

# The Sub-Structural Pseudo Dynamic Tests Of A Full-Scale Two-Story Steel Plate Shear Wall

*Keh-Chyuan Tsai, National Center for Research on Earthquake Engineering, Taipei, Taiwan*

*Chih-Han Lin, National Center for Research on Earthquake Engineering, Taipei, Taiwan*

## Introduction

In recent years, several researchers have confirmed that the steel plate shear wall (SPSW) can be a viable seismic force resisting system for building structures. But the experimental research on large-scale SPSW frame is limited. A typical SPSW frame structure is given in Fig. 1. Considering that the small-scale structure tests could not obtain precise seismic behavior close to the performance of real buildings, a full scale 2-story SPSW specimen was constructed and tested recently in NCREE.

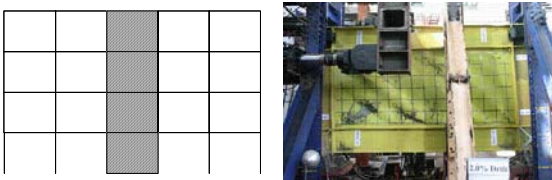


Fig. 1. SPSW frame system

## Experimental Program

The specimen is a two-story steel plate shear wall frame measuring 4m wide and 8m high. The thickness of steel plate for the first story wall is 3mm and for the second story is 2mm. Considering the preparation of steel plate, the SS400 grade steel is chosen for the steel shear wall. All the boundary beam and column elements are A572 GR50 steel. In order to minimize the annoying buckling sounds and the out-of-plane displacement of steel plate, the specimen is restrained by three horizontal steel tub restrainers in each side of infill plate. The specimen elevation is given in Fig. 2.



Fig. 2. Specimen elevation

In phase I tests, the specimen was planned to be tested using pseudo-dynamic test procedures, and a Chi-Chi earthquake record was scaled up to represent seismic hazards of 2%, 10%, and 50% probabilities of exceedance in 50 years. After Phase I tests, the steel panels were removed and a new set of steel panels were

installed for Phase II tests in order to study the seismic performance of the SPSWs without the steel tube restrainers.

## Test Procedure and Result

After Phase I test, it was found out in the specimen that significant buckling and a number of small cracks had occurred in the steel plate for both floors. It was also observed that various boundary members had yielded, but no fracture was found in those boundary elements. At phase II test, significant fracture was found in the middle beam as shown in Fig. 3. Then this specimen was tested under cyclic loads. At 3% drift ratio of cyclic test, the steel plate tore near the edge of fish plate (Fig. 3). And the cyclic test was then stopped at 5% drift because of cracks of concrete slab as shown in Fig. 3.



peak story drift for 2/50 and 10/50 events are 0.025 and 0.02 radians, respectively. Figure 4 shows the inter-story drift versus story shear relationships in 2/50 event. It appears in Fig. 4 that the energy dissipation ability of the SPSW is satisfactory.

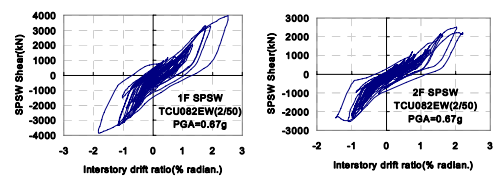


Fig. 4. Hysteresis loops for SPSWF (2/50 event)

## Conclusions

1. After Phase I tests, the SPSWF specimen has found no significant strength degradation. It appears that the member sizes of the boundary frame are adequate to sustain the tension field actions developed in the steel plate.
2. The restrainers applied to SPSW have decreased greatly the buckling sounds and the out-of-plane displacement of infill steel plate.

(Keh-Chyuan Tsai, E-mail: kcttsai@ncree.org)

## In-Situ Pushover Tests of Reui-Pu Elementary School Buildings in Taiwan

*Shyh-Jiann Hwang, Deputy Director of NCREE  
Lap-Loi Chung, Section Head of NCREE  
Yuan-Tao Weng, Associate Research Fellow of NCREE*

There are various common seismic evaluation methods that are used to apply monotonic static pushover to obtain the capacity curve, which represents the structural seismic resistant capacity simply, but monotonic loading pattern could not present the actual cyclic behavior induced by an earthquake. Therefore, in order to overcome this drawback through in-situ experiments, an 8-classroom building constructed in 1979 was cut in the staircase, where one part of this building was set for monotonic loading (Fig. 1) while the other part was set for cyclic loading or earthquake loading (Fig. 2) along the longer axis of building. These two frame specimens were arranged to be co-responsive with each other. Moreover, on the other side, a 4-classroom building specimen retrofitted by adding composite columns to partition brick walls was cut in the middle and jacks were set up for monotonic loading along the longer axis (Fig. 3). The one-half of the said building was reinforced by steel bracings to provide reaction support, while the other half was pushed to failure.



Fig. 1 Pseudo dynamic test and the static cyclic pushover test of frame specimen I



Fig. 2 Monotonic static pushover test of frame specimen II



Fig. 3 Monotonic static pushover test of seismic retrofitted frame specimen III

Figure 4 shows the capacity curves of Specimen I, II, and III. By comparing the capacity curves of Specimens I and II, the effects of the seismic performance of a school building subjected to cyclic lateral loading collocating with the PsD seismic tests.

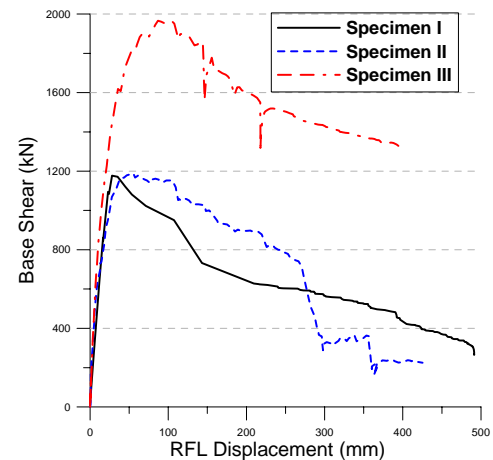


Fig. 3 Comparison with base shear-roof displacement results of Specimen I, II and III

These in-situ tests provide a great opportunity to realize the behavior of a real building and the strength of verification by analytical methods. Especially, the experimental results of cyclic pushover test collocating with the PsD seismic tests confirmed the damaging behavior of school buildings observed during Chi-Chi earthquake, and revealed the effects of cyclic loading patterns. Typical failure characteristics of school buildings, such as short-column effect and strong-beam-weak-column behavior, did happen to the specimens.

(Shyh-Jiann Hwang, E-mail: sjhwang@mail.ntust.edu.tw)

## 4th International Conference on Earthquake Engineering Held in Taipei with Great Success

*Chiun-lin Wu, Associate Research Fellow of NCREE*

The Fourth International Conference on Earthquake Engineering (4ICEE) is a major technical event in Taipei, Taiwan and was held last October 12 to 13, 2006. It provided an outstanding forum to facilitate international exchange of state-of-the-art earthquake engineering research and practice. The year's theme was entitled, "Promoting International Collaborations on Earthquake Engineering Research Frontiers and Hazard Mitigation Practice." The 4ICEE program covered all aspects of earthquake engineering, from structural control, smart structures, and structural health monitoring to integrated new technologies that enable hazard-resistant resilience of buildings and public infrastructure systems. In total, more than 210 conference papers from 19 countries and regions with significant topics about theoretical, analytical, and experimental studies and their integration were covered. The 4ICEE conference received a broad attendance of more than 250 delegates from 19 countries and various regions. It ended perfectly with a marvelous technical visit to NCREE's Laboratory in the afternoon of October 13 after the closing ceremony was conducted. All participants were able to witness a dynamic collapse

tests on brick masonry bearing walls under out-of-plane seismic motions, in which NCREE research group had demonstrated its high-end experimental technologies and showcased its capability of conducting interdisciplinary and multidisciplinary researches. There were also two post-conference activities held at NCREE just after the international activity and was called US-Taiwan workshops on Self-Centering Structural Systems and on Smart Structural Technology for Seismic Hazard Mitigation, which had led to a concrete plan in strengthening R&D collaborations between the US and Taiwan. For further information including online conference proceedings and activity photos, visit the 4ICEE website at <http://icee2006.ncree.org.tw/>.



4ICEE Opening Ceremony (Courtesy of Min-Lang LIN)

## Chinese Taiwan Society for Earthquake Engineering (CTSEE) Honored Distinguished Professors

*Chiun-lin Wu, Associate Research Fellow of NCREE*

The 4ICEE Organizing Committee Chair, Director Keh-Chyuan Tsai of NCREE, also took the great opportunity during the conference to present CTSEE Honorary Awards to four world-renowned professors for their significant contributions to the development and advancement of earthquake engineering research and

practice in Taiwan. Awardees included Dr. Chau-Shiung Yeh (Professor, National Taiwan University), Dr. Joseph Penzien, (Professor Emeritus UC Berkeley), Dr. Maw-Shyong Sheu (Professor Emeritus, National Cheng Kung University), and Dr. S.T. Mau (Professor, California State University, Northridge).



Dr. Chau-Shiung Yeh



Dr. Joseph Penzien



Dr. Maw-Shyong Sheu



Dr. S.T. Mau

## 4ICEE Technical Tour: Brick Wall Collapse Test

*Yuan-Sen Yang, Associate Research Fellow of NCREE*

A shaking table test of brick masonry walls in an RC frame under out-of-plane seismic motions was presented to 4ICEE participants at NCREE after the close ceremony on Oct. 13, 2006. The presenting test was performed after a series of tests, which were to study of the vulnerability of school house brick walls along their out-of-plane direction. The brick wall did not collapsed until a 0.8g sine wave with frequency ranging from 2.5 to 1.0 Hz was applied. Wireless sensors and image-based displacement measurement were applied to measure the response and to identify the damage of the RC specimen. Further information and the archived videos of the test are available at web page <http://exp.ncree.org/bwall/>



Fig. 1. Shake table test collapsing brick walls  
(Yuan-Sen Yang, E-mail: ysyang@ncree.org.tw)

## Report on the 2nd Indo-Taiwanese Workshop of Seismic Evaluation and Retrofitting of RC Buildings

*Yuan-Tao Weng, Associate Research Fellow of NCREE*

Last October 11 and 12, 2006, the 2<sup>nd</sup> Indo-Taiwanese Workshop of Seismic Evaluation and Retrofitting of RC Buildings was held in Taipei, Taiwan. The workshop had three independent sessions, where parts were in subordinate with the 4ICEE, in presenting research papers for technology exchange.

A team of seven members from India joined the above workshop (Fig.1), and fifteen papers were presented on the activity. In order to achieve cooperation between research groups, researchers and institute staff and their exchange visits for teaching and research, a draft of memorandum of understanding was established during the panel discussion.

NCREE and India Institute of Technology (IIT) both agreed to research retrofitting technology, seismic evaluation, and risk analysis of low-rise school buildings and hospital buildings, as well as seismic risk assessment including seismic microzonation, vulnerability assessment and risk and loss assessment in the future.



Fig. 1. The group photo of all participants in the 2<sup>nd</sup> Indo-Taiwanese Workshop of Seismic Evaluation and Retrofitting of RC Buildings.

## US-Taiwan Workshop on Self-Centering Structural Systems 2006

*Pei-Ching Chen, Assistant Research Fellow of NCREE*

Recently, coordinated research programs have been launched between the US and Taiwan to address various issues on post-tensioned seismic building systems. In these joint research efforts, national and international collaborations have been emphasized in order to promote the effective use of laboratory and human resources. It is believed that through the collaboration between university professors, graduate students and practitioners, the advancement of knowledge and dissemination of research results can be accelerated.

There were a total of 18 summaries of papers presented at the 2<sup>nd</sup> US-Taiwan Workshop on Self-Centering Structural Systems held at NCREE last October 14, 2006 covering a wide spectrum of research work on self-centering structural systems in the two regions, e.g. the seismic responses of self-centering beam-to-column connections, column base connections, braces and walls, and frame systems, and the reliability assessment of self-centering structures. In addition, a panel discussion was included and organized in the workshop to formulate bilateral collaborations and future perspectives on this topic (Fig.1). The agenda is shown in Table1.

Slab became the most important issue which was discussed seriously at the workshop. Some common views on test frame with slabs were collected. A full-scale self-centering test frame will be constructed in the end of 2007 to integrate and verify the research results in the past three years on self-centering

