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## Steel Energy Absorbers for Seismic Building Rehabilitation

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### Summary

Experimental responses of two type of seismic energy dissipators, namely the triangular-plate added damping and stiffness (TADAS) device and the shear link energy absorber (SLEA) are briefly summarized. Both two types of energy absorbing devices can sustain a large number of yielding reversals and increase the damping and stiffness of the frame structures. It is illustrated that the force versus deformation relationships of a building structure constructed with these two types of energy dissipator can be adequately characterized by a tri-linear model. Based on the results of extensive response spectrum analyses, optimal stiffness and strength ratios between the device and frame are recognized for the rehabilitated structures. The paper concludes with examples illustrating the seismic design procedures for building rehabilitation using the proposed energy dissipators to resist severe earthquake excitations.

**Keywords:** energy dissipator, seismic retrofit, rehabilitation, seismic resistant building design

### 1. Introduction

Modern seismic resistant design procedures generally adopt a set of reduced seismic forces to account for the ductility capacity of the structures. In the meantime, it often requires the compliance of specific ductility design provisions in order to assure a ductile behavior of the system. While a new building can be designed to achieve certain strength and ductility, however, a large number of existing buildings may not possess the needed strength and ductility to sustain strong earthquake excitations. In addition, structural failures of modern buildings observed following some recent earthquakes have suggested that a ductility-based, rather than a performance based, design methodology may not be reliable for modern seismic hazard mitigation of buildings, particularly from the socio-economical point of views. This is evidenced by the brittle fractures of welded steel moment connections due to the difficulties of controlling material properties, construction workmanship and inspections. Thus, in addition to searching for sound technology for the construction of ductility-enhanced members or connections, the general consensus has been on how to find reliable solutions to reduce ductility demands imposed on these structural components. For this purpose, two types of energy absorbing devices have been developed at the National Taiwan University and proven promising in improving the performance of existing and new building structures in resisting severe earthquake excitations. This paper addresses the design issues of the proposed energy absorbers for the rehabilitation of existing building structures.

## 2. Steel Hysteretic Energy Dissipators (HEDs)

Since the bending curvature of a transverse load applied at the end of a triangular plate is uniform over the full height of the triangular plate, the plate can deform well into the inelastic range without curvature concentrations. As shown in Fig. 1, the proposed steel triangular-plate added damping and stiffness (TADAS) device consists of several triangular plates welded to a common base plate. Similarly, a short steel wide flange beam under cantilever load can yield in shear while remain elastic in flexure. As shown in Fig. 1, the proposed shear link energy absorber (SLEA) consists of a short steel wide flange beam segment welded to an end plate. Experimental results (see Fig. 1) have confirmed that properly constructed TADAS and SLEA elements possess highly predictable mechanical properties, and can sustain a large number of yielding reversals.

The energy dissipator and the moment resisting frame (MRF) are combined in series, and the force versus deformation relationships of a hysteretic energy dissipated frame (HEDF) can be adequately characterized by a tri-linear model as illustrated in Fig. 2. This paper summarizes the results of the extensive response spectrum analyses for seismic rehabilitation:

- For short period structures ( $T < 0.8$  sec.), a  $SR$  value ranging from 2 to 4 and an  $\Omega$  value between 1.2 and 2.0 should be considered. For long period structures ( $T > 2.0$  sec.), it is recommended that a  $SR$  on the order of 1.0 to 2.0 and an  $\Omega$  value between 1.2 and 2.0 be considered.

## 3. Conclusions

The following conclusions can be drawn from this study:

- Experimental response of well constructed TADAS and SLEA can sustain large inelastic cyclic deformations. Thus, they appear promising for seismic resistant constructions of building structures.
- The nonlinear deformational demands imposed on the beam-to-column connections of steel MRFs can be effectively mitigated by incorporating properly proportioned steel energy absorbers.
- The proposed design strategies incorporate the modern two-level seismic-resistant design methodologies, ensure to satisfy the service limit state while facilitate the review of the overstrength factor for controlled nonlinear responses.

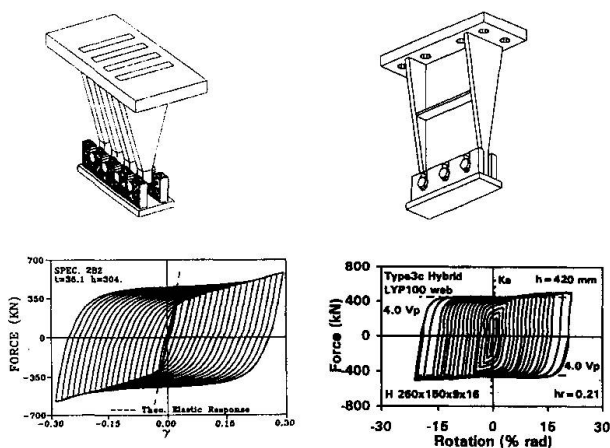


Fig. 1 Schematics and typical responses of the TADAS and SLEA devices

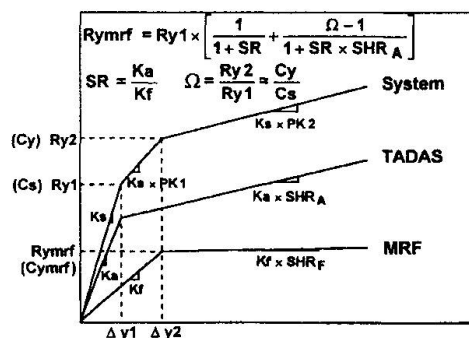


Fig. 2 Tri-linear force vs. deformation relationships of the HEDF system