Mechanical performance of self-centering dual-stage yielding BRB and its application for seismic control

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Extended Abstract

Self-centering energy-dissipation devices are important for seismic damage control and post-earthquake recoverability. Traditional buckling-restrained braces, or BRBs, can provide stable energy dissipation capacity. However, they may also lead to large residual deformation after strong earthquakes. Traditional self-centering devices can reduce residual deformation, but their force-transfer mechanisms are often complex. To address these issues, this study proposes a new Self-Centering Dual-Stage Yielding Buckling-Restrained Brace, or SCDYB.

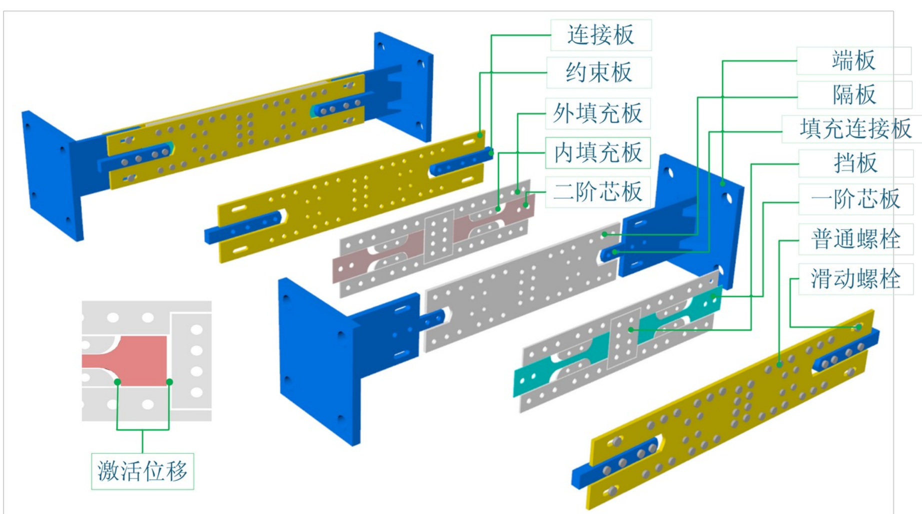

Figure 1- SCDYB configuration

The proposed SCDYB is an assembled device. It mainly consists of core plates, restraining plates, and connecting components. The first-stage core plates are made of shape memory alloy, or SMA. They are used to provide self-centering capacity. The second-stage core plates are made of low-yield-point steel. They are used to provide energy dissipation capacity. The damaged core plates can be replaced after earthquakes. Therefore, the device has good post-earthquake repairability and reusability.

The working mechanism of the SCDYB is based on staged activation. At small displacement levels, only the first-stage SMA core plates work. They provide restoring force and help reduce residual deformation. When the displacement reaches the preset activation displacement, the second-stage core plates are activated. Then the two types of core plates work together. In this stage, the device can provide both self-centering capacity and energy dissipation capacity.

This presentation focuses on the configuration, working mechanism, mechanical model, and mechanical performance of the SCDYB. A simplified mechanical model is established to describe the force-displacement behavior of the device. The model combines the flag-shaped behavior of the self-centering component and the bilinear behavior of the energy-dissipation component. Because the second-stage core plates have a preset activation displacement, their force-displacement behavior starts after the activation displacement is reached.

The mechanical behavior of the SCDYB is controlled by several key parameters. These parameters include the yield displacement ratio, stiffness ratio, post-yield stiffness ratio, and activation displacement ratio of the core plates. According to the relationship between the activation displacement and the yield displacement of the first-stage core plates, three typical skeleton curves are identified. These curves are used to describe different working stages of the device. They also provide a basis for the parameter design of the SCDYB.

To verify the feasibility and mechanical performance of the proposed device, quasi-static cyclic tests are carried out. Material tests are first conducted on the SMA plates, low-yield-point steel plates, and restraining plates. The test results show that the SMA plates have self-centering characteristics. The low-yield-point steel has good ductility and can provide stable energy dissipation. The restraining plates have higher strength and can provide reliable restraint for the core plates.

The quasi-static test results show that the SCDYB has stable hysteretic behavior and a clear dual-stage yielding mechanism. Before the second-stage core plates are activated, the response is mainly controlled by the first-stage SMA core plates. After the activation displacement is reached, the second-stage core plates participate in the force-transfer path and dissipate energy. The hysteretic loops become fuller, and the energy dissipation capacity increases significantly.

The test observations show that damage is mainly concentrated in the core plates. The first-stage SMA core plates show only small residual deformation. The second-stage low-yield-point steel core plates show larger plastic deformation and clear friction marks. Most non-energy-dissipating components show no obvious damage. This indicates that the proposed device can achieve replaceable core plates and reusable non-energy-dissipating components.

Finite element analysis is also conducted to study the mechanical behavior of the SCDYB. The numerical model is verified by the quasi-static test results. The analysis shows that the second-stage core plates are more sensitive to the activation displacement. A smaller activation displacement can make the second-stage core plates work earlier and increase the energy dissipation capacity. However, it may also increase the fluctuation of the hysteretic response. A larger activation displacement can make the energy dissipation process more stable, but it may reduce the total energy dissipation capacity.

The study also investigates the ductility demand spectrum and residual displacement spectrum of systems equipped with the SCDYB. The results show that the key parameters of the device have clear effects on seismic response. A smaller yield displacement ratio can make the device yield earlier and dissipate seismic energy sooner. A larger stiffness ratio can reduce deformation demand. A proper activation displacement ratio can improve the balance between energy dissipation and residual displacement control.

The results show that the proposed SCDYB has good self-centering capacity, stable energy dissipation capacity, and clear dual-stage yielding behavior. It can reduce residual deformation while maintaining effective energy dissipation. The assembled configuration also makes post-earthquake repair more convenient. The highlights of the device configuration, working mechanism, simplified mechanical model, quasi-static test, finite element analysis, ductility demand spectrum, residual displacement spectrum, and main conclusions will be presented.

Keywords: *Self-centering dual-stage yielding buckling-restrained brace; Damage control; Seismic performance enhancement; Structural fuse; Inelastic response spectra.*