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Seismic Study of RCC Building With Regular and Irregular Plan Using NBC 105:2020

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ABSTRACT- In building construction various regular structures are provided. Irregular structures are also provided during the construction. Due to earthquake various studies should be made for these irregularities. For the minimization of the damage of the structure due to earthquake necessary precautions should be taken during the design phase. Various damages may occur during construction due to seismic excitations. Damage in the structure will not be same due to various configuration, region, etc. The seismic behavior of the structure depends upon structural system, soil location, quality of the construction, earthquake characteristics and its maintenance. In this paper 10 storey building is considered for both regular and irregular structure. Model of the building is done in ETABS-2016. Loads that are considered such as earthquake/ dead/ and live load in both axis for purpose of analysis. Various types of load combinations are taken according to NBC 105:2020. In this paper regular and irregular plan of building are put under various seismic conditions. The primary goal of the paper is to observe the various performances between the models and which will have a better performance between the two. In the present study RCC building models having G+9 stories with regular and irregular plan considered for analysis. The analysis of model is done using dynamic method in ETABS software. At last, the results of seismic behavior of buildings are compared about the base drifts, shear, displacement, member forces, overturning moment, time period, stiffness.

KEYWORDS- Base shear; Storey Shear; Seismic Analysis; Storey Drift.

I. INTRODUCTION

Today's growing urban population need additional homes and land for habitation. Residential structures with many stories may accommodate more homes while using less land. The majority of buildings have asymmetrical designs and vertical arrangements. Compared to structures with irregular configurations, which have basic regular geometry and evenly distributed mass and stiffness in plan and elevation, buildings suffer substantially less damage during earthquakes. Building irregularities lead to eccentricity between the mass and stiffness centres, which has a negative impact on the structure. Additionally, although a regular structure may be simply assessed and planned without too many issues, an irregular building requires a substantially higher degree of engineering and designer work. We need a model to assess and construct a multistory structure that is safe from earthquakes. 1. Sound structural design. 2. System selection for lateral load resistance. 3. Dynamic attributes.

The term "plan irregularity" often refers to the structure's plan's unequal distribution of stiffness or strength. In earthquake situations, structures with plan irregularities often sustain serious damage. The term "plan irregularity" often refers to the structure's plan's unequal distribution of stiffness or strength. In earthquake situations, structures with plan irregularities often sustain serious damage.

Tall buildings are now considered to be technical marvels generally. From previous earthquakes, it has been shown that a large number of buildings are either completely or partially damaged as a result of earthquakes, and therefore it is crucial to determine seismic responses over such structures. The field of structural analysis involves the assurance of structures with the aim of predicting the responses of actual structures, such as buildings, spans, trusses, and so on. Before construction, each building must undergo a seismic inspection and fundamental research. In order to adequately accommodate this growing population in the restricted area, the building's height has increased to that of a medium-to-tall structure. Thus, seismic examination research and quake protection structure design are required to provide safety against the seismic forces of multi-story buildings. When there is an earthquake, a structure's dissatisfaction starts as a result of a deficiency. In most cases, geometry, mass brokenness, and solidity of structure are to blame for shortcomings. Structures usually collapse during earthquakes for this reason because of vertical irregularity. This paper' main objective is to consider structural seismic inquiry for static and dynamic evaluation in typical minute opposing casing. For the seismic analysis, we have considered the private building, a G+9 storey structure.

Only a small number of the constructions have regular layouts. Due to a variety of factors, irregular plans are taken into account in the current environment both in terms of plan and elevation, which might eventually result in a disastrous situation because of the risk of earthquakes. The damage caused by the earthquake should be taken into account while studying abnormalities, and the hazard's behaviour should be carefully examined. An object's (building's) regular geometry, ductility, enough lateral strength, and stiffness are all desirable qualities. A building with a regular shape and configuration and evenly distributed stiffness and mass will be less damaged than one with an uneven layout.

A regular building will perform better during an earthquake than an unplanned, irregular construction. The construction should be basic, rigid, and have a minimal amount of lateral strength. Building structural analysis is the study of how a structure responds to a variety of loads. During the design and construction of the structure, irregularities cannot be completely eliminated. As a result, several investigations of irregular structures and their behaviour should be conducted. The purpose of earthquake engineering is to lessen the risk that an earthquake.

A sizable area of Nepal is vulnerable to seismic risks that might be destructive. As a result, while designing buildings, the seismic load must be considered. The lateral stresses caused by earthquakes in structures are a worry. These lateral forces may result in critical structural stresses, unfavourable structural stresses, unfavourable vibrations, or excessive lateral sway of the structure. The degree of lateral movement at the top of the structure in relation to its base is known as sway or drift.

Seismic design methods are traditionally outlined because a building has to be able to withstand moderate and frequent shaking without being compromised, allowing it to continue serving its purpose even after an earthquake. The building should remain standing during mild earthquake ground motion, but with some structural and non-structural damage. It's possible that the greatest earthquake ever recorded or predicted for the area corresponds to this limit condition. The outcomes of the response spectrum approach are analysed here.

Contravention of the Plan:-Seismic response in asymmetric or planar structures is both translational and tensional due to stiffness and/or mass eccentricity. Uncertainty in evaluating the centre of mass and stiffness, as well as error in measuring the size of structural members, may lead an otherwise symmetrical construction to actually be asymmetrical.

Uneven Torsion:-to be taken into account when the floor diaphragms are stiff in their own plan relative to the vertical structural components that resist the lateral forces. A tensional irregularity is present when the greatest storey drift, when calculated with the design eccentricity, is more than 1.2 times the average of the storey drifts at the two ends of the structure along a transverse axis.

Aspects of Re-entry:-Plan and lateral force resisting system of a building have re-entrant corners if the two projections of the building past the corner are more than 15% of the plan dimension in the given direction.

In reality, modal analysis, of which the response spectrum method is a simplified subset, is the more general method of study. The period and form of the vibrational modes are typically calculated, and the maximum response magnitudes for each mode are then computed with reference to a response spectrum. In comparison to other methods, the response spectrum approach is both quick and inexpensive. There are two key drawbacks to this method. To begin with, the approach generates a great deal of output data, which may need a huge amount of computing work to run all potential design checks as a function of time. Since the response spectrum for a single earthquake in a given direction is not a smooth function, it is necessary to repeat the study for many earthquake movements to guarantee that all the important modes are stimulated. The code allows for dynamic analysis to be carried out using either the response spectrum approach or the time history method. Since the response spectrum of a single earthquake in a given direction is not a continuous function, it is essential that all the important modes are activated in either approach. For dynamic analysis, the code says that either the response spectrum method or the time history method can be used. When it comes to earthquakes in South Asia, Nepal is at the top. Since this is a very earthquake-prone area, it is crucial that any new construction undergoes a thorough seismic performance examination. New seismic design regulations require structural engineers to conduct both linear and nonlinear analyses for the design of structures in order to verify the findings and improve the performance of reinforced concrete (RCC) buildings. The purpose of this research is to perform equivalent static analysis (ESA) and pushover analysis on both regularly shaped and differently shaped RCC building frames with the same span size in mind.

Significant destruction may be caused by earthquakes. It is impossible to forecast where or when an earthquake will occur because of how random and unpredictable the factors behind them are. According to the 2019 Earthquake Disaster Danger Index assessment, over 60% of our country's geographical area is at risk of destructive levels of seismic hazard. Proper building safety measures may significantly cut down on costs and suffering. The way in which earthquake pressures are transmitted to the ground and the building's general design, scale, and geometry all play crucial roles in determining how it reacts during an earthquake. How well a building holds up during an earthquake depends on how well the forces that build up at different levels are transferred to the ground below.

Imperfection in Building ConstructionSeismic analysis must take into account building imperfections in both the horizontal and vertical planes. The code specifies allowable ranges for each kind of deviation and lays out what to do if a deviation is found to be very severe. The following are examples of irregular building plans and heights.

- Problems with the plan:
- Torsion that is abnormal
- With re-entering corners
- Overly sliced-up or hole-riddled floor slabs
- Out-of-plane displacements in vertical elements
- The system of non-parallel lateral forces
- Disparities in the vertical plane:
- Uneven stiffness (soft store)
- There has been a widespread anomaly.
- Vertebral geometric irregularit.
- Break in the plane of lateral force-resisting vertical components

- Problems with Strength Irregularity (Weak storey)
- Stub or floating columns.
- Oscillations with non-standard amplitudes and phases in two main axes

II. OBJECTIVES OF THE STUDY

This paper paper's objective is to analyse several models of multi-story buildings, both regular and irregular, in light of the recently implemented Nepali building code (NBC:105:2020). The goals of the research are as follows

- use ETABS to create a G+9 building with either a regular or irregular floor layout.
- To compare and contrast the values and conduct a dynamic analysis of the models.
- Based on analysis of output regarding storey shearing, drifts, deformations, storey rigidity, and reinforcements, draw conclusions about earthquake risk on the nature of the building with regular and irregular design
- Reviewing the data, from which we can draw conclusions and have a conversation, is the next important and necessary step.

III. LITERATURE REVIEW

Professor Mayur G. Vanza and Prajapati P.B. [1]- The following paper compares and contrasts the seismic responses of C-, rectangular-, and L-shaped structures. The two separate analyses were run using the (SAP- 2015) programme. Accelerograms were collected at Bhuj, Chamoli, and Uttarkhasi for use in studying the passage of time. Different models were examined with respect to a number of criteria, including storey shears and joint deflection.

According to Mr. S. Mahesh et al. [2] - This STADD PRO application is similar to others in that it may be used to plan the layout of a building with a regular or atypical number of stories in a number of different seismic zones. The technique of time series analysis followed them. Tolerance for seismic zone 4 led to the discovery that drift was minimal in otherwise normal construction.

Dr.S.K.Dubey&P.D.Sangamnerkar [3]- A five-story frame building was analysed and modelled in STAADPRO for the paper "Seismic behaviour of asymmetric R.C. structures." The building is intended to serve as a business complex. The T-shaped structure has open parking on the lowest floor. The data for Area IV has been evaluated.

Acc. To priyabrata Guha and Sanhik Kar Majumder [4]- The relative effects of wind and seismic load on many types of buildings have been compared and contrasted. This study will compare the effects of earthquakes and winds at a site with medium soil using the standards established by IS 875(part 3)1987 and IS 1893(part 1)2002.

Research by Shreyasvi.C and B.Shivakumaraswamy [5]- Examines the responses of buildings (both re-entrant and conventional) in a variety of seismic zones. Time history and spectral processing were performed in ETABS. Bhuj earthquake and accelerogram analyses using the elecentro technique of time history analysis.

According to Arvindreddy and R.J. Fernandes [6]- In this case, we survey the behaviour of both regular and irregular configurations in zone v. Static and dynamic procedures were arranged using ETABS. It was determined that the dynamic technique resulted in less displacements than the static method by comparing the displacements of both regular and irregular models.

Acc. To Priyabrata Guha and Arunava Das [7]- The results of a study that compared the seismic responses of both regularly constructed and irregular four-story buildings are presented. Analyses of pushovers and time histories were performed in SAP2000. The elecentro acceleration data was utilised for the time-history technique. Data analysis revealed that the time history analysis approach resulted in less dislocation in the irregular model situation compared to the pushover analysis.

Abhay Guleria [8]- Studies of RCC high-rises with a variety of floor plans were presented. The structure functioned well when subjected to seismic forces. Lateral load requirements were adopted from IS 1893(part 1)2002. Using finite element analysis, the analysis and modelling were carried out in ETABS programme. According to the results, I- and L-shaped buildings have the same overturning moment, storey displacement, and storey drift.

According to research by Sameer Pardeshi et al. [9]- Four different models were collected for this study: an L-shape, a T-shape, a regular, and a plus-shaped one—all employing a time-history analysis. The results of the -seismic study showed that the shear force was greatest when the building was oriented perpendicular to the seismic direction of movement. Visible displacement took the form of a T.

Acc. To MagliuloG.,Maddaloni.&PetroneC[10]- The "Influence of earthquake direction on the seismic response of irregular design R.C. frame structures" used three multi-story R.C. buildings in Italy as a case study. A (L-plan) follows a (rectangular plan) in order across the courtyard. It is analysed and modelled using (G+5) structure (STAAD –pro).

Prof. Vedantee Prasad Shukla et al. Published [11]- Response-spectrum analysis is used to compare the performance of buildings without and with shear walls in varying earthquake zones with slopes greater than 3 degrees. And the results were shown with respect to such factors as storey drift, storey displacement, period, and base shear. Shorter time frames are achieved with uneven construction. Additionally, (irregular component) base- shear is less than (regular component).

IV. METHODOLOGY

Here, two 10 stroey building is taken for the analysis. The building consist of 3 bay in both the direction. It has regular plan and the dimension of the building is kept constant. Using ETABS, we model a 10-story structure with both a normal and an irregular floor plan for this investigation. These scale models of buildings have a floor space of 9m x 11.3m. The standard story height used across all models is 3.175 m. In both the X and Y axes, you'll find a variety of storage compartments. We use a footing depth of 1.6 metres.

In these representations, the size of the beams and columns is assumed to be the same on every floor.

The following models are used in this investigation:
Regularly-Shaped Buildings as a Model1
Shapeless Model 2 structure.

Dead loads

Brick masonry : Unit Weight 20KN/m3
Finishes (Floor Finishes) : 1 KN/m2
Reinforced Concrete Elements : Unit Weight 25KN/m3
Live load: 3 KN/m2 on all floors except roof.
Lateral loads : Earthquake Loads as per NBC:105:2020

Lateral Load

Time periods of the modes are computed using ETABS 2016 software, and lateral forces are computed using the equivalent static approach at each storey level in accordance with NBC: 105:2020. The lateral forces in the buildings were determined by taking into account the following factors.
Zone factor (Z) = 0.3
Importance factor (I) = 1
Response Reduction Factor(R)= 5(SMRF)
Soil Type = C

The above-mentioned load combinations are taken into account in the analysis, and additional combinations are taken into account for the dynamic analysis.
For Regular
DL+0.3LL+REX
DL+0.3LL+REY
For Irregular
DL+0.3LL+REX +0.3REY
DL+0.3LL+REY+0.3REX

Material properties

i. Concrete grade: M25 for beam and Slab,M25 for column
ii. Steel grade:Fe 500
iii. Modulus of Elasticity of Steel (Es): 2x105N/mm2
iv. Element Dimensions

All of the versions use a slab thickness of 125 mm. All beams are assumed to be model 1:-355.6mm x 609.6mm model 2:-355.5x660.4mm. The assumed thickness of the outside walls is 250 mm and the assumed thickness of the inner walls is 125 mm.

In this study following models are prepared for the study:

First Model 1- Building model using NBC:105:2020 for regular building
Second Model 2- Building model using NBC:105:2020 for irregular building.

Model Generated in ETABS-

Here figure 1 shows 3D view of model for both models, figure 2 shows elevation of model which is similar for both models, figure 3 represents the wall load acting in the models ,figure 4 shows the live load of both models and figure 5 represents the floor finish load for the both models.

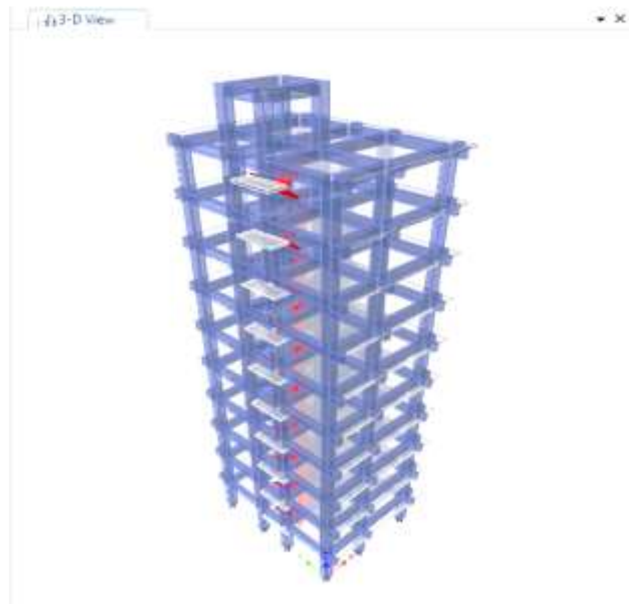

Figure 1: 3D view

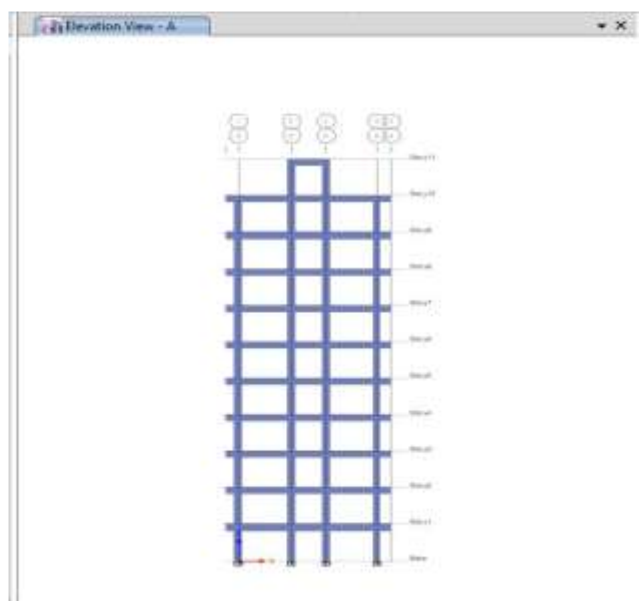

Figure 2: Elevation View

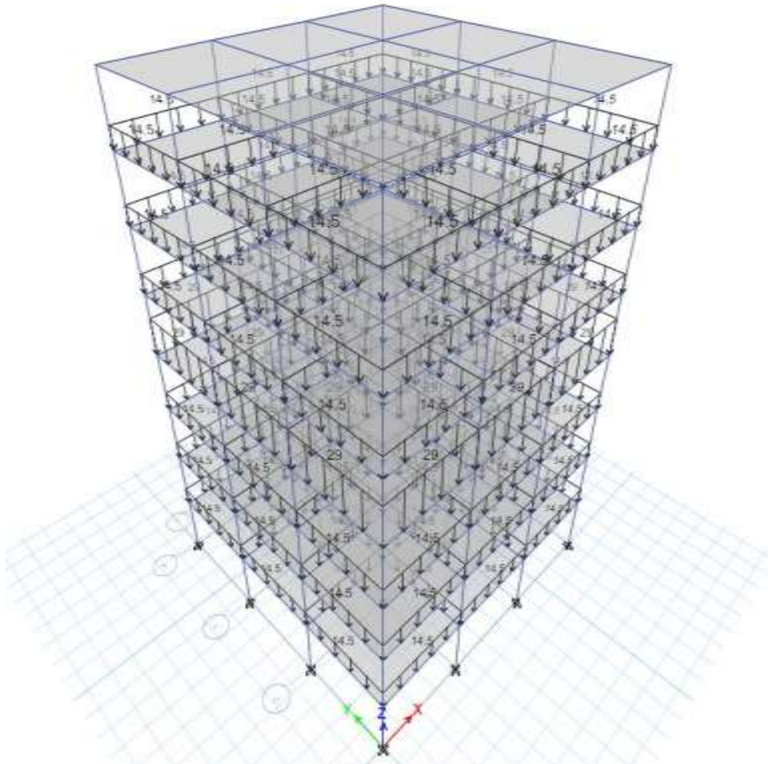

Figure 3: Wall load

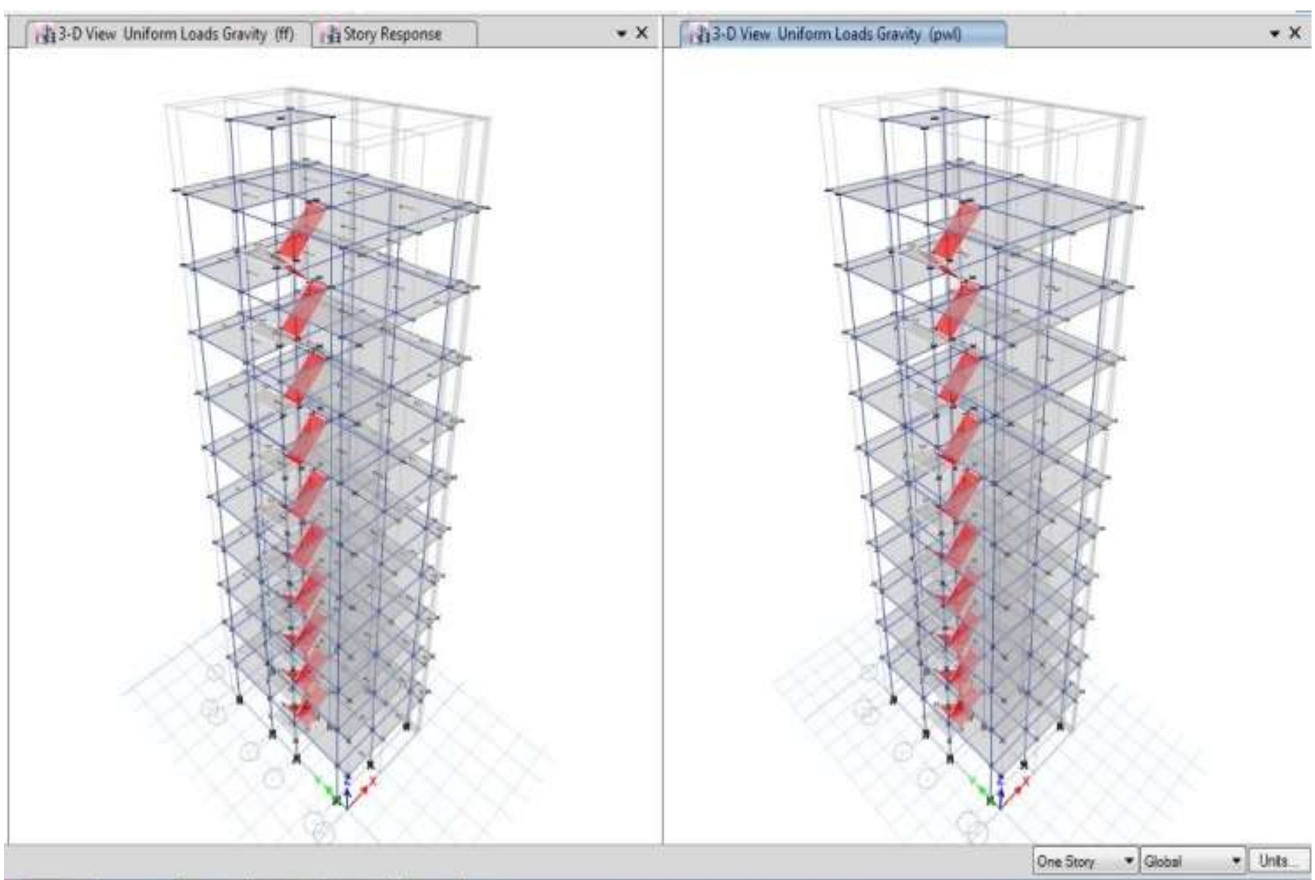

Figure 4: Live load

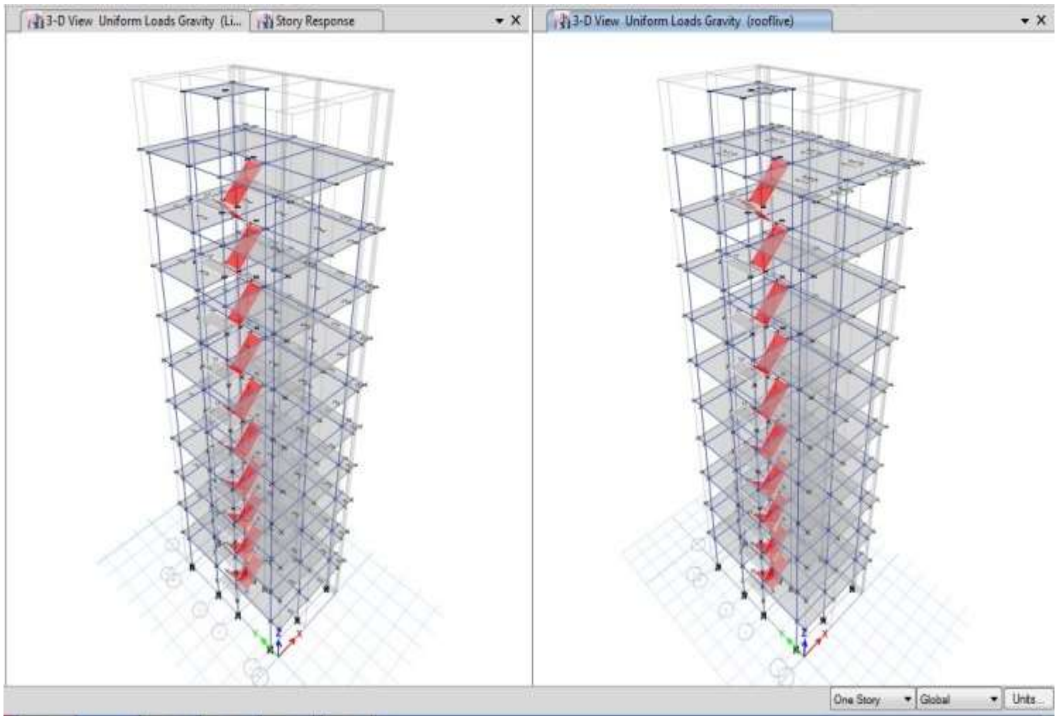

Figure 5: Floor FInish load

V. EXPERIMENTAL RESULTS

A. Displacements

Here table no.1 shows that Model 1 has the higher displacement than model 2. This shows that regular building analyzed by NBC 105:2020 has higher displacement value than irregular building.

Table 1: Displacements of models

	Displacement in mm	
Storey Level	Model 1	Model 2
10	159.308	152.077
9	152.447	145.624
8	142.321	136.061
7	128.985	123.393
6	112.913	108.045
5	94.606	90.54
4	74.619	71.422
3	53.547	51.27
2	32.171	30.823
1	12.136	11.653
0	0	0

Figure 6 which is the graph of displacement for both models which shows shows that Model 1 has the higher displacement than model 2. This shows that regular building analyzed by NBC 105:2020 has higher displacement value than irregular building

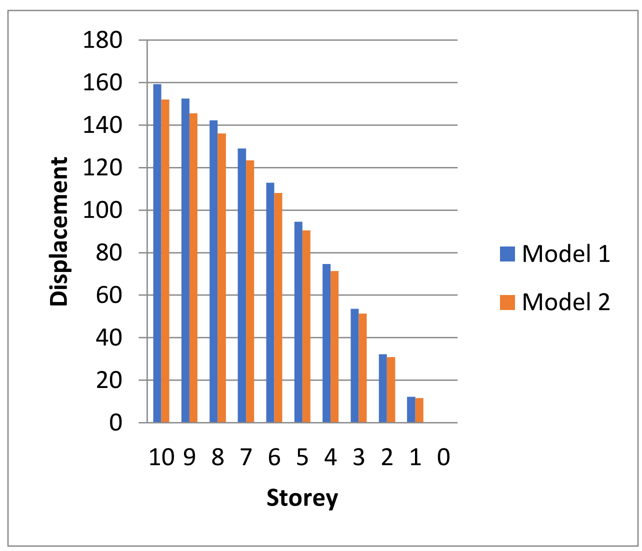

Figure 6: Storey Displacements

B. Drift

Table no.2 shows that Model 1 has the higher drift than model 2. This shows that Model 1 has the higher displacement than model 2. This shows that regular building analyzed by NBC 105:2020 has higher driftt value than irregular building.

Table 2: Drift of Models

	Drift	
Storey Level	Model 1	Model 2
10	0.002161	0.002033
9	0.003189	0.003012
8	0.004205	0.00399
7	0.005079	0.004834
6	0.00579	0.005514
5	0.006328	0.006021
4	0.006669	0.006347
3	0.006752	0.00644
2	0.00631	0.006038
1	0.003714	0.003569
0	0	0

Figure 7 which is the graph of drift for both models which shows that Model 1 has the higher displacement than model 2. This shows that regular building analyzed by NBC 105:2020 has higher driftt value than irregular building.

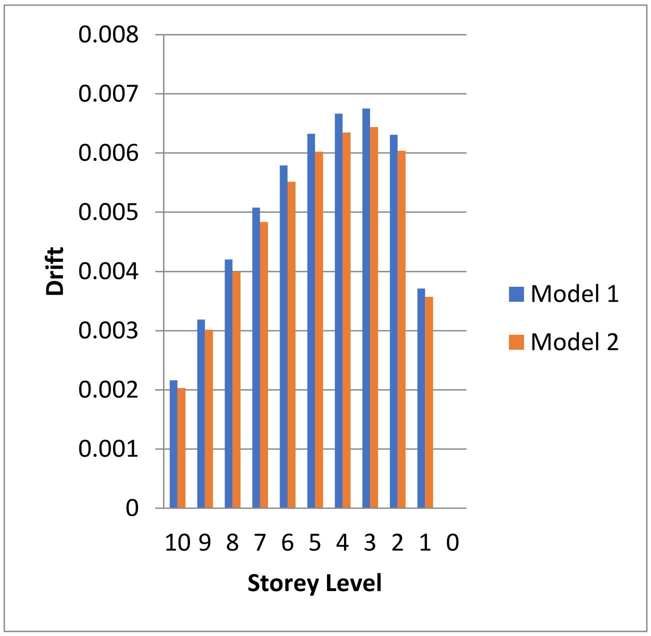

Figure 7: Storey Drifts

C. Storey shear

Table no.3 shows that Model 2 has the higher storey shear than model 1. This shows that Model 2 has the higher storey shear than model 1. This shows that regular building analyzed by NBC 105:2020 has less storey shear value than irregular building.

Table 3: Storey shear of models

	Storey Shear kN	
Storey Level	Model 1	Model 2
10	-340.2262	-317.715
9	-756.4886	-718.9603
8	-1117.6725	-1067.1142
7	-1425.1746	-1363.5229
6	-1680.5489	-1609.6843
5	-1885.5536	-1807.2933
4	-2042.2241	-1958.3118
3	-2152.9976	-2065.089
2	-2220.9565	-2130.5962
1	-2250.435	-2159.0112
0	0	0

which is the graph of storey shear for both models which shows that Model 2 has the higher storey shear than model 1. This shows that regular building analyzed by NBC 105:2020 has less storey shear value than irregular building.

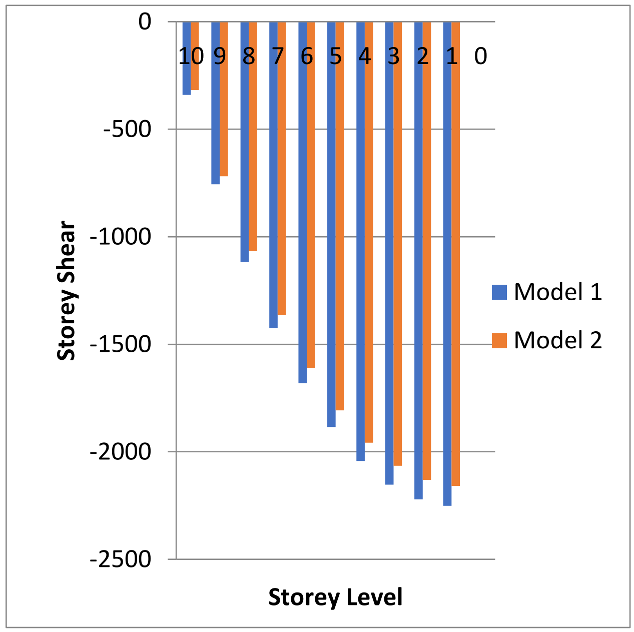

Figure 8: Storey Shear

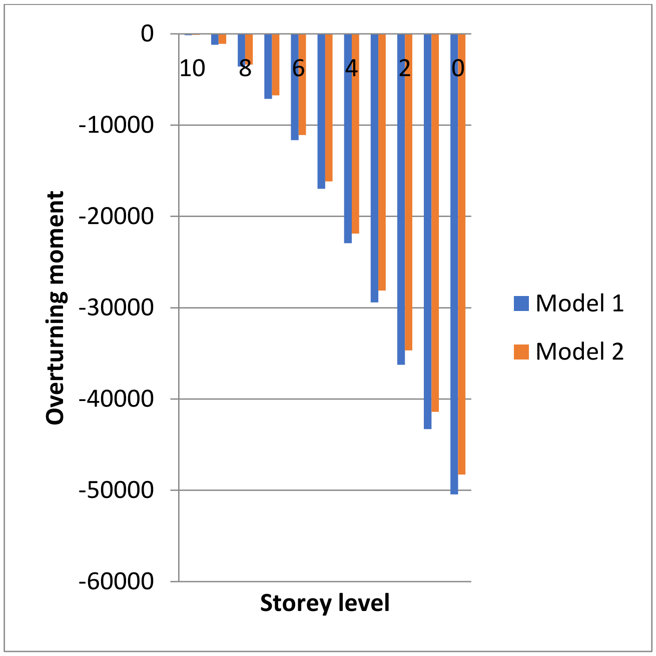

Figure 5: Overturning moment

D. Base shear

Table no.5 shows that Model 2 has the higher base shear than model 1. This shows that Model 2 has the higher base shear value than model 1. This shows that regular building analyzed by NBC 105:2020 has less base shear value than irregular building ..

Table 1: Base shear of models

Models	Base shear in kN	
	EQX(ULS)	EQY(ULS)
Model 1	-2250.435	-2250.435
Model 2	-2159.0112	-2159.0112

Figure 10, which is the graph of base shear for both models Model 1 and 2. Model 2 has the higher base shear value than model 1. This shows that regular building analyzed by NBC 105:2020 has less base shear value than irregular building.

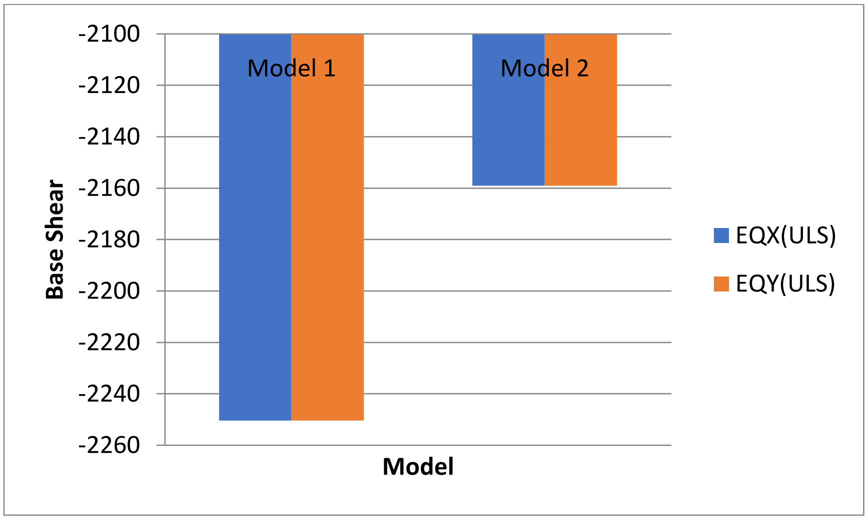

Figure 10: Base Shear

VI. CONCLUSION

Using ETABS, we studied two models of a 10-story structure, one with a normal layout and the other with an unusual one. From the analysis findings, parameters such as floor displacements, floor drift, floor stiffness, time period, base shear, and overturning moment are calculated from the analysis findings and compared. The following conclusions are obtained from the analysis:

- When a standard 10-story building and an irregular 10-story building with the same number of floors are compared, the irregular building has less displacement.
- When compared to a similar building with a regular layout, the displacement of a 10-story building with an irregular layout is reduced by 7%.
- A building with an irregular layout has less drift between floors than a similarly sized structure with a regular plan. If the building has an uneven layout, the drift is 2% less.
- We find that the storey share of regularly planned buildings is greater by 6.6% compared to that of irregularly planned buildings.
- When compared to buildings with a regular layout, those with an irregular plan have a shorter basic time period.
- As compared to a regular layout, an irregular plan will have a higher base shear.
- The overturning moment of a structure with a regular layout is 16.58 percent greater than that of an irregularly planned structure.

- Building using an uneven layout increases the structure's rigidity.

Since the NBC code of Nepal has been improved for irregular as well as regular plans, both will operate extremely effectively during earthquakes, as stated above. Furthermore, irregular plans have much lower basic time periods, axial pressures, torsion in columns, storey shear, and floor displacement, making them better suited for earthquake-prone areas.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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