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Structural Safety Evaluation of Residential Apartment Located at Indore City Having Plan Irregularity and Considering Different Importance Factors

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Abstract: In the domain of structural engineering, significant focus has been placed on the issue of plan irregularities in multistoried buildings. Plan irregularities have been defined as the misalignment or displacement of structural components in relation to vertical load resisting members. To investigate this, a series of simulations were conducted considering importance factors of 1.0, 1.2, and 1.5 as per Indian standards (SS-A1 to G1, SS-A2 to G2, SS-A3 to G3). A total of 21 distinct cases involving plan irregularities were examined to develop a comprehensive understanding. By conducting the drift analysis as per special limitations for plan irregularities, the performance of each case has carefully documented. Among all variations, several cases like SS-A1, SS-B1, and SS-C2 remained well within the codal drift limits, even for Z-direction displacements. On the other hand, configurations like SS-G3 approached the upper bound of permissible drift, underscoring the need for careful placement of irregularities and appropriate factor selection. Through this approach, optimal structural resilience in buildings with plan irregularities has effectively identified.
Keywords: Drift Analysis, Plan irregularities, Residential Apartment, Response Spectrum Method, Actual Soil.

I. INTRODUCTION

In multistoried building construction, columns are typically expected to be positioned vertically and beams horizontally, as per design norms. However, deviations from these ideal alignments are often introduced due to foundation settlements, fabrication inaccuracies, or construction tolerances. While minimal deviations are generally considered to have an insignificant effect on structural performance, larger offsets may cause serious issues. The structural capacity of beams and columns is known to be reduced when out-of-plane displacements result in additional bending stresses. Structural stability is also threatened, as major deviations may lead to column buckling or beam tilting. Aesthetic damage is frequently observed when alignment mismatches affect surface finishes like plaster or tile installations. In order to prevent such complications, strict monitoring and control of out-of-plane offsets must be implemented during design and execution stages.

To address these challenges effectively, several preventive measures are recommended:

1. Throughout the construction process, consistent quality checks must be conducted to ensure deviations remain within permitted limits.
2. Structural members should be reinforced appropriately to resist anticipated stress levels and prevent failure.
3. Accurate installation of beams and columns is to be ensured by adopting verified construction techniques in line with the approved design.

In conclusion, plan irregularities due to out-of-plane offsets have been shown to affect both the stability and performance of multistorey structures, making their careful management essential to long-term safety and durability.

In IS 1893:2016, the importance factor has been specified as a vital multiplier to address the differing occupancy levels and functional significance of structures under seismic conditions. Additional safety provisions are required to be offered for critical and high-risk buildings under this guideline. An importance factor of 1.0 has been allocated to ordinary structures, while values of 1.2 or 1.5 have been designated for facilities like emergency response centers, hospitals, and educational institutions. The calculation of design base shear is notably impacted through the use of this multiplier, thereby reinforcing the structural framework. Variations in structural design, based on a building’s purpose, are facilitated by integrating this factor into seismic codes.

Seismic safety practices in India are brought into alignment with global standards through this provision. Protection of lives and maintenance of essential services during earthquakes have been prioritized with the use of this factor.

II. PROCEDURE AND 3D MODELLING OF THE STRUCTURE

Seismic analysis of a ten-story residential apartment has conducted using a software-based approach. The earthquake data is collected according to the IS 1893(PART1):2016 standards. The analysis of the building is performed utilizing the response spectrum analysis method. Detailed information about the model and input parameters is provided below.

Table 1: Various cases used for analysis with importance factor = 1

S. No.	Abbreviation	Description of structure
1.	SS-A1	Apartment with plan irregularity provided at foundation level considering importance factor = 1
2.	SS-B1	Apartment with plan irregularity provided at ground floor level considering importance factor = 1
3.	SS-C1	Apartment with plan irregularity provided at first floor level considering importance factor = 1
4.	SS-D1	Apartment with plan irregularity provided at third floor level considering importance factor = 1
5.	SS-E1	Apartment with plan irregularity provided at fifth floor level considering importance factor = 1
6.	SS-F1	Apartment with plan irregularity provided at seventh level considering importance factor = 1
7.	SS-G1	Apartment with plan irregularity provided at ninth floor level considering importance factor = 1
Here,	SS	Structural Stability
	A1 to G1	Cases with importance factor = 1

Table 2: Various cases used for analysis with importance factor = 1.2

S. No.	Abbreviation	Description of structure
1.	SS-A2	Apartment with plan irregularity provided at foundation level considering importance factor = 1.2
2.	SS-B2	Apartment with plan irregularity provided at ground floor level considering importance factor = 1.2
3.	SS-C2	Apartment with plan irregularity provided at first floor level considering importance factor = 1.2
4.	SS-D2	Apartment with plan irregularity provided at third floor level considering importance factor = 1.2
5.	SS-E2	Apartment with plan irregularity provided at fifth floor level considering importance factor = 1.2
6.	SS-F2	Apartment with plan irregularity provided at seventh level considering importance factor = 1.2
7.	SS-G2	Apartment with plan irregularity provided at ninth floor level considering importance factor = 1.2
Here,	SS	Structural Stability
	A2 to G2	Cases with importance factor = 1.2

Table 3: Various cases used for analysis with importance factor = 1.5

S. No.	Abbreviation	Description of structure
1.	SS-A3	Apartment with plan irregularity provided at foundation level considering importance factor = 1.5
2.	SS-B3	Apartment with plan irregularity provided at ground floor level considering importance factor = 1.5
3.	SS-C3	Apartment with plan irregularity provided at first floor level considering importance factor = 1.5
4.	SS-D3	Apartment with plan irregularity provided at third floor level considering importance factor = 1.5
5.	SS-E3	Apartment with plan irregularity provided at fifth floor level considering importance factor = 1.5
6.	SS-F3	Apartment with plan irregularity provided at seventh level considering importance factor = 1.5
7.	SS-G3	Apartment with plan irregularity provided at ninth floor level considering importance factor = 1.5
Here,	SS	Structural Stability
	A3 to G3	Cases with importance factor = 1.5

Table 4:Data assumed for analysis of structure

Constraint	Assumed data for all buildings
Soil type	Actual soil data used

Seismic zone	III (Z = 0.16)
Response reduction factor (ordinary shear wall with SMRF)	4
Importance factor (For all commercial building)	1.5, 1.2 and 1
Damping ratio	5%
ndamental natural period of vibration (T_a)	$0.09*h/(d)^{0.5}$ For X direction = 0.8625 sec For Z direction = 0.7874 sec
Plinth area of building	575 sq. m
Floors configuration	G + 10
Structural type	Residential Building
Height of building	47.92 m
Floor to floor height	3.66 m
Depth of foundation	4 m
Beam sizes	650 mm X 550 mm
	550 mm X 350 mm
	450 mm X 300 mm
Column sizes	750 mm X 650 mm
	650 mm X 550 mm
	500 mm X 400 mm
Slab thickness	130 mm (0.130 m)
Shear wall thickness	145 mm (0.145 m)
Stair case waist slab thickness	130 mm (0.130 m)
Material properties	M 30 Concrete Fe 550 grade steel

III. RESEARCH OBJECTIVES

On keeping in mind the above problem statement outline for new research work is proposed in the form of conclusive outcomes given below :-

1) To create various cases of residential apartment with plan irregularities introduced at various floor levels, under varying seismic importance factors (I = 1.0, 1.2, and 1.5).
2) To use actual soil condition in all simulated cases to determine the actual behaviour of residential apartment.
3) To use Response Spectrum Method of dynamic analysis for computation using analysis software.
4) To evaluate and compare the story drift responses in X and Z directions across different structural models (SS-A1/A2/A3 to SS-G1/G2/G3), identifying the influence of irregularity.
5) To validate structural responses against codal storey drift limitations as per IS 1893 (Part 1): 2016, with special attention to more stringent drift criteria (L/500) applicable to irregular buildings.

The main and foremost objective is to decide of the best case of plan irregularity, considering different importance factors provided in the residential apartment with plan irregularity that will be recommended for construction in the similar field as per special drift provisions of Indian Standards.

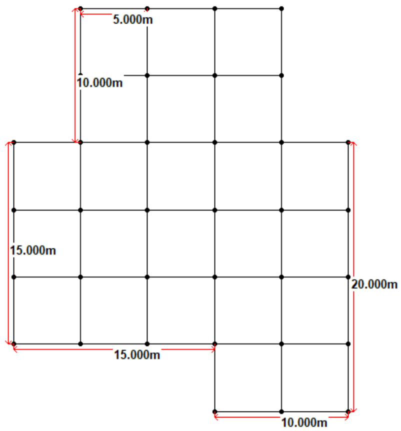

Fig. 1: Plan of all residential apartments cases

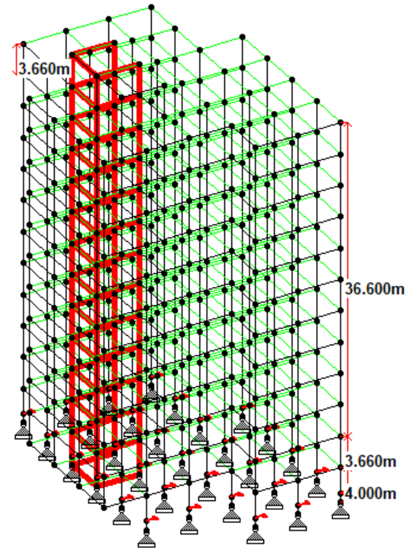

Fig. 2: 3- D view of all residential apartments cases

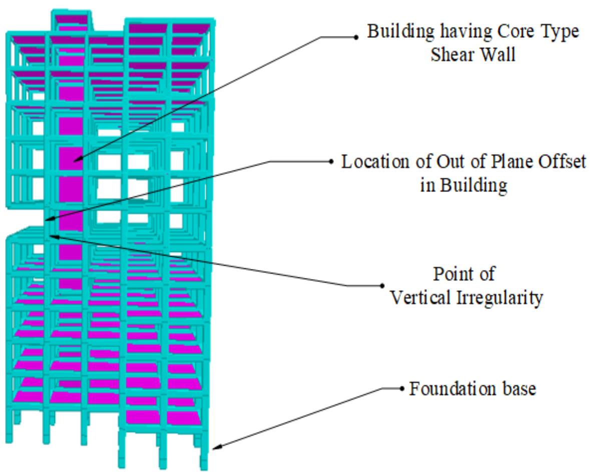

Fig. 3:Plan irregularity provided in any structure

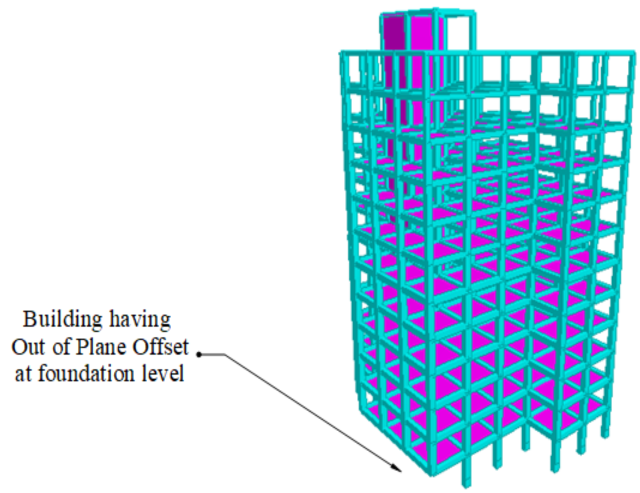

Fig. 4:SS-A1/SS-A2/SS-A3 - Residential Apartment having plan irregularity set at foundation level

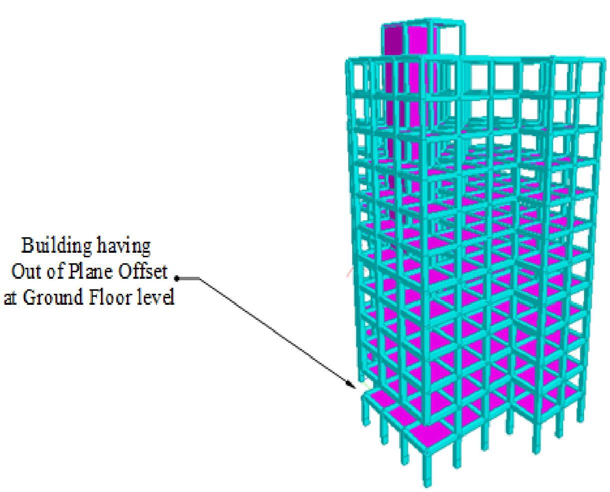

Fig. 5: SS-B1/SS-B2/SS-B3 - Residential Apartment having plan irregularity set at ground floor level

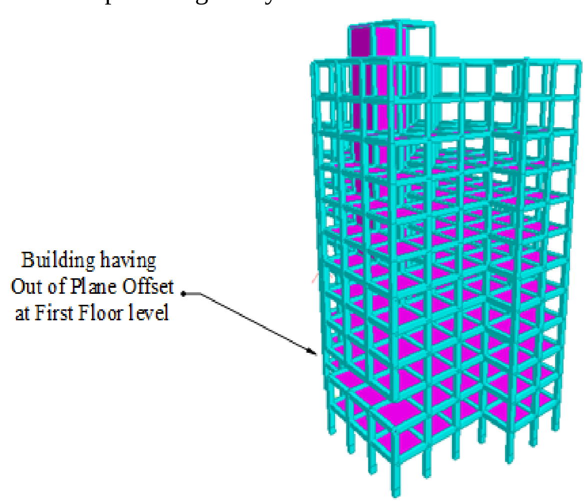

Fig. 6: SS-C1/SS-C2/SS-C3 - Residential Apartment having plan irregularity set at first floor level

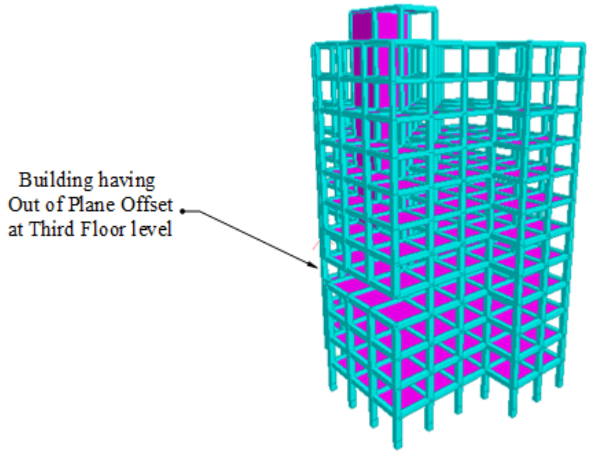

Fig. 7: SS-D1/SS-D2/SS-D3 - Residential Apartment having plan irregularity set at third floor level

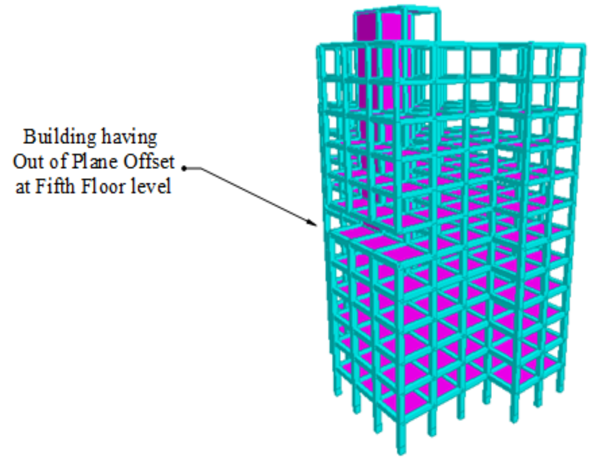

Fig. 8: SS-E1/SS-E2/SS-E3 - Residential Apartment having plan irregularity set at fifth floor level

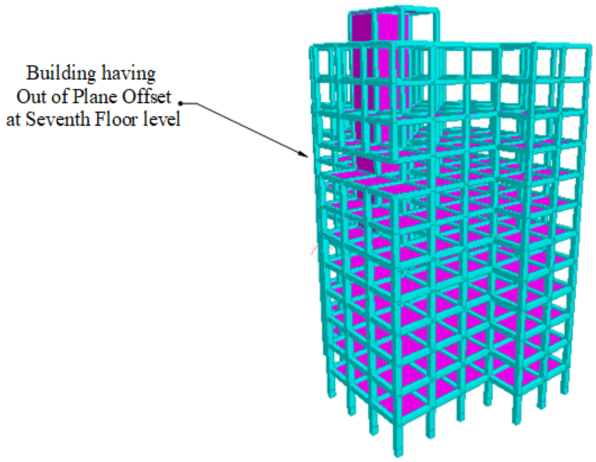

Fig. 9: SS-F1/SS-F2/SS-F3 - Residential Apartment having plan irregularity set at seventh floor level

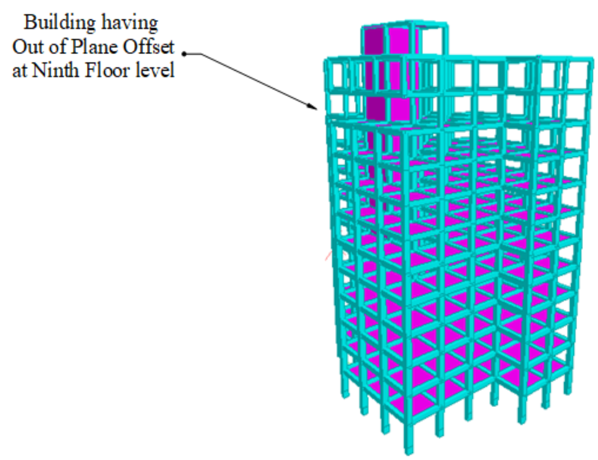

Fig. 10: SS-G1/SS-G2/SS-G3 - Residential Apartment having plan irregularity set at ninth floor level

IV. RESULTS ANALYSIS

The application of loads and their combinations on different cases as per the Indian Standard 1893:2016 code of practice yield result parameters:-

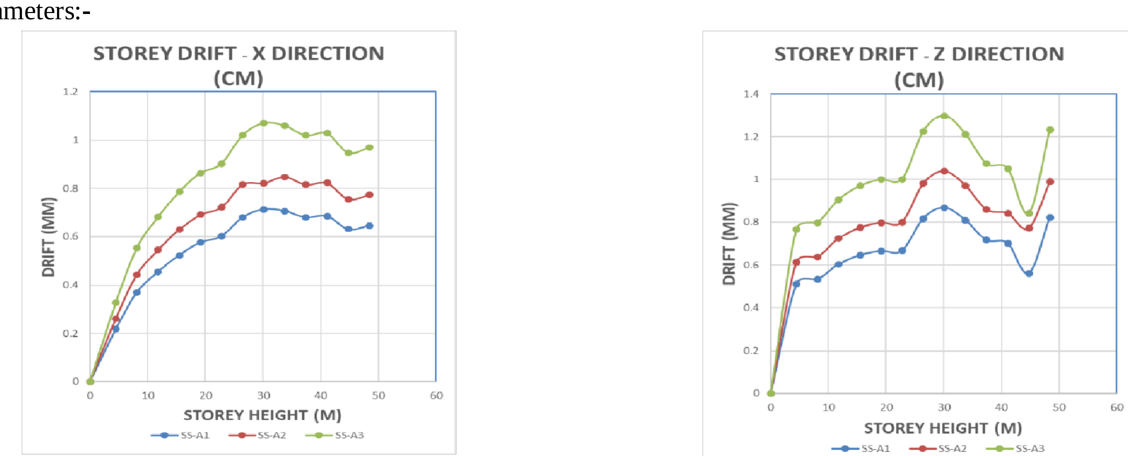

Fig. 11: Comparison of storey drift in X and Z direction for all importance factor cases for all SS-A1/A2/A3

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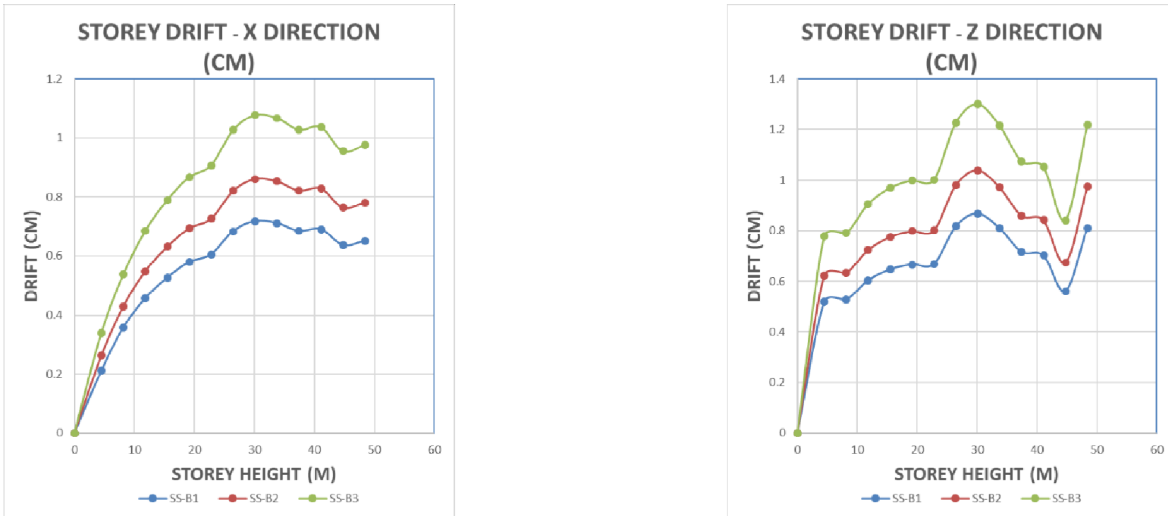

Fig. 12: Comparison of storey drift in X and Z direction for all importance factor cases for all SS- B1/B2/B3

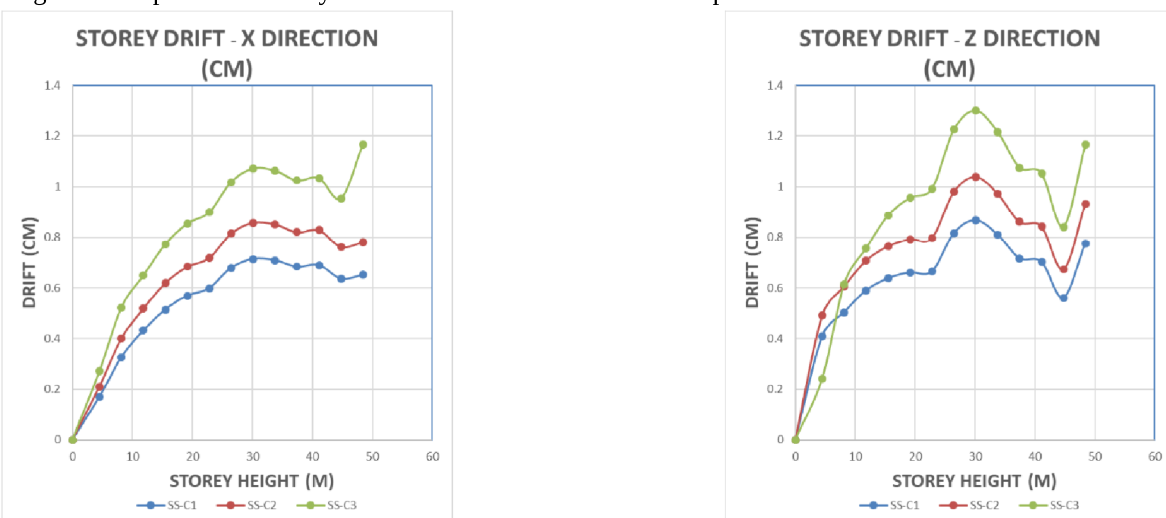

Fig. 13:Comparison of storey drift in X and Z direction for all importance factor cases for all SS- C1/C2/C3

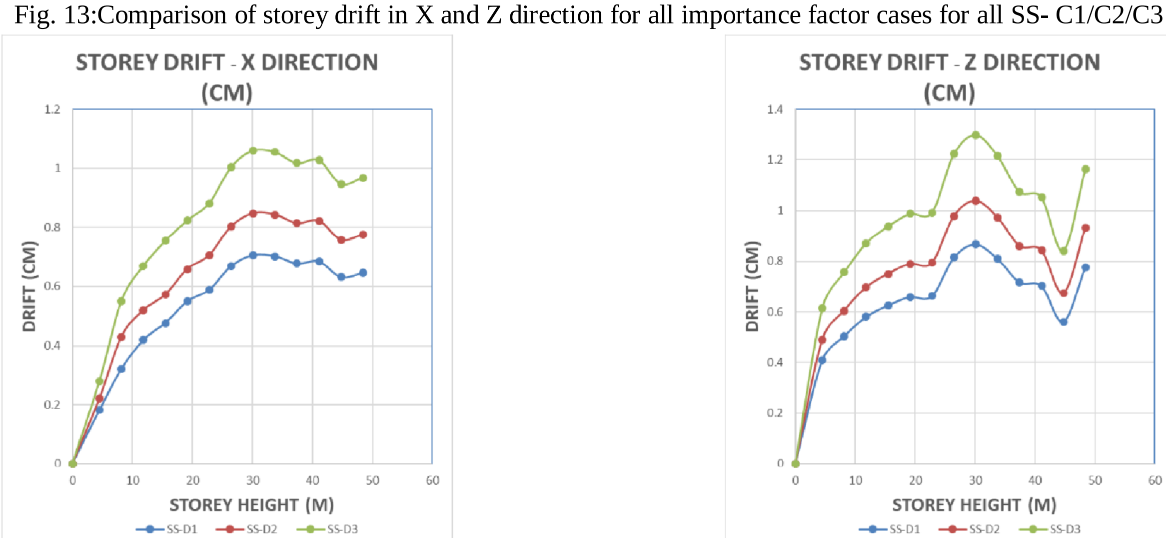

Fig. 14: Comparison of storey drift in X and Z direction for all importance factor cases for all SS- D1/D2/D3

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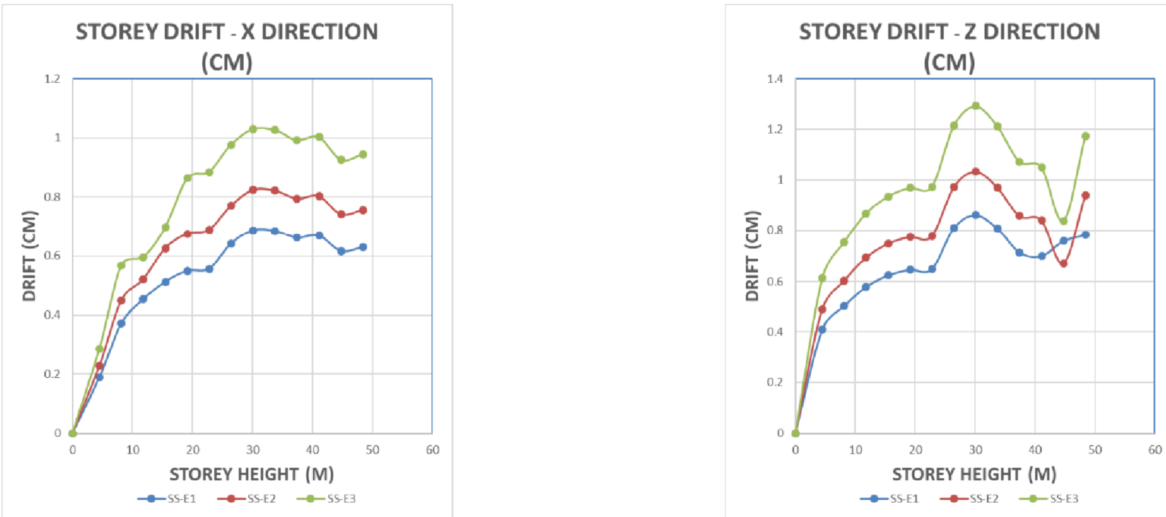

Fig. 15: Comparison of storey drift in X and Z direction for all importance factor cases for all SS- E1/E2/E3

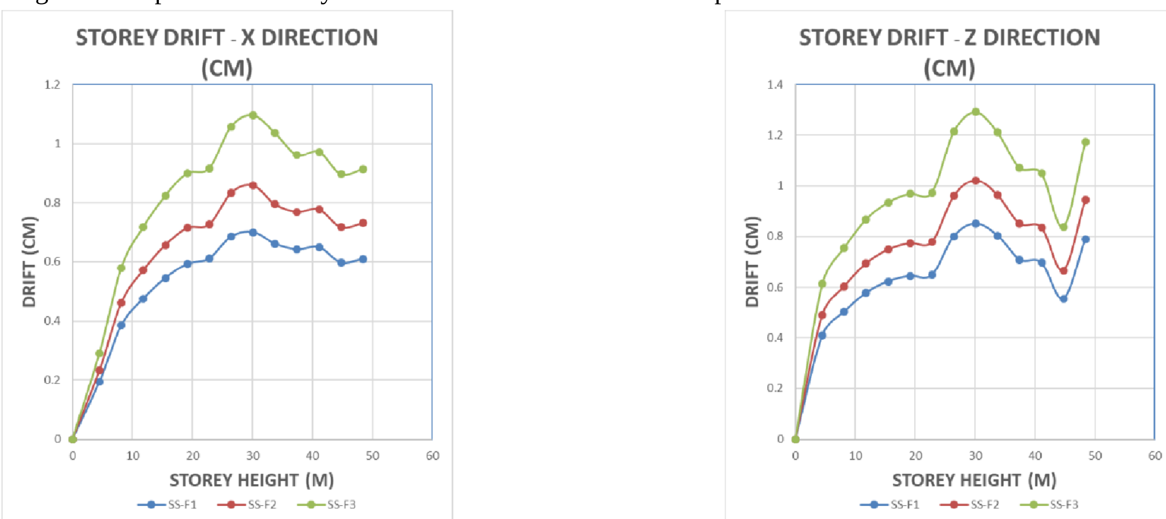

Fig. 16: Comparison of storey drift in X and Z direction for all importance factor cases for all SS- F1/F2/F3

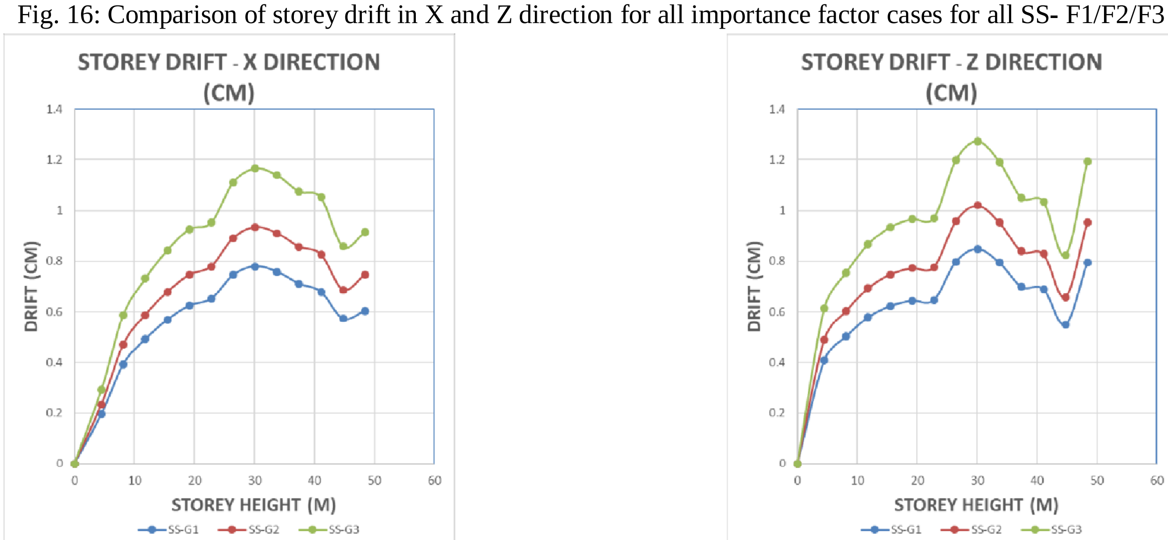

Fig. 17: Comparison of storey drift in X and Z direction for all importance factor cases for all SS-G1/G2/G3

V. CONCLUSIONS

Conclusion pointed out as per objectives selected are as follows:-

1) The creation of various cases of residential apartment with plan irregularities introduced at various floor levels, under varying seismic importance factors (I = 1.0, 1.2, and 1.5) has completed, considered 7 each importance factor related cases, modelled total of 21 cases.
2) The actual soil condition has introduced in all simulated cases by taking a soil investigation report and determined the horizontal spring stiffness (in this research, the value comes to be 7544444 kN/m respectively)
3) The Response Spectrum Method under dynamic analysis has used with zone factor Z = 0.16 using analysis software.
4) The evaluation and comparison of story drift responses in X and Z directions across different structural models (SS-A1/A2/A3 to SS-G1/G2/G3) has conducted. The results obtained for story drifts in both X and Z directions indicate a consistent trend as the importance factor increased, the corresponding story drifts also increased.

For all structural series (SS-A through SS-G), it was observed that:

- Models with higher importance factors consistently recorded greater drift values, especially at the mid and upper storeys.
- Among all levels of plan irregularity, irregularities placed at higher storeys (e.g., SS-G series at 9th floor) showed more significant drift amplification, such that upper level irregularities are more critical in seismic response.
- The Z-direction drift was generally higher than the X-direction, suggesting directional stiffness variation in the structural layout or irregularity impact.
- The increase in drift was not linear across importance factors, the jump from I = 1.2 to I = 1.5 induced relatively larger increments compared to I = 1 to I = 1.2, highlighting the more seismic sensitivity.
- This analytical investigation thus confirms that both the placement of plan irregularities and the selection of importance factor critically influence the seismic behaviour of multistory residential buildings.

The validation of drift responses against codal storey drift limitations as per IS 1893 (Part 1): 2016, with special attention to more severe drift criteria (L/500) applicable to irregular buildings obtained as:

Storey Drift Limitation as per IS Code (Clause 7.1, Table 5, sub section iv)

According to IS 1893 (Part 1): 2016, the maximum allowable storey drift under seismic loading for general buildings shall not exceed 0.004 times the storey height (L/250). However, for buildings with discontinuities such as plan irregularities, vertical offsets, or setbacks, the permissible limit is more stringent i.e. 0.002 times the storey height (L/500) to ensure structural integrity under seismic excitation.

In the present study, the evaluated models with different importance factors and irregularity levels were assessed against these codal limits. It was observed that in most configurations, models with higher importance factors (I = 1.5) exhibited higher story drift values, especially in cases where the plan irregularity was located at upper storeys (e.g., SS-G3). However, in several cases like SS-A1, SS-B1, and SS-C2 remained well within the codal drift limits, even for Z-direction displacements. On the other hand, configurations like SS-G3 approached the upper bound of permissible drift, underscoring the need for careful placement of irregularities and appropriate factor selection.

Hence, ensuring compliance with these drift limitations is has recommended that the codal checks confirm the analytical results and highlight the importance of combining importance factor selection with architectural regularity to prevent drift-induced damage or instability during earthquakes.

VI. ACKNOWLEDGEMENTS

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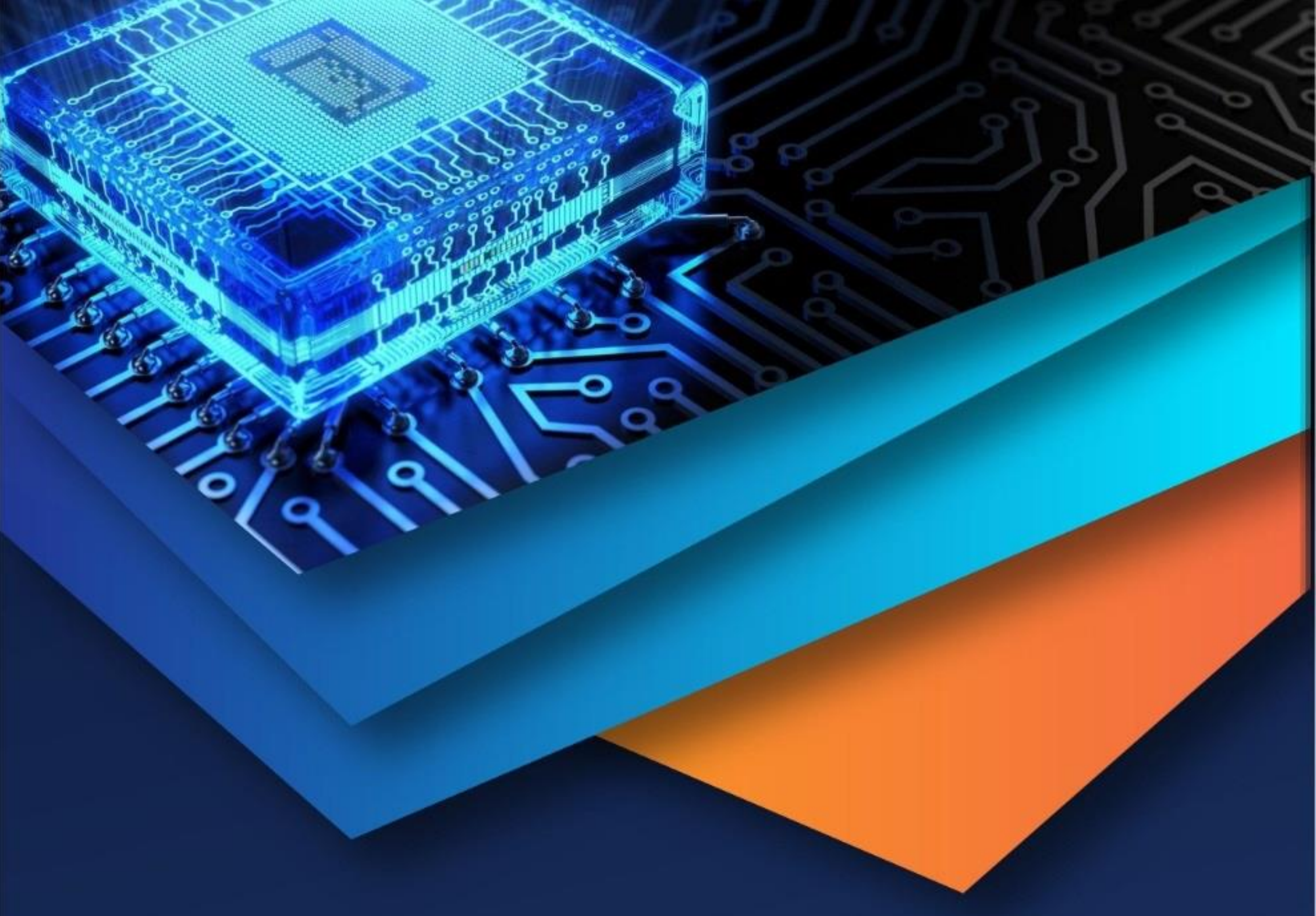

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