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Seismic Analysis of Irregular Diaphragm Reinforced Concrete Building with Fluid Viscous Dampers

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Abstract: Fluid viscous damper is the most commonly used tool for controlling structures' responses. Fluid viscous dampers with different construction technologies are applied in order decrease the responses of structures to the seismic vibrations. During the recent years, controlling structure has turned into a scientific technology to protect structures against wind and earthquake loads. In the present study linear dynamic and non-linear static analysis was adopted to assess the seismic performance of an irregular diaphragm building. Building with and without fluid viscous damper have been taken.The outcomes of the study will be beneficial to assess the performance of existing building vulnerable to seismic loads after the installation of fluid viscous dampers.
Keywords: Diaphragm, Fluid Viscous Damper, Hinges, Irregular, Seismic Analysis, Storey Drift

I. INTRODUCTION

The viscous fluid dampers (VFD) are the more applied tools for controlling responses of the structures. These tools are applied based on different construction technologies in order to decrease the structural responses to the seismic excitation. In last few years, many essential developments in seismic codes are turned up. Utmost of the modification in the seismic design area derive from greater awareness of actual poor buildings performances in contemporary earthquakes. Due to the renewed knowledge of the existing buildings behaviour, retrofit of buildings is a paramount task in reducing seismic risk. New techniques for protecting buildings against earthquake have been developed with the aim of improving their capacity. Seismic isolation and energy dissipation are widely recognized as effective protection techniques for reaching the performance objectives of modern codes. However, many codes include design specifications for seismically isolated buildings, while there is still need of improved rules for energy dissipation protective systems. When the structure has much absorbing capacity than the Seismic energy then it can withstand the structural damage. Equivalent viscous damping can be used as a feasible means of decreasing the structural damage. By absorbing seismic energy and reducing structural deformations, damper structures are designed and engineered to protect structural integrity, limit structural damages, and prevent injuries to residents. With the use of seismic dampers, a structure is able to withstand high input energy and reduce destructive deflections, stresses, and accelerations to its occupants and other structures. In FVD damper, by using viscous fluid inside a cylinder, energy is dissipated. Due to ease of installation, adaptability and coordination with other members also diversity in their sizes, viscous dampers have many applications in designing and retrofitting. In viscous dampers, a silicone-based fluid that circulates between a piston-cylinder configuration absorbs seismic energy. High-rise structures in seismic zones require viscous dampers. It can function in temperatures between 40 and 70 degrees Celsius. Strong winds and earthquakes both cause vibrations, which are reduced by viscous dampers. The term diaphragm discontinuity or irregularity refers to a diaphragm with a cut or open area that is greater than 50% of the gross diaphragm area or a sudden break or variation in stiffness that is greater than 50% in the effective diaphragm stiffness. Table 5 of IS 1893:2016, has explained the criteria of diaphragm irregularity. Opening in slabs causes flexible diaphragm behaviour, thus the frames and/or vertical elements do not share the lateral shear stress according to their lateral translational stiffness. When the opening is near the slab's edge, the issue is most severe. A few decades ago, the majority of residential and commercial buildings being developed tended to be simple, redundant constructions with lateral resisting systems that were informally structured. There were very few horizontal and vertical offsets in these buildings. The structural designs of many modern structures, on the other hand, demand for complicated lateral load paths that incorporate diaphragms at various elevations, several re-entrant corners, numerous irregularities, and fewer vertical lateral force-resisting features. To ensure complete load paths throughout the building, it is crucial to remedy these design flaws and inconsistencies, but doing so doesn't have to be difficult.

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The main objectives of the study is to compare the seismic response of irregular diaphragm buildings, with and without fluid viscous damper at different locations.

II. METHODOLOGY

A. Model

In this study10 storey building having 3m storey height is taken for study. The geometry of the building is rectangular. The buildings are modelled on Etabs 2018 software. The code used for designing these buildings is IS 456:2000 “Code of practice for plain and reinforced concrete”, IS 1893:2002 “Criteria for earthquake resistant design of structures”. Following models and nomenclature have been used in the model to categorise different models used in this study.

1) IRDB - 10 storey diaphragm irregular building without FVD
2) IRDB - 2FVD - 10 storey diaphragm irregular building with FVD on 2 faces
3) IRDB - 4FVD - 10 storey diaphragm irregular building with FVD on 4 faces

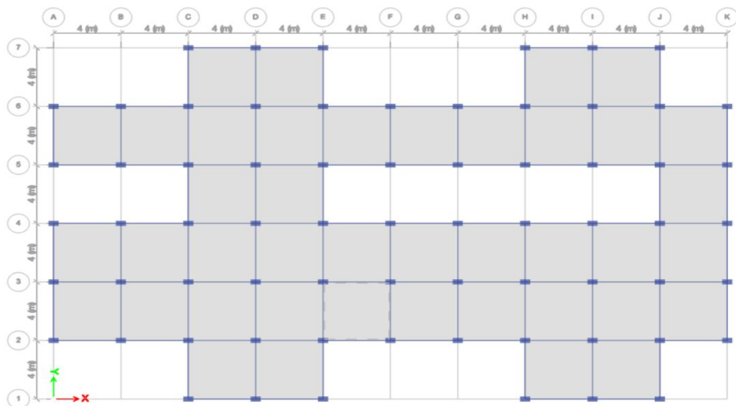

Fig. 1 Plan of 12 Storey Building

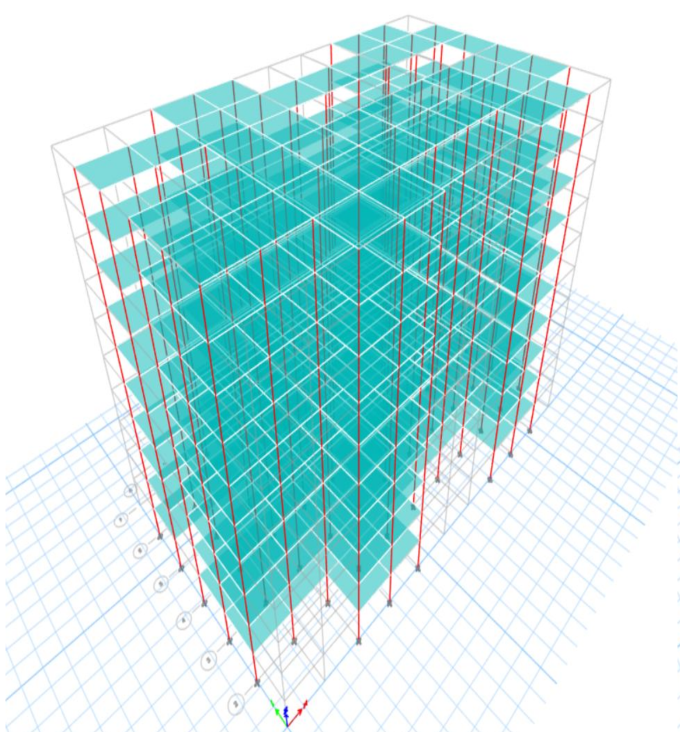

Fig. 2 3D view of diaphragm irregular building

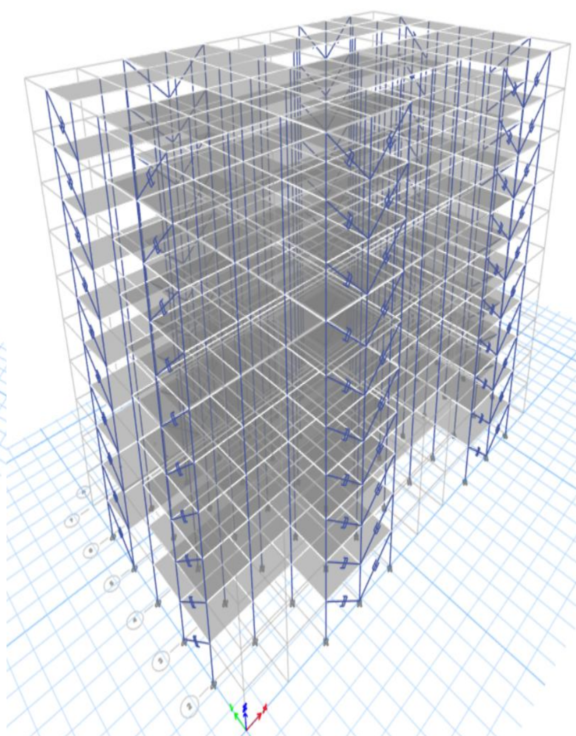

Fig. 3 3D view of diaphragm irregular building with damper

B. Geometrical Properties

The geometric parameters of structures considered for study consist of the geometric plan structure height, storey height, span & floor area of structures. The geometric details are given in table 1. The beam sizes and column sizes are determined by the hit and trial method until the safe design is achieved.

Table 1. Element Properties

S.No.	Description	Specification
1	Number of stories	10
2	Story height	3 m
3	Length of the building	40 m
4	Width of the building	24 m
5	Spacing between grids	4 m
6	Grade of the concrete	M25
7	Size of beam	400 mm x 600 mm
8	Size of column	400 mm x 600 mm
9	Thickness of Slab	200 mm
10	IS Code	IS 456:2000, IS 1893:2002

C. Loading

The designing criteria given in IS13920:2016 were followed for current work. Thus, the criteria given for selecting a grade of concrete and grade of steel has also been followed and as per clause 5.1 of IS 13920:2016 the grade of material given in table. 2. The loads applied on the structure were floor finish load and live load where live load on the roof and floor level are same.

Table 2. Loading Properties

S.No.	Parameter	Details
1	Floor Finished Load	1.2 kN/m2
2	Exterior Periphery Wall	12.14 kN/m2
3	Interior Wall	8 kN/m2
4	Roof Live Load	1.5 kN/m2
6	Live Load on other levels	3 kN/m2
7	Density of Masonry Wall	20 kN/m2
8	Density of RCC	25 kN/m3
9	Grade of Concrete	M30

The Indian standard code 1893:2016 (Part I) gives information of seismic parameters that are required in analysis of structures for the considered seismic zone. Zone 4 has been considered for this study.

D. Viscous Damper Modelling

The dampers used in modelling these buildings are from Taylor Devices Inc. made in USA. FVD is added to structure after defining in Link properties by adding a new Damper-Exponential in Link Property Data. Since FVD 250 is linear it is used for direction U1 with fixed end properties. The Mass is 44 kg and Weight is 250 kN from the figure.

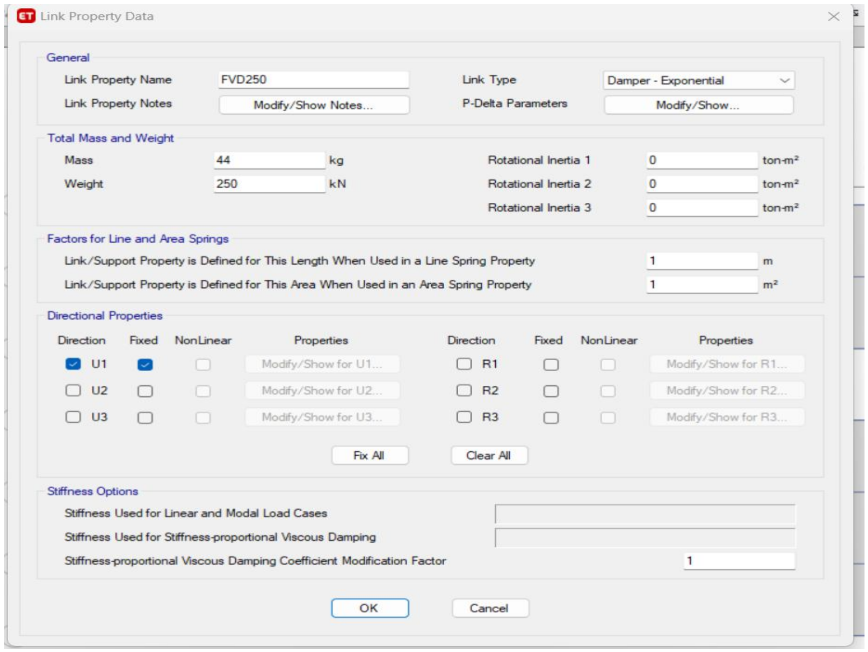

Fig. 4 Fluid Viscous Damper Modelling Parameter

III. RESULTS AND DISCUSSION

The linear dynamic analysis was carried out on diaphragm irregular building with and without fluid viscous damper (FVD) at different locations for zone IV. The results are so obtained that were influenced by seismic load are discussed and compared to understand the effects of fluid viscous damper on diaphragm irregular building under different seismic parameters.

A. Time Period

It has been found that on incorporating fluid viscous damper at two sides of the irregular diaphragm building time period reduces by narrow extent. On fluid viscous damper at four sides building time period reduces by 24%.

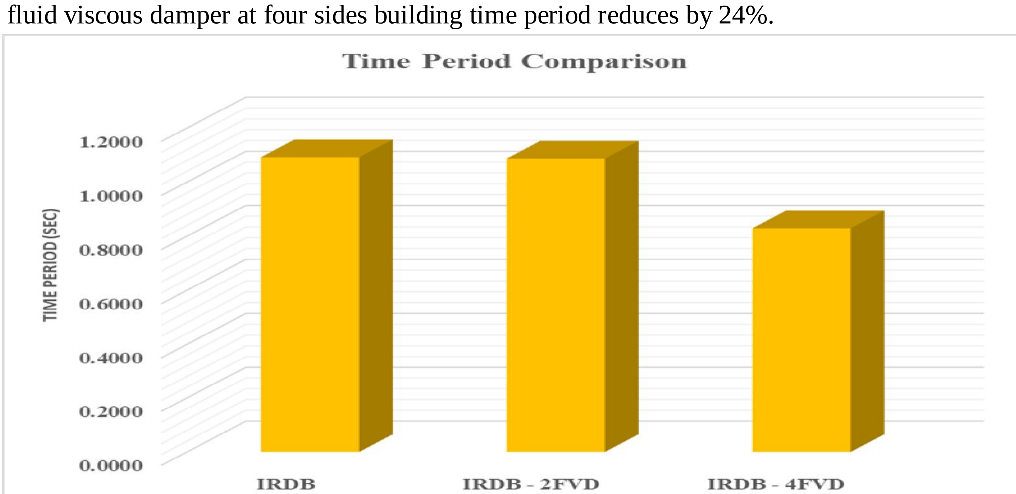

Fig. 5 Time Period Comparison

B. Storey Drift

Storey drift is shown in fig. 6 & 7. On using fluid viscous damper on two and four sides of building storey drift reduces by 37%. On incorporating damper, the storey drift is nearly similar in all storeys. Due to diaphragm irregularity storey drift in Y direction is more as compared to X direction. On using fluid viscous damper on two and four sides of building storey drift reduces by 46%. $ side damper building shows better results in all three cases.

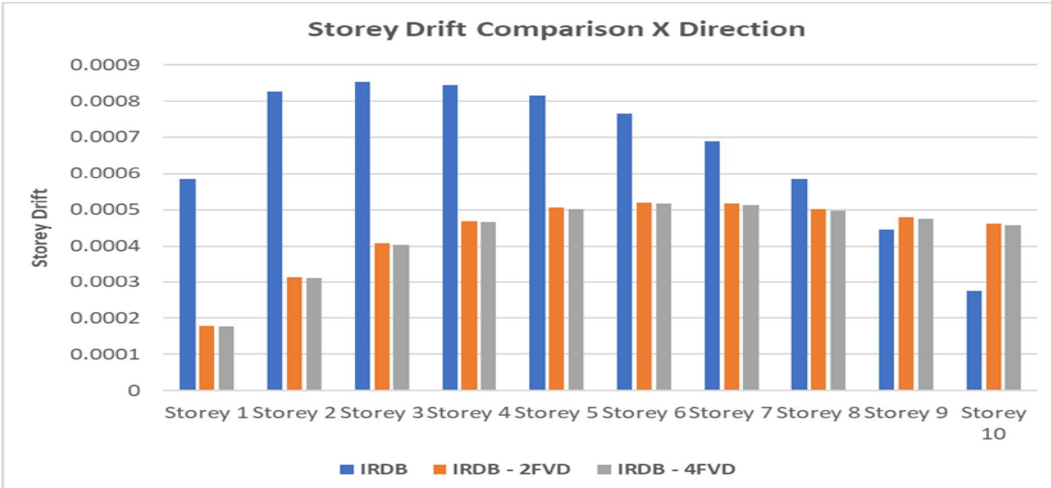

Fig. 6 Storey Drift Comparison

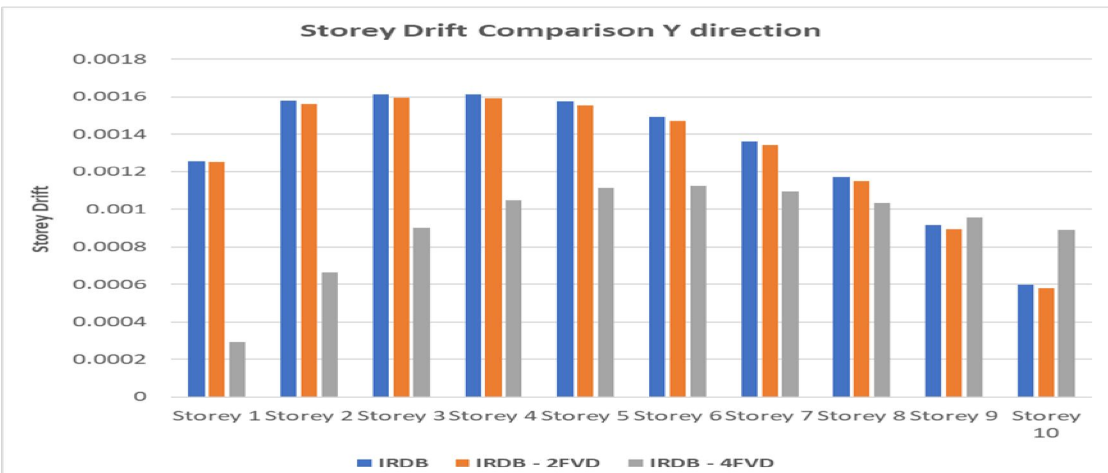

Fig. 7 Storey Drift Comparison

C. Storey Stiffness

Storey stiffness is shown in fig. 8 & 9. As fluid viscous damper are placed in selected positions, therefore the stiffness of building is enhancing only at higher levels in X direction. For Y direction storey stiffness is nearly similar to building without viscous damper. But on moving towards higher storey stiffness enhances due to incorporation of fluid viscous damper.

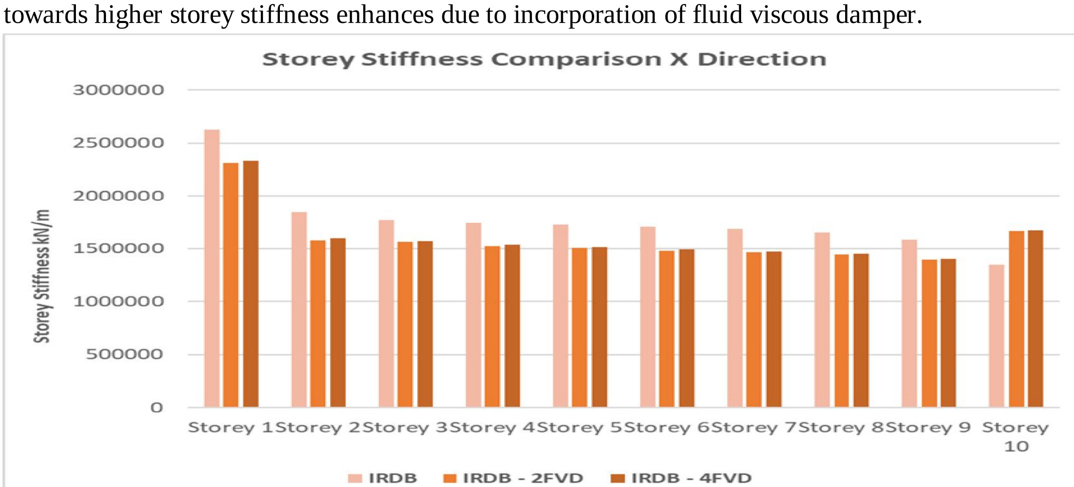

Fig. 8 Storey Stiffness Comparison

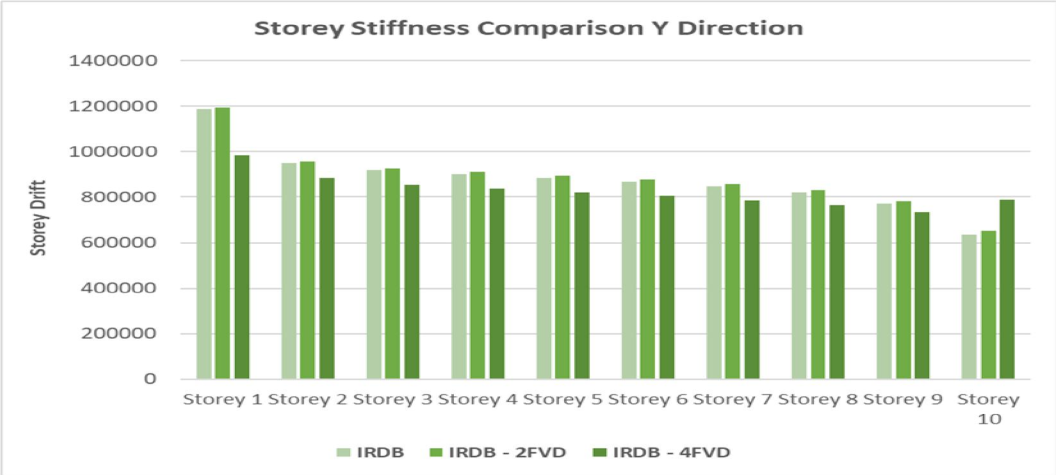

Fig. 9 Storey Stiffness Comparison

D. Pushover Curve

Pushover Curve has been compared as shown in fig. 10. It has been concluded that on incorporating FVD, base force decreases by 67% and monitored displacement corresponding to base force also decreases by 83%. Although marginal change has been observed between two side and four side FVD condition. From pushover curve it has been found on incorporating fluid viscous damper building with diaphragm irregularity will attract less structural deformations.

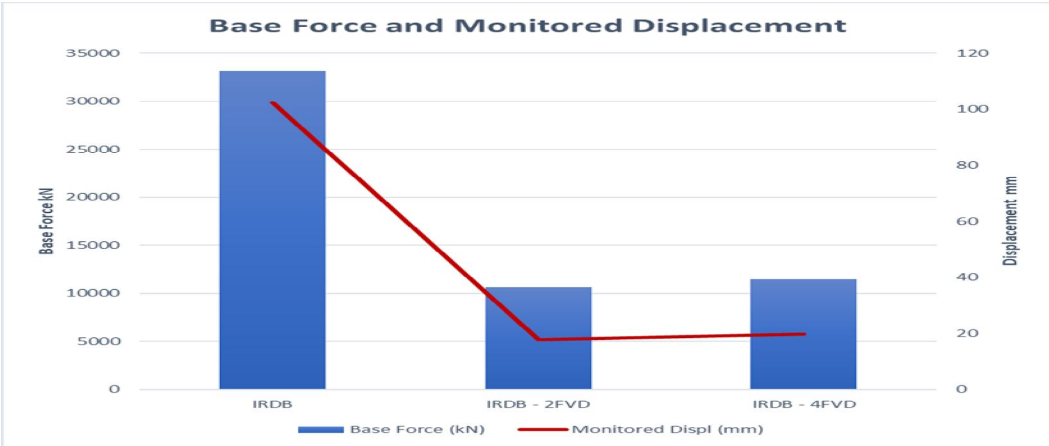

Fig. 7 Storey Stiffness Comparison

E. Hinge Formation

Hinge results are shown in form of total hinges formed in specific zone of force displacement curve. Hinge formation in all three models has been compared in table 3. In force displacement curve hinge formation at different levels suggests condition of building during seismic force excitation. For IRDB case due to formation of hinges in collapse prevention zone degradation in strength and stiffness will be observed and building will be subjected to permanent structural damage. For IRDB 2FVD and IRDB 4FVD case, major hinges are formed in AB zone which means no structural damage will be observed.

Table 3. Hinge Formation

Model	A-B	B-C	C-D	D-E	>E	A-IO	IO-LS	LS-CP	>CP	Total
IRDB	5924	1076	0	0	0	6954	6	0	40	7000
IRDB-2FVD	6984	16	0	0	0	7000	0	0	0	7000
IRDB-4FVD	6984	16	0	0	0	7000	0	0	0	7000

IV. CONCLUSIONS

Following are the conclusions of the study –

1) It has been concluded from the study that on incorporating fluid viscous damper in existing diaphragms irregular building will perform better during seismic excitation.
2) In between two side FVD and four side FVD arrangement, it has been found that four side FVD performs well in terms of seismic parameters along Y direction. For X direction, both FVD performs nearly same.
3) Storey drift reduces significantly in FVD building which means that chances of structural damages in partition wall will be less.
4) Although due to number and location of FVD, storey stiffness did not enhance significantly.
5) From the pushover results it has been concluded that on applying FVD in existing building, most hinges formed in elastic range as compared to without FVD building in which hinges are formed in collapse zone.
6) From the study, it has been concluded that although assembling FVD in existing building will incur cost but for high seismic zone, the seismic performance of diaphragm irregular structure will enhance.

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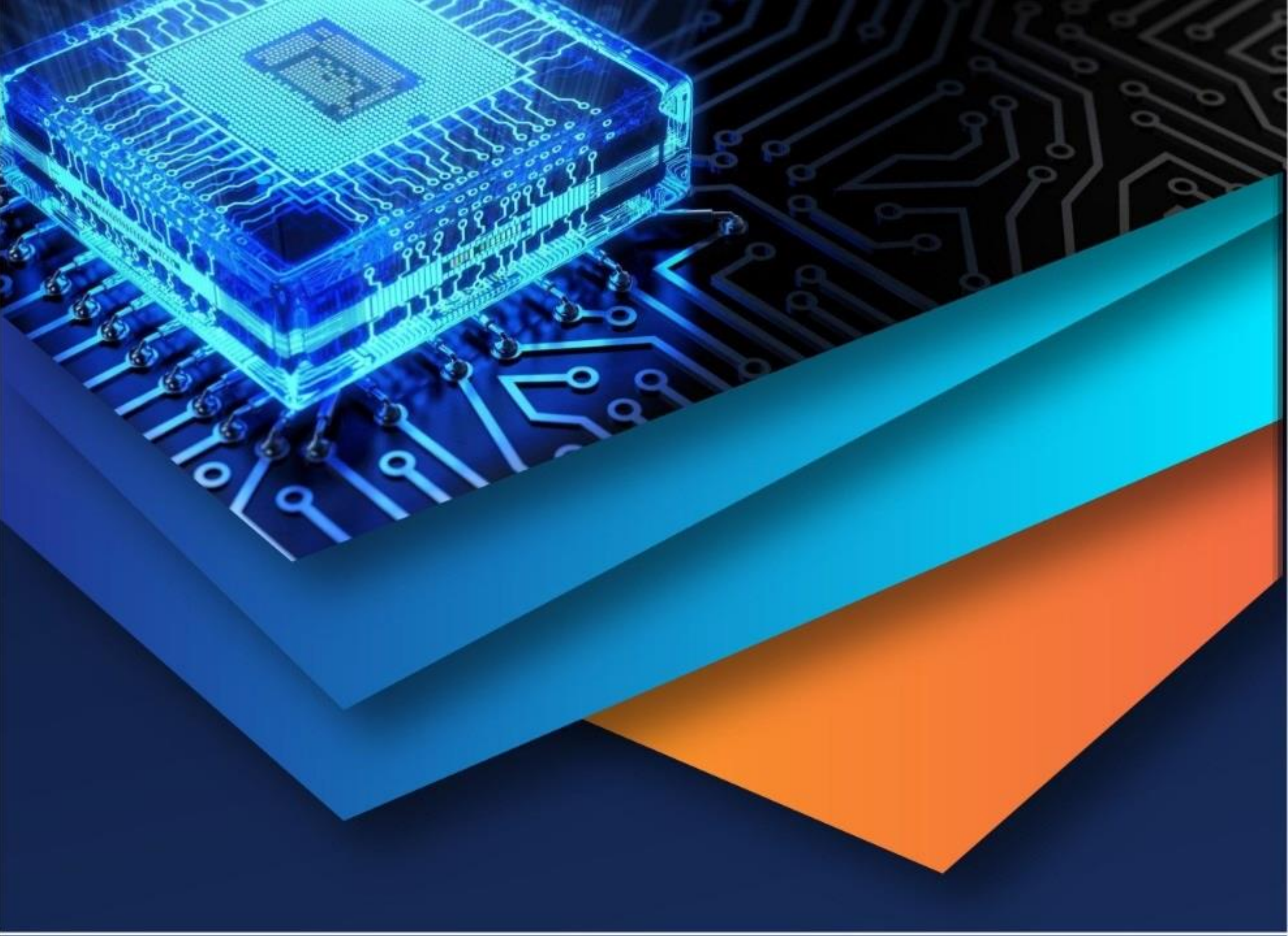

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