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Introduction to Construction Work of NCREE Tainan Laboratory

Fu-Pei Hsiao, Research Fellow NCREE

The near-fault effect on buildings and infrastructures is a significant issue of human life and property in Taiwan because there are numerous active faults inside this island. It is well-known that special characteristics with large displacement and high velocity can be observed close to a near-fault. However, it is difficult to reproduce such a near-fault earthquake record by using the existing test facilities of National Center for Research on Earthquake Engineering (NCREE). Thus, the experimental studies on the near-fault effect are rare. The National Applied Research laboratories established NCREE Tainan Laboratory to include a high performance 8m×8m six degree-of-freedom seismic simulation testing system. This new facility can simulate the near-fault motions with large displacement and fast speed. In the future, NCREE can provide better seismic experimental services to the government agencies, the academia and the industry, which is beneficial to improving public safety against earthquake disasters.

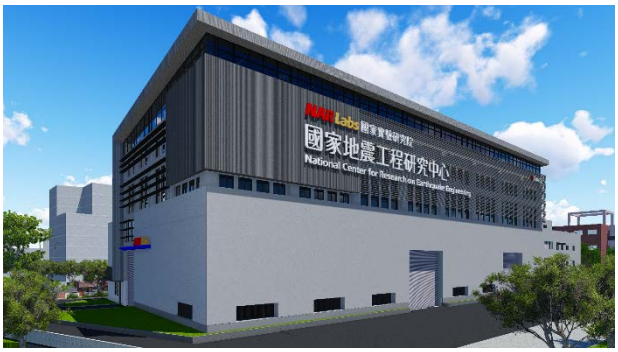
NCREE Tainan Laboratory located at the eastern part of the Gueiren Campus of National Cheng Kung University (NCKU) in Tainan City. The NCREE Tainan Laboratory is include a research building and a laboratory building. The research building is a three-story Reinforcement Concrete building with one-story basement, as shown in Fig. 1. The construction work of NCREE Tainan Laboratory is process by a turnkey project. The contractor of the turnkey project is the Formosa Builders Inc.. The turnkey project is assisted by Sinotech Engineering Consultants, Ltd. with professional construction management (PCM) and construction supervision.



(a) Western view of Tainan Laboratory



(b) Southern view of Tainan Laboratory



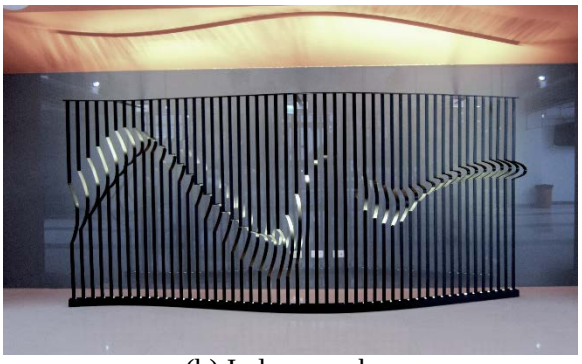
(c) Eastern view of Tainan Laboratory

Fig. 1. 3D design drawings of NCREE Tainan Laboratory

NCREE Tainan Laboratory also contained two pieces of public art works (as shown in Fig. 2), entitled “Within The Wave.” The public art is included an outdoor work, an indoor work, and a series of activities of public participation. The outdoor and indoor works are based on a dialogue with seismic waves and transforming them into works of art. Seismic waves were detected and recorded on the paper by seismometers. The artist collected these recordings (lines) of seismic waves. Line to plane: to create this serious of artwork. Especially, the outdoor work is composed of vertical and horizontal seismic waves transformed into the street furniture.



(a) Outdoor work



(b) Indoor work

Fig. 2. The public art in NCREE Tainan Laborator

The construction work of NCREE Tainan Laboratory was started from July 2015. All construction work of NCREE Tainan Laboratory was finished and the Building Use permit is got in November 2016, as shown in Fig. 3. After the new experimental facilities on NCREE Tainan Laboratory is completed in the first quarter of 2017, NCREE can provide better seismic experimental services to government agencies, academia, and industry, which are beneficial to improving public safety during earthquake disasters.



(a) Western view of Tainan Laboratory



(b) Southern view of Tainan Laboratory



(c) Eastern view of Tainan Laboratory

Fig. 3. Photos of NCREE Tainan Laboratory

Testing and Verification of Pile Foundation Design

Jiunn-Shyang Chiou, National Taiwan University
Hsuan-Chih Yang and Shang-Yi Hsu, Associate Researcher, NCREE.

Introduction

The second facility of the National Center for Research on Earthquake Engineering is located at National Cheng Kung University's Guiren campus. The excavation depth of this building is about 5.8 m. The geological composition of the base is mainly unconsolidated sediments with gravel, sand, and mud.

Foundation Design and Verification

The foundation of the building is designed with a bored precast concrete (PC) pile. This method, which involves installing a PC pile into the formation, can avoid impact noise and vibration during the construction process. The pile diameter is 50 cm. The lengths of the piles are designed to be 18 m, 23 m, 28 m, and 33 m in different conditions.

To confirm the bearing capacity of the foundation piles and the applicability of the foundation design, a pile ultimate loading test was conducted on site. The test included vertical loading tests (TPL1 and TPL2) and a lateral loading test (TPL2).

The length of the TPL1 pile was 27.5 m, with 6.5 m extending into the bedrock. The lead section length was 4.65 m. The maximum vertical test load was 435 T. The length of the TPL2 pile was 37 m, with 9.2 m extending into the bedrock. The lead length of the pile was 8.95 m. The maximum vertical test load was 435 T. The TPL2 pile was used to investigate the lateral limit loading. The maximum test load was 24 T. The test photos are shown in Fig. 1. Figs. 2 and 3 show the loading and pile-head displacement curves in the vertical test and the lateral test, respectively.

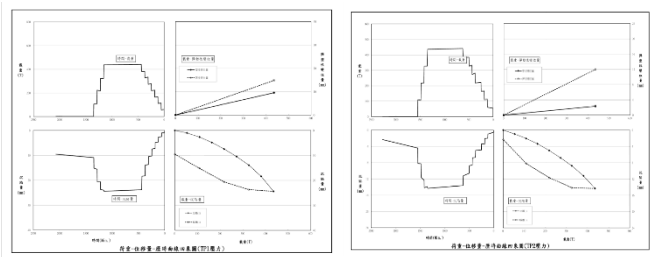


(a) Vertical (b) Lateral

Fig. 1. The ultimate loading test of PC piles

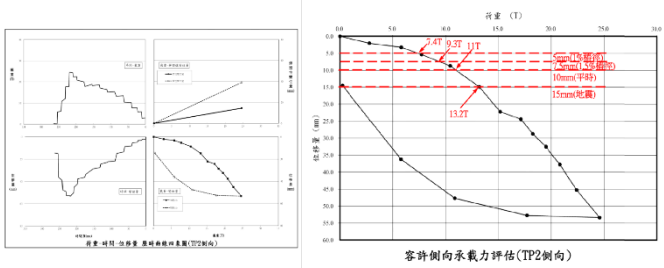
According to the design code for the foundation of the building, the allowable lateral displacement of the pile head is 1 cm for normal conditions and 1.5 cm for seismic conditions. However, the diameter of the pile used in this project was smaller than 1–2 m in the general pile. Therefore, it is suggested to adopt a 1% pile diameter and a 1.5% pile diameter to represent the allowable lateral displacements at normal and seismic conditions, respectively. The corresponding allowable lateral bearing forces for the normal and seismic conditions were 7.4 T and 9.3 T, respectively.

To analyze the impedance of the pile, the curve of the pile was used to determine the spring stiffness. The slope of the secant of the 1% pile diameter was used to determine the stiffness of the pile spring. Figure 4 shows the vertical stiffness of the pile. The TPL1 and TPL2 test results were 33000 T/m and 43850 T/m in the vertical direction. The lateral stiffness of the pile was 1520 T/m from the TPL2 test.



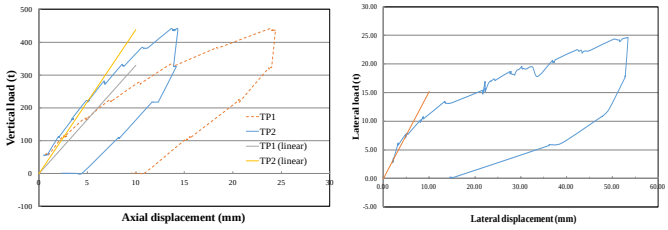
(a) TPL1 (b) TPL2

Fig. 2. Results of the vertical ultimate loading test



(a) Duration curves (b) Lateral bearing capacity

Fig. 3. Results of the lateral ultimate loading test



(a) Vetrical (b) Lateral

Fig. 4. Stiffness of the pile foundation

Conclusion

Foundation engineering is an important process during construction. The design rationalization must consider the in-site geological conditions and the construction conditions. The colleagues of the geotechnical division of NCREE joined together from the design and planning stages to verify and confirm all of the processes. According to the results and the analysis of the ultimate loading test, the stiffness parameters of the pile head were obtained and as used as feedback for the structural analysis.

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Strong Floor Design Investigation and Construction Process

Ren-Zuo Wang, Associate Researcher, Fu-Pei Hsiao, Research Fellow NCREE

Introduction

In the National Applied Research Laboratory, second experimental facility building of the National Center for Research on Earthquake Engineering (NCREE) at the Guilin Campus of National Cheng Kung University (Tseung Kwan Yan Road, Tainan City) is constructed with a strong floor 72 m in length and 28.2 m in width.

Strong Floor Construction Process

The NCREE Tainan laboratory has been built for this year. This laboratory is to build the strong floor with length, width, and thickness of 34.3 m, 21.5 m, and 1.2 m, respectively, and 10 shear walls (50 cm thick with a spacing of 250 cm). It can be used to serve and support many researches and technological developments of earthquake engineering. These strong floors were embedded in the 595 sets of casings (which contained some kind of rack).

The strength of strong floor using the high-performance concrete (HPC) is 560 kgf at 56 days. The HPC was poured twice to produce two layers, each 60 cm in height. Figure 1a shows the pre-buried strong floor-embedded casing of the rack. Figure 1b shows the strong floor before grouting. Figure 1c shows the grouting process of the strong floor. Figure 1d shows the strong floor after completion.

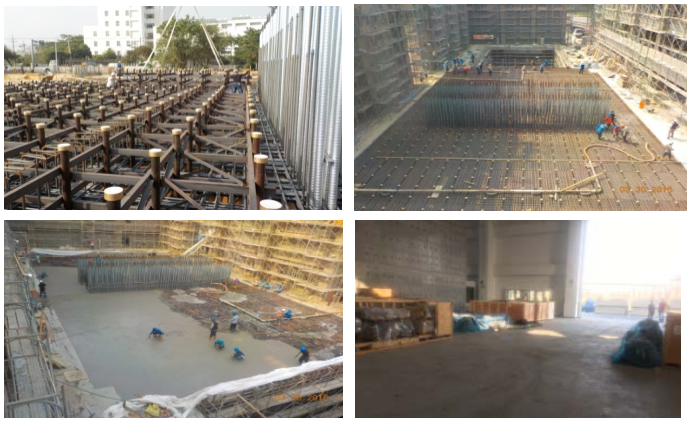


Fig. 1. Construction of the strong floor: (a) strong floor-embedded casing of the rack (top left), (b) strong floor before grouting (top right), (c) strong floor on grouting (bottom left), (d) completion of strong floor (bottom right)

Strong Floor Design

Figure 2a shows the results from computing the deformations of the strong floor using LS-DYNA software. In order to build the FEM of the strong floor, a solid element was constructed. The design concept of the floor considered a 100-ton loading applied perpendicular to the floor at intervals of 3 m in both horizontal directions of the strong floor. The reaction wall is subjected to uniform loading of the horizontal forces under extreme loading conditions. In addition, the strong floor is subjected to uniform loading from vertical forces. Figure 2b shows the simulated maximum bending moments between the strong floor and the reaction wall. The horizontal force is 2040/12 (m) = 170 tf/m^2, while the strong floor experienced 100/(3*3) = 11.1 tf/m^2 of vertical load.

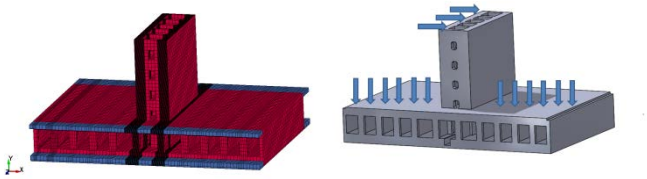


Fig. 2. Finite element model of the strong floor (left) and reaction wall under extreme loading conditions (right)

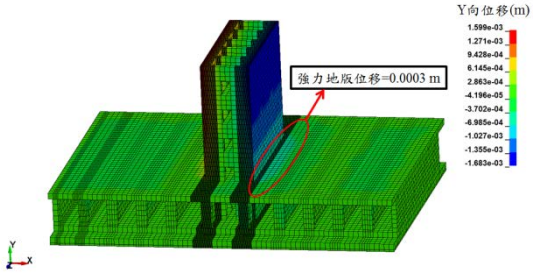
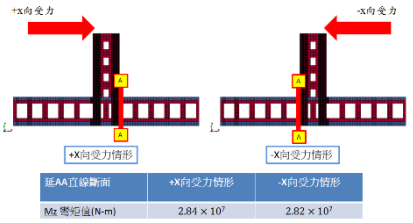


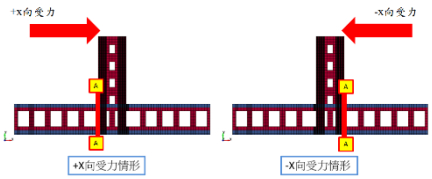
Fig. 3. Maximum displacement of strong floor

Under extreme loading conditions, the reaction wall was applied with the +X and –X directions, calculated the maximum bending moment of the strong floor, in accordance to the maximum bending moment then designed reasonable amount of steel reinforcement. Figures 4 and 5 show the maximum strength of the floor position under the bending moment, checked the results of the current floor design of the steel reinforcement can met the strength requirements.



延AA直線斷面	+X向受力情形	-X向受力情形
Mz 彎矩值(N-m)	2.84×10^7	2.82×10^7

Fig. 4. The maximum positive bending moment of the strong floor



延AA直線斷面	+X向受力情形	-X向受力情形
Mz 彎矩值(N-m)	-3.18×10^7	-2.83×10^7

Fig. 5. The maximum negative bending moment of the strong floor

Design and Verification of Reaction Wall and Construction Course

Chia-Chuan Hsu and Te-Kuang Chow, Assistant Researcher NCREE

NCREE is building a second experimental facilities building in the Guiyin District of National Cheng Kung University. The wall is composed of two 1.2 m and six 0.5 m thick (15 m long × 5 m width × 2 m high) reaction walls (Fig. 1). The spacers are provided at regular intervals and the hollow section of the box section can provide access to personnel. The main functionality of the reaction wall is provided by a fixed hydraulic system. The pressurized hydraulic system provides a reaction force when the test force is applied.



Fig. 1. Reaction wall

The main components of the reaction wall are # 10 @ 25m, # 4 tendons, two 120 cm walls, and six 50 cm walls. The concrete is composed of 8000 psi-SCC. The concrete is reinforced with 36 mm diameter pre-stressed steel bars, organized in 492 groups. It also has a vertical pre-force steel base and a sample rack for 578 groups. Construction began by the end of 2015. The work items include pre-stressed steel bar construction steel sets, sample frame construction, template group stand, steel construction, concrete pouring, etc. It also includes materials and construction inspection procedures to ensure their quality. To date, the reaction wall with all structural items and the pre-force to pre-stressed steel bars (shown as Fig. 2) have been completed.



Fig. 2. Pre-stressed steel bar

The reaction wall was verified using ABAQUS finite element software. The main items checked includes the tensile stress of the reinforcement, the deflection stress of the concrete, and the stiffness of the reaction wall structure. The meshed model of the reaction wall is shown in Fig. 3.

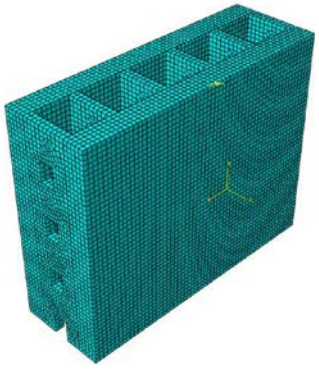


Fig. 3. Meshed model of the reaction wall

The verified result is shown in Fig. 4. The maximum deflection stress is 74.021 kgf/cm^2 (shall not exceed the maximum allowable deflection stress 0.45 f'c = 252 kgf/cm^2); the Von Mises stress of the bottom reinforcement is 336.608 kgf/cm^2 (shall not exceed the maximum allowable tensile stress 1600 kgf/ cm^2); the maximum angular deformation can be calculated by the maximum displacement of the top of structure (0.004948 m) and the height of the reaction wall (12 m), which is 0.004948/12 = 1/2425 (shall not exceed 1/1000).

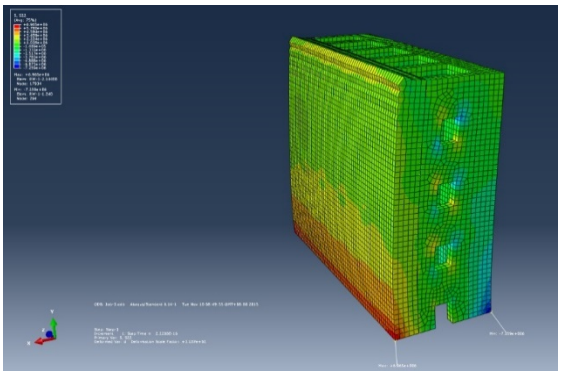


Fig. 4. Result of the analysis of the reaction wall

Design and Construction of the Floating Foundation for the Shaking Table System

Chiun-Lin Wu, Research Fellow, Tsung-Chih Chiou, Associate Researcher, NCREE
Hu-Jhong Lu and Che-Yu Chang, Assistant Researcher NCREE

Introduction

For the Tainan Laboratory of the National Center for Research on Earthquake Engineering, one of the major pieces of equipment is the advanced tri-axial seismic simulator. Seismic simulation tests conducted by this type of apparatus will illustrate the structural dynamic behavior and reactions in a way that will further enhance and improve our understanding of and contribution to structural safety studies and issues. The reaction mass of the seismic simulator is located under the shaking table and provides reaction forces to the actuators during testing. Figure 1 shows the plan view and a 3-D view of the reaction mass. The reaction mass is made of concrete and weighs approximately 10 times more than the shaking table and the specimens. The reaction mass is 19.9 m in length, 14.9 m in width, and 8.96 m in height, and weighs about 3,992 tons with a compression strength of 560 kg/cm^2, a unit weight of 2.4 tons/m^3, and a Young's modulus of 354965 kg/cm^2. There are four vertical static actuators supporting the shaking table, and additional four actuators in each of the three directions to stimulate tri-axial forces. To reduce the vibrations transmitted beyond the site and lower the impact on the surrounding environment, 120 air springs and 240 dampers are utilized to support the reaction mass.

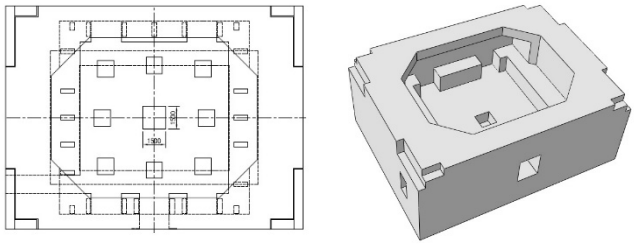


Fig. 1. Plan view and 3-D view of the reaction mass.

Reaction Mass Analysis

The reaction mass analysis is conducted using a finite element model with 12 loading cases. Such an analysis takes into consideration of factors such as the condition/functionality of the air springs, the static actuator supports, and the dampers, the changes in the shaking table position, and the tri-axial loading actuators' maximum reaction forces. Static linear analysis is performed for observing whether the stress produced exceeds the concrete strength and safety limits. Figure 2 shows the reaction mass finite element model results of the stress produced under the maximum horizontal forces. The maximum stress is within the safety limit. The analysis results of all 12 cases showed no safety concerns. The structural design is produced based on these analysis results, and additional reinforcements are added where significant geometry changes occur for safety assurance.

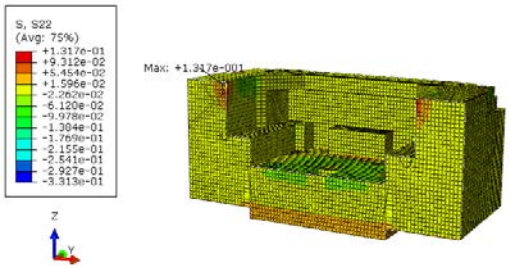


Fig. 2. Results of the stress analysis

Construction

The concrete reaction mass is constructed via four pouring steps. The pouring process proceeded from elevation −8900 mm to −8155 mm, −8155 mm to −5390 mm, −5390 mm to −3540 mm, and −3540 mm to +60 mm with pouring volumes of 52.15 m^3, 810.78 m^3, 322.86 m^3, and 467.10 m^3, respectively. Corresponding guidance is followed for the mass concrete construction while the temperature between the surface and core mass concrete is monitored. Figure 4 shows the photos taken throughout the reaction mass construction.

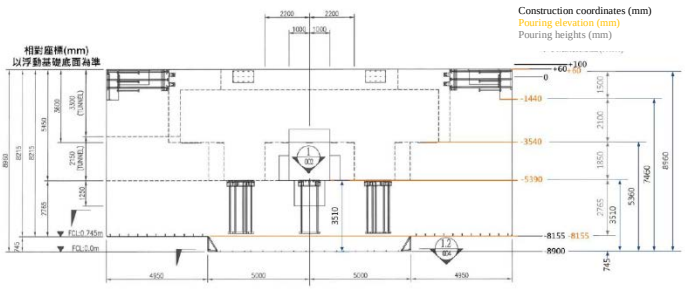
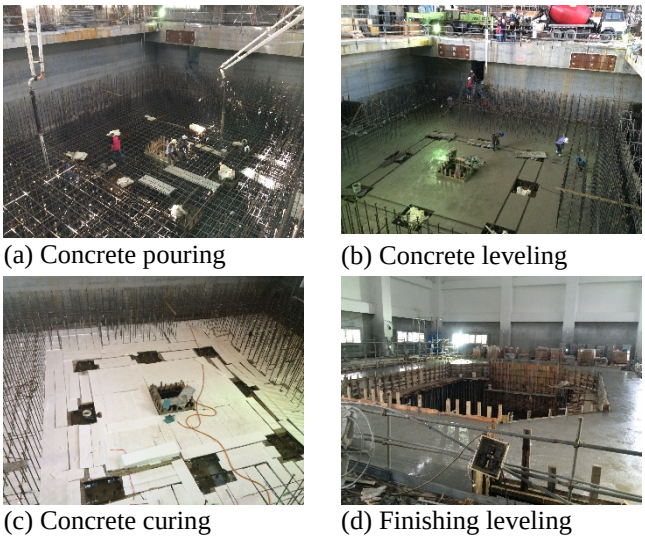


Fig. 3. Pouring plan for the concrete reaction mass.



(a) Concrete pouring (b) Concrete leveling

(c) Concrete curing (d) Finishing leveling

Fig. 4. Photos of the reaction mass construction.

Workshop on the International Training Program for Seismic Design of Structures 2016

Chia-Chuan Hsu, Assistant Researcher NCREE

Recent major earthquakes around the Pacific Rim resulted in loss of life and serious property damage. In order to promote seismic design technology to mitigate the seismic hazard of the high-seismicity regions of the Pacific Rim, such as in South-East Asia and Latin America, the Ministry of Science and Technology (MOST) of Taiwan has continuously sponsored the National Center for Research on Earthquake Engineering (NCREE) to hold the International Training Program for Seismic Design of Structures (ITP). This training program allows the participants from the mentioned areas to learn about the research and practices on earthquake engineering in Taiwan, to exchange their ideas, and to share their experiences.

The ITP has been held annually since 2002. A total of 439 participants from 23 different countries have attended the training programs from 2002 to 2015. The ITP 2016 was held on October 17–21, 2016 at NCREE. In total, 19 technical lectures were scheduled in this program, including topics on earthquake engineering and seismic hazard analysis, lessons learned from past earthquakes, seismic evaluation and loss estimation, structural design and health monitoring, introduction and application of seismic control and retrofit, early earthquake warning systems, seismic loss analysis, and the latest research programs conducted at NCREE. Twenty two participants from Indonesia, Malaysia, El Salvador, Nicaragua, Vietnam, Laos, Haiti, India, the Philippines, and Thailand successfully completed all the courses.

NCREE would like to express the sincerest appreciation for the efforts devoted by all the instructors. The financial support provided by the National Science Council of Taiwan is also gratefully acknowledged. We believe that this training program is successful in strengthening international friendship as well as in sharing experiences on earthquake hazard mitigation.



Introduction and Demonstrating Earthquake Engineering Research in Schools (IDEERS) 2016

Mu-Hsuan Li, Technologist, NCREE

The sixteenth annual Introducing and Demonstrating Earthquake Engineering Research in Schools (IDEERS) competition was held thanks to the efforts of the National Applied Research Laboratories (NARLabs), the National Center for Research on Earthquake Engineering (NCREE), and the British Council (BC), on September 9–11, 2016. A total of 13 graduate teams, 49 undergraduate teams, and 42 high school teams participated in the IDEERS modeling and testing event this year. The foreign teams came from United Kingdom, Australia, New Zealand, Korea, Indonesia, Malaysia, Hong Kong, Macao, the Philippines, Singapore, and Vietnam.

On September 10, participants were given 6.5 hours to complete their models using simple materials and tools, including long strips of wood, rectangular wooden base boards, PVC hot melt glue, rubber bands, and strings. The theme of this year's competition for high school teams was "Elevated First Floor". Each high school team had to construct a model that required the elevated first floor to resist strong ground motions. The theme of this year's competition for the undergraduate teams was to construct a leisure hotel within the assigned building site. There was no restriction on the shapes of floor plans, but an outdoor swimming pool was to be included at the top of the hotel. Every model of the high school teams and undergraduate teams had to resist strong ground motions from 250 cm/s^2 to 800 cm/s^2 while carrying loads of up to 26 kg. Meanwhile, the competition of the postgraduate teams was focused on how to apply advanced technologies to build a seismic structure with energy dissipation and/or seismic isolation. All models were ranked using the efficiency ratio (ER), which was computed based on the mass of the model itself, the number of mass blocks supported by the model, and the PGA eventually resisted by the model. The winner was the team whose model obtained the largest ER value.

Participating students showed their creativity with diverse types of structural designs. On September 11, after the opening ceremony, models were tested on a shaking table with earthquakes of different intensities. In the end, the Kaohsiung Industrial High School team won the first prize in the high school division, the National Taiwan University of Science and Technology team won the first prize in the undergraduate division, the National Taiwan University team won the first prize in the graduate division, and the National Chung Hsing University won the Innovation Award for Seismic Isolation and Energy Dissipation in the graduate division. More information about IDEERS is available at http://www.ncree.org/ideers/2016/..



Fig. 1. Models were tested on a shaking table

"Taiwan Earthquake Loss Estimation System" Seminar 2016

Chi-Hao Lin, Assistant Researcher, NCREE

The Taiwan Earthquake Loss Estimation System (TELES) is a software that integrates the natural, engineering, and humanities databases to develop earthquake damage assessment models. TELES can assist governments and public or private institutions to conduct earthquake scenario simulations and earthquake early seismic loss estimations to develop mitigation, response, and risk management strategies. On November 22, 2016, NCREE held the TELES seminar. The topics of the lecture included (1) reflections on the Meinong Earthquake in Kaohsiung, (2) the potential assessment of the ground motion, (3) the interpretation and application of soil liquefaction assessment, (4) the potentials and warning patterns of the regional landslides induced by rainfall, 5) the seismic evaluation and retrofitting of water pipelines, and (6) research and development of cloud services for earthquake disaster prevention and mitigation. The total number of participants in the seminar was about 80. Participants were from the Directorate General of Highways, the Taiwan Area National Freeway Bureau, the Construction and Planning Agency, the Taipei Water Department, the Taiwan Water Corporation, the City Fire Department, etc. With this seminar, TELES will be extended to multifaceted users and will learn valuable experiences from users who can facilitate the future application and development.



Symposium on Seismic Design Analysis of Structural Frames with Steel Panel Dampers or Buckling- restrained Braces

An-Chien Wu, Chao-Hsien Li, Assistant Researcher, NCREE

Stub columns and buckling-restrained braces (BRBs) can effectively provide lateral stiffness and resistance for a building structure, and so have been widely adopted in Taiwan. The latest research results related to the two devices were introduced in this symposium held on November 3, 2016. The proposed steel panel damper (SPD), which is recognized as a stub column, is composed of three segments with H-shaped cross-sections. The use of thicker webs at both end segments ensures that the end segments are elastic connection regions. The middle segment of an SPD is designed to absorb seismic energy through cyclic shear yielding of the web. This symposium introduced the seismic design, numerical simulation, fabrication methods, and cyclic test results of the proposed SPDs. The recommendations on the seismic design and analysis of steel moment-resisting frame equipped with SPD (SPD-MRF) were also proposed.

In addition, the implementation of BRBs in new RC buildings was presented. The BRBs in the proposed system are arranged in a zigzag configuration with adjacent BRBs sharing gusset plates attached to the side of the beam-column joints using a pre-cast steel bracket. Cyclic loading test results of a beam-column sub-structure specimen and the analytical results of a 12-story BRB-RCF using 240 ground motions at three hazard levels were introduced. Five Taiwanese engineers were invited to share their experience in implementation of stub columns or BRBs in their projects.



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