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Performance Analysis of Mass Irregular Reinforced Concrete Building With and Without Damper

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Abstract:
The structural irregularities such as mass irregularities significantly influence the seismic performance of reinforced concrete buildings by causing an uneven distribution of mass, stiffness, and lateral forces. These irregularities often result in excessive storey displacement and storey drift during earthquake excitation. This study investigates the seismic performance of a 16-storey reinforced concrete building with mass irregularities. Two structural configurations were analyzed: a conventional building without dampers and a building equipped with fluid viscous dampers. The analytical models were developed and evaluated using ETABS software in accordance with IS 1893 (Part 1): 2016 provisions. The effectiveness of the dampers was evaluated by comparing critical response parameters, namely storey displacement and storey drift, under seismic loading in both X and Y directions.

Keywords ***RC building, ETABS, fluid viscous damper, mass irregularity, storey drift.***

I. INTRODUCTION

The need for earthquake-resistant structures became highly apparent in the early 20th century following several destructive global earthquakes. Earthquakes generate dynamic forces that can cause significant damage or collapse if structures are not properly designed. In India, the first design code for earthquake-resistant structures (IS 1893-1962) proposed seismic coefficients to define equivalent static horizontal forces.

Building irregularities make a structure highly vulnerable to earthquake damages. According to IS 1893 (Part 1): 2016, vertical irregularities occur due to sudden variations along the height of the structure. Mass irregularity, specifically, is defined as a sudden increase in mass at any floor level.

To mitigate these effects, fluid viscous dampers (FVDs) are utilized to dissipate seismic energy. FVDs are velocity-dependent devices that allow the structure to remain elastic, converting kinetic energy into heat without causing severe structural damage. This study focuses on utilizing fluid viscous dampers to reduce seismic force and deformation demands in a mass irregular RC building.

1931 M7.4 Mach earthquake. However, the recommendations for earthquake loads were not formulated

in India till the first code for earthquake resistant design of structures was published in 1962 (IS 1893–1962), which proposed the values of seismic coefficients for different types of structures in each zone [1].

II. LITERATURE REVIEW

Several studies have highlighted the adverse effects of mass irregularity on the dynamic response of buildings:

- Sadashiva et al. (2009) investigated the influence of vertical mass irregularities on shear-type RC structures. They discovered that the location of the mass irregularity plays a critical role in the seismic response, noting that added mass at the top or bottom of a structure generally increases interstorey drift demands.
- Sudeepthi et al. (2016) analysed an RC building by introducing a mass irregularity at the 9th floor. The study confirmed that buildings with mass irregularity experience higher seismic demands, observing a sudden increase in bending moments and shear forces at the irregular storey.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive.”
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads

to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.

- Do not mix complete spellings and abbreviations of units: "Wb/m2" or "webers per square meter," not "webers/m2." Spell units when they appear in text: "...a few henries," not "...a few H."
- Use a zero before decimal points: "0.25," not ".25." Use "cm3," not "cc." (*bullet list*)

III. METHODOLOGY

Numerical analysis of reinforced concrete building structure was carried out for irregular building using ETABS software. The numerical analysis of the reinforced concrete building was carried out using ETABS software, a globally recognized tool for structural and earthquake engineering.

General Considerations (IS 1893-2016):

- **Seismic Zone Factor:** Zone V (0.36).
- **Response Reduction Factor (R):** 5.
- **Importance Factor (I):** 1.2.
- **Soil Type:** Type II (Medium or Stiff Soil).

Problem Statement Details: The model represents a 16-storey RCC building. To introduce mass irregularity, increased mass was applied to the 2nd, 3rd, 4th, 5th, and 6th floor levels. Furthermore, the height of these specific floors was increased from 4250 mm to 6000 mm. The remaining floors maintained a standard height of 4250 mm. Models were analysed with and without the provision of fluid viscous dampers to evaluate storey displacement and drift.as program calculated was applied in Etabs.

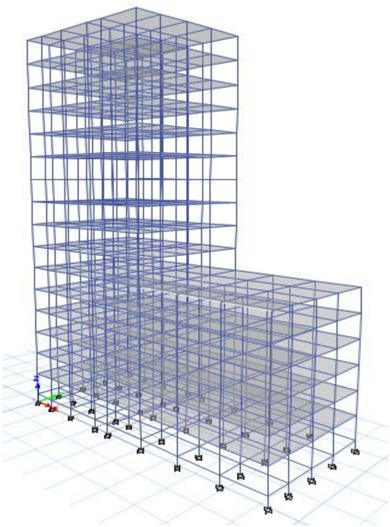

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Fig. 1. Elevation of a building

IV. RESULTS & DISCUSSION

Storey displacement represents the absolute lateral translation of an individual floor level with respect to the ground. Excessive displacement indicates inadequate lateral stiffness.

The application of fluid viscous dampers resulted in a considerable reduction in lateral displacement across all floor levels.

Table 1- Storey displacement in mass irregular building-without damper

Story Displacement without damper mass irregularity				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		mm	mm
Floor 16	76.5	Top	293.893	398.42
Floor 15	72.25	Top	287.181	391.25
Floor 14	68	Top	278.49	382.04
Floor 13	63.75	Top	267.571	370.59
Floor 12	59.5	Top	254.506	356.94
Floor 11	55.25	Top	239.519	341.31
Floor 10	51	Top	222.881	323.85
Floor 9	46.75	Top	204.924	304.73
Floor 8	42.5	Top	185.949	283.93
Floor 7	38.25	Top	166.431	261.32
Floor 6	34	Top	147.239	236.36
Floor 5	29.75	Top	129.024	207.79
Floor 4	23.75	Top	99.319	160.14
Floor 3	17.75	Top	67.727	109.49
Floor 2	11.75	Top	36.772	59.518
Floor 1	5.75	Top	11.075	18.115
Ground floor	1.5	Top	0.943	1.536
Base	0	Top	0	0

The table 2 below shows the values of Storey displacement in mass irregular building-without damper

Table 2- Storey displacement in mass irregular building-without damper

Story Drift Mass Irregularity Building without Damper				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m			
Floor 16	76.5	Top	0.00159	0.00182
Floor 15	72.25	Top	0.00205	0.00229
Floor 14	68	Top	0.00257	0.00284
Floor 13	63.75	Top	0.00307	0.00337
Floor 12	59.5	Top	0.00353	0.00386
Floor 11	55.25	Top	0.00392	0.00429
Floor 10	51	Top	0.00423	0.00465
Floor 9	46.75	Top	0.00447	0.00492

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Floor 8	42.5	Top	0.00459	0.00532
Floor 7	38.25	Top	0.00452	0.00587
Floor 6	34	Top	0.00431	0.00672
Floor 5	29.75	Top	0.00495	0.00794
Floor 4	23.75	Top	0.00527	0.00844
Floor 3	17.75	Top	0.00516	0.00833
Floor 2	11.75	Top	0.00429	0.0069
Floor 1	5.75	Top	0.00239	0.00391
Ground floor	1.5	Top	0.00063	0.00102
Base	0	Top	0	0

The table 3 below shows the values of Storey displacement in mass irregular building-with damper

Table 3- Storey displacement in mass irregular building-with damper

Story Displacement with Damper - mass irregularity				
Story	**Elevation**	**Location**	**X-Dir**	**Y-Dir**
	m		mm	mm
Floor 16	76.5	Top	198.719	235.97
Floor 15	72.25	Top	192.126	225.273
Floor 14	68	Top	183.964	213.173
Floor 13	63.75	Top	174.197	199.757
Floor 12	59.5	Top	163.001	185.182
Floor 11	55.25	Top	150.568	169.64
Floor 10	51	Top	137.097	153.308
Floor 9	46.75	Top	122.885	136.434
Floor 8	42.5	Top	108.138	119.219
Floor 7	38.25	Top	93.216	106.206
Floor 6	34	Top	79.248	94.95
Floor 5	29.75	Top	67.991	82.483
Floor 4	23.75	Top	52.241	63.705
Floor 3	17.75	Top	36.899	45.045
Floor 2	11.75	Top	21.771	27.049
Floor 1	5.75	Top	7.906	10.608
Ground floor	1.5	Top	1.113	2.053
Base	0	Top	0	0

The table 4 below shows the values of Storey drift in mass irregular building-with damper

Table 4 Storey drift in mass irregular building-with damper

Story Drift Mass Irregularity Building with Damper				
Story	Elevation	Location	X-Dir	Y-Dir
Floor 16	76.5	Top	0.0017	0.00281
Floor 15	72.25	Top	0.00207	0.00321
Floor 14	68	Top	0.00241	0.00363
Floor 13	63.75	Top	0.00271	0.00413
Floor 12	59.5	Top	0.00297	0.00467
Floor 11	55.25	Top	0.00319	0.00515
Floor 10	51	Top	0.00335	0.00554
Floor 9	46.75	Top	0.00347	0.00581
Floor 8	42.5	Top	0.00351	0.00582
Floor 7	38.25	Top	0.0033	0.00516
Floor 6	34	Top	0.00264	0.00534
Floor 5	29.75	Top	0.00237	0.00551
Floor 4	23.75	Top	0.00226	0.00534
Floor 3	17.75	Top	0.00212	0.0052
Floor 2	11.75	Top	0.0022	0.0047
Floor 1	5.75	Top	0.00157	0.00307
Ground floor	1.5	Top	0.00068	0.00126
Base	0	Top	0	0

The figure 2 and 3 shows, that the displacement values with dampers are considerably lower than those without dampers, demonstrating enhanced lateral stiffness and energy dissipation capacity of the structural system in X and Y both directions.

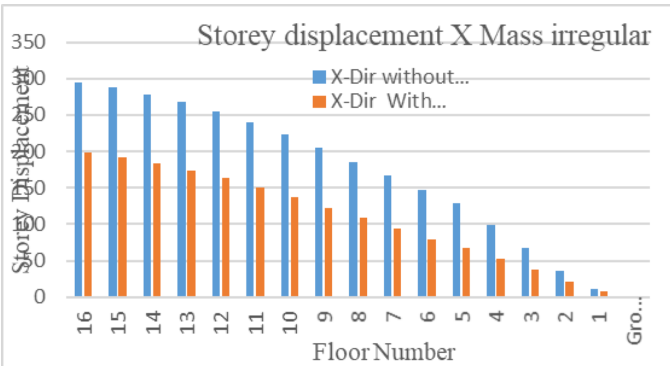

Fig. 2 Storey displacement X Mass irregular

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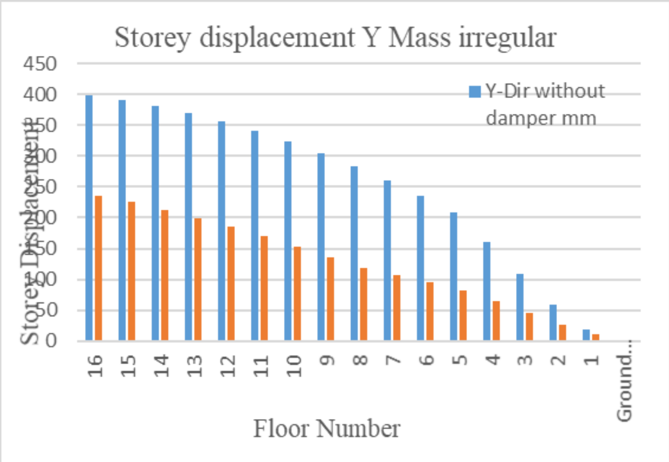

Fig. 3- Storey displacement Y Mass irregular

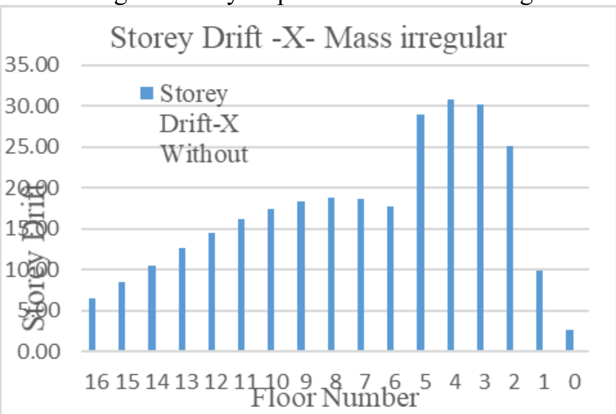

Fig. 4 Storey drift X-mass irregular

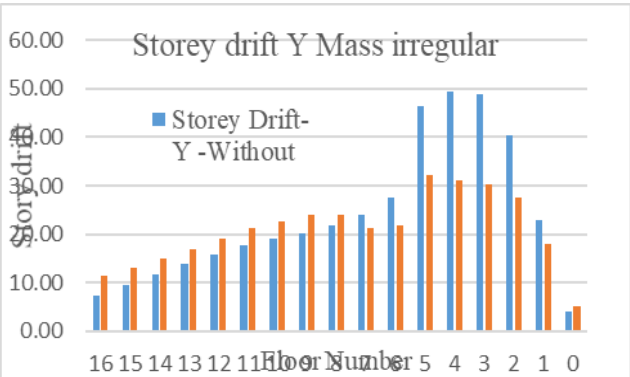

Fig. 5- Storey drift Y-mass irregular

V. CONCLUSIONS

Based on the comparative seismic analysis of the mass irregular RC building, the following conclusions are drawn:

1. **Storey Displacement:** The provision of fluid viscous dampers caused a substantial decrement in drift and displacement values, particularly at the irregularity levels (Floors 2 through 6). At the setback/irregular levels, the percentage reduction in storey displacement was above 45%.

2. **Structural Flexibility:** The structure without dampers exhibited significantly higher displacement in the Y-direction, indicating relative flexibility and vulnerability to seismic action along this axis.

3. **Drift Compliance (X-Direction):** The un-dampered building failed to meet IS 1893 drift requirements in the X-direction (max drift 30.83 mm > 24 mm allowable). The dampers successfully constrained this to 14.43 mm, making the building code-compliant and highly effective in controlling lateral deformations.

4. **Drift Compliance (Y-Direction):** While the dampers provided a drift reduction of 30.40% to 37.58% at the critical mass irregular floors in the Y-direction, the final values still exceeded prescribed limits. This indicates that additional stiffness enhancement or optimization of the damper configuration is required for full compliance along the Y-axis

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