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STUDY OF THE SEISMIC RESPONSE OF DIFFERENT TYPES OF IRREGULAR BUILDING SHAPES WITH A REVIEW

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Abstract
The design and analysis of earthquake-resistant structures plays an important factor all over the world. Hilly areas like Ambikapur, Korea, Dantewada and Jagdalpur as part of Chhattisgarh are more vulnerable in terms of seismic collapse structures in recent years and today the demand for high-rise structures with irregularities as shown below is increasing due to high cost of high-rise buildings. Land. There is a significant need or requirement for infrastructure to verify seismic stability. This article deals with the analysis of different RCC frames with different shapes such as regular and irregular building planes such as square, L-shape, C-shape and T-shape. The objectives of this article are to examine seismic parameters such as floor shear and displacement. To check stability and validate the most suitable shape of construction to avoid such shapes before any destruction.
Keywords: Asymmetry, Displacement, Storey Shear, Regular, Irregular.

Introduction
Seismic analysis is a subset of structural analysis and is the calculation of the response of a building structure to earthquakes. It is part of the process of structural design, seismic engineering, or structural evaluation and retrofit in areas where earthquakes occur frequently. A lot of research has been done on seismic analysis and is still ongoing, because the more we try to learn, the more we can reduce damage and save lives by changing different parameters of structural elements. During an earthquake, the structure begins to fail at weak points. This weakness arises due to instability in the mass, rigidity and geometry of the structure. Structures that have this discontinuity are called irregular structures. Plane irregularities are one of the main causes of failure of structures during earthquakes. In order to perform well in the event of an earthquake, a building must have four main features: simple and regular configuration, sufficient lateral strength, rigidity and ductility. Buildings that have simple regular geometry, uniformly distributed mass, and rigidity in plan and height suffer much less damage than buildings of irregular configuration. Traditional earthquake-resistant design philosophy requires that ordinary buildings be able to resist:

(a) Minor (and frequent) vibrations without damage to structural and non-structural elements;
(b) Moderate shaking with minor damage to structural elements and some damage to non-structural elements;
(c) Strong (and rare) shaking with damage to structural elements, but without collapse (to save lives and property within or adjacent to the building).

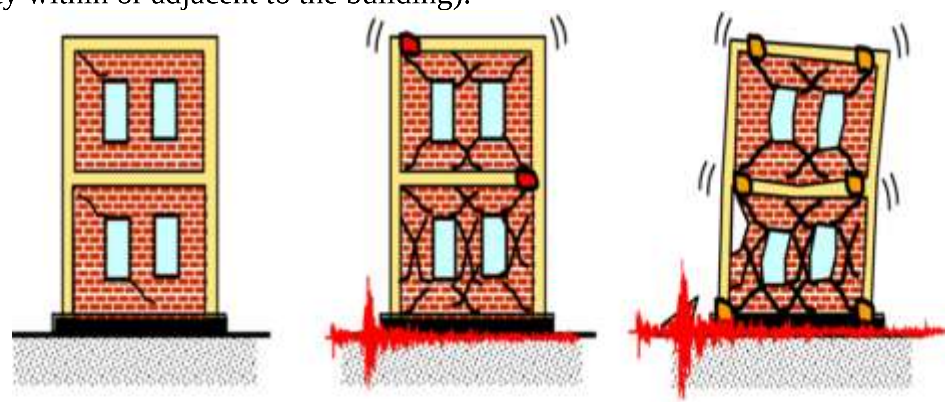

Fig. 1. Earthquake-Resistant Designs

Different Methods of Seismic Analysis

The selection of seismic analysis method type to analyze the structure depend upon the external action, the behavior of structural material and type of structural modal selected. In bureau of Indian Standards, these four methods of analysis are defined i.e., Linear Static Analysis, Linear Dynamic Analysis, Non-Linear static analysis &non-Linear dynamic analysis.

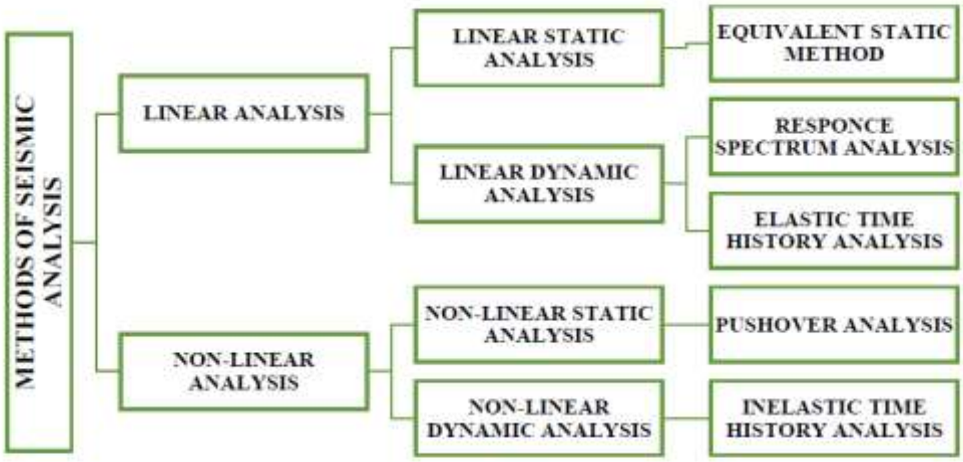

Fig. 2 Flow Chart of Methods of Seismic Analysis

Literature Study of RCC Buildings with Shear Walls and Reinforcements According to (Akash Panchal, 2017) working on a structure in a way that minimizes damage during an earthquake makes the structure ineffective as seismic action can occur or not. It occurs throughout your life and is an irregular phenomenon. In this article, the STAAD Pro V8i was used to analyze and design an existing RCC G+6 framed structure. The building is designed in accordance with IS 1893 (Part 1): 2002 for seismic forces in various seismic zones. The main objective of this research is to compare the change in steel ratio, strength in the X direction, shear moment and deformation in different seismic zones. The differences increase dramatically from zone II to zone V. From zone II to zone V, the steel ratio, maximum shear strength, maximum bending moment, and maximum deflection increase. (Balaji.U. A1, 2016) He studied that in ancient times we knew that an earthquake is an occasion that causes a disaster. Nowadays, structures are narrower and more susceptible to swaying and thus damage during an earthquake. In the past, researchers and engineers worked to make buildings more resistant to earthquakes. After numerous functional reports, it was shown that the use of lateral load resisting methods in the building configuration resulted in a significant increase in the seismic performance of the structure using ETABS 9.7.4, and work was carried out for various cases using COURT. Wall and reinforcement for exceptional heights, the maximum height considered for the award is 93.5m. Modeling was completed to study the effects of special conditions, as well as specific elevations, on seismic parameters such as base shear, lateral displacements, and lateral drifts. Learning for zone IV and zone V was carried out in soil type II (intermediate soil), as defined in IS 1893-2002. (Mahesh Rao, 2014) studied the behavior of G+11 multi-storey buildings with symmetrical and asymmetric configurations under seismic loads, and assumed that wind loads act simultaneously with seismic loads. In this article, a multi-storey commercial building is studied for earthquake and wind loads using CSI product software. Assuming that the material property is linear elastic, static and dynamic response spectrum analyzes are performed taking into account seismic zones, and the behavior of all zones is measured using three different soil types, i.e., hard, medium and soft. Different responses, such as story deflection and core shear displacements, are plotted for different regions and soil types. (Piyush Tiwari, P.J.Salunke, 2014) studied the performance of a multi-storey building under strong seismic movements and evaluated the effect of mass distribution, stiffness and strength in the horizontal and vertical planes of the building. In multi-storey buildings, ground movement typically causes crushing at locations of structural weakness in frames resisting lateral loads. This research examines the performance and behavior of a vertical, regular and irregular RCC frame structure subjected to seismic movement. This project uses five types of building geometry: one regular frame and four irregular frames. A comparative study was conducted between all of these building configurations in terms of height and area. Building frames are designed and analyzed using the software. Seismic responses such as shear force, bending moment, floor drift, and floor deformation are obtained. Seismic analysis is performed according to IS 1893 (Part 1), 2002. In all cases, the fourth seismic zone and the average soil layers are taken. The change in different seismic responses is observed along the building height. In 2016, (Mohiminul Haque, Sourav Rai, Amit Chakraborty, Muhammad Ilyas, 2016) studied that ETABS v9.7.1 and SAP 2000 v14.0.0 are used to analyze four different shapes (W-shape, L-shape, rectangle, square) of RCC building frames composed Ten floors of Seismic Zone 3 (Sylhet) in Bangladesh. In a comparative study, the deformation of buildings of various shapes due to static loads and nonlinear dynamic spectrum was studied. (Kakpure & Mundhada, 2017) in their paper, they studied that the present paper uses nonlinear static thrust analysis to conduct analytical investigation of buildings with regular and irregular shape. It is used to study and determine the seismic behavior of buildings with floors G+5, G+10 and G+15. According to the results of the study.

Review Based on Irregular Shaped Building

(Krishna, 2014) is concerned with investigating the optimal location of shear walls in an asymmetrical high-rise building. They examined high-rise buildings with different areas and shapes of shear walls (L, U, box, H, T, W). (Mohod, 2015) Buildings with irregular geometry respond differently to seismic action, according to research. The plan geometry is the parameter that determines its behavior under different loading conditions. STAAD Pro V8i structural analysis software was used to study the effect of irregularity on the structure. There are many factors that influence the behavior of buildings, and storey drift and lateral displacement play an important role in understanding the behavior of buildings. The results are presented in graphs and bar charts. According to research, a simple plan and configuration should be used during the planning stage to reduce the impact of the earthquake.

(Raoul et al., 2019) presented the paper based on numerical analysis to compare the structural analyzes of rectangular and hollow high-rise buildings. Shear, drift, and displacement were tested for construction analysis using the response spectrum method.

(Ramchandani & Mangulkar, 2016) studied response spectrum analysis in two different forms of structure, namely, regular and irregular, using STAAD PRO. The comparison results are studied and compared taking into account seismic characteristics and structural dynamic characteristics. According to the results, the values of the maximum earthquake response and the main response frequencies are very close and comparable.

(Santhosh & Mathew, 2017) mentions the study of improving the shape of shear walls in symmetrical high-rise buildings. Shear walls are placed symmetrically in symmetrical buildings because the centers of gravity and rigidity coincide. This article analyzes a high-rise building with different forms of shear wall. ETABS software is used to analyze the floor deflection and base shear of a multi-story building consisting of floors G+14 and G+29. For the seismic load analysis of the building, two different zones were taken into account (Zone III and Zone V). The dynamic method of building analysis (response spectrum analysis) was used.

(Sachdeva et al., 2018) Investigating the behavior of column shapes This work considers two shapes: circular and rectangular. The height and cross-sectional area of both column shapes are kept constant and OMRF is used. Seismic forces are taken into account when determining the realistic behavior of structures. The analytical strategy is based on two models. The dimensions of columns and beams are determined by construction practice. The conclusion of the work is presented, which is based on the variation of the shear forces in the direction of the floor and the development of its equations.

(Guleria, 2014) Different design configurations were examined such as rectangular, C, L and I. ETABS software is used to design a 15-storey R.C.C building. Building framed for analysis. After analyzing the structure, the maximum shear forces, bending moments and maximum floor displacements are calculated and compared for all analyzed cases.

(Harshitha & Vasudev, 2018) studied that since earthquakes are one of the most devastating natural disasters known to humanity, earthquake engineers have made significant contributions to structural safety. Adopting structural steel supports in the structure is an option to reduce earthquake damage. These members can be used as a horizontal load resistance system in a building to improve the rigidity of the frame to seismic forces. The present study is based on the analysis of an RC frame structure with structural steel braces performed using ETABS software. This work is carried out to know the behavior of different reinforcement systems for different arrangements. Building G+10 in District 4 was selected and analyzed with different brackets. The effectiveness of braces has been studied using 16 different models, one of which is the bare frame model. The behavior of the building was studied in terms of lateral displacement, shear at the base and span. The analysis values were compared and it was found that the seismic performance of buildings with reinforced frames is better than that of buildings with unreinforced frames. It was also found that different arrangements of anchoring systems have a significant impact on the seismic behavior of the(Krishna, 2014) is concerned with investigating the optimal location of shear walls in an asymmetrical high-rise building. They examined high-rise buildings with different areas and shapes of shear walls (L, U, box, H, T, W). (Mohod, 2015) Buildings with irregular geometry respond differently to seismic action, according to research. The plan geometry is the parameter that determines its behavior under different loading conditions. STAAD Pro V8i structural analysis software was used to study the effect of irregularity on the structure. There are many factors that influence the behavior of buildings, and storey drift and lateral displacement play an important role in understanding the behavior of buildings. The results are presented in graphs and bar charts. According to research, a simple plan and configuration should be used during the planning stage to reduce the impact of the earthquake.

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General Considerations for Planning Methodology of Seismic Analysis

In this study, equivalent dynamic analysis for different cases of regular and irregular shapes of building floor frames was performed using ETABS software. The loads considered are as per IS-875 (Part 1 and Part 2), IS-1893:2002/2016 and the load combinations are IS-875 (Part 5) compliant. This article analyzes the seismic analysis of the asymmetry plan carried out by Seismic Zone-V using the ETABS or ETABS software.

Structural Properties of Different Frames Being Analyzed

The constructed area of the asymmetric buildings mentioned here is considered the same in all cases. The construction area is 20 m x 20 m, which is equivalent to 400 m2, with a height of (low + 4) floors. The height from floor to floor is taken as 3 m for all structures, and the section characteristics are also common for all frame-frame structures. Below is the case study that will be analyzed and designed in this regard -

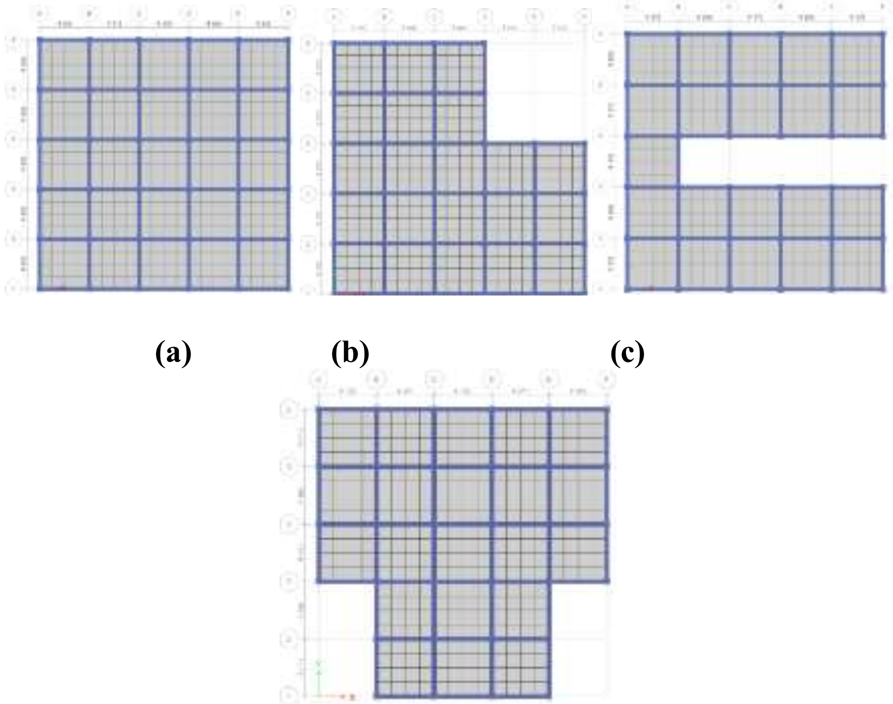
Table 1 Proposed Model Cases for the Research Study

Description	***Case ID***
Regular Square Shape Building	***REC***
L-Shape Building made with 16 % deduction	***L16***
C-Shape Building made with 16 % deduction	***C16***
T-Shape Building made with 16 % deduction	***T16***

The data of structure used in this work is in the form of tabulation considered for design and analysis of frame are given below-

Table 2 Structural Specification for the study

PARTICULARS	**STRUCTURAL PROPERTIES**
Total Built-Up Area	**20 X 20 m**
Number of Stories	**G+4**
Floor to floor Height	**3.0 meter**
Size of Columns	**450X 450 mm**
Beam Size	**230 X 450 mm**
Slab/Plate thickness	**150 mm**
Shear Wall thickness	**250 mm**
Bracing dimension	**230 X 450 mm**
Dead load	**IS 875 Part-1**
Live load	**IS 875 Part-2**
Roof live load	**IS 875 Part-2**
Earthquake load	**IS 1893:2016**



(a) (b) (c)

(d)

Fig. 1 Plan ofBuilding (a) Regular Square (b) L-Shape from 16% deduction (c) C-Shape from 16% deduction (d)T-Shape from 16% deduction

Material Specifications Considered for Design & Analysis of Cases

These models of building structures consist of two basic materials: concrete and reinforced steel. The following table shows the material properties considered for the design and analysis of all RCC structural buildings.

Table 3 Material Properties used in all Frames

Particular	Details
Grade of Concrete	**M30**
Grade of Main Steel	**Fe500**
Grade of Secondary Steel	**Fe500**
Beam & column cover	**25 mm & 40 mm**
Density of Reinforced Concrete	**25 KN/m^3**
Density of Brick walls, Plaster	**18 KN/m^3**
Young's modulus of steel	**2 X 10 ^{5} N/mm^2**

Loading Specification & Calculations Common for All Frames Used in Software

The loads which are to be studied in the project is discussed under following clauses below in which their calculation detail is also been discussed such as Primary load, Seismic Load & their load combination etc.

Primary Loads Applied for Analysis -

In Software, the loads are taken in the form of load cases i.e., primary load cases and the load combination of primary load cases also which are used same for all frame buildings. Firstly, here are the primary load cases which have been used in ETABS software analysis are given below in table 3.4 with their load type & numbers-

Table 4 Primary Load Cases

Load Case Number	Load Type	Name
1	Dead Load	DL
2	Live Load	LL
3	Seismic Dynamic Load	DQX
4	Seismic Dynamic Load	DQY

Load Calculations Used for All Frame Cases

The calculated load acting on the structures of dead load, floor live load, roof live load is given below-
Dead Load (D.L) –
In this analysis, dead load includes dead load of the slab, dead load of beam & column, dead load
Self-Weight of Slab/Plate = (unit weight of concrete X thickness of slab)
= 25 X 0.15
= 3.75 KN/m^2

Self-Weight of Column (0.45x0.45) =
= (unit weight of concrete X size of column)
= (25 X 0.45X 0.45)
= 5.0625 KN/m (per meter height)

Self-Weight of Beam in all floors =
= (unit weight of concrete X depth of beam X width of beam)
= 25 X 0.45 X 0.23
= 2.5875 KN/m

Live Load (L.L)

In this research, live load includes live load for all the floors as it is considered from the commercial building category given in IS 875 Part -1 and live load for roof is also considered from same above code. LIVE LOAD is designated as
L.L. and ROOF LIVE LOAD is designated as R.L.Lin ETABS. Here we consider-Live load for all the floors = 5 KN/m^2
Live load for roof (at Terrace)= 1.5 KN/m^2

Earthquake or Seismic Load (EQX & EQZ)

The calculation of the seismic load or aseismic load includes the total dead load plus the percentage of live or imposed load as per the considerations of IS 1893:2016 and most importantly the calculation of the seismic or seismic load. Moreover, as per IS 1893, the seismic weight of each floor is its total dead load plus the approximate amount of live or imposed load. In this study, the approximate amount of live or imposed load considered is 50% of the total live load as per IS 1893 (Table 8) and the rest of the calculation is done with the help of ETABS software. The seismic or seismic load is specified as DQX and DQY, where “DQ” means dynamic seismic load, and X and Y represent their lateral directions.

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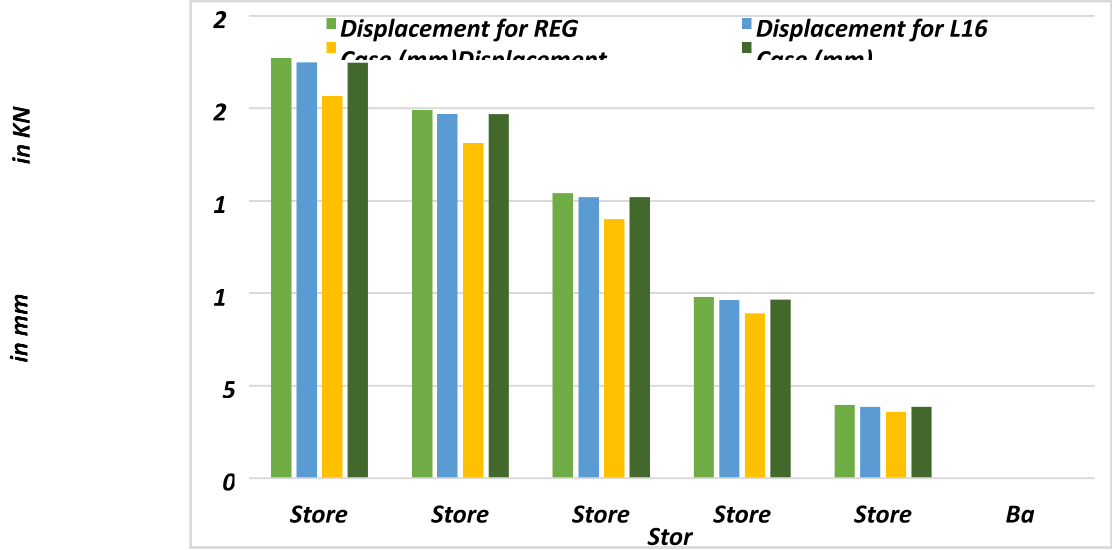
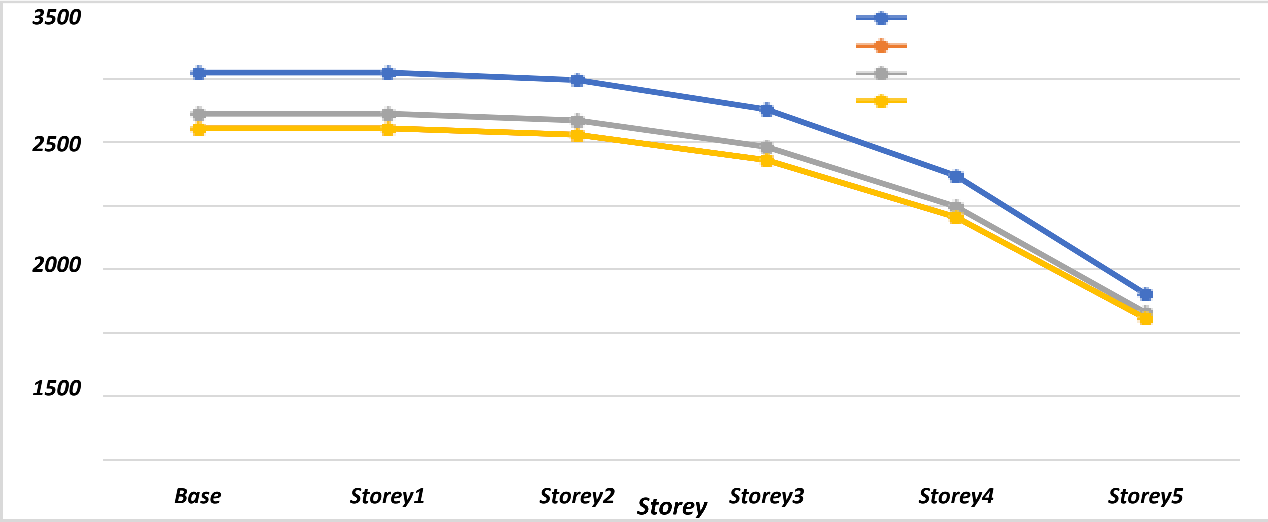
RESULT & DISCUSSIONS

The reports for the analysis is been exported from the modelling, and further collected and compared with all the casesshown below-



Graph 1 Comparison of Maximum Displacement Along X-Direction



Graph 2 Comparison of Storey Shear (KN)

CONCLUSIONS

The following conclusions were reached from the investigation:

1) It is observed that T-shaped buildings and regular buildings are more displaced compared to C-shaped buildings. It is found that the displacement of T16 (22.66 mm) is about 8.8% larger than that of the C-shaped frame (20.66 mm).). While the size of the T-32 (22.71 mm) is 9% larger than that of the C frame. This shows that the C frames have more rigid members, resulting in minimal displacement. We conclude that the greater the return angle, the greater the displacement.

2) It was observed that the displacement on the upper floor needed to be adjusted and modified. Therefore, to reduce the displacement to a minimum, several corrective measures, such as T-frame shear wall and C-frame X-bracing, are taken to avoid future weak points.

3) The floor cut of the normal model shows the maximum base cut. The cut-off value for C16 frame cases is 43% and L16 frame cases are 57% less than REG frame cases. This indicates that the larger the return angle, the lower the cutting value.

References

[1] Rahul Manojsingh , Pawar, S.B. Sohan, "Analysis Of Set Back Step-Back Building resting On Sloping Ground", Journal of Emerging Technologies and Innovative Research (JETIR) , ISSN-2349-5162, Volume 4, Issue 06 ,June 2017.
[2] Krishna Kumar, Sristi Gupta, Shivam Kumari "Dynamic Study Of Step Back And Set Back Building", International Journal of Civil Engineering and Technology (IJCIET) , Volume 9, Issue 5, May 2018, pp. 185-190.
[3] Nagarjuna, Shivakumar B. Pati "Lateral Stability of Multi-storey Building On Sloping Ground", International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056, Volume: 02, Issue: 04, July- 2015.
[4] Dr. S. A. Halkude, Mr. M. G. Kalyanshetti, Mr. V. D. Ingle, "Seismic Analysis of Buildings Resting on Sloping Ground with Varying Number of Bays and Hill Slopes", International Journal of Engineering Research & Technology (IJERT) , ISSN: 2278-0181, Vol. 2 Issue 12, December - 2013.
[5] IS: 875 (Part I) - 1987, "Code of Practice for Design Loads (Other than Earthquake) For Buildings and Structures", Part 1 Dead Loads - Unit Weights Of Building Materials And Stored Materials, Second Revision, September 2003.
[6] Miss. Pratiksha Thombre, Dr.S.G.Makarande, "Seismic Analysis of Building Resting on Sloping Ground", Journal of Emerging Technologies and Innovative Research (JETIR) ISSN-2349-5162, Volume 3, Issue 6 , June 2016.
[7] Sujit Kumar, Dr. Vivek Garg , "Effect Of Sloping Ground On Structural Performance Of Rcc Building Under Seismic Load", International Journal Of Science, Engineering And Technology (IJSET), ISSN: 2348-4098, Volume 2 Issue 6 August 2014.
[8] IS: 875 (Part 2) - 1987, "Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures", Part 2 Imposed Loads, Second Revision and June 1998.