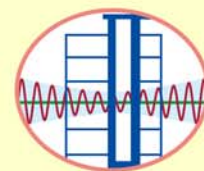


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CONTENTS

- ▶ Beyond Design Performance of Full-scale Viscoelastic Dampers
- ▶ Analytical and Experimental Study on Sloped Sliding-type Bearings
- ▶ Optimum Dynamic Characteristic Control Approach for Building Mass Damper Design
- ▶ Dynamic Behavior of High-damping Rubber Bearings under Non-proportional Plane Loading
- ▶ Periodic Foundation for Seismic Mitigation Application
- ▶ Advanced Dynamic Testing Facilities for Velocity-dependent Dampers and Seismic Isolators
- ▶ A Versatile Small-scale Structural Laboratory for Development and Validation of Advanced Experimental Technology
- ▶ NCREE Tainan Laboratory Grand Opening Ceremony and Forum
- ▶ MTS Worldwide Seismic Solutions Users Group Meeting
- ▶ CSSE/CTSEE Joint Conference on Structural Control and Health Monitoring Technology

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Beyond Design Performance of Full-scale Viscoelastic Dampers

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Introduction

Viscoelastic (VE) dampers, with their stiffness and energy dissipation capabilities, have been widely applied in civil engineering for mitigating wind-induced vibration and seismic responses of buildings. In engineering practice, VE dampers are often designed to remain intact under design basis shaking. However, the damage caused to them, if any, their actual performance under earthquakes greater than design basis shaking, and their residual performance under aftershocks were rarely discussed. In this study, to clarify these concerns, full-scale VE dampers were dynamically tested by using a high-performance damper testing facility, as shown in Figure 1.

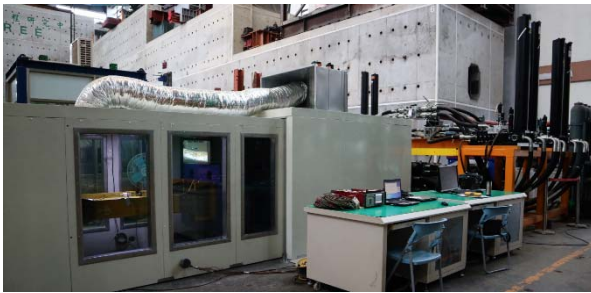
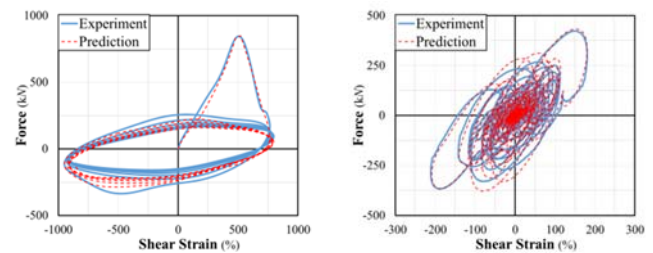


Fig. 1. Tested VE dampers and testing facility

Experimental Study

At the first stage, for characterizing the fundamental mechanical behavior of VE dampers, a series of sinusoidal reversal tests with different excitation frequencies, ambient temperatures, and shear strain levels less than 300% were conducted. Accordingly, four coefficients of the fraction differential model considering ambient temperature, temperature rising, cyclic soften, and strain hardening effects can be determined. At the second stage, VE dampers were tested with larger shear strain levels of 480%, 600%, 720%, 840%, 960%, and 1000% to realize their ultimate performance. In addition, in between each shear strain level, the basic performance test under 300% shear strain at an ambient temperature of 20°C was performed to further understand VE dampers' residual performance after damage. The fraction differential model is also adopted for characterizing their post-damage behavior. At the third stage, VE dampers were subjected to seismic response histories, which can be numerically analyzed in an off-line manner, rather than sinusoidal reversal ones. Moreover, the test results were compared with the predictions by the fraction differential model, as shown in Figure 2. It was observed that during the tests the visible damage of VE material occurred at about 600% shear strain. Test results indicate that the stiffness and damping coefficient of VE dampers decrease proportionally with varying shear strain levels from 600% to 840%, and can still remain half of the original values at

least after 840% shear strain. In addition, the force amplification at the first cycle becomes more significant when subjected to a larger shear strain level. This effect should be considered seriously for practical design of connected members and structures. Either before or after damage, the predictions by the fraction differential model agree well with the test results.



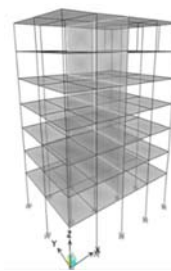
(1) cyclic test with 840% shear strain

(2) seismic response history test

Fig. 2. Comparison of test results and predictions

Numerical Study

A typical 7-story street house with a weak first story and a 26-story residential building were numerically analyzed to verify the effectiveness of adopting VE dampers for retrofit and new design purposes, respectively, as presented in Figure 3. In the former example, two VE dampers were installed only at the first story in each principal horizontal direction. Numerical results reveal that retrofitting the structure by using VE dampers can directly and effectively improve the weak story deficiency, thus reducing the seismic responses at higher stories. Even though VE dampers are damaged, their residual performance is still enough to protect the structure. In the latter example, four VE dampers were installed in each principal horizontal direction of the third to nineteenth story. Both shear and rotation spring elements were incorporated in the simplified stick model. Similarly, numerical results demonstrate that the building equipped with VE dampers exhibit a superior seismic performance compared to the bare building.



(1) 7-story street house



(2) 26-story residential building

Fig. 3. Numerical models and verification

Analytical and Experimental Study on Sloped Sliding-type Bearings

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Lap-Loi Chung, Deputy Director, NCREE, Kuo-Chun Chang, Professor, NTU

Introduction

The sliding mechanism of a slider between upper and lower bearing plates designed with a sloped surface in two principle horizontal directions imparts an in-plane seismic isolation performance to the sloped sliding-type bearing, as illustrated in Figure 1. In this study, an analytical model of the sloped sliding-type bearing was theoretically investigated, and sensitivity analyses of varied design parameters were performed. After characterizing its dynamic behavior, a series of shaking table tests on two different isolated superstructures were conducted, and the test results were compared with the numerical predictions.

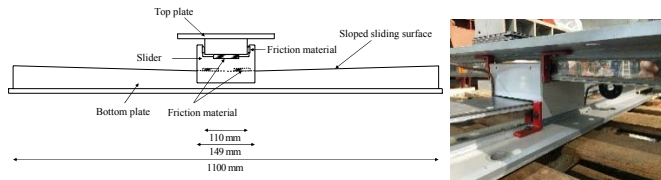


Fig. 1. Sloped sliding-type bearings

Analytical Model and Sensitivity Analysis

The following simplification assumptions are first made: (1) the slider and bearing plates are ideally in contact and in pure sliding motion; (2) the sliding motions in two principle horizontal directions are identical; (3) the Coulomb friction law is employed to represent the sliding friction–displacement relation between the slider and bearing plates; (4) the pounding effect at the intersection of two inclines of V-shaped surfaces is negligible; (5) there is no vertical excitation; and (6) the projection component of horizontal excitation along the direction of normal force on the sloped surface is negligible. Considering Lagrange’s equation and Hamilton principle, the horizontal equation of motion of the sloped sliding-type bearing can be derived. It is found that the transmitted horizontal acceleration response can remain constant regardless of any excitation and only depends on two design parameters, the slope and sliding friction coefficient. Accordingly, its hysteresis behavior can be represented by a simplified twin-flag hysteresis model, which can be simulated without difficulty by a combination of multi-linear elastic and plastic (Wen) models in the readily available analysis programs such as SAP2000 or ETABS, as shown in Figure 2.

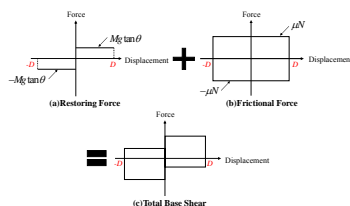


Fig. 2. Simplified twin-flag hysteresis model

The sensitivity analysis results under harmonic excitation indicate that the transmitted horizontal acceleration response of the sloped sliding-type bearing is proportional to the slope and sliding friction coefficient. The larger the slope, the larger the displacement response, which can be suppressed by increasing the sliding friction. In addition, the transmitted horizontal acceleration response is inversely proportional to the excitation frequency. The same tendency for the acceleration performance can be observed under seismic excitation. In addition, the sloped sliding-type bearing has been demonstrated to have a satisfactory self-centering capability.

Experimental and Numerical Verification

A rigid mass (Specimen 1) and a 3-story 2-bay steel structure model (Specimen 2) isolated with the sloped sliding-type bearings at four corners were designed and fabricated, as presented in Figure 3. The mass of the two isolated superstructures is about 34 kN-s²/m. The identified fundamental modal frequencies of the isolated superstructure of Specimen 2 in the X and Y directions are 10.5 and 4.1 Hz, respectively. The design slope and sliding friction coefficient of the tested bearings are 1.5° and 8%, respectively. Seven ground motions recorded during the El Centro, Kobe, Tohoku, Kokuji, Kumamoto, Chi-Chi, and Meinong earthquakes with varied intensities were selected for unilateral and bilateral acceleration inputs. The test results reveal that the horizontal acceleration responses transmitted to the isolated superstructures can be effectively reduced and controlled to be constant in general, as shown in Figure 4. In addition, the residual displacement after excitation is very limited.



Fig. 3. Test specimens

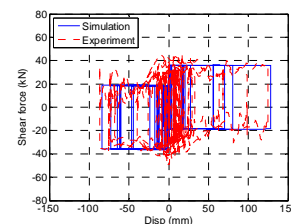


Fig. 4. Test results and numerical predictions

The test results are also compared with the numerical predictions by the proposed analytical model, as shown in Figure 4. Apparently, the predictions have a very good agreement with the test results, in terms of acceleration and displacement histories as well as hysteresis loops.

Optimum Dynamic Characteristic Control Approach for Building Mass Damper Design

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Kuo-Chun Chang, Professor, NTU

Introduction

To overcome the concern of limited response reduction owing to insufficient tuned mass in the conventional tuned mass damper (TMD) design, a new design concept, namely, the building mass damper (BMD), has been developed and studied. As the name implies, a part of the structural mass, instead of additional mass, is intended to be an energy absorber. In this study, an optimum BMD (OBMD) design approach, namely, optimum dynamic characteristic control approach, is proposed to seismically protect both the superstructure (i.e., tuned mass) and the substructure (i.e., primary structure), respectively, above and below the control layer composed of rubber bearings and linear viscous dampers.

Analytical Model and Objective Function

A simplified 3DOF structure model whose three lumped masses are, respectively, assigned at the superstructure, control layer, and substructure is rationally assumed to represent a building structure designed with a BMD system. By means of the state space method under coupling approximation, the system matrix in terms of the nominal frequency ω_1 , frequency ratio $f_i = \omega_i / \omega_1$ ($i = 2, 3$), mass ratio $\mu_i = m_i / m_1$ ($i = 2, 3$), and component damping ratio ξ_i ($i = 1-3$) are obtained, where $i = 1, 2$, and 3 denote the substructure, control layer, and superstructure, respectively; the nominal frequencies ω_1 , ω_2 , and ω_3 are defined as $(k_1/m_1)^{1/2}$, $[k_2/(m_2 + m_3)]^{1/2}$, and $(k_3/m_3)^{1/2}$, respectively.

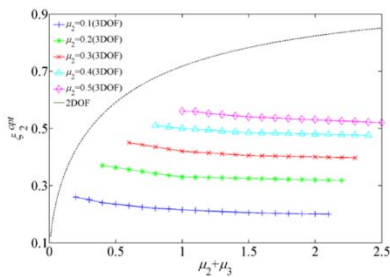


Fig. 1. Optimum damping ratios (2DOF and 3DOF)

The objective function for determining the OBMD design parameters is to control the modal damping ratios in the three complex modes of vibration as an approximately equal value. In most past studies relevant to the TMD design, a simplified 2DOF structure model was usually used to study the optimum TMD design parameters. Under this circumstance, only one mass ratio, i.e., a total of μ_2 and μ_3 , was required to be defined. As shown in Figure 1, when using the 2DOF model, the larger the mass ratio, the higher the damping demand required. Nevertheless, when using the 3DOF model, an opposite tendency is observed in that the optimum damping ratio, in general, is inversely proportional to the total of μ_2 and μ_3 but still proportional to μ_2 . More importantly, a more

reasonable and applicable damping demand can be obtained especially when μ_2 decreases.

Experimental and Numerical Results

For experimental demonstration, the bare specimen was designed to be a 1/4 scaled eight-story steel structure model. Seven BMD specimens (BMD-1 to BMD-7) and one OBMD specimen were designed with a control layer at the fourth floor to study the influence of different f_2, f_3 , and ξ_2 values on the control performance, as shown in Figure 2. Four ground motions recorded at I-ELC270, KJM000, TCU047, and THU stations during the El Centro, Kobe, Chi-Chi, and Tohoku earthquakes, respectively, with varied intensities were selected as earthquake inputs.

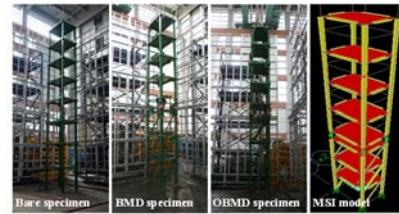


Fig. 2. Experimental and numerical structure models

For further comparison, a typical mid-story isolated building model in which the isolation layer is inserted into the same level as the control layer in the OBMD specimen, denoted as MSI and shown in Figure 2, is numerically built and analyzed as a counterpart.

At the substructure and superstructure, the average ratios of the maximum acceleration and inter-story displacement responses of the bare specimen, seven BMD specimens, and MSI to those of the OBMD specimen (AR and IDR , respectively) are calculated and presented in Figure 3. Obviously, the seismic performances of the OBMD specimen and MSI are much better than those of the bare and BMD specimens. The OBMD specimen, basically, has a comparable control performance to MSI. It even has a superior control performance at the substructure to MSI. In addition, the inter-story displacement response at the control layer of the OBMD specimen is much smaller than that at the isolation layer of MSI, which further demonstrates that these two design methods are essentially different.

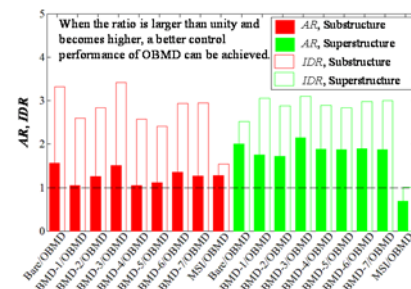


Fig. 3. Experimental and numerical comparison

Dynamic Behavior of High-damping Rubber Bearings under Non-proportional Plane Loading

Wang-Chuen Lin, Assistant Researcher, Shiang-Jung Wang, Research Fellow, NCREE
Jenn-Shin Hwang, Professor, NTUST

Introduction

There can be differences between the hysteretic behaviors of high-damping rubber (HDR) bearings under unilateral reversal and non-proportional plane loading, which might lead to the design not being conservative. These differences have been, however, rarely discussed so far. In this study, HDR bearings were unilaterally and bilaterally tested. A modified mathematical model is accordingly proposed for accurately and conservatively characterizing their hysteretic behavior under unilateral and plane loading.

Unilateral Reversal and Non-proportional Plane Loading Tests

Small-scale HDR bearings were tested by using the dynamic tri-axial testing facility, as shown in Figure 1. The diameter of the tested bearings excluding the rubber cover is 150 mm. It comprises 25 HDR layers of thickness 1.97 mm each and 24 steel shims of thickness 1.2 mm each. The total height including the upper and lower flanges is 102.1 mm. Exerting a constant compression stress of 50 kg/cm², the unilateral test protocols include sinusoidal and triangular reversal loading, and the plane test protocols include circular, figure-eight, and square orbits, shown in Figure 2, with different displacement amplitudes and excitation frequencies. Assuming that U_x and U_y are the displacement components at time t in two principal horizontal directions and U_0 is the displacement amplitude, the maximum displacement vector sums for circular, figure-eight, and square orbits are U_0 , $\text{Max}((U_x^2 + U_y^2)^{1/2})$, and $2^{1/2}U_0$, respectively.

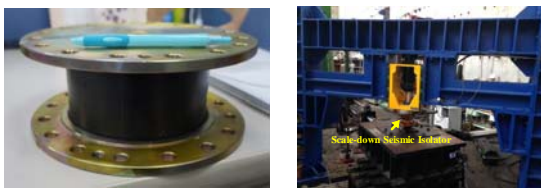


Fig. 1. Tested HDR bearings and testing facility

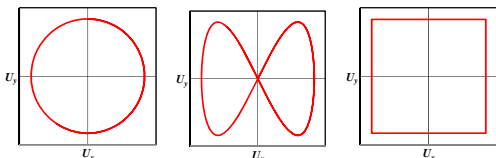


Fig. 2. Non-proportional plane loading paths

Test Results and Mathematical Model

By comparing the sinusoidal reversal loading test results with the triangular ones, it is found that the hysteretic behavior of HDR bearings is less dependent on the loading path and rate, except at the transition from loading to unloading. It is evident that the larger the excitation frequency, the higher the effective stiffness and the lower the damping ratio obtained. However, there is a

significant discrepancy between the hysteretic behavior of HDR bearings under unilateral, plane, and different plane loading, as shown in Figure 3. It is attributed to the torsional coupling effect. In other words, when an HDR bearing is subjected to plane loading, which can usually be decomposed into the X and Y directional components, the shear strain responses will not uniformly distribute along the two principal horizontal directions. This effect will cause a significant increased local shear strain as well as more complicated and unpredictable hysteresis behavior for HDR bearings.

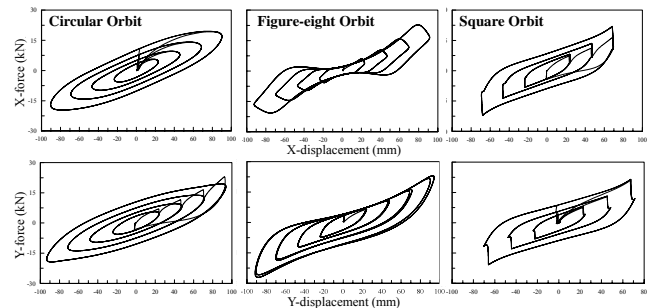


Fig. 3. Non-proportional plane loading test results

Since the previously developed mathematical model that considers ten to-be-determined coefficients might not be appropriate for characterizing the hysteretic behavior of HDR bearings at the transition of velocity directions under unilateral triangular reversal loading, a modified one that incorporates only nine to-be-determined coefficients is proposed in this study. In addition, by employing the plane vector concept, the modified model can be extended to characterize the hysteretic behavior of HDR bearings under plane loading. As shown in Figure 4, apparently, the hysteretic behavior of HDR bearings can be well captured by the proposed model, which verifies its accuracy and practicability. The prediction accuracy is still satisfactory although the nine coefficients are identified from different plane loading tests.

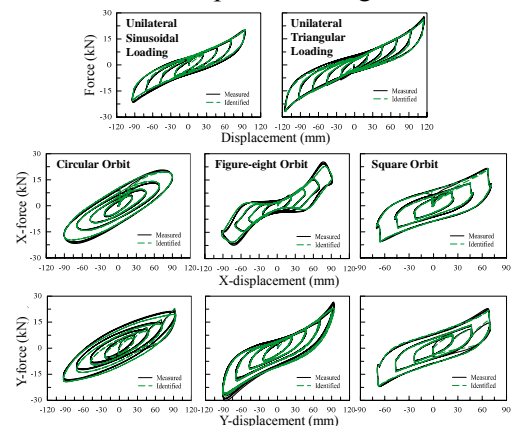


Fig. 4. Comparison of test results and predictions

Periodic Foundation for Seismic Mitigation Application

*Cho-Yen Yang, Assistant Researcher, NCREE, Witarto, Doctoral Candidate, UH
 Shiang-Jung Wang, Research Fellow, NCREE, Yi-Lung Mo, Professor, UH
 Kuo-Chun Chang, Professor, NTU*

Introduction

Past researches on periodic materials showed that an infinite series of lattice layers has the ability to manipulate certain elastic waves travelling through its medium. According to the number of directions where the unit cell is repeated, periodic materials or phononic crystals can be classified as 1D, 2D, and 3D, as shown in Fig. 1. This man-made material has the property of preventing the propagation of elastic waves having frequencies within certain frequency bands, which are often termed as frequency band gaps or attenuation zones. As illustrated in Fig.2(a), the wave cannot propagate through the phononic crystal lattice when the elastic wave oscillates with the frequency falling within the frequency band gap. Only when the frequency of the wave falls outside of the frequency band gap, as shown in Fig.2(b), the wave can propagate into and through the phononic crystal lattice.

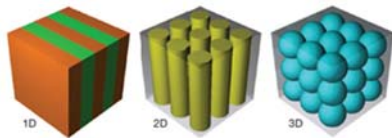


Fig. 1. Classification of phononic crystals

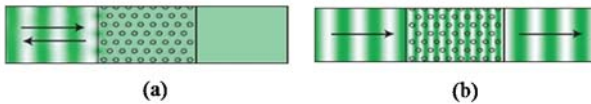


Fig. 2. Illustration of wave propagation

Utilizing the unique feature of phononic crystal lattices, researchers in the civil engineering field have started to apply crystal lattices into structural elements. In this study, phononic crystal lattices were implemented into the structural foundation (i.e., periodic foundation) of a critical facility to isolate seismic waves, thus protecting the superstructure, as illustrated in Fig.3. Periodic foundations are also categorized into 1D, 2D, and 3D, as presented in Fig.4.

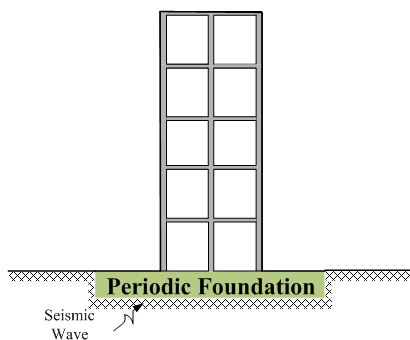


Fig. 3. Periodic foundation

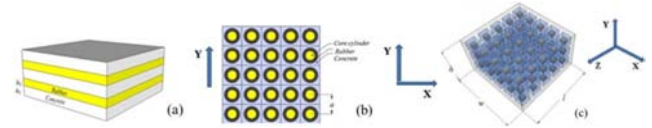


Fig. 4. Classification of periodic foundations

Test Schemes

Three test schemes were conducted to verify the effectiveness of 1D, 2D, and 3D periodic foundations subjected to ambient vibration, harmonic excitation, and seismic waves, as shown in Fig.5. Specimen A was a 3-story structural model fixed to the shake table while Specimen B was an identical structural model connected to the top of a 1D periodic foundation and placed on the shake table. Specimen C was a frame placed directly on a concrete foundation, while Specimen D was designed with a 2D periodic foundation placed between the same frame and concrete foundation. Specimen E was a cantilever column connected to a concrete foundation, while Specimen F was an identical cantilever column connected to a 3D periodic foundation.



Fig. 5. Experimental setup

Experimental Verification

The comparative test results are presented in Fig.6. It is particularly evident that under ambient vibration, the acceleration response at the top of Specimen B was significantly reduced compared to that of Specimen A. It is because the main frequency of the ambient vibration was within the attenuation zone of the 1D periodic foundation. In addition, subjected to seismic waves, the 2D and 3D periodic foundations helped in reducing the acceleration responses transmitted to the superstructures by more than 50% and 90%, respectively. It is also because the main frequencies of the seismic waves were within the frequency band gaps of the 2D and 3D periodic foundations. The test results demonstrate that the periodic foundations are effective to mitigate seismic responses transmitted to the superstructure.

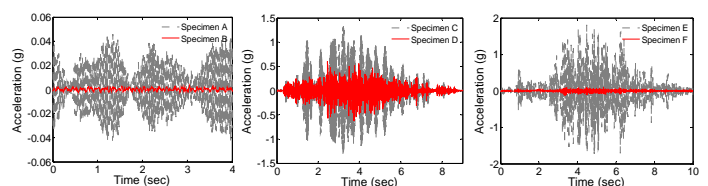


Fig. 6. Comparison of test results

Advanced Dynamic Testing Facilities for Velocity-dependent Dampers and Seismic Isolators

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High Performance Damper Testing Facility

To experimentally verify the dynamic behavior and temperature dependency of full-scale velocity-dependent dampers, a high-performance testing facility, shown in Figure 1, has been designed and established at the NCREE Taipei Laboratory. It consists of three steel reaction components, a temperature control system, and a high-speed servo-hydraulic actuator that possesses a maximum stroke capacity of ± 600 mm and a maximum force capacity of ± 2 MN. The maximum velocity capacity is ± 1 m/s when the force reaches ± 1 MN. Prestressed rebars are employed to mount the three reaction components on the strong floor as well as assemble the actuator, reaction components, and any necessary fixtures. The reaction component connected to the actuator piston end is designed with a linear guide system, thus guaranteeing a nearly perfect uniaxial cyclic control with very limited friction force. Specimens are installed horizontally at the space between the two reaction components, which can be adequately adjusted in compliance with different specimen sizes. By using the temperature control system, the ambient and operating temperatures of specimens varying from 5°C to 50°C can be controlled and monitored in the chamber.

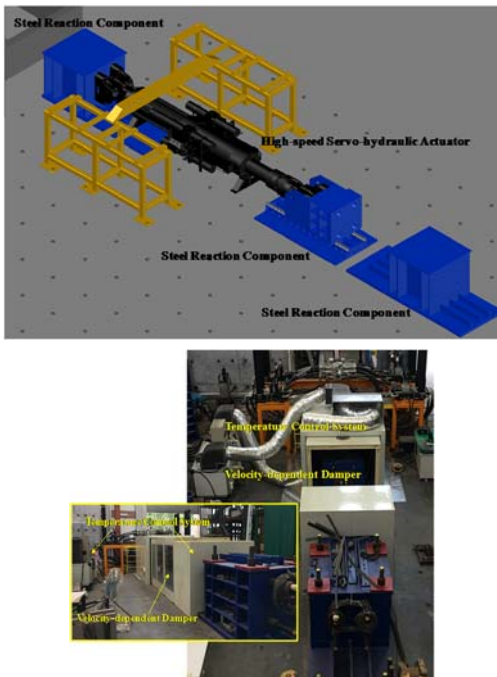


Fig. 1. High performance testing facility

Dynamic Tri-axial Testing Facility

To dynamically test scale-down seismic isolators under a vertical compression force with different non-proportional plane loading paths, a dynamic tri-axial testing facility shown in Figure 2 has been designed and established at the NCREE Taipei Laboratory. It is composed of a reaction frame, a bilateral sliding system, and one vertical and two lateral dynamic servo-hydraulic actuators. The two lateral actuators are installed to be horizontally perpendicular to each other. Their maximum stroke and force capacities are ± 250 mm and ± 250 kN, respectively. The actuator piston end is connected to the bilateral sliding system. Two in-plane mutually orthogonal linear guide systems are designed for the bilateral sliding system; therefore, it can have an in-plane movement executed by the two lateral actuators. Specimens are installed on the bilateral sliding system. The vertical actuator is mounted underneath the cross beam of the reaction frame. Its maximum stroke and force capacities are ± 50 mm and $+250$ kN in compression (-150 kN in tension), respectively. By employing a linear guide system to laterally restrain the vertical actuator, compression force exerted on specimens can be well controlled while under non-proportional plane loading.

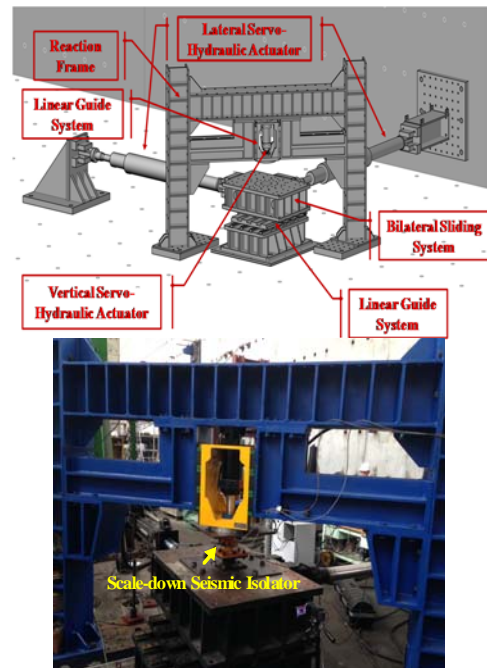


Fig. 2. Dynamic tri-axial testing facility

A Versatile Small-scale Structural Laboratory for Development and Validation of Advanced Experimental Technology

Pei-Ching Chen, Assistant Professor, National Taiwan University of Science and Technology

Introduction

In the past decades, National Center for Research on Earthquake Engineering (NCREE) has been dedicating to developing novel and advanced experimental methods to meet the test requirements for new structural systems and energy dissipating devices in a cost-effective manner. A versatile small-scale structural laboratory, financially supported by the Ministry of Science and Technology, has been completed by the end of June 2017. It consists of all the necessary software and hardware for verifying the effectiveness of newly developed technology before it is actually applied to full-scale structural testing for the safety purpose.

Hardware and Software

The small-scale structural laboratory, schematically illustrated in Fig. 1, is located at R109 of the NCREE Taipei Laboratory. The hardware and software are briefly introduced as follows.

(1) Hydraulic and control systems

The small-scale structural laboratory is equipped with six dynamic servo-hydraulic actuators. The maximum stroke and force capacity of each actuator are ± 127 mm and ± 15 kN, respectively. A two-stage servo valve can provide a maximum flow rate of up to 15 gpm. The actuators are regulated by an MTS FlexTest® Controller FT-100 digital controller, which can operate two stations and control six actuators simultaneously. Furthermore, an MTS SilentFlo™ 515 Hydraulic Power Unit is installed in the basement, supplying a maximum sustainable flow rate up to 60 gpm under 3,000 psi hydraulic pressure. Meanwhile, two hydraulic service manifolds can provide independent pressure regulation of hydraulic fluid to test stations.

(2) Reaction walls and reaction floor

Two reaction walls with heights of 2.0 m and 1.5 m and widths of 3.5 m and 4.5 m are allocated in the laboratory. The natural frequencies of the 2.0-m and 1.5-m reaction walls are 55.08 Hz and 100.35 Hz, respectively. The fixtures and specimens can be mounted on the reaction wall through M20 or M12 threaded bolts. On the other hand, the reaction floor with a dimension of 4.85 m \times 4.35 m is T-slotted every 250 mm in the direction orthogonal to the surface of the 1.5-m reaction wall. The fixtures and specimens can be mounted on the reaction floor through M12 or M10 threaded bolts.

(3) Material testing system

The laboratory is equipped with an MTS 810 material testing system that can be used to conduct high cycle fatigue testing for nonstructural components. The maximum stroke and force capacity of the system are ± 75 mm and ± 100 kN, respectively.

(4) Real-time computing machines

Three different real-time computing machines are obtainable in the laboratory—a dSPACE MicroLabBox, a MathWorks xPC Target, and a National Instruments (NI) PXI. In particular, the xPC Target and the PXI are equipped with SCRAMNet GT200, which can simultaneously handle network data streams between the digital controller and the computing machine.

(5) GPU-based numerical engine

A high-performance computing system powered with a graphical processing unit (GPU) is equipped for numerical structural analysis in the laboratory. An instant numerical analysis shortens the elapsed time required for predicting and correcting the dynamic response of the numerical substructure, improving the promptness and reducing the error of an experiment. The computing efficiency of finite element analysis can be improved through multi-threading with parallel finite element algorithms.

(6) Data acquisition system

The laboratory possesses a 32-channel MTS FlexDAC™ 20 for acquiring experimental data of strain and bridge-type devices. In addition, 88 analog inputs are available on the NI PXI mentioned previously for collecting experimental data with a high sampling rate of up to 15.6 kHz during the test.

(7) Software

The MTS Series 793 Control Software is used to calibrate and tune the actuators. Meanwhile, the NI VeriStand and LabVIEW are adopted to configure the hardware and perform real-time testing in a more efficient manner.

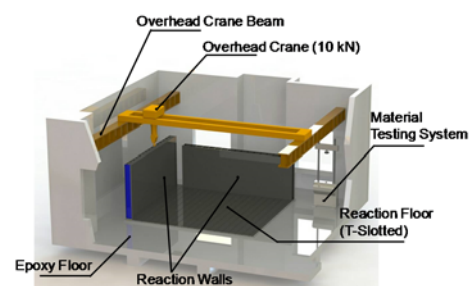


Fig. 1. Schematic of the small-scale structural laboratory

Future Works

The small-scale structural laboratory provides a safe and versatile environment for researchers to develop and validate novel and advanced experimental technology, which has been recognized essential for future earthquake engineering studies. International collaboration between NCREE and the institutes worldwide can be expected in order to achieve considerable success on advanced experimental technology in the future.

NCREE Tainan Laboratory Grand Opening Ceremony and Forum

NCREE GOF Local Organizing Committee

Under the joint efforts of NCREE and National Cheng Kung University, the NCREE Tainan Laboratory Grand Opening Ceremony was held on August 9, with a participation of approximately 350 guests from all over the world, including USA, Japan, South Korea, India, China, Singapore, Canada, New Zealand, Australia, Chile, Indonesia, Czech, Italy, Kuwait, Russia, and Taiwan. The unveiling ceremony invited the following dignitaries to mark this historical moment: Liang-Gee Chen (Minister of Science and Technology), Ding-yu Wang (Member of the Legislative Yuan), Huey-Jen Jenny Su (President of NCKU), Hwung-Hweng Hwung (former President of NCKU), Bei-hong Ku (former Chairperson of Formosa Builders, Inc.), Steven B. Harrison (President of MTS Vehicles & Structures Test Systems), Tungyung Chen (Vice President of NCKU), Woei-Shyan Lee (Dean of Engineering College, NCKU), Shen-Haw Ju (former Chair of Civil Engineering Department, NCKU), Yeong-Her Wang (President of National Applied Research Laboratories, NARLabs), Kuang-Chong Wu (Vice-President of NARLabs), Shyh-Jiann Hwang (Director General of NCREE), Der-Her Lee (Director of the Southern Taiwan Experiment Division, NCREE), and former NCREE Directors General (Drs. Chau-Shiung Yeh, Chin-Hsiung Loh, Keh-Chyuan Tsai, and Kuo-Chun Chang).

According to the Central Geological Survey, there are twenty Holocene (i.e., Category-I) active faults in Taiwan. Based on this fact, 2.5 million buildings and 8.6 million residents live within a 10 km perimeter of these faults. As such, the Ministry of Science and Technology, National Development Council, NARLabs, and NCKU jointly supported the construction of the NCREE Tainan Laboratory in the NCKU Gueiren (歸仁) Campus to enable research toward mitigating potential near-fault catastrophic threats. In the immediate neighborhood of the NCREE Tainan Laboratory, there are Fire Experiment Center and Mock-up Testing and Wind Tunnel Laboratory operated by the Architecture and Building Research Institute (ABRI), the Ministry of Interior. These three laboratories together will form a Research Park for Near-Fault and Multiple Hazards Mitigation; which provides a great opportunity to see how far academics and professionals can push the boundary and deal with technological challenges from near-fault threat and multiple hazards.

The NCREE Tainan Laboratory features an 8 m × 8 m high-speed long-stroke triaxial shaking table for earthquake response simulation, and a high-speed bi-axial testing system (BATS) for dynamic high axial load tests. The NCREE Tainan Laboratory is close to the Taiwan High Speed Rail Station of Tainan, and has a comparable floor area to that of the NCREE Taipei Laboratory, but it houses far more advanced cutting-edge testing facilities. On August 9, the shaking table demonstration tests were conducted on a 1:2-scale 3-story concrete building model that was subjected to the 1999 Chi-Chi earthquake accelerogram recorded at station TCU052 anchored at 0.8

g peak table acceleration with obvious near-fault velocity pulses (1.3 m/s) and static fling steps (1.8 m). On the other hand, BATS tested a high-damping rubber bearing at a loading rate of 0.25 Hz lasting for three complete loading cycles and 400 mm maximum deformation was reached.

The Grand Opening Forum (<http://go.ncree.org/gof/>) was held on August 9–10 under the joint efforts of the NCREE and NCKU Civil Engineering Department; it comprised three plenary session topics: (1) structural safety under near-fault and/or multiple hazards (earthquake, wind, flood, fire, etc.) threats, and disaster mitigation strategies and technologies for enhancing resilience; (2) innovative experimental technologies and numerical simulation methods; (3) lessons learned from disastrous earthquakes. The forum attracted some 235 participants worldwide. To facilitate experimental technology innovation, MTS and NCREE jointly staged the first MTS Worldwide Seismic Solutions Users Group Meeting on August 7–8 at Shangri La's Far Eastern Plaza Hotel Tainan, and will continue to work closely together to advance experimental technologies through their strategic partnership. The purpose of the international forum is therefore two-fold: first, to celebrate the grand opening of the NCREE Tainan Laboratory; second, to envision research needs in the near future by assimilating opinions and recommendations collected from world-leading experts and professors to ultimately reach community resilience under near-fault and multiple-hazards threats; in this regard, a proceedings publication from the forum will become the most up-to-date reference to guide the future research of the NCREE Tainan Laboratory, and its collaborations with domestic as well as international researchers in the upcoming years.



Fig. 1. Dr. Jack Moehle (Member of the US National Academy of Engineering, and Wilson Presidential Professor of Structural Engineering at University of California, Berkeley) delivered a keynote speech entitled “Earthquake Simulation and Near-Fault Ground Motions” at the Forum

MTS Worldwide Seismic Solutions Users Group Meeting

Kung-Juin Wang, Technologist, NCREE

Since the inauguration of the research building of National Center for Research on Earthquake Engineering (NCREE) in 1998, its laboratory has contributed tremendously to the domestic and international communities of earthquake engineering by carrying out numerous large or even full-scale structural tests. The most important testing facilities in NCREE laboratory include the tri-axial seismic simulator, the reaction wall and strong floor test system, the test system for energy dissipation devices, and the multi-axial testing system (MATS). All these testing systems use testing apparatus manufactured by MTS systems corporation. They include devices such as hydraulic actuators of all kinds, various actuator and testing facility controllers, and the fundamental hydraulic supply systems. The main reasons that MTS equipment is widely used in NCREE include: (1) the performance quality of MTS equipment is widely considered high, and (2) MTS holds a long-term corporation relationship with NCREE in not only customizing the equipment for NCREE's specific needs but also investing human and hardware resources to jointly develop testing technologies with NCREE. In the past, NCREE and MTS have collaborated together in several development projects, including developing a software program that supports two-dimensional pseudo-dynamic testing (PDT) for 3D frame structures and the technology of SDOF real-time PDT as well as working jointly in designing and building MATS.

The NCREE Tainan laboratory officially came into operation on August 9th, 2017 with a grand opening ceremony. Many prestigious domestic and international experts in the field of earthquake engineering were invited to celebrate the opening and to jointly envision the possible research directions in the near future. MTS just hosted the first worldwide seismic solution users group meeting in the Tainan City on 7th August 2017. In this two-day meeting, from 13 countries of Asia, Europe, and North America, 71 world renowned individuals from both the academic and industrial fields attended this meeting. Its main objective is to provide a platform that facilitates exchange of experiences of using MTS equipment and to share the advancement of the latest developed test technologies. After two introductory remarks given by the MTS President Steve Harrison and NCREE Director General Shyh-Jiann Hwang, technical presentations were given in this meeting.

Mr. Tim Zappia from MTS reviewed the evolution of the MTS seismic-related products, from the past to the present. In another presentation, he also gave an overview on the University of Nevada-Reno laboratory along with some of the advanced testing methodologies developed and used in that laboratory. Dr. K. J. Wang from NCREE presented a hybrid test on a steel panel damper substructure using MATS with the technique of online model updating. Dr. Alberto Pavese from EUCENTRE talked about advanced techniques on real-time hybrid simulation (RTHS) by jointly using the bearing tester and the structural testing systems. Senior Staff Engineer Brad

Thoen from MTS gave a presentation on the newly developed shake table controller "Specimen Dynamic Compensation" in which the iterative tuning process is not required to achieve good table control. He also gave another presentation on the modeling of the seismic systems using Simulink and MTS proprietary shake table control programs. Prof. G. Hemalathe from Karunya University talked about an experimental study on magnetorheological dampers for seismic application. Mr. H. L. Ko from MTS Korea introduced several pre-engineered seismic simulators available from MTS. Prof. Steve Mahin from University of California (UC), Berkeley talked about recent applications of using OpenSEES and OpenFresco to conduct real-time hybrid simulation using the bearing tester system "Seismic Response Modification Device" in UC San Diego. Another application of RTHS using the shake table in UC Berkeley was also presented. Dr. Shawn Yu from MTS introduced the software package available from MTS that supports real-time hybrid simulation. He also talked about some MTS customers' research results of hybrid tests using MTS equipment and the software package. Dr. Hitoshi Kumagai from Shimizu Construction Co. introduced the newly completed shaking table (E-Beetle) in Shimizu Corporation. He also addressed some characteristics of the 2016 Kumamoto earthquake. The ability of E-Beetle to reproduce the Kumamoto earthquake was also demonstrated. Senior Product Manager Jim Hennen from MTS talked about two newly developed computer programs that enhances test efficiency and prognoses the failure in hydraulic test systems.

After all the presentations were completed, all the attendees were divided into five small groups for interactive discussion. This meeting offered great opportunities for the researchers to share thoughts and experiences on new testing technologies and future research directions. It also allowed the academic and industrial experts to communicate face-to-face with MTS engineers regarding the challenges in seismic research and some of the possible technical support that MTS can provide in the future.



Fig. 1. All the attendees of the users group meeting

CSSE/CTSEE Joint Conference on Structural Control and Health Monitoring Technology

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Introduction

Many disastrous earthquakes occurred in the past decade, e.g., the 2011 Tohoku earthquake in Japan and the 2008 Wenchuan earthquake in China. These lessons not only awake again our suffering memory during the 1999 Chi-Chi earthquake but remind us of continuing developing aseismic technology. The National Center for Research on Earthquake Engineering (NCREE) was founded in 1998 and has been actively working on practical research and innovative technology. NCREE also plays an important role of communication bridges between governments, academia, and industry. Several well-prepared testing facilities in NCREE, including a shaking table, multiaxial testing system, damper testing system, and reaction wall, have been serving well academic and engineering communities in conducting various experiments. Recently, many countries that already play an important role in earthquake engineering, e.g., the U.S., Japan, and China, have been enhancing their testing capacities. In view of this, NCREE's second laboratory project was launched in 2002. After efforts of more than ten years, the construction was started in 2015. The structure and testing facilities were completed in 2017. The laboratory is officially named the "NCREE Tainan Laboratory". To share the gladness and this good news with scholars, engineers, and government officers, the Joint Conference on Structural Control and Health Monitoring Technology organized by the NCREE, the Chinese Society of Structural Engineering (CSSE), and the Chinese Taiwan Society for Earthquake Engineering (CTSSE) was held in the NCREE Tainan Laboratory on August 11, 2017. Many renowned domestic and international scholars and engineers were invited, and the enrollment was very enthusiastic (Figure 1).



Fig. 1. Group photo

Abstracts of Speeches

First, Professor Kazuhiko Kasai (Figure 2), who serves in Tokyo Institute of Technology, addressed a keynote speech regarding several past international collaborative experimental studies by using the world's largest shaking table together with some potential future research topics. Then, the other two keynote speakers, Professor Chin-Hsiung Loh and Professor Chi-Chang Lin, who correspondingly serve in the National Taiwan University and the Chung Hsing University, talked about

their advanced research results on structural health monitoring (SHM) by using the on-line subspace identification method and multiple tuned mass dampers (MTMDs), respectively. Afterward, several professors and researchers talked about their valuable research results on development and application of fluid dampers, development and experimental verification of leverage-type stiffness-controllable device (LSCMD) and piezoelectric friction-controllable device (PFCMD) systems, and the testing of seismic isolation and energy dissipation devices. In addition, several senior engineers shared their valuable experiences in seismic design isolation for a nuclear power plant (NPP) facility and a research center, application of viscoelastic (VE) dampers and SHM technology in a residential building, and a combined design of velocity- and displacement-dependent dampers. The speakers and audiences had a very enthusiastic discussion and communication, thus showing that it is a very successful conference. During this conference, Dr. Cho-Yen Yang and Dr. Wang-Chuen Lin also guided the audiences to visit the NCREE Tainan Laboratory.



Fig. 2. Keynote speech by Professor Kazuhiko Kasai

Touring of NCREE Tainan Laboratory

The NCREE Tainan Laboratory features two testing facilities (Figure 3), the 8 m × 8 m long stroke and high-speed earthquake simulator and bi-axial dynamic testing system (BATS). By means of the earthquake simulator, near-fault velocity pulse-like ground motion can be reproduced, and its effect on structural and non-structural designs can be thoroughly studied. By using BATS, performance tests and further research on full-scale seismic isolators can be conducted.



(a) BATS

(b) Earthquake simulator

Fig. 3. Testing facilities in NCREE Tainan Laboratory

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