THE ENGINEERING GEOLOGICAL DATABASE FOR STRONG MOTION STATIONS IN TAIWAN

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Abstract

More than 650 seismograph stations all over Taiwan have been installed by the Central Weather Bureau (CWB) to record the ground motion data. In order to obtain the geological conditions and soil profiles of these strong motion stations, a site investigation project was established by the National Center for Research on Earthquake Engineering (NCREE) and CWB in 2000. The site investigation mainly consists of three parts: the basic description of a site, the on-site boring, and the Suspension P-S Logger Technique which is used to determine the shear wave velocities of the stratum at various depths. The Suspension P-S Logger Technique, using a single down-hole probe with one source and two receivers, allows continuous measurements of wave velocities with high resolution. With reference to Kyoshin Net in Japan and ROSRINE in USA, a preliminary engineering geological database for 175 seismograph stations has been constructed on a web page for convenient accession.

Keyword: Geology, Database, wave velocity

INTRODUCTION

Taiwan is located on the Circum-Pacific seismic belt which is the most active seismic region in the world. Preventing severe losses of lives and properties from large earthquake is a major concern for the people in this region. The Taiwan Strong Motion Instrumentation Program (TSMIP) was initiated by CWB in 1991 to monitor the ground motions at over 650 free-field stations around Taiwan as shown in Figure 1. Once a major earthquake happens, all the records of ground motions from TSMIP provide useful information for the operation of hazard mitigation. The ground responses monitored by seismographs reveal the characteristics of ground motions in different geological conditions which can be used to improve the design spectrum and the building codes of current use.

More than 1,000 seismograph stations have been installed in Japan to monitor the ground response during earthquake. Users can download the data of ground response on a web site called "Kyoshin Net". The basic information of a station site, the physical properties of soils, and the wave velocity of the stratum measured by the down-hole velocity logging technique are also available on the Kyoshin Net. After 1994 Northridge earthquake, a project called "Resolution of Site Response Issues from the Northridge Earthquake", ROSRINE, has been activated to study the site response in the USA. Users also can assess to a web site to download the geological information and the wave

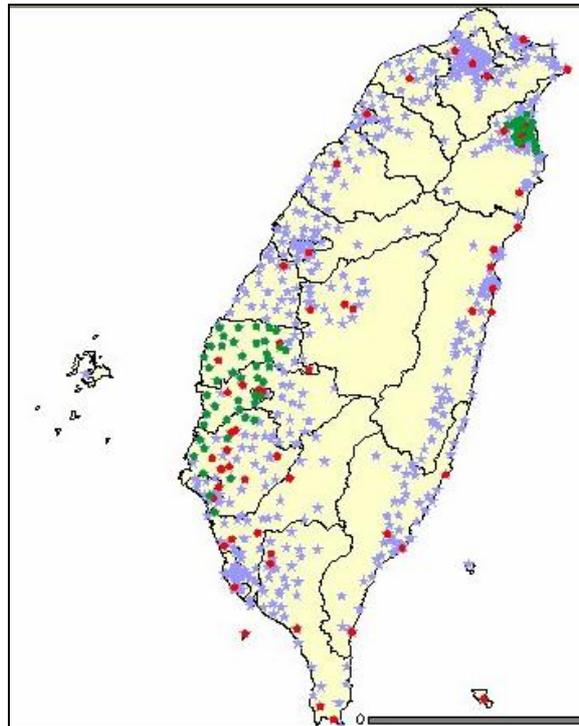velocity profile of a station site.

Fig. 1: Distribution of stations in the Taiwan Strong Motion Instrumentation Program (TSMIP)

The distribution of seismograph stations in Taiwan is the densest in the world, although the amount of seismograph stations installed by CWB in Taiwan is less than that in Japan and USA. However, the application of earthquake data would be restricted without a complete geological database. Therefore, NCREE and CWB collaborated to perform the site investigation to obtain the basic soil properties and the wave velocity of the stratum in 2000. The engineering geological database established on a GIS web site provides convenient access for researcher in earthquake engineering.

The local site conditions play an important role in the ground response during earthquake. Different site conditions could induce amplification or deamplification at different period ranges in the response spectra. It is called the site effect. Besides, in the seismic hazard analysis, the motion at bed rock of a site is predicted by the attenuation low from the earthquake source. According to the 2000 Uniform Building Code (UBC), 1997 National Earthquake Hazards Reduction Program (NEHRP) provisions in the USA, and the revising earthquake-resistant codes in Taiwan, the ground motion at free field is evaluated by the response at bed rock times the coefficient of site effect. The coefficient of site effect is related to the magnitude of earthquake and the local site conditions. Thus, a complete geological database is essential to the evaluation of site effect for earthquake engineering.

SUSPENSION P-S LOGGING TECHNIQUE

The wave velocity profile at a site can be measured by various conventional methods including the up-hole, down-hole, and cross-hole logging techniques. The source and the receiver in those logging techniques are separated in different units. For the up-hole and the down-hole logging techniques, the distance between the source and the receiver is varied at different measuring points. The

Suspension P-S Logging Technique, developed by the OYO Corporation in Japan, is used in this project to measure the primary wave velocity (v_p) and the shear wave velocity (v_s) of the stratum. The source and the receiver of this measuring system are integrated into a single probe within a short distance. Therefore, the wave velocities of the stratum can be measured continuously and precisely.

As shown in Figure 2, the P-S Logging system mainly consists of a weight, a source and its driver, filter tubes, lower and upper geophones, a head reducer, and a logging computer. With the filter tubes, the overall length of the probe is about 7.8 m. The elevation of the probe can be adjusted by the winch. The signals are triggered and recorded by the logging computer. The distance between the upper receiver and the lower receiver is only 1 m, so the resolution of measurements is higher than any other conventional logging techniques.
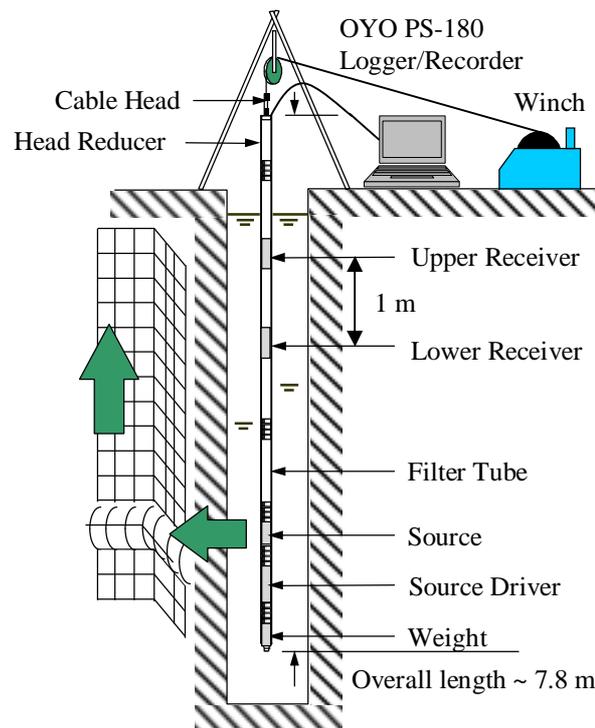

Fig. 2: The Suspension P-S Logging System

The borehole was first drilled at an interest site and filled with water. If the borehole is not well-standing, the borehole may be lined with a plastic tube. The probe was then put into the borehole at a specified depth. A primary wave or a shear wave could be generated by the source in the probe. The primary wave would be propagated through the surrounding soil in the direction perpendicular to the borehole axis (horizontal direction). The shear wave would be propagated through the soil along the vertical direction. Each receiver consists of a hydrophone for receiving the primary wave and a geophone for receiving the shear wave. A normal pulse and a reverse pulse are triggered by the source respectively in order to check the signals received by two receivers. The time histories of those received signals should be in the same shape but with 180 degrees of the phase difference, since the two shear waves were propagated through the same soil media.

Typical measured signals of the primary waves and the shear waves from the logging computer are shown in Figure 3, where H1 and /H1 represent the signals received by the upper receiver in normal and reverse directions, H2 and /H2 represent the signals received by the lower receiver in normal and

reverse directions, V1 and /V2 represent the signals received by the upper and lower receivers, respectively.   From the time histories of H1 and H2, the first arrival time for the upper receiver and the lower receiver could be picked as t_{s1} and t_{s2}.   Since the distance between the two receivers is 1 m, the shear wave velocity could be determined as:

$$v_s \text{ (m/sec)} = \frac{1}{t_{s1} - t_{s2}} \tag{1}$$

Similarly, the primary wave velocity is:

$$v_p \text{ (m/sec)} = \frac{1}{t_{p1} - t_{p2}} \tag{2}$$
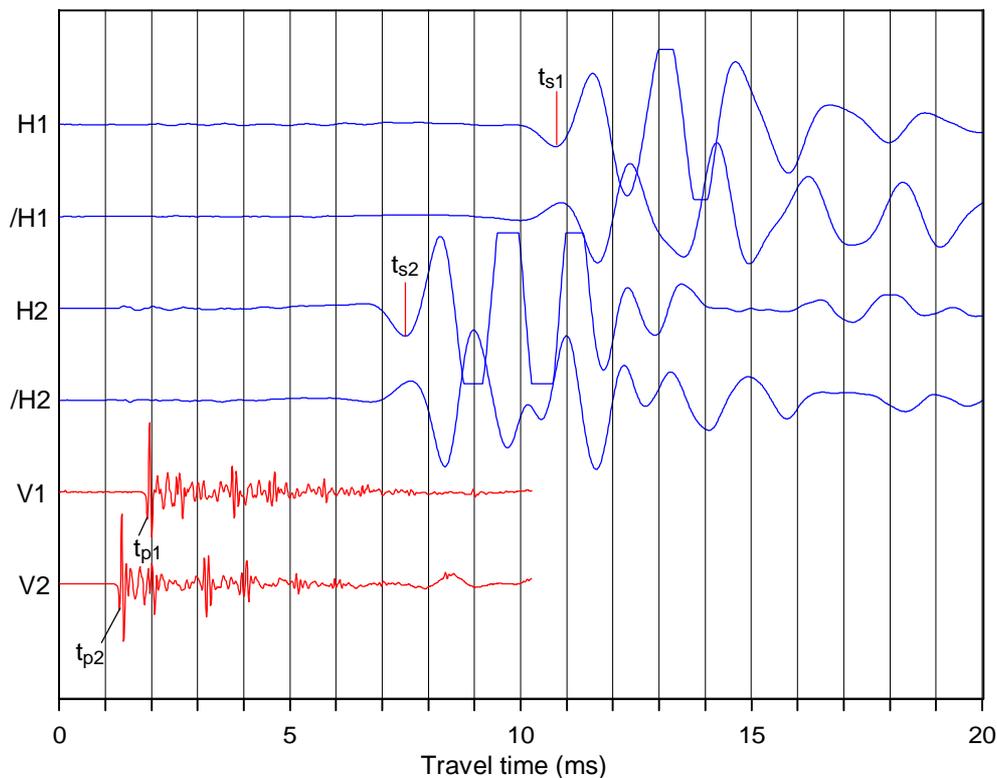

Fig. 3: Typical measurements from the Suspension P-S Logging System

ENGINEERING GEOLOGICAL DATABASE

There are three major items in the Engineering Geological Database in Taiwan.   The first item is the general information of the station site, including latitude and longitude of the station site, ground water level, geographical/topographical conditions, and surrounding structures.   The second item is the physical properties of soils.   The SPT-N value, water content, unit weight, soil classification, and grain size distribution are obtained by on-site boring, sampling, and laboratory testing.   After the borehole was drilled, the Suspension P-S Logging Technique was used to measure the wave velocity of the stratum in depth for every 0.5 m.   The wave velocity of the stratum is an important index for site classification, so it is selected as the third item in the database.   If the geological condition of the station site is classified to the rock outcrop, only the general environmental investigation was

performed to collect the basic information of the station site.

This project has been conducted for three years. Till now, the site investigations at 175 station sites were completed, including 60 stations in 2000, 65 stations in 2001, and 50 stations in 2002. The stations are located on the alluvial deposit, gravel or even rock sites. All the results are summarized on a web page: http://geodata.ncree.gov.tw/overview_cht.htm. As shown in Figure 4, the general information for station TCU110 (the photo of the seismograph, the plan section and the cross section of the surrounding environment), the soil profile, the SPT-N value, the shear wave velocity, and the primary wave velocity of the stratum are all available on the web page.
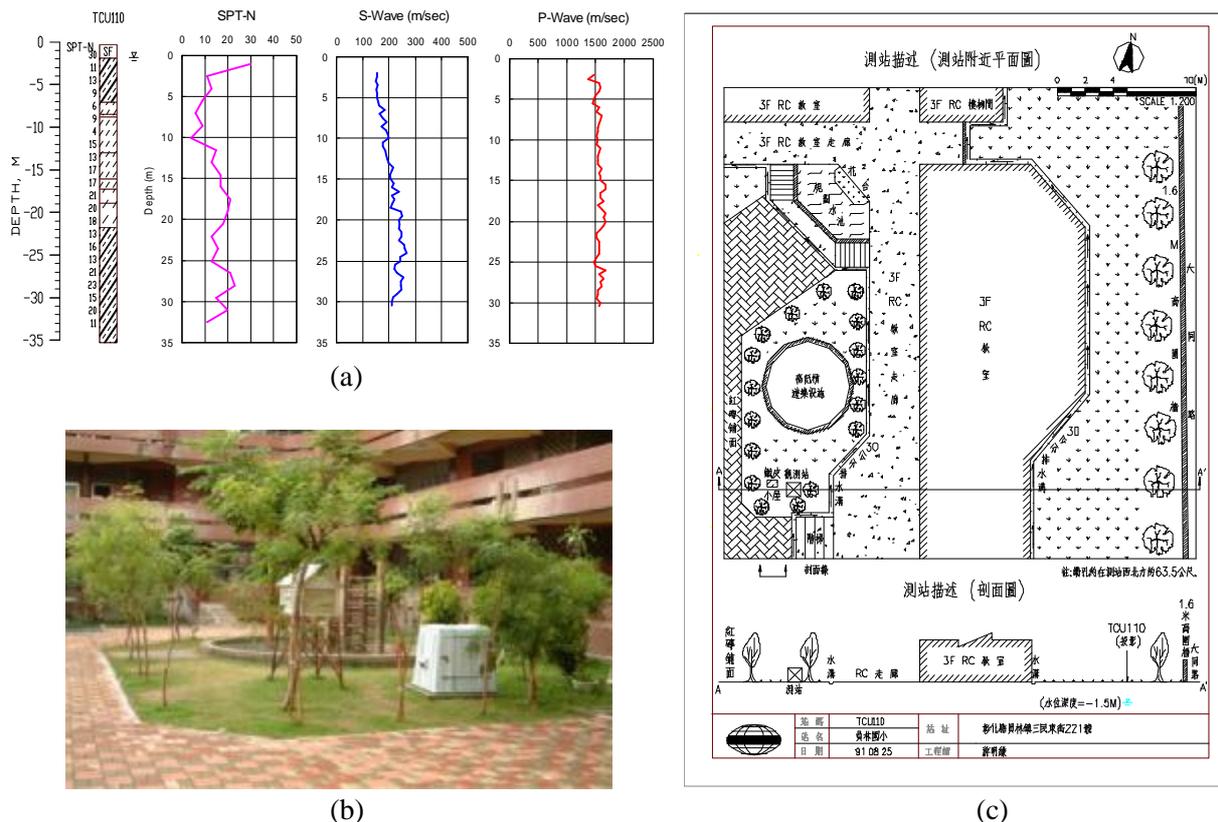

(a)

(b)

(c)

Fig. 4: The information for station TCU110 in the database shown on the web site; (a) The soil profile, SPT-N value, and wave velocity profile; (b) The photo of the seismograph in the field; (c) The description of the plan section and the cross section in the field

Most studies of site effect for earthquake ground motion are based on the soil properties in the upper 30 m. In the 1997 UBC and 1997 NEHRP provisions in the USA, the average of the shear wave velocity for the top 30 m of soils is used as an index for the site classification. In the site classification of Taiwan free-field strong-motion stations (http://gis.geo.ncu.edu.tw/query/site/), the site conditions are classified as class B (rock), class C (soft rock or very dense soil), class D (stiff soil), and class E (soft soil) according to the geological age, rock type, and the average of SPT-N values for the upper 30 m of the stratum. With detailed subsurface soil profile and quantitative soil properties (SPT-N values and wave velocities) on a station site, the site effect of ground motions could be thoughtfully analyzed for a certain class of site conditions. Engineers may evaluate appropriate peak ground acceleration for the earthquake-resistant design of structures.

CONCLUSIONS

The site investigation at 175 TSMIP stations was completed by NCREE cooperating with CWB in Taiwan. By sampling soils in the borehole and using the Suspension P-S Logger Technique, specific geological and geotechnical data are obtained including the soil profile, the physical properties of soils, and the wave velocities of the stratum. All the results of investigation are systematically organized in the database available on a preliminary web site. This project will be continuously performed in the following years. Combining with the GIS technique, the engineering geological database for strong motion stations in Taiwan will be more convenient for web querying. If an engineering project site is close to the strong-motion station, engineers may retrieve the geological and geotechnical properties of soils from the database for evaluating the ground response at the site. This database is helpful to the site effect analysis and the earthquake-resistant design.

ACKNOWLEDGEMENTS

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