International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 12 Issue: 04 | Apr 2025 www.irjet.net p-ISSN: 2395-0072

IDENTIFICATION OF OPTIMUM USE OF ISOLATION AND DAMPING SYSTEM FOR RCC REGULAR AND IRREGULAR BUILDINGS

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Abstract - *Seismic hazard refers to the probability or likelihood of certain levels of ground shaking (earthquake intensity) occurring in a specific region over a given period of time. Seismic hazard assessment is typically a map or model that shows areas with varying levels of earthquake hazard, based on the potential for ground shaking, faulting, and other seismic phenomena. Seismic risk is typically assessed by combining seismic hazard data with information on the exposure and vulnerability of a region. It is a measure of the potential impact of earthquakes on people, buildings, infrastructure, and the environment. Seismic disaster mitigation techniques are being adopted which causes reduction in earthquake forces by different methods. The proposed paper investigates the ability of base isolation and energy absorption systems using rubber isolators and fluid viscous dampers to protect the structure by controlling seismic response. Concrete building structures of regular and irregular type have been modelled in SAP 2000 for various story heights of G+5 & G+15 building. Non-linear Time history has been performed for both conventional and isolated buildings. Seismic responses e.g. base shear, max drift/displacement etc. have been compared for the conventional and isolated structures for each of the building models with same seismic considerations. The optimum zone for selection of the ideal combination of isolation and damping system has been identified for all the building types from the parametric study of change in isolation and deformation ratio using various stiffness and damping properties.*

***Key Words*: Base Shear; Non-linear; Energy absorption; Damping; Isolation ratio; Deformation ratio**

1 INTRODUCTION

Seismic disaster mitigation for structures is of paramount importance because it directly affects the safety, stability, and functionality of buildings and infrastructure during an earthquake. It aims to anticipate and minimize the risks associated with earthquakes, leading to safer communities, less economic loss, and quicker recovery in the aftermath. When designing structures for seismic conditions, engineers consider two main earthquake scenarios: the Design Basis Earthquake (DBE) and the Maximum Considered Earthquake (MCE). These scenarios help determine how much seismic force a structure should be able to withstand during an earthquake, guiding the design of the structure's components to ensure safety, stability, and performance. The design structure in DBE is done to ensure that the structure can survive moderate earthquakes without significant damage and that it provides a safe environment for occupants. The MCE represents a more severe earthquake scenario, often associated with the largest earthquake that could reasonably be expected in a region over the lifetime of the structure. Under MCE conditions, the structure may experience significant damage, such as cracking, permanent deformation, or failure of non-essential systems. However, the key objective is for the building to not collapse. The structure should maintain its stability and not pose a danger to occupants, but repairs will likely be needed afterward.

Seismic disaster mitigation involves a range of strategies designed to reduce the impact of earthquakes. There are several methods for making structures safe against earthquake; earthquake resistant design using Base isolation and damping systems, retrofitting existing structures etc. Base isolation is one of the most effective seismic disaster mitigation techniques used to protect buildings and infrastructure from earthquake damage ([4], [5], [12]). It involves placing a building or structure on bearings (known as isolators) that allow the building to move independently from the ground motion during an earthquake. This technique reduces the amount of seismic energy transmitted to the building, helping to minimize damage and enhance the safety and resilience of the structure. Base isolation can be applied to a wide range of structures, from residential buildings to large, complex infrastructure projects for both the conditions; retrofitting and new construction. Base isolation technique includes some isolation devices between top and bottom structure and uses the stiffness to lengthen the time period of the entire structure and thus reduces the seismic force to a desired level. Seismic dampers are devices that absorb and dissipate the energy generated by an earthquake, reducing the amount of shaking experienced by a building or structure.

Among the many supplemental base isolation and energy dissipation devices proposed and implemented for earthquake hazard mitigation, elastomeric bearings and fluid viscous dampers seem to be a popular solution in recent applications. Effectiveness of the isolator and damper behavior depends on the non-linear viscous characteristics of isolators. For elastomeric isolators (EB) elastic stiffness helps in making structure flexible and base isolated with larger time period whereas fluid viscous dampers (FVD) helps in energy dissipation through the damping property of the viscous fluid and the combined effect can be suitable for any structure in purpose of reduction of earthquake forces and safe design [13]. Marqua et. al studied the behaviour of low-rise, mid-rise and high-rise RC buildings with use of fluid viscous dampers [1]. Yenhul et. al [2] analysed the effectiveness of dampers with inter-story isolation. Sime S et. al. [5] analysed the performance of FVDs for SMRF RC building using both DBE and MCE earthquake acceleration and compared the results. Mujeed et. al [8] studied the response of G+10 builidng with and without fluid viscous dampers.

The design spectral acceleration (Sa/g) as per IS 1893:2016 for equivalent static and Response spectrum method is shown in Fig 1.1.

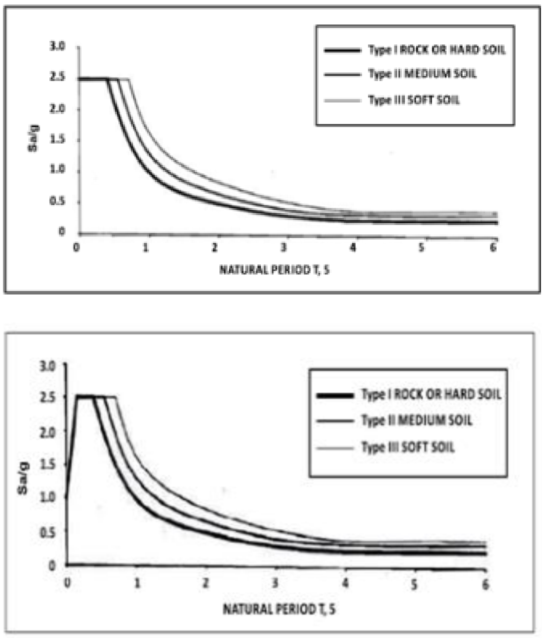

Fig-1.1: General Response Spectrum from IS 1893:2016

The spectral acceleration value gets reduced if the structure is flexible with an increased time period as shown in Fig 1.2.

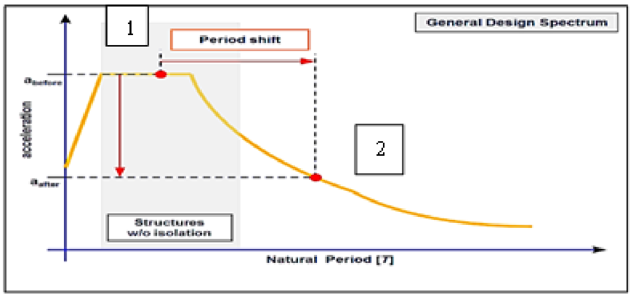

Fig-1.2: Reduction of Sa/g due to period shift

Point 1 denotes the initial time period of structure for conventional support. Adoption of base isolation method lengthens the time period making supports flexible. Point 2 defines the increased time period for isolated support.

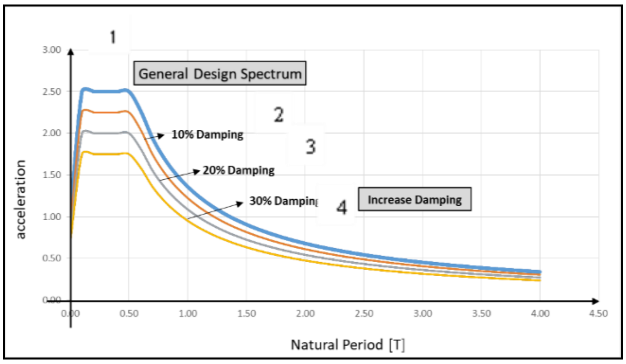

Fig-1.3: Reduction of Sa/g due to increased damping

Point 1 defines the initial time period for 5% damping as per the standard response spectrum in accordance to IS 1893:2016. Further increase in damping helps in further reduction of Sa/g. Point 2, 3, 4 are showing the decrement of Sa/g for a specific time period with increase in damping; 10%, 20%. 30%.

The time period for regular stiff and conventional building structures is generally less than 1s for which spectral acceleration value maximum. The level of damping in normal structure is also typically very low and the amount of energy dissipated during elastic behavior is very small. The supplemental isolation and damping devices operate on the principle of increasing time period with additional flexibility and further reducing acceleration by damping property. The devices are designed to isolate top and bottom structure and dissipate earthquake-induced energy through inelastic action.

The objective of the proposed study is to check the variation of seismic forces and deformation values for different building structures with same seismic inputs using various properties for isolators and dampers. The requirement is to find out the optimum zone from the interaction between isolation and deformation ratio, which can help to decide the combined isolation and damper system for effective control of structural response. The base shear and max deformation are aimed to be within the limit which can be comfortable and serviceable for the structure.

The scope includes the numerical parametric study based on dynamic analysis (Non-linear Time history) of concrete building structure with following variation:

C: Structure without elastomeric bearings and fluid viscous dampers; conventional support system

D: Structure with elastomeric bearings and fluid viscous dampers between Superstructure and foundation at each column support

R: Buildings regular in elevation

IR: Buildings irregular in elevation

Comparison studies have been made for important building models with and without the use of EB and FVD for the following different parameters considered in Seismic analysis Importance factor (1.5 for both conventional and isolated models)

- Seismic zone V
- Response Reduction factor (1.0 for both conventional and isolated models)
- Soil type - Medium

The type of conventional and isolated building structures considered are defined in Table 1.1.

Table-1.1: Different type of structure models

Storey	Plan	Support	Designation
G+5	Regular	Conventional	CRM5
G+15	Regular	Conventional	CRM15
G+15	Irregular	Conventional "L"	CIRML15
G+15	Irregular	Conventional "T"	CIRMT15
G+15	Irregular	Conventional "Opp T"	CIRMT15'
G+5	Regular	Isolated/damped	DRM5
G+15	Regular	Isolated/damped	DRM15
G+15	Irregular	Isolated/damped "L"	DIRML15
G+15	Irregular	Isolated/damped "T"	DIRMT15
G+15	Irregular	Isolated/damped "Opp T"	DIRMT15'

The study has been done for Non-linear Time history for Elcentro, Turkey and Sikkim earthquake acceleration matched to target response spectrum corresponding to different seismic zones and soil types.

2 NUMERICAL STUDY

Numerical Models have been developed with and without isolators made of elastomeric bearing system and dampers as Fluid viscous dampers. Study has been made of different kinds of structures for different seismic parameters with similar isolation and damping system.

Analysis has been done in SAP:2000 software by Non-linear Time history Method. The FEM based software seems to be applicable for analysis of different types of structural system with respect to state-of-the-art practice with non-linear and dynamic consideration.

RCC regular building models have been developed for G+5 & G+15 storey. All the building models are regular in plan with 8x8 grid. Each panel area is 4mx4m. The height of each storey is 4m. The columns are of 300mm width and 400mm depth, beams are assigned with 250mm width and 300mm depth. Slabs are 150mm depth and walls are 250mm thick. The grade of concrete is M30 for all the models. Supports are defined as conventional for fixed and isolated/damped using EB and FVDs. EB and FVD are assigned as link elements. Link element for EB has been defined with non-linear properties, initial stiffness, yield force and post yield stiffness ratio. Though for regular elastomeric isolators the damping percentage is only 2-3%, hence yield force will be very less in comparison to other isolators, Lead rubber or High damping rubber bearings.

The plan and elevation of each regular building are shown in Fig 2.1 to Fig 2.3.

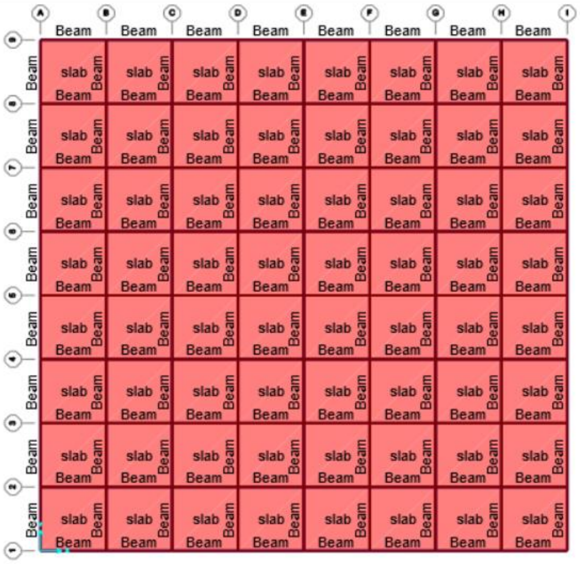

Fig-2.1: Plan of CRM5/CRM15/DRM5/DRM15 bldg

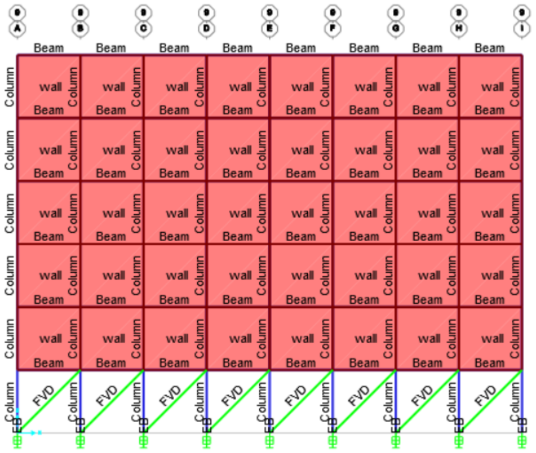

Fig-2.2: Elevation of CRM5/DRM5 bldg

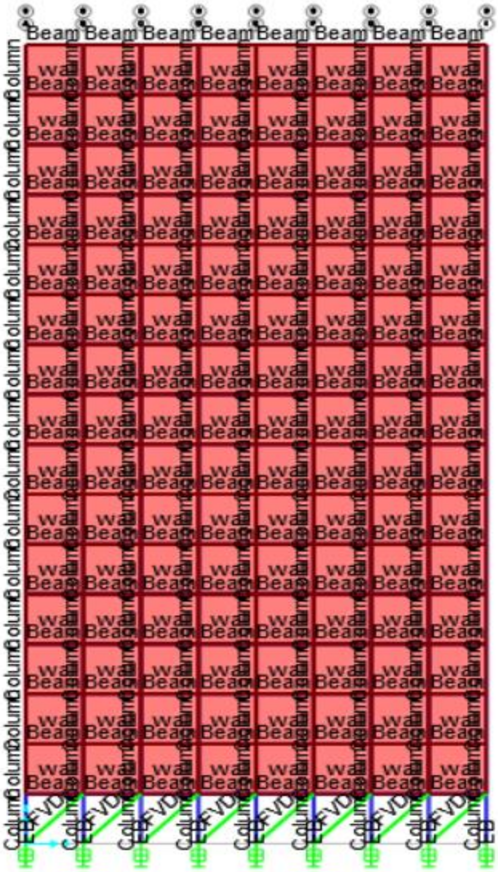

Fig-2.3: Elevation of CRM15/DRM15 bldg

The plan and elevation of each irregular building are shown in Fig 2.4 to Fig 2.6.

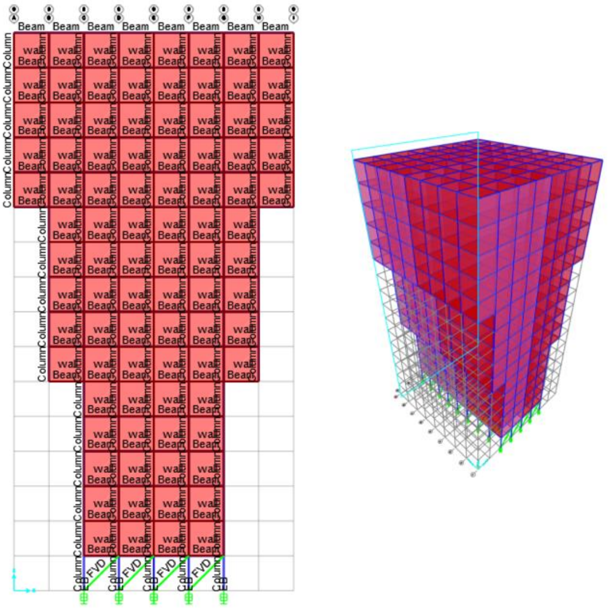

Fig-2.4: Elevation of DIRMT15 bldg

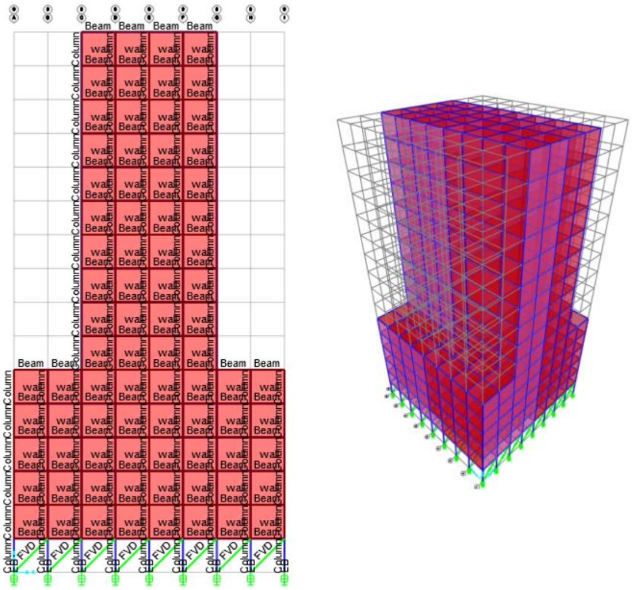

Fig-2.5: Elevation of DIRMT15’ bldg

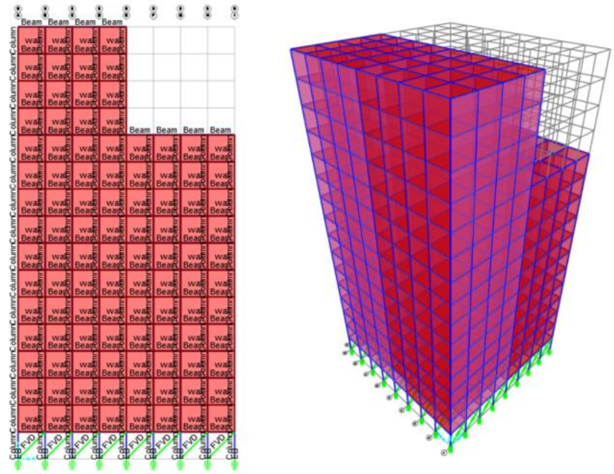

Fig-2.6: Elevation of DIRML15 bldg

Different material properties, load cases for various zones and soil types, support restraints, non-linear properties of links have been incorporated in the models. The time history function has been derived by matching the accelerogram data from Elcentro, Sikkim and Turkey earthquake with target response spectrum for various zones and soil types. Input function for non-linear dynamic analysis has been defined for load pattern as acceleration in X & Y direction with scale/conversion factor as 9.81. Scale conversion factor is the value of “g” to match the unit of both input and matched accelerogram. Total duration of Time history acceleration function is 30s (time step of 0.02s) for Elcentro and 145s (time step of 0.005) for Sikkim and 105s (time step of 0.001) for Turkey earthquake.

The non-linear properties of Link/Support for Lead rubber bearings are considered as shown in Table 2.1.

Table-2.1: Non-linear properties of Elastomeric isolators

Initial stiffness (kN/m)	Yield force (kN)	Post yield stiffness ratio
0.5 to 10 at each 1 kN/m difference	2	0.95

Initial stiffness is the combination of stiffness of rubber till the yield point and it can be defined as elastic stiffness. Yield force is the force required to yield and go beyond the elastic limit. Post yield stiffness ratio is the ratio between post yield stiffness and initial/elastic stiffness. The elastomeric isolators mainly helps to reduce the seismic force with the elastic property, not the damping.

Link properties of Fluid viscous dampers are defined using constitutive law:

$F=Cv^n$, where
F = Force or capacity of FVD
C = damping component in kN/ $(m/s)^n$
V = velocity in mm/s

n = damping exponent, generally the value is 0.1 or 0.2 (here n=-0.1 considered).

FVDs are placed as diagonal bracing. In this arrangement, the amplification factor of the relative displacement between the two ends of the damper depends on the angle of the brace that will hold the damper. In this case, the axial displacement devices are less than or equal than the story drift, thus lowering their efficiency energy dissipation. In general Fluid viscous dampers are placed as diagonal bracing in buildings to effectively dissipate energy from seismic events or strong winds, reducing structural vibrations and deformations by converting kinetic energy into heat. K V Sharma et. al. [6] shows the effect of use of FVDs at various places or locations in G+20 building. Rinaldin et. al [7], and Agha et. al [9] studied and investigated the hysteretic behaviour of FVDs. Zoccolini et. al [10] did research on semi-active and adaptive behaviour of FVDs and Prajapati et. al [13] studied performance of RCC structures using FVDs as energy dissipation devices. Waghmare et. al [11] investigated influence of FVDs on seismic response on reinforced concrete elevated storage tanks.

Fig. 2.7 to 2.9 shows the hysteresis graph of link force vs deformation behavior of a fluid viscous damper as per the analysis done in SAP. The area of hysteresis graph depends on damping exponent, n and the increase in the value from 0.1 to 1 makes the hysteresis graph more circular type.

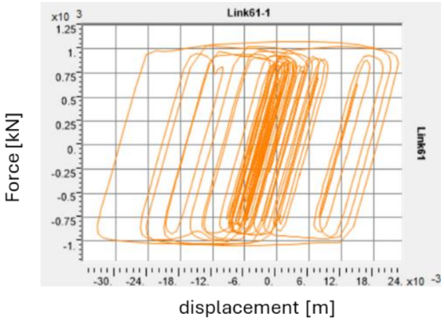

Fig-2.7: Force-displacement behavior of FVD (n=0.1)

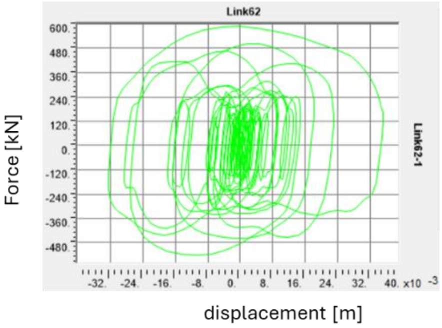

Fig-2.8: Force-displacement behavior of FVD (n=0.5)

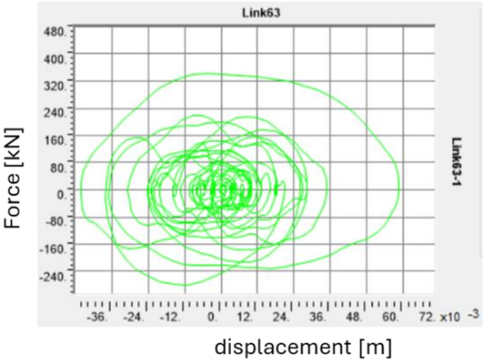

Fig-2.9: Force-displacement behaviour of FVD (n=1)

The non-linear properties of Link/Support for fluid viscous dampers are considered as follows in Table 2.2.

Table-2.2: Non-linear properties of dampers

Force (kN)	**Initial stiffness (kN/m)**	**Damping constant (kN/ $(m/s)^n$)**	**Damping exponent**
100	20000	126	0.1
200	40000	252	0.1
300	60000	378	0.1
400	80000	504	0.1
500	100000	630	0.1

3 RESULTS AND DISCUSSIONS

3.1 Prob-1- Isolation and deformation comparison for G+5 and G+15 regular buildings

The Conventional regular building models have been developed without isolators and dampers for fixed support conventional design. The non-linear analysis has been carried out for different time history functions and base shear and deformation values have been recorded in Table 3.1.

Table -3.1: Base shear for conventional buildings

Building	Fixed base shear [kN] as per Non-linear Time history analysis			Seismic weight [kN]
	Elcentro	Sikkim	Turkey	
CRM5	55653	51949	48863	107320
CRM15	65917	68658	64041	275690

The buildings have been analysed using only elastomeric bearings as isolators and the base shear got reduced considerably.

Table-3.2: Base shear using elastomeric bearings [Stiffness= 3.5 kN/mm]

Building	Base shear [kN] using Elcentro time history	Reduction on fixed base shear
CRM5	20814	37%
CRM15	30672	47%

The displacement of isolated buildings using only EB is higher in comparison to fixed support buildings.

In the next step the RCC building models with isolated and damped system have been analyzed using three different time history functions. The isolation ratio and deformation ratio have been derived from the data and plotted to see the variation.

Isolation ratio = (Isolated base shear) /(Fixed base shear)

Deformation ratio = (isolated deformation) /(Fixed deformation)

The interaction between isolation and deformation ratio for DRM5 building for elcentro time history analysis using is shown in Fig. 3.1.

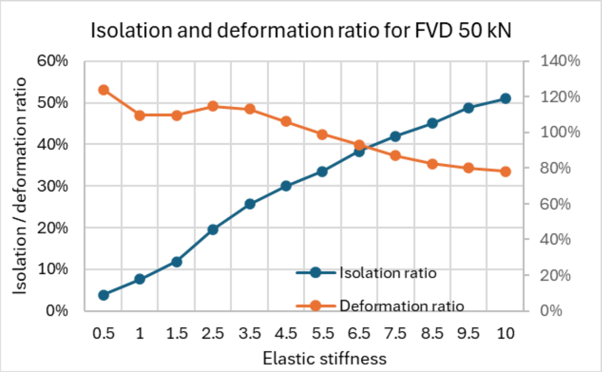

Fig-3.1: Isolation-deformation for DRM5 building (Elcentro)

The base shear for isolated and damped buildings gets reduced up to 49% and deformation increases up to 124% than the conventional fixed support buildings. The same non-linear time history analysis has been performed for DRM5 building with FVD of capacity 500 kN and the interaction graph is shown in Fig. 3.2.

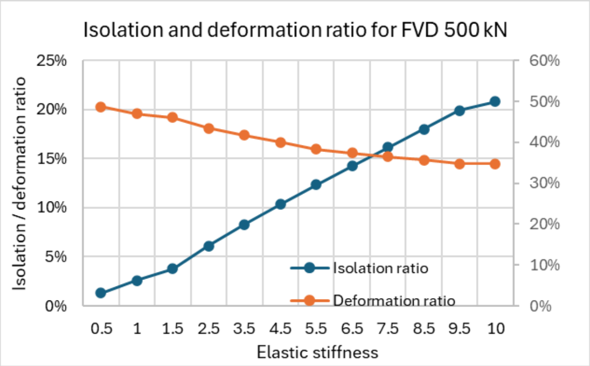

Fig-3.2: Isolation-deformation for DRM5 building (Elcentro)

The base shear for isolated / damped building gets reduced to 21% of fixed support base shear and deformation value also decreases to 50%. It has been observed that the combination of isolator and damper, i.e. EB and FVD is working and effective for reduction of base shear and target deformation. Similar analysis has been performed for DRM5 buildings with Sikkim and Turkey accelerogram data as well and result has been shown here in Fig. 3.3 and Fig. 3.4.

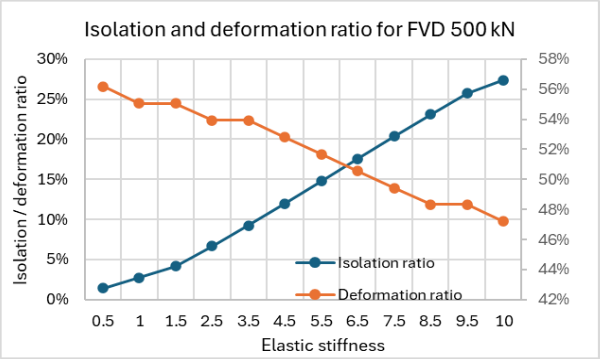

Fig -3.3: Isolation-deformation for DRM5 building (Sikkim)

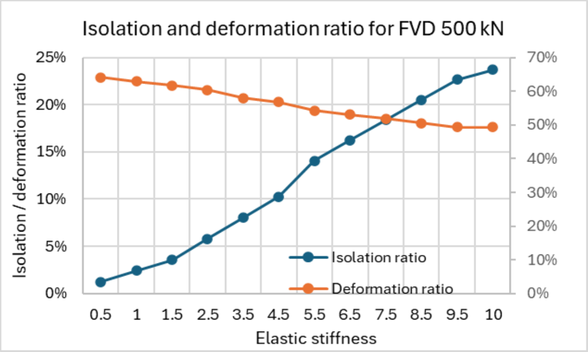

Fig -3.4: Isolation-deformation for IRM5 building (Turkey)

Since the accelerogram function for time history analysis are different, the reduced base shear and deformation also vary. Using Turkey earthquake function, the base shear can be reduced minimum of 75% for FVD of 500 kN capacity and stiffness of EB as 10 kN/mm.

DRM15 building model has also been analysed using all different time history functions. The base shear and deformation values have been recorded for Sikkim earthquake data. Using FVD of 300 kN and elastic stiffness of 0.5 kN/mm, base shear can be reduced to 47% and deformation up to 94% (Fig. 3.4).

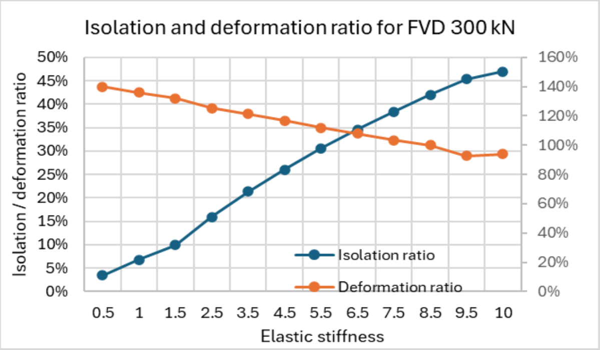

Fig-3.5: Isolation-deformation for DRM5 building (Sikkim)

The deformation ration can go up to 65% for the analysis using elcentro time history data and it has been observed that the deformation ratio is maximum for Sikkim time history for any combination of EB and FVD.

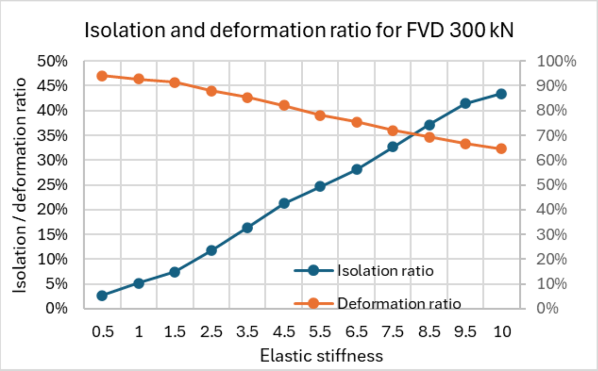

Fig-3.6: Isolation-deformation for DRM5 building (Elcentro)

The interaction between isolation and deformation ratio for DRM5 building has been plotted for all three different time history functions. The isolation has been done using EB with stiffness of 0.5 to 10 kN/mm and damping has been added using FVD with capacity from 50 to 500 kN. Following graphs represent the isolation-deformation interaction and from this an optimum zone can be selected where the range of stiffness for EB and capacity for FVD can be determined.

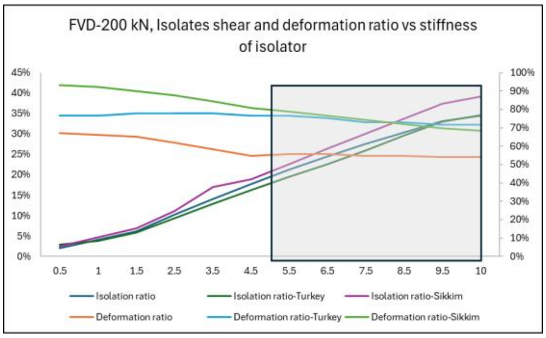

Fig -3.7: Isolation-deformation for CRM5 building

In Fig. 3.7, the isolation ratio has been selected from 15% to 40% and accordingly the range is elastic stiffness has been derived as 5 to 10 kN/mm for FVD capacity of 200 kN. Deformation ratio varies from 45 to 85% which is within the acceptable range. However, the selection of isolation and deformation ratio entirely depends on the designer's choice and other boundary conditions for which the structure is designed. Similarly, Fig. 3.8 and 3.9 present the optimum choice of stiffness of EB for FVD of 300 kN and 500 kN for a selected range of isolation and deformation ratio.

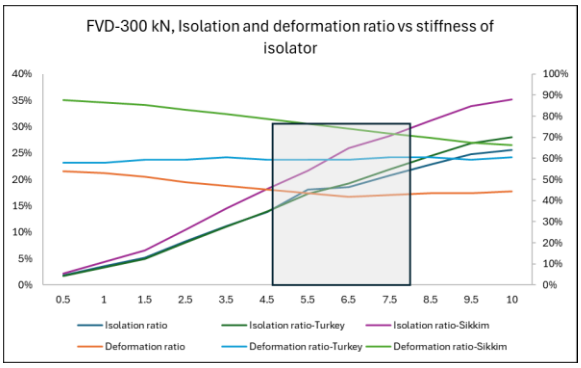

Fig -3.8: Isolation-deformation for DRM5 building

Another example can be taken from the results due to the analysis of the DRM5 building with FVD of 300 kN in Fig. 3.8. If the isolation ratio is considered from 15% to 30%, the optimum range of elastic stiffness is 4.5-8 kN/mm. Deformation ratio varies from 80% to 40%.

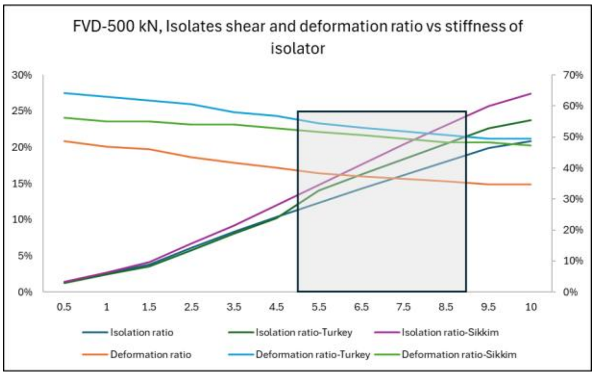

Fig -3.9: Isolation-deformation for DRM5 building

Fig. 3.9 shows the isolation-deformation interaction for FVD of 500 kN for a selected zone of isolation ratio from 10% to 25% and deformation ratio from 60% to 35%.

The stiffness of EB is in the range of 5 to 9 kN/mm. By changing the FVD properties, different optimum zones for isolator stiffness can be derived depending on structural design demand.

For any specific design seismic base shear several options can be defined from the analysis and results of isolation-deformation interactions. There can be multiple options for the isolation and damping combinations to achieve a target base shear. Fig. 3.10 shows the different EB-FVD combinations for a design isolation ratio of 10%. Deformation ratio varies from 51% to 78%. Non-linear time history has been performed for Elcentro function.

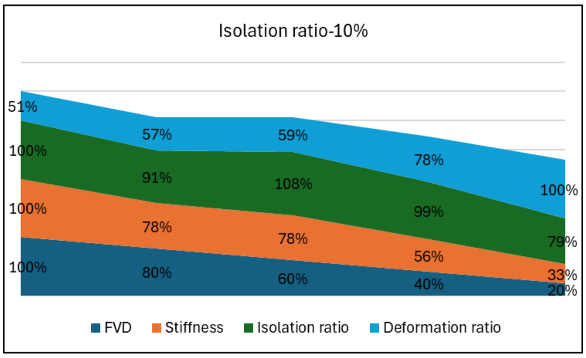

Fig-3.10: Isolation-deformation combination for DRM5 building (Elcentro)

For a target design isolation ratio of 20%, the several combinations of EB-FVD are shown in Fig. 3.11. The optimum solutions for each EB-FVD combination have been selected and the corresponding deformation ratio has been noted. Deformation ratio varies from 36% to 85%. Even for any range of design isolation ratio from 25-50%, the optimum EB-FVD interaction can be selected (Fig. 3.12).

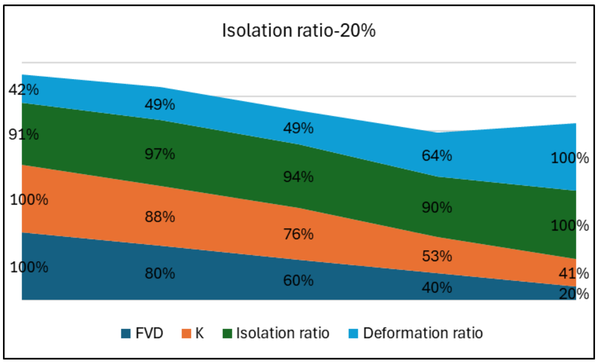

Fig-3.11: Isolation-deformation combination for DRM5 building (Elcentro)

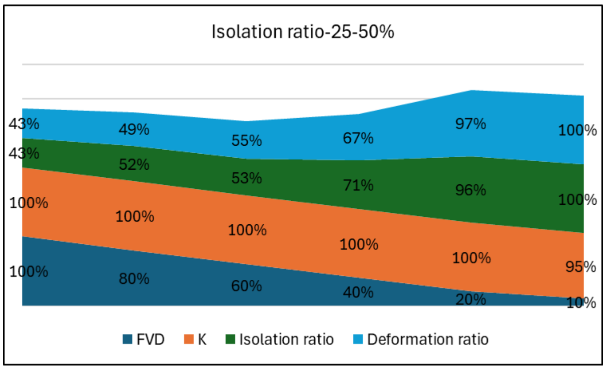

Fig-3.12: Isolation-deformation combination for DRM5 building (Elcentro)

The above figures Fig. 3.10 to Fig. 3.12 show the contribution percentage for each parameter; FVD capacity, EB stiffness, isolation ratio and deformation ratio. Here in the graphs, the different values are defined as a percentage of the maximum value in the range.

Analysis has been carried out for DRM15 buildings and optimum zone for selection of EB and FVD for a desired seismic isolated / damped base shear has been derived using time history functions. Fig 3.13 shows the isolation and deformation interaction for different stiffness of EB and FVD capacity of 300 kN.

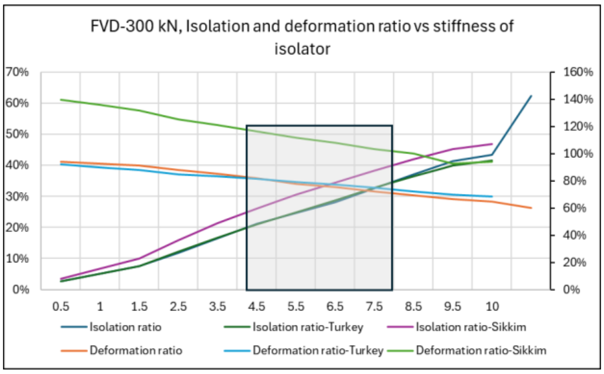

Fig -3.13: Isolation-deformation for DRM15 building

Considering a design isolation ratio of 20-40% the combination of EB-FVD has been selected for the optimum design and stiffness of EB is in the range of 4.5 to 8 kN/mm. Deformation ratio varies from 120% to 60%. Similar analysis has been performed for FVD capacity of 500 kN, the optimum zone is selected, and stiffness range is from 6-9.5 kN/mm. Fig 3.14 defines the interaction between EB-FVD using FVD of capacity 500 kN and three types of time history functions. The isolation ratio or reduced seismic base shear is maximum using Sikkim time history function matched to target response spectrum for a specific stiffness of EB and FVD capacity.

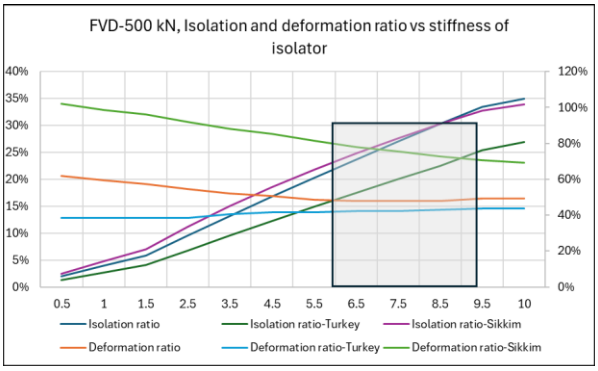

Fig- 3.14: Isolation-deformation for DRM15 building

From the analysis of DRM15 buildings the optimum zone for the ideal combination of EB-FVD can be defined. Considering design isolation ratio of 20%, for the analysis using Elcentro time history function the different EB-FVD properties are defined in Fig. 3.15. It has been observed that when isolation ratio decreases FVD capacity, stiffness decreases but deformation ratio increases. For a design isolation ratio of 10-50% range, the combination of EB-FVD has been selected and shown in Fig. 3.16. In Fig. 3.16, it has been noticed that the FVD capacity decreases, stiffness value increases and with the increase in isolation ration from 10 to 50%, deformation ratio increases 49 to 90%.

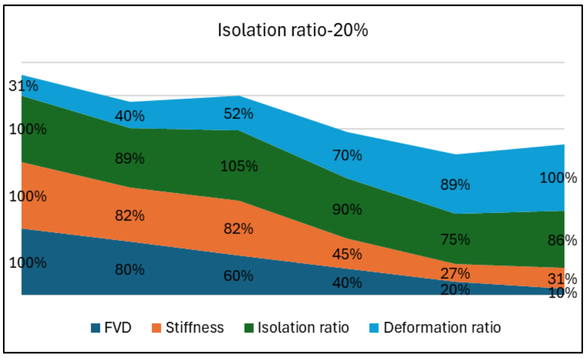

Fig-3.15: Isolation-deformation combination for DRM15 building (Elcentro)

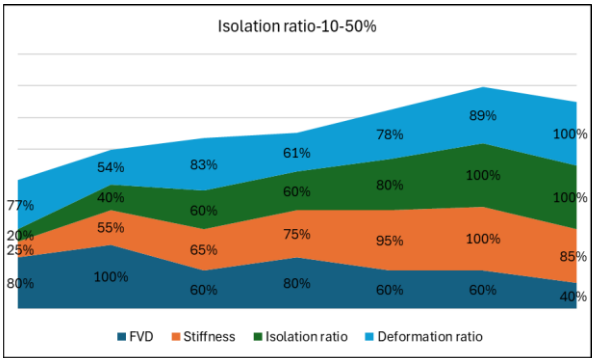

Fig-3.16: Isolation-deformation combination for DRM15 building (Elcentro)

It has been noticed that using FVD of capacity 50 kN, the deformation ratio is always greater than 100% which means the deformation for isolated / damped building DRM15, always gets increased due to the elastic stiffness and damping. The reason can be due to the use of very less capacity FVDs and also elastic stiffness, the stiffness of overall structure becomes less, and it leads to increase in deformation further. Fig. 3.17 shows the isolation and deformation behaviour for this analysis using Elcentro time history data.

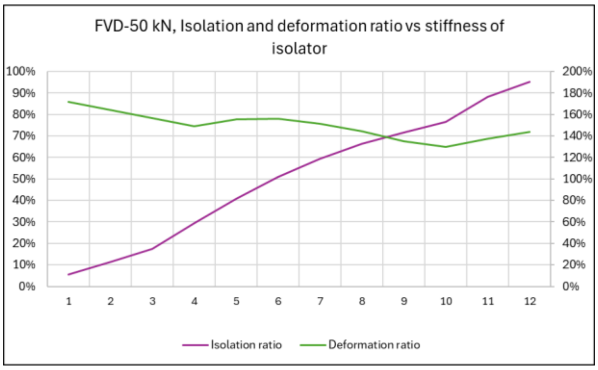

Fig-3.17: Isolation-deformation combination for DRM15 building (Elcentro)

For DRM5 building also, a similar analysis has been done using FVD of capacity 50 kN and the deformation ratio reduces to maximum 78% using maximum stiffness of EB in the range (Fig. 3.18).

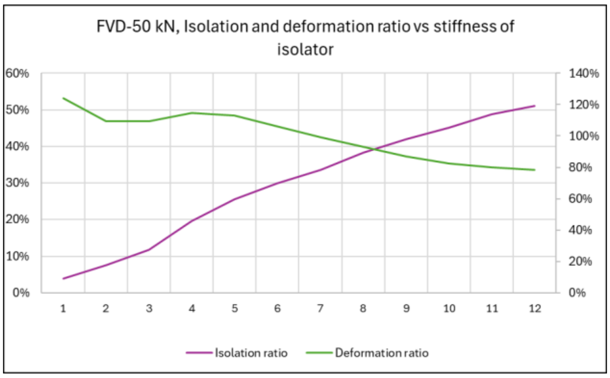

Fig-3.18: Isolation-deformation combination for DRM5 building (Elcentro)

3.2 Prob-2- Isolation and deformation comparison for G+15 irregular buildings

3.2.1 Irregular "L" shaped G+15 building

RCC buildings of G+5 and G+15 with vertical irregularity in geometry have been analysed for all the time history data as selected and base shear, deformation values are recorded for the change in capacity of FVD along with stiffness of EB. The interaction between isolation and deformation ratio are plotted and optimum zones are identified. The base shear and deformation both for conventional fixed support are maximum for Sikkim time history analysis. The results from the analysis of irregular DIRML15 building shows that the isolation ratio is not maximum for Sikkim time history for all combinations of stiffness of EB. The isolation ratio is maximum for Sikkim time history for certain stiffness of EB and then when the stiffness gradually increases, the isolation ratio also becomes higher than the value resulting from the analysis using other time history functions.

The interaction between isolation and deformation has been noted for DIRML15 building and plotted to define the optimum range of stiffness of EB and capacity of FVD. The ideal combination of EB-FVD is shown in Fig. 3.19. Considering isolation ratio from 10% to 30%, the optimum range of stiffness for EB is 4-8 kN/mm and capacity of FVD is 500 kN. The approx. range of deformation ratio is 75%-40%. A similar analysis has been carried out for FVD capacity of 200 kN and the optimum range of stiffness data has been recorded (Fig. 3.20). The deformation ratio has been noted within the optimum zone and found within the permissible or serviceable limit for the design of structures. The optimum zone for stiffness of EB is from 3-8 kN/mm for a target isolation ratio of 20-50%. Deformation ratio varies from 140% to 80%.

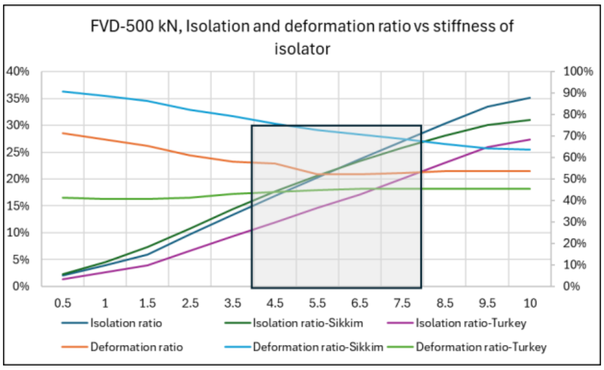

Fig-3.19: Isolation-deformation for DIRML15 building

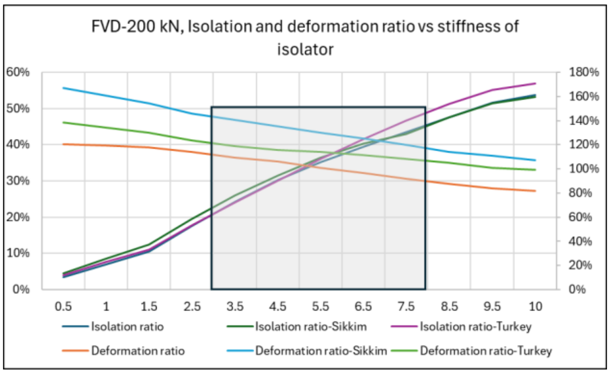

Fig- 3.20: Isolation-deformation for DIRML15 building

3.2.2 Irregular "T" shaped G+15 building

The irregular G+15 building DIRMT15 has been analysed using all three time history functions and optimum combination of EB stiffness and FVD capacity of 500 kN have been derived in Fig. 3.21.

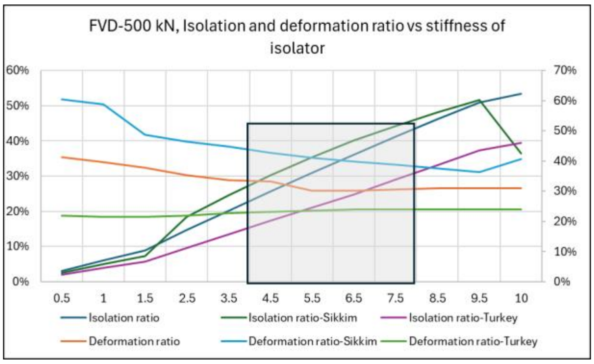

Fig-3.21:Isolation-deformation for DIRMT15 building

For a design target of isolation ratio of 15-45%, range of stiffness of EB is 4-8 kN/mm. Deformation ratio varies from 45% to 25%. The isolation ratio for Sikkim time history analysis is maximum and is minimum for Elcentro. Fig. 3.22 presents similar analysis data for FVD capacity of 200 kN.

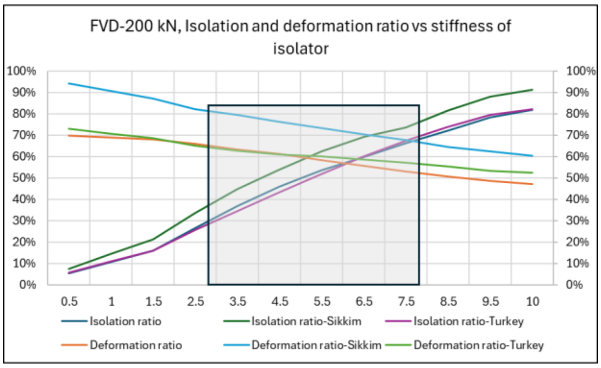

Fig-3.22:Isolation-deformation for DIRMT15 building

Stiffness of EB ranges from 3 to 8 kN/mm and deformation ratio varies between 95% to 50% for the target isolation ratio of 30% to 80%. Optimum range for selection of stiffness of EB can be defined for all other capacity of FVD. Due to the irregular geometry in vertical direction the deformation for conventional support is very large. Use of FVD with additional damping and EB for isolation helps to reduce deformation and hence deformation ratio gradually decreases with the increase in damper capacity and stiffness of isolators.

3.2.3 Irregular "Opp-T" shaped G+15 building

The DIRMT15' building has been modelled with the same isolator stiffness and FVD capacity and the isolation and deformation ratio are noted. The interaction between isolation and deformation has been plotted to find the optimum use of EB stiffness for a particular capacity of FVD. Fig. 3.23 shows the graph for isolation-deformation behaviour for FVD of capacity 500 kN and the optimum range for stiffness of EB is 4 to 9 kN/mm considering an isolation ratio zone from 15 to 40%. Deformation ratio for the isolation ratio range changes from 30 to 20%. It has been observed that for the vertical irregularity and shape as opposite "T" in the elevation, the fixed support seismic displacement is very high and exceeds the serviceable limit. For the isolated / damped building, the deformation becomes much less due to the addition of damping from FVD. Deformation for isolated / damped building gets reduced to 60% of the fixed support deformation.

Fig 3.24 presents the result for isolation-deformation interaction using FVD of capacity 200 kN and the optimum zone has been selected where stiffness varies between 2.5-7 kN/mm for isolation ratio of 10-50%. The range of deformation ratio falls within 60-30%.

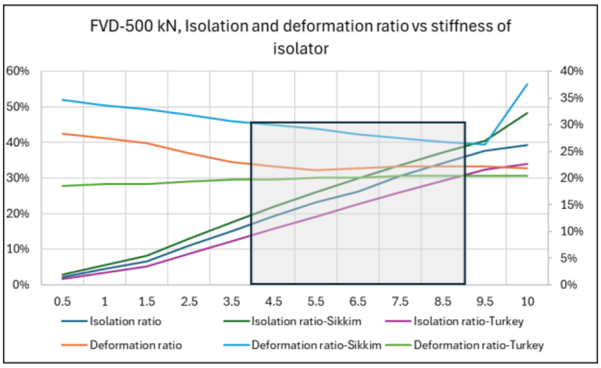

Fig-3.23:Isolation-deformation for DIRMT15' building

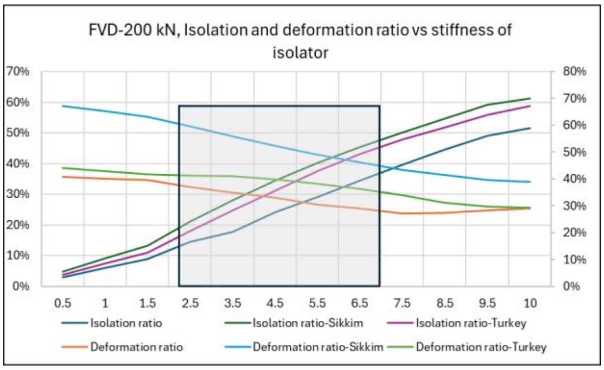

Fig-3.24:Isolation-deformation for DIRMT15' building

4 CONCLUSIONS

Based on the numerical and comparative study on elastomeric bearings isolation system and fluid viscous dampers with different parameters, the following conclusion may be made:

1) Isolation system seems to be effective tool in mitigating seismic forces (base shear) with proper selection of non-linear properties. There is huge reduction of base shear with reciprocate increase of drift and flexibility due to incorporation of stiffness.

2) Base isolation system using isolators which have only isolation property with minimum damping

effect, increases the displacement of the structure and hence it may not be serviceable in some cases.

3) Using the combination of isolators and dampers can reduce the base shear is seismic as per design target and parallelly reduce the displacements as well.

4) Performing analysis for various combinations of stiffness of isolators and capacity of dampers can help to find the suitable option for any particular structure as per design requirement.

5) Different time history accelerogram data may provide different results for base shear and to go for the suitable choice, analysis using more than two-time history functions is recommended.

6) The interaction between isolation and deformation ratio helps to select a possible range of isolation and damping combination for a certain range of reduction in base shear and displacements.

7) When only elastic stiffness of EB helps to reduce the force, additional damping also helps in reduction of force and displacements both.

8) Th combination using lower stiffness of EB and lower capacity of FVD result in an increase of displacements value even larger than the conventional support. Hence, stiffness as 0.5 kN/mm and FVD capacity as 50 kN may not be suitable choice for any of building models shown in this paper.

9) For any particular building type, considering the various options to select the isolation-damping combination, any option can be chosen depending on design requirement.

10) The irregularity in vertical direction may not have much impact in reduction of base shear but can have an influence on displacements as there is a tendency to get larger displacement at some locations.

11) Using FVD at some column support locations results in irregular deformation at the base support and may be larger for the locations where there is no FVD considered. Also, the deformation depends on the stiffness and FVD capacity and may not be same for all structures.

12) The numerical analysis confirms elastomeric bearings and fluid viscous dampers effective in enhancing the performance of structure and that its use may reduce total construction cost by reduction of structural acceleration response in case of earthquakes.

13) It is observed that there is bandwidth of optimal design and Damping, stiffness in which the Structure can be equipped with dampers with reduced base shear but within stipulated drift as per serviceability criteria.

14) Based on the study on Isolation and deformation ratio optimum design is possible by selecting the target reduced base shear and deformation for any structure.

15) The limitations of present study include use of Eb as isolator and FVD as damper, damper layout as diagonal bracing, building models for G+5 and G+15, Elcentro, Sikkim and Turkey time history matched to target response spectrum.

16) Future research can be done with different FVD layout, different types of isolator, more different types of structures and also using different types of dampers to check the benefits using other devices as well. Also, time history analysis can be performed for various other ground motion data matched to design response spectrum.

17) The present study has been conducted for seismic zone V and medium soil. For further validation analysis can be carried out for other seismic zones and soil types.

18) The targeted design base shear in seismic needs to be targeted at a level where the design force including all load cases for a structure is same or lesser than the reduced seismic force. In any case, if damped shear is lesser than the force derived from other load cases, the structure has to be designed for the larger force.

Acknowledgement

I would like to take this opportunity to express my deepest gratitude to our reverent Professor Dr. Debashis Bandyopadhyay, for his resourceful guidance, active supervision, continued support and constant encouragement to help me bring this paper to its present shape. I offer my sincere appreciation for the learning opportunities provided by CSIESPL during model development. I would also like to take this opportunity to thank all my colleagues and seniors in office and university who encourage me continuously.

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