An Experimental Study on Seismic Behavior of Shear Friction Damper using Shaking table Test

PARK, Eun-soo
Chosun University, Korea

JANG, Jeong -hyun
Chosun University, Korea

KWON,Jin-seok
Kobe University, Japan

PARK, Jong-min
EDM E&C, Korea

Kamiya, Takashi
YAHAGI CONSTRUCTION CO., LTD, Japan

CHOI, Jae-hyouk†
Chosun University, Korea

LEE, Sang-ho
Pusan National University, Korea

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SUMMARY:
The shear type friction damper, which is Energy absorption device, can control excessive displacement between upper-structure and ground during the earthquake. So it plays a great role to prevent structure damage through energy absorption by friction behaviour. In this paper, shear type friction damper was developed and to evaluate its seismic performance the shaking table test was carried out. And also to examined the characteristics of dynamic response, the shear-type friction damper where Installed at SDOF structure using El-centro NS(1940) and Kobe EW(1995) seismic wave and the result is compared with numerical analysis result using bi-linear hysteresis model.

Keywords: Seismic Behaviour, Friction Damper, Shaking table Test, Loading test, Initial tension

1. INSTRUCTIONS

Increase in the number of large-scale earthquakes worldwide has caused tremendous property loss such as collapse of structures and personal injuries. Massive earthquakes higher than 7.0 take place an average of 14 times a year. In Korea, felt earthquakes constantly take place an average of 30 times a year. Moreover, as the frequency of earthquakes is recently increasing, the importance of seismic design is emphasized in architectural design. So far, the structural design for strongly resisting the seismic force has been the mainstream of the concept of structural design for resisting the seismic force. However, the technology is rapidly developing to actively introduce the concept of seismic isolation and vibration control to the architectural structure design for preventing the energy generated by the seismic force from being transferred to structures.

A friction damper is a type of passive energy absorbing device, which effectively controls an excessive response of a structure when an earthquake takes place. The friction damper can dissipate vibrational energy input to a structure into a form of heat generated from friction behavior caused by relative motion between two materials. Especially, the friction damper is characterized by performing stable energy absorption instead of depending on the amplitude or vibration of the input displacement.

Accordingly, this study presents a review of a response behavior of a shear friction damper during an earthquake through a shaking table test for simulating a vibration wave so as to understand behavior of a shear-type friction damper during an actual earthquake. The characteristics of dynamic behavior of two shear-type friction dampers, provided for a single degree of freedom (SDOF) steel structure, is also studied by using El-centro NS (1940) and Kobe EW (1995) earthquake waves. Additionally, in this paper, nonlinear time history analysis is performed by using the perfect elasto-plasticity hysteresis model and compared to the result of the shaking table test.

2. Shaking Table Test of the Shear Type Friction Damper

2.1 Detail of Shear-type Friction Damper specimen

With regard to a friction damper, friction is generated in the opposite direction of sliding, as a contact point between two materials slides due to relative displacement. A friction damper generates a form of heat energy from the friction based on plastic deformation caused by vibration of an architectural structure.

In a damper used in this study, a long slotted hole with a diameter of 25mm and a length of 80mm is provided with the upper T-type base material, and a total of 8 round fixed protrusions with a diameter of 25mm provided with both side surfaces of the lower T-type base material to combine with a gusset plate, with a tension applied by using 2 high tension bolts, thus integrating the gusset plate with the lower t type base material. 8 fixed protrusions, installed on both side surfaces of the lower T type base material, serve to adjust unconformity that may be generated in case of installation of the upper and lower part base materials. 8 fixed protrusions also allow vertical travel of the gusset plate according to reduction in thickness caused by abrasion and wear of friction material, thus effectively maintaining the initial tension.

When forced displacement is applied to the specimen, the upper T type base material begins to slide. As presented in FIG. 1, a shear-type friction damper specimen is manufactured to include a T type upper base material (SS400 steel) and a gusset plate (SS400 steel) connected by two high tension bolts M20 (F10T). A high strength aluminum plate (A2017P-T5) with a thickness of t = 5mm, which has a relatively low fluctuation in friction according to temperatures, is installed as a friction material between the T type material and the gusset plate to serve for friction behavior.

In order to obtain high friction, the specimen is processed with shot blasting so as to keep roughness of the contact surface between the gusset plate and the friction material to a maximum height (Rmax) of higher than 50 μm, so that the friction surface is limited to between the upper T type base material and the friction material. The characteristics of the specimen materials are as presented in Table. 1.

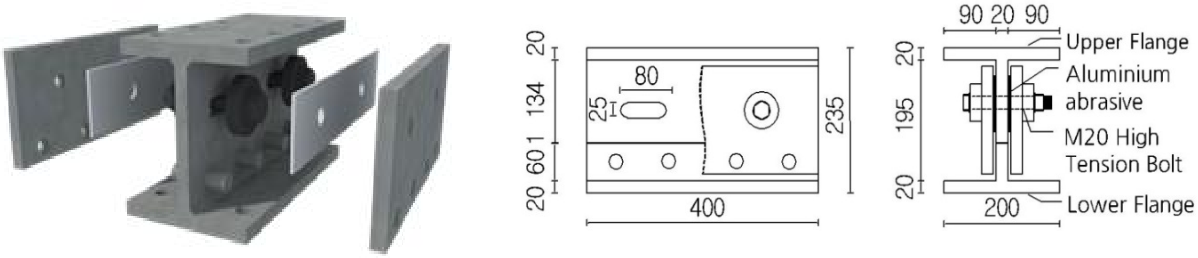


Figure 1. Shear-type friction damper specimen details

Table 1. Characteristic of materials of the specimen

Name	Specifications	Yield strength (MPa)	Tensile strength (MPa)	Elongation (%)	Shear yield strength (MPa)
Friction material	A2017P–T5	357.1	435.3	14.6	206.2
T type base material, Gusset plate	SS400	397.6	589.0	45.6	244.7
High tension bolt	F10T	900	1000~1200	14	-

2.2. Overview of the Shear Type Friction Damper Shaking Table Test

2.2.1 Specifications of shaking table

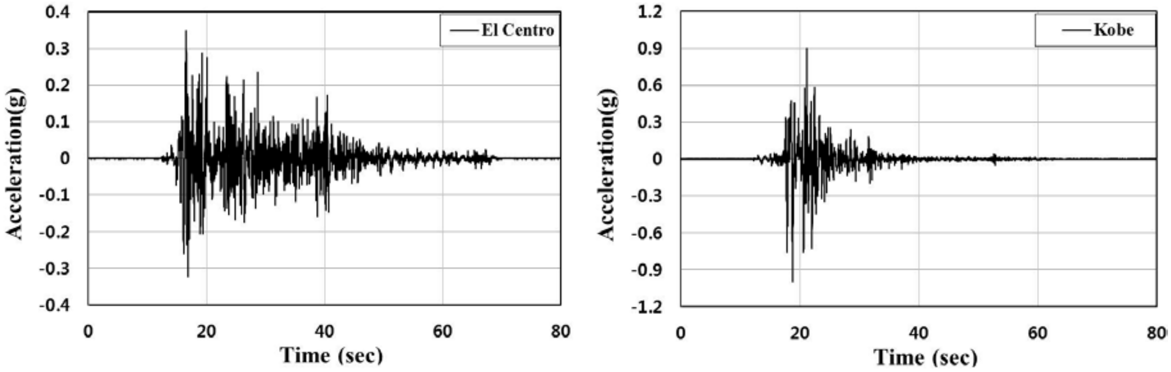
A shaking table test is conducted by using 3 degree of freedom shaking table (5.0 x 5.0m) of the KOCED earthquake simulating building located at Yangsan campus in Busan University. Table 2 shows the specifications of the shaking table.

With regard to the SDF steel frame on the shaking table, dampers are respectively installed in two load frames equipped with the K type brace, and a slab with very strong stiffness are formed by the using X type turnbuckle at the upper part of both the load frames for integration. Especially, both ends of 4 columns are provided with a segregation point which is rotatable in one direction to allow vibration in one direction. The column is designed only to resist the vertical load, and both the two friction dampers are to resist the lateral load. As presented in FIG. 3, the mass of 176.4kN is installed at the uppermost part. In order to understand the characteristics of the hysteresis behavior of the shear-type friction damper during the earthquake, the input waveform is obtained at the shaking table test by using two earthquake waves including EL-centro NS (1940) and the JMA Kobe EW. (FIG. 3)

Figure 2. Shaking table

Table 2. Specifications of the Shaking Table

Performance	Specifications
Degree of Freedom	3DOF (5m x 5m)
Maximum loading weight	600 kN
Maximum acceleration	2G
Maximum Speed	100 cm/sec
Maximum Displacement	± 29.5 cm
Range of Excitation Frequencies	0.1~60 Hz



(a) El Centro (b) Kobe

Figure 3. Input Earthquake wave (El Centro, Kobe)

Table 3. presents the size of the earthquake wave and the initially installed tension value of the high tension bolt. The tension is installed at the bolt by using a torque wrench and applying the same strength at a room temperature. The same shear-type friction damper as in the static load test in Section 2 is used for this test. The measurement plan includes installation of two acceleration sensors at the column base and two acceleration sensors and a displacement sensor at the upper part of the front and rear frames, as presented in FIG. 4. Additionally, a displacement sensor is installed at the side of the upper T-type base material of the damper, in order to obtain the displacement of the shear-type friction damper. The lateral load applied to the specimen may be obtained by multiplying the sum of the weight of the specimen by the average value obtained from two acceleration sensors installed at the uppermost part.

Table 3. Overview of Shaking Table Test

Test Code	Input E.Q. wave	Scale (%)	PGA	Bolt Tension (kN)
FD-El-180	El-cento NS (1940)	180	0.45	80
FD-Ko-60	JMA Kobe EW	60	0.48	

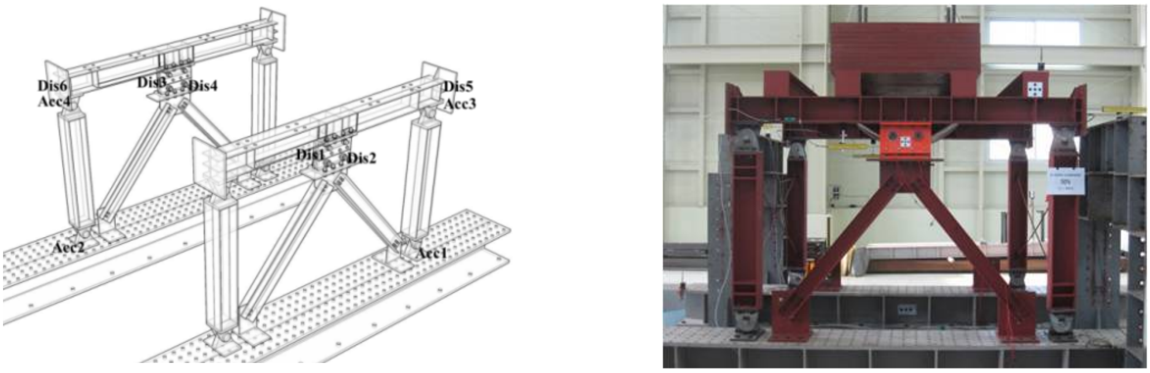
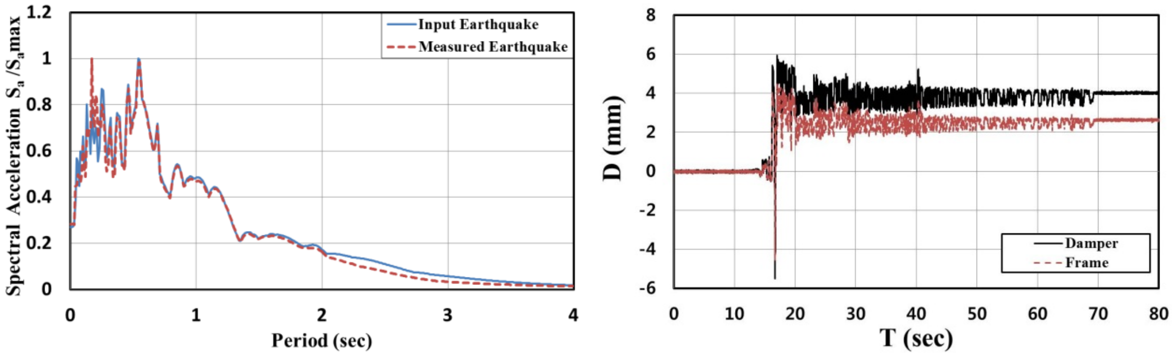


Figure 4. Complete view of the test and the location of installation of the measurement equipment

3. The result of the shaking table test

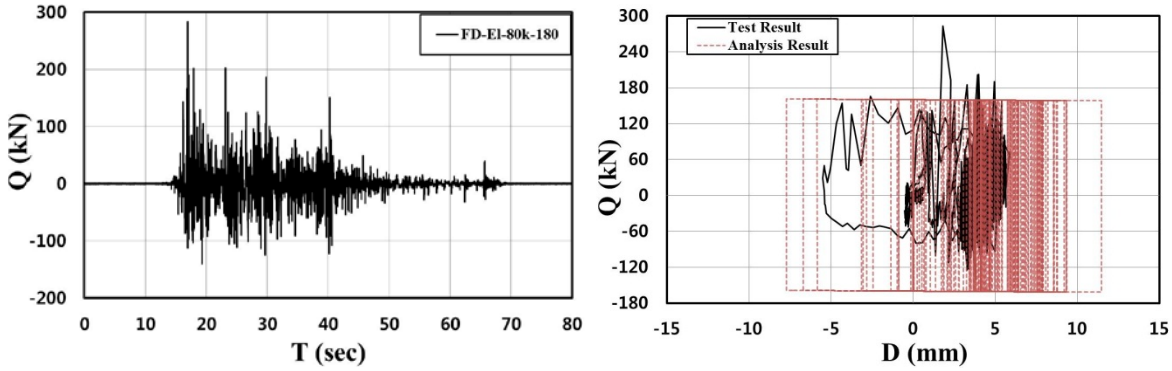
3.1 Hysteresis Behavior of FD-El-180

The result of the FD-El-180 shaking table test is presented in FIGS. 5 and 5. As presented in the FIG. 5 (a), the input earthquake wave comparatively matches the acceleration response waveform observed at the base. Increase in the initial proof force is observed simultaneously with the beginning of the friction behavior during input of the earthquake wave, but the friction damper system presents the hysteresis behavior of perfect elasto-plasticity along as the energy is effectively absorbed. Thus, as a result of time history analysis performed by modeling the non-linear behavior using a perfect elasto-plasticity model, the value of the initial elastic stiffness almost matches the value of the maximum sliding–proof force. Thus, the test result is deemed to be relatively finely simulated. (FIG. 6)



a) El-centro input Seismic wave b) Slip force and displacement

Figure 5. El-centro input Seismic wave and displacement response

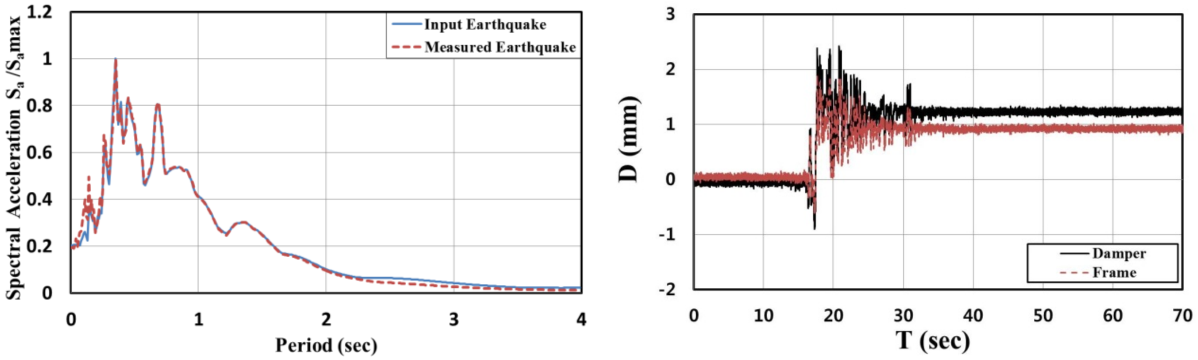


(a) Shaking table test result (b) Comparison of the test result and the analysis results

Figure 6. Comparison of the FD-E1-180 test and analysis result

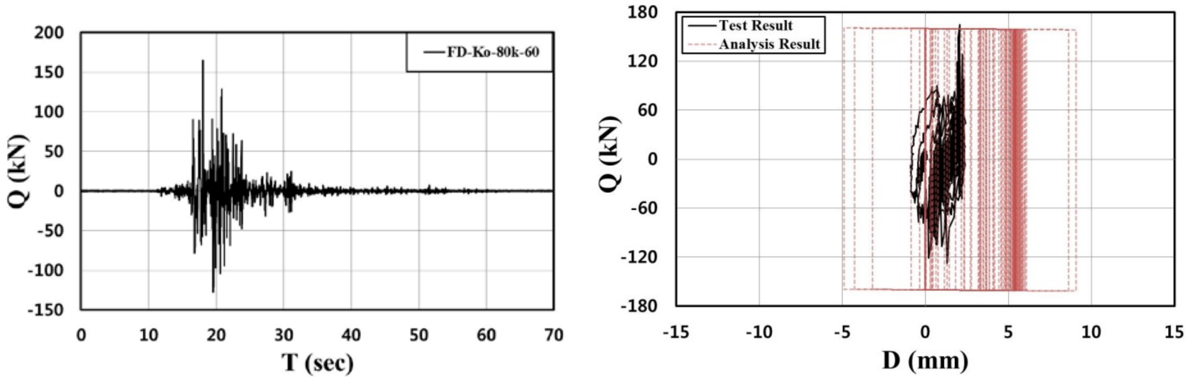
3.2 FD-Ko-60 Test Result

FIGS. 7 and 7 show the FD-Ko-60 test results. Similarly to the FD-El-180 shaking table test, it is shown that the energy absorption behavior of the friction damper is effectively performed. Additionally, as a result of non-linear time history analysis performed by modeling the non-linear behavior using a perfect elasto-plasticity model, the test result is deemed to be relatively finely simulated. (FIG. 8)



a) El-centro input Seismic wave b) Slip force and displacement

Figure 7. El-centro input Seismic wave and displacement reponse



(a) Shaking table test results (b) Comparison of the test result and the analysis results

Figure 8. Comparison of the FD-Ko-60 test and analysis result

4. Conclusions

In this study, the following conclusions are drawn as a result of the static cyclic load test and the shaking table test performed by using two types of earthquake waves, in order to understand the structural characteristics of the shear-type friction damper behaviour.

1) By performing the artificial friction behavior on the B shear type friction damper in advance, the problem of a rapid increase in the initial proof may be relieved and the reliable friction damper with a higher retention rate of the sliding force may be manufactured.

2) As a result of performing a shaking table test for simulating the earthquake wave, the friction damper is deemed to be used as an energy absorption device through a friction behavior during the earthquake. Additionally, as a result of a time history analysis performed by using a perfect elasto-plasticity model, the value of the initial elastic stiffness almost matches the value of the maximum sliding–proof force. Thus, the test result is deemed to be relatively finely simulated.

ACKNOWLEDGEMENT

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