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Study on Seismic Analysis of Multi Storey RCC Building With Mass Irregularities Using NBC 105:2020

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ABSTRACT- Most of the multi-storey buildings are analysed based on an assumption that the structure is subjected to whole load after modeling the entire structure. But in reality, each storey is subjected to some assumed loads to act during construction period itself as they are constructed in stages as storey wise. Sequential analysis in a structure is ignored by many structural engineers while analysing the structure. Because of this ignorance, variation may occur in structural members in the below storey with respect to above storey as the construction proceeds which leads to incorrect distribution of forces in the member. So, analysis has to be done only by sequential application of loads in each storey for the safety of the structure and cost-effectiveness. In order to study the structural behavior of a 10-storey building with mass irregularity has been modeled and analyzed by equivalent static method using different structural systems in CSI ETABS V16 as per NBC 105:2020. Finally, results such as axial force, shear force, overturning moment are drawn for the structural members and response such as storey displacement, storey shear and storey drift are plotted and compared for each structural system.

KEYWORDS- Displacement; Base Shear; Seismic Analysis; Storey Drift, Overturning Moment.

I. INTRODUCTION

As used in the field of Civil Engineering, "building" refers to a structure made up of several parts, such as a base, walls, columns, floors, roofs, doors, windows, ventilators, stair lifts, different kinds of surface treatments, etc. Through the application of structural analysis and design, a structure is created that can withstand all loads for its entire expected lifespan without failing. A thorough geotechnical assessment of the site's supporting soil is required as a prerequisite to the study and design of any construction. For the sake of planning and building a stable structure's foundation, it is necessary to conduct geotechnical site research. In order to ensure that a building will serve its intended purpose for its entire design life, structural engineers must balance the need for the most efficient and affordable design with the accuracy of the solution. RISA, STAADPRO, ETABS, STRUDL, MIDAS, SAP, RAM, etc. are only some of the many software programmes now available for structural analysis and design. Foreseeing how various parts of a structure will react to external loads is the goal of structural analysis. The four main types of loads—dead, living, earthquake, and wind—are all factors that must be taken into account while designing a building. To study and design buildings, architects and engineers utilise a programme called ETABS (Extended Three-Dimensional Analysis of Building Systems), which includes all the key analysis engines (static, dynamic, linear, non-linear, etc.). The goal of our project, titled "Analysis and Design of Commercial Buildings using ETABS software," is to use ETABS to do such an analysis and design. In this analysis, we focus on a building with G+9 levels. Both the static analysis and the design are completed. Additionally, an effort has been made to hand design the structural parts. In terms of potential death toll, earthquakes are among the worst natural disasters. Engineering methods for analysing buildings under earthquake activity need to be fine-tuned since earthquake forces are unpredictable and erratic. Nearly 60% of the United States is vulnerable to major earthquake destruction. Quakes in the future are inevitable, but they need not be disastrous if proper planning and building practises are used. How earthquake forces are transmitted to the ground, as well as the size, form, and geometry of the building as a whole, are all crucial factors in deciding how the building will behave during an earthquake. The forces that build up in a building during an earthquake must be gradually discharged to the ground. The building's efficiency will suffer if they don't. The thesis focuses mostly on the seismic assessment and analysis of a ground-level plus nine-story structure. For this, we utilised a programme called ETABS. This thesis's primary objective is to use ETABS for the study of a multi-story structure. When it comes to analysis and design, ETABS is the most practical, cutting-edge, cost-effective, and user-friendly technology available. This thesis discusses parameters such as strength, stiffness, damping, mass, and ductility in relation to earthquakes. There was a maximum allowable storey drift for structures, and the guidelines put that number in zone V. Zone V had the greatest increase in base shear and storey forces, whereas zone II saw the least, by 37%. As a result of the analysis, it was shown that the building was suitable for zone. There is a term for the irregularity of structures that have this type of break in continuity: Many of the essential components of city life are housed in these buildings. It's possible that earthquake-induced building collapse is significantly influenced by vertical abnormalities. These buildings do not behave like "normal" buildings in terms of motion because their stiffness and mass change as they rise. Researchers haven't been able to pinpoint when or where earthquakes will occur, despite their best efforts. We can now anticipate with high precision where and how severe an earthquake will be, design resilient buildings, and mitigate the effects of its aftershocks. horizontally, and in terms of architectural planes Shear walls made of reinforced concrete are used to protect a building from the damage that comes from earthquakes.

II. OBJECTIVES OF THE STUDY

The major objective of this study is to evaluate R.C. modeling techniques both with and without mass irregularities in accordance with the most recent edition of Nepal's building code (NBC: 105:2020). The study aims to find:

- Using ETABS, model a G+9 structure with and without a mass irregularity.
- Using the functional static method, we can compare the values of the various models.
- In order to properly understand the effect of earthquake loads on the behaviour of structures with and without mass irregularity, it is necessary to draw crucial conclusions from research findings (storey shears, drifts, displacements, storey stiffness, reinforcements).

Ultimately, this paper aims to draw reasonable conclusions based on the available evidence.

III. LITERATURE REVIEW

Acc. To Tsefamariam and Rajeeva [1]- Buildings with a soft storey (SS) and poor construction quality were used in the 1970s to demonstrate the fragility-based seismic vulnerability of three-, five-, and nine-story reinforced concrete (RC) structures (CQ). A probabilistic seismic demand model (PSDM) was created for gravity load designed buildings using non-linear finite element analysis to take into consideration the interactions between SS and CQ. To forecast the PSDM parameters as a function of SS and CQ, we may use a response surface model. The findings of this research highlight the extreme sensitivity of the model parameters to the interplay between SS and CQ.

According to a paraphrasing of Sarkar et al [2]-They came up with a novel approach to characterising building frames with vertical inequalities by considering their dynamics (mass and stiffness). Here are some main takeaways: The vertical irregularity of multi-story structures with varying mass and stiffness along their height may be quantified with the use of a regularity index that we supply. Second, we provide a method for estimating the initial period of a stepped structure using a data-driven regularity index.

Karavasilis et al. [3]- They investigated how mass irregularity along the vertical axis affected the inelastic seismic response of steel moment frames. The analysis of the response database revealed that the height-wise distribution and amplitude of inelastic deformation demands are impacted by the number of stories, the ratio of beam and column strength, and the location of the heavier mass, but that the mass ratio itself does not seem to impact the response.

Athanassiadou [4]- Given that the performance of all irregular frames exposed to shocks seems to be as great, if not worse, than that of the regular ones, even at twice the design seismic pressures, they concluded that the ductility class does not effect construction costs very much. DCM frames were discovered to be more robust, whereas DCH frames were shown to be less adaptable, making the choice between the two simple. Over-strength was shown to be comparable across regular and irregular frames in this research, with DCH frames having greater over-strength than DCM frames. The quantity of replies seemed to be underestimated by pushover analysis at the highest levels of the irregular frames.

Acc to Lee and Ko say [5]- Three 1:12 scale models of 17-story RC wall constructions were subjected to the identical set of simulated earthquake excitations in order to analyse their seismic response characteristics. The first prototype included symmetrical bracing and a frame that could withstand significant moment loads. Both Model 2 and Model 3 featured infilled shear walls, however in Model 3 it was only in one of the outer frames on the ground and first levels. When considering the overall amount of energy absorbed by damage, the presence or absence of an infilled shear wall is irrelevant. When compared to overturning, shear deformation wastes less energy.

Devesh et al. [6]- Both the seismic requirement for buildings with discontinuous distributions of mass, strength, and stiffness, and the rising necessity for drift in the tower component of set-back structures. Together, the stiffness and strength inconsistency were shown to generate a significant seismic demand. Seismic activity was shown to vary depending on the model used.

Moehle and Shahrooz [7]- They used experimental techniques with analytical modelling to foretell how buildings distant from the epicentre of an earthquake would behave. As part of the experimental investigation, a quarter-scale model of a multi-story, reinforced concrete, setback frame was built and tested. The analytical research included the inelastic analysis and design of different multistory frames with varied degrees of setback. We started by discussing the consequences of setbacks on dynamic response. Subsequently, we discussed whether the present static and dynamic design guidelines for buildings with setbacks are enough. The last topic we covered was designing more resilient structures.

Acc toValmundsson and Nau [8]- At UBC, researchers evaluated the seismic behaviour of frame structures with different numbers of stories (5, 10, and 20) and distributions of mass, stiffness, and strength across these levels, then used ELF to forecast the building's response and TH analysis to compare it to the predictions. The purpose of the comparison was to establish the threshold at which a structure might be deemed normal, and hence under which ELF regulations.

Das (2000)[9]- The majority of ELF-designed buildings had satisfactory performance, as reported. In order to properly address the issue, capacity-based criteria must be applied to the surrounding area.

Sadjadi et al [10]- The seismic stability of RC frames was evaluated using nonlinear time history analysis and push-over analysis. The seismic behaviour of these 5-story frames was evaluated in a research, and analytical models were validated against existing experimental data. GLD structure was found to have poor seismic performance, however both the ductile and less ductile frames performed well. Once the upgrades were performed, the GLD frame became more earthquake resistant.

In their opinion, structures built to current seismic standards were safe from the quake's destruction. Contrarily, the shear strength of the vertical members would have been drastically reduced due to the vertical motion.

Acc to Duan et al. [11]- the numerical findings show that the designed-to-code buildings react inelastically and within the maximum plastic rotation and inter-story drift restrictions specified by ASCE/SEI 41-06. As shown by the pushover investigations, even moderate side forces may shatter a vulnerable mechanism on the ground level of a structure.

Acc to Poonam [12]- the numerical evaluation proves that the lowest floor is just as safe as the levels above and below it. If the building's mass isn't distributed evenly, it might have a more intense response. When the disparities are needed, they must be carefully and meticulously prepared for.

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. In this study following models are prepared for the study:

First both model Model NBC:105:2020 is used.

A. Loads

Dead loads Brick masonry:Unit Weight 20KN/m^3
Finishes (Floor Finishes) : 1.5 KN/m^2
Reinforced Concrete Elements: Unit Weight 25KN/m^3
Live load : 3 KN/m^2 on all floors except roof.
Lateral loads: Earthquake Loads as per NBC:105:2020

B. Lateral Load

Equivalent static method use for analysis of the building. Parameter considered using NBC code are as follows:

Zone factor (Z)	=	0.4
Importance factor (I)	=	1.25
Response Reduction Factor (R)	=	5(SMRF)
Soil Type	=	A”

Load Combination considered in the analysis are mentioned below

- 1.2Dead Load+1.5Live Load
- Dead Load +0.3Live Load+EQX(Service limit State)
- Dead Load +0.3Live Load -EQX(Service limit State)
- Dead Load+0.3Live Load +EQY(Service limit State)
- Dead Load+0.3Live Load -EQY(Service limit State)
- Dead Load+0.3Live Load+EQX(Ultimate Limit State)
- Dead Load+0.3Live Load-EQX(Ultimate Limit State)
- Dead Load+0.3Live Load+EQY(Ultimate Limit State)
- Dead Load +0.3Live Load-EQY(Ultimate Limit State)

C. Material Properties

- Grade of concrete: M25 for beam and Slab M 25for Column
- Grade of steel : Fe 500
- Modulus of Elasticity of concrete (Ec): 5000√fck N/mm2
- Modulus of Elasticity of Steel (Es)”: 2x105 N/mm2

D. Element Dimensions

Following are the element diemension considered in the building for analysis:
Slab =125 mm
Wall thickness exterior =230 mm
Interior wall thickness=115mm
Size of column=600mmX600mm
Size of beam=350mmX650 mm

E. Model Generated in ETABS-

Here, figure 1 shows 3D view of model for both models, figure 2 shows live load view of moel 1,figure 3 represents the wall load view of model 1 ,figure 4 shows live load view of model 2 and figure 5 represents the wall load view of model 2.

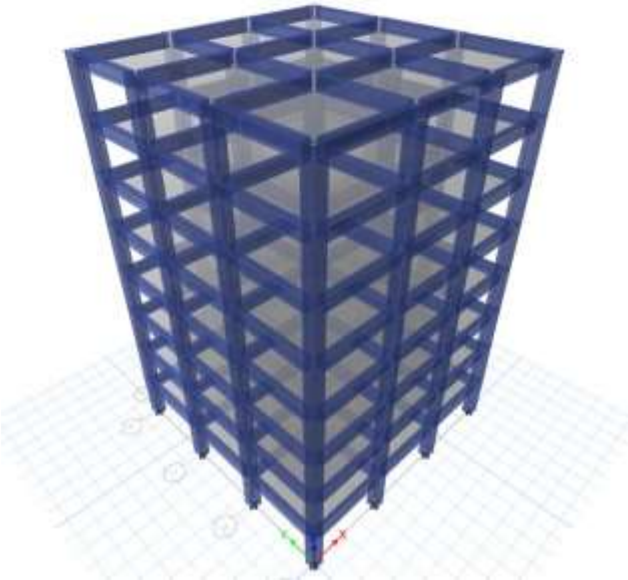
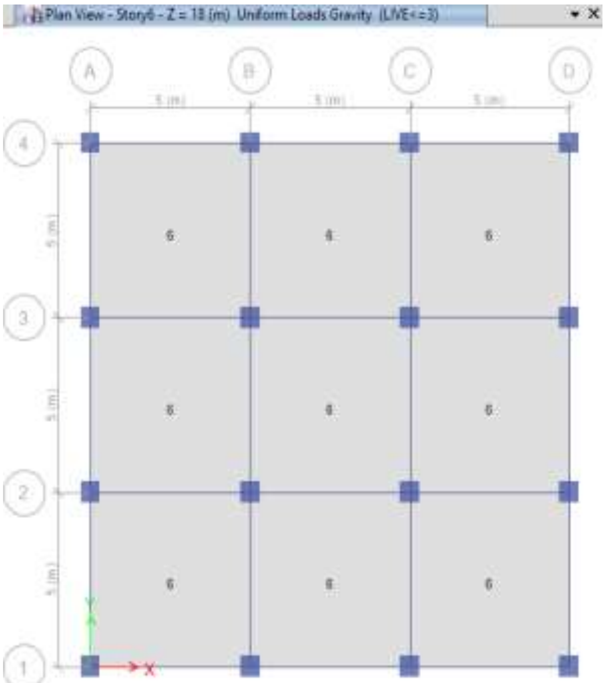


Figure 1: 3D view



Plan View - Story6 - Z = 18 (m) Uniform Loads Gravity (LIVE<=3)

Figure 2: Live load View of model 1

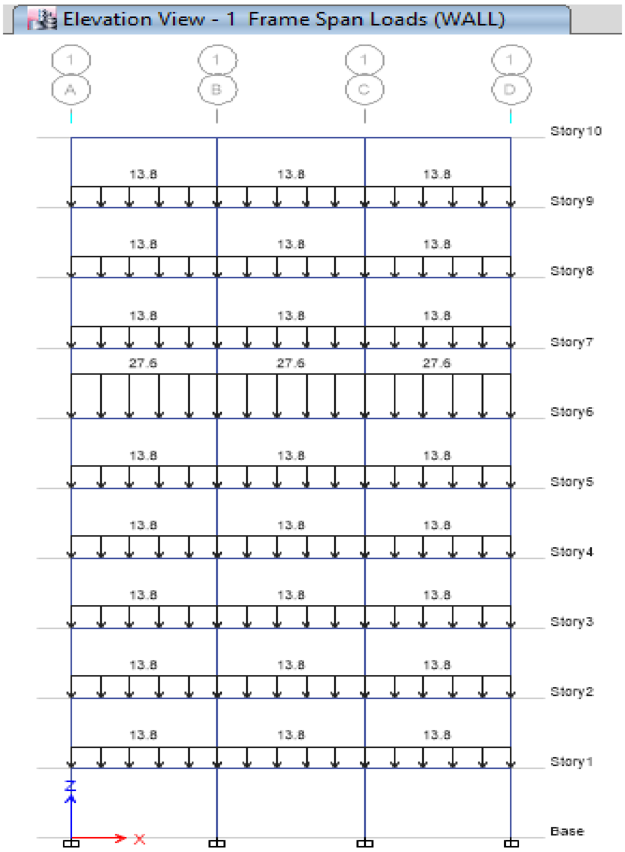


Figure 3: Wall load view of model 1

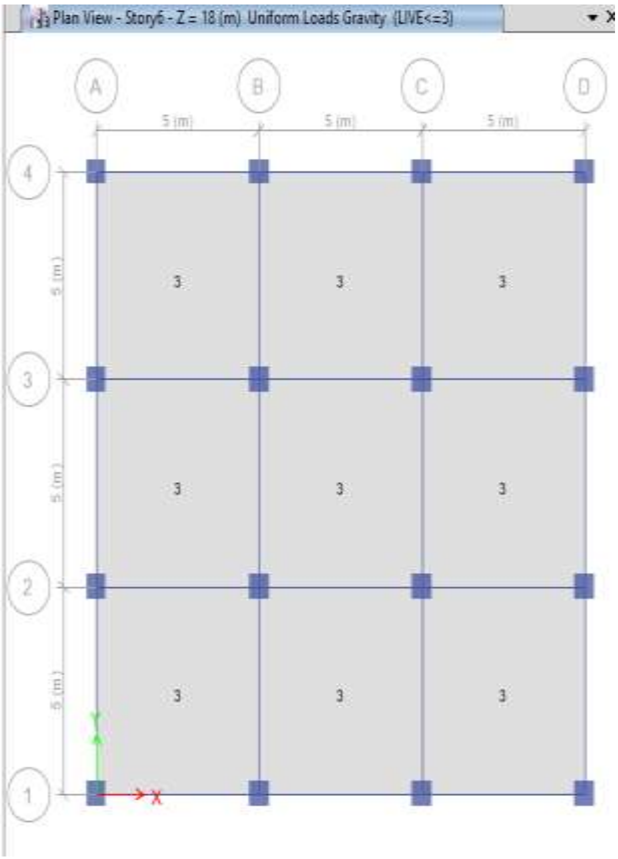


Figure 4: Live load view of model 2

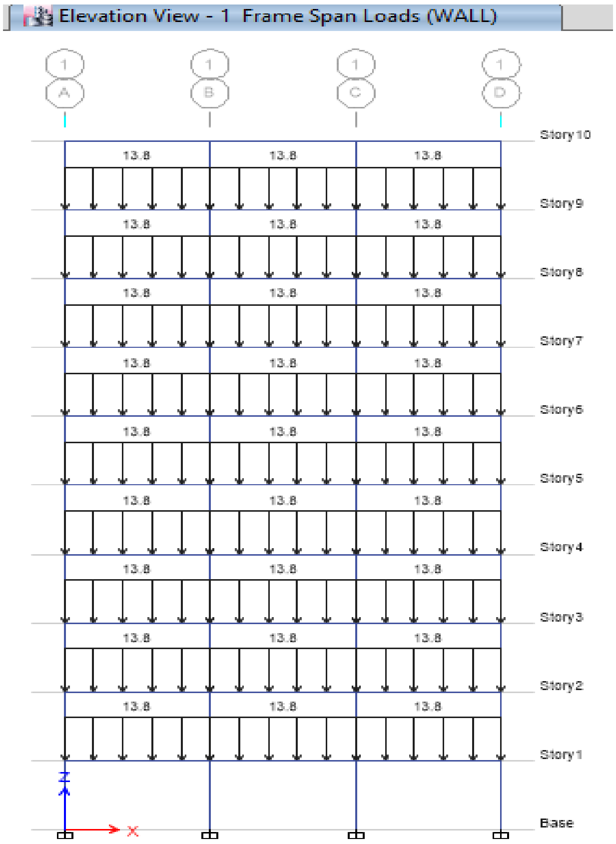


Figure 5: Wall load view of model 2

V. EXPERIMENTAL RESULTS

A. Displacements

Table no.1 shows that Model 2 has the higher displacement than model 1. This shows that building with mass irregularity has higher values of displacement.

Table 1: Displacements of models

Models	Displacement in mm	
	EQX(ULS)	EQY(ULS)
Model 1	52.563	52.563
Model 2	56.143	56.143

Figure 6 which is the graph of displacement for both models which shows that model 2 has higher value of displacement.

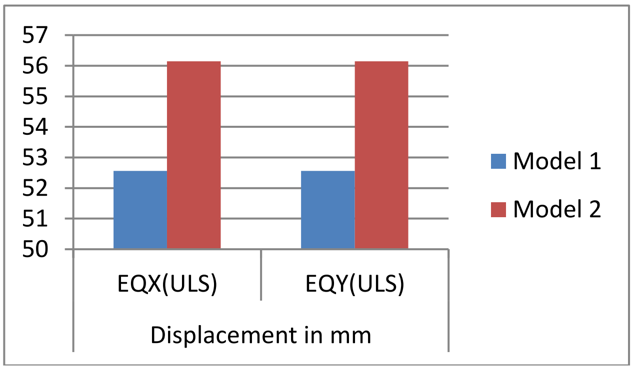


Figure 6: Storey Displacements

B. Drift

Table no.2 shows that Model 2 has the higher drift than model 1.

Table 2: Drift of Models

Models	**Drift**	
	EQX(ULS)	**EQY(ULS)**
Model 1	0.00254	0.00254
Model 2	0.002743	0.002743

Figure 7 which is the graph of drift for both models which shows that model 2 has higher values of drift than model 1.

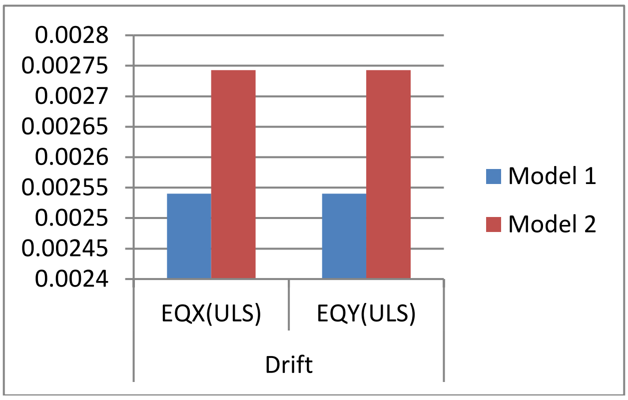


Figure 7: Storey Drifts

C. Storey Shear

Table no.3 shows that Model 2 has the higher storey shear than model 1.

Table 3: Storey shear of models.

Models	**Story shear in kN**	
	Rx	**Ry**
Model 1	3382.52	3382.52
Model 2	3633.373	3633.3173

Figure 8 which is the graph of storey shear for both models which shows that model 2 has higher values of storey shear than model 1.

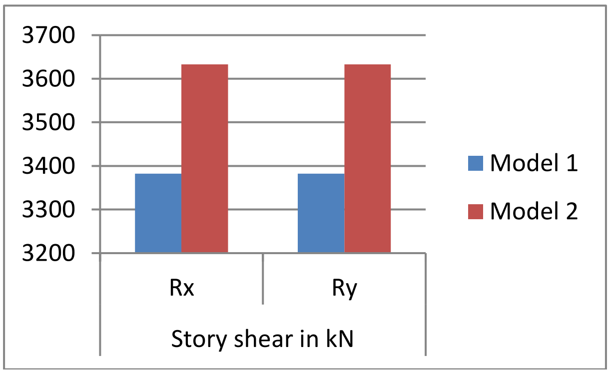


Figure 8: Storey Shear

D. Overturning Moments

Table no.4 shows that Model 2 has the higher overturning moment than model 1.

Table 4: Overturning moment of models

Models	**Overturning moment in kN-m**	
	EQX(ULS)	**EQY(ULS)**
Model 1	67210.5428	67210.5428
Model 2	80335.8618	71839.9517

Here figure 9 is showing the graph of overturning moment for both models, which shows that model 2 has higher values of overturning moment than that of model 1.

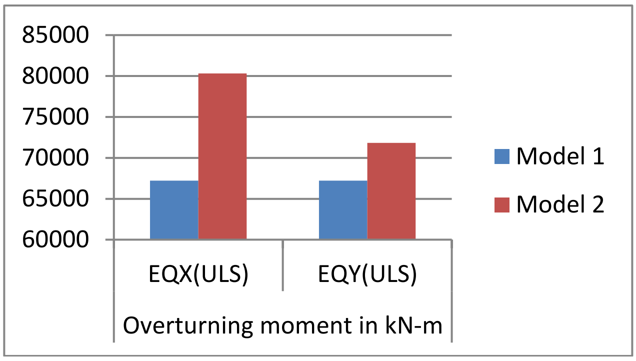


Figure 9: Overturning moment

E. Base Shear

Table no.5 shows that Model 2 has the higher base shear than model 1.

Table 5: Base shear of models

Models	**Base shear in kN**	
	EQX(ULS)	**EQY(ULS)**
Model 1	3382.5173	3382.5173
Model 2	3633.3173	3633.3173

Figure 10 which is the graph of base shear for both models which shows that model 2 has higher base shear than model 1.

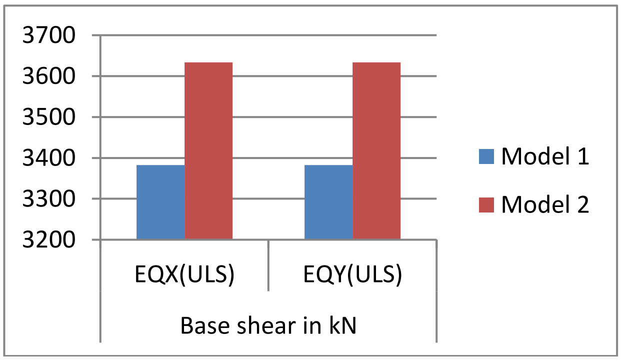


Figure 10: Base Shear

VI. CONCLUSION

Using NBC 105:2020 and the ETABS programme, two models of a 10-story structure are analysed: one without any mass irregularity (model 1), and the other with mass irregularity (model 2). For the purpose of comparison investigation, the parameters obtained from the results of the analysis include storey displacements, storey drift, storey stiffness, time period, base shear, and overturning moment. Following are some conclusions that may be taken from the analysis that was carried out:

- The displacement of model-2, which is a 10-story structure with mass irregularity, is greater than that of model-1 (i.e. same building with no mass irregularity).
- The drift of model-2 (i.e. a 10-story structure with mass irregularity) is increased by 6.81% compared to that of model-1 (i.e. same building with no mass irregularity).
- The storey drift of model-2 has a value that is 7.99% higher than that of model-1.
- In comparison to model-1, model-2 has a 7.42% higher narrative shear value.
- The basic time period used in model-2 is longer than the one used in model-1.
- In comparison to model-1, model-2 has a base shear that is much higher.
- model-2 has a 19.53% greater overturning moment compared to model-1.
- Model-1 has a greater degree of rigidity than model-2 does.

Based on the findings presented above, it can be deduced that the seismic performance of model-1 (i.e. a 10 story structure with no mass irregularity) is superior than that of model-2 (i.e. a 10 storey building with mass irregularity) because of the following reasons: In addition, the inclusion of a shear wall in a structure shortens the fundamental time period and significantly lowers axial forces, torsion in columns, storey shear, and floor displacement, making the building more acceptable for use in regions prone to earthquakes.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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