Seismic Behavior of Flexural-type Steel Truss Coupling Beams Using Friction Devices (FTCB)

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Abstract—**A flexural-type steel truss coupling beam using friction damper (FTCB) was proposed. By design, the deformation and energy consumption are concentrated on the friction damper to ensure the elasticity of the steel truss body. Through cyclic pseudo-static tests of four 2/3 scaled test specimens, seismic performance of the FTCB with different span ratio and friction material was tested. The friction devices exhibited stable hysteretic responses and full energy dissipation in coupling beam subassemblage tests.**

I. Introduction

In RC shear wall systems and shear wall-frame interacting systems, coupling beams are supposed to undergo significant inelastic deformation, therefore, are preferred elements with adequate energy dissipation ability. Deng [1] proposed a new type of steel truss coupling beam, which mainly dissipates energy by shear deformation of inclined web members. However, the damage of steel truss will reduce the synergistic effect of the coupling beam and there is rare research about flexural-type coupling beams.

This paper presents a kind of flexural-type steel truss coupling beams using friction damper (FTCB) to concentrate damage on friction damper. Compared to other types of dampers, friction dampers [2],[3] have the advantages in their large stroke and large initial stiffness. A friction damper is usually an assembly of multiple friction interfaces clamped by a single or multiple pretensioned bolts. It can be disassembled simply by loosening the bolts no matter if it is in its original position or sustains a residual deformation. This allows for the quick recovery of the damper whenever it is deemed necessary.

II. Mechanism of FTCB

Connections between FTCB and shear wall are designed as pin connection to ensure the flexible deformation of friction devices. The FTCB specimens were designed that: (1) the shear strength V of the FTCB specimen is determined by the slipping force F_{slip} of friction damper (Fig.1); (2) the rotation capacity of the subassembly is determined by slot length L_{slot} (Fig.2);

$$L_{\mathrm{slot}}=d_{bolt}+p_{bolt}+\delta_{slip} \quad (1)$$

(3) the steel truss segments on the FTCB specimens remain elastic.

where, d_{bolt} is the bolt diameter, and p_{bolt} is the bolt pitch, and δ_{slip} is the slip distance.

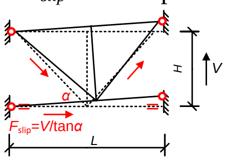


Fig.1 Force mechanism

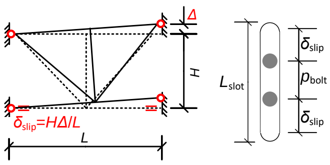


Fig.2 Deformation assumption

III. Test Program

A. Specimen Design

Four 2/3 scaled specimens were tested. The main parameters are span ratio(a=L/H) and friction material. The test specimens are shown in Table 1.

TABLE I Parameters of specimen

	Span ratio a	Friction material	Pretension N (kN)	V_{design} (kN)
FTCB2-BA	2.0	brass	89	236
FTCB2-BP	2.0	brake plate	89	148
FTCB3-BA	3.0	brass	134	239
FTCB3-BP	3.0	brake plate	134	123

A welded T-shaped section was adopted for the top and bottom chord members, and square steel tube was adopted for the web members for all specimens. Moreover, FTCB specimens are welded to the RC walls with pre-embedded plates [4]. The connection plate simulates the pinned connections during loading.

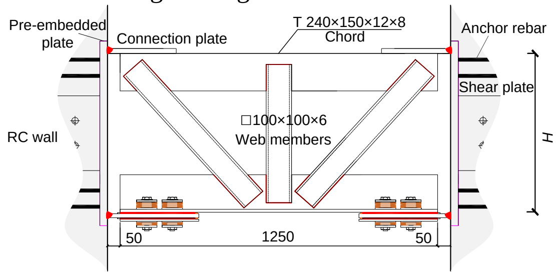


Fig.3 Specimen information (unit: mm)

Friction damper consisted of two frictional interfaces which were clamped by four M22 high-strength bolts. A set of six parallel disc springs were installed to reduce the effect of possible thermal strain on the clamping force. Horizontal slots were made on the friction plates, the length L_{slot} are 220mm, 200mm for FTCB2 series and FTCB3 series, respectively. These slots ensured a deformation capacity of no less than 5% chord rotations of the coupling beam, for the bolt not to contact the steel plates.

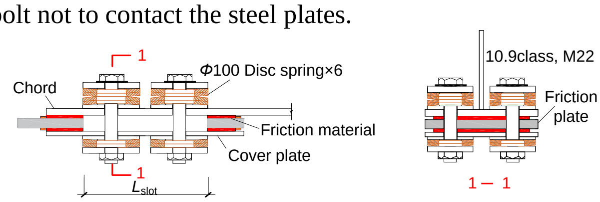


Fig.4 Friction damper information (unit:mm)

The loading frame is shown in Fig. 5. Loading is in displacement control, and two cycles were conducted at each amplitude including 1/2000, 1/1000, 1/800, 1/500, 1/200, 1/120, 1/75, 1/50, 1/30, 1/20.

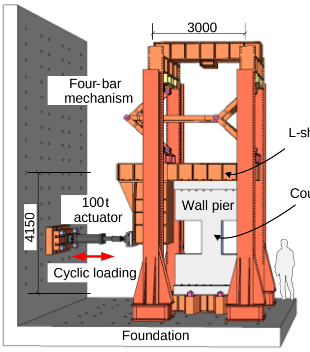


Fig.5 Test setup

IV. TEST RESULTS

A. Test observation

The RC walls were basically not damaged during the entire loading process, the rebars in the walls were all within the elastic range, and the steel truss members also remained elastic. The FTCB deforms obviously.

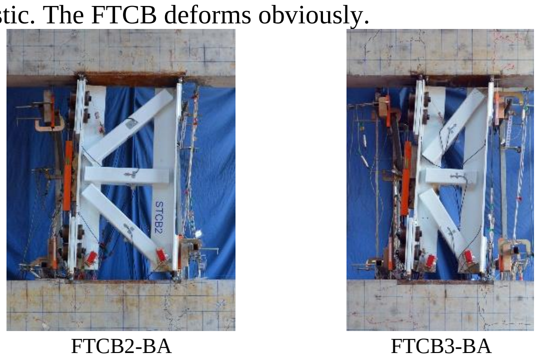
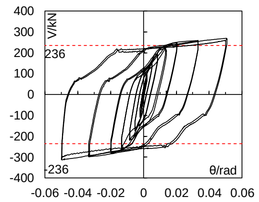


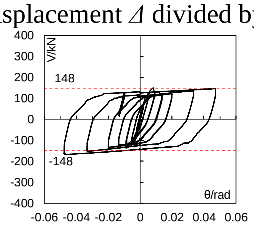
Fig. 6 Ultimate failure mode

B. Hysteretic responses of the FTCB

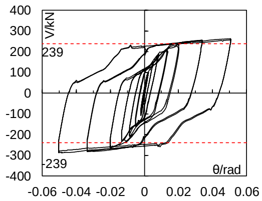
Hysteresis curves of all specimens are shown in Fig.7. The vertical axis is the shear strength of the coupling beam, measured from actuator. The horizontal axis is the coupling beam rotation calculated by displacement $\varDelta$ divided by L.



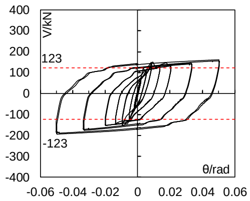
(a) FTCB2-BA



(b) FTCB2-BP



(d) FTCB3-BA



(e) FTCB3-BP

Fig. 7 Hysteresis curves

The hysteresis curve is very stable and the theoretical values agree well with the test values, which indicates that the shear strength of FTCB is easy to predict.

Hysteresis curve of specimen FTCB2-BA and FTCB3-BA is consistent with the characteristics of asymmetric friction mechanisms [5],[6], which means sliding occurs firstly between friction plate and chords, then sliding fully occurs on both surfaces as the increase of coupling beam rotation. However, for specimen FTCB2-BP and FTCB3-BP， the transition is not obvious because the low hardness of brake plate. Therefore, friction material with high hardness is preferred.

C. Performance of friction dampers

The hysteresis curves and the deformation process of the friction damper are shown in Fig. 8. The horizontal axis is the slip displacement of the friction damper, and the vertical axis is the sliding force of the damper, which is calculated based on shear strength V.

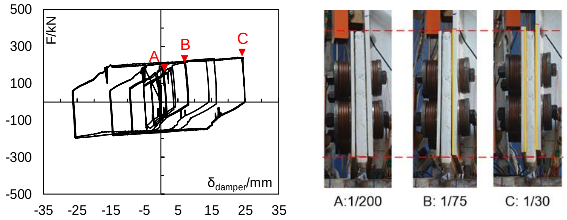
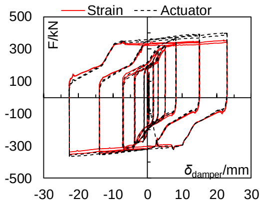
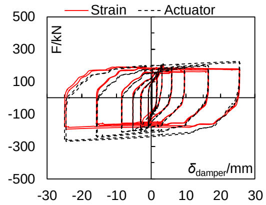


Fig.8 Friction damper of specimen FTCB2-BA

The sliding force also can be calculated from the axial force of the inclined web members (Eq. (1)). The good agreement in Fig.9 proves the validity of force mechanism.



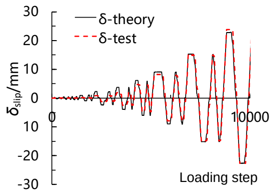
(a) specimen FTCB3-BA



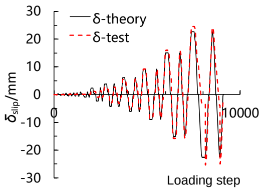
(b) specimen FTCB3-BP

Fig.9 Validation of force mechanism

From Fig. 10, the deformation of the friction damper also fits the theoretical value δ_{slip} well, which indeed proves the deformation mechanism of FTCB.



(a) specimen FTCB3-BA



(b) specimen FTCB3-BP

Fig.10 Validation of deformation mechanism

V. CONCLUSION

Test results proved that bearing capacity of the FTCB was mainly contributed by the friction damper. The rotation capacity of the FTCB also met the design requirements, which proved the effectiveness of the design suggestions.

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