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Microearthquake Monitoring of the Shanchiao Fault in Northern Taiwan

Che-Min Lin, Associate Researcher, NCREE

The Shanchiao Fault, located to the west of the Taipei Basin, is the primary active fault in northern Taiwan. The fault length is 33 kilometers on land. Its normal faulting resulted in the deep Tertiary basement of the Taipei Basin. Two nuclear power plants are located several kilometers from the north end of the Shanchiao Fault. This fault may trigger an earthquake of Mw 6.0 or larger and hence is undoubtedly the most significant potential seismic threat to the Taipei metropolitan area. Moreover, a dormant volcano, the Tatun volcano, is located at the southwestern hanging wall of the Shanchiao Fault. The seismicity of this fault is unclear because of the complex tectonic environment. To assess the seismic hazard of the Shanchiao Fault, a dense microearthquake monitoring can provide valuable information about its recent seismicity and source parameters. National Center for Research on Earthquake Engineering (NCREE) was under contract with the Taipower Company to monitor the Shanchiao Fault for understanding its seismicity.

Microearthquake Network

In this study, a real-time microearthquake monitoring network was set up with thirteen broadband seismometers to observe the seismicity of the Shanchiao Fault since April 2015. All the stations were located in isolation to provide high signal-to-noise ratio (S/N) data for detecting small earthquakes. The continuous and real-time waveforms from these stations were transmitted to the server in the NCREE by the internet.

In addition, there are some existing stations operated by the other organizations, including the Central Weather Bureau (CWB), the Institute of Earth Science (IES) of Academia Sinica, the Taiwan Volcano Observatory (TVO), and the Industrial Technology Research Institute (ITRI). We cooperate with these organizations to integrate an additional thirty-four stations into our network. The integrated network of the forty-seven stations covers all of the onshore fault zone and a part of the offshore part, as two stations are located at the northern islands.

Monitoring and Analysis

Almost 2,500 microearthquakes were observed in the monitoring region between April 2015 and December 2017. Most of the magnitudes (M_d) were smaller than 2. The number of monthly seismicities varied between 20 and 143 with an average of 67. Figure 1 shows the distribution map of the relocated epicenters obtained using the double-difference earthquake location algorithm (HypoDD) and two NW-ES cross-sections of the hypocenters. Most of the epicenters concentrate on the Tatun volcano area with several earthquake swarms. The focal depths of this area are mostly between 2 and 6 km and extend to the ground surface at Dayoukeng, which is the largest fumarole of the Tatun volcano area. It may mean that the relatively high seismicity in this area is dominated by the geothermal structure. In addition, there is a secondary seismogenic zone along the coastal line at the northern end of the on-land fault trace. Although the seismicity is much lower, the hypocenter cross-section (bb' in Figure 2) shows a clear NW–SE dipping structure. The relationship between the linear seismogenic zone and the Shanchiao Fault need more data and analysis to clarify. Figure 2 shows the first-motion focal mechanisms of the micro-earthquakes we solved. The number of normal fault mechanisms are the most because of the extensional regime of northern Taiwan.

This monitoring will be continued for several years to understand the Shanchiao Fault further. The long-term data will benefit the earthquake disaster prevention of northern Taiwan.

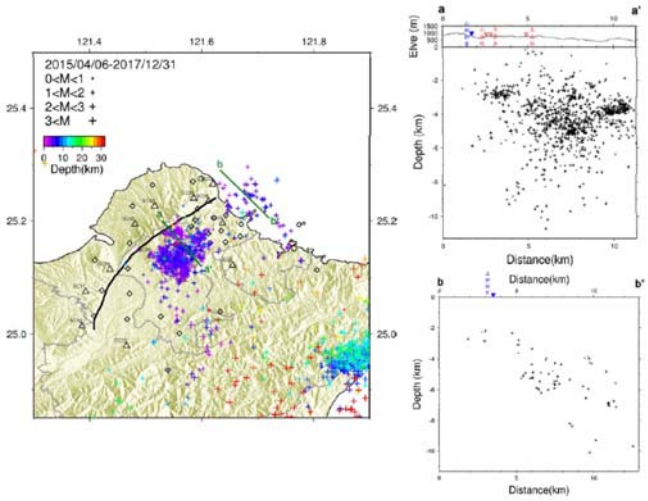


Fig. 1. Distribution of stations and relocated epicenters (left), and two NW–ES cross-sections (right)

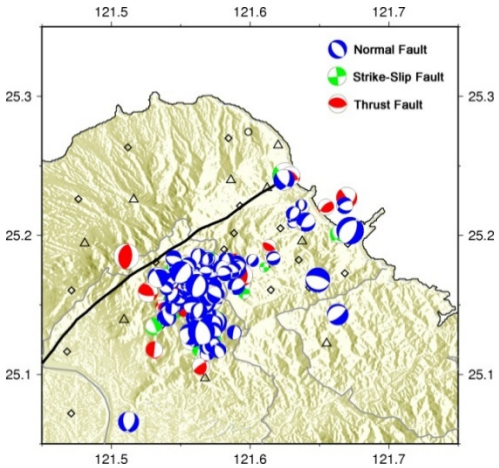


Fig. 2. First-motion focal mechanisms of the micro-earthquake

Volcano Monitoring and Prevention in Northern Taiwan

Ya-Chuan Lai, Hsiao-Fen Lee, Associated Research Fellow, NCREE

A series of volcanic eruptions occurred recently, such as the Agung, Sakurajima, and Kilauea volcano. Volcanic disasters pose considerable treat to human activities and society and greatly impact the safety of life, residential properties, and the ecological environment. To investigate whether the Tatun volcano, located in northern Taiwan in the Pacific volcanic chains, presents a potential threat, the possibility of activities of the Tatun Volcano Group (TVG) has been analyzed. The high helium isotope ratio found by Yang et al. (1999) implies that a magma reservoir probably exists beneath the TVG. Furthermore, ash dating reveals that the last eruption at the TVG was 5000–6000 years ago (Belousov et al., 2010). Based on these observations, it has been concluded that the TVG is an active volcano. Since the distance between the TVG and Taipei metropolitan area is less than 15 km, a strong volcanic impact may occur if the TVG is active again in the future. Thus, improving the understanding of the volcanic characteristics and activities in the TVG is an interesting scientific issue and is associated with the safety of the Taipei metropolitan area. To monitor volcanic activities in the TVG, the Taiwan Volcano Observatory at Tatun (TVO) has been established in 2011. A variety of observation systems, including seismic monitoring, crustal deformation, volcanic gas analyses, and geothermal measurement, are operating.

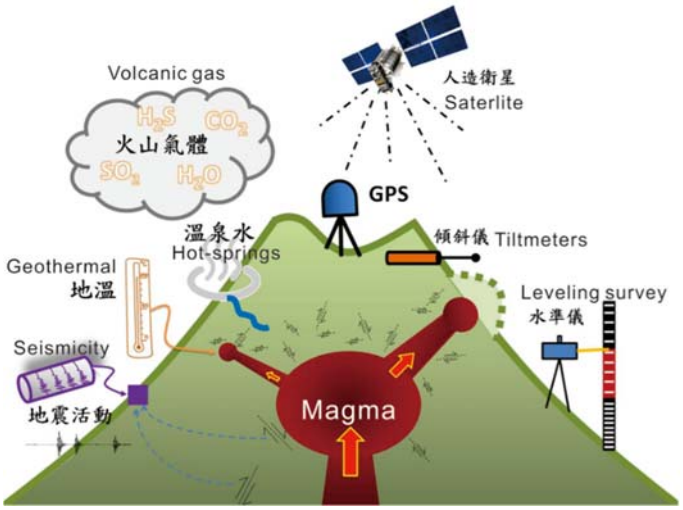


Fig. 1. Monitoring system of the TVG

Seismic Monitoring

A typical magma reservoir is located at depths ranging from several to tens of kilometers. When the magma uplifts, several microearthquakes are triggered along the path of magma migration. Therefore, we can detect seismicity for knowing the possible eruption time, location, and scale. Until now, 40 broadband seismic stations have been deployed to monitor the seismic activities in the TVG area. The small, shallow, and clustered earthquakes detected in the TVG are typical events observed in other volcanoes; such earthquakes are named volcano-tectonic (VT) earthquakes. The majority of VT earthquakes are clustered around Mt. Cising and Dayoukeng (DYK), where hydrothermal activities are high from geochemical observations. During a limited time period, hundreds of microearthquakes have occurred within a small area. Such a frequent sequence with no significant mainshocks among them is defined as a swarm. Such earthquake swarms are related to the variation of local hydrothermal system or the activity of magma. In contrast to VT, the events related to the fluid activity caused by pressure fluctuations or thermodynamics of fluid, such as monochromatic frequency, tornillos, and long-period events, are also observed in the TVG area.

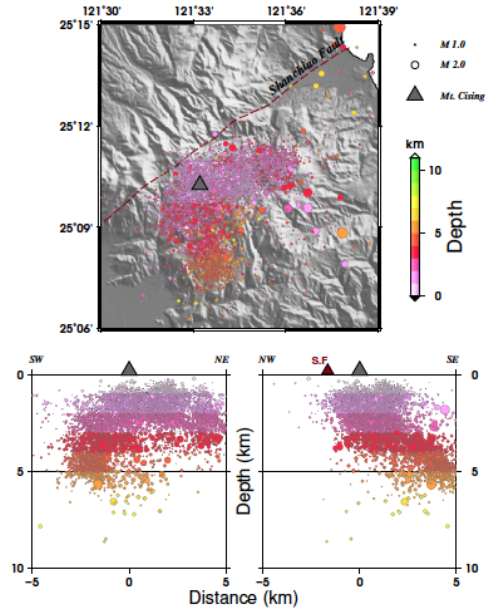


Fig. 2. Seismicity of the TVG

Not only the seismic activity but also the structure beneath the volcano has been understood with this dense seismic network. A deep magma reservoir beneath the northeast part of TVG has been identified from the evidence of both S-wave shadows and P-wave delays (Lin, 2016).

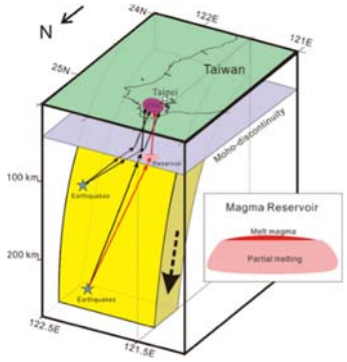


Fig. 3. Model of the magma reservoir beneath the TVG

Geodetic Survey

Crustal deformation detected by different geodetic surveys is another powerful method to discern the behavior of the magma chamber before eruption. Clearly, the crust surface might be deformed if the magma migrates or expands from the reservoir. The crustal deformation can be obtained from a variety of measurements. In the TGV, we have installed 8 GPS, 3 tilt-meters, and several leveling-survey routes for detecting any surface deformation. High uplifting of about 5 mm/yr has been obtained in Chintenkeng in the past several years.

Geochemical Analyses

It is well known that the variations in compositions of fumaroles and bubbling gases of hot springs are closely related to the volcanic activity. However, the relationship between gas variation and volcanic activity varies from each volcanic area. For better monitoring of the volcanic activity, we need to identify the sources and variation in compositions of fumaroles and bubbling gases of hot springs in one area. Samples were collected from the TVG by using “Giggenbach bottles”. The highest temperatures of these geothermal areas are around the boiling point of water. All of these samples show a similar composition as those of low-temperature fumaroles in other parts of the world. H_2O is the major species of these gas samples, and CO_2 is the dominant component after de-watering. Both the gas compositions and temperatures indicate that water vapor separated from the boiling water near the surface.

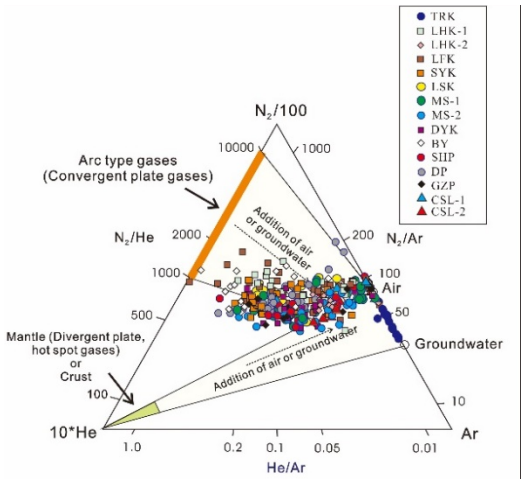


Fig. 4. N_2–He–Ar triangular plot for the TVG gases. Most samples fall in the range of a mixing trend between convergent plate gases and air/groundwater

The high $^3He/^4He$ ratios of all samples indicate a mantle-derived degassing source in the origin, i.e., magma chambers could still exist beneath the volcano. The carbon isotopic values of CO_2 of the TVG area exhibit a magmatic source.

The results of long-term observation in this area show that there is no significant change in gas composition. However, from 2005 to 2007, SO_2/H_2S ratios from DYK varied from 0 to 3. Meanwhile, HCl concentrations also increased dramatically. A large gravity variation and volcanic earthquake swarms took place subsequently. The same process happened again in 2010. In addition, we observed another phenomenon: only HCl concentration increased rapidly after a large tectonic earthquake in 2014.

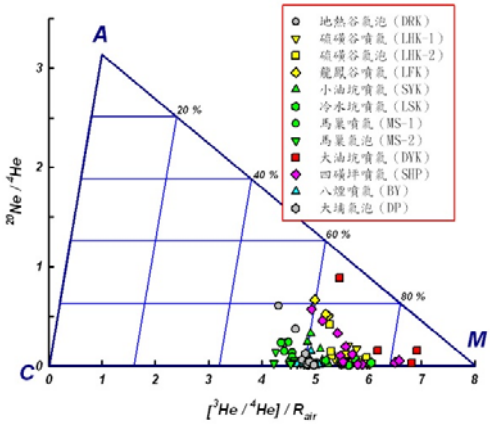


Fig. 5. $^3He/^4He$ ratio in Tatun area. More 60% of helium comes from the mantle source

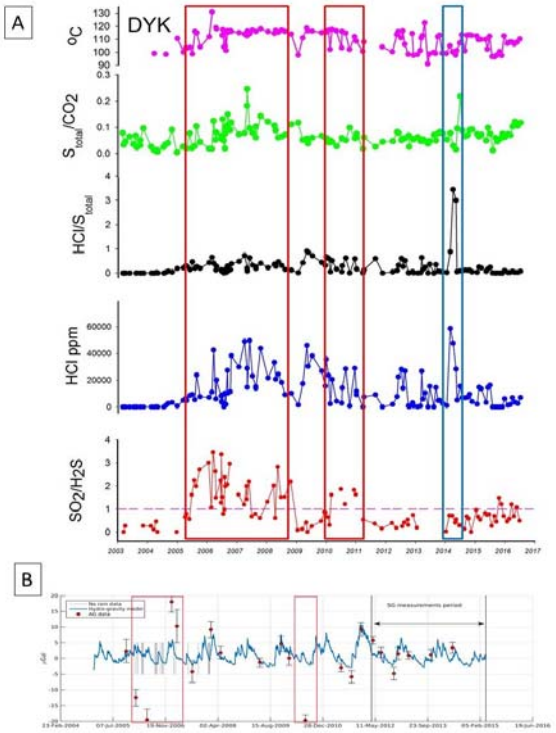


Fig. 6. (A) Long-tern variation in the DYK area (Red squares: SO_2/H_2S ratio > 1, Blue square: variation after the 2014 Shin-lin earthquake) (B) The gravity anomalies. Note that time scales are different

Integrating our observations with seismic and gravity data, we can associate fluid variations with two mechanisms. First, the variations of fluid concentration, seismic events, and gravity fluctuations occurred in a time series. We infer that magma chamber disturbance and/or deep fluid transportation might be the major cause. Second, the variations are reckoned as the consequence of a shallow hydrothermal reservoir disturbed by earthquakes, and the responding time is short and rapid.

Soil Radon Observation in the Tatun Volcanic and Shanchiao Fault Areas for Seismic and Volcanic Surveillance

Vivek Walia, Researcher, NCREE
Arvind Kumar, Associate Researcher, NCREE
Shih-Jung Lin, Liang Ming Chang, Assistant Researcher, NCREE

Since last few decades, scientific community has recognized that the variations of soil gas radon concentration as a useful tool for geodynamical monitoring in active fault zones, for surveillance in volcanic areas and for tracing neotectonic. In the last twenty years, new instruments and methods were developed to measure radon-thoron by using grab, integrating and continuous modes of sampling. The most common instruments used for radon-thoron monitoring since the mid1970's till today, consist into two categories: (i) passive detectors such as diffusion barrier type, electret ion chambers and alpha track detectors, (ii) active detectors such as RAD7, RTM 2200 etc. Although the active detectors are more accurate and precise than passive detectors, they are cost prohibitive and we cannot install these instruments near the volcanic areas because of the high probability of contamination due to high temperature and sulphur content. Alpha Track Detectors (ATDs) are cheap and can be installed near the volcanic areas. Because of their low cost we can also establish a number of long term radon-thoron monitoring stations in a particular area under observation which may not be possible by other techniques.

In views of this cellulose nitrate alpha detector films (LR-115) were installed in discriminative cups at selected sites in Hsiaoyoukeng (SYK), Dayoukeng (DYK), Gungtzeping (GTP) and Byen (BY) of Tatun volcanic Group (TVG) areas of northern Taiwan (Fig.1).

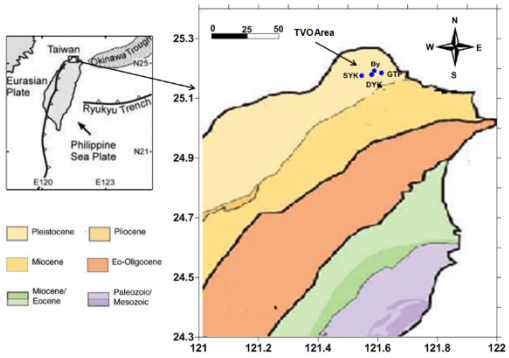


Fig. 1. Simplified geological map of Taiwan showing the locations of monitoring stations in TVG area

The observations have shown potential precursory signals for some earthquakes that occurred during the observation period. Most of the earthquakes correlated with anomalous radon value are within 60kms from the monitoring stations (Fig. 2). In order to build a continuous radon monitoring station in Shanchiao fault soil gas geochemical surveys had been undertaken in and around Shanchiao fault and three sites have been chosen (Fig. 3) for integrated radon monitoring using SSNTDs to visualize the tectonic activity of the fault systems.

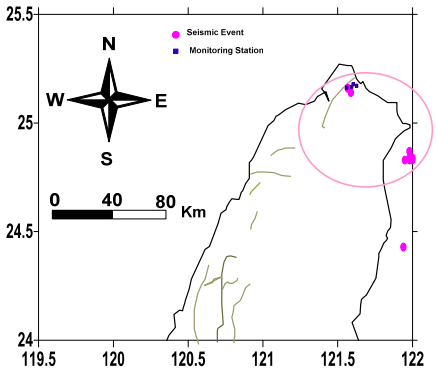


Fig. 2. Map showing the locations of monitoring stations and correlated earthquakes in TVG area

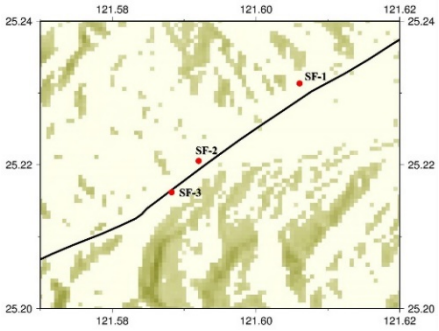


Fig. 3. SF-1, SF-2 and SF-3 sites for integrated radon monitoring using SSNTDs

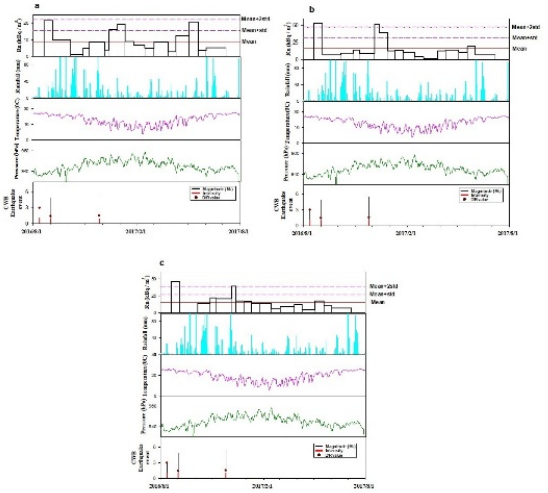


Fig. 4. Radon data recorded at (a) SF-1, (b) SF-2 and (c) SF-3 sites

The seismic sensitivity of three sites has been analyzed by integrated radon monitoring using SSNTDs (Fig.4) and site SF-3 has been selected for establishing the continuous and long term radon monitoring station which will be helpful for earthquake prediction study in Taiwan.

Possible Correlation between Faults, Volcanism and Shallow Crustal Velocity Structures in the Tatun Volcano Group

Yu-Chih Huang, Associate Research Fellow, NCREE
Cheng-Horng Lin, Research Fellow, IES, Academia Sinica
Tsuneomi Kagiyama, Emeritus Professor, Kyoto University

Various recent lines of evidence suggest that the Tatun Volcano Group (TVG) is a potentially active volcano and that future volcanic eruptions cannot be ruled out. Geothermal activities are largely constrained to faults, but the relationship between volcanism and detailed velocity structures is not well understood. We analyzed ambient seismic noise of daily vertical components from 2014 using a dense seismic network of 40 broadband stations. We selected a 0.02° grid spacing to construct shallow crustal phase velocity maps in the 0.5–3 s period band.

The footwall of the Shanchiao Fault is dominated by low velocity, which may relate to the Tertiary bedrock buried under andesitic lava flows dozens to hundreds of meters thick. The hanging wall of the Shanchiao Fault is the location of recent major volcanic activities. Low-velocity zones in the southeast of Dayoukeng may be interpreted as hydrothermal reservoirs or water-saturated Tertiary bedrocks related to Cenozoic structures in the shallow crust. High velocities conspicuously dominate the east of the TVG, where the earliest stages of volcanism in the TVG are located, but where surface hydrothermal activities were absent in recent times. Between the Shanchiao Fault and Kanchiao Fault, high velocities were detected and may be related to early stages of magma conduits that gradually consolidated. These two faults may play a significant role with the TVG.

Seismic Network

Figure 1 shows that the seismic network used in this study is composed of three sub-networks. All equipped with Güralp CMG-6TD broadband seismometers and are operated by the Taiwan Volcano Observatory at Tatun (TVO).

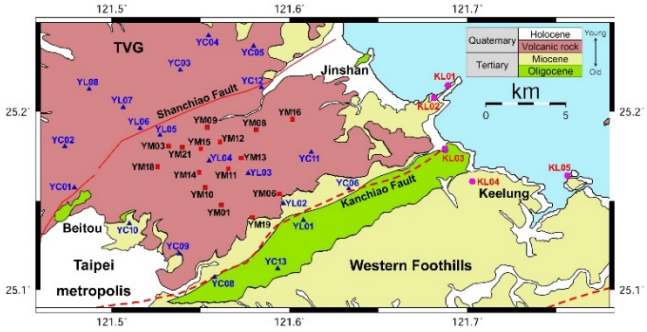


Fig. 1. Surface geology and broadband seismic network in this study

Ambient Seismic Noise Studies

The time domain empirical Green's function (TDEGF) can be obtained from the cross-correlation of station pairs with simultaneous and continuous ambient seismic noise signals. This method uses diffuse wave fields with passive structural signals. The depth range of the obtained velocity structure is positively related to the aperture of the seismic network, and its lateral resolution is positively related to the density of path coverage. Ambient seismic noise studies have been routinely used to investigate subsurface velocity structures in various parts of the world over the past decade. Figure 2 demonstrates examples of the calculated 0.5–7 s CCFs and measured 0.5–5 s Rayleigh wave phase velocity dispersion curves.

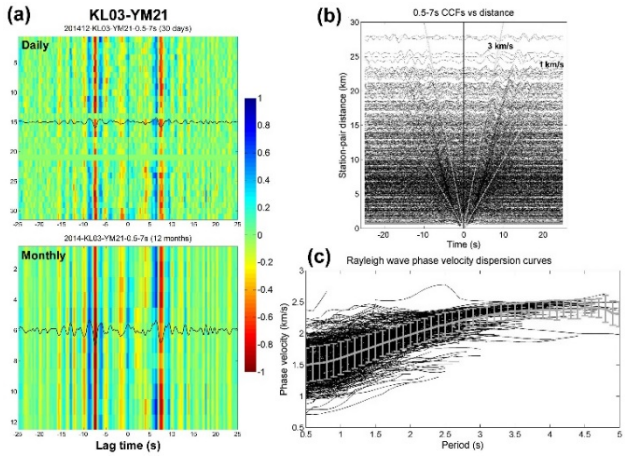


Fig. 2. Examples of (a) daily and monthly 0.5–7 s CCFs for KL03-YM21; (b) annual CCFs against interstation distance; (c) measured 0.5–5 s Rayleigh wave phase velocity dispersion curves for all station pairs

Phase Velocity Maps

We constructed phase velocity maps in the 0.5-3 s period band to determine the predominant velocity distributions (Figure 3). The lateral resolution of the phase velocity maps was approximately 2.5 km in the TVG and 5 km in its eastern parts and margins. Rayleigh wave phase velocities are more closely related to the Vs structures and are more sensitive to fluid distributions. In general, Rayleigh waves are sensitive at depths approximating one-third of wavelengths and vary with periods. Therefore, the sensitive depth of S-wave velocity structures is ~3 km in this study.

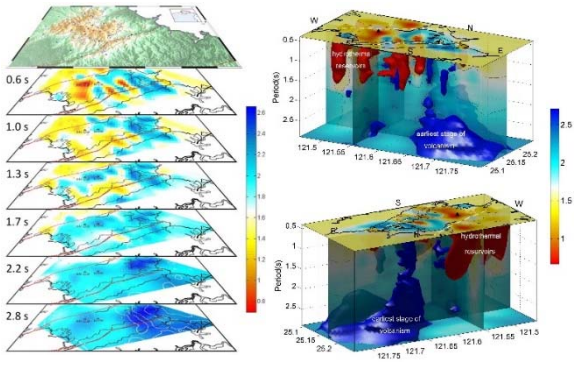


Fig. 3. Rayleigh wave phase velocity maps in the TVG

2018 International Educational Tour of the University of Santo Tomas, Philippines Visited NCREE Taipei Laboratory

Chiun-lin Wu, Pei-Yang Lin, and Shyh-Bin Chiou, NCREE

The National Center for Research on Earthquake Engineering hosted 145 guests from the University of Santo Tomas, Philippines, who visited its Taipei Laboratory on April 24, 2018. The Philippines delegation composed of one staff leader, six professors, and 138 undergraduate civil engineering students. The Pontifical and Royal University of Santo Tomas, the Catholic University of the Philippines, or simply the University of Santo Tomas (UST), is a private, Roman Catholic research university in Manila, Philippines, founded on April 28, 1611; it has more than 44,000 students. The visit program started with a warm welcome address by NCREE's Director-General Shyh-Jiann Hwang, followed by a 20 min film introducing NCREE's institutional profile, testing facilities in the Taipei Laboratory, an oral PowerPoint presentation introducing the new NCREE Tainan Laboratory opened in 2017, and Q&A interaction with students and professors. The Philippines delegation was divided into two groups for the guided tour to the Taipei Laboratory facilities, including the 5 m × 5 m triaxial earthquake simulator, the L-shape reaction wall and the strong floor quasi-static testbed, the Multi-Axial Testing System (MATS) for LRBs and structural sub-assemblages, and the high-speed dynamic actuator testing system for seismic energy dissipating devices under a prescribed operating temperature. The tour was successfully ended with a group photo of professors and students from the University of Santo Tomas together with Mr. Shyh-Jiann Hwang and his staff. It is the great pleasure of NCREE that the University of Santo Tomas students chose Taiwan for their 2018 International Educational Tour.



Group photo of professors and students from the University of Santo Tomas, Philippines, together with Director-General S.J. Hwang of NCREE and his staff

Blind Analysis Contest on a 7-story Reinforced Concrete Building under Near-fault Earthquakes

Yuan-Tao Weng, Assistant Researcher, NCREE
Fu-Pei Hsiao, Research Fellow, NCREE

On February 6, 2016, an earthquake of Richter magnitude scale M_L 6.6 occurred at Meinong District of Kaohsiung City, Taiwan. The earthquake caused significant damage in and around Tainan city, with a number of collapsed and severely damaged buildings and 117 deaths (Fig. 1). The collapsed buildings all contained irregularities and soft stories. In Taiwan, near-fault effects on building structures are an important issue. The performance of the shaking table in the NCREE Tainan Laboratory can present the characteristics of near-fault ground motions. A blind prediction contest will be held as a contribution to the development of computational prediction of seismic responses and efficient modeling techniques for reinforced concrete frame buildings involving near-fault effects and a "soft/weak" first story condition. The goal is to promote efficient seismic performance assessment methods for reinforced concrete frames. Accordingly, shaking-table tests of a 1:2-scale seven-story reinforced concrete frame building (Fig. 2) will be carried out. Each participant should predict the responses before and after the tests, and the closest prediction to the test results will be awarded.



Fig. 1. Collapse of Weiguan Jinlong Complex in the M_L-6.6 Meinong Earthquake



Fig. 2. 1:2 scale 7-story RC building model

Seminar on Technology for Structural Health Monitoring

Fu-Pei Hsiao, Research Fellow, NCREE

A seminar on the Technology for Structural Health Monitoring was held by the National Center for Research on Earthquake Engineering (NCREE) and UBE Taiwan Co., Ltd. on May 24st, 2018. This seminar invited Prof. Masaomi TESHIGAWARA (Professor at the Division of Environmental Engineering and Architecture, Nagoya University) and Prof. Koichi KUSUNOKI (Professor at Earthquake Research Institute, the University of Tokyo). Prof. Masaomi TESHIGAWARA and Koichi KUSUNOKI gave the lecture, entitled "seismic performance evaluation of an eight-story steel-reinforced concrete building using performance curves of the building" and "building damage evaluation after an earthquake with sensing technology", as shown in Figs.1 and 2, respectively. Many engineers from the consultant company joined this seminar to learn about technology for structural health monitoring.



Fig. 1. Photo of Prof. Masaomi TESHIGAWARA from Nagoya University



Fig. 2. Photo of Prof. Koichi KUSUNOKI from University of Tokyo

International Workshop on Post-earthquake Seismic Performance Assessment and Retrofit Technology

Fu-Pei Hsiao and Shu-Chin Liu, NCREE

Taiwan is located at the circum-Pacific belt. A large earthquake disaster will cause varying degrees of damage status to buildings. The use of buildings that suffer severe damage within a short time must be avoided in order to prevent human casualties during aftershocks. The government has issued an ordinance related to the emergency assessment of dangerous buildings after a disaster.

The damage caused by the M_L 6.26 earthquake event that hit Hualien City on February 6, 2018 is difficult to estimate. As a result, the National Center for Research on Earthquake Engineering (NCREE) and Department of Civil and Construction Engineering of NTUST held the International Workshop on Post-Earthquake Seismic Performance Assessment and Retrofit Technology on March 2, 2018. This seminar invited Prof. Nakano YOSHIAKI (Professor at Institute of Industrial Science, The University of Tokyo), and Prof. Maeda MASAKI (Professor at Department of Architecture and Building Science, Tohoku University) to give lectures. Their photos are shown in Figs.1 and 2. They introduced the development of post-earthquake seismic performance assessment and retrofit technology in Japan. We expect this seminar to provide a substantial contribution to the academia and industry in Taiwan.



Fig. 1. Photo of Prof. NAKANO Yoshiaki from the University of Tokyo.



Fig. 2. Photo of Prof. MAEDA Masaki from Tohoku University

2018 the 11th Taiwan–Japan Workshop on Structural and Bridge Engineering

Fang-Yao Yeh, Research Fellow, NCREE

The M_L-6.2 Hualien Earthquake hit Taiwan at 23:50 am on February 6, 2018. This earthquake resulted in 282 people with injuries and the death of 17 people. Bridges such as the Qixingtan Bridge and the Hualien Bridge were significantly damaged and four buildings collapsed. After the disastrous earthquake, researchers have paid more attention to bridge damage due to earthquake and multiple hazards. The 11th Taiwan–Japan Workshop on Structural and Bridge Engineering (2018), jointly organized by Kyoto University and National Center for Research on Earthquake Engineering (NCREE), was held over April 3–4, 2018, at the NCREE, Taipei, Taiwan.

The objective of this workshop was to exchange information on the latest research undertaken and practical experience as well as to address future challenges in structural and bridge engineering. Some outstanding professors and senior researchers were invited to present their achievements in structural and bridge engineering and to share their experiences. Workshop attendees came from Japanese organizations, including Kyoto University, Osaka City University, Akashi National College of Technology, Hanshin Expressway Company Limited and SHO-BOND Corporation, and Taiwanese organizations, including the National Taiwan University, National Chiao Tung University, National Cheng Kung University, National Taipei University of Technology, National Taiwan University of Science and Technology, National Pingtung University of Science and Technology, Tam Kang University, and NCREE. The topics of this workshop focused on four parts: (1) structural engineering, (2) bridge engineering, (3) damage report on 2018 0206 Hualien Earthquake, and (4) other problems currently faced by structural and bridge engineers. The success of this event is believed to contribute to the development and promotion of bridge engineering in Taiwan and that local researchers and engineers are expected to gain useful information.



Fig. 1. Participants of the 2018 the 11th Taiwan–Japan Workshop on Structural and Bridge Engineering

NGI-NCREE Workshop for Foundation Issues of Offshore Wind Turbine

Shang-Yi Hsu, Associate Researcher, NCREE

To sign a Memorandum of Understanding (MoU) between Norwegian Geotechnical Institute (NGI) and the National Center for Research on Earthquake Engineering (NCREE), a workshop was held in the R101 Conference Room of the NCREE on June 4, 2018, in which the foundation design issues of offshore wind turbines (OWTs) were examined. This workshop brought together the experiences of NCREE and NGI and provided a forum to discuss some of the challenges and solutions for OWTs in Taiwan.

The main topics of this workshop included (1) seismic considerations and foundation design issues, (2) geotechnical design of foundation piles, anchors and cables, (3) advances in soil–structure interaction for OWTs, (4) challenges of the foundation design for OWTs in Taiwan, (5) seismic requirement for OWTs in Taiwan, and (6) earthquake and wave-induced soil liquefaction. Workshop attendees were both foreign and local developers of offshore wind farms and members of Taiwanese organizations, including the authorities of OWTs, the engineering consultants companies for OWTs, and the universities and research institutions. The success of this event is believed to contribute to the development and promotion of seismic considerations and foundation design of OWTs in Taiwan and local researchers and engineers are expected to gain useful information.

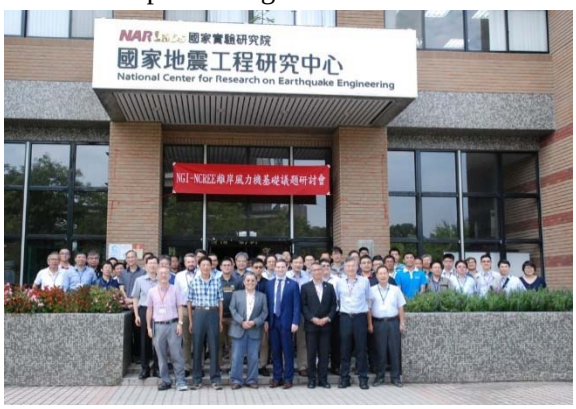


Fig. 1. Group photo of the NGI-NCREE workshop for foundation issues of offshore wind turbine



Fig. 2. Speaker presenting in the conference

Workshop on Investigation of the February 6, 2018 Hualien Earthquake, Taiwan

Jui-Liang Lin, Research Fellow, NCREE

On May 29, 2018, the NCREE, Chinese Institute of Civil and Hydraulic Engineering, and Department of Civil Engineering at National Cheng-Kung University co-hosted a workshop entitled "Investigation of the February 6, 2018 Hualien Earthquake, Taiwan" (Fig. 1). This workshop attracted about 70 attendees, including professors, experts, and practicing engineers. The workshop contained eight lectures with the following topics:

The 1st topic "Characteristics of ground motions" dealt with the earthquake mechanism and the site effects. In addition, the response spectra were compared with those stipulated in the current seismic design code. The 2nd topic "Investigation of building damage" showed the statistics of the damaged buildings under this ground shaking. NCREE's rapid seismic evaluation method was verified again in terms of these statistic results. The 3rd topic "Seismic responses of buildings with soft/weak bottom stories subjected to near-fault ground motions" introduced the shaking table test performed on the opening date of NCREE's Tainan laboratory. The specimen of the shaking table test was a three-story reinforced concrete building with a soft/weak bottom story. The simulation and analysis of this building subjected to far-field and near-fault ground motions were introduced. The 4th topic "Seismic assessment of base-isolated Hualien Tzu Chi Hospital" verified the consistency between the measured seismic responses of the base-isolated building and those estimated by using the numerical model. In addition, the displacement demands of base-isolated buildings subjected to ground motions with high-velocity pulses were investigated. The 5th topic "Seismic demands and loss of non-structural components in critical buildings" showed the damage states of non-structural components in schools, hospitals, and important transportation facilities. The seismic demands and damage types of non-structural components were systematically categorized. The 6th topic "Effect of crossing fault on seismic resistance of bridges" showed the damage states of bridges in the seismic event. Through some actual cases and numerical comparative analyses, the characteristics of seismic responses of bridges crossing fault lines were highlighted in comparison with those of bridges not crossing fault lines. The 7th topic "Investigation and preliminary analysis of seismic damage of the harbor district of Hualien Port" showed not only the damage states but also the liquefaction potential of the port. In addition, the results of seismic fragility analysis of the port were compared with the actual damage states. The 8th topic "Seismic damage of the water supply system and the preliminary study" detailed the damage states of the water supply system. The estimated seismic loss of the water supply system by using NCREE's seismic evaluation programs was also presented. The countermeasures for the piping crossing fault lines were suggested.

The scope covered by the lectures was extensive. Not only the damage states collected from seismic reconnaissance but also the associated further analysis results were presented. As a result, through this workshop with the purpose of sharing the knowledge we gained, the capacity of seismic resistance on every aspect of our society was certainly improved. In particular, more insights were attained regarding the near-fault ground motions and their effects on seismic responses of structures and non-structural components.



Fig. 1. A scene of the workshop

IDEERS 2018

In order to encourage student participation in science games and stimulate their creativity, an earthquake engineering education project titled "Introducing and Demonstrating Earthquake Engineering Research in Schools (IDEERS)" will be held by the National Applied Research Laboratories (Narlabs), the National Center for Research on Earthquake Engineering (NCREE), and the British Council in Taipei on September 13–15, 2018.

IDEERS is a science-based project with a competition developed by the Earthquake Engineering Research Center at Bristol University. The target participants of the IDEERS competition are graduate and undergraduate students majoring in civil engineering-related subjects and high school students. Students entering the competition will construct models using cheap materials at NCREE and have them tested on the "Tri-Axial Seismic Simulator". Models will be shaken to destruction and the best-designed models will win prizes.

For further information, please visit the IDEERS website: http://www.ncree.org/ideers/2018/.

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