Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

7-10-8

STUDY ON THE FRICTION DAMPER AS THE DEVICE OF A BASE ISOLATION SYSTEM

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SUMMARY

We developed the new damper that uses a friction force. The objective of this study is to grasp the fundamental properties of a friction damper and the behaviour of this device during earthquake by experimental and analytical studies. Following are the results.

The friction force is nearly proportional to the clamping force and is independent of the velocity of sliding. The acceleration level can be reduced to 1/2 - 1/3 by using our damper. The behaviour of this system can be traced by simple dynamic analysis with adequate accuracy.

INTRODUCTION

For base isolation systems, the capacity for energy absorption is important.Many types of dampers to absorb energy have been developed by many research organizations. For instance, elasto-plastic dampers, viscous dampers, liquid mass dampers, and so on (Refs.1,2). However, we have developed a new damper to utilize friction force. This damper has a large capacity for energy absorption and the friction force can be controlled easily. In the first part of this paper,fundamental properties of the friction damper were examined by dynamic loading tests. Next, the behaviour of this damper during earthquakes was studied by shaking table tests.

FRICTION DAMPER

Figure 1 gives details of a friction damper. Friction pads, which are sintered metal used for a brake of vehicle, are fixed on both surfaces of a middle plate. Stainless steel discs are fixed on the inner surface of upper and lower plates by welding. One end of a middle plate is mounted under the base of a superstructure and one end of upper and lower plates are on the foundation. The friction part is composed of other ends. Torque force of a clamping bolt is transmitted to a friction surface through coned disc springs to keep constant pressure. This damper transforms translational motion to rotational motion by a link mechanism. In other words, during earthquake the friction part rotates by changing the distance between two mounting parts. As a result, friction force is produced between friction pad and stainless steel plate, and energy earthquake is absorbed.

Before shaking table tests, dynamic repeated loading tests of the basic element of friction damper were done to grasp fundamental properties. Fig.2-Fig.4 show the relationships of three main factors of friction force (Fx,Fy). First is a clamping force (Fc),second is velocity of sliding (V),and last is a loading direction(0). The friction force is nearly proportional to the clamping force. However, the difference between specimens was about 10% at most. Therefore, the friction force itself should be controlled in actual use. A friction force is independent of the velocity of sliding. The friction force in the direction of loading and in the vertical direction to that varied according to the direction of loading ,but the sum of force vectors was constant.

PROGRAM OF SHAKING TABLE TESTS

Test Structure Photo 1 shows the structure. Test structure is set on an electro-hydraulic type shaking table of Building Research Institute, Ministry of Construction. Table 1 lists the main performance of the shaking table. Weight (10tonf) is supported by linear guide in vertical direction and by coiled springs which simulate the stiffness of a multi-rubber bearing, in the horizontal direction. A specimen is composed of 4 units taking account directional properties (see photo 2).

Measurement Main measured items are acceleration of shaking table and weight by accelerometer, relative displacement between weight and shaking table by displacement transducer, and restoring force of coiled springs by the load cell. All measured data were recorded on an analog data recorder, and were converted to digital values after tests.

Test Parameters Test parameters are the natural period of the weight-spring system, clamping force, and input wave as shown in Fig.5. Values of stiffness of coiled springs were 0.101tonf/cm and 0.045tonf/cm so that the natural period (T) of weight-spring system may be 2 seconds and 3 seconds. Clamping force has 4 levels (0.32, 0.48, 0.72, 0.96 tonf). Table 2 lists the main properties of 4 kinds of input waves. Velocity level of input waves are 25 kine and 50 kine. For MYNS, however,the performance of the shaking table limits the maximum velocity of input waves to 35 or 40 kine.

TEST RESULTS

Resonance tests Before random tests, in order to grasp the fundamental dynamic properties of the spring-weight-damper system, resonance tests were performed under a sinusoidal wave with two levels,i.e. 100gal and 110gal. The resonance frequency of this specimen was 0.55 Hz, which was 10% higher compared to that of weight-spring obtained by a free vibration test. This system is sensitive to the input level. When maximum acceleration of input wave was 100 gal, relative displacement was 16 mm at a resonance frequency. Meanwhile, when the maximum acceleration was 110 gal, response of this specimen diverged and then the weight collided with a safety stopper, whose clearance was 90 mm.

Random Test Figure 6 compares random tests of S3F48E with dynamic response analyses. The configuration of hysteresis loop is a bilinear type with a very high first stiffness and a low second stiffness. Next, Figure 7 shows, the reduction ratio of acceleration level. In this figure, Y-axis indicates maximum value of response acceleration (A) divided by that of input acceleration (Ag). X-axis indicates clamping force of the friction face. This device is more effective for larger earthquakes. For a well-selected friction force, the reduction ratio can be about 40%. For a friction force that is too high, this device don't have much effect in small earthquakes. The difference in characteristics of the input wave have very little effect on response, but for

MYNS, the results of the test were different from the other waves. Figure 8 shows the effect of the damper on displacement. As the effect becomes larger,so dose the clamping force.

ANALYTICAL STUDY

Method of Analyses Analyses are composed of dynamic response analysis and spectral analysis. Spectral analyses were done to understand the performance of the base isolation device in the frequency domain. Response spectra of input waves and response waves, which were measured on the shaking table and on the weight individually, were obtained and both were compared. In addition, the same spectral analyses were done on the response acceleration obtained by above-mentioned dynamic analyses.

Analytical Results Examples of results are shown in Fig.9. This device has a lot of effect on acceleration, but little on displacement. These spectra don't have a distinctive peak at natural frequency of weight-spring system, that is, 0.5 Hz and 0.33 Hz. For lower frequency than 1 Hz, the effect of this device was little, a response was excited in some cases. This phenomenon resulted from elastic deformation of the mounting pin. This effect is significant for a small deformation. This results from elastic vibration of the mounting pin with no slide for the friction face of the damper. The response analyses were made with a rigid-plastic hysteresis model, which means that the mounting pin is perfectly rigid. For lower frequency than 1 Hz, the peak value was reduced to about 60% compared to that of test result. This result means that the mounting pin should be made as rigid as possible.

CONCLUSION

1) The friction force itself should be controlled in actual use. For a single unit, a geometrical directional property exists, but that can be anticipated by geometrical calculation.
2) The effect of this damper to displacement and acceleration have opposite properties to each other.
3) The clamping force should be selected taking account of the level of the earthquake.
4) The mounting part should be made as rigid as possible.
5) The behaviour of this system can be traced by dynamic response analysis with a simple hysteresis model.

ACKNOWLEDGEMENT

This study was a part of research series done by the Experimental Research Committee on the Feasibility of Base Isolation System (Chairman: Prof. Kawamata of the Tohoku Institute of Technology) organized by Japan Association for Building Research Promotion. The authors express their gratitude to the members of this Committee for their valuable suggestions.

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2. Kawamata, S., Abe, Y., and Mori, K., "Accelerated Liquid Mass Damper To Control The Structural Response To Earthquake," Proc. of the 7th JEES,Tokyo, pp. 1609-1614.

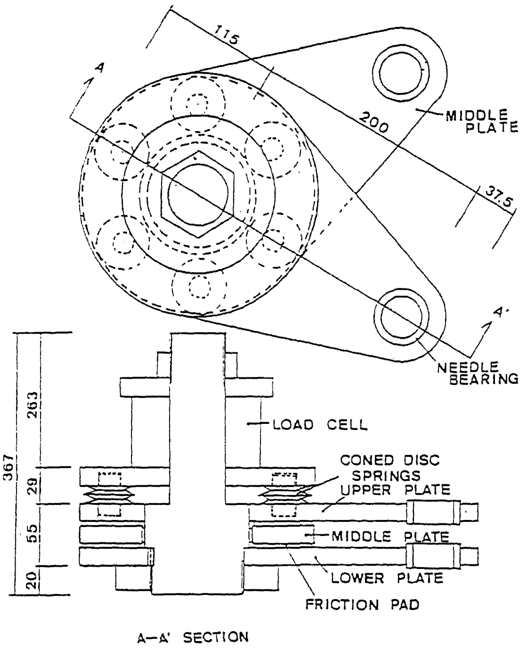


Fig.1 Detail of Friction Damper

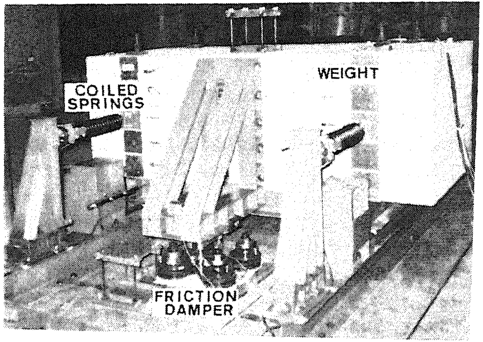


Photo 1 Test Structure

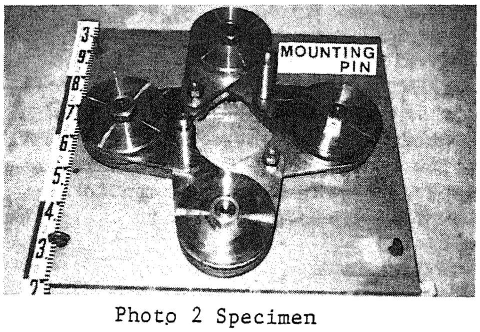


Photo 2 Specimen

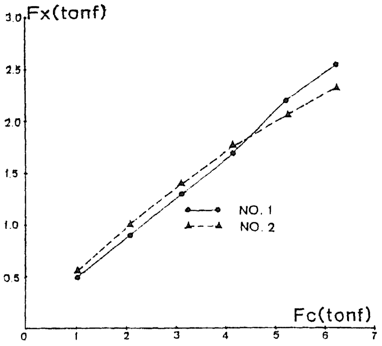


Fig.2 Clamping Force vs. Friction Force

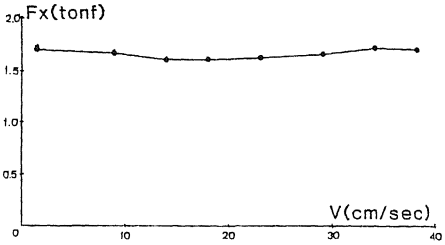


Fig.3 Velocity vs. Friction Force

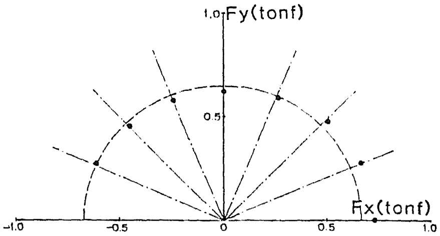


Fig.4 Directional Property of Friction Force

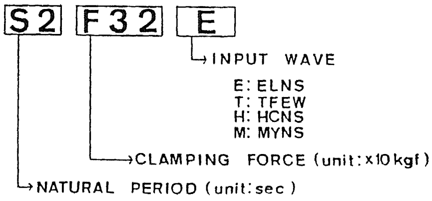


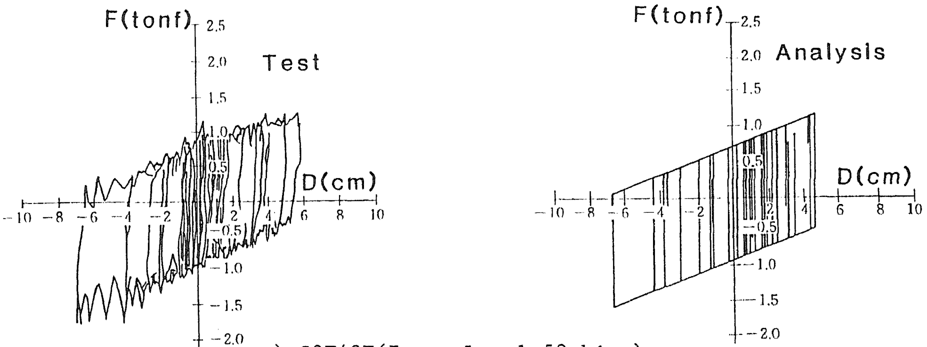
Fig.5 Test Parameters

Table 1 Main Performance of Shaking Table

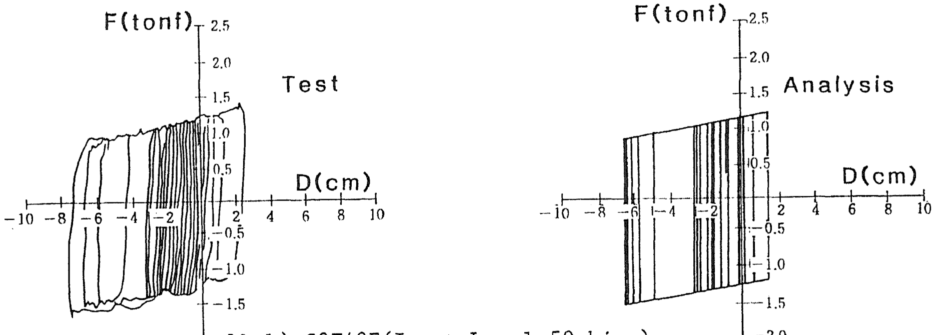
MAXIMUM POWER	30tonf·G
FREQUENCY RANGE	0-50 Hz
MAXIMUM DISPLACEMENT	±100 mm
MAXIMUM VELOCITY	±75 cm/SEC
MAXIMUM ACCELERATION	+ 1 G
MAXIMUM LOAD	20 tonf

Table 2 Main Characteristics of Earthquake

SYMBOL	EARTHQUAKE	DATE	MAGNITUDE	SITE	DIRECTION
ELNS	IMPERIAL VALLEY	1940.5.18	6.7	EL CENTRO	NS
TFEW	KERN COUNTY	1952.7.12	7.7	TAFT	EW
HCNS	TOKACHIOKI	1968.5.16	7.9	HACHINOHE	NS
MYNS	MIYAGIKEN-OKI	1978.6.12	7.4	TOHOKU UNIV.	NS

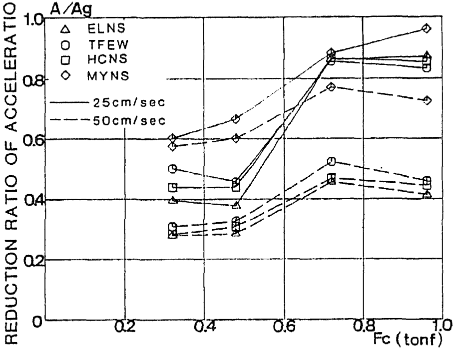


a) S2F48E(Input Level:50 kine)

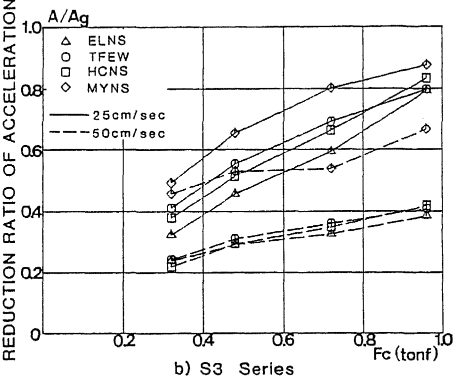


b) S3F48E(Input Level:50 kine)

Fig.6 Comparison between Test Results and Analytical Results

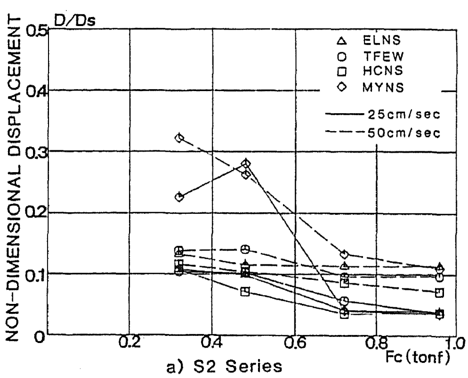


a) S2 Series

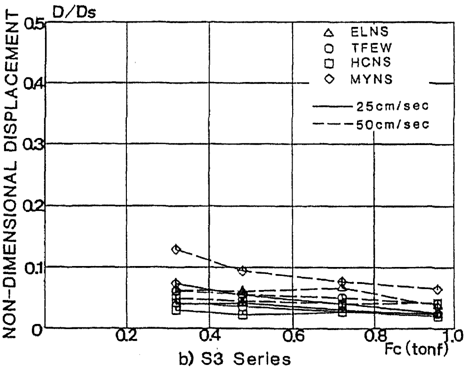


b) S3 Series

Fig.7 Effect of the Damper to Acceleration

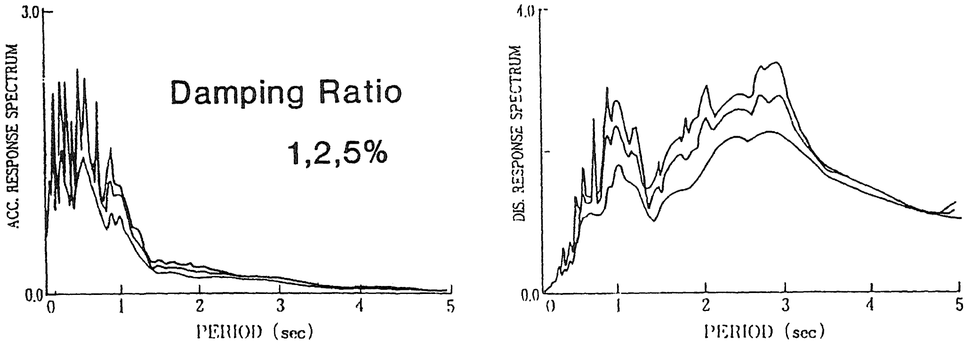


a) S2 Series

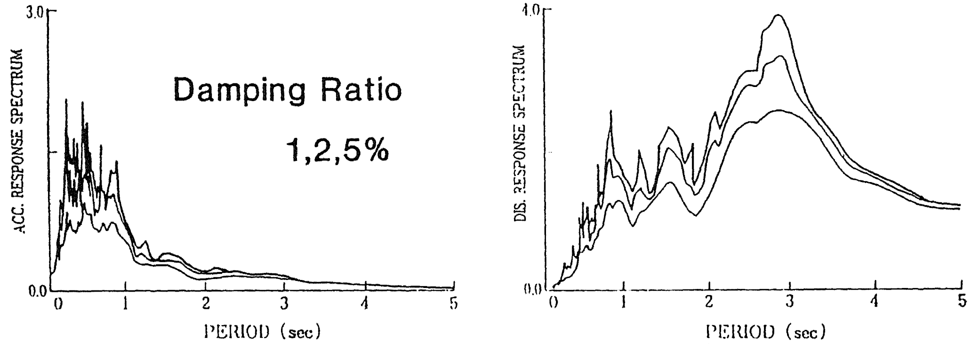


b) S3 Series

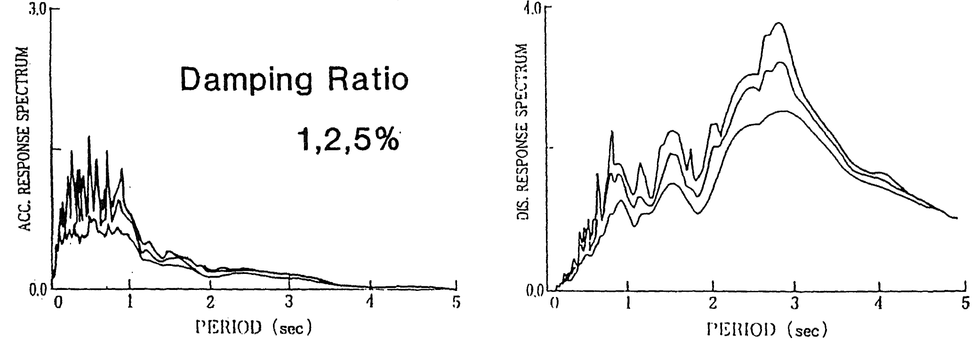
Fig.8 Effect of the Damper to Displacement



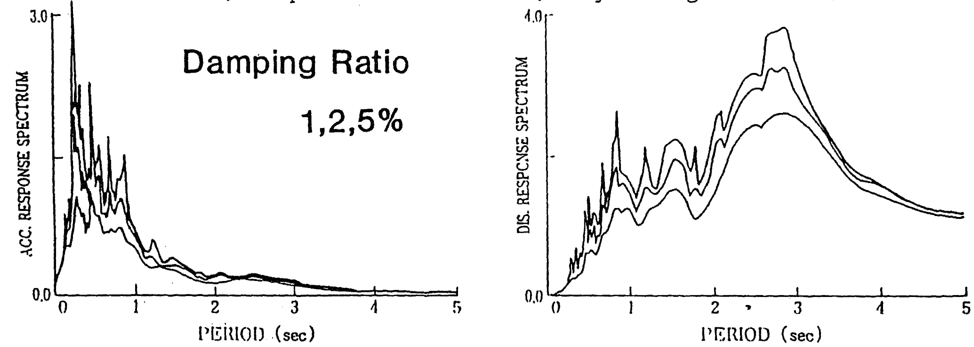
a) Ground Acceleration



b) Response Acceleration (Test)



c) Response Acceleration (Analysis:Rigid-Plastic)



d) Response Acceleration (Analysis:Elastic-Plastic)

Fig.9 Results of Spectral Analysis