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Reduction of Earthquake Response of Steel Framed Buildings by FVDs

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Abstract: **- In this paper an advanced application of fluid viscous damper is investigated. This study investigated whether fluid viscous damper is an alternative for base isolators. The non linear time history analysis result clearly indicates that the use of fluid viscous damper in midrise steel buildings will reduce the earthquake response and is an efficient seismic retrofitting method.**

Index Terms— Base shear, Earthquake response, Fluid viscous dampers, Non linear time history analysis, Retrofitting, Roof displacements, Roof accelerations, SAP 2000.

1. INTRODUCTION

Fluid viscous dampers operate on the principle of fluid flow through orifices. A stainless steel piston travels through chambers that are filled with silicone oil. The silicone oil is inert, non flammable, non toxic and stable for extremely long periods of time. The pressure difference between the two chambers cause silicone oil to flow through an orifice in the piston head and seismic energy is transformed into heat, which dissipates into the atmosphere. The force/velocity relationship for this kind of damper can be characterized as F= CV α where F is the output force, V the relative velocity across the damper, C is the damping coefficient and α is a constant exponent which is usually a value between 0.3 and 1.0. Fluid viscous dampers can operate over temperature fluctuations ranging from –40°C to +70°C. These devices originated in the early 1960's for use in steel mills as energy absorbing buffers on overhead cranes. Variations of these devices were used as canal lock buffers, offshore oil rig leg suspensions, and mostly in shock isolation systems of aerospace and military hardware. Fluid viscous dampers in recent years have been incorporated into a large number of civil engineering structures [4]. Fluid viscous damping is a way to add energy dissipation to the lateral system of a building structure. A fluid viscous damper dissipates energy by pushing fluid through an orifice, producing a damping pressure which creates a force. These damping forces are 90 degrees out of phase with the displacement driven forces in the structure. This means that the damping force does not significantly increase the seismic loads for a comparable degree of structural deformation. The addition of fluid viscous dampers to a structure can provide damping as high as 30% of critical, and sometimes even more. This provides a significant decrease in earthquake excitation

II. NEED OF THE STUDY

The trend of using energy dissipating devices such as fluid viscous dampers for seismic retrofitting is gaining popularity nowadays. Significant research work has been done previously in the field of passive energy dissipating devices especially on FVDs. One of the drawbacks observed during the literature study is that majority of the previous works include complicated mathematical formulations which are difficult to follow and apply in the field. Thus it is essential to have an easier design procedure which will help practising engineers to adopt fluid viscous damping.

Fig 1.Hysteresis curve for various dampers [25]

After analysing the hysteresis loops in figure 1, it is clear that more energy is dissipated by friction dampers. But more research works have already been carried out in friction damper. So, fluid viscous damper is selected for this investigative study since it dissipates more energy compared to viscoelastic damper.

Base isolation of large structures has proven to be an effective way to attenuate seismic excitation. However it can be costly, and can also involve major building modification. It is now possible to secure a comparable degree of earthquake mitigation with fluid viscous dampers located throughout a structure, without having to isolate the building [8]. So by investigating the feasibility of using fluid viscous damper as an alternative for base isolators will helps to know the seismic efficiency of FVDs over base isolators.

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III. DETAILS OF STEEL BUILDING

A regular steel MRF building is selected for validation which was studied by J. K. Whittle, M. S. Williams, T. L. Karavasilis and A. Blakeborough. It is designed according to the Eurocodes (EC3 [BS EN 1993-1-1, 2005], EC8 [BS EN 1998-1, 2004]). The building is validated according to the journal paper, "A Comparison of Viscous Damper Placement Methods for Improving Seismic Building Design", by above mentioned authors which was published in Journal of Earthquake Engineering in 2012. The building has 10 storeys and has a floor height of 3.2 m. So the total height of building is about 32 m. All the floors have same floor plan as shown in figure 2, with a lateral force resisting system of MRFs in the north-south direction and braced frames in the east-west direction. The building has a rectangular plan shape with two axes of symmetry. Typical gravity loads (4 kN/m2 dead load and 2 kN/m2 live load) and an assumed 5% inherent damping are provided.

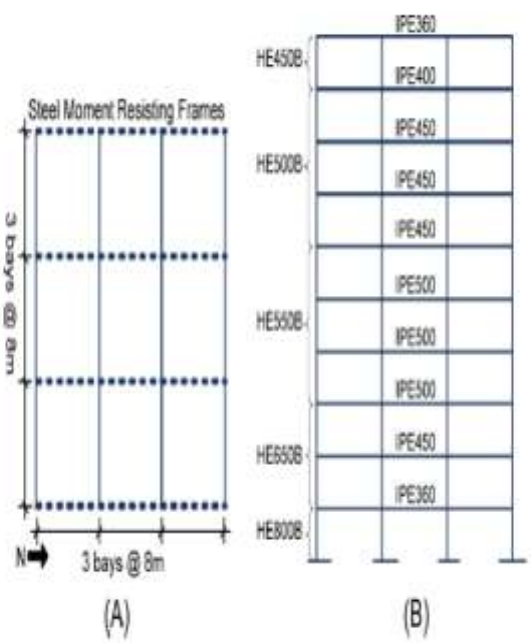

Fig. 3.Building layouts: (a) plan; (b) elevation [14]

The ten storeyed steel framed building is designed according to Eurocode soil B site conditions. The members in the building are European standard beams and columns and its pROPERTIES ARE SHOWN IN TABLE 1. The grade of steel is S355 (Structural steel 355) as per Eurocode.

Table 1. Details of all steel sections used in the structure (confining to S355) [5]

Designation	Dimensions					Area
	H	B	t_w	t_f	R	A
	mm	mm	mm	mm	mm	mm^2
IPE 360	360	170	8	12.7	18	7270
IPE 400	400	180	8.6	13.5	21	8450
IPE 450	450	190	9.4	14.6	21	9880
IPE 500	500	200	10.2	16	21	11600
HE 450 B	450	300	14	26	27	21800
HE 500 B	500	300	14.5	28	27	23860
HE 550 B	550	300	15	29	27	25410
HE 650 B	650	300	16	31	27	28630
HE 800 B	800	300	17.5	33	30	33420

IV. PARAMETRIC STUDY ON COMPARISON BETWEEN EFFECT OF FVD AND BASE ISOLATOR

Base isolation is an effective way to protect large structures from earthquake damage. It is a costly approach, as the entire structure must be supported on elastomeric or sliding bearings. Viscous dampers distributed throughout the structure also achieve the same result at significantly lower cost. Base isolation of large structures has proven to be an effective way to attenuate seismic excitation. However it can be costly, and can also involve major building modification. It is now possible to secure a comparable degree of earthquake mitigation with fluid viscous dampers located throughout a structure, without having to isolate the building [8].

In this parametric study, 10 storeyed steel framed building is only considered for analysis. Because FVDs are more effective in midrise buildings rather than highrise buildings. Response reduction is more prominent in midrise buildings with FVDs. For this study base isolator is modelled in SAP2000 as rubber bearing isolator in link/support type having axial stiffness as 1751.268 kN/m and ratio of post yield shear stiffness to initial shear stiffness as 0.2.

The three cases considered for this study are

Case 1: Building without damper

Case 2: Building with damper in exterior bay uniformly throughout

Case 3: Building with base isolators

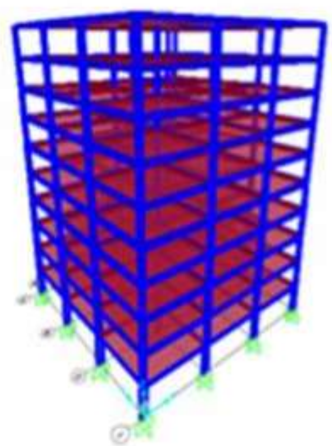

Fig. 3.Undamped 10 storeyed structure

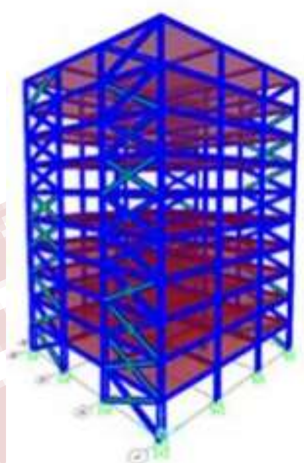

Fig. 4. Building with FVDs

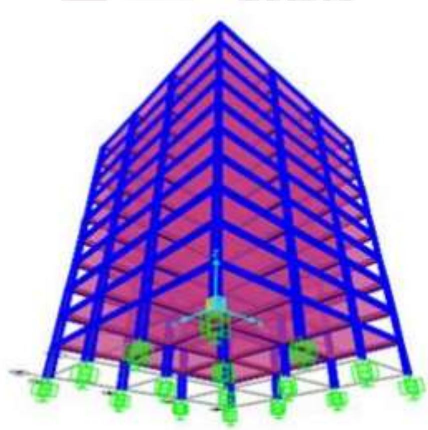

Fig. 5. Building with base isolator

Nonlinear time history analysis using design based earthquake ground motion is carried out on 3 building models shown in figures 3, 4 and 5. From the analysis results, it was observed that the building with base isolators shows more reduction in base shear than buildings with FVD. But there is more than 30% reduction in roof acceleration, roof displacement and base shear in buildings installed with FVDs than undamped 10 storeyed structure. Reduction of seismic response by FVDs is acceptable, since there is 30 % reduction in seismic response. From the technical papers from TAYLOR DEVICE, it is found out that the construction and installation cost of base isolators is 40% more than that of FVD. The cost per piece of fluid viscous damper is around Rs.20,000/-. So by considering the cost effective way, FVD is a good alternative to base isolators since it has 30% reduction in seismic response.

V. ANALYSIS RESULTS AND DISCUSSION

The earthquake accelerations which give peak results are depicted as separate graphs in this study. The LA09 (Yermo Fire Station) is taken from the 1940 El Centro earthquake with a peak ground acceleration (PGA) of 0.52g having highest magnitude among the 20 design based earthquakes. The magnitude of LA09 is 7.3. The time history of base shear, roof displacement and roof acceleration are shown in figure 6, 7 and 8 respectively.

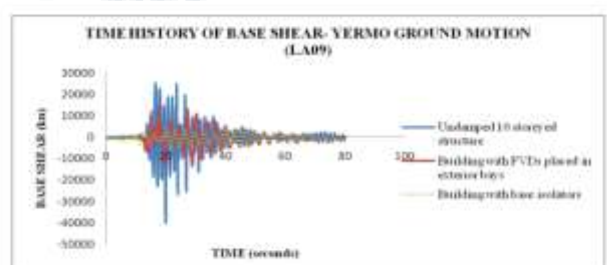

Fig. 6. Time history of base shear in 10 storeyed building

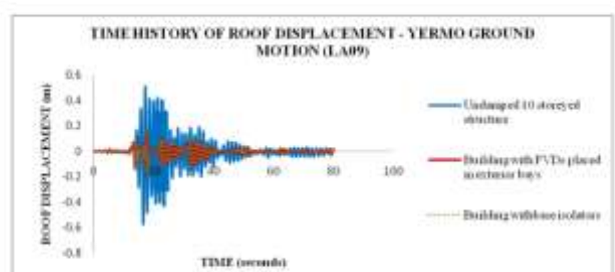

Fig. 7. Time history of roof displacement in 10 storeyed building

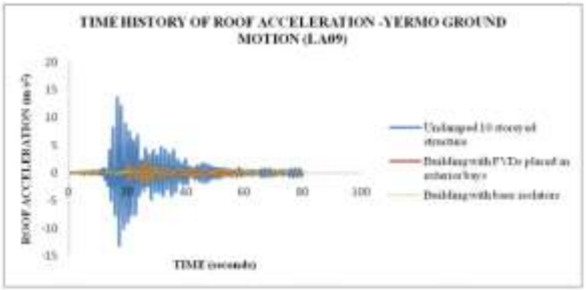

Fig. 8.Time history of roof acceleration in 10 storeyed building

From the time history of base shear, it was clearly observed that the base shear of the building reduced more when the base isolators are installed in the building. Reduction in roof displacement and roof acceleration are almost similar in both cases (building with FVDs placed in exterior bays and building with base isolators). The percentage reduction in base shear, roof accelerations and roof displacement in different cases considered for this study are shown in figure 9.

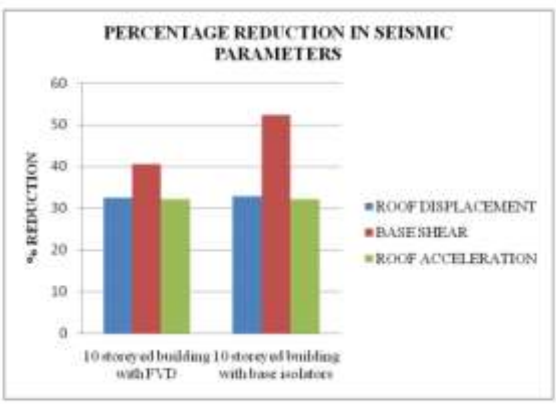

Fig. 9 Percentage reductions in seismic responses

The main advantage of using base isolator is that, it will reduce base shear in large amount. In this study, the base shear of 10 storeyed framed building is reduced up to 52%. But roof acceleration and displacement reduced as same as 10 storeyed building installed with FVD. But FVD also reduce base shear up to 41%. Moreover cost of an FVD comes around Rs. 20,000/-. Construction and installation cost of base isolators is more than 40% of that of FVD. So by considering the cost and reduction in seismic response, FVDs are suitable alternative for base isolators in steel buildings. So by considering the cost effective way, FVD is a good alternative to base isolators since it has 30% reduction in seismic response

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