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Reduction of Damage Concentration in Seismic Retrofitted RC Building with Friction Dampers

Terapat Sirinipitakul[1], Rawirot Suwannatrai[1], Hnin Hnin Hlaing[1] and Panumas Saingam[1]
[1]Department of Civil Engineering, School of Engineering,
King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
panumas.sa@kmitl.ac.th

Abstract **-** Because of their lack of lateral force resistance or energy dissipation capability, reinforced concrete (RC) structures have suffered significant damage in previous earthquakes. There is a demand to develop and improve the seismic performance of vulnerable existing RC buildings, particularly those not initially designed for seismic events or designed to an outdated seismic standard. Seismic retrofit of RC buildings using friction dampers is an innovative method to improve the seismic performance of the structures. In this study, nonlinear response history analysis was performed to investigate and compare the seismic performance of retrofitted buildings. The numerical results suggest that the maximum displacement was substantially improved after retrofitting the existing RC building with friction dampers. The damage concentration of the retrofitted buildings with friction dampers is reduced significantly when compared to the existing RC buildings.

Keywords**:** Seismic retrofit; Damage Concentration; RC Buildings; Friction damper

1. Introduction

Many old-reinforced concrete (RC) structures were destroyed in recent earthquakes because they lacked suitable lateral force resisting systems, as learned from previous earthquakes [1-5]. Demolition of seismically unstable existing buildings and replacement with new construction is an option based on these criteria [6-7], but it is generally time-consuming and costly. Furthermore, when the number of schools or hospitals in a rural area is limited, rebuilding incurs additional expenditures because there may be few other options for providing education or medical care. As a result, historic RC structures that were either not equipped for seismic effects or were built to outdated seismic requirements must be updated. In order to ensure that the retrofitted RC building can withstand future earthquakes, new seismic design criteria are frequently referred to for seismic retrofit design.

The installation of RC walls [6], the addition of traditional steel bracing [7], and the wrapping of the RC columns with carbon fiber reinforced polymers (CFRPs) are some of the most often utilized retrofit methods for RC frames to enhance the lateral force capacity [8]. Because the braces may be prefabricated and the weight of the braces is less than the weight of the new structural walls, the traditional braced frame method has proven to be advantageous [7].

For an innovative method, the installation of energy-dissipation devices such as buckling-restrained braces (BRB) [9-15], viscous dampers [16-17], and friction dampers [24-30] are innovative approaches for improving the seismic performance of RC structures. Friction dampers (FD) offer a promising alternative, as they provide significant energy-dissipation from smaller story drift [18-22] at a relatively low cost, and are easy to install and maintain [2]. Friction dampers may be employed as braces, in rocking walls, or at beam ends, as in the sliding hinge joint (SHJ) for steel moment frames [24-26]. Friction brace dampers, in particular, affect the dynamic response by increasing stiffness and damping.

The seismic design method is based on the constant drift method (CD method) under the same target story drift ratio of 0.5% rad. Nonlinear response history analysis was performed to investigate and compare the damage concentration in seismic retrofit RC building with friction dampers.

2. Seismic retrofit design concept

Because the approach is successful in controlling the maximum story drift ratio below and near to the set target story drift ratio without iterative methods, this study chooses to expand the constant drift (CD) method [11-12, 18] to design the requirement for energy-dissipation devices. The following is a quick step-by-step overview of the suggested design technique procedure:

1. Fit the roof displacement - base shear relationship to a trilinear backbone model with elastic, cracking, and post-yielding stages using a nonlinear modal pushover analysis on the RC frame (based on the fundamental mode). Obtain the RC frame's story strengths and stiffness properties.

2. Reduce the multi-story RC frame to a single-degree-of-freedom model, known as the $SDOF_{RC}$ model (Fig 1.), and compute the present structure's energy dissipation behavior at the target drift.

3. Using the $SDOF_{RC}$ displacement spectrum, determine the present RC frame's maximum story drift. If maximum story drift exceeds the intended story drift ratio, seismic retrofitting is required.

4. Determine the friction damper's required lateral strength ratio in terms of $SDOF_{RC}$.

5. Distribute energy-dissipation devices to control the target story drift ratios for each story, as shown in Fig 2.

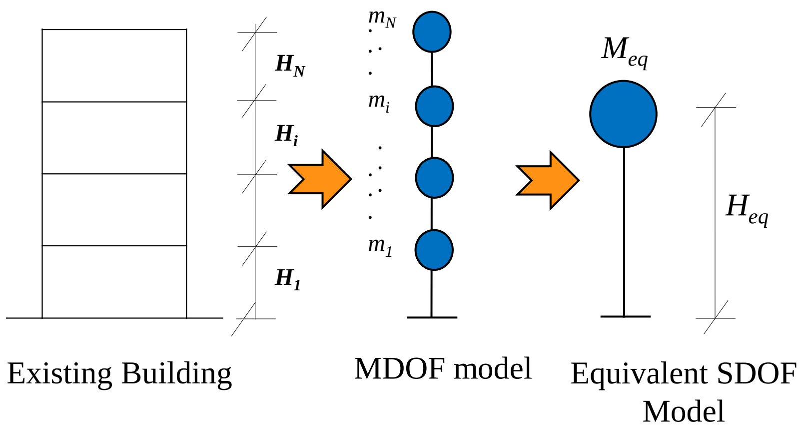


Fig. 1: Simplification of the RC building to a $SDOF_{RC}$ [15].

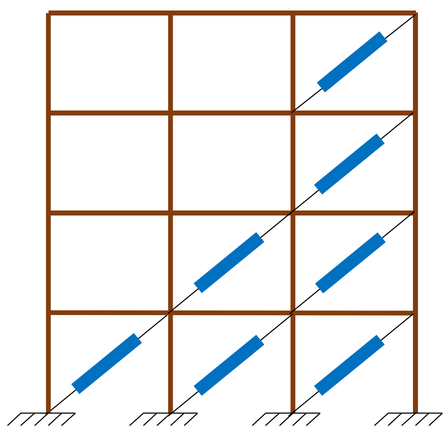


Fig. 2: Seismic retrofit configuration.

3. Nonlinear response history analysis

Nonlinear response history analysis (NLRHA) was performed for existing RC building (3D-R model) and retrofitted building with friction damper (3D-RF model) using a suite of eleven scaled ground motions. The detail of the ground motion motion can be found in the previous study [15]. An average of each response is compared in this section.

3.1. Ground motions for NLRHA

Fig 3 shows the target scaled ground motion elastic response spectra (5% damped), which is used to validate the retrofit method. The average results from all ground motions of each model are compared.

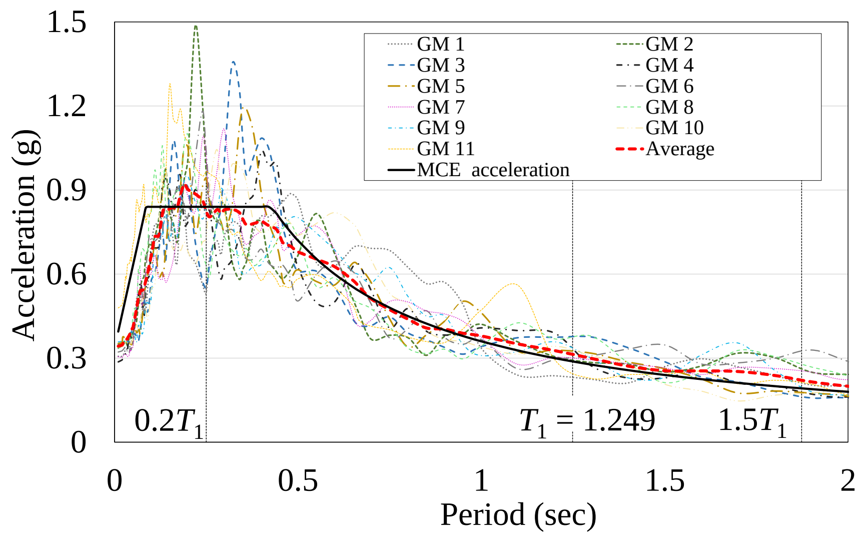


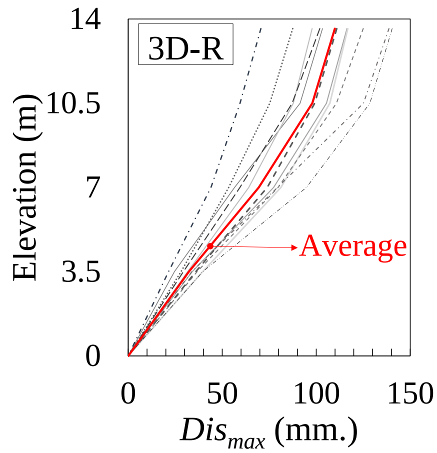
Fig. 3: Target MCE and scaled ground motion.

4. Numerical results

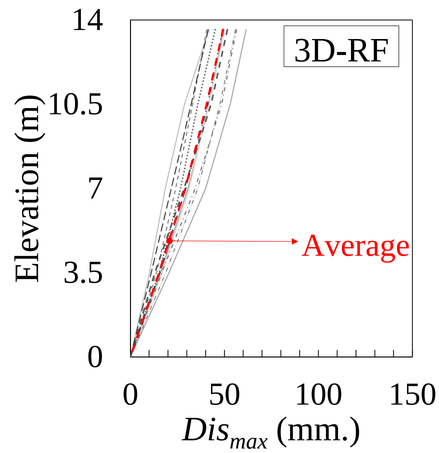
The numerical results will be shown and discussed in this section.

4.1. Maximum displacement (*Dis*$_{max}$)

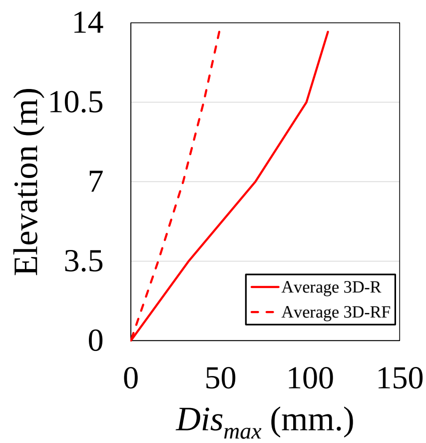
Fig.4a and Fig.4b shows the maximum displacement (*Dis*$_{max}$) for both before (Fig 4a) and after retrofit the RC building with friction dampers (Fig 4b). Based on the CD method [11-12, 18], the numerical results indicates that the *Dis*$_{max}$ of the retrofitted building with friction damper reduces significantly when compared to the non-retrofitted building, as shown in Fig 4c. This may imply that the friction dampers improve the seismic performance of the building.



(a) 3D-R model



(b) 3D-RF model



(c) comparison of the average results between 3D-R and 3D-RF model

Fig. 4: Maximum displacement

4.2. Drift concentration factor (DCF)

The effectiveness of retrofitted with dampers in reducing inter-story drift concentration may express of the terms of the drift concentration factor (DCF), as defined in Equation (1), where $SDR_{max,i}$ is the maximum inter-story drift ratio from all stories, u_r is the roof displacement; H is the total height of the building [31-32].

$$\mathrm{DCF} = \frac{max\left|SDR_{max,i}\right|}{u_r/H} \tag{1}$$

As shown in Fig 5, the overall results indicate that drift concentration factors (DCFs) of the retrofitted buildings are significantly decreased for several of the ground motions. It implies that individual stories in the retrofitted buildings tend to resist earthquake action and the weak story failure of the retrofitted building may be avoided [31-32]. It implies that the friction damper may improve the prevention of the damage concentration for the retrofitted buildings.

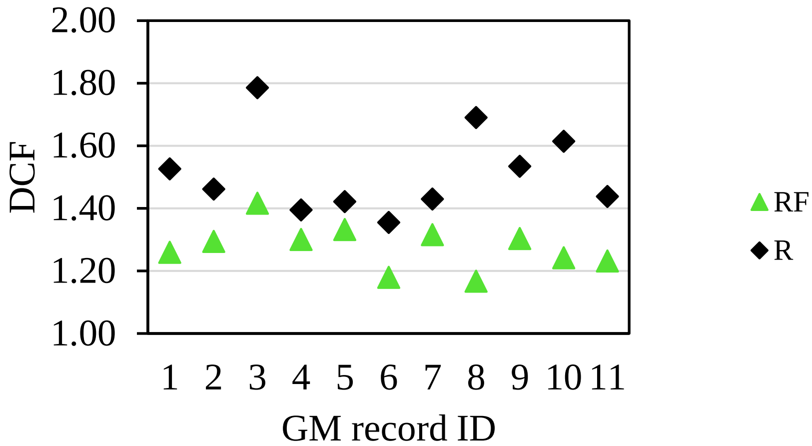


Fig. 5 Drift concentration factor (DCF)

4. Conclusion

The seismic retrofit of RC building with friction dampers are compared and discussed with their performances. The following conclusions may be drawn:

1) The NLRHA results indicated that the maximum displacement and maximum story-drift ratios were substantially improved after retrofitting the existing RC building with friction dampers.
2) The friction dampers may improve the prevention of the damage concentration for the RC retrofitted buildings when compared to the non-retrofitted RC building.

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