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Seismic Performance Analysis of Vertically Irregular Buildings with Soft Storey and Fluid Viscous Dampers in Earthquake Zone V

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ABSTRACT: The construction of vertically irregularly shaped structures has significantly increased due to aesthetic considerations and limited site availability. Previous research has shown that structures with irregular designs sustain damage under intense ground motion. Structural anomalies in edifices result in an uneven allocation of story drift and displacement, which may precipitate collapse during seismic activity. Moreover, vertically uneven edifices result in stress concentration within structural components. This dissertation examines the stiffness irregularity of structures exposed to seismic zone V conditions. Seven distinct models were evaluated: the first model is the fundamental version without a soft narrative and fluid viscous damper, followed by three models including a soft story, and three models featuring both a soft story and fluid viscous dampers. reaction Spectrum Analysis was used in the evaluation procedure to quantify the seismic reaction concerning displacement, drift, and base shear. The results indicate that structures including a soft story and dampers perform more efficiently than those lacking dampers.

KEYWORDS: Vertically Irregular Buildings, Soft Storey, Fluid Viscous Dampers, Seismic Response, Stiffness Irregularity, Earthquake Zone V, Story Drift, Displacement, Base Shear, Response Spectrum Analysis, Structural Irregularities, Stress Concentration.

I. INTRODUCTION

Conventional construction is mostly an idealization, although the bulk of structures are inherently irregular. Principal seismic regulations categorize structural irregularities into those occurring in plan and elevation; nevertheless, structural irregularities sometimes manifest in structures as a mix of both types. Structural imperfections arising from unequal distribution of mass, stiffness, and strength throughout the plan induce torsional behavior, causing in significant damage due to floor rotations and translations, as shown by several earthquake damage assessments. Stiffness irregularity is the most extensively studied kind of irregularity among the vertical varieties of structural irregularity in structures. Stiffness irregularity presents the greatest seismic demand, particularly when coupled with strength fluctuations, rendering structures more susceptible than other forms of irregularity. Fluid viscous dampers, which efficiently mitigate vibrations and sustain structures under dynamic loads, are a widely used solution to this issue. This study aims to evaluate the effectiveness of fluid viscous dampers with stiffness irregularity in mitigating structural vibrations caused by earthquakes. The research evaluated structural performance based on displacement, drift, and shear values. Fluid viscous dampers have superior effectiveness in controlling floor vibrations induced by diverse external loads, especially those resulting from earthquakes and wind, as compared to conventional horizontal load-resisting systems.



Fig.1.1: Bhuj Earthquake

The paper is structured as follows. Section II delineates automated text identification using morphological procedures, linked component analysis, and a set of selection or rejection criteria. The flowchart illustrates the stages of the algorithm. Following the identification of text, the text area is filled with an inpainting approach described in Section III. Section IV delineates the experimental outcomes derived from the tested photographs. Ultimately, Section V provides the conclusion.

II. LITERATURE SURVEY

This chapter reviews the following literature to provide a comprehensive overview of current understanding, identify gaps, and highlight trends.

Bryan Chalarca, Danniell Perrone et al. (2023) [1] conducted a parametric study on the floor acceleration response of three buildings used in case studies using fluid viscous dampers via nonlinear time-history analysis. The results indicated that various design parameters of fluid viscous dampers substantially alter the floor acceleration response, with some damper configurations producing floor accelerations greater than those seen in structures without dampers.

Kul Vaibhav Sharma et al. (2023) [2], The objective of this study is to evaluate the effectiveness of fluid viscous dampers at various locations in mitigating earthquake-induced structural vibrations. The results are compared across three distinct damper placement scenarios: uniformly on all floors and at three specific levels (top, bottom, and center) for a G+20 storey framed structure. The structural performance has been evaluated based on displacement, drift, and shear values throughout the investigation. Installing dampers on each floor is the most effective method to reduce the building's seismic response.

Bin Wang et al. (2023) [3] examined the behavior of flanged reinforced concrete walls subjected to biaxial cyclic loads. Flanged RC walls are often used for their capacity to provide stiffness and strength in two directions. This significantly influences their response to seismic activity. They are, however, elucidating the performance of flanged walls under biaxial cyclic stresses. Testing was conducted on three L forms in comparison to two T shapes; the L shapes exhibited worse seismic performance relative to the T shapes.

Pinar Okumus et al. (2023) [4] investigated the retrofit technique by integrating the principles of targeted weakening and self-centering (rocking). The suggested solution decreases shear demand by transforming conventional in-situ concrete shear walls into rock walls. Two extensive horizontal load tests are conducted to verify the retrofit idea on a concrete shear wall built to 1970s standards. The assessment indicated reduced damage and enhanced resilience levels.

Limin Lu et al. (2022) [5] performed static tests on shear walls including post-openings of several dimensions, namely 550 mm x 650 mm, 700 mm x 850 mm, and 850 mm x 1000 mm. The impact of steel plate reinforcement on load-bearing capacity, flexibility, and energy absorption.

The dissipation capacity and shear deformations of shear walls with different aperture dimensions were examined. The findings demonstrate that affixing steel plates near the apertures effectively mitigates corner cracking and

strengthens the shear wall. The load-carrying capacity of the enhanced shear wall is significantly boosted, with the larger opening speeding up this enhancement.

The research by Munni et al. (2022) [6] evaluated three distinct soil conditions in accordance with IS 1893 (Part 1): 2016 for a seismic zone-V site including an irregularly shaped building layout. The assessment in the ETABS program used the Response Spectrum method. High-performance concrete, steel fibers, and steel are used in the construction to enhance its seismic resistance. The results of the numerical analysis for irregular buildings are correlated with those of a typical building design when examining hard, medium, and soft soils. The numerical analysis yields diverse dynamic response features, such as displacement, storey shear, storey drift, storey stiffness, fundamental time period, and modal mass participation ratio, accompanied by a comparative examination. M.A. Waseya et al. (2022) [7] examined the use of non-linear time history analysis (NLTHA) for evaluating vertically irregular buildings. Buildings of five, ten, and fifteen stories, together with a conventional structure, were developed and assessed. To identify the optimal seismic control method for vertical irregularities, all structure models are assessed using alternatives such as base isolators, fluid viscous dampers, and stack walls. The zone factor Z is 0.36, used for seismic analysis. During the assessment of these architectural models for gravitational and seismic impacts. Structures including shear walls, isolators, and dampers shown superior efficacy in mitigating the effects of earthquakes.

Mohamed Mouhine et al. (2022) [8] aim to evaluate the susceptibility of RCC structures to seismic forces. According to Mohamed Mouhine, the vulnerability peaks of 20 models including various setbacks are established for this objective. A nonlinear static analysis was conducted using a FEM computational tool. The fourth-floor setback buildings low seismic stability suggests a high likelihood of significant damage, according to the research. Konstantinos Kostinakis et.al (2021) [9], conducted a study to investigate how the random placement of masonry infills caused in-plan defects that resulted in structural harm to RC structures during earthquakes. Five different buildings are examined, each having various infill distributions, in order to conduct nonlinear time-history analysis and assess their vulnerability to seismic impacts. The results suggest it is crucial to consider the irregularities when placing the infills.

Kyoung Min Ro et.al (2021) [10], suggested a simplified design approach for impractical vertical structures. The method was created or proposed to transform structurally uneven buildings into geometrically consistent ones through the utilization of a stiffness equation based on storey telling. The suggested approach might be applied in the early phases of the creation of buildings to speed up project completion by estimating nonlinear seismic effects like shear and drifts in vertical asymmetrical structures.

Mareim M. Abd-Alghany et.al (2021) [11], investigated the durability of RC structures with weak storeys through the finite element method. The factors being examined include the height of the soft storey, the asymmetry in the design, and the positioning of the soft storey within the structure. This research aims to identify the optimal location of a soft storey within the building structure to minimize its impact. Research is being conducted to enhance the structural safety by examining the effectiveness of implementing basic strengthening methods. R.M. Tejashwini et.al (2021) [12], studied how setbacks structures respond to earthquakes by combining empirical and quantitative approaches, considering the evaluation of the soil-structure interface. The regulations for piling foundation were established with different setbacks for buildings.

Reza Siami Kaleybar et.al (2021) [13], This study analyzed the seismic performance of 84 RCC bridges, including twelve straight bridges and seventy-two curved bridges, conducted by Reza Siami Kaleybar. The planning and construction followed AASHTO regulations. Both nonlinear and linear analyses were conducted and their results were tabulated to evaluate the precision of seismic response predictions produced through elastic analysis, in accordance to AASHTO. There are restrictions on the use of straighter bridges due to certain limitations on inclination.

Rohan Bhasker et.al (2020) [14], examined thirteen three-storey gravity-designed RC moments frame structures that were subjected to bilateral seismic excitation, forming the foundation of the computational investigation into nonlinear earthquake assessment. A vector composed of the normalized static eccentricity ratio and the ratio of torsional radius to mass radius of gyration is shown to be efficient in lower phase angles.

Bharat Khanal et.al (2020) [15], evaluated how deviations in plan layout impacted by the varying angle of the input response spectrum. This included analyzing one typical and six different L-shaped RC building frames through computational assessment, involving linear static and dynamic evaluations. It's been discovered that the existing standards for the code are insufficient and must be modified. The flaws are identified within the constructions.

Pranab Kumar Das et.al (2020) [16], apart from to the tremors that happened in Kern County in 1954, they stated outcomes from two additional recent quakes that took place in Nepal and Imphal, India in 2015 and 2016. Although buildings after being carefully examined, there are no defined criteria for multistorey asymmetric skyscrapers .

After reviewing the literature, the objectives that were derived are as follows.

- To analyze the stiffness irregular RC frame building using ETABS.
- To determine the optimum location of soft storey along with fluid viscous damper byconsidering seismic zone 5.

III. METHODOLOGY

GENERAL

The current study uses ETABS 2016 software to analyze stiffness irregular buildings through vertical irregular RC frames with fluid viscous dampers. The model was evaluated for zone five and there was usage of linear response spectrum analysis techniques following IS: 1893 2016 part 1. Appropriate grades of concrete and steel are designated for elements such as column, beam, and slab. The loads are defined as per the structural system's configuration based on IS 875.

A comprehensive examination has been conducted and findings have been compiled. Conclusions are made regarding the way the structure performs being compared.

3.1 SEISMIC ANALYSIS OF BUILDING

It is included in structural analysis that focuses on calculating a building's or non- building's response to earthquakes. In earthquake-prone areas, it is a critical aspect of structural design, earthquake engineering, and structural valuation and retrofitting. During an earthquake, a structure can "wave" back and forth, similar to its response during a severe wind storm. The fundamental mode, or "basic mode," is the lowest frequency of the building's response. However, most structures also exhibit higher modes of response that are activated during earthquakes.

The primary and secondary modes typically cause the most significant damage. The visual representation often highlights the second mode, but higher 'shimmy' (abnormal vibration) modes also exist. From the earliest times of earthquake engineering, the field has made significant advancements. Today, some of the most complex designs incorporate specialized earthquake protection components, such as base isolation in the foundation or dampers distributed throughout the structure. These innovations are aimed at enhancing the building's resistance to seismic forces and minimize damage.

3.2 RESPONSE SPECTRUM ANALYSIS

A linear-dynamic statical analysis technique known as response spectrum analysis (RSA) calculates the contribution from each natural mode of vibration to determine the likely maximum seismic response of a primarily elastic structure. Using pseudo-spectral acceleration, velocity, or displacement as a structural period measure for a particular time history and damping level, response spectrum analysis sheds light on dynamic behavior. It is practicable to use envelope response spectra to generate a smooth curve for each realization of a structural period. Because response spectrum analysis links structural type to dynamic performance, it is useful for making design decisions. Shorter period structures accelerate more, while longer period structures shift more. During the initial design and response phase, structural performance objectives must be taken into account in order to obtain optimal dynamic performance.

3.3 ETABS SOFTWARE

ETABS offers a single user interface to perform modeling, analysis, design, and reporting. There is no limit to the number of model windows, model manipulation views, and data views. CSI software stores model data and other information in database tables which may be edited directly through interactive database editing. This important feature allows models to be developed or edited quickly. Utilize interactive design capabilities to maximize efficiency like

design of steel frame concrete frames, concrete slabs, shear walls, composite beams, composite columns and steel joist can be carried out depending on variety of us and international design codes. ETABS offers a broad variety of code-based design features for steel and concrete frames, cold form steel, and aluminum frame. View a full list of supported design codes. With CSI software, collaboration between different AEC teams is handled efficiently through compatibility with other BIM software.

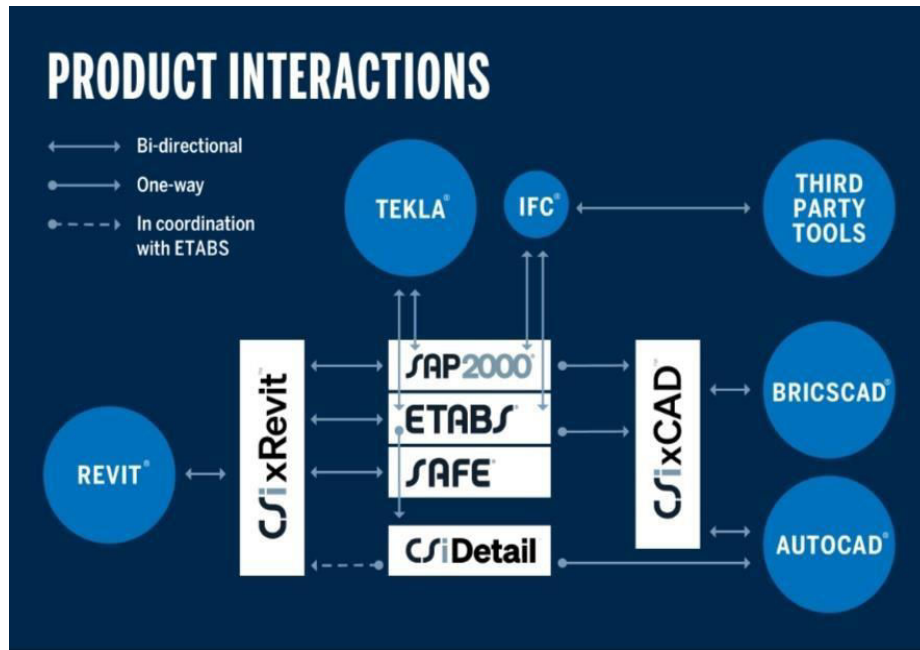


Fig.3.1: Product Interaction (BIM)

3.4 MODEL DETAILS

This study focuses on a building with vertical irregularity of model that has G+10 storeys and a plan size of 30.91 m in X direction and 36.98 m in Y direction.

Table 3.1: Attributes of the Model Materials and Sections

Structural Parameters	Values
Dimension of Plan	30.91 m x 36.98 m
Number of stories	G+10
Support condition	Fixed
Height of Storey	3 m
Soft storey	5 m
Grade of Concrete	M 25
Steel Grade	HYSD 550

Size of Column	600 mm x 300 mm
Size of Beam	350 mm x 400 mm
Thickness of Slab	150 mm
FVD	500 kN
Brick Infill Density	20 kN/m ³
Structure's total height	35 m

Table 3.2: Details of the model's load specification

Load type	Values
Wall load	15 kN/m ²
Live load	3 kN/m ²
Load Combination	1.2 (DL + LL + EL)
Soil type	Hard soil
Importance factor	1.2
Response reduction factor	5
Zone factor(Z)	Zone-V: (0.3)

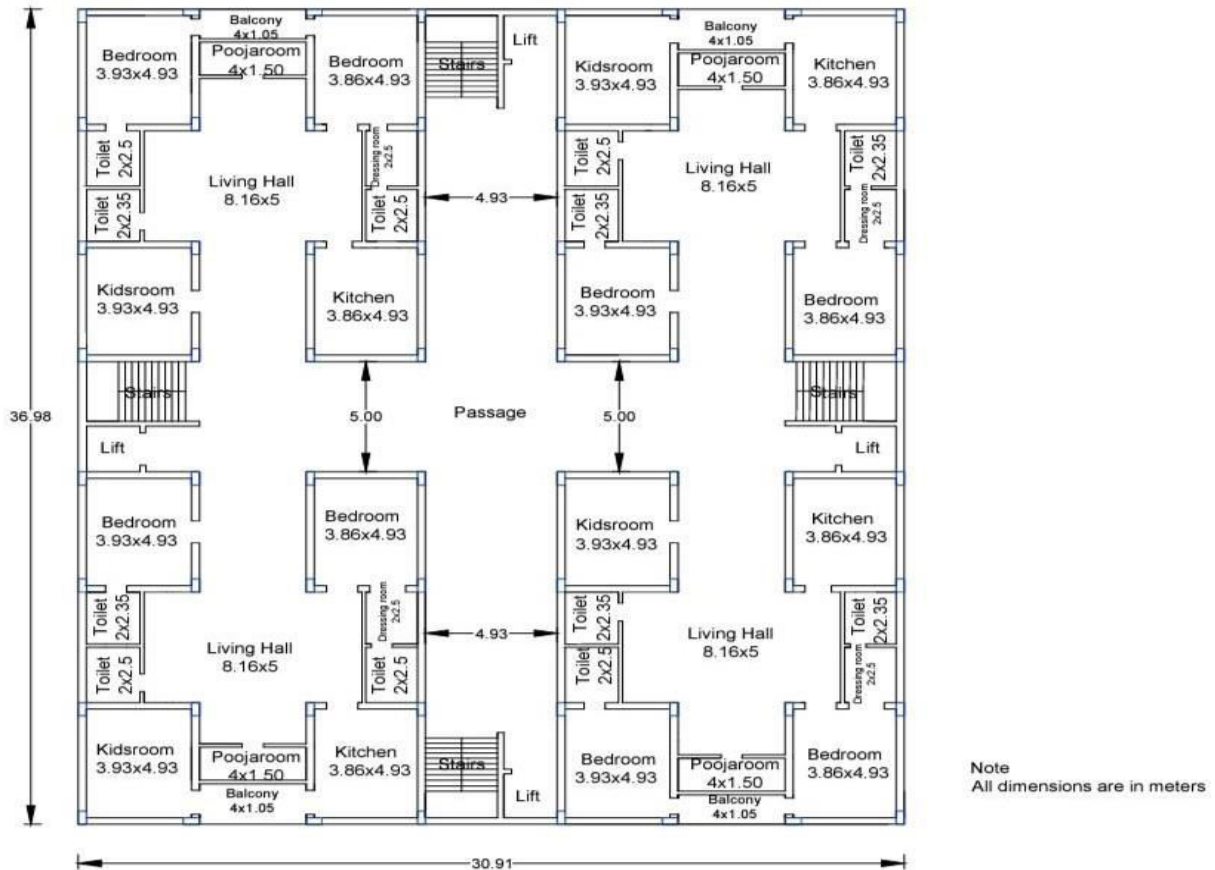


Fig.3.2: Architectural plan

Analysis steps in ETAB's

1. Model initialization.
2. Defining the grid system.
3. Defining material properties.
4. Defining sectional property.
5. Load pattern and load combination.
6. Assigning the loads to the section.
7. Check model
8. Run Analysis

IV. EXPERIMENTAL RESULTS

This study emphasizes on analyzing the seismic impact on a building with vertical irregularity, specifically a G+10 storey building equipped with fluid viscous damper, to lessen the seismic effects on the structure.

STOREY DISPLACEMENT

It is described as the building's movement in relation to its foundation. Seismic ground motion could cause the building to move, causing harm to both structural and non- structural elements.

Table 4.1.: Storey Displacement in X-direction (mm)

Storeys	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
11 th	183.778	210.166	202.434	194.117	134.682	134.722	142.253
10 th	178.926	206.089	198.078	178.772	121.934	121.616	118.276
9 th	170.751	199.212	190.784	170.058	108.573	107.881	103.893
8 th	159.694	189.753	180.873	158.905	94.446	93.356	89.173
7 th	145.758	177.66	168.233	144.908	79.596	78.076	74.089
6 th	129.629	163.481	152.075	128.702	64.231	62.262	58.8
5 th	111.331	147.285	101.126	110.32	48.719	45.68	43.631
4 th	90.949	129.22	82.418	89.908	33.613	30.429	29.196
3 rd	68.552	109.391	62.73	67.587	19.694	16.915	16.296
2 nd	44.267	87.811	40.893	43.518	8.023	6.274	6.065
1 st	18.911	62.9	17.601	18.544	3.074	2.115	2.005
Base	0	0	0	0	0	0	0

Discussions

From the table 4.1, the displacement goes on increasing as the storey height does, it is observed that lower displacement values in model 7 having stiffness irregularity along with the combination of fluid viscous damper. The displacement has reduced by placing the soft storey at upper level.

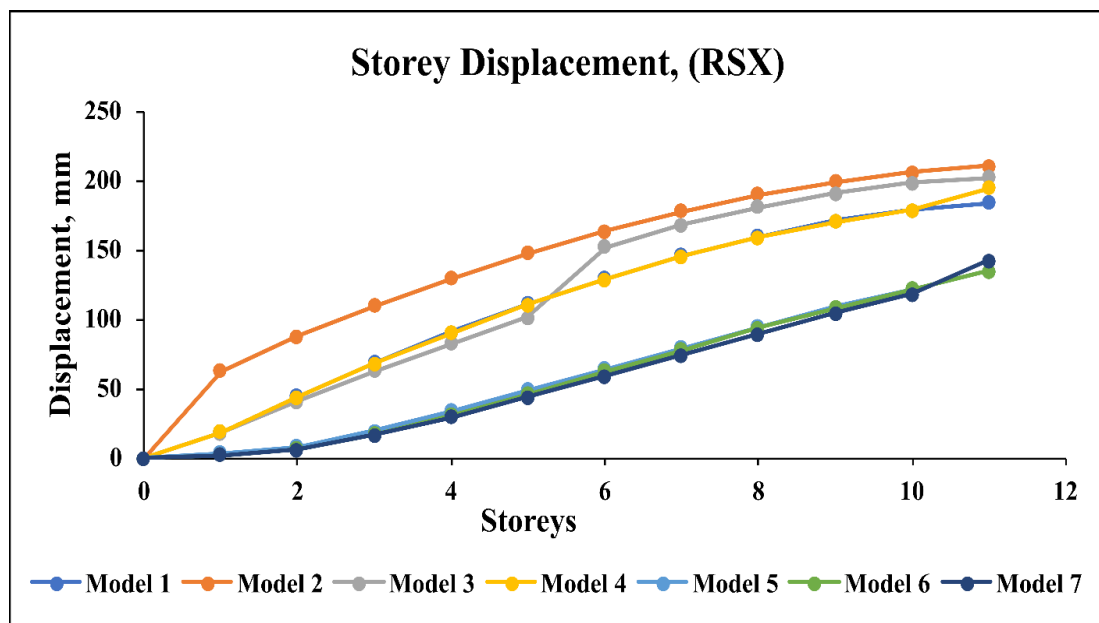


Fig.4.1: Storey Displacement in (RSX)

Observation

The graph shows that greater heights in each model result in higher displacement. Model 7 had the lowest displacement of 2.005 mm, while model 1 had a displacement of 18.911 mm at the base.

Table 4.2: Storey Displacement in Y-direction (mm)

Storeys	Model 1	Model 2	Model 2	Model 4	Model 5	Model 6	Model 7
11 th	152.898	169.569	165.907	160.107	112.905	112.484	117.037
10 th	148.782	165.899	162.142	149.135	102.112	101.348	103.7
9 th	141.908	159.779	155.885	141.634	90.756	89.653	90.95
8 th	132.428	151.275	147.225	131.977	78.748	77.325	77.811
7 th	120.66	140.618	136.215	120.153	66.144	64.443	64.391
6 th	106.824	128.017	121.919	106.27	53.149	51.283	50.936
5 th	91.057	113.632	84.713	90.456	40.107	37.153	37.304
4 th	73.426	97.549	67.711	72.81	27.509	24.713	24.847
3 rd	54.038	79.805	50.086	53.477	16.014	13.682	13.781
2 nd	33.278	60.341	30.996	32.864	6.479	5.044	5.086
1 st	12.773	38.536	11.925	12.591	3.449	2.558	2.431
Base	0	0	0	0	0	0	0

V. CONCLUSION

The current work looks at soft storey at different elevations, fluid viscos dampers, and stiffness irregular buildings with vertical irregularity in order to lower seismic parameters with regard to seismic zone V. The values are within the allowable limit of storey drift $0.004H$, where H is the height of the structure. Drawing from the work, the following deduction may be made:

- The greater the height of the structure, the larger the vertical displacement of the storey due to increased exposure to environmental forces. Adding a soft storey results in a rise of 14.35% in displacement for model 2, 10.15% for model 3, and 5.62% for model 4. Conversely, the displacement decreases by 26.71% for model 5, 26.69% for model 6, and 22.595% for model 7 when a combination of soft storey and fluid viscous damper are used compared to model 1.
- The rise in storey drift is not constant as the building elevation increases, with higher storey drift observed in the mid-levels of the structure because of an eccentric center of mass and resistance. Placing the soft storey leads in a 48.64% increase in model 2, a 37.89% increase in model 3 and it is decreased of up to 1.57% in model 4, 38.20% in model 5, 36.19% in model 6, and 38.43% in model 7.
- Base shear decreased up to 6.20% in model 2, 6.52% in model 3, 1.58% in model 4, 55.19% in model 5, 49.57% in model 6, and 58.19% in model 7.
- The soft storey's location plays a crucial role in building safety, from the analysis it is seen that placing the soft storey at lower elevation makes the building relatively flexible and placement of soft storey at upper level makes the building relative stiff.
- The fluid viscous damper has a significant impact on controlling the floor vibration by decreasing the acceleration of earthquake force through hydraulic action.

FUTURE SCOPE OF THE WORK

- The study can be expanded by including other seismic zones.
- The study can be done for other types of irregularities.

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