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VERTICAL IRREGULAR RC BUILDING SEISMIC ANALYSIS WITH STIFFNESS & SETBACK

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ABSTRACT: - The distribution of stiffness, strength, and mass in both vertical and horizontal orientations affects how well a high rise structure performs during powerful earthquake events. A building is considered irregular if there is a difference in stiffness, strength, and mass between the adjoining storeys. The performance and behavior of regular and vertical irregular G+10 reinforced concrete (RC) buildings under seismic loading are the main topics of the current study. In this study, stiffness and setback, two types of vertical abnormalities, are taken into consideration. Response spectrum analysis (RSA) is used to conduct seismic analysis on a total of eight normal and irregular structures. It is possible to get several earthquake reactions, including storey displacement, storey drift, overturning moment, storey shear force, and storey stiffness. These replies have been used to compare the differences between regular and irregular structures. The outcome suggests that a stiff building construction with uneven setbacks causes instability under earthquake stress. In RC construction, a proportional quantity of stiffness is advantageous to regulate the instability.

Keyword: *Setback, Vertical irregularity, Storey displacement, Storey drifts, Response spectrum analysis.*

1- INTRODUCTION

When a multistory building is subjected to seismic loads, the failure often starts where the building is weakest. Due to this flaw, the structure deteriorates and eventually collapses structurally. The main cause of this weakness is the existence of abnormalities in a building's mass, stiffness, and stiffness. Plan irregularity and vertical irregularity are the two categories into which these irregularities fall. The following categories apply to vertical abnormalities according to IS 1893:2002 (part I):

1- **Stiffness irregularity:**

a) A soft storey is one whose lateral stiffness is lower than either 0.7 times of the storey above or 80% of the average lateral stiffness of the three storeys above.

b) Extremely low lateral stiffness: An extreme low lateral stiffness storey has a lateral stiffness that is less than 0.6 times of the storey above it or less than 1.7 times of the average stiffness of the three storeys above it.

2- **Mass irregularity:** When a storey's seismic weight is greater than 200 times that of its neighboring storey’s, mass irregularity is deemed to occur.

3- **Vertical geometric irregularity:** Where the horizontal dimension of the lateral force resisting system in any storey is greater than 1.5 times of that in its adjacent storey, vertical geometric irregularity will be deemed to exist.

4- **Vertical elements resisting lateral force in plane discontinuity:** a lateral force resisting element offset in plane that is longer than the element's length.

5- **Capacity fluctuation:** When the lateral strength of a storey is less than 80% of that of the storey above, it is considered to be weak.

2- LITERATURE REVIEW

According to the requirements of IS 1893:2002 (part I), Shaikh and Deshmukh (2013) did linear static & dynamic analysis on a G+10 vertically irregular building. The structure was represented as a simple lump mass model with a fourth-floor stiffness irregularity. The building's reaction characteristics, including storey drift, storey deflection, and storey shear, were assessed. The findings demonstrate that uneven stiffness contributes to the building's instability and draws significant story shear.

Mahesh and Rao (2014) investigated how G+11 residential buildings, both regular and irregular, responded to seismic motion. They took into account three different soil types—hard, medium, and soft—as well as various seismic zones. Two programs, ETABS and STAAD PRO, were used to do the analysis.

Response spectrum analysis (RSA) and time history analysis (THA) of vertically uneven RC building frames were performed by Bansal and Gagandeep in 2014. They took into account vertical geometric irregularity, rigidity, and mass. They discovered that compared to comparable regular buildings, mass irregular buildings experience more base shear.
The base shear experienced by the rigidity irregular building was smaller, and its inter-story drifts are bigger.

The effectiveness of vertical geometric irregular RC frame constructions during seismic motion was explored by Rana and Raheem (2015). Four irregular construction frames were compared to one conventional frame in a comparative study. Numerous earthquake reactions were recorded, including shear force, bending moment, storey drift, storey displacement, etc. It was determined that compared to setback irregular frames, regular building frames had a very low shear force.

The current study's goals are to (i) examine the behavior and performance of a total of eight regular and irregular RC buildings with stiffness and setback irregularity, and (ii) use CSI ETABS 2015 software to analyze all G+10 RC structures in accordance with IS1893:2002 (part I) standards. In each case, a response spectrum analysis is performed while taking seismic zone V and medium soil strata into consideration, and (iii) to compare the responses of regular and vertical irregular buildings in terms of storey displacement, storey drift, overturning moment, storey shear force, and storey stiffness.

3- METHODOLOGY

All eight of the RC buildings—both regular and irregular—were subjected to a seismic analysis for this study. Stiffness and setback, two different forms of vertical abnormalities, are taken into consideration. Table 1 illustrates the conventional building's structural details.

Specification	For stiffness irregulatity	For setback irregulatity
No. of Stories	G + 10	G + 10
Story Height	3m	3m
No. of bays in X & Y direction	3	4
Spacing of frame in X & Y direction	4m	4m
Grade of concrete	M 25	M 25
Modulus of elasticity	25×10^3 MPa	25×10^3 MPa
Thickness of slab	0.125 m	0.125 m
Beam size	0.45 m × 0.30 m	0.45 m × 0.30 m
Column size	0.45 m × 0.45 m	0.45 m × 0.45 m
No. of modes used	30	30
Damping Ratio	5%	5%
Seismic zone	V	V
Response reduction factor (R)	5	5

Soil type	Medium	Medium
Zone factor (Z)	0.36	0.36
Importance factor (I)	1	1

Table 1- Structural Detail of Regular Building Model

A. STIFFNESS IRREGULARITY

In this instance, three irregular buildings—the ground storey, fourth storey, and seventh storey—as well as one regular building (B1) as depicted in Fig (a) are all examined. These structures are represented as G+10 story structures with three bays extending in each directions. The structure's irregularity is created by raising the storey's height. As may be seen in Fig (b), the height of the uneven story is 4.5 m.

Stiffness of each column= $\frac{12EI}{L^3}$

Therefore, stiffness of ground storey/stiffness of other storey = (3/4.5)3 = 0.3 < 0.7

Hence as per IS 1893:2002 (part I) the building has stiffness irregularity.

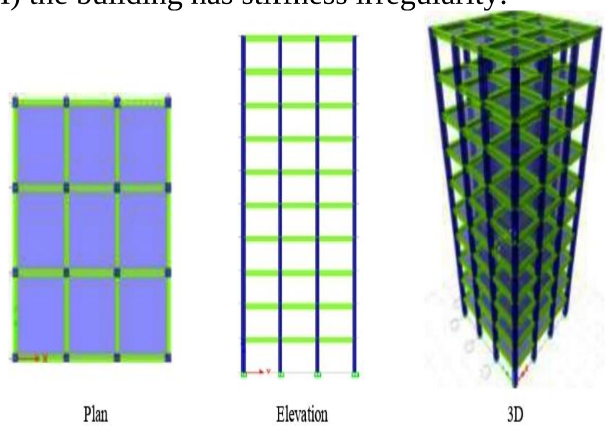

Fig (a) Plan, elevation and 3D of regular building model (B1)

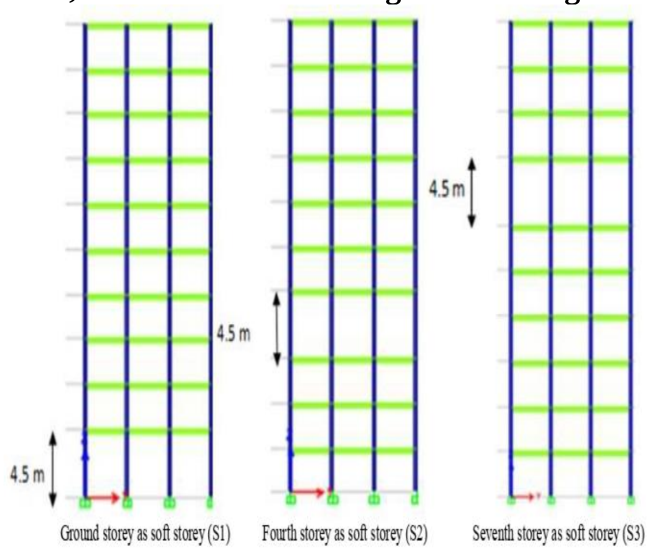

Fig (b) Elevation of stiffness irregular building models

B. SETBACK IRREGULARITY

In this instance, four different building model types are chosen: one conventional building (B2), as shown in Figure (c), and three irregular structures, as shown in Figure (d), with setback irregularities in the eighth, fifth, and second storeys in the X-direction. These structures are represented as G+10 story structures with four bays extending in each directions.

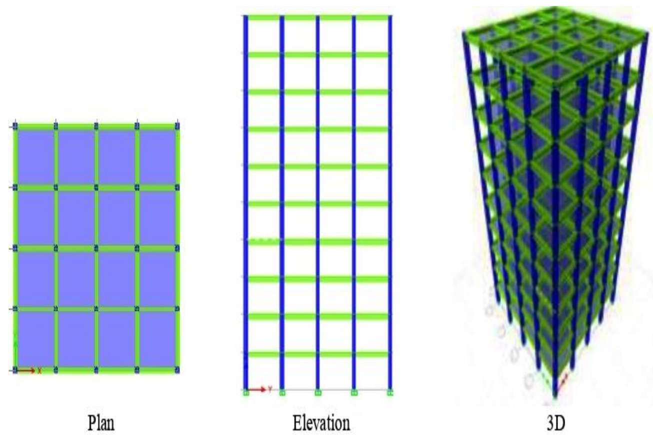

Fig (c) Plan, elevation and 3D of regular building model (B2)

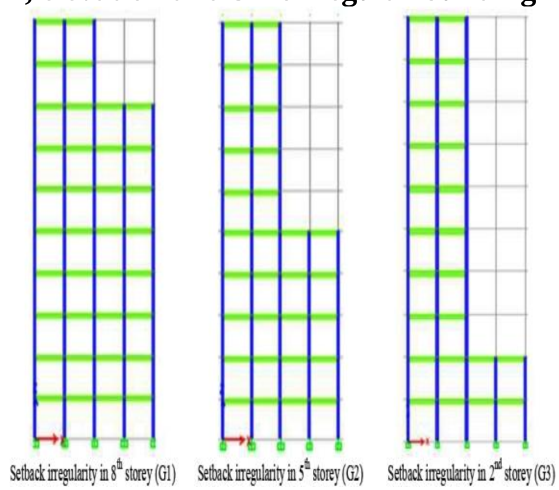

Fig (d) Elevation of setback irregular building models

4- RESULT AND DISCUSSION

A. STIFFNESS IRREGULARITY

According to the storey displacement curve in Fig (e), rigidity irregular structures experience substantially more displacement than regular buildings. The displacement in the ground level of model S1 is 1.5 times more than that of ordinary building model B1, and it decreases as the building rises.

With a change in a storey's stiffness, a rapid shift in the slope of the storey displacement curve has been noted. The storey drift curve in Fig (f) shows that, in contrast to a regular construction, there is a quick and dramatic shift in storey drift as a result of stiffness irregularity.

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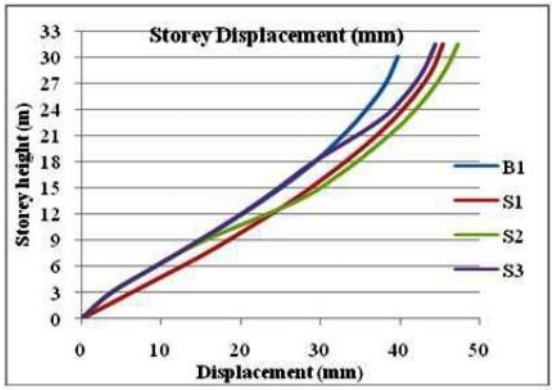

Fig (e) Storey displacement

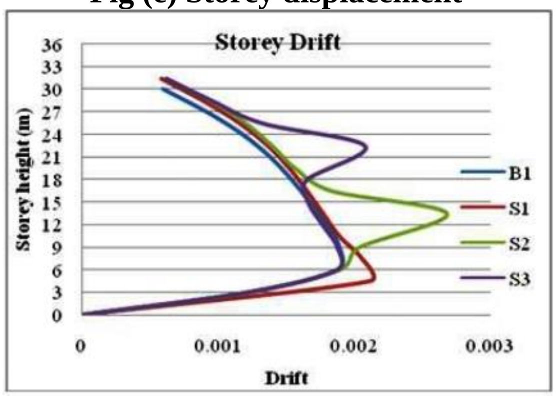

Fig (f) Storey drifts

According to Figures (g) and (h), the overturning moment and storey shear force for irregular structures are somewhat higher than those for regular buildings. at the instance of model S2 at the building's ground floor, both of these parameters are at their maximum values. The slope of the shear force curve has been seen to gradually grow in the uneven stories.

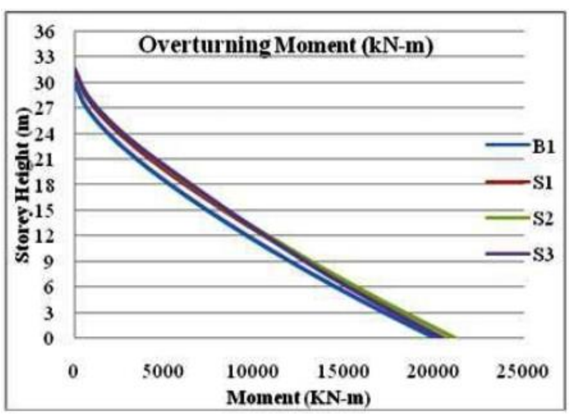

Fig (g) Overturning moment

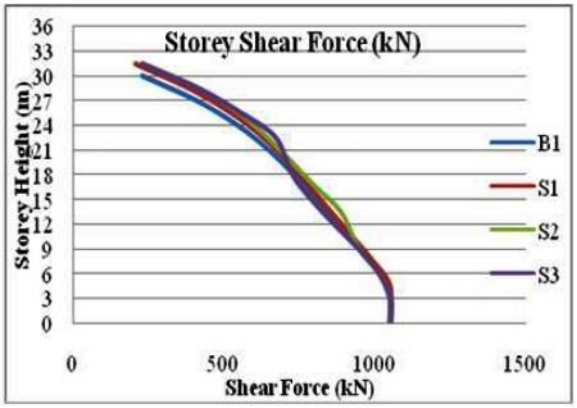

Fig (h) Storey shear force

According to Fig (i), the uneven floors of the structure experienced an abrupt, dramatic shift in stiffness.

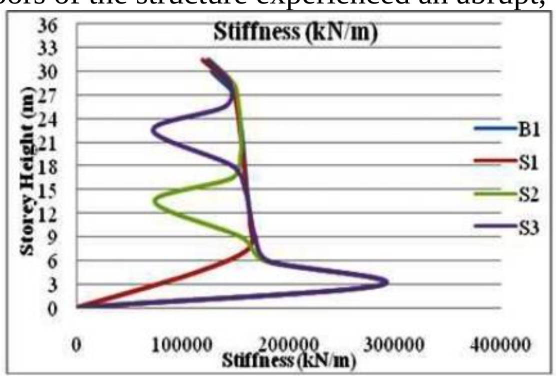

Fig (i) Storey stiffness

B. SETBACK IRREGULARITY BUILDING

The storey displacement curve in Fig (j) shows that, with the exception of model G1, the top node displacement in setback irregular structures is greater than that of regular buildings. In model G1, the displacement is greater in the lower levels but lessens near the building's peak. This behavior could be brought on by the building's bulk being reduced as a result of the setback. A significant shift in the slope of the displacement curve has been seen for model G2 due to setback at the fifth floor, however its top node displacement is 25% more than that of model B2. Model G3's displacement is around 22% less at the second level than that of model B2, but it has 12% greater displacement at the top node. From Fig (k), it is clear that setback has caused a quick, dramatic change in storey drift. The storey drift curve's slope first declines before to setback before abruptly increasing soon after setback.

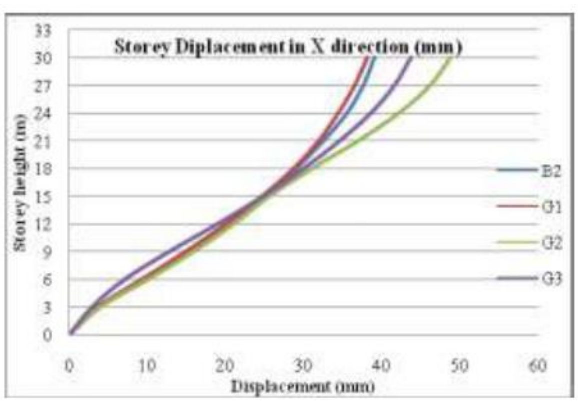

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Fig (j) Storey displacement

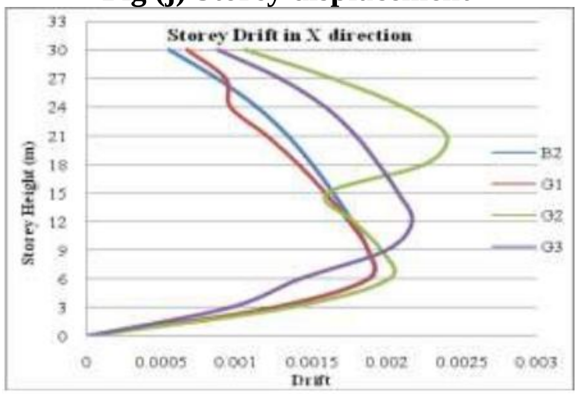

Fig (k) Storey drifts

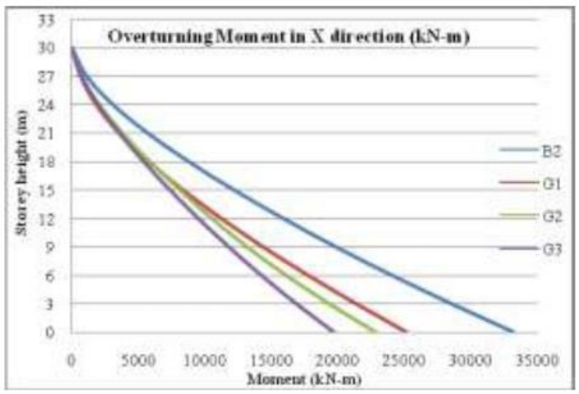

Fig (l) Overturning moment

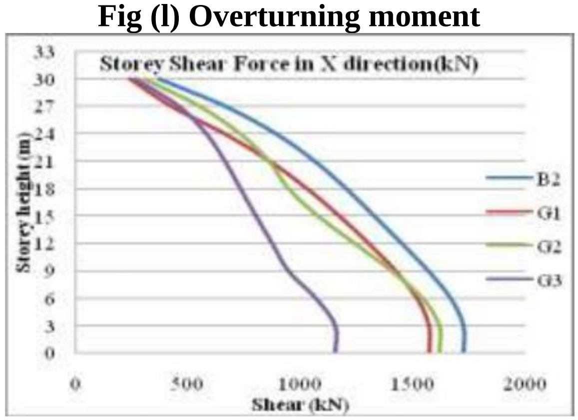

Fig (n) Storey shear force

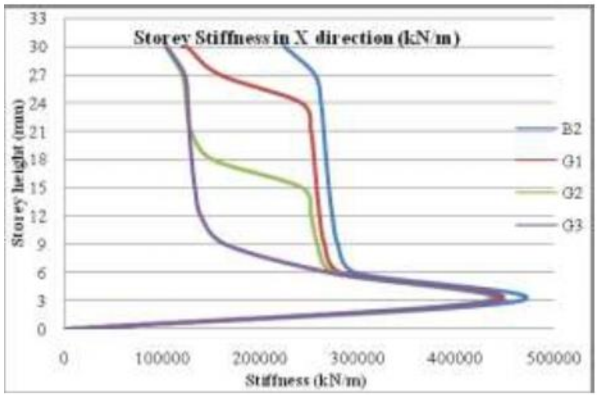

Fig (n) Storey stiffness

According to Figures (l) and (m), the overturning moment and storey shear force in the case of setback irregular structures are lower than those of regular buildings.

As the amount of setback rises, the storey stiffness reduces, as illustrated by the storey stiffness curve in Fig (n).

5- CONCLUSION

The following results are reached after researching the behavior and performance of regular and vertical irregular G+10 reinforced concrete buildings under seismic stress.

1. Stiffness irregular structures have a higher story displacement than a regular building. When it comes to storey displacement, the ground soft storey (S1) is the most serious example since its displacement in the ground storey is 1.5 times more than that of a standard building (B1). The outcome demonstrates that, with the exception of model G1, the top node displacement is greater for setback irregular structures than it is for regular buildings.
2. Storey drift is greatest at irregular storeys in stiffness irregular constructions. Model S2 is the most important scenario when considering storey drift. A abrupt, dramatic shift in story drift as a result of setback has been noted in structures with irregular setbacks.
3. The overturning moment and storey shear force in the case of rigidity irregular structures are somewhat higher than those in the case of regular buildings. At the irregular storeys, there has been a little rise in the shear force curve's slope. The overturning moment and storey shear force for setback irregular structures are lower than for regular buildings. The overturning moment reduces as the amount of setback rises.
4. In the instance of stiffness irregular structures, an abrupt reduction in the building's stiffness has been noted at the uneven floors. The findings of setback irregular structures demonstrate that the rigidity of the building diminishes as the degree of setback grows.
5. According to the investigation, vertical irregularities have a significant impact on how well an RC structure performs when subjected to seismic loads. These anomalies must be avoided wherever feasible, but if they must be present, they must be carefully planned.

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