TEST REQUIREMENTS AND ITS EXECUTION FOR THE VELOCITY DEPENDENT ENERGY DISSIPATION DEVICES

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Abstract

Both of cyclic dynamic test and drop hammer test are performed to the identical fluid dampers. Physical properties detected through both of the test data are compared with ignorable error. Consequently, it is emphasized that drop hammer test is not only low cost but also simpler on the purpose of detecting the damping factor of the fluid dampers.

PREFACE

Recent earthquake disasters experienced around the world, locally occurred in Taiwan as well, have alerted people to improve seismic engineering in the countries with high rate of earthquake occurrence. Due to these experiences, structures with seismic isolation devices such as LRB isolator, and some of the passive control devices, including energy dissipation devices such as VE-damper, fluid damper etc., have increased in their applications. Structural engineering integrating control devices has become one of the core technologies.

Some efforts have been done for the designing, manufacturing, and application of the fluid dampers (Taylor, 2002; Pekan *et al*., 1999; Fu, Y. and Kasai, K., 1998; U.S.P. 5870863, 1999; Constantinou *et al*., 2000). Testing and experimental work is certainly plays essential work in the developing stage of dampers (Taylor, 1995; Constantionu, M.C. and Symans, M.D.; 1992).

Experiment plays one of the very important roles for engineering applications. For example, design step can not be ignored before the steel reinforce member is settled in reinforce concrete structures. In the design procedure, Young's modulus of the steel member is certainly needed to be known so that the design can be done accordingly. Sampling test is necessary to investigate the properties of the materials to be used. Why only few of element is tested in sampling test? Because most of the test specimen be failed during test action. It is impossible to test every single member that is going to be used. We can not use a member that has already been failed under test action. There is no alternative that we have to take sampling test. It is recognized that we are not hundred percent assure the quality of the members which we used be satisfied the design requirements.

When we are talking about seismic devices, it is necessary to know the insight properties and the operation functions of the seismic devices before it can be designed and installed in the structures. No

matter the device is displacement dependent or velocity dependent, test, not only static test, but also dynamic test, is needed to know its behavior functions. It is recognized that even the manufacturing process is specified controlled, the properties of the seismic devices are still very sensitive to the small differences of the relative variables, specially for those of velocity dependent devices, for example, the resisting force produced with the excitation velocity is highly sensitive to the orifice ratio of the piston, to the density of the fluid, etc., for the fluid damper devices. It is fortunate that for most of dampers installed to take dynamic excitations for energy dissipation can be tested without failure. That means test can be done to each of the dampers going to be installed in the structures. The properties of the damper devices can be investigated not only by sampling test, but by testing performed to each of the individual dampers.

The essential reasons of this are two folded: (1) Non-failure test can be executed to the damper devices and (2) the property function of damper devices are highly sensitive to the primary variables related. That is why it is required in the SEAOC(Structural Engineers Association of California) Blue Book recommended:

"All devices should be tested to confirm acceptable behavior under large earthquake loading." (Taylor, 2002).

Furthermore, it is recognized that the analysis, design and construction issues associated with the use of energy dissipation devices, specially for fluid viscous velocity dependent devices, are not well understood by most of design professionals and building officials. With the installation of such devices, panel review for the design and the tests to the devices will be much more important.

Full scale cyclic test be certainly considered can reflect the actual property function of the energy dissipation devices be installed in the structures, particularly for the velocity dependent energy dissipation devices. One of the typical examples for the cyclic test result is shown in the Fig.1. The hysteresis loop (force – displacement relationship) and the force vs. velocity relationship for a small scaled fluid viscous damper are plotted in Fig.1(a) and Fig.1(b), respectively.
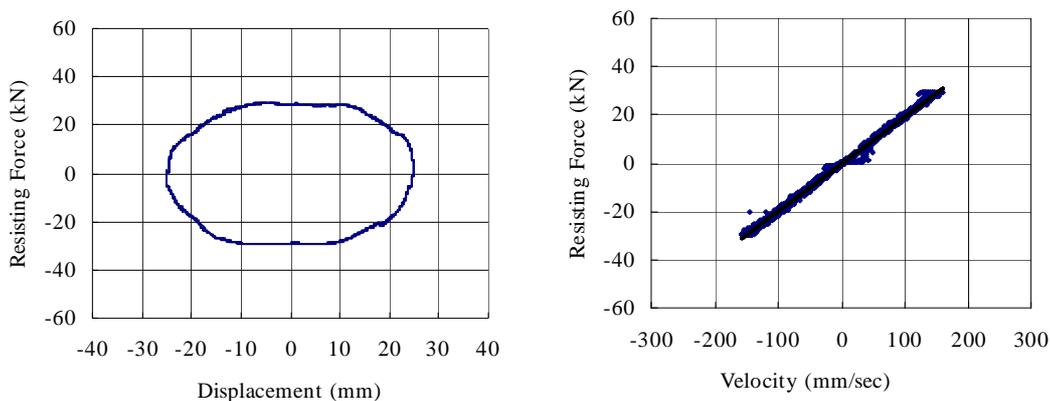

Fig.1: Cyclic test result for a small scaled fluid viscous damper (frequency 1.0Hz, amplitude 25mm).

In real projects, problems faced are not trivial. It is not so easy to fulfill the requirement regulations because of reasons at least listed as follows:

1. It is time consumed if all of the devices are required to be tested. Well, it can really be done if we do have enough time for the test task, or if we really believe the sampling test could be enough to reflect the property functions of the specified manufacturing products. However, in some of the existing projects, for instance, the Tai-Shin bank building at somewhere near Taipei (Pekan *et al*., 1999), some of three hundred fluid viscous dampers are installed in the building for the aseismatic purposes. Tests are performed to every one of the dampers to assure the quality of each one of the dampers.

2. It is difficult to perform cyclic test for full scale specimen due to the physical limitations of available testing equipment. This kind of test need to have the actuators with very high capacity that is hard to prepare in most of the laboratories. Once the input loading required as earthquake excitations, the test equipment for most of the laboratories are not available for the tests at real time rates of loading.

Fortunately, it is why, for the devices which is prevented to perform cyclic test due to the physical limitations of the testing equipment, it is allowed to use impact tests of full size units, combined with both cyclic test and impact test of reduced – scale units to detect the properties of the devices, in particular for the velocity – dependent devices such as fluid viscous dampers (FEMA, 1997).

HAMMER TEST EQUIPMENT AND TEST PURPOSE

Hammer test is performed to the fluid dampers just like to hit a nail by the hammer. Fig.2 is a sketched diagram to show a hammer test machine. Damper under tested is settled vertically on the stiffed foundation. The damper is hit by a lumped mass dropped from certain height. The impact force subjected to the damper will force the damper to induce relative displacement in – between the piston and the tube system. The load cell arranged at the top of the damper take the force instantly, and the LVDT take the relative displacement information meanwhile. It is recognized that hammer test did not afford the response functions with respect to the excitations such as subjected by real earthquake.

Fig.2: Photo picture of the fluid damper under tested.

However, some of the factors reveal the physical properties of the damper, such as damping factor of

the damper, can be obtained by the test. Of course the damping factor is essentially needed in the design procedure for the structural integrating control design. And the primary function which reveal the property of the damper, Eq.1, can be obtained empirically.

$$F = CV^n \tag{1}$$

Where F, C, V stand for resistance force, damping factor, and velocity of the damper, respectively, while n is a variable in a range of 0.5 ~ 2.0 with respect to the orifice ratio of the damper.

On the purpose of introducing the energy dissipation devices into the real world of seismic engineering application, Hammer test is needed. Because once the input is considered as earthquake excitations, the force and the energy going to be taken by the dissipation devices is tremendous huge that the energy for the dynamic test facilities in general laboratory usually can not afford. That is why instead of preparing and maintaining such facilities to meet the required test capacities, hammer test is introduced. Furthermore, it is relied on for the existing companies, such as Taylor's company, which are popularly known on producing seismic devices.

TEST EXAMPLE

A locally produced fluid damper as shown in Fig.2 is tested both for cyclic test and hammer impact test. The cross section of the damper is sketched as shown in Fig.3. The orifice ratio is defined as

$$A_1/A_2 \text{ x } 100\% \tag{2}$$

The orifice ratio for the damper under testing is 1.607%. In addition, the fluid filled in the damper is Si100 silicon glue.
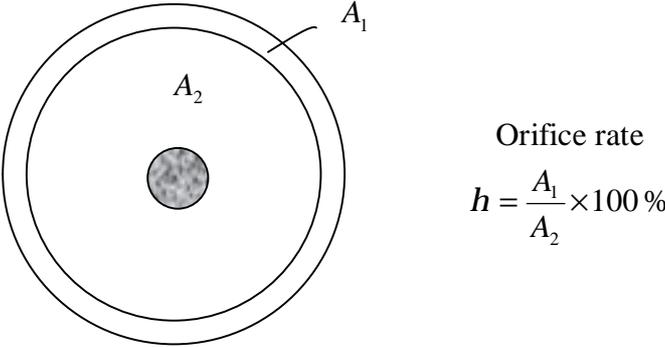
Orifice rate

$$h = \frac{A_1}{A_2} \times 100\%$$

Fig.3: The cross section of the damper under tested.

The test is executed with the range of the frequency from 0.05Hz to 3.5Hz and the thrusts are limited in plus/minus 10mm, 15mm, 20mm, 25mm, and 30mm. Some of the typical output, for the cases of plus/minus 10mm thrust with various frequencies (i.e., 2.5Hz, 3.0Hz, 3.5Hz), showing the relationship of resisting force with respect to displacement and velocity are plotted in Fig.4 to Fig.6.
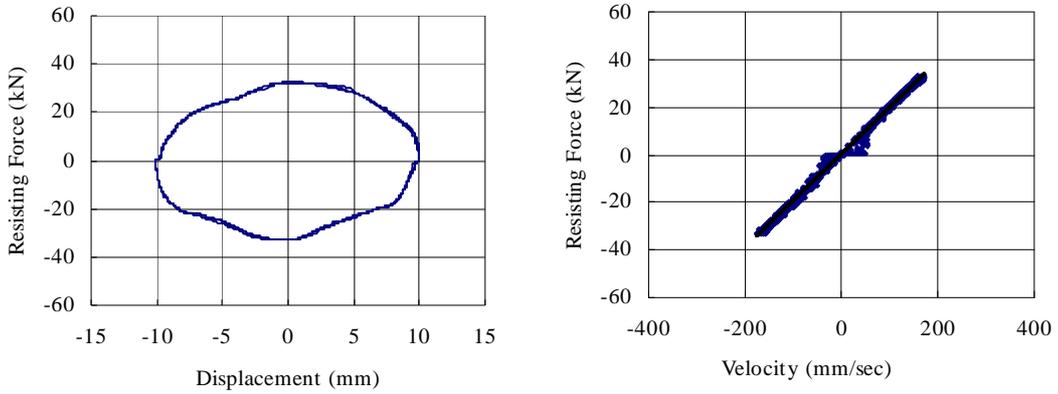
Fig.4 :Testing result for the case of frequency 2.5Hz and amplitude 10mm).
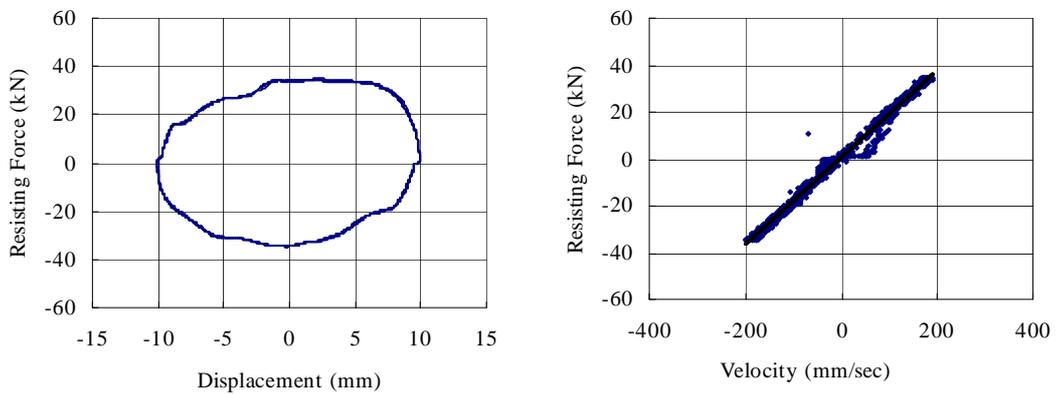

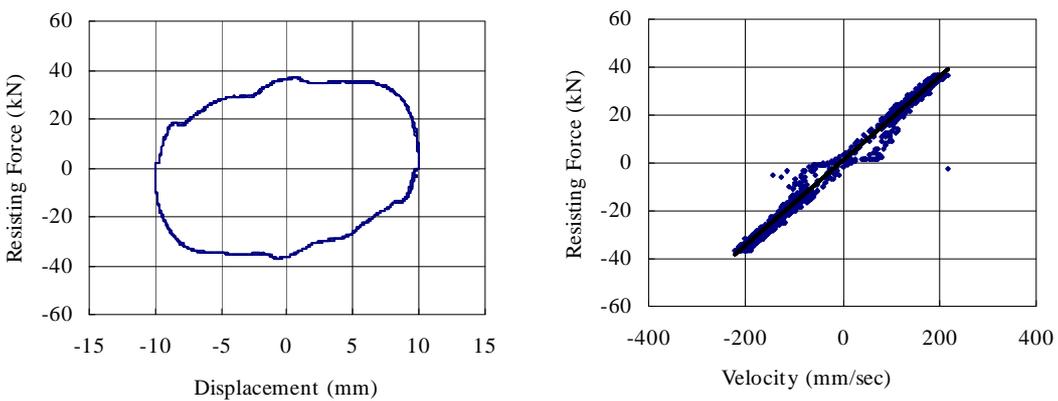Fig.5: Testing result for the case of frequency 3.0Hz and amplitude 10mm).

Fig.6: Testing result for the case of frequency 3.5Hz and amplitude 10mm).

5

By the data collected from the cyclic test, the relationship of the resisting force with respect to the velocity can be found. It is plotted in the Fig.7. A linear function of resisting force with respect to velocity is obtained as

$$F = 0.19 \, V \tag{3}$$

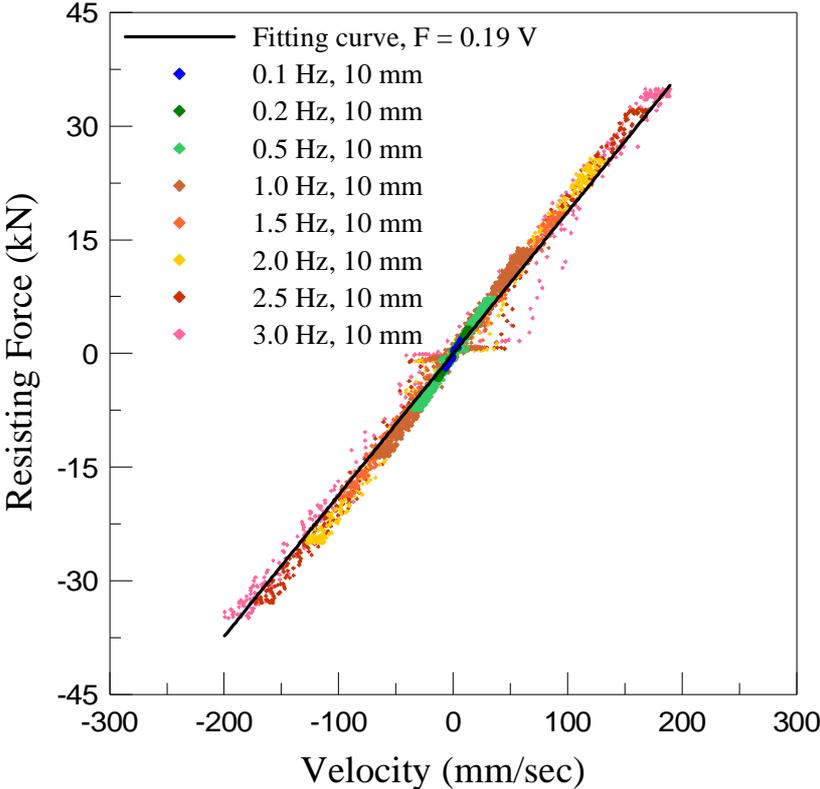That means a constant damping factor is obtained for this particular damper under tested.

Fig.7 :The relationship of the resisting force vs. velocity by the data collected from the cyclic test for the damper under tested.

Alternatively, the damper is also tested by hammer impact test. The test results are shown by the time history plots of displacement, force, and velocity. The data is taken for every 0.005 second. The plots of the case with 750kg mass dropped in a dropped heights of 120mm are shown in the Figs.8, Fig.9, and Fig.10, in terms of displacement, force, and velocity with respect to time, respectively. Through the group test cases with various masses and drop heights, by taking the data point of the maximum force and velocity responses, the relationship of force with respect to velocity can be plotted by curve fitting. As displayed in the Fig. 11. The force – velocity relationship can be fitted by a linear function as following,

$$F = 0.19 \, V \tag{4}$$

It is found that the value of damping factor obtained by hammer test is very close to that obtained from cyclic test with an error not more than 5%.
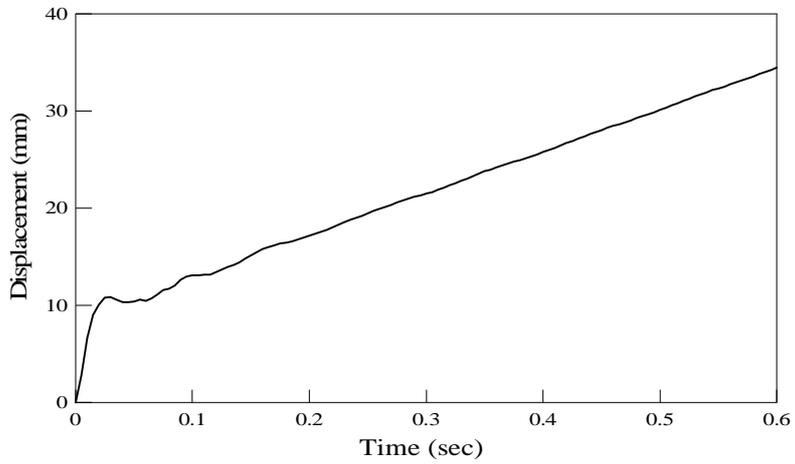
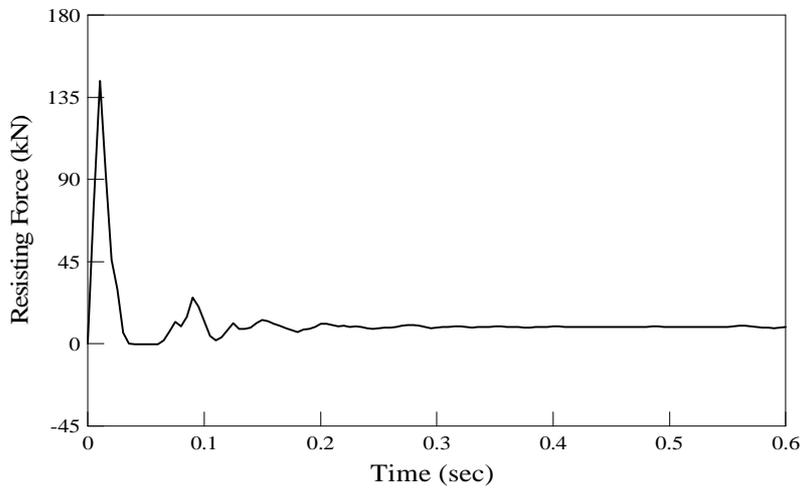Fig.8: A typical single test data plotted by displacement with respected to time.

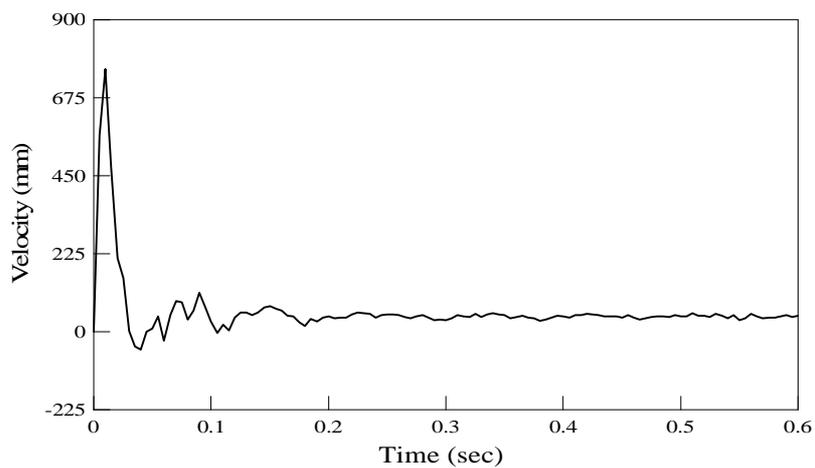Fig.9: A typical single test data plotted by force with respected to time.

Fig.10 :A typical single test data plotted by velocity with respected to time.
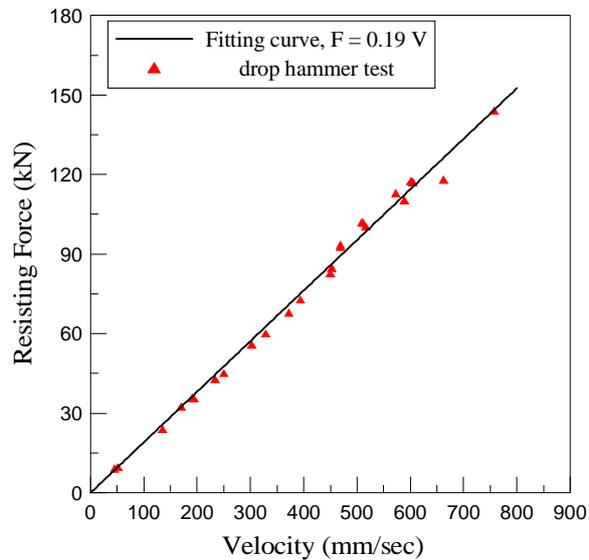
7

Fig.11: The relationship of the resisting vs. velocity by the data collected from the drop hammer test for the damper under tested.

CONCLUSIONS

Impact test, or so called drop hammer test, probably is one of the necessary tool for the practical development and application for the use of the velocity dependent energy dissipation devices to the aseismatic engineering. Once the suitable relation functions is derived, or experimentally found, it is believed that part of physical properties of full scale devices which was considered to be detected by cyclic tests only, can be alternatively obtained by impact tests of full size units combined with both cyclic test and impact test of reduced scale units. The example displayed herein does introduce some of the available inter-relation functions in between the cyclic dynamic test and impact hammer test.

It is worthwhile to emphasis that the properties of dampers are quite different from one of another. The damper under test described in the paper shows the linear relationship in resisting force and velocity, i.e., $F = CV$. In fact, the function of the resisting force with respect to velocity is recognized to be $F = CV^n$, in general, where n can be greater or smaller than 1. It is highly probable that non-linear relationship is existed for the relationship of resisting force with respect to velocity. However, cyclic test, as well as hammer test, can obtain the function and damping factor can be estimated accordingly. Furthermore, due to the highly sensitivity of the damper property with slightly difference of the possible variables, in order to assure the quality of the practically used dampers, performance test executed to each one of the devices could be necessary. In other words, can not be ignored by the excuse of lacking of testing facilities.

ACKNOWLEDGEMENT

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