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Development of Horizontal and Vertical Ground Motion Models for Shallow Crustal and Subduction Earthquakes in Taiwan

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Probability seismic hazard analysis (PSHA) requires an estimate of the expected median ground motion and its uncertainty at the site of interest, which is usually obtained using the ground motion model. Several models have been proposed for the prediction of the ground motion in Taiwan in the past few decades. However, their PSHA applications are limited for several reasons:

(1) Some models are based mainly on either data for shallow crustal earthquakes or mixed usage without consideration of the apparent differences between shallow crustal and subduction earthquakes.

(2) Some models are only available for peak ground acceleration (PGA) prediction.

(3) The site condition applicability of some models is not known.

(4) Many models only consider total sigma, while single-station sigma has not been considered.

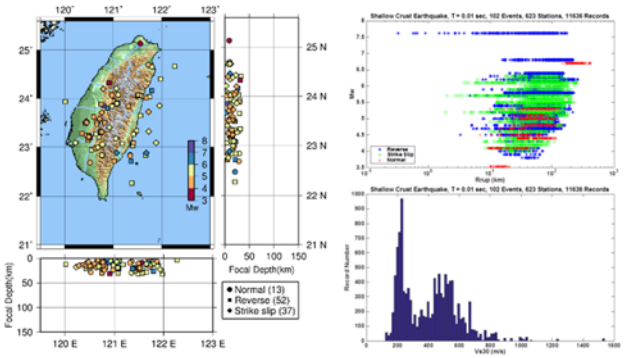


Fig. 1. Selected ground motion data of a shallow crustal earthquake for developing ground motion models

As a result, new ground motion models are being developed for Taiwan using the ground motion database of the Taiwan SSHAC Level 3 Project in this study (http://sshac.ncree.org.tw). The proposed models aim to capture the key ground motion characteristics in Taiwan and to meet the requirements of PSHA and other real engineering applications. Key features of the proposed models in this study include the following:

(1) Ground motion models for shallow crustal and subduction earthquakes are developed separately. Selected ground motion data of shallow crustal earthquake are shown in Figure 1.

(2) Both horizontal and vertical ground motion models are developed. The orientation-independent horizontal component RotD50 is used as the horizontal ground motion intensity measurement.

(3) The applicable spectral acceleration period range is from 0.01 s to 10 s to cover the fundamental period of general civil structures.

(4) Instead of the hypocenter distance, different distances from the site to the fault rupture plane are considered to capture the ground motion characteristics more accurately.

(5) Unit step functions at different break points are used for moment magnitude Mw scaling to simulate the saturation of ground motion at large magnitude ranges..

(6) Focal depth, focal mechanism, and rupture dip angle scaling of ground motion are evaluated.

(7) A magnitude-dependent attenuation function is used to capture the extended rupture source effect of near source ground motion.

(8) Vs30 (the average shear wave velocity of soil layers 30 m deep) scaling is evaluated for different site condition applications and Z1.0 (depth to V_s = 1.0 km/s) scaling is evaluated to include the basin effect.

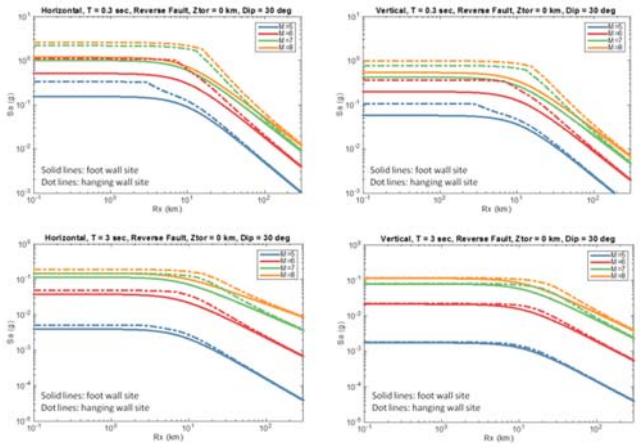


Fig. 2. Hanging wall effect on vertical and horizontal spectral acceleration for periods 0.3 s and 3 s

(9) The hanging wall effect is evaluated to capture accurate near-fault ground motion of shallow crustal earthquakes, as shown in Figure 2.

(10) The statistical uncertainty of the model prediction is evaluated to capture the epistemic uncertainty of the ground motion models.

(11) The total residual term is divided into an event-specific residual term, a site-specific residual term, and a record-specific residual term. The variances of each residual term as well as a single-station sigma are evaluated for site-specific PSHA applications.

The proposed ground motion models will be useful to conduct site-specific PSHA in Taiwan. Due to the page limitation, the function forms as well as the coefficients of the proposed models are not shown, although they can be provided by the author through email. In the future, the nonlinear site effect and the near-fault directivity effect should also be considered to improve the accuracy of the median prediction.

Zoneless Approach for Areal Seismic Source Modeling in Taiwan

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In probabilistic seismic hazard assessment (PSHA), it is common practice to construct a seismic source model that delineates areal zones based on regional seismicity and tectonic structures. However, where there is lack of seismicity and geology data due to limited observation time periods and surveying space, the seismicity characteristics within each areal zone are supposed to be homogeneous (uniform). Therefore, the construction of the area zone geometry may become subjective.

An alternative method for areal source modeling uses a zoneless approach and is mainly based on the kernel density estimation inferred from the earthquake catalog. The basic assumption for the zoneless approach is that damaging earthquakes in the future will occur at or near the locations of past events. In the study, a two-dimensional Gaussian smoothing method is used to calculate the spatial probability distribution for event occurrences, and the regional maps of smoothed-gridded seismicity are modeled.

The procedure for the zoneless approach for areal source modeling is as follows: (1) a historical earthquake catalog with complete treatment (e.g., seismicity declustering, catalog completeness, and network data integration) is prepared; (2) a grid alignment is constructed over the study region for gridded seismicity; (3) the number of earthquakes with magnitudes greater than the reference level (or minimum magnitude) in each grid cell is counted, and these are then distributed smoothly and spatially using a Gaussian function; (4) the distribution results from each grid cell are superpositioned, and then a two-dimensional probability distribution model of seismic occurrence rates is established.

The earthquake data used to implement the zoneless approach for the area seismic source model in Taiwan is from the Central Weather Bureau's Geophysical Database Management System. The essential attributes of the earthquake catalog are as follows: (1) the period of time is from 1900 to June 2015; (2) it covers the region of 21–26°N, 119–123°E; (3) it accounts for fore- and after-shocks declustering and catalog completeness; (4) it includes shallow seismicity (depth ≤ 35 km) with the removal of subduction-zone earthquakes; and (5) the minimum level of moment magnitude (M_w) is 4.0.

In the zoneless approach, a two-dimensional Gaussian distribution is applied as the kernel function. The smoothed seismicity rates of each grid cell is obtained from

$$\lambda_{m_0}(x,y) = \frac{N(m_0)}{2\pi n}\sum_{i=1}^{n}\left(\exp(-\frac{1}{2}\frac{d_i^2}{h^2})\right) \qquad (1)$$

where $N(m_0)$ is the regional seismicity rate, m_0 is the minimum level of the gridded seismicity, x and y are the longitude and latitude coordinates of the central grid cell, respectively, n is the total number of earthquakes with magnitudes greater than or equal to m_0, d_i is the distance between grid cells, and h is the smoothing parameter (also called correlation distance).

For the trial map of smoothed-gridded seismicity, each grid cell has dimensions of 0.1° latitude by 0.1° longitude. m_0 is 5.0 according to the hazard aspect. The smoothing parameters are given 15 and 30 km depending on the uncertainty of the epicenter location which is estimated by statistics regarding the maximum distances between each main-shock and its after-shocks. In addition, the regional activity rate N(5.0) is 8.219 based on the G-R relation with minimum M_w of 4.0.

The zoneless approach and the trial smoothed- gridded seismicity results are shown in Fig. 1. In summary, the zoneless approach of spatially smoothed seismicity may be an alternative method for areal source modeling, rather than using a zoning scheme that assumes a uniform seismic probability in each zone. The smoothing parameter affects the results of the smoothed seismicity. Using adaptive distance according to event magnitude or location will be discussed in future studies.

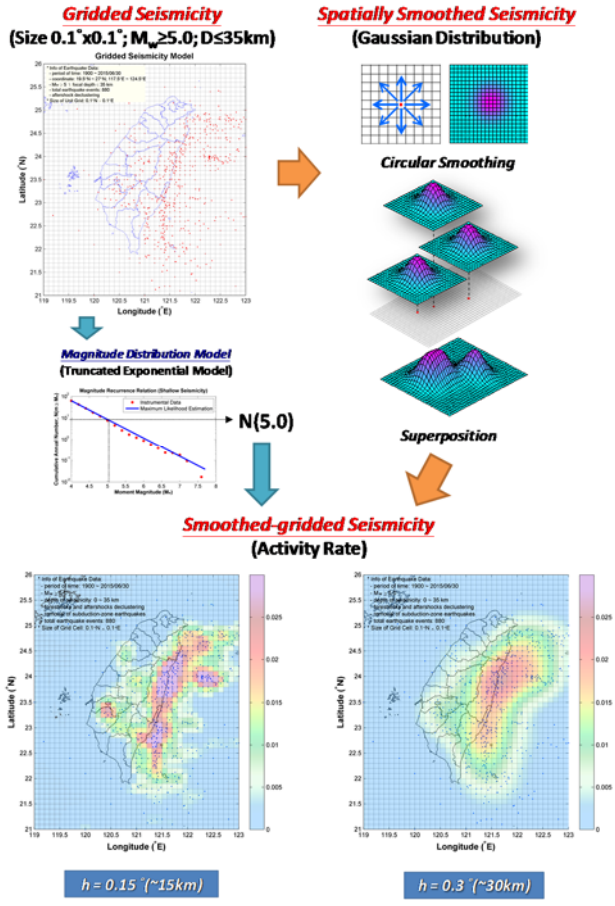


Fig. 1. Example flowchart for areal seismic source modeling using a zoneless approach

The Seismicity of b-Value Map in Southwestern Taiwan

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A complete seismic catalogue is important for understanding the background seismicity in a tectonic regime. Better knowledge about the background seismicity in a seismically active area may provide a way to investigate abnormal activity that may act as a precursor to a strong earthquake. Gutenberg and Richter (1942) propose a remarkable empirical equation to describe the relationship between event magnitude and the frequency of occurrence in a region. The formula is logN = a – bM where N is the cumulative number of events with a magnitude greater or equal to M. The b-value indicates the proportion of large and small seismic events, while the a-value is associated with the total seismicity rate in a region. The global variations of b-values are in the range of 0.5 to 2.5, depending on the tectonic environment of the region. In general, the b-value is close to 1.0 in seismically active regions and greater than 2.0 in the source regions that also have swarm-like seismic events. A number of studies (Tsai, 1981; Wang, 1988; Cheng and Yeh, 1989) have been conducted to investigate b-values in the Taiwan region. The results show that b-values range from 0.8 to 1.2 for the whole island. In addition, the Central Weather Bureau (CWB) increased the spatial coverage of seismic stations since 1974 and upgraded the seismic networks for continuous recording. This has greatly improved the overall capability for the detection of smaller earthquakes. Currently, the magnitude of completeness (Mc) is down to 1.6.

A fundamental and crucial procedure before the calculation of the b-value is to de-cluster the seismic catalogue. The main purpose is to remove the aftershocks produced by strong earthquakes to truly reveal the "background seismicity". In this research, we have divided the study area into grids of dimensions 4 km x 4 km. At least 100 events within a radius of 15 km are necessary to obtain a b-value. We analyzed the seismic catalogue compiled by the CWB from 1991 to 2015. The depth of events used in the calculation is from 0-30 km. The spatial distribution of b-values in SW Taiwan is illustrated in Fig.1(b). Fig. 1(c) depicts the recurrence time map of events M≧ 6 in southwestern (SW) Taiwan.

From Fig. 1(b), our results indicate that a low b-value is located in the hanging-wall of the Chukou Fault as well as in the areas of Chishan, Meinong and Jiasian, Kaohsiung County. The relatively lower b-value in the above areas reflects the high stress accumulation due to plate collision. From the b-value map from 1991 to 2015, we can summarize three key points: (1) the greatly deformed western foothills have higher b-values, this implies a highly fractured crust where vast microearthquakes have occurred; (2) Lower b-values exist in the Chishan and Meinong areas, probably due to high stress accumulation, which leads to less seismic activity but with strong earthquakes if a rupture occurred (Fig. 2). The 2016/02/06 Meinong earthquake also occurred in this area.

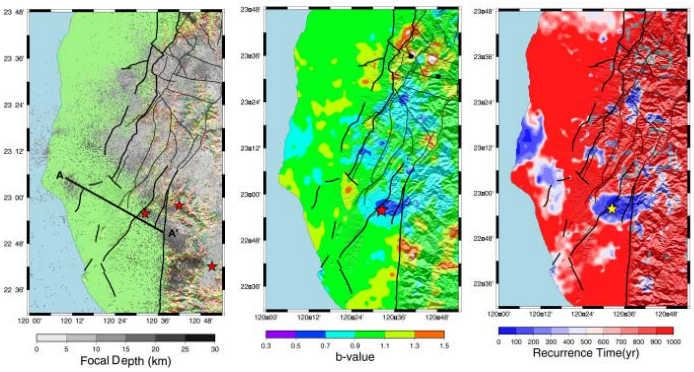


Fig. 1. (a) Seismicity in SW Taiwan from 1991 to 2015; (b) the b value map in SW Taiwan; (c) the recurrence period for M≧ 6

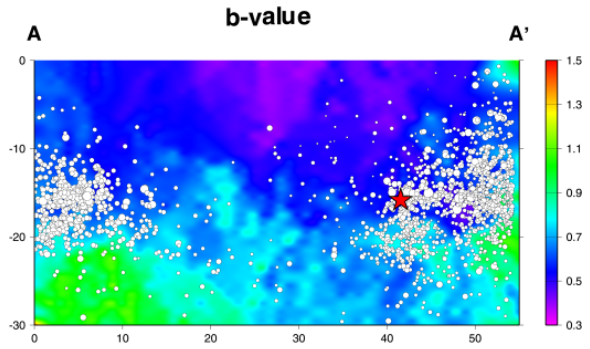


Fig. 2. Distribution of b-values in profile AA'. The red star is indicated as the 2016 Meinong Earthquake.

(3) The b-value is ranging from 0.3 to 1.5 in SW Taiwan, which indicates complex geological structures in our study area. Huang and Turcotte (1988) suggest that b-value is also related to different types of focal mechanisms, which the thrust faulting is with lower b-value and normal faulting is with higher b-value. Our results indicated that the b value is consistent with the observations from Huang and Turcotte (1988) (Fig. 1(b)).

Investigating and monitoring abnormal seismic activity are extremely important issues in seismic precursors, hazard mitigation and preparation. These abnormal seismic activities may be associated with stress changes in the crust before a strong earthquake strikes. Therefore, carefully analysis of spatial-temporal variations in seismicity and b-value provides great help in understanding the earthquake nucleation process in seismogenic zones.

Characterization of Selected Mud Volcanoes in Southern Taiwan

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Mud volcanoes are features that episodically emit gases, fluids, and mud on land, causing damage to life and property, including buildings, crops, and other facilities. The main gas component emitted during a mud volcano eruption is methane, one of the key greenhouse gases that affect the environment. This study not only provides insight into the activity of mud volcanoes and the mechanism of fluid transportation but also enables the control of mudflow and gases to reduce the damage.

Two mud volcanoes were selected for the present study: the Wan-Dan mud volcano in Pingtong and the Niau-sung mud volcano in Kaohsiung (Fig.1). Both are above the mud diaper system in southern Taiwan. Three different sampling techniques were used to collect samples in and around these two mud volcanoes.



Fig. 1. The Wan-dan mud volcano (left) and the Niau-sung mud volcano (right) in southwestern Taiwan

The water from a nearby river and the mud flow samples were collected after passing through a 0.2 μm filter. Later, the collected samples were analyzed with an Isotope Analyzer-LGR (δO18/δD for H_2O). The results show that the river water samples from different locations fall on the meteoric line (Fig.2). However, the mud samples are heavier in the oxygen isotope, while the hydrogen isotope remains the same. This indicates that the fluids come from a deeper source and interact with the rock

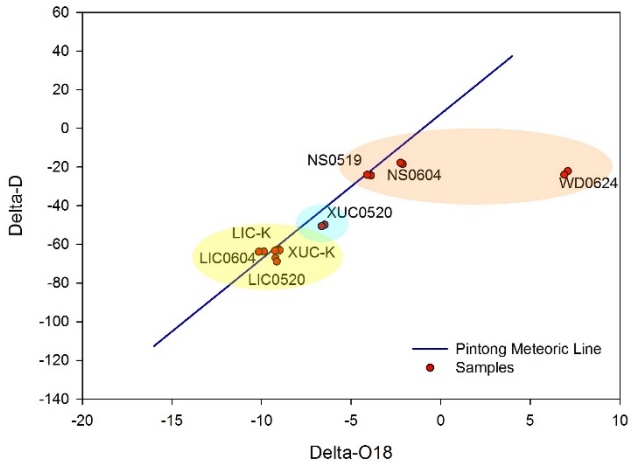


Fig. 2. Water isotope composition of mud volcanoes and surface water in comparison to the meteoric line of southwestern Taiwan

Soil gas samples were collected at a depth of 1 m and dissolved gases from the mud volcanic site (or nearby) were collected for gas chromatography (GC) analysis. The result (Fig.3) shows that the dissolved gases of the Niau-sung mud volcano and the Wan-dan mud volcano contain up to 9% carbon dioxide, whereas the ground water samples in Wan-dan contain a high concentration of methane of up to 35%.

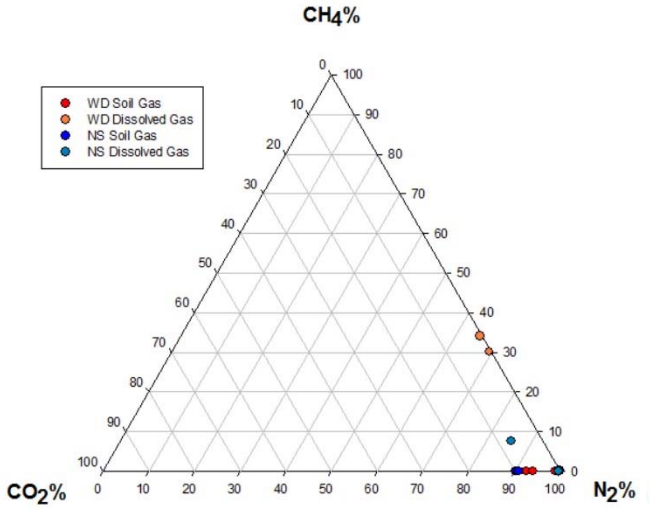


Fig. 3. Ternary plot of gas percentage of mud volcano fluid

Soil gas samples and dissolved gas from mud pools and ground water were analyzed bi-weekly for radon concentrations using Rad7 (a solid-state nuclear track detector). Fig.4 shows the variation in radon concentrations from May to July 2016. To compare the collected data with the eruption cycles of the Wan-dan mud volcano (i.e., 57 days) and the Niau-sung mud volcano (i.e., 61 days), a long-term investigation will be needed to understand the relationship of mud volcanoes and their tectonic activities with gas composition variations.

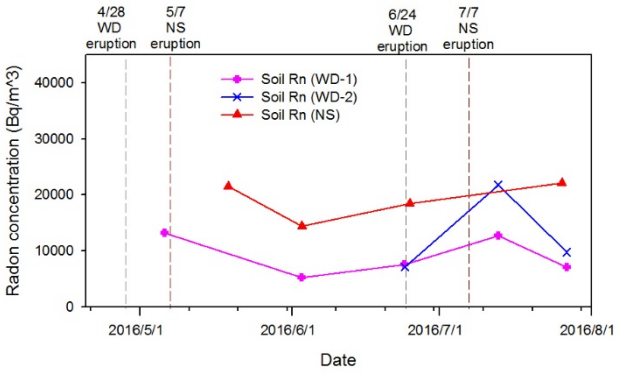


Fig. 4. Radon concentration variations from May to August 2016

A Site Database for the Strong Motion Network in Taiwan

Chun-Hsiang Kuo, Che-Min Lin, Associate Researcher, Hung-Hao Hsieh, Assistant Research, NCREE
Kuo-Liang Wen, Division Director, NCREE, National Central University

Ground motion prediction is an important part of seismic hazard assessment. The Ground Motion Prediction Equation (GMPE) is commonly used in earthquake engineering. Because of the active tectonic setting, various climate conditions, and complex geology in Taiwan, seismic site conditions can vary substantially by region. Therefore, a seismic site database is quite important in addition to the essential strong motion database for ground motion predictions. Due to the efforts of the Central Weather Bureau (CWB), a strong motion network with the highest density in the world is in operation in Taiwan. Much strong ground motion data have already been provided to seismologists and earthquake engineers for related studies. A site database for the strong ground motion network is therefore necessary, especially for studies on ground motion prediction and seismic hazard assessment in Taiwan.

The National Center for Research on Earthquake Engineering (NCREE) of the National Applied Research Laboratories (NARL) carried out an investigation on free-field stations in the Taiwan Strong Motion Instrumentation Program (TSMIP) along with the CWB from 2000 to 2012. A total of 483 stations were investigated, with 451 stations subjected to complete investigations, including surface investigations, borehole drilling, and measurement of velocity. Only surface investigations were conducted at the other 32 stations for reasons such as the inability to transport the drilling equipment to the site or the denial of permission to drill from the land owner. NCREE subsequently compiled the results into the Engineering Geological Database for TSMIP (EGDT). This database provided important information such as soil classification, plasticity indices, gravel sizes, geology conditions, velocities, and blow numbers of the penetration test (SPT-N values). The data have been provided to universities, institutes, and companies. Empirical Vs equations for Taiwan evaluated using the database have been prepared according to the national seismic design code.

However, the GMPEs, which already considered site effects, still use a simple way to include site parameters in their equations. Velocity profiles are not fully considered in the present approach. We have to simplify the profiles to obtain the site parameters that could be directly used in GMPEs. The derived site database for the strong motion network in Taiwan is able to provide two site parameters, i.e., Vs30 and Z1.0, at more than 800 free-field strong ground motion stations in Taiwan at this moment.

Vs30, the average S-wave velocity in the top 30 m, is the most common site parameter and widely be used in many GMPEs and seismic design codes in many countries including Taiwan. It is argued that a disadvantage of Vs30 is that it is indistinguishable for sites located in plains and basins that are usually covered with thick sediments. An alternative site parameter called Z1.0, depth to velocities horizons with Vs equal to or larger than 1000 m/s, is therefore proposed. The GMPEs consisting of both Vs30 and Z1.0 are able to consider average velocity and total thickness of soft sediments, which can reflect more site effects at specific sites. Similar parameters such as Z1.5 and Z2.5 are still difficult to consider due to the large thickness of sediments that cover the plains and basins in Taiwan.

The purpose of constructing a site database for the strong motion network in Taiwan is to provide site parameters for all strong motion stations. Because of funding limitations, a measured Vs30 is only available at 451 stations, which is around 55.6% of all 812 free-field strong motion stations in Taiwan. Results from other studies have to be considered and collaborated. For Vs30, we follow the policy of the Next Generation of Attenuation (NGA) project. They also adopted estimated Vs30 derived from various proxies, such as surface geology, terrain, geotechnical data, and topographic slope. After testing the model bias of the result of related studies, we decided to use two additional models from previously studies: Lee and Tsai (2008) and Allen and Wald (2009). Lee and Tsai (2008) used velocity profiles of 257 stations obtained from the EGDT and boring data of 4,885 sites obtained from the Geo2005 database, which belongs to the Central Geological Survey (CGS) of Taiwan. They adopted a geological statistical approach as well as considering surface geological distributions to estimate Vs30 for free-field strong motion stations, and evaluated a Vs30 map for the whole of Taiwan. Wald and Allen (2007) calculated the topographic slope using digital data with a resolution of 30 arc seconds (approximately 900 m) from the Shuttle Radar Topography Mission (SRTM30) and then developed two sets of correlations between topographic slopes and Vs30 values. A Vs30 map of the whole of Taiwan was also derived and can be downloaded from their website (Global Vs30 Map Server). The priority of adopting those Vs30 models are in the order of Kuo et al. (2012), Lee and Tsai (2008), and Allen and Wald (2009) after an examination. The final result of the Vs30 map for 812 strong motion stations is shown in the left side of Fig. 1. The Taipei Basin, Ilan Basin, and Western Plain are low Vs30 regions; Taoyuan, Hsinchu, Miaoli, and Taichung have higher Vs30, whereas the Central Mountain extending to the northern-east and eastern Hangchun Peninsula has the highest Vs30.

A new site parameter for sedimentary depth, such as Z1.0, is used in several GMPEs in recent years to supplement site effect in addition to Vs30. However, the parameter is only available in Japan, California, and a few European countries. We started to acquire Z1.0 for strong motion stations in Taiwan recently. It was obtained from the EGDT, microtremor array

measurements, the receiver function method, and the Horizontal to Vertical Spectral Ratio inversions at around 300 stations at present. A Vs30-Z1.0 relation was used to estimate Z1.0 for the other stations. A map showing the distribution of Z1.0 is illustrated in the right side of Fig. 1. Larger Z1.0s were distributed in the basins and the Western Plain, which also have lower Vs30.

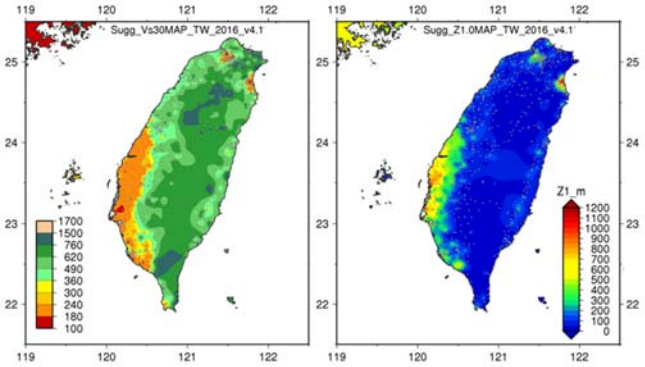


Fig. 1. Vs30 (left) and Z1.0 (right) maps

Fig. 2. Shows that Z1.0 tends to decrease as Vs30 increases. This property is similar to the results proposed by NGA's research, especially for the relationship using data from Japan. The derived relationship is shown in Fig. 2, where a black curve is used to estimate Z1.0 for other stations without a measured or inversed Z1.0, although lower accuracy is expected.

We proposed a site database for the strong motion network in Taiwan in order to provide accurate site parameters for strong ground motion predictions. Based on the EGDT, we further added results from other studies. We still continued to derive Z1.0 using various approaches and thus complete the site parameters such that Vs30 and Z1.0 are available for all strong motion stations. The site database is updated when new data is available.

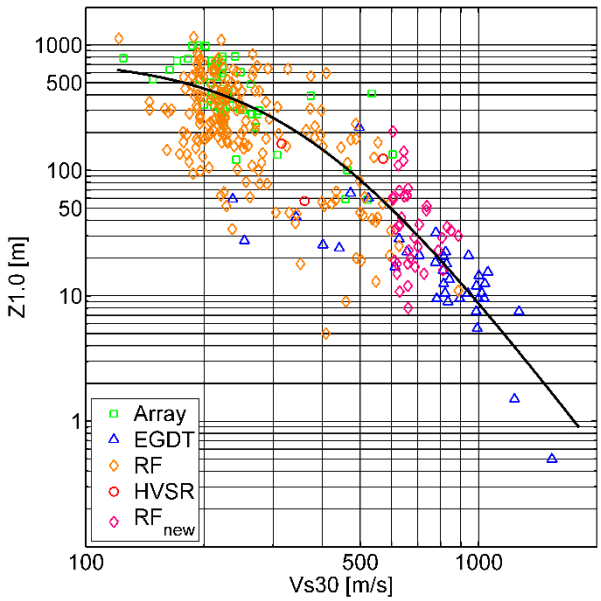


Fig. 2. Distribution and relationship of the Vs30 - Z1.0 data in Taiwan

Workshop on International Training Program for Seismic Design of Structures and Hazard Mitigation 2016

Chia-Chuan, Hsu, Assistant Researcher NCREE

Recent major earthquakes around the Pacific Rim, resulted in loss of life and serious property damage in the affected areas. It is therefore necessary to promote seismic design technology to mitigate the seismic hazard in the high-seismicity regions of the Pacific Rim. A training program for both researchers and practical engineers should be considered as a top priority.

The World Seismic Safety Initiation (WSSI) under the International Association for Earthquake Engineering (IAEE) recently suggested that countries such as the United States, Canada, 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 NCREE, funded by the Ministry of Science and Technology, R.O.C., for researchers and engineers from other countries.

The 15th International Training Program for Seismic Design of Structures and Hazard Mitigation (ITP2016) will be held on October 17–21, 2016 at NCREE. This training program, which focuses on promoting the seismic design technology of structures worldwide, is sponsored by the Ministry of Science and Technology, R.O.C. The workshop was first held in January 2002. To date, a total of 439 participants from 23 different countries have attended the past fourteen training programs. These training activities are designed as a short-term workshop aimed at training government officials and engineers from countries within the Pacific Rim region. It is through these kinds of activities that disaster-preventing technology and the earthquake-resisting ability of the participating countries can be gradually improved and thereby reduce the impact and the massive losses caused by natural disasters. Some of the important sessions in this program include the following:

- 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

For more details, please visit the official website of ITP2016
http://conf.ncree.org.tw/indexEng.aspx?n=I10510170

The 5th International Symposium on the Effects of Surface Geology on Seismic Motion (ESG5)

Che-Min Lin, Associate Researcher
Jyun-Yan Huang, Assistant Researcher, NCREE

ESG5 was held on August 15–17, 2016 in Taipei, Taiwan. The symposium mainly discussed site effect related topics, especially focusing on the main theme of "Challenges of Applying Ground Motion Simulation to Seismology and Earthquake Engineering". The symposium was jointly hosted by the National Center for Research on Earthquake Engineering, Taiwan (NCREE) and National Taiwan University, Taiwan (NTU).

Due to the great contributions of all participants, ESG5 was a great success. The program of ESG5 included 8 keynotes, 20 invited speakers, and 100 poster participants, and it involved about 160 participants from 28 countries, majorly from Japan, America, Taiwan, France, and China.

All participants described their research in poster sessions, except for the invited speakers, so ESG5 had long poster sessions over the three days of the conference to allow full discussion for each participant. Meanwhile, ESG5 had arranged an interactive presentation program during the poster session. The interactive presentation is an innovative type that provides advantages for authors and attendees. The authors can briefly present the key aspects of their work to attract attendees to discuss the details at their posters. There were 20 volunteers for this program.

The main theme of ESG5 was "Challenges of Applying Ground Motion Simulation to Earthquake Engineering," which focused on discussing topics such as the characteristics of different geological subsurfaces, strong ground motion responses, observations of ground motion, and near fault effects. Improving step by step the development of strong motion simulation and its application to topics such as seismic hazard analysis, and disaster evaluation to prevent and reduce earthquake-induced damage.

We extend our thanks to each participant who attended ESG5. According to decision of the ESG Joint Working Group Meeting on August 16, 2016, the next symposium of ESG6 will be held in Kyoto, Japan in 2020.



Opening speech from director of MOST on ESG

2016 Workshop on Soil Liquefaction Evaluation

Chih-Chieh Lu, Assistant Researcher, NCREE

To make liquefaction potential index (LPI) contour with middle accuracy is a key working item of "the project of homeland safeguard against soil liquefaction" by the Construction and Planning Agency, MOI. Since the project will be divided into many sub-projects executed by the corresponding local governments, it is important for the executor of each sub-project to have the same standard and program to evaluate soil liquefaction potential. To enable this, NCREE held a workshop and invited researchers and engineers from industry, the government, and academia to discuss simplified procedures based on SPT-N, CPT-qc, and seismic-Vs. In this workshop, the simplified procedures developed by Taiwanese scholars were presented along with their research results. The NCREE-coded simplified procedures using EXCEL software, called NCEER_Liq, after a careful check by peers in July 2016 will go on record and be downloadable for free by the public..

The 2016 workshop on soil liquefaction was held on August 29th and 30th; it promoted the research results of native scholars with this opportunity. The discussed topics are shown in Table 1

Table 1 Topics and speakers of the workshop

Date	Topic	Speaker
8/29	Study of the simplified procedures base on SPT-N	Dr. Tsai, C.C.
8/29	Study of the simplified procedures base on CPT-qc	Dr. Ku, C.S.
8/29	Study of the simplified procedures base on seismic-Vs	Dr. Chang, W.J.
8/30	The development and verification of NCEER_Liq	Dr. Lu, C.C.
8/30	The key issue to make the soil liquefaction potential map	Chief Geologist Chi, C.C.

At the 2016 workshop on soil liquefaction evaluation, the local researchers and engineers from the industry, the government, and academia gathered together to gain consensus on the unification of the approaches of soil liquefaction evaluation and for making a soil liquefaction potential map. The feedback from the workshop will be gathered and will serve as a reference for the amendment of the seismic design specifications.



Fig. 1. Participants of the 2016 conference on soil liquefaction evaluation

The 5th International Geo-hazards Research Symposium (IGRS-2016): In memory of Prof. Tsanyao Frank Yang

Vivek Walia Research Fellow
Arvind Kumar, Postdoctoral Fellow, NCREE

The 5th International Geo-hazards Research Symposium (IGRS 2016) will be held from Monday, October 17 to Thursday, October 20, 2016 at the Union Development Building, Ta-Pinglin, which is in Xindian District, New Taipei City, Taiwan. The symposium will be jointly organized by the International Geo-Hazards Society, National Taiwan University, Taiwan (NTU), and the National Center for Research on Earthquake Engineering, Taiwan (NCREE). In order to help plan the Taiwan IGRS 2016 meeting and ensure the involvement and participation of the scientific communities worldwide, several committees have been set up. An International Scientific Committee, chaired by Prof. Sheng-Rong Song (National Taiwan University, Taiwan) has been established and a National Organizing Committee, supported by a group of scientists from various universities and institutes across Taiwan, is overseeing the organization of the Conference.

Taiwan as the next venue for the 5th IGRS, 2016 was confirmed during the 4th IGRS held at the NASA Ames Research Center in California, USA in December 2014. After the demise of Prof. Tsanyao Frank Yang in March 2015, who was the Convener for the upcoming conference, the International Committee decided to organize the 5th IGRS as a memorial conference for Prof. Yang to commemorate his monumental contribution toward the International Geo-Hazards Society and research in various fields of geo-hazards. He envisioned holding the IGRS in Taiwan to bring together the scientific advances in obtaining perception and response to geo-hazards. Similar to the previous IGRS conferences, we aim to bring together researchers from all aspects of the Geo-hazards Science community.

The focal topics of the IGRS 2016 symposium are of great relevance from the viewpoint of Taiwan. Parts of the deliberations of the symposium will facilitate local research outcomes that are aimed at prevention and mitigation of possible damage caused by geo-hazards in Taiwan. The diverse presentations and broad-spectrum discussions during the symposium will be beneficial to engineers, geo-scientists, nuclear/radiation scientists, social scientists, and public authorities to explore the human, environmental, and economic consequences of geo-hazards. Learning and interaction between international and domestic attendees and innovative approaches to manage disaster risk should be the major outputs yielded by the symposium. In addition, a short and informative field visit to various natural geo-hazard areas in the Taipei region will be organized. More than 100 researchers from different parts are expected to participate in this conference. About 6 Keynote Speeches and more than 15 Invited Talks will be delivered at the conference.

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