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Study on Special Moment Resisting Frames With Fluid Viscous Dampers As A Seismic Retrofit

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Abstract: **The objective of this paper is to investigate the effect of Fluid Viscous Dampers (FVDs) on the seismic response of a structure. This study includes seismic retrofit of FVDs to Special Moment Resisting Frames (SMRFs) and comparison of its behavior. A 15 storey structure was considered in this study which was modelled in the ETabs software. The diagonal bracing system was considered for the damper configuration. The structures i.e., the bare frame and the retrofitted frame were subjected to response spectrum analysis. Various parameters such as storey displacements, storey drifts and storey shears were compared for the bare frame and the retrofitted frame. Results indicated that the Fluid Viscous Damper significantly reduces the effects due to an earthquake and is an effective retrofit tool against seismic actions.**

***Keywords*:** **Fluid Viscous Dampers (FVDs), Response Spectrum analysis, Special Moment Resisting Frame (SMRF)**

I. INTRODUCTION

An Earthquake is an abrupt movement of the earth's crust that is initiated below or at the surface. Earthquakes can cause huge destruction to the structures and weaken the buildings thereby reducing its useful life. Seismic resistant design now involves a lot of innovations, although no structure can be entirely immune to the damage from earthquake, the aim is to reduce the damages caused due to them. One of them being installation of Fluid Viscous Dampers (FVD'S). These dampers can be installed in newly constructed as well as existing structures. This study involves addition of FVD's in Special Moment Resisting Frames (SMRF's) and Special Truss Moment Frames (STMF's) as a seismic retrofit.

The SMRF consist of beams and columns both rigidly connected to each other. It involves resistance to lateral forces by rigid frame action i.e., by development of bending moment and shear force in beams and columns. The joints or connections, between columns and beams are designed to be rigid.

This causes the columns and beams to bend during earthquake. So these structural members are designed to be strong in bending.

Ras, N. Boumechra[1] conducted a numerical exploration of the seismic response of a 12 storey Steel Moment Resisting Frame (SMRF) retrofitted with Fluid Viscous Dampers (FVDs) in a diagonal configuration. Hamidia, et.al.,[2] presents a procedure to assess the side sway collapse capacity of a frame retrofitted with linear and nonlinear viscous dampers. Pekcan, et.al.,[3] developed an alternative concept involving energy dissipating devices such as Buckling Restrained Braces (BRBs) installed in special truss moment frames. Vamsi Prasad Gade, Dipti Ranjan Sahoo[4] evaluated the collapse performance of a 9 storey steel truss moment frame (STMF) which was designed based on both ASCE standards and performance based plastic design (PBPD) method keeping in mind the FEMAp695 recommendations for extreme earthquake loading conditions.

2. FLUID VISCOUS DAMPERS

Fluid viscous dampers have been widely used to mitigate earthquake induced damage of structures effectively. They operate on the principle of fluid flow through orifices. Such device consists of a stainless steel piston that travels through chambers filled with silicone oil. The pressure difference between the two chambers causes silicone oil to flow through an orifice in the piston head and seismic energy is transformed into heat which is dissipated into the atmosphere. Fluid viscous dampers have the unique ability to simultaneously reduce both stress and deflection within a structure subjected to a transient. This is because a fluid viscous damper varies its force only with velocity which provides a response that is inherently out -of phase with stresses due to flexing of the structure. They are installed in the form of diagonal bracings at suitable locations in the case of SMRF's.

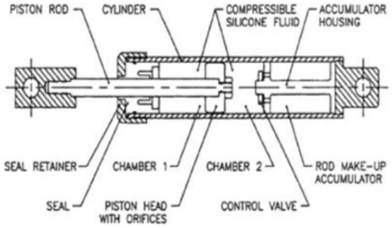


Figure 1 Fluid Viscous Damper

2.1 Equation of FVDs

FVD are characterized by a resistance force F. It depends on the velocity of movement, the fluid viscosity and the orifices size of the piston [1]

$$P = C_d \cdot (\dot{u}_d)^{\alpha} \cdot \sin(\dot{u}_d)$$

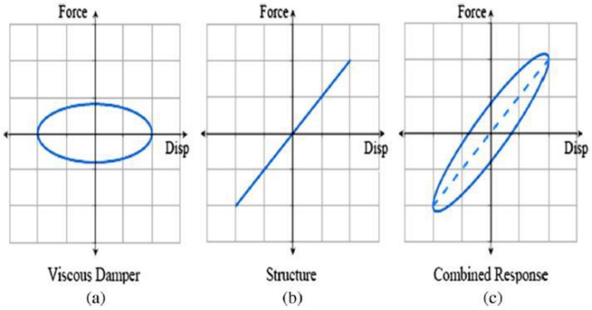
with

$$u_d(t) = u_0 \cdot \sin(\omega \cdot t)$$

……………(1)

where

$\dot{u}_d$ is the velocity between two ends of the damper;
C_d is the damping constant;
u_0 is the amplitude of the displacement, ω is the loading frequency, and t is time;
α is an exponent which depends on the viscosity properties of the fluid and the piston.



Viscous Damper (a) Structure (b) Combined Response (c)

Figure 2 Hysteretic Curve of FVD [1]

III. METHODOLOGY

3.1 Steps followed

- Special Moment Resisting Frame (SMRF) is modelled using the Extended 3D Analysis of
- Building System (ETabs) software Structure is subjected to linear static analysis as well as response spectrum analysis
- The structure is then retrofitted with Fluid Viscous Dampers (FVD's) at specific locations
- The retrofitted structure is then analyzed by linear static and response spectrum analysis
- The comparisons are made between the bare frame and the retrofitted frame.

3.2 Calculation of Damping Coefficients

The following procedure is used to obtain the damping coefficients in this study [2]:

- A Normalized lateral stiffness distribution of the entire structure with respect to the top storey is obtained
- The steel structures generally have 0.02 of the critical damping ratio and the remaining damping is assumed to be provided by the FVD's
- The damped time period is then calculated for the structure

$$T_d = \frac{T}{\sqrt{(2\zeta_v + 1)}} \qquad (2)$$

- The structure is fitted with linear springs of trial stiffness k_{tr} and distributed according to the lateral stiffness distribution to obtain its time period (T_t) by Eigen value analysis
- If T_t matches with T_d, then the trial stiffness is considered to calculate the damping coefficient C_L, where

$$k_0^{\,n} = \frac{k_{tr}^{\,n}}{1 - \left(\frac{T_d^{\,2} - T_t^{\,2}}{T_d^{\,2} - T^2}\right)} \qquad (3)$$

$$C_L = \frac{k_0 T}{2\pi} \qquad (4)$$

- If the T_t doesn't match with the T_d, then the trial stiffness is changed till T_t matches with the T_d

3.3 Model and Analysis

A Special Moment Resisting Frame was modelled in the ETabs software. The lateral dimensions of the frame were 24m x 24m and the building was 15 storeys tall with each floor height being 3m. Steel of grade Fe250 was considered. Supports at the base were fixed. [6]Live Loads were applied as per IS-875 part II. ISMB 500 sections were used for beams and 300x300x10 box sections were used for columns.

- Response spectrum analysis was carried out on both the bare frame as well as the retrofitted frame
- Earthquake load case was defined as
- Response reduction factor = 5

- Importance factor = 1
- Seismic zone factor = 0.36
- Soil type = II
-
- Scale factor for the Response spectrum load case was calculated by **(Ig/2R)** [7]
- The behavior of the bare and retrofitted frame was compared using the response spectrum analysis

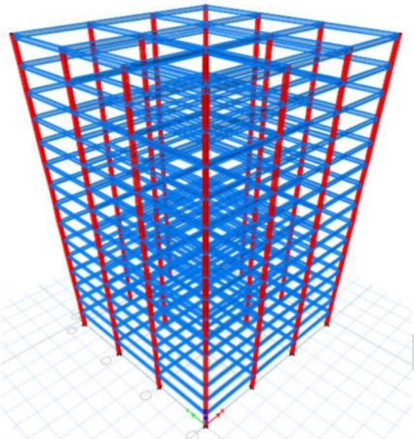


Figure 3 Isometric view of the SMRF

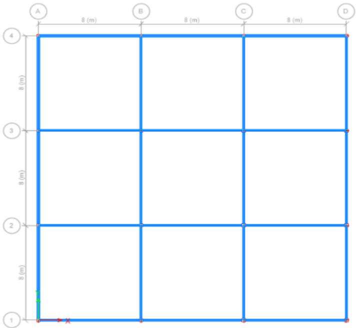


Figure 4 Plan view of the structure

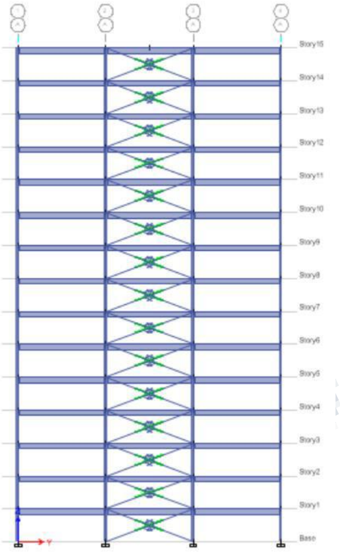


Figure 5 Elevation view of the Retrofitted frame

IV. RESULTS

The Response Spectrum analysis was performed for the two models and the responses are as shown below

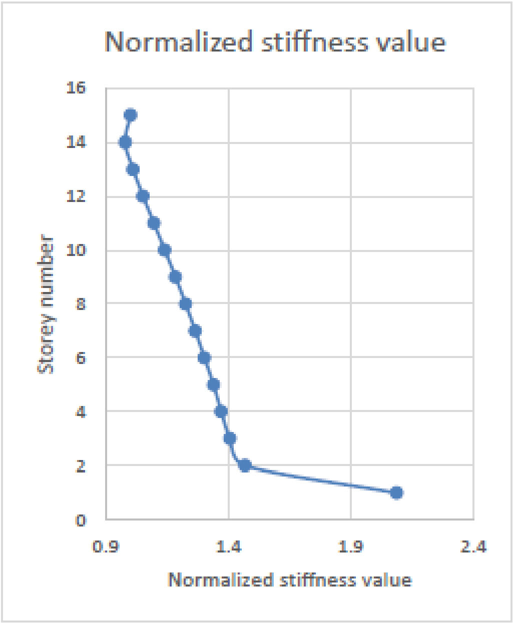


Figure 6 Graph showing variation of normalized stiffness value storey wise

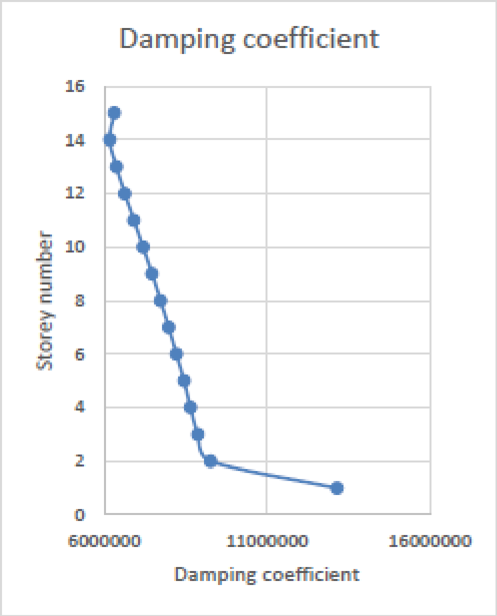


Figure 7 Graph showing variation of damping coefficient value storey wise

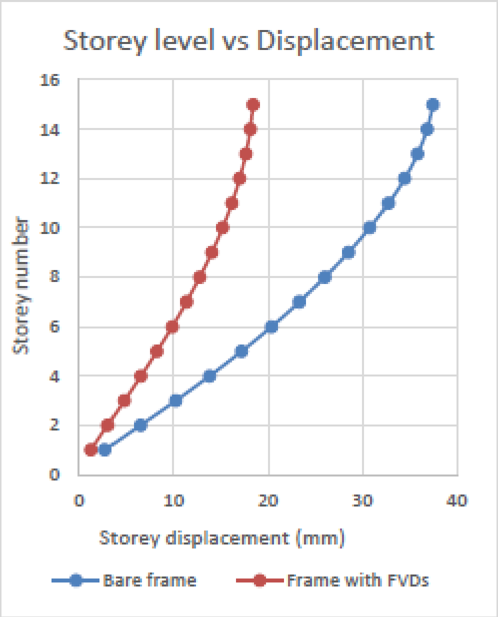


Figure 8 Graph showing comparison of storey displacement vs storey level between a bare frame and a retrofitted frame

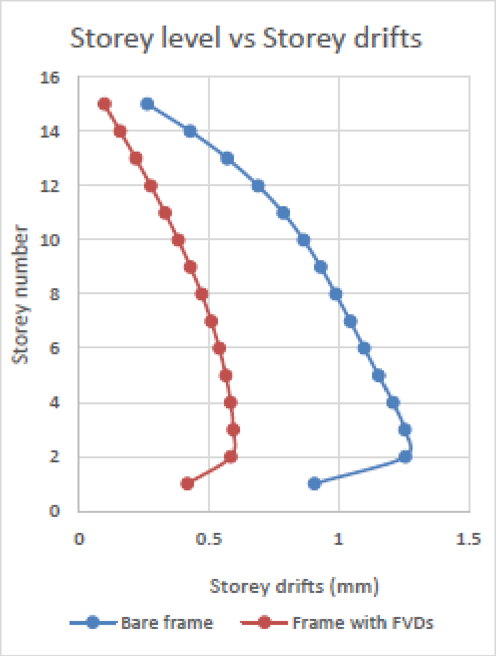


Figure 9 Graph showing comparison of storey drifts vs storey level between a bare frame and a retrofitted frame

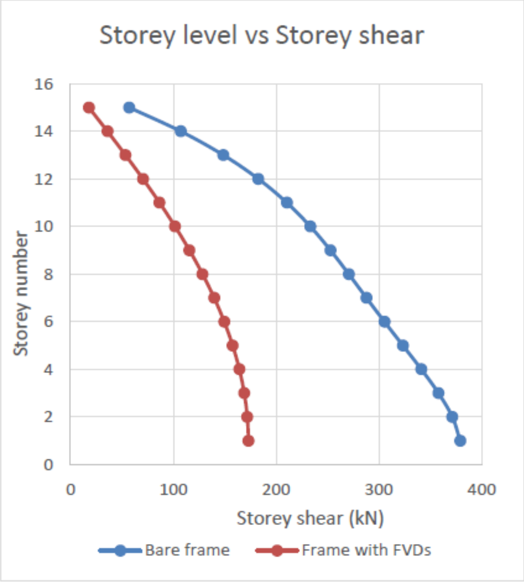


Figure 10 Graph showing comparison of storey shear vs storey level between a bare frame and a retrofitted frame

V. DISCUSSIONS

- The Normalized stiffness values obtained with respect to the top storey shows that as the storey level decreases, the natural stiffness of the structure is greater, in general.
- The results obtained show that various parameters such as Maximum storey displacement, storey drift and storey shears reduce with the addition of Fluid Viscous Dampers to existing as well as newly constructed structures.
- Considering the above results, the addition of FVDs is an effective way to resist earthquakes and can be used as a part of seismic retrofit in the seismic analysis

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