Cover page

Title: **Introduction of The Taiwan National Center for Research on Earthquake Engineering**

Authors:

Prof. Keh-Chyuan Tsai (Presenter)
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0808
Fax: +886-2-6630-0858
E-mail: kctsai@ncree.org.tw
http://www.ncree.org.tw

Prof. Kuo-Chun Chang, Deputy Director, NCREE
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0866
Fax: +886-2-6630-0858
E-mail: kcchang@ncree.org.tw; ciekuo@ccms.ntu.edu.tw

Mr. Chien-Chih Hsu, Deputy Director, NCREE
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0855
Fax: +886-2-6630-0858
E-mail: cchsu@ncree.gov.tw

Dr. Lap-Loi Chung, Division Head, NCREE
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0800
Fax: +886-2-6630-0858
E-mail:chung@ncree.gov.tw

Dr. Chin-Hsun Yeh, Division Head, NCREE
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0900
Fax: +886-2-6630-0858
E-mail: chyeh@ncree.org.tw

Ms. Tsu-Hui Huang (Contact person)
National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhar Rd., Taipei 106, Taiwan
Phone: +886-2-6630-0810
Fax: +886-2-6630-0858
E-mail: thhuang@ncree.org.tw

Introduction of The Taiwan
National Center for Research on Earthquake Engineering

Keh-Chyuan Tsai, Kuo-Chun Chang, Chien-Chih Hsu
Lap-Loi Chung and Chin-Hsun Yeh

ABSTRACT

Future disastrous earthquakes are inevitable in Taiwan. To reduce the risk of seismic disaster, the National Center for Research on Earthquake Engineering (NCREE) was officially established in 1990 with the joint effort of the National Science Council (NSC) and the National Taiwan University (NTU). NCREE brings together academic resources and researchers to carry out joint projects on pre-earthquake preparedness, emergency response, and post-earthquake recovery. The NCREE has one of the world largest earthquake simulation laboratories, equipped with state-of-the-art shaking table, servo-hydraulic actuators, a large strong floor area and two-directional reaction walls, capable of accommodating large or full scale earthquake simulation tests. In this paper, the background, objectives, missions, organization, facilities and recent research activities of NCREE are described.

Keh-Chyuan Tsai, Director of National Center for Research on Earthquake Engineering (NCREE), 200 Section 3 Xinhai Rd., Taipei 106, Taiwan
Kuo-Chun Chang, Deputy Director of NCREE
Chien-Chih Hsu, Deputy Director of NCREE
Lap-Loi Chung, Division Head of NCREE
Chin-Hsun Yeh, Division Head of NCREE

BACKGROUND

Located in one of the most active seismic regions in the world, Taiwan suffers from frequent earthquakes caused by the Circum Pacific Seismic Belt. In fact, about twenty disastrous earthquakes have been recorded in the history of Taiwan. Occurrence of such strong earthquakes is an inevitable aspect of Taiwan's future. To reduce the risk of seismic disaster, appropriate seismic design should be taken into consideration for all new and existing civil infrastructures to ensure sufficient resistance against strong ground shaking. With the joint effort of the Taiwan National Science Council (NSC) and the National Taiwan University (NTU), the National Center for Research on Earthquake Engineering (NCREE) was officially established in 1990. In order to enhance the administrative efficiency and technical performance of several national research laboratories which belong to the NSC, the National Applied Research Laboratories (NARL) was established in June, 2003. Since then, NCREE has become a non-profit organization and is one of the six laboratories in NARL

OBJECTIVES

In accordance with the needs for pre-earthquake preparedness, emergency response, and post-earthquake recovery, NCREE brings together Taiwan national academic resources and researchers to carry out joint projects to advance earthquake engineering technologies and to reduce life and property losses in earthquakes. NCREE also actively promote international collaborations in selected fields to initiate consolidation and innovation in academic research and engineering practice. Consequently, it may promote Taiwan's academic excellence, and make contributions on the advancement of earthquake hazard mitigation. It is hoped that NCREE will become a well known national and international earthquake engineering research center through its modern large-scale experimental facilities, newly developed experimental technologies, highly skillful technical supports and up-to-date earthquake database.

MISSIONS

With an aim to promote innovation and integration of national earthquake engineering research and to transfer the state-of-the-art technologies to the industry, NCREE unites researchers and practicing professionals to integrate knowledge and expertise with the computational and experimental facilities in earthquake-related fields, and to participate in the basic and applied research that resolves critical seismic engineering issues. As such, the missions of the NCREE include:

- Planning, integration, facilitation and implementation of multidisciplinary research projects on earthquake engineering.
- Operation and management of large scale structural laboratories and implementation of related experiments.
- Distribution and dissemination of information collected and research findings in the fields of earthquake engineering.
- Facilitation of region-dependent seismic design codes suitable for civil infrastructure systems and engineered structures in Taiwan, and new construction methods to reduce earthquake hazard.
- Assessment of earthquake-induced loss through computational simulations.

- Miscellaneous duties such as earthquake reconnaissance and international collaborations.

ORGANIZATION, HUMAN RESOURCES AND BUDGET

The management group at NCREE consists of a director, two deputy directors and ten division heads. The administrative missions and research projects are supervised by the management group. The ten divisions include:

- Administration Division
- Planning & Dissemination Division
- Experimental Technology Division
- Information Management Division
- Geotechnical & Strong Ground Motion Division
- Building Engineering Division
- Bridge Engineering Division
- Structural Control Division
- Earthquake Disaster Simulation Division
- Branch Laboratory in Southern Taiwan

The latter six divisions are integrated into the research and development group. However, they are not limited to the currently assigned research topics. In order to maintain the flexibility to fulfill state-of-the-art research missions, these divisions can be rearranged to meet the specific requirements. For example, Branch Laboratory in Southern Taiwan was recently established balance regional resources in Taiwan.

NCREE currently employs 72 people. 20 (about 28%) of them have Ph.D. degree and 39 (about 54%) have master degree. The total income in 2004 is NT$176,880,000 dollars. 76% of the total income is the approved annual budget from the National Science Council; the remaining 24% comes from research projects and technical services sponsored by the National Science Council, Ministry of Transportation, Ministry of Interior, and other public or private organizations.

FACILITIES

Shaking Table

The earthquake simulator at NCREE can simulate earthquake ground motions in six degrees of freedom, i.e. three translational components and three rotational components. Most historical earthquake records can be reproduced by the seismic simulator at NCREE.

The shaking table is 5m × 5m and has a mass of 27 tons. Test specimen with a maximum payload of 50 tons can be accommodated on the table. The shaking table's boxed-shape provides large bending and torsional stiffness, even with its limited mass. The shaking table is shown in Figure 1 with a typical specimen.

The shaking table is driven by 4 actuators on each axis, totaling 12 hydraulic actuators in all. The hydraulic power is driven by 2 electrical pumps and 3 diesel pumps, which offer a total flow rate of 1,235 gpm with a working pressure of 210 kg/cm^2. The weight of the shaking table and the test specimen is balanced by 4 static supports.

The reaction forces of the actuators are balanced by the reaction mass which is 16 m (length) × 16 m (width) × 7.6 m (height) in dimension and about 4,000 tons in mass. In order to further improve the testing environment quality, the reaction mass is isolated from the fixed foundation by 96 air springs and 80 dampers.

Figure 1. The shaking Table and a typical frame structure specimen

Reaction Wall

The reaction wall and strong floor provides the capability to test multiple large-scale structural experiments. The wall can be used to perform large or full scale seismic tests by using various experimental methods, such as traditional quasi-static tests, cyclic loading tests and pseudo-dynamic tests.

The L-shaped reaction wall in NCREE uses a cell type design with stepwise arrangement of wall heights of 15 m, 12 m, 9 m and 6 m and the respective wall width of 15.5 m, 15.5 m, 12 m and 12 m. The reaction wall consists of two 1.2 m thick post-tensioned reinforced concrete plates, which are parallel at a centerline distance of 2.6 m, and are stiffened with an additional 0.4 m thick reinforced concrete plate between each block at an interval of 3 m. The strong floor was designed as a reinforced concrete slab which has a size of 60 m × 29 m×1.2 m. The specified compressive strength of the concrete for both the reaction wall and the strong floor is 350 kg/cm^2.

There are 18 sets of static hydraulic actuators and 6 sets of dynamic hydraulic actuators in this laboratory. Five hydraulic hard-line ports are conveniently located in the reaction wall and strong floor. These ports provide for a total of 1,325 gpm hydraulic power supply and return as a drain line. The working pressure for the hydraulic system is 210 kg/cm2. An overhead view of the reaction wall is shown in Figure 2.

Figure 2. Overview of the reaction wall

RECENT RESEARCH ACTIVITIES

Most recent research topics include, but not limited to, the following:

Experimental Technology Studies

- Collaborative experiment technology using the internet
- Application of optical fiber sensors in civil engineering structures

Earthquake Scenario Studies

- Establishment and application of geotechnical earth science hazard database
- Most probable and historical earthquake ground motion simulation
- Establishment of hazards consistent with earthquake scenarios and its applications
- Development of Taiwan seismic scenario database and its applications

Geotechnical and Strong Ground Motion Studies

- Studies on earthquake prediction models
- Establishment of geological databases for strong motion stations of the Central Weather Bureau
- Seismic behavior investigation of the large bi-axial shear box on the shaking table

Building Engineering Studies

- Seismic evaluation and retrofit technologies of existing buildings
- Development of advanced innovative construction technology
    1. Studies on post-tensioned seismic structural systems
    2. Development of smart concrete wall structures with shape memory alloy (SMA) wires
- Revision of building seismic design codes

Bridge Engineering Studies

- Seismic performance-based design of bearing system in bridges
- Seismic evaluation and retrofit technologies of existing bridges

Structural Control and System Identification Studies
- Studies on structural health monitoring and structural control
- Seismic mitigation strategies for high-tech industrial structures

Information Technology Studies
- Establishment of an earthquake engineering database
- Integration of numerical and experimental simulation

Figure 3 through 11 highlight a few of the many research projects that are conducted at NCREE.

Figure 3. Seismic Retrofit of Full-Scale Bridge Columns

Figure 4. Columns Full-Scale Pseudo-Dynamic Tests of a Buckling Restrained Braced Frame

Seismic Retrofit of Full-Scale Bridge Columns: After eleven 0.4 scale rectangular RC bridge specimens were tested, as shown in Figure 3, one full-scale specimen containing a octagonal steel jacket retrofit lap splice was tested in order to verify its seismic performance. Test results confirmed that octagonal steel jacketing scheme is cost-effective and can provide lateral confinement and strength to mitigate seismic failures of rectangular RC bridge columns due to a lack of lateral confinement, improper lap-splice length or inadequate shear capacity.

Full-Scale Pseudo-Dynamic Tests of A Buckling Restrained Braced Frame: This experiment provides great opportunities to explore international collaboration and data archiving envisioned for the Networked Earthquake Engineering Simulation (NEES) or the Internet-based Simulations for Earthquake Engineering (ISEE) research programs launched in the United State and Taiwan. During the full-scale frame test, ISEE was applied to allow remote participants witness the real time video images of the specimen in the laboratory as well as the digital response data through the Internet.

Figure 5. Collapse Test of RC Columns

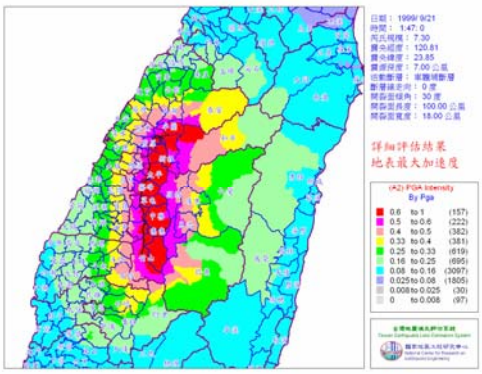

Figure 6. Taiwan Earthquake Loss Estimation Systems (TELES)

Collapse Test of RC Columns: The next generation seismic design at the 2/50 hazard level has required consideration of post-peak structural behavior. The world's first time ever shake table tests on dynamic gravity load collapse of RC columns were conducted in May 2004. Image processing techniques were employed to monitor large displacements of test specimens. Figure 5 shows the collapse test specimen.

Taiwan Earthquake Loss Estimation Systems (TELES): NCREE has developed TELES as shown in Figure 6 to aid in seismic disaster mitigation plans and emergency response strategies. The figure shows PGA estimates due to Chelongpu fault (indicated by thick black line), which ruptured during the 1999 Chi-Chi earthquake. This Loss estimation system can model several different ground motion characteristics such as those produced on the hanging-wall and the foot wall.

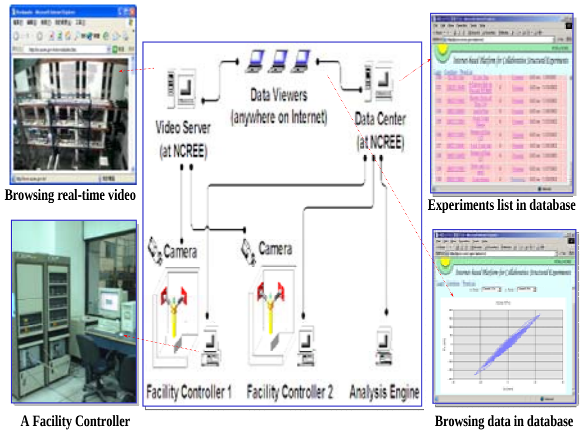

Figure 7. ISEE Experiment Platform

Figure 8. Large-Scale Laminar Bi-axial Shear Box Tests on Shaking Table

ISEE Experiment Platform: An Internet-based experiment platform, named ISEE (Internet-based Simulation for Earthquake Engineering) is prototyped as shown in Figure 7. Collaborative experiments among geographically distributed laboratories can be conducted through this network. A series of networked experiments between the NCREE Lab and the NTU Lab and simulation of transnational experiments have been completed and the feasibility of the ISEE for future networked collaborative experiments on earthquake engineering has been validated.

Large-Scale Laminar Bi-axial Shear Box Tests on Shaking Table: For the study of the soil behavior under earthquake shaking, a physical model test using a large laminar shear box on the shaking table at NCREE has been developed as shown in Figure 8. The preliminary test results show that the performance of the biaxial shear box is outstanding. The associated shear box will be used in future studies to study problems associated with soil liquefaction, strong ground motions, and soil-structure-interaction during earthquakes.

Figure 9.The IDEERS Competition

Figure 10. Seismic Evaluation and Retrofit of School Buildings

The IDEERS Competition: 'Introduction and Demonstration on Earthquake Engineering Research in Schools' IDEERS aims to draw young students' interest in structural engineering and related research. The challenge is for high school, undergraduate and postgraduate students to design and construct a small-scaled model of a building to withstand an artificial earthquake generated by the shaking-table at NCREE. Figure 9 shows the IDEERS competition at NCREE.

Seismic Evaluation and Retrofit of School Buildings: Deficiency of seismic performance is still a common problem for primary and secondary schools buildings. In order to prevent disastrous casualties and utilize these buildings as emergency shelters, their seismic performance is important. The main purpose of this research is to understand the behavior of typical primary and secondary school structure under earthquake loadings in Taiwan. Figure 10 shows such an experimental specimen.

Figure 11. Semi-active Controlled Base-isolation System with HDRB and MR damper:

Semi-active Controlled Base-isolation System with HDRB and MR damper: This experimental study investigates performance of a 24-ton mass that is supported by a semi-actively controlled base-isolation system. The hybrid isolator includes four HDRBs and a 30-ton MR damper as shown in Figure 11. According to the experiment results, the benefit of a semi-active controllable damper in a base-isolation system is obvious, especially when a near-field earthquake occurs.

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National Center for Research on Earthquake Engineering (NCREE)
200 Section 3 Xinhai Rd., Taipei 106, Taiwan
Tel: +886-2-6630-0888; Fax: +886-2-6630-0858
http://www.ncree.org.tw
Director: Prof. Keh-Chyuan Tsai
Contact Person: Ms. Tsu-Hui Huang, Email:thhuang@ncree.org.tw