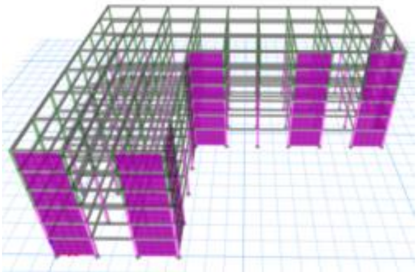
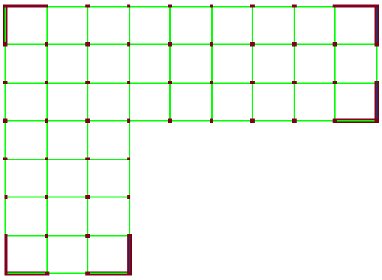
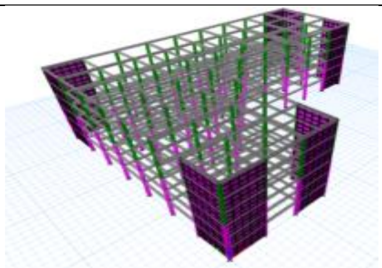
Table 3 Material properties of the concrete and steel materials.

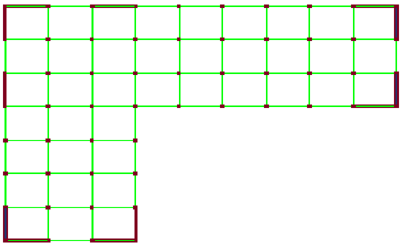
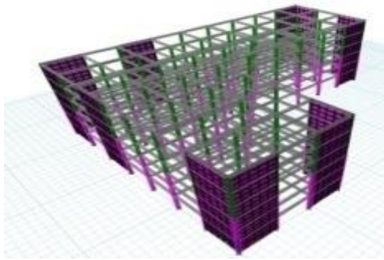
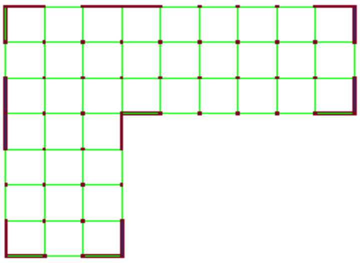
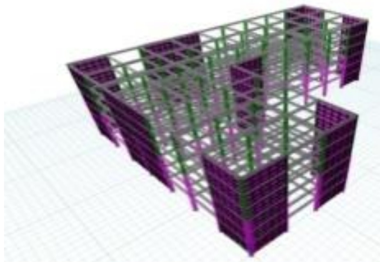
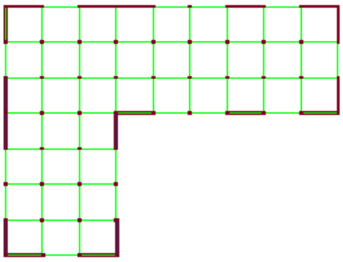
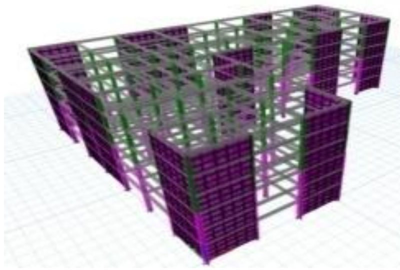
Material properties	Concrete	Grade = M25 Modulus of elasticity= 25000 MPa Poisson’s ratio= 0.2 Density = 7850 Kg/m^3
	Steel	Grade = FE415 Minimum yield stress= 415 MPa Minimum tensile stress= 485MPa Modulus of elasticity= 200000 MPa

	Density = 7850 Kg/m^3

Table 4. different plan and 3D of the selected buildings with and without shear walled L shaoped buildings.

Models	Plan View	3D view
L1		
L2		
L3		
L4		

L5		
L6		
L7		
L8		
L9		

L10		
L11		
L12		

IV. RESULTS AND DISCUSSIONS

In After the successful analysis of the model the result section, the result is described and a discussion will be made based on the result. The methodology adopted in the previous chapters is used to find the building responses. Story displacements, story stiffness, overturning moments, base shear, fundamental time period, torsional irregularity, etc. are compared for different arrangements of shear walls using a number of lateral load cases. The observations are presented in the form of tables and graphs. The established results are then discussed, validated and compared with existing literature.

To understand the seismic behaviors of different shear-walled buildings, each model is divided into two cases. Case 1 shows an incomplete shear-walled building, where models L2 to L8 are categorized in this case. whereas L9 to L12 show proper shear-walled buildings which is categorized in case 2. In the above-only buildings, L1 is without shear walled buildings and is used as reference model to compare other types of buildings.

4.1 Fundamental time period

The fundamental time period (FTP) of a structure affects its ability to deal with seismic demands. Buildings' translational natural periods in the direction of the design lateral force are a product of their design horizontal base shear coefficient. Typically, the code gave the empirical formula to determine the FTP of the buildings. However, the formula only applies to regular structures; when buildings are irregular, the formula given by the code does not provide an accurate FTP [7], [12]. On the x- and y-axes of Figure 6, the structures' periods are shown to fluctuate. In Fig. 5, it is shown that the base shear rises at the axis where the shear wall is being used to resist the lateral load while the fundamental time period is reduced. In models L9 to L12, the fundamental time period of the structures is reduced and is found to be at a minimum when the shear wall is provided in both axes. It is observed that due to the shear wall, the fundamental time period of the structure decreased from 1.44 s for model L1 to a minimum of 0.286s for model L12 in x direction, which means almost 80% value of FTP is decreased. When the number of bays is shear walled, the time period of the structure also decreased. In Figure 6 it is clearly observed that the FTP of the structure along the x and y axis are nearly equal for models L1 and L2. It is noticed that The FTP is decreasing that axis where the shear wall is placed and it is due to the increase of stiffness of the models while adding a shear wall on it.

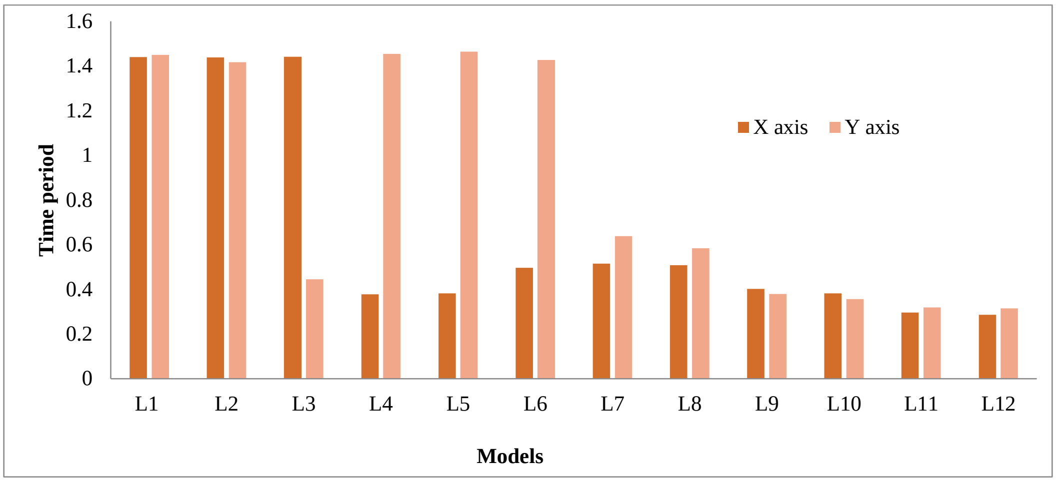
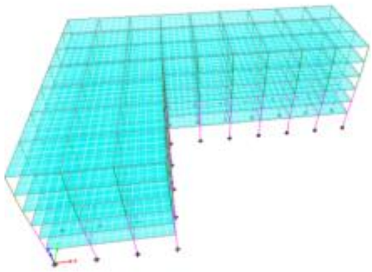


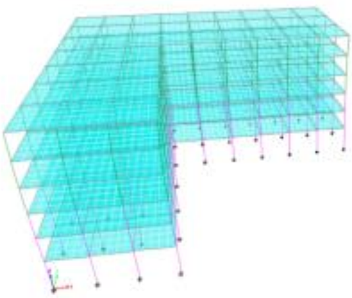
Figure 6. Fundamental time periods of the different models

4.2 Vibration Mode shapes

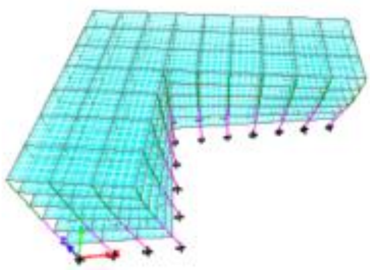
The deformed shape of the building when shaken at the natural period is the mode shape of oscillation linked with the building's natural period. There are therefore as many mode shapes in a structure as there are natural periods. There are an infinite number of natural periods for a structure. For the purposes of this research, the building's deformed shape connected to the oscillation at the fundamental natural period is referred to as its first mode shape. Similar to this, the second mode shape, the third mode shape, and so on refer to the deformed forms connected to oscillations at higher natural periods, such as second, third, and so forth. (see Figure 7). Pure translational along the X-direction, pure translational along the Y-direction, and pure spin about the Z-axis are the three fundamental oscillation types. These pure-mode shapes are present in regular structures. Structures with irregular geometry, non-uniform mass and rigidity distribution in plan and along the height have mode shapes that are a combination of these pure mode shapes. Each of these mode shapes is independent, which means that none of the other mode forms can be combined to produce it. Care should be taken to position and size structural components in regular buildings so that mixed and torsional modes of oscillation contribute little to the building's total oscillatory motion. Increasing the torsional stiffness of a building is one method of preventing torsional modes from becoming the first modes of vibration in structures. In order to accomplish this, in-plane stiffness in the vertical plane is added in a few bays along the building's perimeter. This addition of stiffness should be made along both of the building's plan directions so that the structure has no stiffness eccentricity. Adding braces or introducing structural walls in select bays are some common ways in which this is done. Figure 7. shows different models with their mode shape with a fundamental time periods. It is observed that when the improper shear wall is provided in the buildings the modes shapes are also affected and no longer a pure mode shapes. The torsional behaviors are observed in the models [12].



Mode1:T1=1.457s

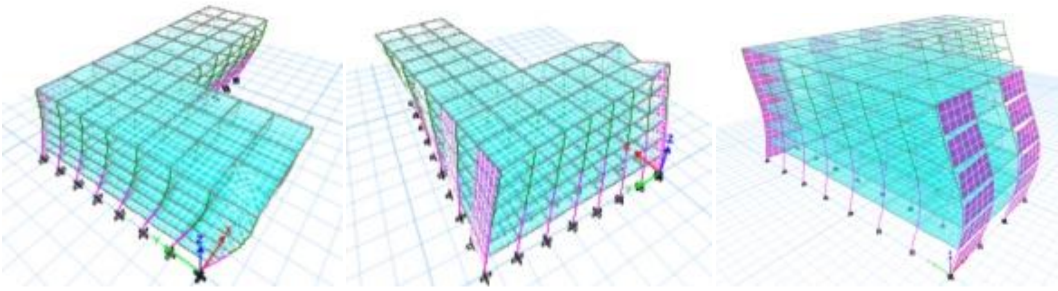


mode 2:T2=1.441s



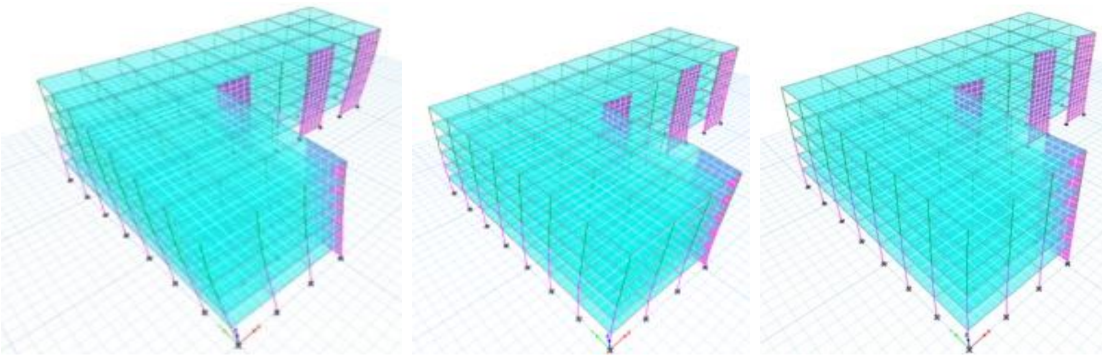
mode 3:T3=1.357s

a) L1



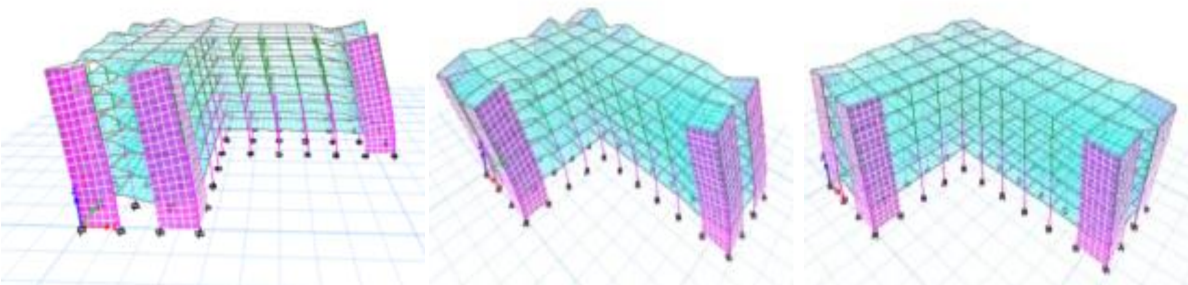
Mode1:T1=1.46 s mode 2:T2=0.632s mode 3:T3=0.48s

b) L5



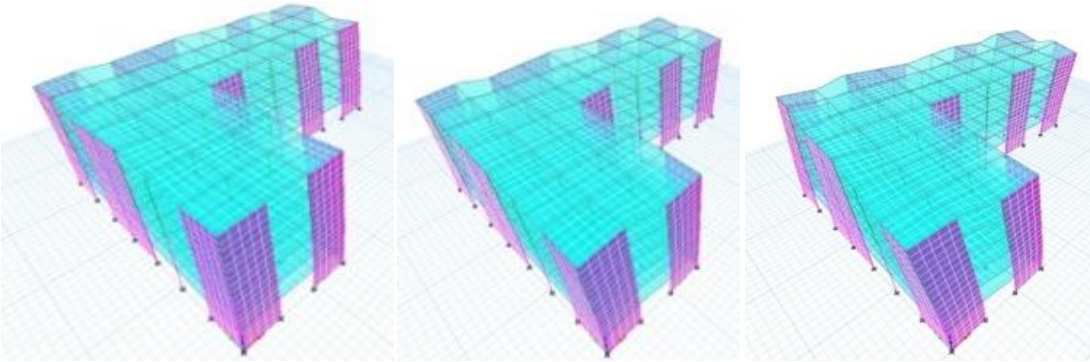
Mode1:T1=1.365 s mode 2:T2=0.639s mode 3:T3=0.514s

c)L7



Mode1:T1=0.383s mode 2:T2=0.357s mode 3:T3=0.226s

d)L10



Mode1:T1=0.315s mode 2:T2=0.285s mode 3:T3=0.201s

e)L12

Figure 7. Different mode shapes for selected buildings

4.3 Design Base shear variations

The lateral total force at the bases of the structures brought on by earthquake ground movements is known as base shear. The plan shape, basic periods, and soil types of the sites all affect how the bases of the structures shear. The building's asymmetrical floor plan and lateral-torsional coupling events both have an impact on the base shear. The seismic weight of the buildings is another factor. For the equivalent static situation, the story shear distribution has a parabolic shape. As depicted in Fig. 8, the design base shear is seen in both orientations in both situations. It has been noted that including a shear wall in the models raises their base shear values [27], [28]. Shear walls are included in model L3 so that bracing is used to withstand the lateral pressure along the y-axis. Therefore, the basic shear values in the L3 models are more along the y-axis than the x-axis. Shear walls are only added to models L4 and L5 to resist the lateral load along the x-axis, increasing the basic shear values only along the x-axis relative to the y-axis. However in model L1, which is represented without shear walled frame L shape structures. In the L1 model, almost the same design shear forces are observed (see figure 8). In the models, L9 to L12 (case 2) almost similar base shear values are observed in both the x and y-axis.

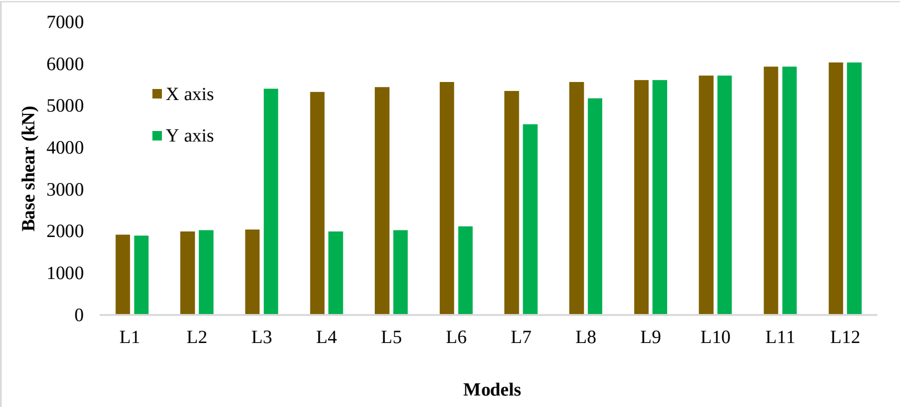
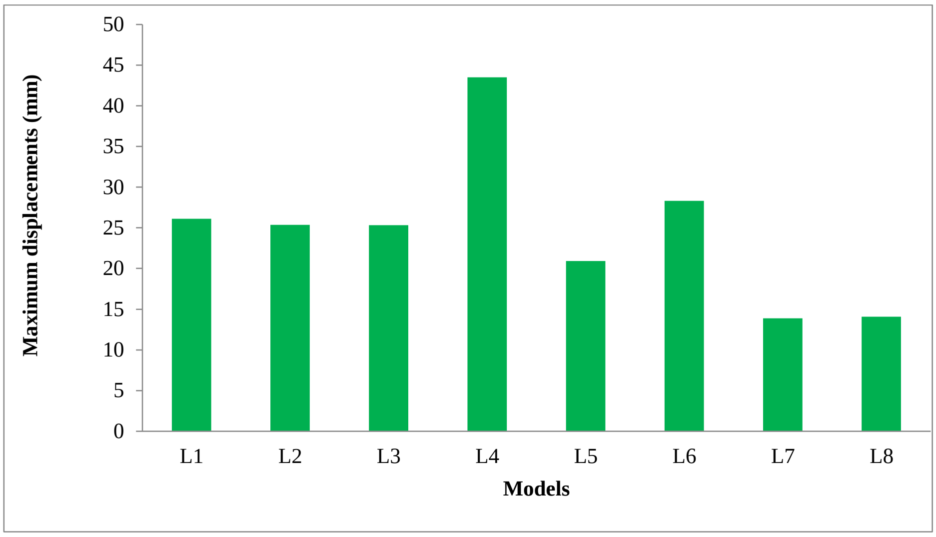


Figure 8. Base shear of the different models along the x and y-axis.

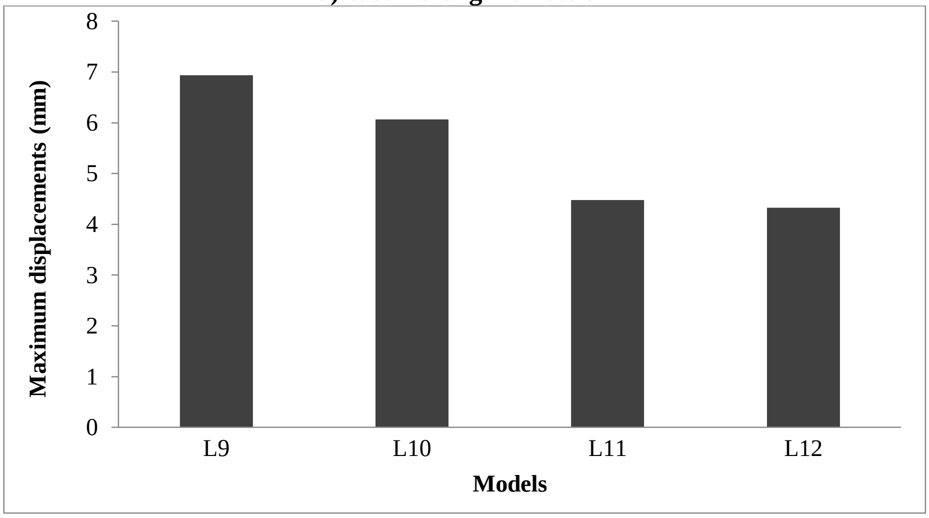
4.4 Maximum displacements response

For the construction of buildings, the story displacements of irregular structures subjected to lateral loads are an important consideration. Understanding the extent of the structures' damage is aided by their top-story displacement responses. [7], [29]. The structural and nonstructural elements of the buildings are damaged by excessive deformations in irregular structures. The maximum displacements in the L-shaped structures are shown in Fig. 9, 10, and 11.

The maximum displacements in the various models, in both the x and y planes, are shown in Figs. 9 and 10. It has been observed that adding shear walls in various locations changed the greatest structural displacements. The shear wall addition in case I (L2-L8) cannot show as much efficient control in the maximum displacements. Even with the torsional impact, the maximum displacements in model L4 along with the x directions rise in comparison to the L1 references model. The shear walls are added to the L4 models in Fig. 9 to withstand lateral load along the x-axis, but this is undesirable because it amplified the displacements due to the torsional effect. The re-entrant corner behavior amplified the displacement along the x-axis [9]. As seen in Figs. 9(b) and 10(b), similar findings were observed in case 2 (L9-L12) models, where the shear wall successfully reduced the maximum displacements [30]. After adding a shear wall to the L1 models, it can be seen that the greatest lateral displacements in the models L9, L10, L11, and L12 are reduced by 74%, 77%, 83%, and 83% along the x-axis and 74%, 78%, 81%, and 80% along the y-axis, respectively. It effectively reduces displacements and exhibits excellent seismic behaviors when shear walls are added along the x and y axes. Due to the lateral-torsional vibration coupled behavior in the L shape of soft-story buildings, the maximum displacements are noted in case 1 to be 44mm along with x directions. In case II, the displacement along the x-axis has values as high as 6.9 mm for the L9 model and as low as 4.3 mm for the L12 model. And as shown in Fig. 10, a comparable response is also seen in the y directions. Figure 11 demonstrates the similarity of the reaction behavior along the x and y axes. It can be seen that shear walls used correctly in L-shaped RC buildings lower the maximum lateral story displacements in the models by comparing the maximum displacements of six-story soft-story buildings with various shear wall designs. The story displacement response demand due to the earthquake load will greatly increase with the increase in lateral-torsional vibration coupling, though, if proper shear wall position is not provided.

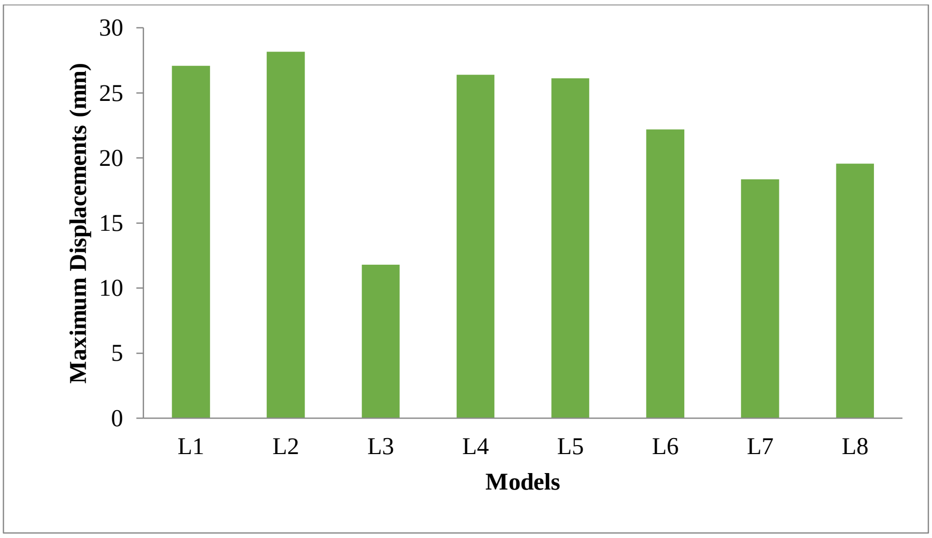


a) case 1 along x direction

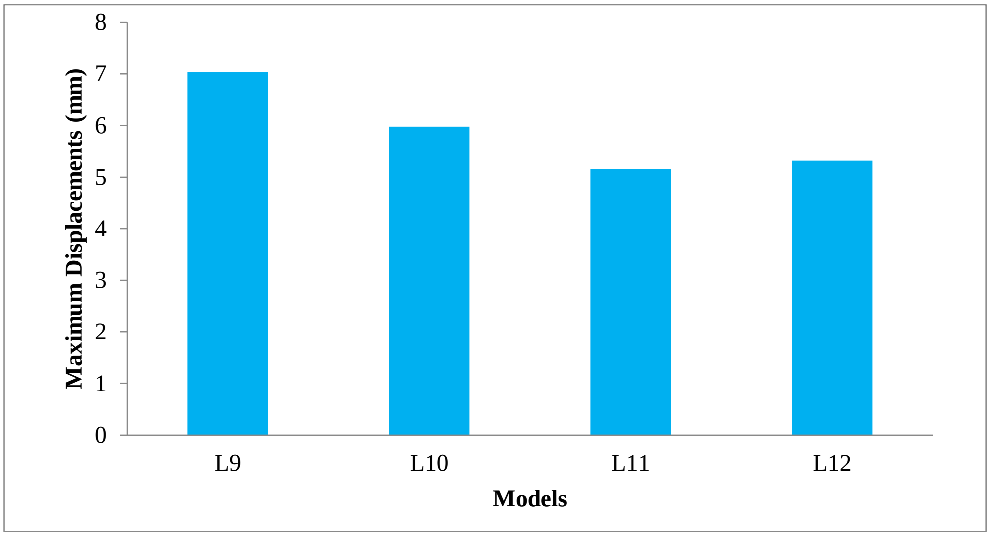


b) Case 2 along x direction

Figure 9. Maximum story displacements in global x direction



a) Case 1 along Y direction



b) Case 2 along Y direction
Figure 10..Maximum story displacements along y axis.

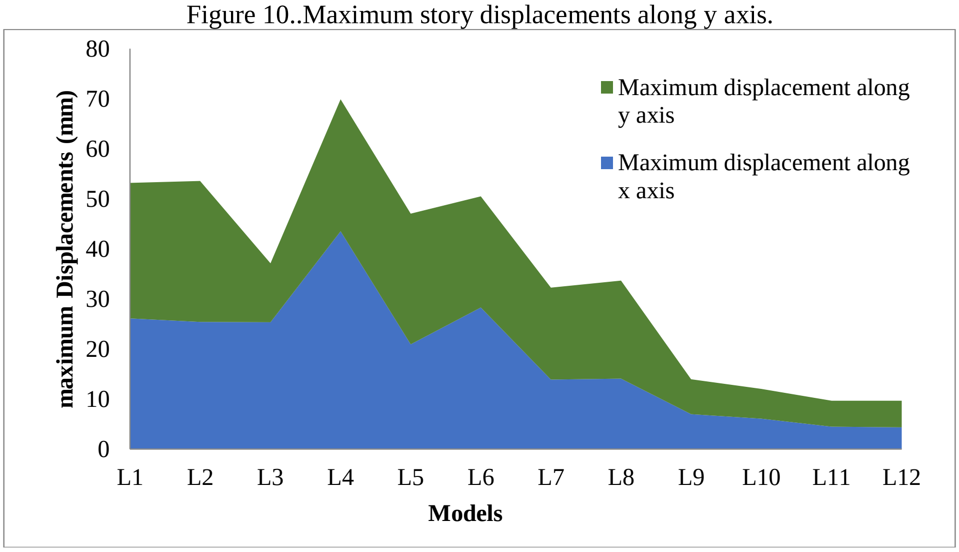
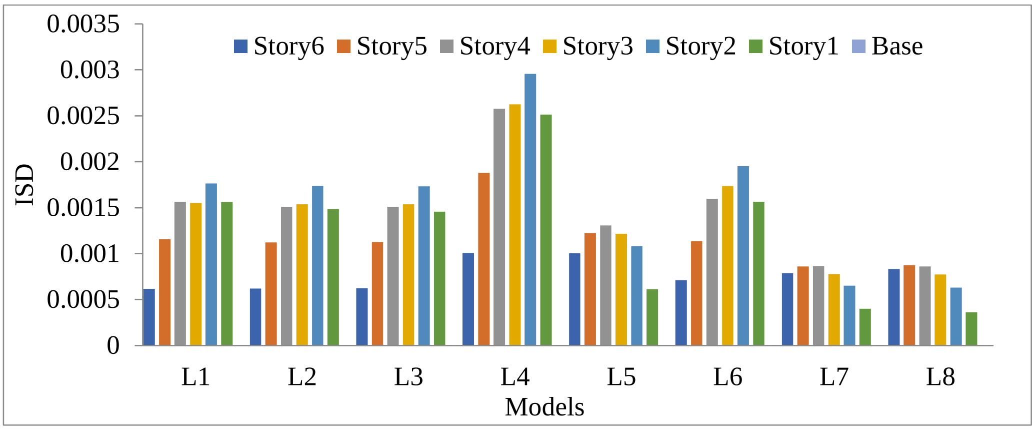


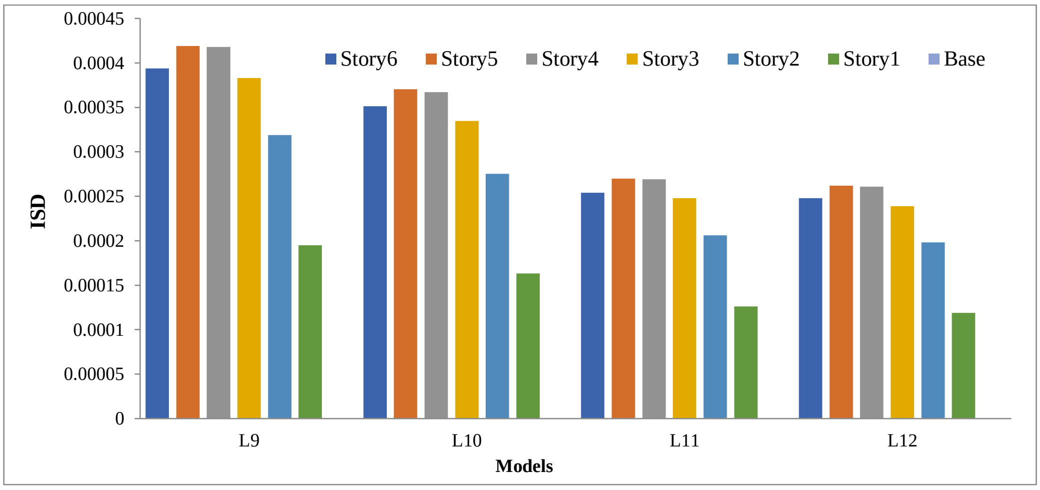
Figure 11: Maximum story displacements along the x and y-axis.

4.5 Inter story drift ratio(ISD)

It is noted that the L-shaped, six-story irregular buildings' story drift varies depending on whether shear walls are present or absent. As depicted in Figures 12 and 13, the graphs are drawn for both Case 1 and Case 2. It is observed that the ISD of all models is under the drift limit of 0.004 as the code suggested [24]. In each case of case 1, the base level's soft story causes the greatest drift to be seen at the second or third-floor level. However, in case 2, the tale with the greatest drift is story 5. Additionally, it is noted that in case 2, the shear walls used to resist the lateral pressure exhibit uniform drift. RC L shape structures are contrasted without shear walls frames L1 and with shear walls frames L2 to L12. When shear walls were used in case II, the inter-story reaction was reduced. The maximum ISD for models L9, L10, L11, and L12 in the L-shaped buildings in Case II is found to be 0.000419, 0.00037, 0.00027, and 0.000262 along the x-axis and 0.000425, 0.000366, 0.00031, and 0.00032 along the y-axis, respectively. The ISD of the models diminishes more as there are more bays with shear walls in the frames in both directions. Model L4 exhibits the highest ISD of 0.00295 along with the x directions as shown in Fig. 12, which is comparable to the maximum displacements in Case 1(a). The model without shear-walled L1 exhibits a maximum amount of ISD along the y-axis. In case II, adding the shear wall properly to the RC buildings successfully reduced the ISD of the structures, as shown by Figs. 12 (b) and 13 (b). But given the torsional behaviors in these models, case 1 ought to demonstrate unexpected ISD of the structures.

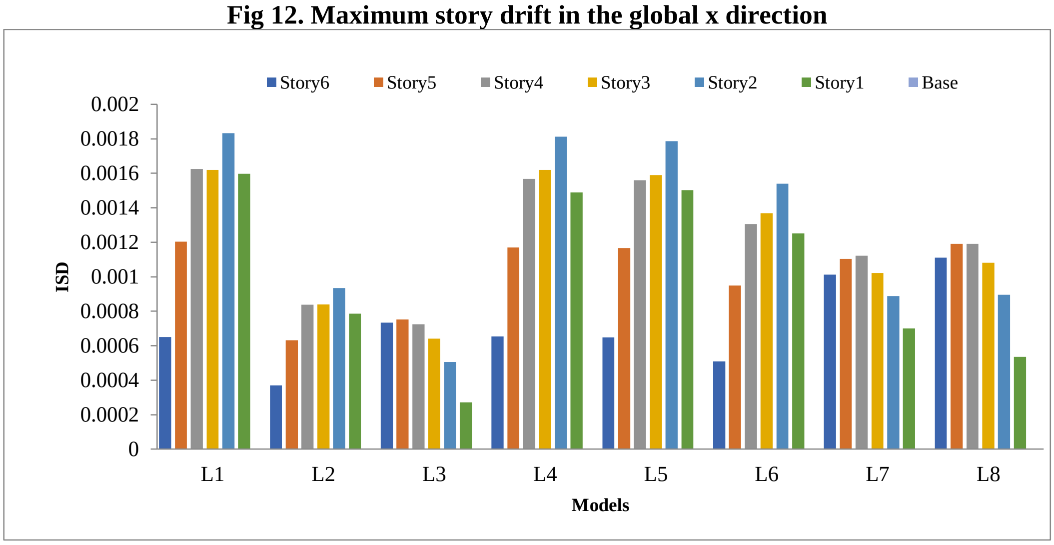


a) Case 1 along the x direction

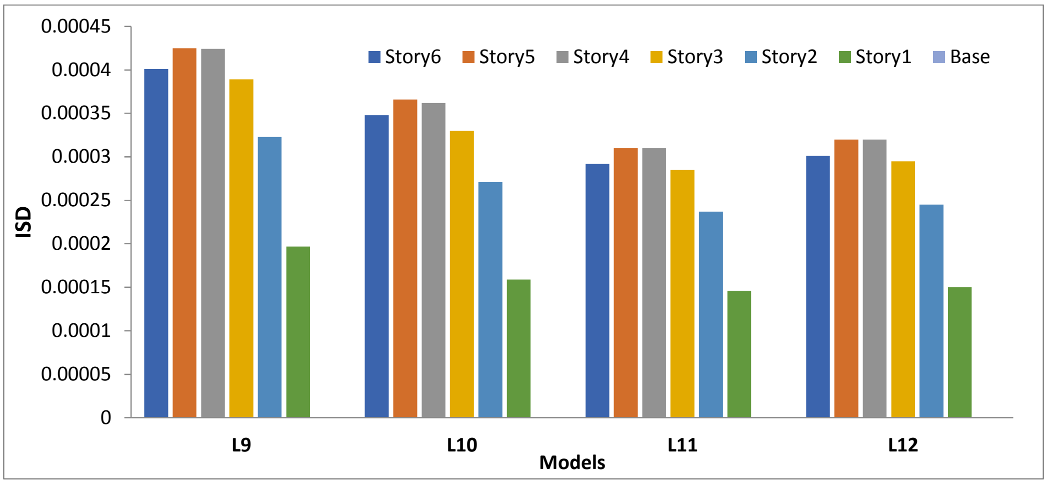


b) Case 2 along the x direction

Fig 12. Maximum story drift in the global x direction



a) Case 1 along y direction



b) Case 2 along y direction
Fig 13 Maximum story drift in the global y direction

4.6 Story stiffness response

The variation of story stiffness for each model is shown in Fig. 14. When compared to L1 models, the highest x-direction story stiffness requirements are nearly the same for L2 models. Along the x and y axes, respectively, the maximum story stiffness of model L3 is raised by 1.09 and 19.45 times that of L1. Similar to L1, story stiffness rose from L4 to L12 along the x-axis by 2.9, 9.899, 4.73, 11.53, 15.90, 24.28, 27.94, 39, and 44.6 times L1. (see Fig. 14). The story stiffness in L1, L2, L4, and L5 is almost equivalent along the y-axis. Models L6 and L7 have maximal story stiffness along the y-axis that is 2.35 and 6.65 times greater than L1's. The maximum story stiffness is also raised for models L8 to L12 by 11.4, 25.03, 28.59, 37.81, and 37.9 times L1 in the y-direction, respectively. (see Fig. 14). It has been observed that adding shear walls to building models to resist lateral loads quickly improves the story stiffness of the structures. In case II, there was a more uniform increase in the story's stiffness in each way. The model L1 shows the lowest story rigidity and the shear-walled L12 shows the highest story stiffness.

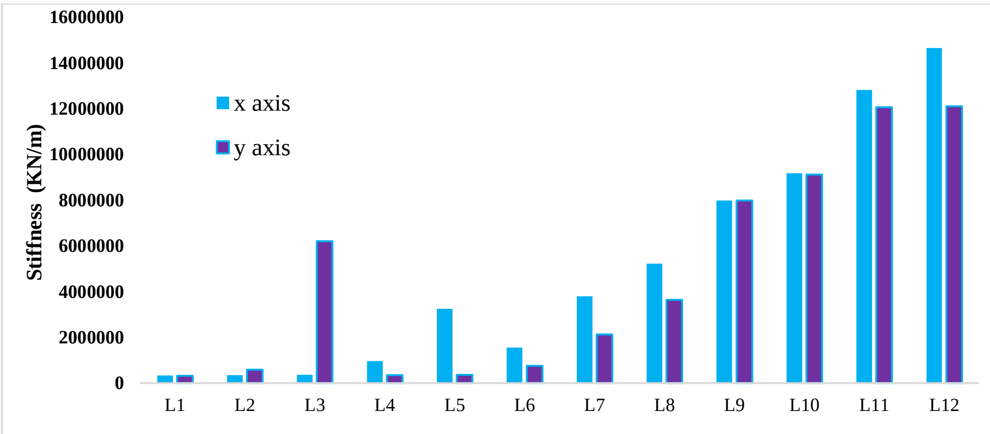
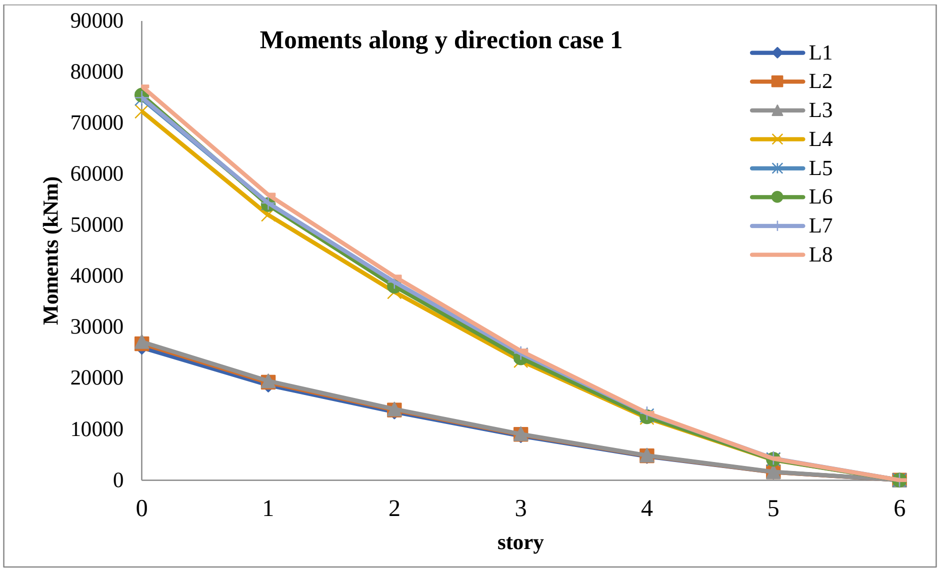


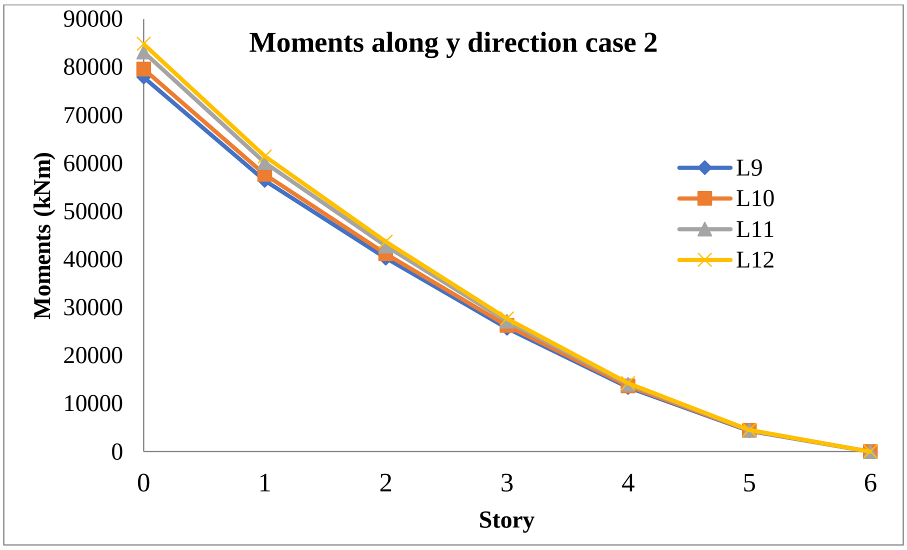
Figure 14. Maximum story stiffness along the x and y axis

4.7 Overturning Moment

The overturning moment response requirement at the base of the building for various model types is shown in Figs. 15 and 16. According to the figure, case 1 has the lowest overturning moment, whereas the addition of the shear wall causes a rise in both directions. In both directions, it is clear that the maximum overturning moment's values are observed in model L12. It is also noticed that similar values are observed in both directions. The data shows that almost 226% of overturning moments are increased in model L12 as compared to L1. In case 1 the maximum overturning moments are observed in model L8 which is 196% more than the L1. The lowest overturning moments are observed in the models L1 and in case 1, the minimum overturning moments are the lowest in the L2 models. In case 2, the lowest overturning moments are observed in models L9 and the maximum in L12.

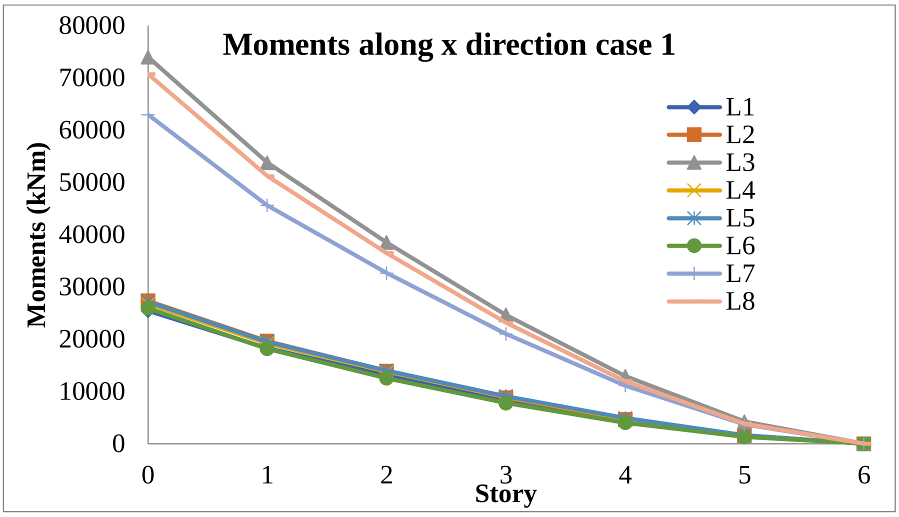


a) Case 1

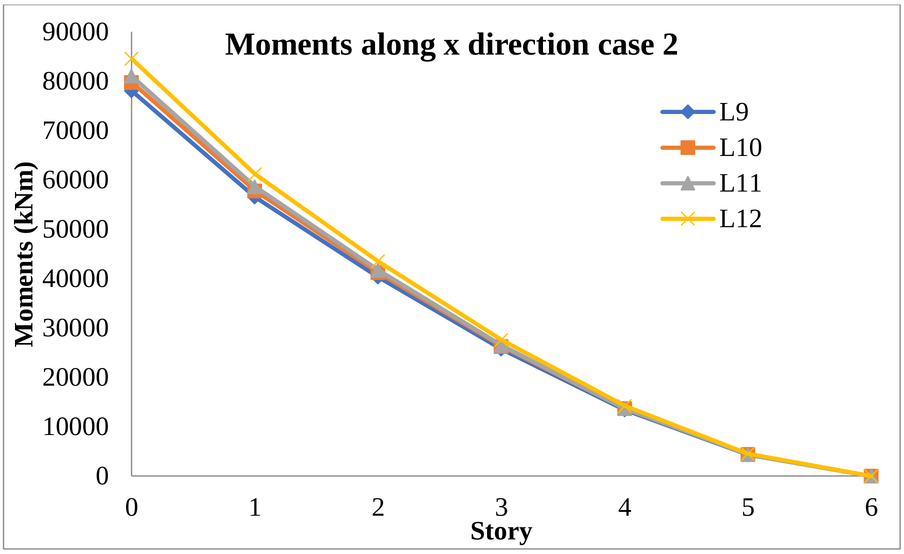


b) For case 2

Figure 15. Overturning moments in y direction due to RSx



a) Case 1



b) Case 2

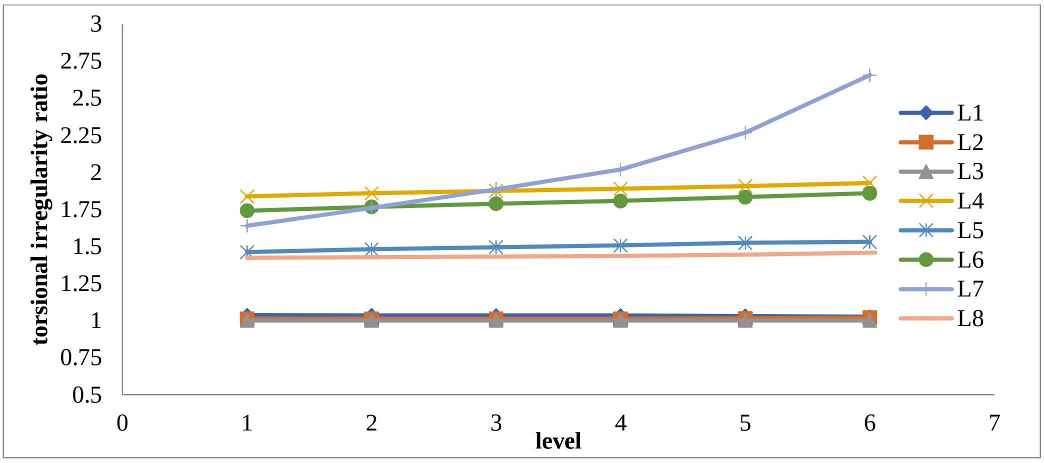
Figure 16. Overturning moments in x direction due to RSy

4.8 Torsional irregularity ratio

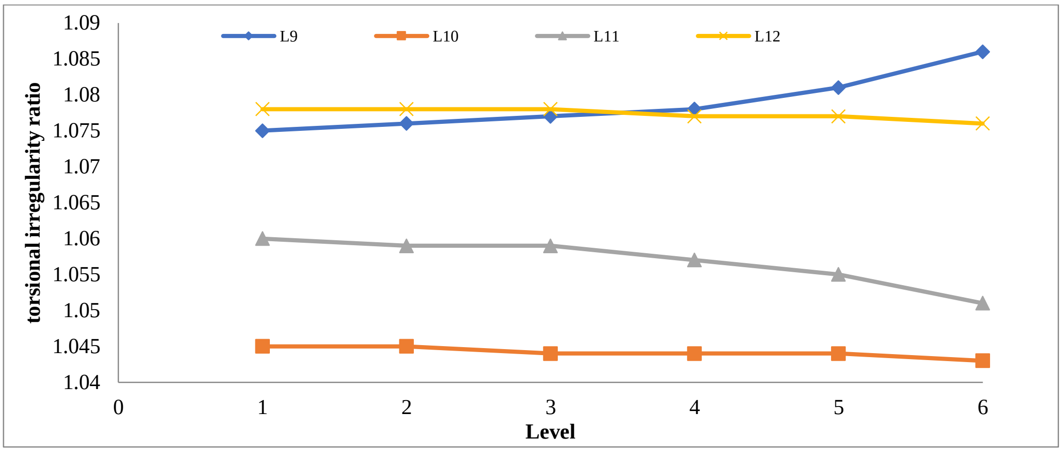
The most crucial data regarding the severity of building damage during seismic loading comes from the torsional irregularity ratio of the structures. It is an analytical index developed based on the multidirectional reaction of the asymmetry structure's structural response. The limit of the torsional irregularity ratio, which is 1.2, was investigated by various studies [12]. This indicates that such structures are impacted by differential displacements in the plan when the torsional irregularity ratio limits are exceeded. The structure's seismic characteristics are impacted. There are no torsional irregularities in the structures when the torsional irregularity ratio is less than 1.2.

The torsional irregularity ratio for an L-shape with and without a shear wall, as well as the story of the structures, are shown in Figs. 17 and 18. Through the height of the building's stories, the torsional irregularity ratio changed. Some models exhibit a higher torsional irregularity ratio in the bottom story than in the upper story. It might be a result of the buildings' L-shaped projection, which results in the lower story being made as a soft story. When a unidirectional spectrum is used along the x-axis, the highest torsional irregularity ratios for models L2–L8 are 1.02, 1.001, 1.92, 1.53, 1.858, 2.654, and 1.458 for case 1, respectively. In case I, it is seen that model L7 exhibits the highest torsional irregularity ratio, whereas model L1 exhibits the lowest. (less than 1.2). In case I, the torsional irregularity ratios of L4–L8 are greater than 1.2 along the x-axis, and L2, L6, L7, and L8 are greater than 1.2 along the y-axis. (see Fig 17 and 18). Since these models in Case I represent configurations of incomplete shear-walled frames, they exhibit torsional irregularity in the structures, particularly in Model L7. It is observed that models L1, L2 and L3 have nearly the same torsional irregularity ratio is one (case 1 along the x-axis). Along the Y axis for case 1, L1, L5 and L5 have one torsional irregularity ratio.

In case II, it is noted that adding the shear wall to the L1 structures improves the torsional behavior of the models within certain bounds. The x and y axes have appropriate walling in the models L9–L12. When shear walls are applied carefully to RC buildings in an L shape, excellent seismic behaviors are seen. The structures exhibit minimal displacements and deviations and are torsionally secure. The shear wall enhances stiffness and is torsionally safe (if properly applied), making it preferable to use for regular purposes in irregular buildings or for retrofitting. [9].

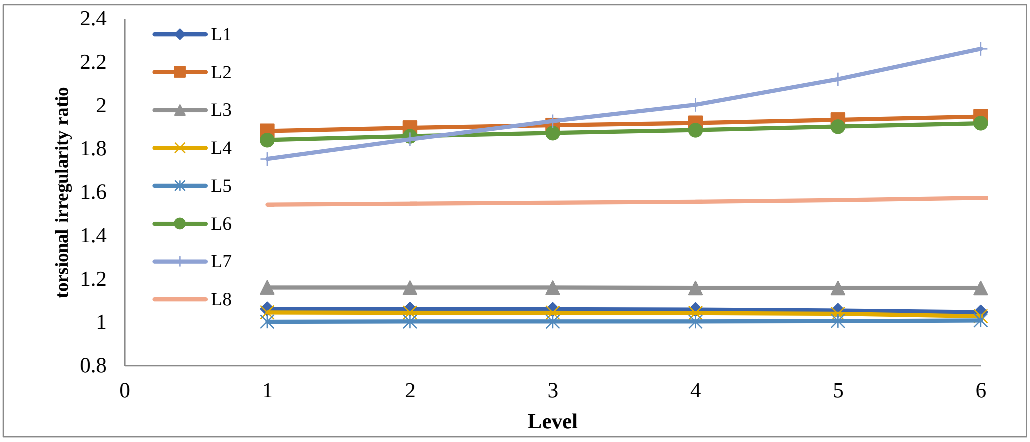


a) Case 1

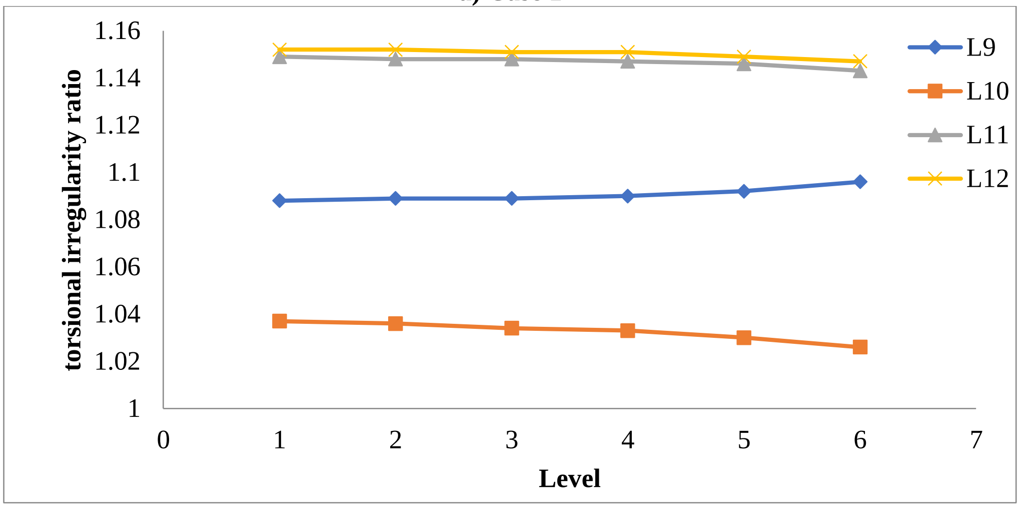


b) Case 2

Figure 17. Torsional irregularity ratio for different models along x axis



a) Case 1



b) Case 2

Figure 18. Torsional irregularity ratio for different models along the y-axis

4.9 Investigation of torsional irregularity coefficient with torsional amplification factor (Ax)

Because the model has a higher torsional irregularity ratio (>1.2), the torsional amplification factors were further investigated for the L4, L5, L6, L7, and L8 along the x-axis. similarly along the y axis models L2, L6, L7 and L8 are studied for torsional amplification factors. Table 5, and 6 shows the amplification factors for models along the x and y axis respectively. When the torsional irregularity coefficient is studied it is noticed that some models show that its values range between 1.2 to 2.083, which means it is suggested that eccentricity amplification factors should be computed by using the equation. It should be less than one as per codel provisions. It is also noticed that model L7 has a torsional irregularity ratio greater than 2.083 so Ax should be equal to 3. In table 5 and 6 shows that eccentricity amplification factors are more in models L2 L4, L6 and L7. These models are especially related to the case 1 building. However, in the case of one eccentricity amplification factors are assumed because these models are safe against the torsional effects.

Table 5. Maximum torsional amplification factor (Ax) for structure along x axis.

Number of stories	Types of structure				
	L4	L5	L6	L7	L8
Story6	2.34	1.48	2.10	1.87	1.40
Story5	2.40	1.52	2.17	2.15	1.41
Story4	2.44	1.55	2.22	2.47	1.42
Story3	2.47	1.58	2.27	2.83	1.43
Story2	2.52	1.61	2.33	3.57	1.45
Story1	2.58	1.63	2.40	4.89	1.47

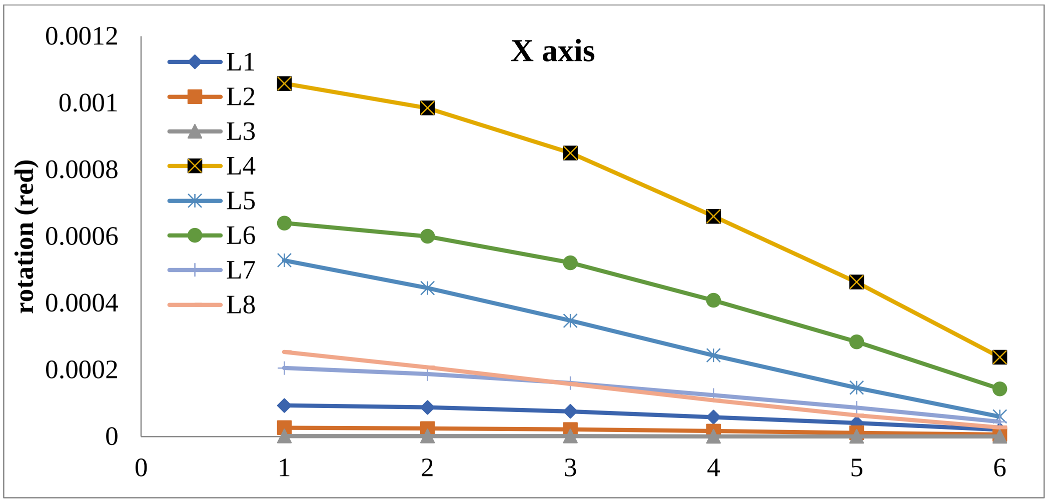
Table 6. maximum torsional amplification factor (Ax) for structure along y axis.

Number of stories	Types of structure			
	L2	L6	L7	L8
Story6	2.46	2.35	2.14	1.65
Story5	2.50	2.40	2.36	1.66
Story4	2.53	2.44	2.58	1.67
Story3	2.56	2.47	2.79	1.68
Story2	2.60	2.51	3.13	1.70
Story1	2.64	2.56	3.55	1.72

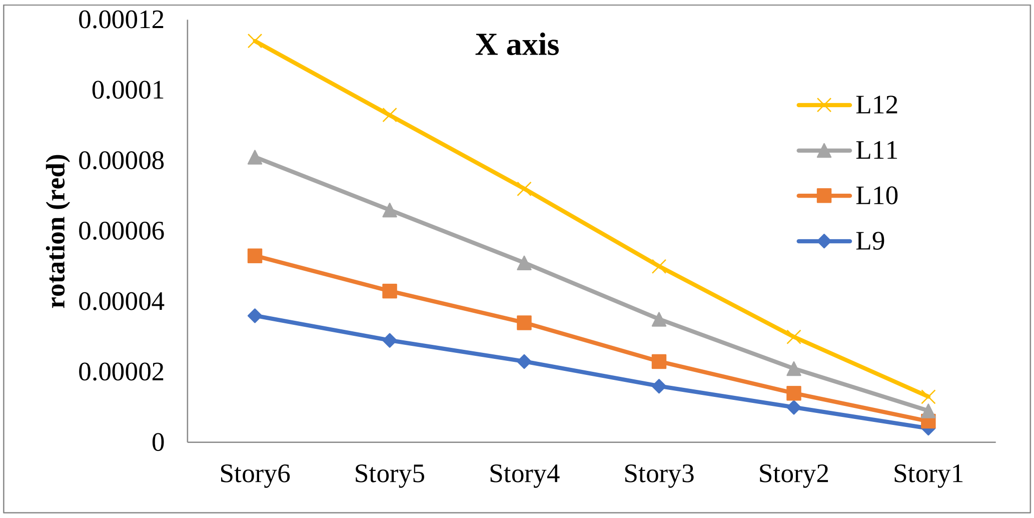
4.10 Torsional diaphragm rotation

The effects of such harmful effects cause twisting of the building along with translation displacement for buildings with complex seismic configurations, despite the fact that the torsional seismic effects caused by the irregularity of plan layout of building structures have been highlighted for seismic design in many codes. Torsional diaphragm rotation is regarded as a significant parameter to evaluate torsion moment plus the chance of local failure for the outer element, posing a threat to a structure's robustness that is heavily reliant on the performance of the diaphragms. In-plane bending is performed on the floor system that twists as a result of the differential movement of the slab sides. The torsional resistance of the frames and the in-plane rotation of the slabs are influenced by the proportional stiffness of the horizontal to vertical structural systems [9].

Figures 19 and 20 demonstrate how the use of shear walls causes a small increase in floor rotation over height for models of irregular L-shaped buildings. The figure also demonstrates that as the irregularity of the structure with shear walls increases, the diaphragm's torsional rotation also increases. In instance, I, the torsional diaphragm rotation values for L1–L8 along the x-axis are: 0.000093, o.oooo26, 0.000001, 0.001058, 0.000528, 0.00064, 0.000205, and 0.000253 rad. In case II, the value is lower than in case I, but it increases as the shear-walled span in L-shaped buildings increases. Case 2 represents the minimum torsional diaphragm rotation among case 1 with the values: 0.000036, 0.000017, 0.000028 and 0.000033rad for L9- L12 respectively along the x-axis. Fig. 19 and 20 show the maximum torsional diaphragm rotation for each model. Similar types of results were also observed in the Y directions. It is also noticed that the maximum rotations are observed in the top level of the buildings and it increased as the height of the structures increases [12].

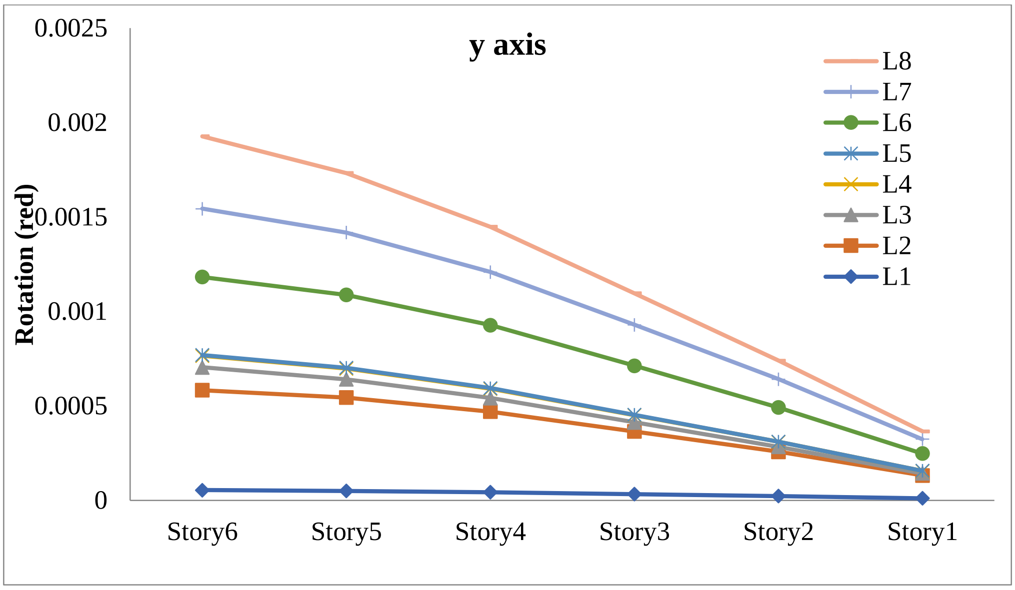


a) case 1

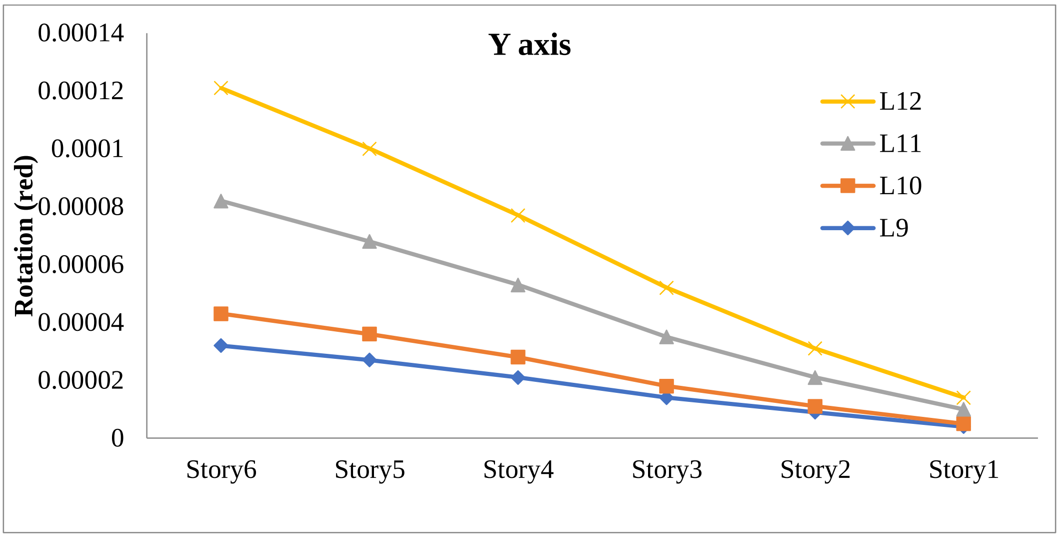


b) Case 2

Figure 19. Variation of floor rotations for structures with x-axis



a) Case1



b) Case 2

Figure 20. Variation of floor rotations for structures with a y-axis

4. 11 Columns Design Property

The columns, beams, slabs, and imposed loads are the same for the reference model L1 and the other walled models L2-L12. All base columns have 3.8% rebar, and this is set for all models. In the L1 model, the columns are appropriately sized and constructed. Models L2 to L12 were created after adding the shear wall in model L1 in a distinct manner. Studying the columns' safety in light of their capacity ratio, design moments, and design axial forces is essential. As shown in Fig. 21, the capacity ratio, axial load, and moment in the chosen columns are examined to determine the impact of the shear wall on the column (corner columns may or may not be directly linked to the shear wall). The corner base columns, C1, C2, C3, and C4, are the subject of comparisons between models L1 and L12 based on changes in their construction parameters.

Models L1 to L12's capacity ratio, design moment, and axial capacity are shown in Tables 7 and 8 for each selected column. The axial load in the columns is seen decreasing when they are connected to the shear wall. Model L1's axial load is 1778 kN, while Model L12's axial load for C1 columns is 723 kN, indicating how the addition of a shear wall reduces the axial weight on the columns. The columns' design moment decreased when they were close to shear wall configurations. Tables 7 and 8 show that the design moment and primary rebar demand in columns both decrease in the columns that are directly attached to the wall. The stress situation is indicated by the columns' capacity ratio. The capacity ratios for the C1, C2, C3, and C4 are 0.738, 0.52, and 0.51 for model L1, correspondingly. Due to the re-entrant impact in corner columns, the C1 columns experience the most stress. Models L4 and L6 are seen to be under duress. The capacity ratio of the columns, however, slightly dropped in case 2, properly shear walled models. Shear walls should be used symmetrically to counteract the torsional impact in L-shaped buildings to lower the torsional hazard level. Several columns will be overstressed as a result of the capacity ratio facing the torsional hazard in L-shaped models, which is defined as a major trend in seismic design requirements for columns due to plan irregularity. If only one way is applied, the shear wall's use of columns may result in failure due to overstress. When compared to other columns, the columns near re-entrant corners experience much greater shear forces; therefore, the extra shear force brought on by torsional moments should be taken into account when designing irregular buildings. The torsional effect should be closely examined when designing L-shaped shear-walled RC buildings.

Table 7. Column design parameter for case 1.

Columns	Columns design parameters	L1	L2	L3	L4	L5	L6	L7	L8
C1	Axial force (kN)	1778	1778	1778	1785	1778	2194	1565	1017
	Moment (kNm)	122	119	116	134	121	45	60	57
	Capacity ratio	0.738	0.732	0.726	0.774	0.737	0.688	0.91	0.648
C2	Axial force (kN)	649	650	1579	819	1955	1130	613	1500
	Moment (kNm)	137	171	44	209	62	202	122	44
	Capacity ratio	0.52	0.65	0.865	1.061	0.66	1.169	0.507	0.827

C3	Axial force (kN)	644	252	1050	801	1108	1376	741	719
	Moment (kNm)	135	114	25	143	32	35	47	44
	Capacity ratio	0.51	0.395	0.564	0.826	0.611	0.754	0.33	0.311
C4	Axial force (kN)	643	270	1045	505	3175	1246	695	1148
	Moment (kNm)	135	109	25.5	312	65	115	46	38
	Capacity ratio	0.51	0.378	0.562	1.355	0.997	0.94	0.337	0.658

Table 8. design parameter for case 2.

Columns	Columns design paramerter	L9	L10	L11	L12
C1	Axial force (kN)	2194	2194	713	723
	Moment (kNm)	45	45	20	21
	Capacity ratio	0.687	0.687	0.234	0.238
C2	Axial force (kN)	412	769	642.6	657
	Moment (kNm)	31	27	25	24
	Capacity ratio	0.29	0.263	0.224	0.226
C3	Axial force (kN)	533	464	663	680
	Moment (kNm)	32	25	20	18
	Capacity ratio	0.347	0.296	0.221	0.222
C4	Axial force (kN)	456	402	630	628
	Moment (kNm)	31	25	22	19
	Capacity ratio	0.309	0.266	0.215	0.209

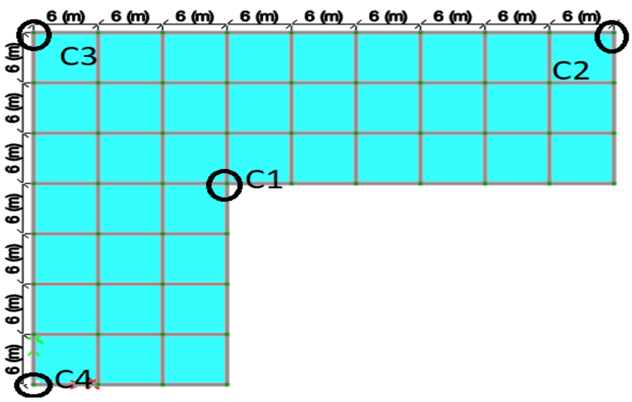


Figure 21. Plan view with selected columns for study

V. CONCLUSIONS

To calculate seismic parameters like base shear, fundamental time period, maximum displacements, inter-story drift, stiffness, torsional irregularity ratio, and column forces (axial forces, moment, capacity ratio), among others, building modeling is done in the ETABs program. The study's findings include the following conclusions:

- It is concluded that almost 80% reductions in time periods were observed when the shear wall was used in the models (L12).
- As observed the effect of the shear wall in RC structures, increased the base shear in the L shape buildings when the shear wall is used. In case 2, the base shear value increases as increases the number of bays is walled along in both directions. Compared to model L1, the base shear values in model L12 increased by 214%.
- Maximum displacements of the structures decreased when the shear wall are used in the L shape buildings. In the structure L9, L10, L11 and L12, it can be observed that the maximum displacements are reduced by 74%, 77%, 83% and 83% along the x-axis and 74%, 78%, 81%, and 80% along the y-axis after providing shear wall in L1 models respectively. If the shear wall is provided symmetrically, it reduced the maximum displacements properly with a minimum torsional effect.

- The maximum value of story drift does not only depend on the direction and the lateral load considered but also on the story number. For linear static load case, RSx, in both upper and lower stories, the minimum story drift in the x direction is for the shear wall aligned in the x direction. As expected, adding a shear wall in the L shape of RC buildings, decreased the ISD of the structures effectively if bracing is used properly.
- In L-shaped buildings, the shear wall efficiently increases the story stiffness of the structures. The stiffness of the buildings was also enhanced when the number of bays had been braced.
- The overturning moment also increases as a shear wall in the L shape of buildings increases. The shear wall was provided in the x and y direction, in both directions the overturning moments also increased. The data shows that almost 226% of overturning moments are increased in model L12 as compared to L1. In case 1 the maximum overturning moments are observed in model L8 which is 196% more than the L1.
- The torsional irregularity ratios are studied it is found that case 1 shows unexpected behaviors. In L-shaped buildings, the shear wall (case 2) depicts the acceptable torsional irregularity ratio. The torsional irregularity ratio should be carefully examined when using the shear wall in the irregular structure.
- Also, eccentricity amplification factors are checked for selected models and observed that amplification factors are more in models L2 L4, L6 and L7 and seriously concerned needed such models.
- Floor rotations increase in direct proportion to the number of stories; the top story numbers experience the highest floor rotations. It is seen that the results obtained for torsional irregularity coefficients and floor rotations are quite contradictory.
- Column C1 shows the maximum axial forces and capacity ratio in the RC L shape buildings. It is observed that the incomplete introducing shear wall in the RC structure affected the capacity ratio in the columns which is directly attached to the wall. It is also noticed that introducing a shear wall in the models decreases the axial load and moment.
- Story drift, story stiffness, story displacement, and base shear all respond differently to earthquake forces depending on the configuration and position of shear walls. Shear walls give structures substantial strength and stiffness in the direction of their orientation. The shear wall should be placed so that it can help reduce eccentricity and distribute gravity and lateral loads as evenly as feasible.
- If shear walls are applied correctly in the models, they can be successfully used as retrofitting in L-shaped buildings. The designer should consider the torsional impact when creating irregular buildings with shear walls.
- However, further study is needed with nonlinear dynamic and static analysis methods. Also, it is necessary to study the interaction of columns and shear wall connections and their effect on the overall structures.

Conflict of interest

There is no conflict to disclose.

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