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RESEARCH REPORT

(รายงานวิจัยฉบับสมบูรณ์)

ON

DEVELOPMENT OF A SHAKING TABLE FOR EARTHQUAKE ENGINEERING RESEARCH

(การพัฒนาโต๊ะสั่นสะเทือนเพื่องานวิจัยด้านวิศวกรรมแผ่นดินไหว)

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สนับสนุนโดย สำนักบริหารโครงการวิจัยในอุดมศึกษา

และพัฒนามหาวิทยาลัยวิจัยแห่งชาติ

สานักงานคณะกรรมการการอุดมศึกษา

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ABSTRACT

Even though Thailand is not located in the earthquake zone it does not mean we are safe from such violent natural disaster, as evident in the 2004 Boxing Day Earthquake triggered under the sea off the coast of Sumatra, Indonesia. The damage was enormous; however, the most important thing was that over 200,000 people died from the incident of which is invaluable. Nonetheless, it can be said that research activities involving earthquake engineering in Thailand is very rare due to the lack of testing facilities.

The main purpose of this research was to design and build a shaking table that moves in one direction only. This is because the past studies show that the uni-directional shaking table also provides the acceleration similar to those generated by actual earthquakes. In addition, it needs quite low budget to build one; and, to operate the table does not need a specialist.

To verify the workability of the table, three test runs were performed. It was found that the average value of g generated from the three tests is about ± 2. This is well over the g value generated by actual major earthquakes about 0.5 to 1.0 g. Thus, the shaking table could be used to simulate the earthquake shaking thereby increasing a number of research projects with respect to earthquake engineering in Thailand.

Keywords: earthquake, shaking table, uni-directional, acceleration, damage

บทคัดย่อ

การที่ประเทศไทยไม่ได้อยู่ในเขตแผ่นดินไหว ไม่ได้หมายความว่ามีความปลอดภัยจากภัยพิบัติธรรมชาติดังกล่าว ดังตัวอย่างที่เกิดขึ้นในปี พ.ศ. 2547 เมื่อเกิดแผ่นดินไหวใต้ทะเลบริเวณเกาะสุมาตรา ประเทศอินโนนีเซีย ความเสียหายในครั้งนั้นมีค่ามหาศาล อย่างไรก็ตาม สิ่งสำคัญที่สุดคือมีคนเสียชีวิตมากกว่า 200,000 คน ซึ่งเป็นสิ่งที่ประเมินค่ามิได้ จากความเสี่ยงดังที่กล่าวมา เป็นที่น่ากังวลที่ประเทศไทยยังมีการทำวิจัยและศึกษาเกี่ยวกับแผ่นดินไหวน้อยมาก ทั้งนี้อาจเนื่องมาจากขาดอุปกรณ์ต่างๆ เพื่อใช้ในการศึกษา

วัตถุประสงค์หลักของโครงการวิจัยนี้ คือ การออกแบบและก่อสร้างโต๊ะสั่นสะเทือนซึ่งเคลื่อนที่ได้ในทิศทางเดียว ทั้งนี้เนื่องจากผลการศึกษาในอดีตแสดงให้เห็นว่า โต๊ะสั่นสะเทือนแบบทิศทางเดียวก็สามารถสร้างความเร่งให้มีค่าเทียบเท่ากับความเร่งที่เกิดขึ้นจากเหตุการณ์แผ่นดินไหวจริง นอกจากนั้นยังพบว่า การสร้างโต๊ะสั่นสะเทือนแบบทิศทางเดียวมีค่าใช้ไม่มากนัก และไม่จำเป็นต้องใช้ผู้เชียวชาญเฉพาะทางสำหรับการปฏิบัติงานจริง

การตรวจสอบความสามารถในการปฏิบัติงานของโต๊ะสั่นสะเทือนที่จัดสร้างขึ้น ทำได้โดยการทดสอบสั่นสะเทือนจริงจำนวน 3 ครั้ง ค่าความเร่งเฉลี่ยจากการทดสอบทั้ง 3 ครั้งให้ความความเร่งเท่ากับ $\pm$ 2 g ซึ่งค่าดังกล่าวมีค่าสูงกว่าความเร่งที่เกิดจากแผ่นดินไหวจริงขนาดใหญ่ซึ่งมีค่าระหว่าง 0.5 ถึง 1.0 g ดังนั้น แสดงให้เห็นว่าโต๊ะสั่นสะเทือนที่จัดสร้างขึ้นสามารถนำไปจำลองเหตุการณ์แผ่นดินไหวได้ และจะทำให้มีโครงการวิจัยเกี่ยวกับแผ่นดินไหวของประเทศไทยมีจำนวนเพิ่มมากขึ้น

คำสำคัญ: แผ่นดินไหว, โต๊ะสั่นสะเทือน, ทิศทางเดียว, ความเร่ง, ความเสียหาย

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CHAPTER 1

INTRODUCTION

1.1 Research Context

An earthquake is a shaking of the land due to the rapid release of energy from the crust of the Earth. It should be noted that the energy released may come from the movement of the crust itself, the eruption of active volcanoes, and the explosion due to man-made events such as underground nuclear experiments and mining activities. Thus, even though earthquakes are regarded as natural phenomena, the source is not necessary from the nature. For instance, an earthquake (Elnashai and Sarno, 2008) may be triggered by the enormous volume of water because of the construction of a dam. If the bed rock beneath contains joints and cracks, the water may be able to seep into. Eventually, the excess pore water pressure may be high enough and is able to break the rock, thereby producing shock waves.

When there is an earthquake, the consequences are as follow:

(1) There is damage to built environment and facilities (see Figure 1.1).

(2) The environment and geography are altered (see Figure 1.2).

(3) Lives and properties are lost (see Figure 1.3).

When a major earthquake occurs (i.e. an earthquake with a magnitude of 6.5 or greater according to the Richter magnitude scale) there will always be damage. The damage of properties could be easily approximated; but, the loss of human lives is invaluable. Furthermore, when an earthquake strikes under the sea there might be chances that a tsunami would also occur. It is virtually impossible to stop the walls of water coming into shoreline. When this happens, the disastrous is predicable, as evident in the 2004 tsunami that caused the damage to the countries around the Indian Ocean.

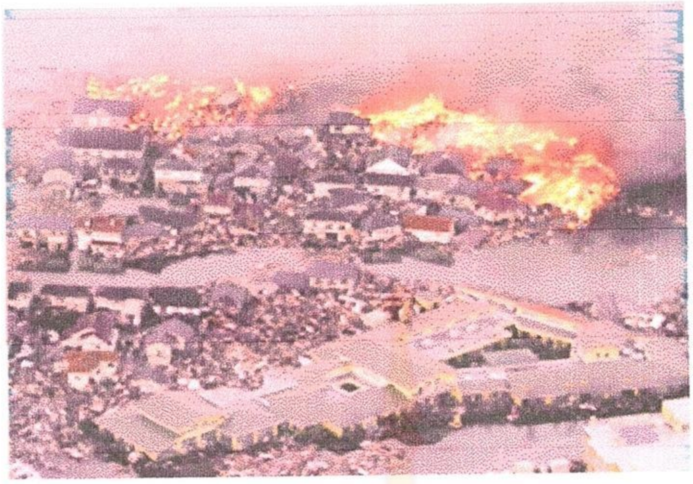

Figure 1. 1 Damage due to the 2011 Earthquake in Japan (after http://rizaaaal.blogspot.com)

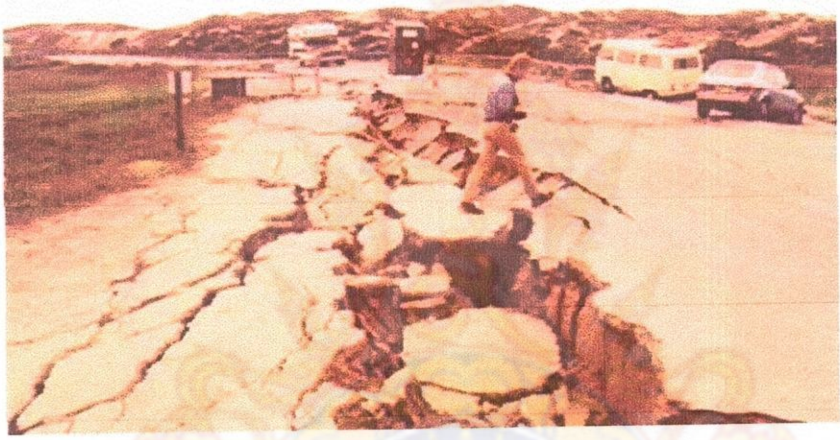

Figure 1. 2 Soil liquefied because of the increase of pore water pressure in the 1989 Loma Prieta Earthquake, California, USA (after FHWA website)

Figure 1. 3 Evidences of loss due to the 2008 Earthquake in China (after Eastvillagers website)

Note that the 2004 tsunami was triggered by the earthquake that occurred undersea off the Coast of Sumatra Island, Indonesia. The consequence is that over 200,000 died, including people from Thailand, Indonesia, Malaysia, Burma, India, Bangladesh, Sri langa, and as far as South Africa and Somalia. More recently, the 2011 tsunami in Japan not only claimed several human lives, but also destroyed a nuclear power plant. Many people died at the nuclear plant instantly; but, the radioactive leaked has caused so much more damage. The consequence is that it might need years for the surroundings to become clean again.

In the case of Thailand, even though not in the earthquake zones, it does not mean we are safe from the earthquake shaking. This is because the shock waves produced from a major earthquake can travel well over 100 kilometres. In addition, Thailand hardly encounters the shaking from earthquakes thereby most Thais are unacknowledged about the incident. Furthermore, there are very few academics and researchers in Thailand conducting the research on this matter.

The behaviour of the land when encountering earthquake shaking is very complex. Indeed, the earthquake is a kind of shaking land that cannot be seen physically. To understand the behaviour it is therefore necessary to employ a mathematical model to explain the phenomenon. This is of course not suitable for general public to comprehend. The behaviour of an earthquake is very complex and not consistent. Therefore, the research on earthquake has been done mostly by means of visual observation together with model tests such as dams, buildings, and bridges. The test results then are verified and adopted for the design for earthquake resistance. Please note that a shaking table has been mostly employed for earthquake engineering research. Figure 1.4 illustrates a model of tall building being tested by a shaking table.

Generally, a shaking table to be used in earthquake engineering research is a one-off design and construction. This is because purchasing a commercial shaking table is far too expensive thereby obtaining one is vitally the best option.

When an earthquake strikes, it is impossible for humans to stop the incident. Moreover, with current technologies and knowledge, we are still unable to predict the occurrence of the earthquake. Thus, we need to design and construct a structure to withstand a curtain magnitude of earthquake for a while in order that people inside would be able to escape before the structure collapses.

It can be said that Thailand is an agricultural country. Each year we produce so much agricultural wastes that most of them are burnt to get rid of. This is an easy method but creates consequent pollutions. It has been known that some of the wastes may be used for resisting and softening the shock waves. These included discarded tyres and ashes from burnt agricultural products. However, to study the behaviour of those wastes in terms of earthquake-resistant design a shaking table with the capability to simulate the shaking produced by an earthquake is needed.

In Thailand, there are quite a few shaking tables. As such, it is almost impossible to investigate and research on earthquake engineering in terms of experimental study. After thorough investigation, it was found that it is quite possible to design and build a shaking table with limited budget. The authors wish that this research would provide a prototype shaking table that might be useful for future research on earthquake engineering.

Figure 1. 4 Earthquake simulation for model building (after UC Berkley website)

1.2 Research Objectives

The main objectives of this research are as follow:

(1) Investigate the advantages and disadvantages of the uni-directional shaking table.

(2) Design and construct a uni-directional shaking table with a capability to simulate the earthquake shaking with a limited budget of about 200,000 Baht.

(3) Perform a shaking test of the table to make sure that it can produce a vibration similar to those produced by an earthquake in terms of acceleration and frequency.

1.3 Research Methods

To achieve the aims of the research the first task was to establish a design for a uni-directional shaking table construction. The design was based on two important factors: (1) limited budget of 200,000 Baht and (2) one-direction shaking.

Then, the main power used to shake a table was selected of which was a pneumatic actuator. The pneumatic system was chosen over the hydraulic system because it is much cheaper as well as easier to operate. After that, a rail and bearing units were designed to accommodate a table. They were designed and chosen very carefully to lower the friction between the rail and the table as much as possible. This is because the lower the friction the greater the acceleration obtained from the shaking.

The shaking table then was performed a real shaking test. To evaluate the performance of the table, two accelerometers were employed. The sensors were connected to a data acquisition system to monitor and record the signals. Finally, the signals were analysed and compared to the actual acceleration produced by an earthquake.

CHAPTER 2

REVIEW OF PREVIOUS WORK

2.1 Introduction

Generally, a shaking table comprises a (see Figure 2.1 a typical shaking table) power unit (normally an actuator, either pneumatic of hydraulic powered) connected to a table that placed over a rail and bearing system. To investigate the shaking behaviour of a structure, a model is constructed and placed over the table. Then, the actuator moves (shake) the table thereby producing the shock waves on the modelled structure. Normally, a set of accelerometers are attached to both of the table and structure to monitor and record the acceleration, velocity, and displacement. The signals are later analysed to provide insight behaviour.

Figure 2. 1 An example of shaking table to be constructed (after SSHT Laboratory Website, John Hopkins University)

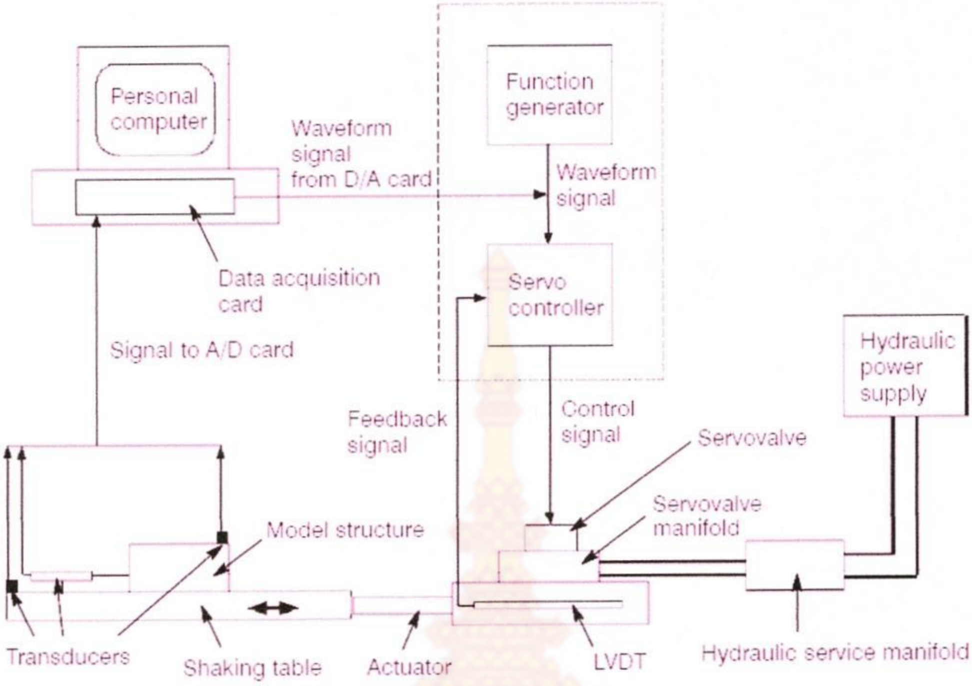

Figure 2. 2 Schematic diagram of a shaking table set up (after Yegian and Kadakal, 1998)

Upon employing the accelerometers, the Finite Element Method (FEM) is also used to analyse the shaking behaviour in details. Furthermore, a high speed digital camera has also been employed to visually monitor the behaviour, both during and after the shaking test. This is very important instrument as the modelled structure destroyed during a test is quite expensive and time consuming to make. As a result, recording the signals for later analyses is essential.

In general, the control of an actuator can be done by employing a computer program such as Labview and Matlab. However, it requires a coding ability to control the system. An example of shaking table test set up is illustrated by Figure 2.2.

2.2 Dynamics of Earth

To be able to comprehend the earthquake behaviour, it is necessary to have the knowledge with regard to the internal structure of the Earth. Figure 2.3 illustrates the section and distance of the Earth. The diameter of the Earth is about 12,750 kilometres. Considering its internal structure, it can be seen that the Earth can be divided into four layers:

(1) The first layer is called Crust having a thickness of about 0 – 100 kilometres.

(2) The next layer is Mantle at which is further divided into two sub-layers called Upper Mantle and Lower Mantle; this layer is approximately 2,900 kilometres thick. Note that the majority of this layer is molten rock.

(3) The third layer is called Outer Core having a thickness of about 2,200 kilometres; this layer mostly consists of molten rock same as the Mantle.

(4) The last one is called Inner Core. It is believed that this is a hard and solid rock and mineral, based on the assumption that there is enormous pressure acting on the layer thereby transforming liquid to be solid.

As described earlier, the causes of an earthquake are from several sources. However, most major earthquakes were triggered from the movement of the crust layer When considering Figure 2.4 it can be seen that the Crust is over the Mantle of which is liquid (molten rock). This situation is quite similar to that of an egg. Nonetheless, under the crust lies the high temperature molten rock. Furthermore, the temperature of the molten rock is very varied, i.e., the lower the hotter. This inconstant temperature causes a phenomenon called convection causing the molten rock flowing from bottom to top thereby moving the crust.

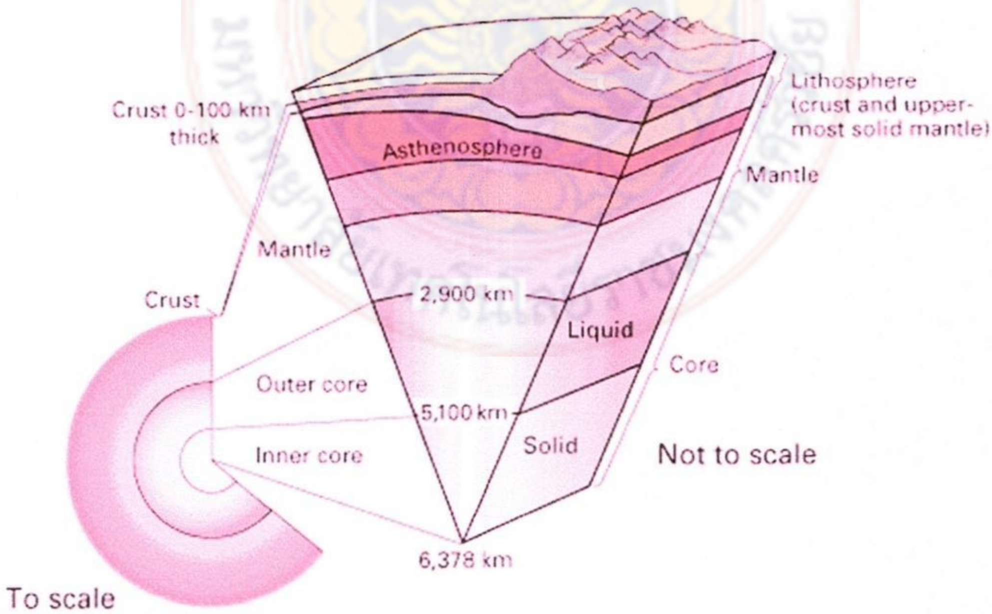

Figure 2. 3 Internal structure of Earth (after USGS Website)

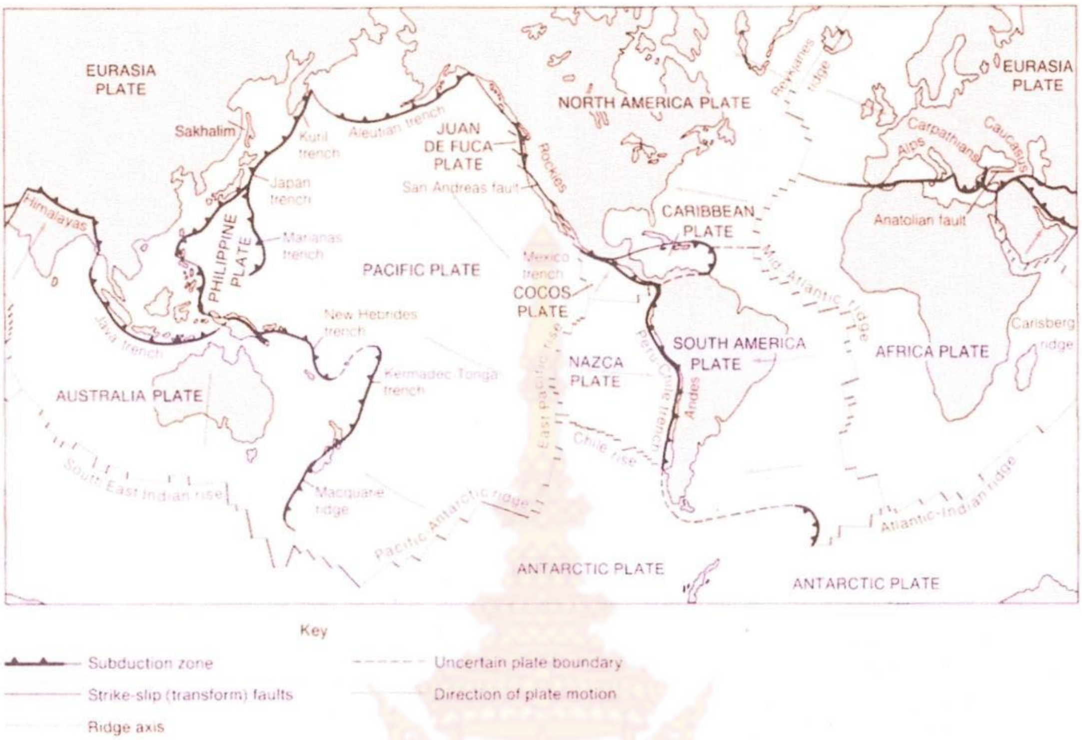

Figure 2. 4 Plate tectonics (after Fowler, 1990)

However, the problem is that the crust is not like an egg; it rather comprises several plates. From current evidence, it was found that the crust comprises seven major plates including Eurasia plate, Australia plate, Pacific plate, North America plate, South America plate, Africa plate, and Antarctic plate, as shown in Figure 2.4.

During the movement of the crust there will be a friction at the boundaries between each plate. Sometimes, a plate may travel through under another plate of which this boundary is called a subduction zone, as shown in Figure 2.5. During a plate subducting under another plate, if there is no resistance at the boundary the earthquake will not occur. However, the edge of each plate is normally not smooth, but rather crumpled. For example, if there is a friction in point X (see Figure 2.5) the movement of the plates would be obstructed. At some time, however, the energy stored at the point will be greater than the strength of the plate. The consequent is that the rock at the zone breaks down thereby releasing huge energy that is called earthquake. Please note that there are several causes that trigger the earthquake; but, the majority of the so called major earthquakes have been from the movement of the plate.

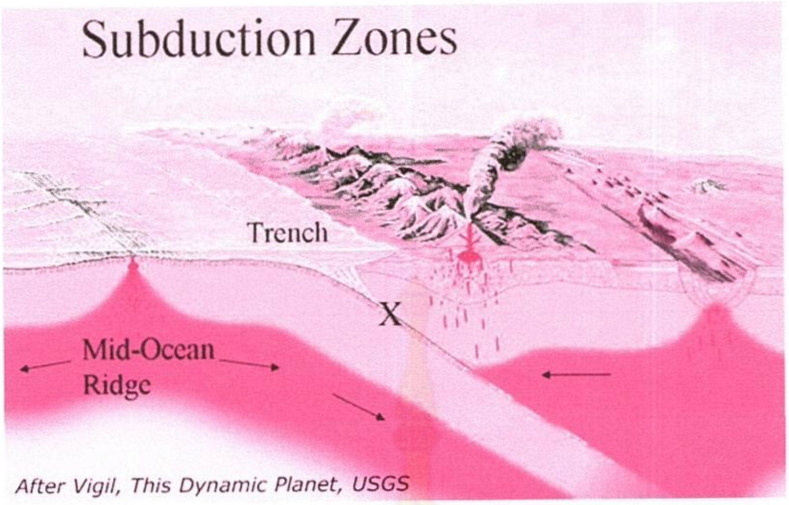

Figure 2. 5 Subduction zone (after Biologyeducation Website)

2.3 Development of the Shaking Table

The most important characteristic of an earthquake is the shaking of the land caused by shocked waves. The simulations of the earthquake as well as its effects on structures have long been studied. However, as the earthquake characteristics are very complex, it requires a high-technology device to study the behaviour. A shaking table has been employed to study the earthquake behaviour; it has proved that the device is capable of simulating an earthquake that is quite similar to actual ones. However, most of the studies done using the shaking table need the knowledge of making a model. Also, making a modelled structure requires the knowledge of using factors to be multiplied by a prototype in order to obtain a model that is equivalent to the prototype. The details of these procedures can be found in Iai (1989) and Wood *et al*., (2002)

Around the world, there are several types of the shaking table available. Normally, its classification depends on the degree of freedom of a table. For example, if there is only one direction of movement; this is call uni-axial or uni-directional shaking table. The others include bi-axial and tri-axial shaking tables. But the most complex shaking table is capable of moving in three directions as well as rotating in three directions. This is called six degree of freedoms (DOF) shaking table.

In the past, it was believed that the tri-axial shaking table is the best in terms of simulating the earthquake. However, building one of them is very costly, and maintaining its functionality is very difficult. In addition, it requires a specialist to operate the machine. Considering these drawbacks the bi-axial shaking table seems to be better in terms of building and operating cost.

Therefore, most laboratories and research centres around the world are turning into the uni-axial shaking table. From the development and vigorously calibration, it has been found that the uni-axial shaking table also provides similar results obtained from the bi- and tri-axial shaking tables. For example, Sinha and Rai (2009) developed a uni-axial shaking table at Indian Institute of Technology, India by selecting the components that can be easily obtained, as shown in Figure 2.6. The developers claimed that the results obtained from the shaking table are quite similar to the actual earthquake.

In the United States, the earthquake is quite common for most of the country. As such, almost every university providing civil engineering course possess a shaking table. For example, at the University of Central Florida, Doheny and Sivaselvan (2008) developed a shaking table called Uni-Axial Shaketable Dynamics, as shown in Figure 2.7.

When closely considering both Figure 2.6 and 2.7, it can be observed that they are very similar. This may imply that the design and built are most suitable. In addition, both shaking tables are also similar to the table developed by Wallen and Larson (2007) at the University of Colorado, Boulder of which also strengthens that the design is well accepted amongst researchers. Therefore, the design was chosen to develop a shaking table for this project.

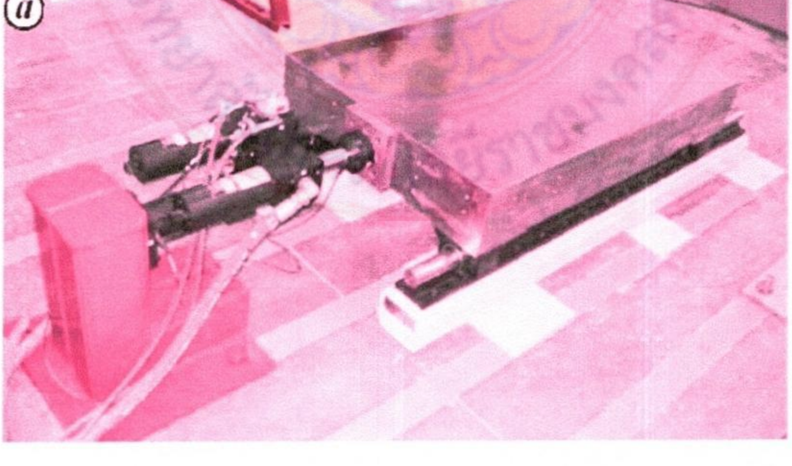

Figure 2. 6 Uni-axial shaking table developed by Sinha and Rai (2009)

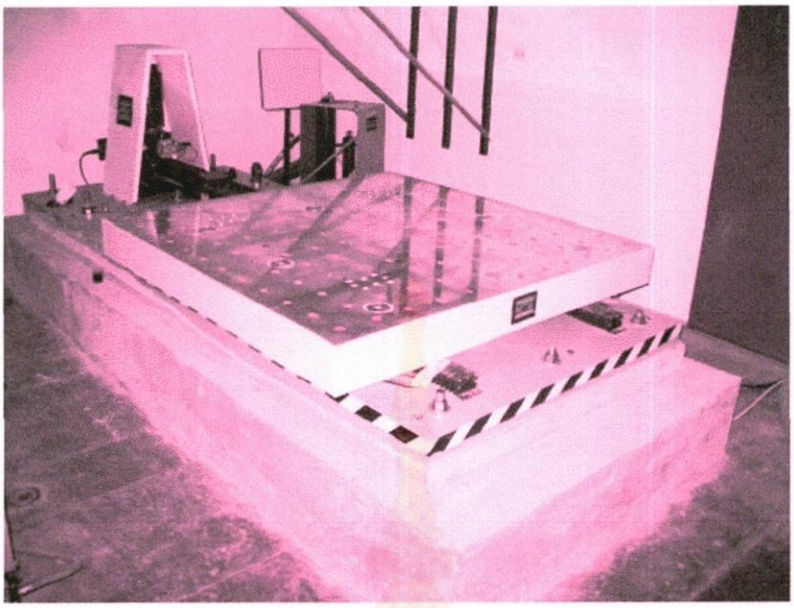

Figure 2. 7 Uni-axial shake table dynamics developed by Doheny and Sivaselvan (2008)

มหาวิทยาลัยเทคโนโลยีราชมงคลศรีวิชัย

CHAPTER 3

METHODOLOGY AND ASSEMBLY

3.1 Introduction

It can be said that in Thailand the research on earthquake engineering is lacking behind its Asian counterparts. However, it may argue that the country is not located in a risky zone such as Indonesia, Burma, Malaysia, and the Philippines. Nonetheless, every year there are earthquakes that can be felt in Thailand even though the foci of the earthquakes are outside the country. This is because the shock waves generated by an earthquake can travel over a hundred of kilometres.

There are organisations that have been monitored the earthquake situation in Thailand. These include Thai Meteorological Department, Electricity Generating Authority of Thailand, Hydrographic Department of the Royal Thai Navy, and the Royal Irrigation Department. Note that the majority of their work is to monitor the occurrence of earthquakes as well as announce any relevant matters to the public. Also note that there are few universities that are active about earthquake research such as Asian Institute of Technology and Chulalongkorn University. However, compared these figures to all of the universities in Thailand, it is a very small. It is therefore necessary for Thailand to gear up for the research on earthquake engineering.

3.2 Controlling System Design

The philosophy behind this research was to design and build a uni-directional shaking table that are low-cost and easy to operate. Yet, the signals generated from the table must resemble the ones produced by actual earthquakes.

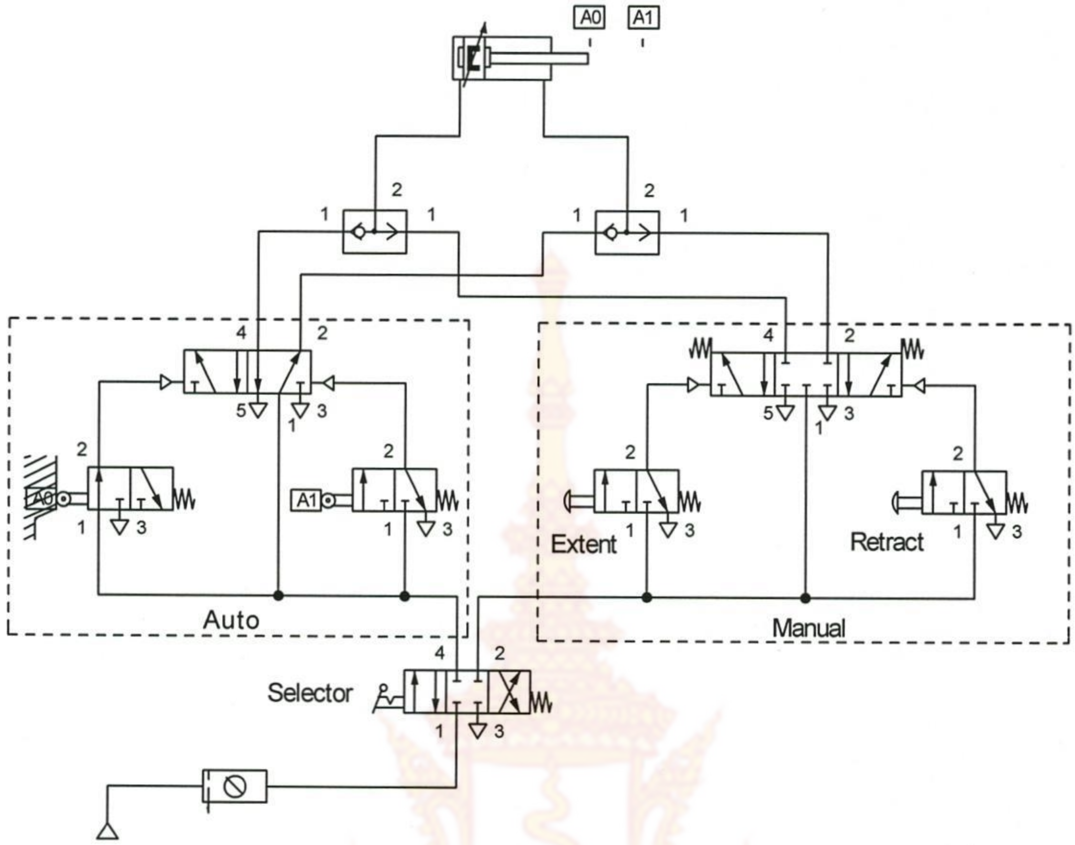

Figure 3. 1 The design and control of the uni-directional shaking table

Due to restricted budget, a pneumatic actuator was chosen over a hydraulic one. This is because the pneumatic actuator requires just an air compressed pump and some valves and controllers. On the other hand, to operate and control the hydraulic actuator needs more equipment and controlling system thereby building it would need much higher budget. The control of the system of this project was designed so that it could be operated both manually and automatically. The design of the uni-directional shaking table for this project is illustrated by Figure 3.1.

3.3 Details of Components

The main part of the shaking table system is a pneumatic actuator made by SMC Thailand Ltd. The actuator is placed over a steel platform designed by the authors. The platform utilises a channel-shape structural steel. The table was built by means of space frame using a small steel tube having ½ by ½ in and 2 mm thick. The space frame shape was chosen to be a table because it is lightweight yet stiff enough to withstand the vibration during a shaking test. The stainless rail guide and very low friction bearings were employed to support the table. The details for each components of the table are described below:

3.3.1 Pneumatic Actuator

The selected pneumatic actuator was manufactured by SMC Corporation and imported by SMC Thailand Ltd. The actuator used to shake the table is an MB1 series having 100 mm diameter of bore with a maximum stroke of 1000 mm. The shape of the actuator is square, as shown in Figure 3.2. The followings are the main features of the actuator:

(1) The adsorption of kinetic energy is higher than other series.

(2) The problem of piston rod lurching due to cracking pressure at starting up has been eliminated by means of floating seal mechanism.

(3) It is compact and lightweight.

(4) The sagging of the piston has been reduced by increasing the precision of the bushing and piston rod, and reducing their clearance.

(5) It is easy to adjust the cushion valve by just using a hexagon wrench key.

(6) The auto switch mounting grooves can be covered with resin fastener strips, which adhere tightly to the tube to prevent the entry and accumulation of dirt.

Figure 3. 2 Pneumatic actuator sitting of a steel platform

3.3.2 Space-Frame Steel Table

The table which will be used to support a modelled structure was designed based on the two requirements: (1) lightweight and (2) very stiff. These were achieved by means of using steel tube having the dimensions of ½ in x 2 mm, as shown in Figure 3.3.

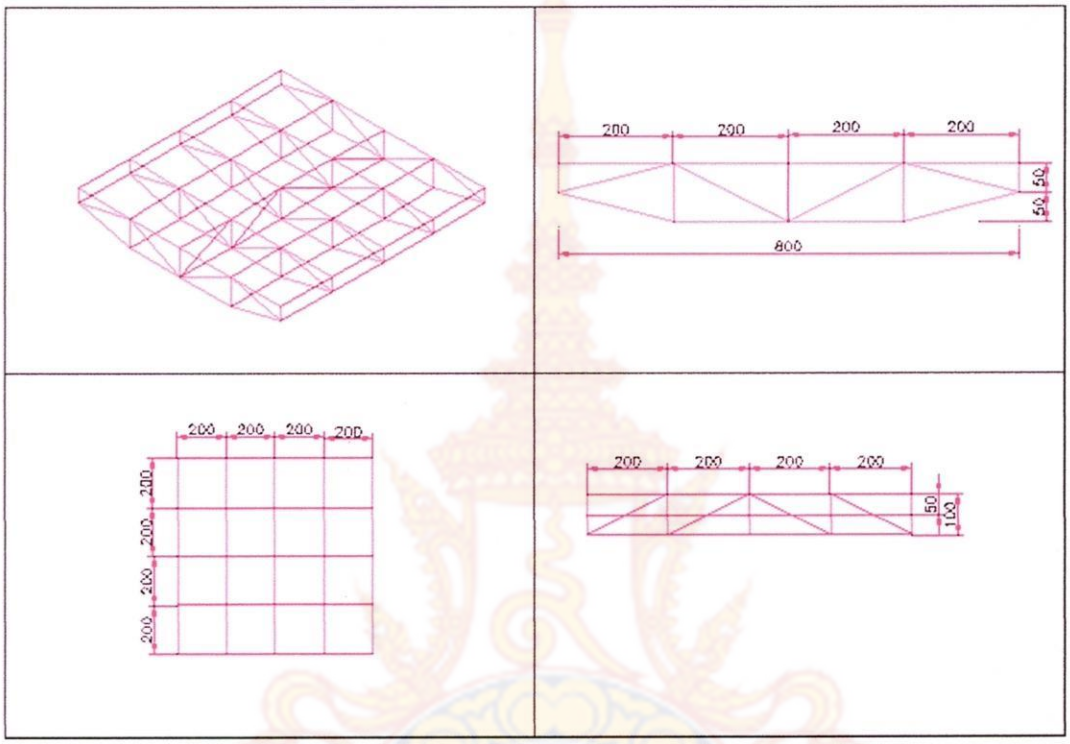

Figure 3. 3 Space framed steel table

3.3.3 Bearing Units and Linear Rail Guides

The bearing units and linear rail guides are one of the most important components of a shaking table. Their main function is to support the table. However, they must have a very low friction so that the signals measured from the table are not interfered by noises. Thus, the bearing units as well as rail guides were selected from NSK Global. This is because its products have been used for this kind of projects around the world. The bearing unit and rail guides are shown in Figure 3.4 and 3.5, respectively. They are miniature PU series manufactured by using the cutting edge technologies from semiconductors to medical equipment. Their main features are as follow:

(1) Improved materials and modified structures of the recirculation component facilitate smooth circulation of steel balls.

(2) The ball slide is fabricated to be approximately 20 % lighter than conventional models by the application of resin to a part of its body.

(3) Steel ball collision is prevented by applying resin to the recirculation hole.

(4) The structure of the ball slide is designed to prevent dust generation.

(5) The labyrinth structure adopted for the side of the rails and the inner walls of the ball slide allows effects equivalent to an under seal.

(6) Corrosion resistant martensite stainless steel is used as a standard feature.

(7) A retainer prevents steel balls from dropping out even when the ball slide is removed from the rail.

(8) Lubrication unit can be attached to the ball to achieve a long-term maintenance free use.

Figure 3. 4 Bearing unit sitting on a stainless steel rail guide

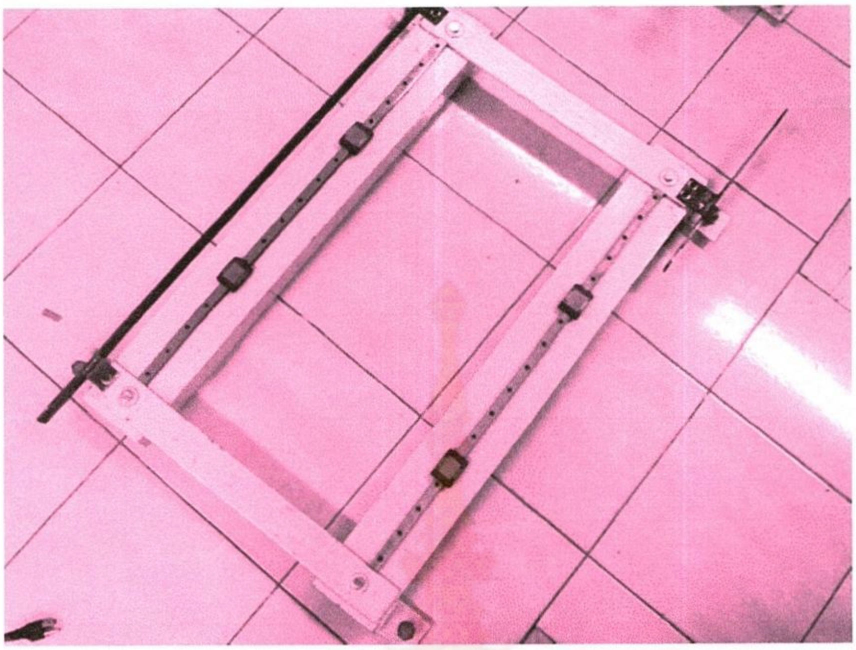

Figure 3. 5 Stainless steel rail guides fixed on a steel platform

3.3.4 Controlling Valves

The control of the actuator used to shake the table is by means of valves. These include shuttle valve, air operated valve, mechanical valve, and filter regulator. The system was designed to be able to shake the table both automatically and manually. To achieve the purpose a small shelf was made to house all of those valves, as shown in Figure 3.6.

Figure 3. 6 Set of controlling valves for operating the actuator

3.3.5 Accelerometers

To assess the workability of the table it requires the measurement of the acceleration generated. The measured acceleration then is compared with the actual acceleration produced by earthquakes. Also, the acceleration was measured using g scale (m/s^2); if the measured g value is about 1.0 g it may be said that a table is capable of simulating the earthquake shaking. Please note that most major earthquakes produce about 0.5 g.

For this project, the acceleration from the table was measured by means of accelerometers, as shown in Figure 3.7. The accelerometer was manufactured by a renowned company called PCB Piezotronics. It is powered by simple, inexpensive, constant-current signal conditioners. The sensor is easy to operate and interface with signal analysis, data acquisition and recording instruments. Their important features are as follow:

(1) Fixed voltage sensitivity, regardless of cable type or length.

(2) Low-impedance output signal, which can be transmitted over long cables in harsh environments with virtually no loss in signal quality.

(3) Two-wire operation with low cost coaxial cable, two-conductor ribbon wire or twisted-pair cabling.

(4) Low-noise, voltage-output signal compatible with standard readout, signal analysis, recoding, and data acquisition equipment.

(5) Low cost per-channel, it requires only an inexpensive, constant-current signal conditioner to operate.

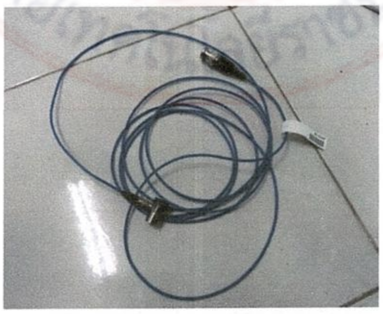

Figure 3. 7 Accelerometer for measuring and recording the vibration generated by the shaking table

3.3.6 Data Acquisition System

The signals generated from the table and measured by the accelerometer were connected to a data acquisition system for monitoring and recoding. This enables us to later analyse the signals recorded. This research employed to following instruments to monitor and record the signals during shaking of the table to assess its workability:

(1) NI Compaq DAQ chassis having four slots for up to four modules. It is manufactured by National instruments, USA. Its functions include timing control, synchronisation, and data transfer between up to four modules. It can manage multiple timing engines to run up to seven separate hardware-time I/O tasks at different sample rates in the same system. The chassis is illustrated by Figure 3.8(a).

The module was connected to a PC using a common USB cable. The NI CompactDAQ USB chassis provides the plug-and-play simplicity of USB to sensor and electrical measurements. Available with one, four, and eight slots, NI CompactDAQ USB chassis are designed for small, portable, mixed-measurement systems on the benchtop or in the field.

(2) The module to be connected with a sensor and the chassis was NI 9234. It is a four-channel C Series dynamic signal acquisition module for making high-accuracy audio frequency measurements from integrated electronic piezoelectric (IEPE) and non-IEPE sensors with NI CompactDAQ or CompactRIO systems. The NI 9234 delivers 102 dB of dynamic range and incorporates software-selectable AC/DC coupling and IEPE signal conditioning for accelerometers and microphones. The four input channels simultaneously digitise signals at rates up to 51.2 kHz per channel with built-in antialiasing filters that automatically adjust to your sampling rate.

Each simultaneous signal is buffered, analogue prefiltered, and sampled by a 24-bit deltasigma analogue-to-digital converter (ADC) that performs digital filtering with a cutoff frequency that automatically adjusts to your data rate. The NI 9234 features a voltage range of ±5 V and a dynamic range of more than 100 dB. In addition, the module includes the capability to read and write to transducer electronic data sheet (TEDS) Class

1 smart sensors. The NI 9234 provides ±30 V of overvoltage protection (with respect to chassis ground) for IEPE sensor connections. The NI 9234 has three software-selectable modes of measurement operation: IEPE-on with AC coupling, IEPE-off with AC coupling, and IEPE-off with DC coupling.

The NI 9234 uses a method of A/D conversion known as delta-sigma modulation. If, for example, the data rate is 25 kS/s, then each ADC actually samples its input signal at 3.2 MS/s (128 times the data rate) and produces samples that are applied to a digital filter. This filter then expands the data to 24 bits, rejects signal components greater than 12.5 kHz (the Nyquist frequency), and digitally resamples the data at the chosen data rate of 25 kS/s. This combination of analogueue and digital filtering provides an accurate representation of desirable signals while rejecting out-of-band signals. The built-in antialiasing filters automatically adjust themselves to discriminate between signals based on the frequency range, or bandwidth, of the signal. The module is illustrated by Figure 3.8(b)

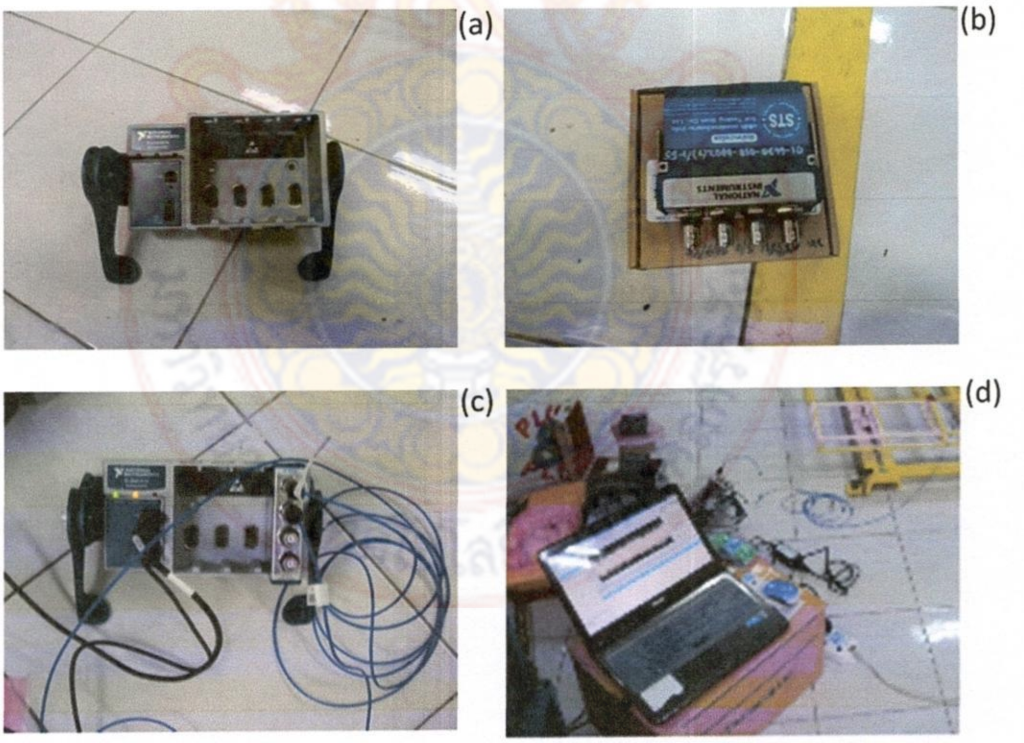

Figure 3. 8 Data acquisition system (a) chassis (b) modul to be connected between sensors and the chassis (c) an accelerometer connected to the module that is wired to a computer (d) complete set up of data acquisition system

3.4 System Building Procedures

The procedures of building the uni-directional shaking table for this project is as follow:

(1) Reviewed the literature and previous shaking tables: This step was to read papers related to earthquake engineering and building a shaking table as many as possible. First, it emphasised on the building cost for different powered systems such as pneumatic, hydraulic, and motor. It was found that using an actuator powered by pneumatic is the cheapest option. In addition, the control of the actuator is not very complex. But, the most advantage is that it is very easy to operate and need not advanced knowledge about mechanical engineering. Finally, a pneumatic actuator having a bore of 100 mm with a maximum stroke was chosen.

(2) Designed and built a space-framed steel table: Most papers investigated do not give more details about the shape and material used to make a table. However, they do provide dimensions and capacity. As such, the table for this project was designed from the ground up based on the principles that it should be lightweight yet very stiff when encountering simulated shaking.

(3) Selected the bearing system to support the table: This step was very straightforward. It needed only the investigation of products available in the market. However, the selection was based on the requirements that the system must have very low friction so that the table can move as much freely as possible. This is because if there is too much friction during shaking there might be noise in the signals thereby interpreting the recorded acceleration would be difficult.

(4) Assembly the system: This step was simply to assemble every single component together to become a single-unit shaking. This took a day to finish.

(5) Run the system to evaluate its workability: After the table was complete, it needed to be tested to ensure it functions as designed. The test run was carried with various frequencies; and, the signals generated were monitored

and recorded for further analyses of which will be described in the next chapter.

3.5 Final Assembly

The final assembly of the shaking table designed and built by this project is illustrated by Figure 3.9. It should be noted that the operation of the table would not be possible without a data acquisition system. This is because it is vital for knowing what the acceleration is the table is generating. Knowing this would enable an operator to adjust the frequency of the table thereby producing the acceleration that is similar to that generated by the actual earthquake.

Figure 3. 9 Final assembly of the table attached with accelerometers and data acquisition system readily for shaking test

CHAPTER 4

TEST RUNS AND RESULTS

4.1 Set Up for Test Run

Earthquake is a kind of natural disaster. It has long been witnessed that when it happens the consequences would be very devastated. Unfortunately, even with current technologies and knowledge we are still unable to accurately predict the incident in terms of both time and magnitude. Even though Thailand is not in the ring of fire zone, it does not mean we are safe from the earthquake. For example, the 2004 undersea earthquake off the coast of Sumatra, Indonesia claimed over 8,000 Thai and other national people. Note that these figures were just about the people died in Thailand; but, around the world over 200,000 died. Nonetheless, the majority of Thai people have very little knowledge about the earthquake. In addition, the research activities involving earthquake in Thailand are very few, compared with its Asian counterparts. It is therefore vital for Thailand to put more efforts on the research with regard to this matter. This will not only provide in-depth knowledge about the earthquake, but also to promote and bring it up for the general public in order to making people aware of the incident of which in turn would make them safer when encountering an the earthquake.

The purpose of this research was to design and build a uni-directional shaking table that is capable of simulating the earthquake shaking in order to be used to conduct further research on earthquake engineering. Therefore, it was vital to conduct test runs to certify that the shaking table could be used for the purpose of earthquake engineering research.

To set up for the test run of the table, it simply assembled all of the components together. However, one of the most important parts of certifying the workability of the table is the ability to visual the signals generated by the shaking table. This was achieved by employing a data acquisition system manufactured by National Instruments together with the accelerometers provided by PCB Piezotronics.

The complete set up of the shaking table for the test run to certify its workability is illustrated by Figure 4.1. Also, the complete set up with data acquisition is illustrated by Figure 4.2. Figure 4.3 shows the shaking table is being tested. To ensure that the shaking table would be used to simulate the earthquake shaking, three test runs were performed; and, the results were averaged. Then they were compared to the signals generated by actual earthquakes.

Figure 4. 1 Complete set up for test run of the shaking table, together with data acquisition system

Figure 4. 2 Test run in progress

Figure 4. 3 The signals generated by the shaking table is being monitored and recorded for further analyses

4.2 Results and Discussion from Test Run 1, 2, and 3

To verify the performance of the shaking table three test runs were conducted. The acceleration signals generated during testing for the Test Run No. 1, 2, and 3 are shown in Figure 4.4, 4.5, and 4.6, respectively.

It was observed that the average acceleration in terms of g values for the Test Run No. 1, 2, and 3 are around ± 2. It should be noted that normally the g values obtained from major earthquakes are just about ± 0.5 to 1.0 g. For example, Figure 4.6 displays the acceleration recorded from the 1989 Loma Prieta Earthquake occurred in the United States having a magnitude of 7.0; its maximum acceleration was about 0.7 g. Also, Figure 4.7 displays the acceleration recorded from the 1995 Kobe Earthquake occurred in Japan having a magnitude of 6.9; its maximum acceleration was about 0.8 g.

Comparing the acceleration generated from the shaking table built by this project to the recorded accelerations from actual earthquakes, it may be concluded that the shaking table could be used to simulate the earthquake shaking. It also implies that the table could be successfully used to conduct the research on earthquake engineering.

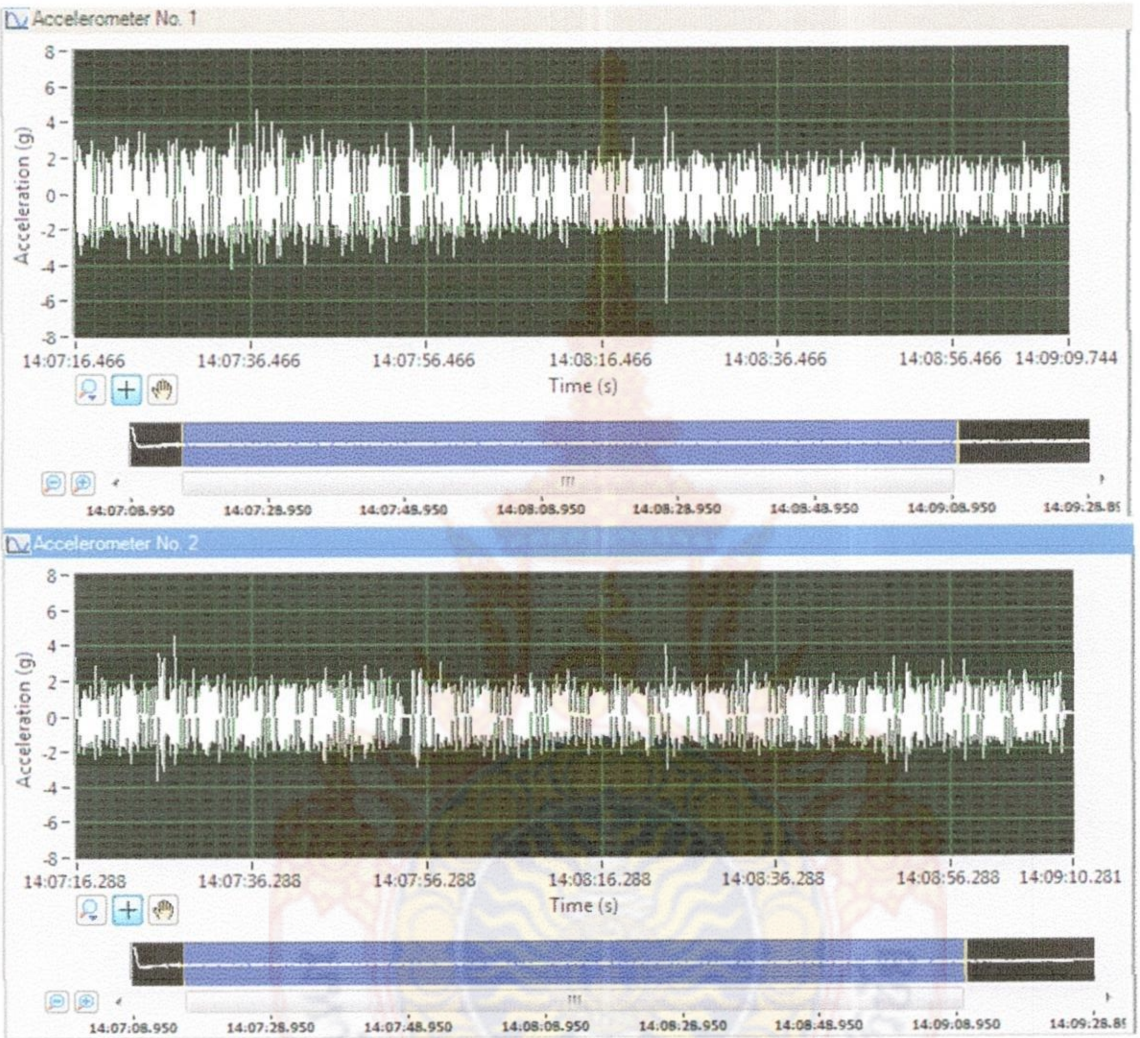

Figure 4. 4 Signals from accelerometer No. 1 and No. 2 from Test Run No.1

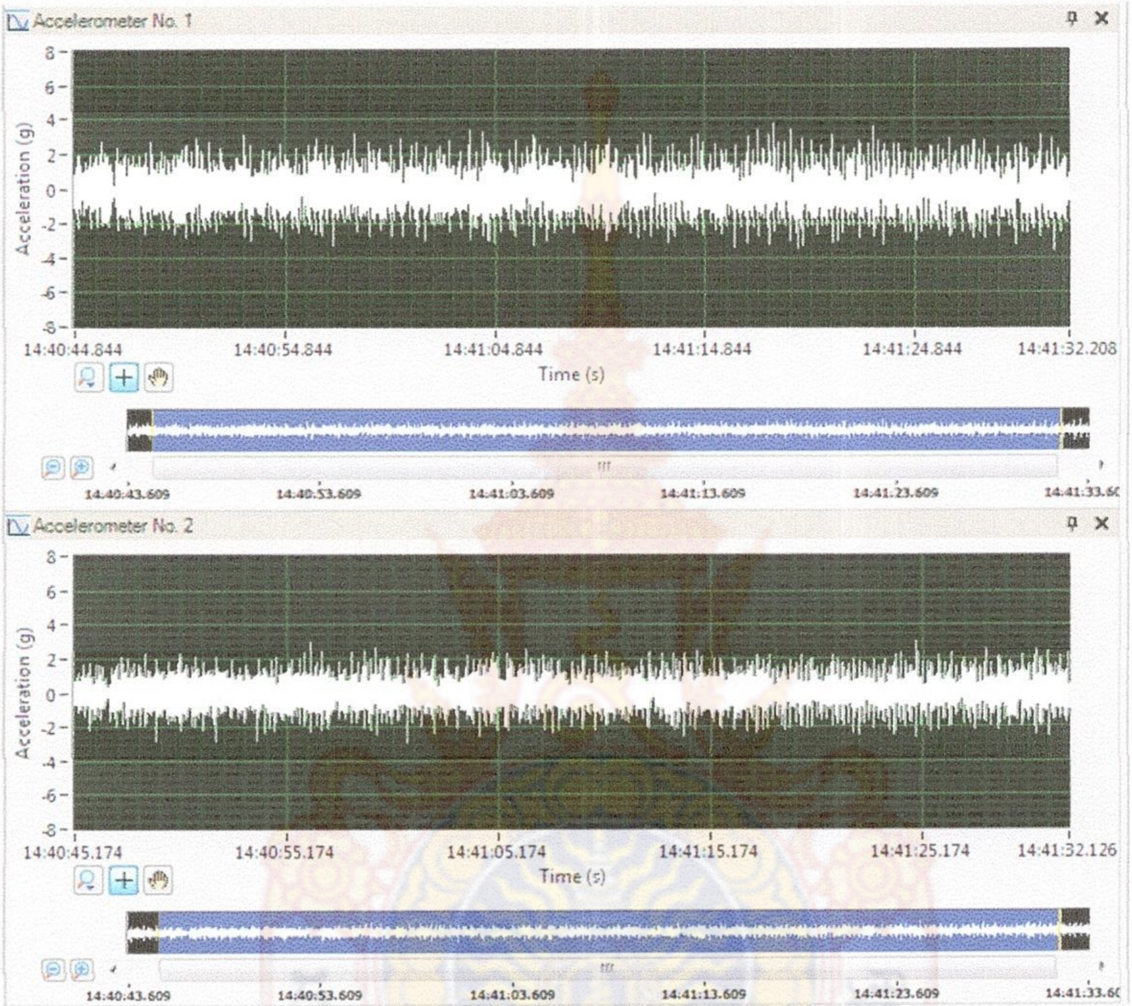

Figure 4. 5 Signals from accelerometer No. 1 and No. 2 from Test Run No.2

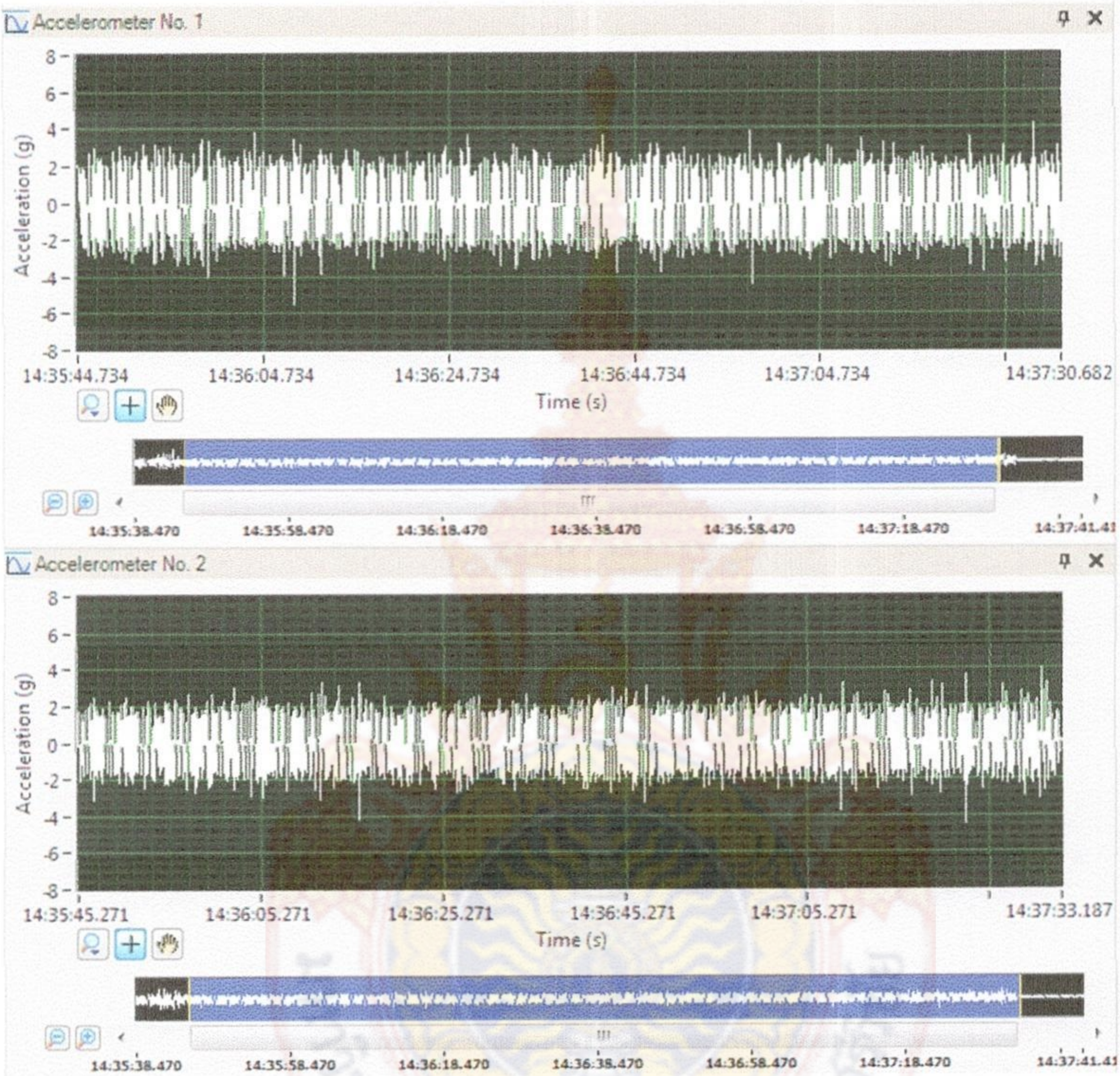

Figure 4. 6 Signals from accelerometer No. 1 and No. 2 from Test Run No.3

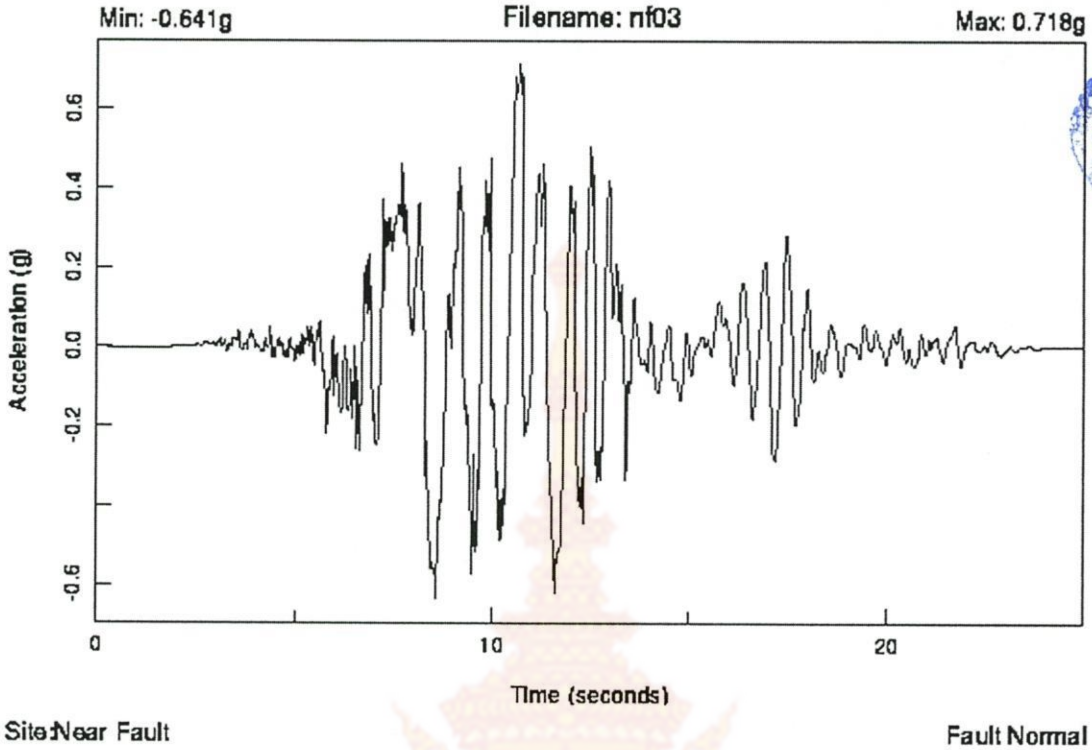

Figure 4. 7 Recorded acceleration from the 1989 Loma Prieta Earthquake indicating a maximum value of about 0.7 g (Earthquake magnitude = 7.0) (after UC Berkley website)

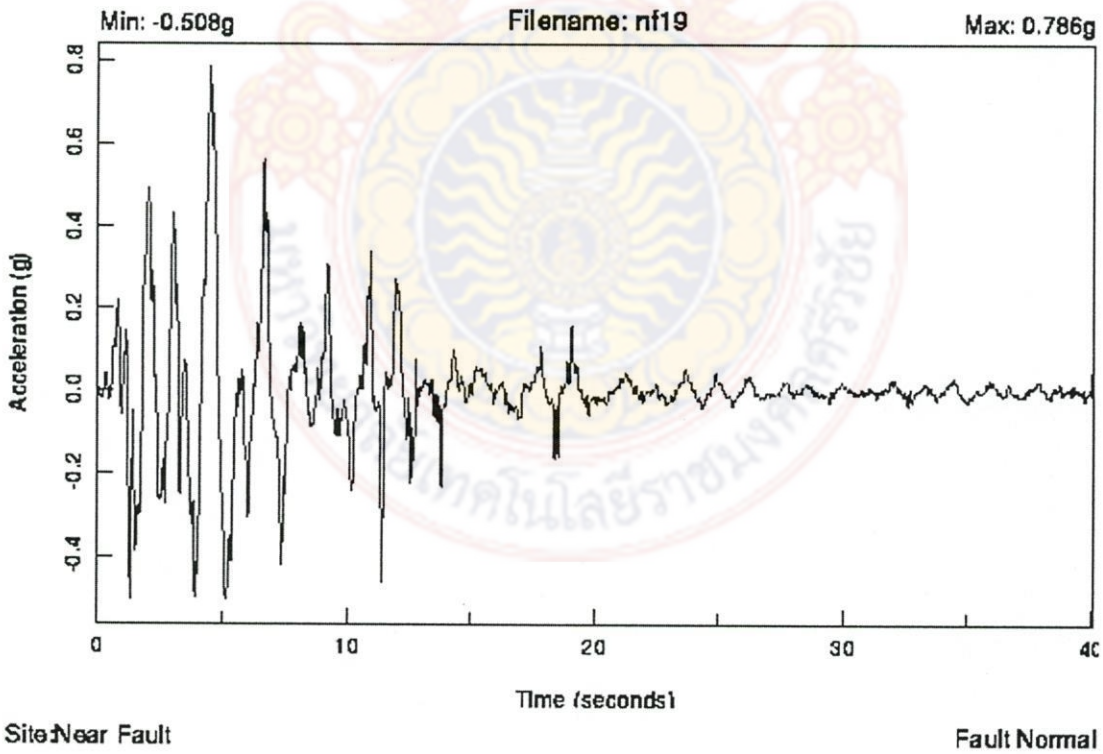

Figure 4. 8 Recorded acceleration from the 1995 Kobe Earthquake indicating a maximum value of about 0.8 g (Earthquake magnitude = 6.9) (after UC Berkley website)

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Earthquake is the shaking of the land due to the rapid release of energy. Even though it is regarded as a natural phenomenon; but, in fact it can also be originated from man-made activities such as mining and underground nuclear testing. There are over 3 million earthquakes happening each year. However, most of them are not the danger to humans and properties. An earthquake with the magnitude of about 6 and greater is regarded as major earthquake at which is capable of damaging human lives and the environment. However, from the history, it was found that by average there are about 20 major earthquakes a year. This figure seems to be insignificant. However, when the major earthquake strikes; the damage is predictable as the population is rapidly growing, and they tend to inhabit in the area that is prone to the earthquake.

From evidences, it can be said that Thailand is not safe from the earthquake at all. For example, we lost so many lives from the Boxing Day 2004 earthquake. However, the research with respect to earthquake in Thailand is not up to the level that it should be. The authors of this research were aware of this issue, thereby proposing to develop a shaking table in order to be used to conduct the research on earthquake engineering.

The shaking table was designed and built from the ground up based on the restricted budget. All of the components used can be purchased from general suppliers. After the completion of the table and test runs, the below conclusions have been drawn:

(1) The design was based on the restricted budget of approximately 200,000 Baht.

(2) The movement of the table was confined to one direction only. This is because of the limited budget. However, one-directional shaking table is easier to build and need not advanced knowledge regarding both Mechanical and Electrical Engineering.

(3) To verify the performance of the table, three test runs were conducted.

(4) The accelerations recorded from the table during the test runs indicated a g value of about 2.0. Comparing this result to the g values from actual earthquakes of about 0.7 to 0.8 g, it may be said that the table are able to simulate the earthquake shaking. This implies that the table could be used to conduct the research on earthquake engineering.

5.2 Recommendation for Future Work

Based on the experiences, test results, and analyses, the following recommendations have been drawn.

(1) Based on this design, the table should be further developed to be able to operate automatically. However, this requires advance knowledge with respect to both programming and electrical engineering. Therefore, it recommends to further research by cooperating with computer scientists and mechanical and electrical engineers.

(2) The rail guides and bearing units used to support the table should be bigger to reduce the noise from the signals generated.

(3) Based on this design, the power of the table may be hydraulic. This may make the control of the system easier.

(4) Further research should be done by adding one or two more actuators in order to be able to move the table in two or three directions. This will generate the acceleration that is more similar to those generated by actual earthquakes.

5.3 Output of This Research

Some information of this research is being in the process of publishing; an abstract submitted to 18th National Convention on Civil Engineering has been accepted. The full paper will be submitted in the end of January 2013. In addition, the shaking table has been accepted by the National Research Council of Thailand to be exhibited in Inventor's Day 2013, which will be held during 2 – 5 February 2013.

รายงานสรุปการเงิน (Financial Report)

เลขที่โครงการ 2555A17162035

โครงการส่งเสริมการวิจัยในอุดมศึกษาและพัฒนามหาวิทยาลัยวิจัยแห่งชาติ

สานักงานคณะกรรมการการอุดมศึกษา

มหาวิทยาลัยเทคโนโลยีราชมงคลศรีวิชัย

ชื่อโครงการ การพัฒนาโต๊ะสั่นสะเทือนเพื่องานวิจัยด้านวิศวกรรมแผ่นดินไหว

(Development of a Shaking Table for Earthquake Engineering Research)

ชื่อหัวหน้าโครงการวิจัยผู้รับทุน / ผู้วิจัย ดร.ภาณุ พร้อมพุทธางกูร

รายงานในช่วงตั้งแต่วันที่ 1 สิงหาคม 2555 ถึงวันที่ 18 ธันวาคม 2555

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รายจ่าย

หมวด	งบประมาณรวมทั้งโครงการ	ค่าใช้จ่ายงวดปัจจุบัน	คงเหลือ (หรือเกิน)
1. ค่าตอบแทน	17,832	0	17,832
2. ค่าจ้าง	25,000	25,000	0
3. ค่าวัสดุ	141,332	141,332	0
4. ค่าใช้สอย	12,000	12,000	0
5. ค่าใช้จ่ายอื่นๆ			
5.1 ค่าสาธารณูปโภค	17,836	17,836	0
รวม	214,000	196,168	17,832

จำนวนเงินที่ได้รับและจานวนเงินคงเหลือ

จานวนเงินที่ได้รับ

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งวดที่ 2 - บาท เมื่อ -

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REFERENCES

Biology education website: http://www.biologyeducation.net/News%20and%20Articles/Tsunamis%20&%20Earthquakes.htm

Bolt, B.A., (2004), Earthquakes, 5th Ed., W.H. Freeman and Company, New York.

Doheny, R., and Sivaselvan, M.V., (2008), Exploration of uni-axial shake table dynamics, University of Colorado, Boulder, Colorado.

Eastvillagers website: http://www.eastvillagers.org/article.php?article_id=11

Elnashai, A.S., and Sarno, L.D., (2008) Fundamentals of earthquake engineering, John Wiley & Sons, Hong Kong.

FHWA website: http://www.fhwa.dot.gov/publications/research/infrastructure/geotechnical/98139/05.cfm

Fowler, C.M.R., (1990), The solid earth – An introduction to global geophysics, Cambridge, UK: Cambridge University Press.

Iai, S., (1989), Similitude for shaking table tests on soil-structure-fluid model in 1g gravitational field, Soils and Foundations, Vol. 29, No. 1, 105-118.

Sinha, P., and Rai, D.C., (2009), Development and performance of single-axis shake table for earthquake simulation, Current Science, Vol. 96, No. 12, 1611-1620.

SSHT Laboratory website http://www.ce.jhu.edu/nakata/uniaxialShakingTable.php

UC Berkley website: http://showcase.erc-assoc.org/accomplishments/earthquake/peer-07-2-competition.htm

UC Berkley website: http://rizaaaal.blogspot.com/

USGS website: http://pubs.usgs.gov/gip/dynamic/inside.html

USGS website: http://pubs.usgs.gov/gip/dynamic/inside.html

Wallen, R., and Larson, K., (2007), CU-NEES Instructional shaking table, Center for Fast Hybrid Testing, University of Colorado, Boulder, Colorado.

Wood, D.M., Crewe, A., and Taylor, C., (2002), Shaking table testing of geotechnical models, International Journal of Physical Modelling in Geotechnics, Vol. 1, 1-13.

Yegian, M.K., and Kadakal, U., (1998), Geosynthetic interface behavior under dynamic loading, Vol. 5, No. 1-2, 1-16.

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2552	เอก	PhD (Doctor of Philosophy)	Civil Engineering	Geotechnical Engineering	The University of Sheffield, UK

6. สาขาวิชาการที่มีความชำนาญพิเศษ :
- Soil mechanics
- Geotechnical earthquake engineering
- Physical modeling
- Non-destructive testing

7. ประสบการณ์ที่เกี่ยวข้องกับการบริหารงานวิจัยทั้งภายในและภายนอกประเทศ โดยระบุสถานภาพในการทำวิจัยว่าเป็นผู้อำนวยการแผนงานวิจัย หัวหน้าโครงการวิจัย หรือผู้ร่วมวิจัยในแต่ละข้อเสนอการวิจัย
8. ผู้อำนวยการแผนงานวิจัย :
-
9. หัวหน้าโครงการวิจัย :
-

10. งานวิจัยที่ทำเสร็จแล้ว (ในฐานะหัวหน้าโครงการ) :

    Cement-Stabilised Soil-Tyre Chips as a Road Construction Material

11. งานวิจัยที่กำลังทำ :

    -

12. ผลงานตีพิมพ์:

Promputthangkoon, P., and Kanchanachetanee, B. (2012), Geomaterials Prepared from Waste Tyres, Soil and Cement, 2nd USM-PSU International Conference on Art and Sciences, Malaysia.

Promputthangkoon, P., and Kanchanachetanee, B. (2012), Using Soil-Tyre Chips Mixed with Cement for Road Construction, 17th NCCE, Udon thani, Thailand. (in Thai)

Promputthangkoon, P., and Kanchanachetanee, B. (2011), Soil-Tyre Chips Stabilised by Cement as a Road Construction Material, ICAGE, Perth, Australia.

Promputthankgoon, P., (2011), Stabilsation of embankments on soft clay with berms, 16th National Convention on Civil Engineering, Chonburi.

Promputthangkoon, P., and Hyde, A. F. L. (2010) Liquefaction mitigation by means of sand-tyre chip mixtures, 6th International Congress on Environmental Geotechnics, India.

Promputthangkoon, P., and Hyde, A. F. L. (2010) Undrained monotonic and cyclic behaviour of sand-tyre chip mixtures, 17th Southeast Asian Geotechnical Conference, Taiwan, Vol. 1, 371-374.

Promputthangkoon, P., and Hyde, A. F. L. (2008) Compound soil with tyre chips as a sustainable fill in seismic zones, proceedings of the eighth ISOPE Pacific/Asia Offshore Mechanics Symposium, Bangkok, Thailand.

Promputthangkoon, P., and Hyde, A. F. L. (2007) Compressibility and liquefaction potential of rubber composite soils, in IW-TDGM, International Workshop on Tire Derived GeoMaterials, Ports and Airports Research Institute PARI, Kurihama, Japan.

Ruenkrairergsa, T., and Promputthangkoon, P. (2001) Stability analysis of bermed embankment on soft clay, 14th Southeast Asian Geotechnical Conference, Hong Kong,1147-1150.

Ruenkrairergsa , T., Taesiri, Y., Petchket, K., Tangbunterm, P., Promputthangkoon, P. (1999) Report: Analysis of bermed embankment on soft clay, Department of Highway, Bangkok, Thailand (in Thai).

Tungsanga, K., Fernando, C. R., Promputthangkoon, P., and Thongyot, T. (1996) Determination of pile capacity for the construction of Donmuang-Rangsit Expressway, Pile Driving Analyzer Users' Day, Malaysia.

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หมายเลขโทรศัพท์ 075 754024-3 โทรสาร 075 754028
5. ประวัติการศึกษา

ประกาศนียบัตรวิชาชีพชั้นสูง	วิทยาลัยเทคนิคกรุงเทพ	พ.ศ. 2519
ปริญญาวิศวกรรมศาสตร์บัณฑิต	วิทยาลัยเทคโนโลยีและอาชีวศึกษา	พ.ศ. 2521
ปริญญาวิศวกรรมศาสตร์มหาบัณฑิต	จุฬาลงกรณ์มหาวิทยาลัย	พ.ศ. 2532

6. สาขาวิชาการที่มีความชำนาญพิเศษ :

- Soil mechanics and Foundation engineering

7. ประสบการณ์ที่เกี่ยวข้องกับการบริหารงานวิจัยทั้งภายในและภายนอกประเทศ โดยระบุสถานภาพในการทำวิจัยว่าเป็นผู้อำนวยการแผนงานวิจัย หัวหน้าโครงการวิจัย หรือผู้ร่วมวิจัยในแต่ละข้อเสนอการวิจัย

7 ผู้อำนวยการแผนงานวิจัย :
-

8 หัวหน้าโครงการวิจัย :
-

9 งานวิจัยที่ทำเสร็จแล้ว (ในฐานะหัวหน้าโครงการ) :
-

10 งานวิจัยที่กำลังทำ :

- การรับรู้เกี่ยวกับพลังงานทดแทนของชุมชนชาวขนอม จังหวัดนครศรีธรรมราช

ทุนสนับสนุน จากงบประมาณเงินรายได้ของมหาวิทยาลัยเทคโนโลยีราชมงคลศรีวิชัย
สถานภาพ ทำการวิจัยลุล่วงแล้วประมาณ 95%

<u>งานวิจัย/สิ่งประดิษฐ์ที่ทำเสร็จแล้ว</u>

- การปฏิบัติการจิตวิทยา และประชาสัมพันธ์เพื่อสนับสนุนการแก้ปัญหาจังหวัดชายแดนภาคใต้

<u>ทุนสนับสนุน</u> จากสถาบันวิชาการป้องกันประเทศ กองบัญชาการกองทัพไทย

- การประดิษฐ์รถเจาะเสาเข็ม อนุสิทธิบัตร เลขที่ 5408 ลว. 4 มิ.ย. 2553

<u>ทุนสนับสนุน</u> หจก. สามช่าก่อสร้าง (หจก.เอส พี แอล บอร์ไพลส์)

11 ผลงานตีพิมพ์:-

1. ชื่อ – นามสกุล นายสุรัตน์ พร้อมพุทธางกูร
   Mr Surat Promputhangkoon

2. เลขหมายบัตรประจำตัวประชาชน 3 8099 00609 20 1
3. ตำแหน่งปัจจุบัน ผู้ช่วยศาสตราจารย์
4. หน่วยงานและสถานที่อยู่ที่ติดต่อได้สะดวก พร้อมหมายเลขโทรศัพท์ โทรสาร และไปรษณีย์อิเล็กทรอนิกส์ (e-mail)

   สาขาวิศวกรรมเครื่องกล คณะวิศวกรรมศาสตร์
   มหาวิทยาลัยเทคโนโลยีราชมงคลศรีวิชัย
   เลขที่ 1 ถนนราชดำเนินนอก ตำบลบ่อยาง อำเภอเมือง จังหวัดสงขลา 90000 โทร 0812727737 , Fax 074317143
   Email : P_Punus@Yahoo.com
5. ประวัติการศึกษา

   ปริญญาตรี ค.อ.บ. เครื่องกล-เทคนิคยานยนต์ จาก คณะวิศวกรรมเทคโนโลยี วิทยาลัยเทคโนโลยีและอาชีวศึกษา เมื่อ พ.ศ. 2528

6. สาขาวิชาการที่มีความชำนาญพิเศษ (แตกต่างจากวุฒิการศึกษา) ระบุสาขาวิชาการ
   ไฮดรอลิกส์ นิวเมติกส์

7. ประสบการณ์ที่เกี่ยวข้องกับการบริหารงานวิจัยทั้งภายในและภายนอกประเทศ โดยระบุสถานภาพในการทำการวิจัยว่าเป็นผู้อำนวยการแผนงานวิจัย หัวหน้าโครงการวิจัย หรือผู้ร่วมวิจัยในแต่ละผลงานวิจัย
   - 7.1 ผู้อำนวยการแผนงานวิจัย : ชื่อแผนงานวิจัย
   - 7.2 หัวหน้าโครงการวิจัย : ชื่อโครงการวิจัย
   - 7.3 งานวิจัยที่ทำเสร็จแล้ว : ชื่อผลงานวิจัย ปีที่พิมพ์ การเผยแพร่ และแหล่งทุน (อาจมากกว่า 1 เรื่อง)
   - 7.4 งานวิจัยที่กำลังทำ : ชื่อข้อเสนอการวิจัย แหล่งทุน และสถานภาพในการทำวิจัยว่าได้ทำการวิจัยลุล่วงแล้วประมาณร้อยละเท่าใด

1. ชื่อ – สกุล นายทวีชัย กาฬสินธุ์
Mr.Thaveechai Kalasin

2. หมายเลขบัตรประจำตัวประชาชน 3 100904507541

3. ตำแหน่งปัจจุบัน ผู้ช่วยศาสตราจารย์ ระดับ 8

4. หน่วยงานและที่อยู่ที่ติดต่อได้

มหาวิทยาลัยเทคโนโลยีพระจอมเกล้าธนบุรี
คณะครุศาสตร์อุตสาหกรรมและเทคโนโลยี
ภาควิชา ครุศาสตร์โยธา
126 ถ.ประชาอุทิศ แขวงบางมด เขตทุ่งครุ
กทม 10140
โทร 02-4708537
Email: thaveechai.kal@kmutt.ac.th

5. ประวัติการศึกษา

ปีที่จบการศึกษา	ระดับปริญญา	อักษรย่อปริญญา ชื่อเต็ม	สาขาวิชา	วิชาเอก	ชื่อสถาบันสถานศึกษา
2536	ตรี	B.S.Ind	Civil Engineering	Civil Engineering	KMUTT, Thailand
2543	โท	M.Eng	Civil Engineering	Geotechnical Engineering	KMUTT, Thailand
2547	เอก	Ph.D.	Civil Engineering	Geotechnical Earthquake Engineering	University of Bristol, UK

6. สาขาวิชาการที่มีความชำนาญพิเศษ :

- Geotechnical Earthquake Modelling
- Geotechnical Engineering
- Site and Material Property Characterization using Field and Laboratory Tests
- Physical Modelling in Geotechnical Testing

7. ประสบการณ์ที่เกี่ยวข้องกับการบริหารงานวิจัยทั้งภายในและภายนอกประเทศ โดยระบุสถานภาพในการทำวิจัยว่าเป็นผู้อำนวยการแผนงานวิจัย หัวหน้าโครงการวิจัย หรือผู้ร่วมวิจัยในแต่ละข้อเสนอการวิจัย

7.1 ผู้อำนวยการแผนงานวิจัย : -

7.2 หัวหน้าโครงการวิจัย : -

7.3 งานวิจัยที่ทำเสร็จแล้ว (ในฐานะหัวหน้าโครงการ) : -

7.4 งานวิจัยที่กำลังทำ :

- COMBINED NON-MONOTOMIC LOADING SUBJECTED TO SHALLOW AND PILE FOUNDATIONS
- NUMERICAL MODELLING OF GRAVITY RETAINING WALLS SUBJECTED TO SEISMIC-COMBINED LOADS BY USING IMPLICIT METHODS
- PHYSICAL MODELLING OF SHEAR STACK AND GEOTECHNICAL EARTHQUAKE ENGINEERING
- COMBINED LOADING TOOLS FOR TESTING SHALLOW FOUNDATIONS AND SHAKING TABLE PERFORMING SEISMIC BEHAVIOUR OF
- FOUNDATIONS DURING EARTHQUAKES OR DYNAMIC LOADING. CONSTITUTIVE MODELS FOR CYCLIC BEHAVIOURS OF SOILS
- NUMERICAL ALGORITHMS; FORMULATION AND PERFORMANCE

7.5 รางวัลที่ได้รับ

2000-2004: Recipient of Thai Government Scholarship for furthering Master and Ph.D. Degrees in UK.

7.6 สมาชิกวิชาชีพ

- SECED (The Society for Earthquake and Civil Engineering Dynamics (SECED))
- BGA (The British Geotechnical Association (BGA))
- ISSMGE (International Society of Soil Mechanics and Geotechnical Engineering)
- ISRM (International Society of Rock Mechanics)

7.7 ผลงานตีพิมพ์ในวารสารและรายงานการประชุม

Muir Wood, D. and T. Kalasin (2002). Nonlinear seismic behaviour of geotechnical systems, Proc. 4th Symposium on Implications of Recent Earthquake on Seismic Risk, Tokyo Institute of Technology: pp 85-94.

Muir Wood, D. and T. Kalasin (2004). Macroelement for study of dynamic response of gravity retaining walls. International Conference on "Cyclic Behaviour of Soils and Liquefaction Phenomena", Bochum, Germany, Taylor&Francis Group.

Muir Wood, D. and Kalasin, T. (2004) Dynamic macroelement model for gravity retaining wall. In G.N. Pande & S. Pietruszczak (ed.), Proc. 9th Int. Symposium on Numerical Models in Geomechanics (NUMOG IX), Ottawa, Canada, A.A.Balkema, pp 731-738 , ISBN: 978-0-203-02396-9 (electronic)

Kalasin, T. and Muir Wood, D. (2005) An investigation into permanent displacement of a gravity retaining wall subjected to earthquake motions. Ulitsky, V. M (ed), Proc. Soil-Structure Interaction: Calculation methods and engineering practice, St.Petersburg, Russia, ASV Publishers., Vol 1, pp 393-399.

Kalasin, T. and Muir Wood, D. (2005) Numerical formulation for combined loading on foundations due to earthquakes. Proc. the 8th Asian symposium on visualization, Chiangmai, Thailand, KMUTT Publishers., ID85, pp 1-8.

Kalasin, T. (2005) Evaluations of lateral earth pressures of a gravity retaining wall against hydrodynamic during earthquakes An International Symposium in Tsunami Reconstruction with Geosynthetics Protection, Mitigation and Rehabilitation of Coastal and Waterways Erosion Control, Bangkok, Thailand, ACSIG , pp 455-464.

Kalasin, T. (2005) Nonlinear Rocking Block under Harmonic Motions Proc. Mahasarakham Conference, Mahasarakham, Thailand, MSU Publishers., E40, pp1-9

Kalasin, T. (2005) Responses of Sliding Block during Earthquakes Proc. the 4th PSU Engineering Conference, Songkhla, Thailand, PCE18, pp 1-7.

Kalasin, T. (2006) Modelling dynamics soil-structure interaction for retaining structure International Conference on Physical Modelling in Geotechnics, Hong Kong, Taylor & Francis Group, Vol 2 , pp 1443-1448.

Kalasin, T. (2006) Modelling Seismic-Foundation Behaviour of Cable Stayed Bridge The 4th International Conference on Earthquake Engineering, Taiwan , S285.(accepted)

อนันต์ ปัจวิทย์ ชัยยุทธ ชินณะราศรี และ ทวีชัย กาฬสินธุ์ (2549) ดัชนีบ่งชี้การเสื่อมสภาพของเขื่อนดินขณะเกิดแผ่นดินไหว , นิตยสารเสนาศึกษา, เล่มที่ 72, ตอนที่ 1, หน้า 66-77.

Chaipanna, P., Jongpradist P,. and Kalasin, T. (2007) Analysis of shield tunnel segment with ground spring model Proc. of the 12th National Convention on Civil Engineering, PhitsanuLok, Thailand, GTE-030.

Kalasin, T., and Wood, D.M (2008) Seismic analysis of retaining walls within plasticity framework, Proc. Of the 14th World Conference on Earthquake Engineering, Beijing, China, 1-11.