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Research Article

The Use Of Viscous Dampers For Retrofitting Of Reinforced Concrete Frames

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Abstract: During last earthquakes, often the conventional reinforced concrete (RC) buildings had suffered damages. So in conventional RC buildings, earthquake-induced energy is dissipated in components of the gravity and lateral-load-resisting system. The action of dissipating energy in framing such as beams and joints in a moment-resisting frame produces damage in those components. Repair of such damage after an earthquake is typically expensive and often requires evacuation of the building while repair work on the gravity system is undertaken. In this research, adding viscose damper to new and existing RC frames have investigated. So nonlinear dynamic analysis of the systems has been carried out and its structural behavior has been investigated. Results indicate that, this damper enhances the seismic behavior of RC frames. It causes the energy applied to structure due seismic loading, concentrate on damper while other members stand in elastic zone. It evacuation of the building for repair might not be necessary and the total repair cost will likely be minor compared with the costs associated with repair and business interruption in a conventional building.

Keywords: reinforced concrete frame structures, viscous dampers, Seismic retrofit

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1.Introduction

A number of reasons may necessitate the need to retrofit existing structures. It may be the rehabilitation of a structure damaged by an earthquake or other causes, or the strengthening of an undamaged structure made necessary by revisions in structural design or loading codes of practice. Here, the collective term, retrofit, which implies the addition of structural components after initial construction, is applied to both rehabilitation and strengthening processes. Also, as the seismic loading and design codes are subject to more frequent revisions than the rather established gravity-based codes, earthquake consideration becomes a prime reason for the need to strengthen existing structures [1].

In conventional construction, earthquake-induced energy is dissipated in components of the gravity and lateral-load-resisting system. The action of dissipating energy in framing such as beams and joints in a moment-resisting frame produces damage in those components. Repair of such damage after an earthquake is typically expensive and often requires evacuation of the building while repair work on the gravity system is undertaken. The objective of adding energy dissipation (damping) hardware to new and existing construction is to dissipate much of the earthquake-induced energy in disposable elements not forming part of the gravity framing system. Key to this philosophy is limiting or eliminating damage to the gravity-load resisting system. Although testing and perhaps replacement of all supplemental damping devices in a building should be anticipated after a severe earthquake, evacuation of the building for repair might not be necessary and the total repair cost will likely be minor compared with the costs associated with repair and business interruption in a conventional building [1].

2. Dampers

Supplemental damping hardware is parsed into three categories: hysteretic, velocity dependent and others. Examples of hysteretic (displacement-dependent) dampers include devices based on friction and yielding of metal. Figure 1 presents sample force displacement loops of hysteretic dampers. Examples of velocity-dependent systems include dampers consisting of viscoelastic solid materials, dampers operating by deformation of viscoelastic fluids (e.g., viscous shear walls) and dampers operating by forcing fluid through an orifice (e.g., viscous fluid dampers). Figure 2 illustrates the behavior of these velocity dependent systems. Other systems have characteristics that cannot be classified by one of the basic types depicted in Figures 1 or 2. Examples are dampers made of shape memory alloys, frictional-spring assemblies with recentering capabilities and fluid restoring force/damping dampers. For information on these dampers, the reader is referred to Constantinou et al .(1998), EERI (1993), Soong and Constantinou(1994), Soong and Dargush (1997) and Hanson and Soong (2001). Only hysteretic and velocity-dependent dampers are discussed in this chapter.

Each of these dampers have advantages and disadvantages. Advantages of Fluid Dampers are ; High reliability, High force and displacement capacity, Force Limited when velocity exponent < 1.0, Available through several manufacturers, No added stiffness at lower frequencies, Damping force (possibly) out of phase with structure elastic forces, Moderate temperature dependency, May be able to use linear analysis Instructional Material Complementing FEMA 451, Design Examples Passive Energy Dissipation and Disadvantages of Fluid Dampers are Somewhat higher cost, Not force limited (particularly when exponent = 1.0)Necessity for nonlinear analysis in most practical cases (as it has been shown that it is generally not possible to add enough damping to eliminate all inelastic response).

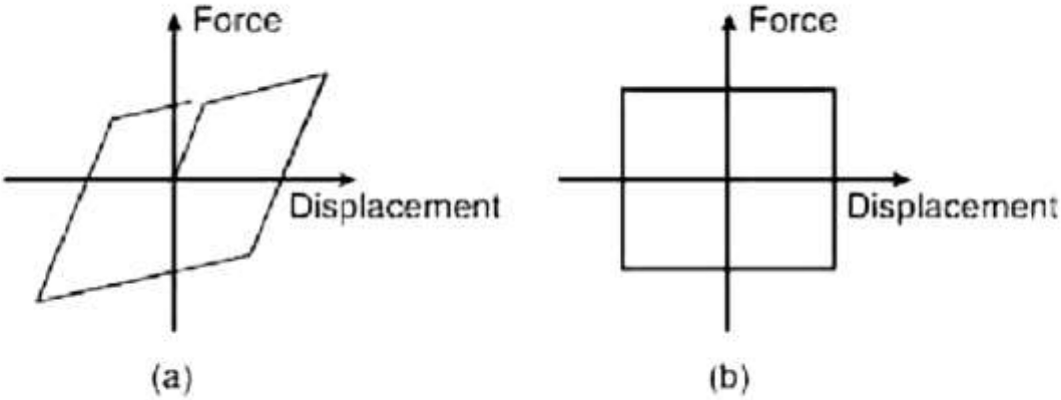

Figure 1 Force-displacement relation for hysteresis dampers

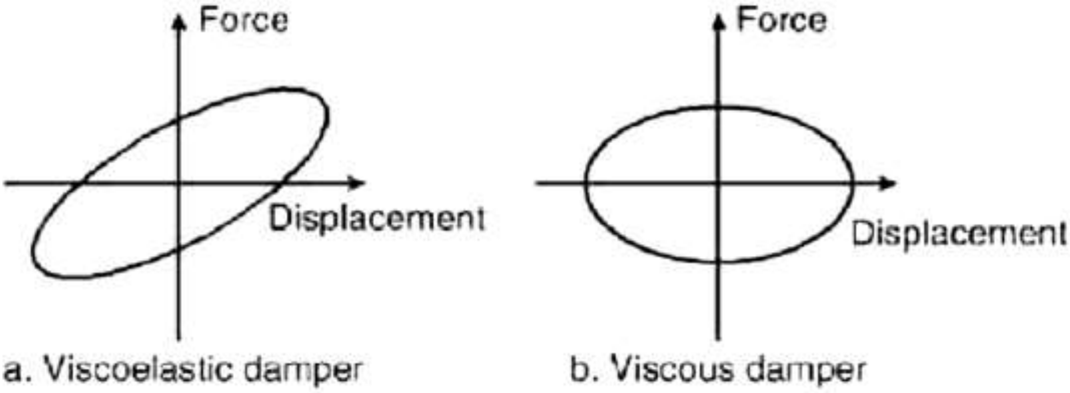

Figure 2 Force-displacement relation for velocity-depended damper

3. Viscous dampers

Figure 3 shows the schematic section through a viscous damper. Relation for that damper is as following;

$$F=C.V^n$$

Where F, V, C, are damping force, relate velocity, damping coefiession, respectively. C is a number is measured based on damper's diameter. Also n is a factor between 0.3 until 1.95 which it is proposed 0.3 until 1.00 for structural application [3]. So it is used 1.00 in this paper.

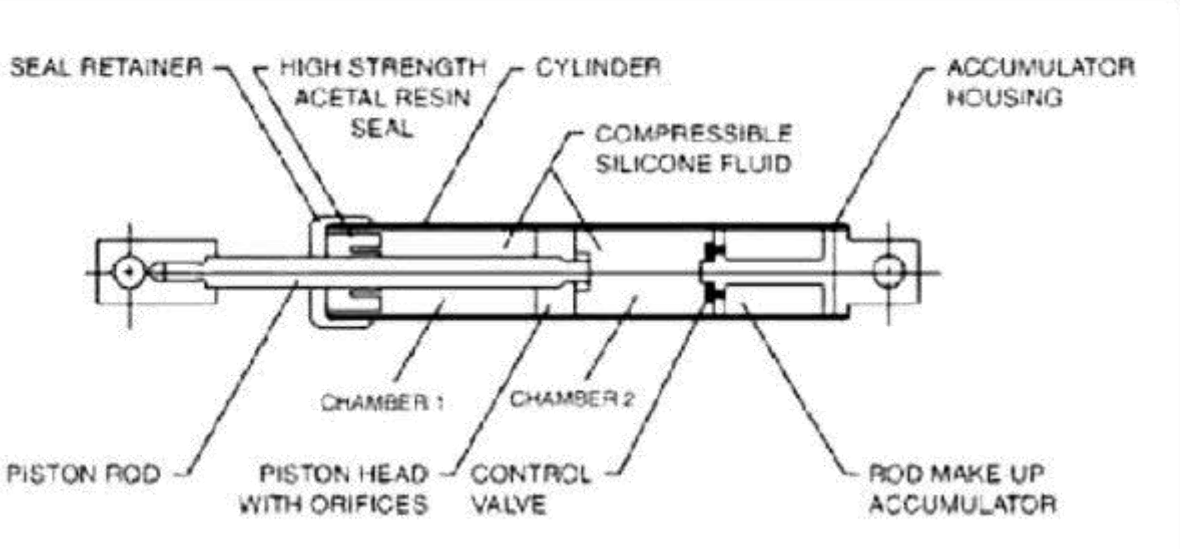

Figure 3 Schematic section through an viscous damper

Viscous damping is a common form of damping which is found in many engineering systems such as instruments and shock absorbers. The viscous damping force is proportional to the first power of the velocity across the damper, and it always opposes the motion, so that the damping force is a linear continuous function of the velocity. Because the analysis of viscous damping leads to the simplest mathematical treatment, analysts sometimes approximate more complex types of damping to the viscous type Viscous damper is modelled as a Maxwell Element consisting of a linear or nonlinear dashpot in series with a linear spring. To model a linear viscous dashpot, KD must be set to a large value, but not too large or convergence will not be achieved. To achieve this, it is recommended that the relaxation time "λ=CD/KD" be an order of magnitude less than the loading time step At. For example, let "KD=100CD/Δt". Sensitivity to KD should be checked. SAP2000 often has difficulty converging when nonlinear dampers are used and the velocity exponent is less than 0.4. To design and estimate the target displacement of structures using NSP process as following are applied. So 1) Estimate Target Displacement (performance point). 2) Calculate Effective Damping Ratio and Secant Stiffness of building with dampers at Target Displacement. 3) Use Effective Damping and Secant Stiffness to calculate revised Target Displacement 4) Compare Target Displacement from Steps 1 and 4. If within tolerance, stop. Otherwise, return to Step 1. Many approaches use for modelling dampers. Fig. shows modelling dampers utilize simple dashpot. This model ignores temperature dependence.

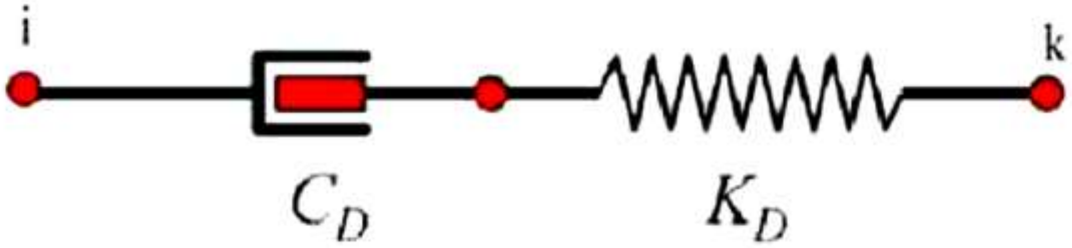

Figure 4 Maxwell Element model [4]

Case studies

In order to assess the seismic behavior of the RC frame strengthen with viscous damper, a 12-storey building are considered. These structures are a dual system composed of a weak moment frame and two braced frames where the braces endure the major part of storey shear, so the effect of the braces is more evident. These structures are 3 m in each storey’s high, 4 m in wide (three beyond which viscous damper is installed at internal bay), fc for concrete is 250 Mpa. Process of analysis performed based in which first RC frames were designed for resisting lateral load and then the steel brace and then the viscous damper is attached to RC frames and analysis is performed again. The lateral loads were calculated based on RANIAN earthquake cod (2800 cod) [5]. Also damper Velocity Exponent “α=0.4” is used [6].

4.Results and discussion

Fig. 5 shows the load-displacement curve obtained from numerical modelling. This curve show that the damper does not effective in shear stiffness. But it decreases the yielding capacity level of system which it is caused to enhance the nonlinear behavior and seismic parameters such as ductility factor, energy dissipation, over strength, etc. One of the accurate ways of measuring seismic performance of a structure relies on energy dissipation. In this study, the dissipated energy of analyzed specimens was measured as the area enclosed by load-displacement curve. As it can be seen in Figure 5, viscous damper has enhanced the energy absorption.

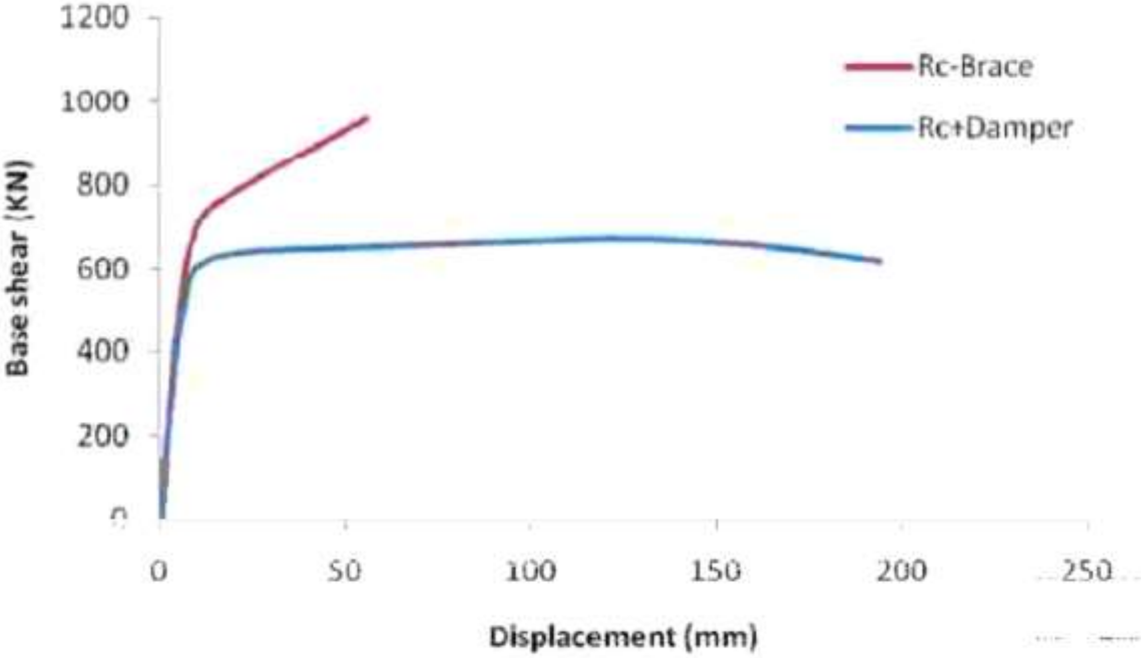

Figure 5 Load-displacement curves

Results show that the viscous damper is increased the damping of structure in inelastic zone (see Fig.5). It is obvious that during an earthquake the seismic energy is dissipated by viscous (increasing the damping ratio of system) damper and other parts that carry the gravity load such as column stand in elastic zone. According to that figure can be seen in elastic zone damping ones are equal. Also, the horizontal axis shows that the system's period has increased which it will decrease the earthquake demand.

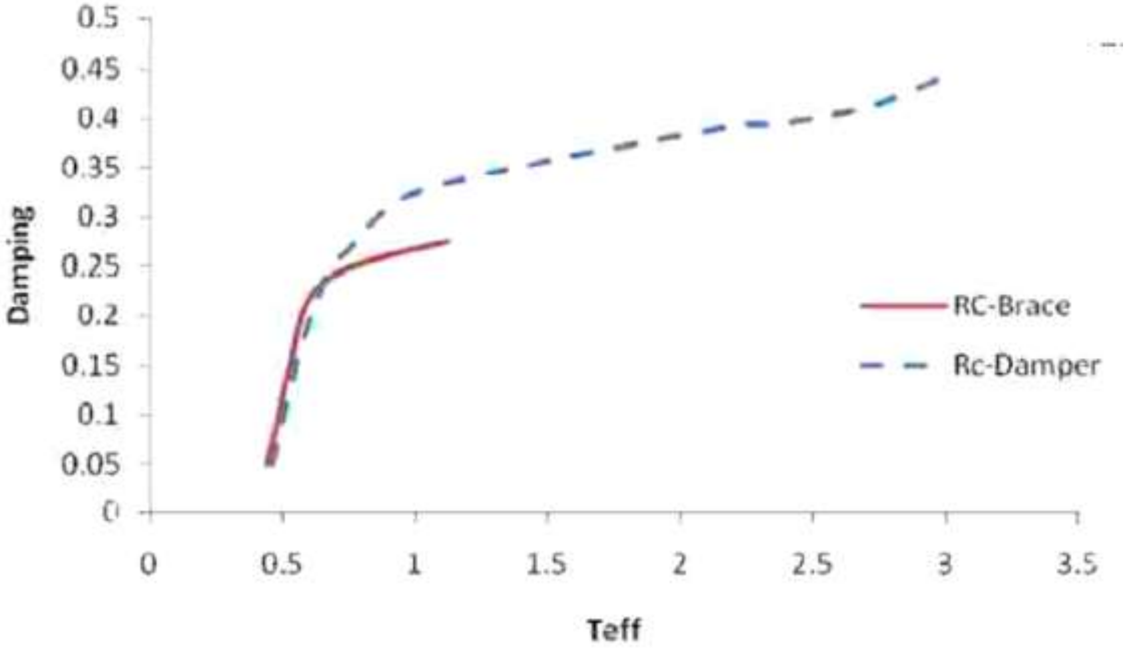

Figure 6 Damping versus Teff

In Fig. 6, the acceleration scaled is shown versus displacement capacity. In elastic zone two models have a similar behavior. So there are main differences in inelastic zone which the system with viscous damper has capability to resist against ground shaking. Also by installation of viscous damper the energy dissipation of structure have enhanced.

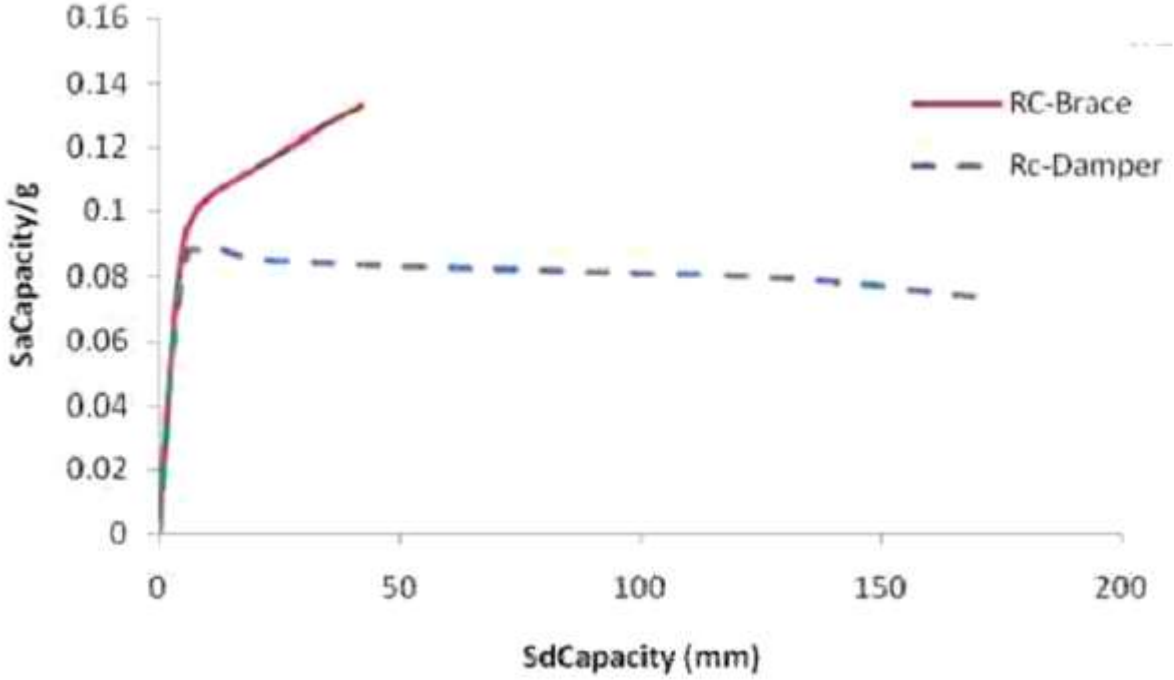

Figure 7 Capacity graph

Ductility is one of important factor to descent earthquake demand. Ductile structure, suffer smaller damage. Fig. 8 shows that, the viscous damper enhance the ductility factor of system while damping is equal.

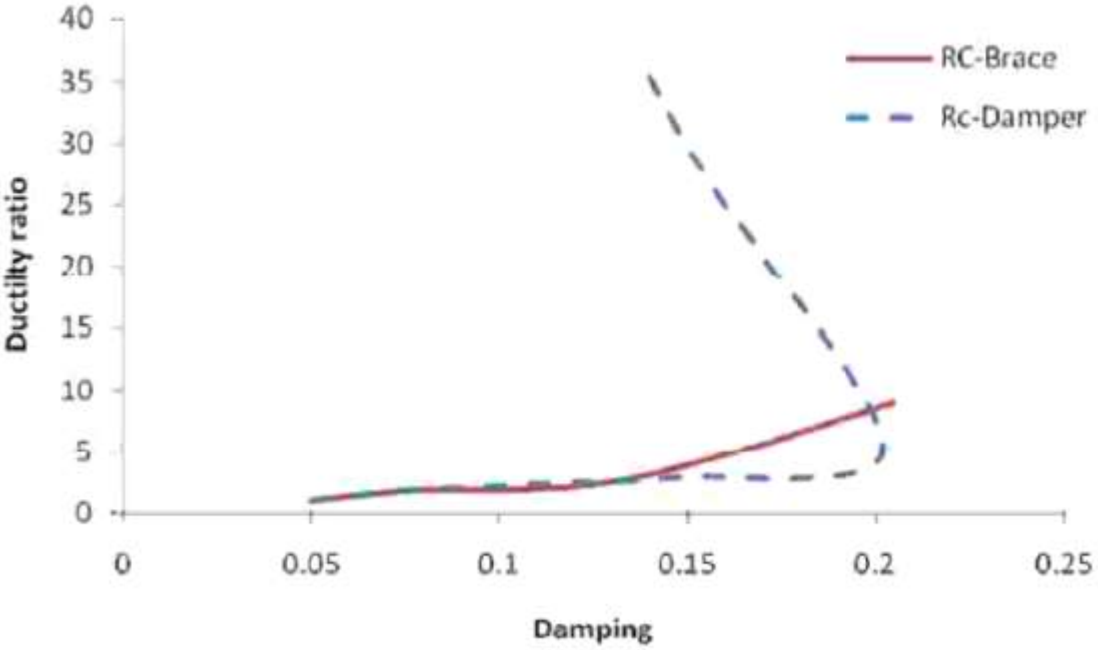

Figure 8 Ductility versus Damping

5.Conclusion

In this paper performance of structure with steel brace and viscous damper were studied. Results showed that the viscous damper enhance the seismic capacity of structure. It is caused to postpone commence nonlinear behavior of columns and the ductility is improved. That damper does not accurate effective in elastic zone. But in inelastic zone increase the damping and structure's period. It concluded that the viscous damper is an effective approach for retrofitting of reinforced concrete buildings.

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