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Development of a Mobile Seismic Disaster Information Application: The Android APP Prototype

Kuang-Wu Chou, Shih-Liang Chen, Chih-Hsin Chen, Gee-Yu Liu, Chin-Hsun Yeh

In the past, people used mobile phones to talk with or send text messages to others. Currently, more advanced mobile devices such as smart phones and tablets are pervasive. Many people use mobile devices not only for daily communication, but also for surfing the Internet. In particular, people can find information by using applications in mobile devices, so-called APPs, instead of Internet browsers. The user interface of an APP can be friendlier and more sophisticated than that of a browser. As a native application of mobile devices, an APP allows users to exploit more services from mobile devices, such as location services, photographing, videoing, and community services. In particular, APPs are supported by Push Technology. This technology enables an APP to quickly receive the latest information from the APP service provider.

This study intends to develop an APP that can quickly notify people of new seismic events. First, a requirement analysis was carried out that helped us determine what functions the APP should offer. According to this function requirement, an Android APP prototype was created to discover the difficulties that we will encounter in the APP development, deployment, and user-application.

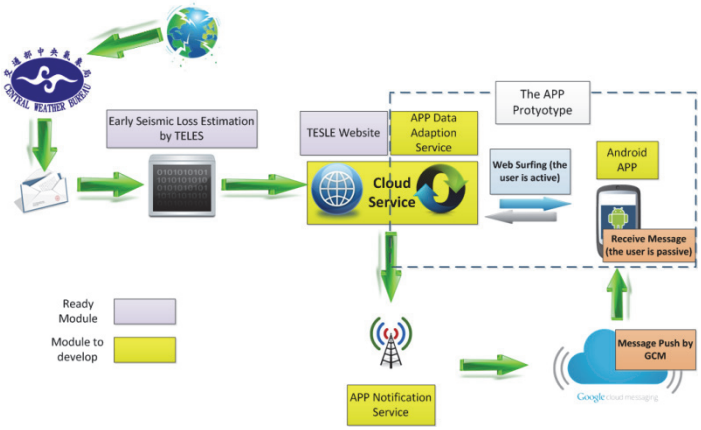


Fig.1 The system architecture of the APP cloud service

Fig. 1 shows the system architecture of the APP, which offers a mobile interface for Taiwan Earthquake Loss Estimation System's early seismic loss estimation (ESLE). Whenever an earthquake occurs, the ESLE module will receive an email that describes the earthquake from the Central Weather Bureau. According to that earthquake description, the ESLE module estimates the seismic loss of buildings. The estimation outcome is then translated by the Taiwan Early Seismic Loss Estimation (TESLE) website into a format people can comprehend. Meanwhile, the APP cloud service brings the same estimation outcome to all mobile devices that subscribe to it. Under such an information-transferring mechanism, the APP service subscribers do not need to visit the TESLE website for querying the loss estimation of an earthquake. The APP service will notify them of the loss estimation outcome right after the earthquake. Despite being passive, APP subscribers can receive seismic information quickly and effortlessly.

Fig. 2 shows the functions of our Android APP prototype. The prototype cooperates with a data server, exploiting the server's data interchange service to help users browse Taiwan's earthquake events. In addition, the prototype applies Android's Google Map technology, visually displaying earthquake events on the Taiwan map. The design of the prototype is given below.

1. The earthquake event list: at startup, the APP reads all earthquake events from the data server and then shows those events in a list view from new to old (See Fig. 3). Fig. 4 shows how the APP displays the detail for an event item in the list. Further, the user may click on an event, and then a single-event view (See Fig. 5) will show to replace the list view on the screen.

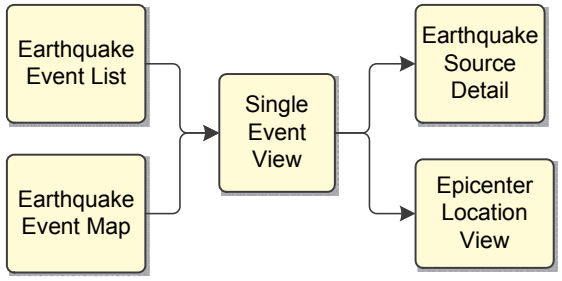


Fig. 2 The functional architecture of the APP prototype



Fig. 3 The earthquake event list

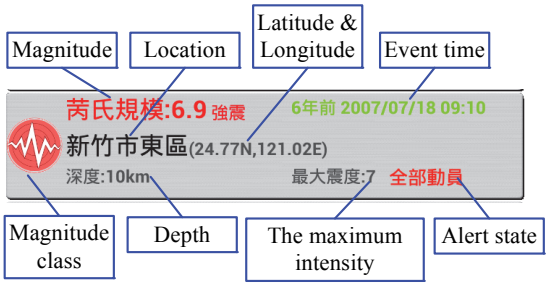


Fig. 4 Detail of an event item in the earthquake event list

2. The single-event map view (See Fig. 5): only an event with its detail is shown in this map view. The design of the single-event map will be improved so that the map can display loss estimation outcome to help people learn more about a seismic event.



Fig. 5 The single-event map view

3. The earthquake event map: such a map view applies Google Map Android Technology to show earthquake events on the Taiwan map (See Fig. 6).



Fig. 6 The earthquake event map

With help of the Android Application Framework and Android SDK, this study created the Android prototype of a mobile APP that will offer seismic disaster information. People responding to seismic disasters can utilize the prototype to learn about seismic events, which the prototype shows with an event list or on the Taiwan map. Based on the prototype, the study will implement all required functions of the APP. Further, Push Technology will be applied to enable the APP cloud service to quickly send seismic information to the mobile devices of users.

Workshop on the International Training Program for Seismic Design of Structures 2014

Mine-Chun Lai, Assistant Researcher

Recent major earthquakes around the Pacific Rim, such as the Northridge earthquake (USA, 1994), the Kobe earthquake (Japan, 1995), the Chi-Chi earthquake (Taiwan, 1999), the Southern Sumatra earthquake (Indonesia, 2000), the Sumatra–Andaman earthquake (Indonesia, 2004), the Tohoku earthquake (Japan, 2011, which caused the tsunami and nuclear power plant accidents), and the East Azerbaijan earthquakes (Iran, 2012) have all resulted in serious fatalities and property damage in the affected areas. It is therefore necessary to promote seismic design technologies to mitigate seismic hazards in high seismicity regions of the Pacific Rim. A training program for both researchers and practicing engineers should be considered as a top priority action.

The World Seismic Safety Initiative (WSSI) under the International Association for Earthquake Engineering (IAEE) suggested that the governments of countries such as the United States, Japan, New Zealand, and Taiwan should propose training programs for the improvement of seismic design specifications of other countries. Therefore, a training program was organized by the National Center for Research on Earthquake Engineering (NCREE), funded by the National Science Council (NSC) of Taiwan, ROC, for researchers and engineers from countries in Asia and Central and South America.

The 13th International Training Program for Seismic Design of Structures (ITP2014) will be held on October 13-18, 2014, at NCREE. This training program is sponsored by the NSC and focuses on the promotion of seismic design technology for structures worldwide. The workshop was first held in January 2002. To date, a total of 387 participants from 23 different countries have attended the workshop over the past decade. It is designed to be a short-term workshop with activities aimed at training government officials and engineers from countries around the Pacific Rim region. It is through this workshop that the earthquake-resistant capabilities of the participating countries can be gradually improved to reduce the impact and losses caused by earthquakes. Some of the important sessions in this program include:

- 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 Retrofitting.

For more details, please visit the official website of ITP2014 (http://w3.ncree.org.tw/ITP/2014/).

Develop on Earthquake Damage Assessment Model of Highway Bridge

Chi-Hao Lin, Lee-Hui Huang, Assistant Researcher
Chin-Hsun Yeh, Division Head, Research Fellow

Introduction

Highway bridge is an important facility of the transportation system. In order to ensure the safety and reduce the social and economic impact caused by the traffic disruption, the authorities need regular conservation and to maintain the seismic performance of the bridge. The vibration intensity on each region is calculated usually based on the magnitude of the earthquake, the shortest distance from the site to the fault rupture surface (or line), and soil properties in all regions, namely the vibration attenuation law and the correction mode of site effect. The vibration intensity can be assessed by peak ground acceleration (PGA) or structural response spectrum of acceleration (Sa). The damage of structural system must be measured from the reaction magnitude under the earthquake. Therefore, the fragility curve of the highway bridge should adopt the accelerated response spectrum for one second period as the evaluation parameters.

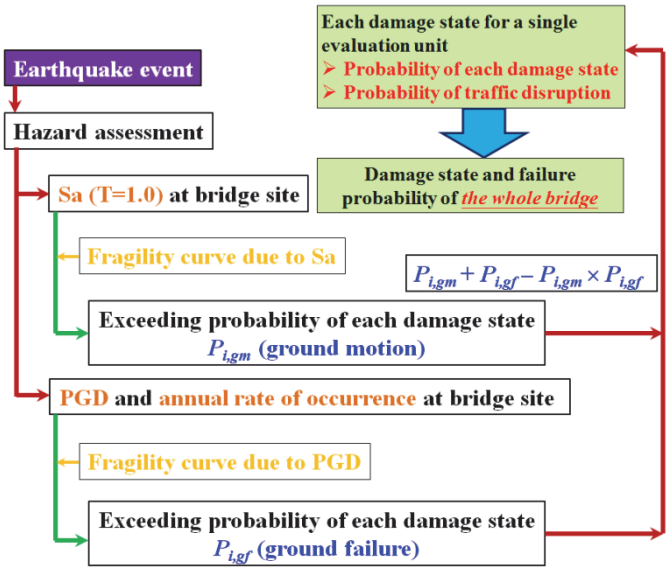


Fig.1 Flow chart of earthquake damage assessment for highway bridge

PGD Assessment of Fault Dislocation

In addition to potential disaster of ground motion caused by the earthquake, there are ground deformation, such as soil liquefaction, landslides and fault rupture, which lead to subsidence, lateral or breakage. From the past experience of 921 earthquake disaster, the most of serious damage of bridges are located on the zone of fault rupture or on the hanging wall. Therefore, how to describe the ground deformation on both sides of the fault rupture surface is very important, especially fracture surface has been exposed to the ground surface.

According to Wells and Coppersmith (1994) and Yeh et al (2005) research, this study is a more realistic , description of the fault rupture phenomenon and its impact on the bridge structure, assuming that the permanent displacement is D for both sides of the fault rupture within 10 meters. Therefore, if there is doubt of a bridge across the fault line, the maximum permanent displacement is D. When the shortest distance (d) is greater than 10 meters from the bridge site to the fault rupture surface, the permanent ground displacement (PGD) could be estimated by eq. (1).

$$\mathrm{PGD} = \begin{cases} \dfrac{1000}{d_{sr}} \cdot f_H \cdot D \cdot \exp\left[-\dfrac{d}{d_{sr} \cdot f_H}\right] & \textit{on hanging wall} \\ \dfrac{1000}{d_{sr}} \cdot f_F \cdot D \cdot \exp\left[-\dfrac{d}{d_{sr} \cdot f_F}\right] & \text{on footwall} \end{cases} \quad (1)$$

f_H and f_F are the adjustment factors respectively located on the hanging wall and footwall, which can be expressed as $f_F = |\alpha| / 180$, $f_H = 1 - f_F$. α is the angle of the fault rupture surface. d_{sr} is the depth for the top of seismogenic zone to the ground surface. D is the maximum slip on the both sides of the fault. d is the shortest distance between the rupture surface to the bridge site. The unit of D, d_{sr} and d are meters. d_{sr} is usually 2-5 kilometers, so that PGD has a dramatic change on the fault rupture surface and it's both sides. When the PGD value estimated from eq. (1) is substituted into the formula of displacement fragility curve, the damage probability could be calculated under this PGD value. To consider the non-uniform or continuous ruptured phenomenon of the ground surface, assuming the probability (p), which structures are located on the rupture line, is related with the shortest distance d. The probability p can be expressed as

$$p = 0.7 \cdot \exp\left[\frac{-d}{2000}\right] \quad (2)$$

Where the unit of d is meter. The 0.7 in the eq. (2) reflects the uncertainty of the fault line (plane) position. The exceedance probability of the different damage states of structures due to the fault rupture should be multiplied by p.

In the past, the center point of the bridge was used to estimate the shortest distance (dc). However, when the highway bridge is more length, it cannot accurately reflect the damage situation of the other parts if only using the center point of the bridge to estimate the PGD. To overcome the aforementioned missing, in this study the main azimuth angle φ of the bridge is defined by using the both ends of the bridge. With the fault strike θ, the included angle |φ-θ| can be calculated. Referring to Figure 1, if dc has been calculated,

according to the bridge length l, the included angle |φ-θ|, and the inclination α of the fault plane, the shortest distance d_e from bridge endpoint to the rupture surface can be estimated by the following equation.

$$d_e = \begin{cases} \max(0, \quad d_c - 0.5 \cdot \sin|\varphi - \theta| \cdot \sin\alpha) & on\ hanging\ wall \\ \max(0, \quad d_c - 0.5 \cdot l \cdot \sin|\varphi - \theta|) & on\ footwall \end{cases} \quad (3)$$

As d_e is less than 10 meters, the bridge may span the fault and its permanent ground displacement is D. d_e is substituted into equations (1) and (2), it can more accurate to estimate the damage probability of PGD caused by the fault rupture.

Conclusion

To ensure the seismic damage assessment model of the highway bridge has the practical application, 921 earthquake is used as an demo example because it has a more completely damage record. The results of the damage assessment of the highway bridge are agreement with the disaster investigation.

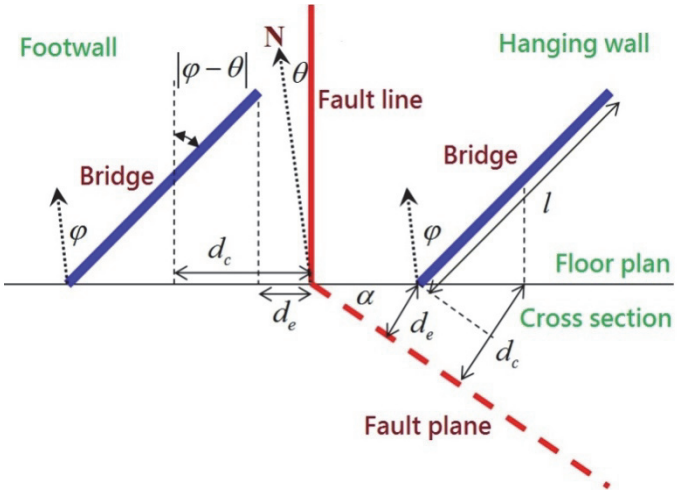


Fig.2 Schematic diagram of the relative position of the bridge and the fault line (and rupture surface)

2014 Taiwan Tech Trek Project

Wen-Cheng Shen, Assistant Researcher

The Taiwan Tech Trek (TTT) project provides an opportunity for overseas youth to gain internships or research experiences. Summer internships are available all across Taiwan at top research institutes, high-tech companies, universities, and world-famous science parks. Each intern will participate in a six-day orientation, followed by a seven-week internship at host institutes. TTT 2014 is seeking 276 overseas Taiwanese youths to participate in the summer internship program.

The National Center for Research on Earthquake Engineering (NCREE) provides two job opportunities for TTT 2014 and the main goal is to introduce the seismic upgrading project in Taiwan to the world through this summer program. The two interns at NCREE are both from the University of California, Davis, and their internship subjects are shown below:

Name	Internship Subject
Connie, Lee	Post-Earthquake Damage Assessment
Gary, Hua	Earthquakes and Schools

During the summer internship program, a visit to the 921 Earthquake Museum was arranged for these two interns to improve their knowledge of earthquakes. Following this field trip, the interns had more understanding of the relationship between earthquakes and Taiwan, and the importance of earthquake disaster prevention. Moreover, it was helpful for them to carry out the internship.



Fig. 1 Field trip to the 921 Earthquake Museum

At the end of the program, participants are required to present their work or research accomplishments either individually or in groups at the TTT 2014 Academic Conference. The conference will be held on August 15th 2014 during the day, followed by the Award Night Banquet in the evening of August 16th 2014. Awards will be conferred to the best three presentations in each field.



Fig. 2 Presentation at the Academic Conference

Seismic Risk Assessment and Retrofit order of Freeway Bridges

Lee-Hui Huang, Chi-Hao Lin, Assistant Researcher,
Chin-Hsun Yeh Division Head, Research Fellow

In order to maintain national freeway traffic safety, the Taiwan Area National Freeway Bureau (NFB) has the responsibility of inspecting and upgrading the seismic capacity of national freeway bridges. Thus, freeway bridges retrofit projects progress in three phases. The first two phases have been completed and the third phase is presently entrusted to T.Y.Lin International Group (T.Y. Lin). There are 1169 freeway bridges in this project. NCREE has assisted in the seismic risk assessment and retrofit order of all 1169 freeway bridges.

Direct and indirect losses are the results of freeway bridges earthquake loss estimations. Direct losses arise from the expected repair cost to repair damaged freeway bridges under certain earthquake simulations. National freeways are main routes that greatly affect the traffic and economy in Taiwan. Indirect losses arise from the detour costs incorporating time and distance due to damaged freeway bridges that block the freeway traffic. According to research findings, the Demand Model of Intercity Transportation Systems under National Sustainable Development by the Institute of Transportation, the Ministry Of Transportation and Communications (MOTC), the traffic loss caused by a blocked freeway section could be analyzed by the application software called TransCAD. Regarding the traffic loss as indirect loss, the indirect loss caused by earthquake damaged freeway bridges could be calculated.

The national freeway is a closed network with entrances to get on/off and therefore, a freeway section between two ramps is a traffic unit. Furthermore, freeway engineering constructions such as repairs and retrofits proceed section by section. Therefore, in order to rank the retrofit engineering order by freeway sections, the seismic risk assessment model divides the freeway network into 88 sections between ramps. Each section includes one or more freeway bridges. After integrating the results of freeway bridges earthquake loss estimation into freeway sections, the annual average loss for 88 sections before and after a retrofit could be estimated as concern factors to rank the retrofit order of freeway bridges.

The result of the seismic risk assessment of freeway bridges before and after a retrofit shown in Table 1 indicates that the seismic risk loss of freeway bridges decreases *greatly* after a retrofit.

Table 1 Freeway Bridges Annual Average Loss

	Direct	Indirect	Total
Before retrofit	430,662	345,971	776,632
After retrofit	51,985	77,644	129,630

(amount to 1169 freeway bridges；unit：thousand)

The seismic risk of freeway bridges could be estimated before and after a retrofit and then the annual average loss for each freeway bridge and section can be obtained. In contrast with the difference of annual average loss before and after a retrofit could be a motive to rank the order of freeway section retrofitting. Besides the seismic risk to freeway bridges, there are other factors such as freeway structural vulnerability and social and economic impact, which should be considered for ranking the freeway retrofit order. In this project, there are six factors schemed to describe the differences among the freeway sections. In order to highlight the importance of the six factors, every factor is normalized from 0 to 1 in proportion as an index as described in the following sections.

Structural Vulnerability

Risk: This factor represents the structural earthquake risk to freeway bridges. Therefore, the result of the earthquake risk assessment, which is the direct annual average loss before a retrofit, can be regarded directly as the freeway section risk factor.

Benefit: The decrease of the freeway structural earthquake risk before and after a retrofit is the profit from a retrofit. To compare this profit with retrofit construction cost by division and subtraction, two kinds of benefit factors of a freeway section retrofit can be obtained.

Preliminary seismic evaluation: There are two scores regarding falling and flexibility for each freeway bridge that are the results of preliminary seismic evaluation by T.Y. Lin. Mean values of the scores in the same freeway section can be regarded as falling and flexibility factor of freeway section retrofit.

Social & Economic Impact

Detour: This factor represents the detour distance and time cost when a certain freeway section is blocked. Therefore, the result of the earthquake risk assessment, which is the indirect annual average loss, can be regarded directly as the freeway section detour factor.

Economy: If a freeway section is close to important facilities such as a port, a science park, and a station, and affects the economy more than others when it is blocked, this factor represents the economic impact difference among freeway sections.

Overpass: This factor represents the impact of a facility that a freeway section overpasses. For example, if a freeway section serves as an overpass to important facilities such as a railway, high-speed railway, and highway roads, a higher score is assigned to this section.

The retrofit order score for each freeway section is calculated by the above six indexes with different weighting proportions. The score could then be used to rank the freeway retrofit order.

10th International Workshop on Advanced Smart Materials and Smart Structures Technology

Shu-Hsien Chao, Assistant Research

The 10th International Workshop on Advanced Smart Materials and Smart Structures Technology was held by the National Center for Research on Earthquake Engineering (NCREE) and National Taiwan University (NTU) at Taipei, Taiwan on August 1-3, 2014. This workshop was organized by the Asian-Pacific Network of Centers for Research in Smart Structures Technology (ANCRiSST), which was established in 2002 and currently consists of 20 research institutions. NCREE is an institution of ANCRiSST.

The purpose of the workshop was to assess the current progress of smart materials and structures technology and to develop synergies among researchers in various disciplines from different countries that will facilitate joint research projects that are of such scope and magnitude that cannot be easily carried out by the individual centers. This workshop consisted of eight keynote presentations and four sessions with twenty-two technical presentations. The workshop was focused on the following topics:

1. Smart Materials for Sensors and Actuators
2. Sensors Network / System Integration
3. Signal Processing / Diagnostics / Prognostics
4. Structural Health Monitoring
5. Energy Harvesting

NCREE has been making a great effort on the development of technology related to structural health monitoring, control, disaster prevention, reduction, and early warning. By holding this workshop, international collaborations and relative technologies are further improved.



Group photo of the workshop participants at NCREE

7th Asia Pacific Summer School on Smart Structures Technology

Shu-Hsien Chao, Assistant Research

The 7th Asia Pacific Summer School on Smart Structures Technology was held by the National Center for Research on Earthquake Engineering (NCREE) and the National Taiwan University (NTU) at Taipei, Taiwan from July 28 - August 15, 2014. This activity originated from the Asian-Pacific Network of Centers for Research in Smart Structures Technology (ANCRiSST), which was established in 2002 and currently consists of 20 research institutions. A member of ANCRiSST organizes the summer school every year.

A total of 45 graduate students from the United States, Japan, Korea, Singapore, and Taiwan participated in the summer school this year. Several domestic and international experts and researchers related to smart materials and structures, sensing, monitoring, and control technology were invited to present lectures at the summer school. The curriculum addressed the basic theory, hardware, software, and real applications of the smart structures technology. Laboratory experiences and site visits were aimed at extending knowledge beyond the classroom and providing students with practical, first-hand experience. The contents of the summer school included the following:

1. Attendance at the 10th International Workshop on Advanced Smart Materials and Smart Structures Technology.
2. 26 lectures in a classroom
3. 20 lectures in a laboratory
4. 2 Student Technical Competitions - Structural Control and Damage Detection
5. A Technical Tour - Feitsui Reservoir and Jhihtan Purification Plant
6. A Cultural Tour - Chelungpu Fault Preservation Park - The 921 Earthquake Museum of Taiwan

Through this 3-week program, graduate students could learn about advanced smart structures technology and its applications. Students were expected to gain valuable experience of global engagement in a culturally rich learning environment. The objectives of knowledge broadening, experience sharing, and science education were achieved by holding this summer school.



Group photo at the Chelungpu Fault Preservation Park

10th U.S. National Conference on Earthquake Engineering

Jui-Liang Lin, Juin-Fu Chai, Research Fellow
Chao-Hsien Li, Tsung-Chih Chiou, Chia-Han Chen,
An-Chien Wu, Assistant Researcher
Chien-Chuang Tseng, Assistant Technologist

The 10th U.S. National Conference on Earthquake Engineering (NCEE) was held in Anchorage, Alaska on July 21-25. NCEE is a large international conference held every four years by the Earthquake Engineering Research Institute (EERI). The host city, Anchorage, was selected to commemorate the earthquake that occurred in the city in 1964. There were nearly 800 papers presented during this conference. The ten-year (2004 - 2014) accomplishment of Network for Earthquake Engineering Simulation (NEES) on earthquake engineering was also summarized and reported at this occasion. The mission of NEES of integrating research resources, e.g., the experiment facilities in the United States, and promoting the awareness of earthquake risks is similar to that of our research center, NCREE. Therefore, NEES's sophisticated strategies and steps marked during the past decade are all valuable for NCREE's future development.

There were seven NCREE colleagues who participated in this conference and presented eight papers. The eight papers were entitled "The Reasons for the Trends in Torsional Effects in Asymmetric-Plan Buildings", "Shear Strength Prediction of Reinforced Concrete Deep Beams with Web Openings", "Seismic Rehabilitation Objectives and Upgrading Strategy for Medical Equipment and Nonstructural Components in a Hospital", "Verification on Seismic Evaluation Models of Reinforced Concrete Frame with Brick Infill", "Behavior of Model Pile in Saturated Sloping Ground in Shaking Table Test", "Seismic Evaluation of Relays in MCC Type Cabinets in Taiwan Nuclear Power Plants", "Experimental Investigations on Steel Plate Shear Walls Using Box Columns with or without Infill Concrete", and "Seismic Performance of Buckling-Restrained Braces Using Welded End and Rectangular Steel Casing". In addition, by taking the opportunity to attend this conference, the NCREE colleagues met with the researchers from Washington University and University of California, Berkeley to discuss the upcoming tasks of collaborative projects. Besides presenting our research work to the earthquake engineering community, it was also a great opportunity for us to exchange mutual views/knowledge directly with worldwide experts participating in the conference. This is definitely beneficial for planning and conducting our future research work.

Sixth World Conference on Structural Control and Monitoring

Ting-Yu Hsu, Associate Researcher

The Sixth World Conference on Structural Control and Monitoring (WCSCM) was held on July 15-17, 2014. It was hosted by the Universitat Politècnica de Catalunya (UPC) under the auspices of the European Association for the Control of Structures (EACS). The precedent conferences were held in Pasadena, USA (1994), Kyoto, Japan (1998), Como, Italy (2002), La Jolla, USA (2006), and Tokyo, Japan (2010). This time, the conference took place in Barcelona, Spain, one of the most charming cities along the Mediterranean coast, which always offers the perfect environment for unforgettable events and plenty of enjoyable social, cultural, and touristic opportunities.

The WCSCM is a premier leading conference devoted to the theoretical, numerical, experimental, and practical advancements of monitoring and control technologies for dynamic structures in a wide range of civil, infrastructure, mechanical, aerospace, and energy systems. It gathers an international community that contributes to the state of the art in multidisciplinary scientific and engineering environment with new results, fresh ideas, and future perspectives.

More than 375 participants presented about 400 papers during 21 special sessions at the conference. Director K.C. Chang, Dr. Y.B. Lin, Dr. T.Y. Hsu, and Dr. K.C. Lu of NCREE attended this conference and presented five papers. These papers were titled "Visible Light Communication Network Monitoring System Development of Bridge Multiple Hazards", "Field Measurement of Riverbed and Bridge Scour in Cho-Shui River in Taiwan", "A Real-Time Structural Health Monitoring Device using Cost-Effective 1-Axis Accelerometers", "The Application of the On-site Earthquake Early Warning System", and "Damage Detection of Beam Structures using Rotary Mode Shapes and Flexibility Matrices". During the conference, Dr. T.Y. Hsu was invited by Prof. Y.Q. Ni from Hong Kong University of Science and Technology to visit Hong Kong and give a seminar about the development of the on-site earthquake early warning technique in September. The visibility and reputation of NCREE was truly improved via this international conference.

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