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Development of the Portable Shake Table for Simulating Building Characteristic under Earthquake Condition

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***Abstract*—In the last few decades, massive earthquakes, which can damage many homes and buildings, have often occurred. To slow down or prevent damage from earthquakes, various technologies are needed. From this technology, simulators of ground motion from earthquakes can be used to remind people of the dangers of earthquakes. This paper introduces a portable earthquake simulator to simulate two-dimensional ground motion from an earthquake. Focusing on the design concept, structure, and features of this new simulator, the author discusses its implementation and verifies its feasibility with the results of the initial experiments.**

***Keywords*—Building Characteristic, Earthquake Simulation, Portable Shake Table.**

I. Introduction

Indonesia is a region that is traversed by two mountain routes that make this region seismically active in the world. Thus technology and activities to reduce the risk of earthquakes are needed. Because most earthquake damage is the collapse of buildings and infrastructure, it is very important to evaluate the existing seismic capacity and then rehabilitate it accordingly [1].

An earthquake is a natural disaster that occurs when suddenly releasing energy in the earth's crust creates seismic waves. This disaster can cause a variety of damage ranging from sensitive equipment such as medical equipment in hospitals, machinery in the industry to infrastructure buildings such as the collapse of office buildings and bridge damage. In addition, earthquakes can cause other disasters such as landslides and tsunamis that cause damage to coastal areas.

This study aims to design and develop Portable Shake Tables that are used to mimic the various types of earthquake ground motion that exist from recorded earthquake data. This tool is used as the main experimental approach to mimic earthquake vibrations for the assessment of building performance, structural or non-structural models that experience ground motion in the event of an earthquake [2].

This Portable Shake Table has two actuators, each of which is driven by a DC motor. These two actuators are controlled by the controller connected to the LabVIEW software on the computer. It is hoped that this tool can help determine whether the structure or model can withstand actual earthquakes if the seismic shock table modeling system is accurate enough to predict and simulate similar ground motions [3]. The project is also expected to help provide solutions to cases of small earthquake incidents that are not strong enough to cause building collapse.

II. Control Strategy

A. Displacement Control

Most of the design of portable shake tables requires control signals with a high degree of precision, which depends on the ability of the controller system on this table. In this study two control variables are applied as a control control for portable shake tables. The signal generation process is implemented in this project which involves adjusting some control parameters and preconditions of the input movement to optimize the drive signal for the portable shake table. The first step of the signal generation process is used to adjust the movement on the X axis and Y axis. The second step is to send the signal through the controller to drive a DC motor actuator.

B. Control of Vibration Amplitude Determinants

Some researchers developed an un-axial shake table that uses electro-hydraulic actuators as drive components seem to have non-linearity which causes harmonic distortion acceleration which results in low control performance and system accuracy [2][4]. In this study vibration length is controlled based on the magnitude of the deviation amplitude and DC motor speed. The vibration amplitude control system uses an open loop system, so that only the input signal is given without the need to verify the results of the vibration generated by assuming the DC motor works well.

III. Concept Design & Research Methodology

A. Operating the Portable Shake Table System

The portable shake table system is known as an earthquake simulator that is used to reproduce or produce

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seismic movements similar to ground motion in the event of an earthquake. This phenomenon is then recorded so that civil engineers and fields can place their products on the vibrating table as test specimens to evaluate and improve the seismic response of the product and the ability to withstand vibrational movements. From Figure 1 below, to reproduce vibrations, a known plate board must be moved within a certain period of time by a DC motor actuator. This plate must allow linear movement that moves on each of the specified axes.

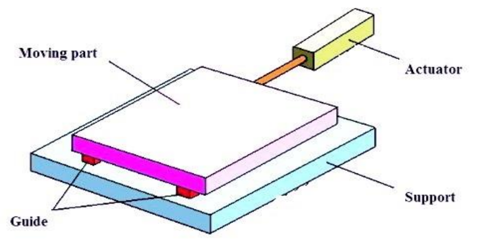

Figure 1. Design of Portable Shake Table System.

To reduce the complexity of the control system, portable shake tables must be constructed to produce one-translation movements to move test specimens. The electrical input signal is generated by the computer through the microcontroller and inserted into the actuator to ensure the desired linear motion that mimics the ground shaking motion. The concept of producing periodic vibrations is to convert electrical seismic signals into mechanical motion through an electro-mechanical actuator in the form of a DC motor to simulate a vibrating ground motion to test the specimen.

B. Control System of Portable Shake Table

The proposed methodology applies the concept of positioning to control the linear motion of a table vibrating through a DC motor as an actuator. Based on Figure 2 below, the reference signal shows the input seismic signal generated from the time-shifting trendline created from the earthquake database. As an open loop system, the controller sends a position signal to the linear actuator to cause mechanical movement in the portable shake table.

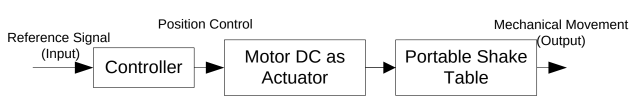

Figure 2. Design of Control System for Portable Shake Table.

Portable shake tables are driven by an electric linear actuator in the form of a DC motor that seems stable enough when used in an open loop configuration. Although there are some researchers who build an feedback system in an actuator such as a speed encoder to stabilize the movement of the actuator rod to produce a more stable.

C. Procedure for Testing the Performance of Elastomers

The standard test procedure for analyzing and evaluating the ability of elastomers to protect specimens from the impact of the horizontal component of an earthquake is to compare the structural response between fixed-base and base-isolated. Configuration under several types of earthquake ground motion. Structural responses can be expressed with several dynamic parameters such as basic acceleration, basic displacement, roof acceleration, and roof displacement as shown in Figure 3.

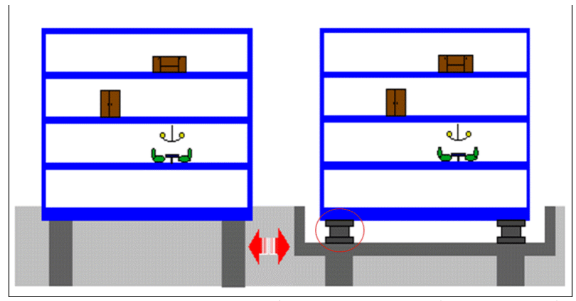

Figure 3. Shaking response for structures with fixed-base (left side) and Elastomer base (right side).

The basic structure will still experience almost complete seismic input energy generated by a portable shake table that results in a vibration experience on test specimens. Whereas, the basic structure of elastomers to eliminate vibration energy minimizes the amount of seismic wave energy transmitted from the ground to the structure to form stability during seismic events. Elastomers are mounted below the test specimen for the purpose of seismic isolation, rigid plates should be installed between the structure and the top of the elastomer to ensure that the bearings acting in concert to produce even distribution of forces throughout the elastomer.

D. System Architecture

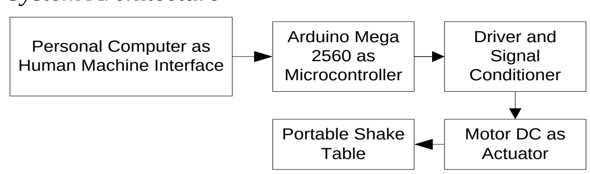

Figure 4. System architecture of proposed Portable Shaking Table.

V. FINAL DESIGN & SYSTEM IMPLEMENTATION

A. Implementation of Prototype

The proposed portable shake table mechanism is shown in Figure 4. This portable shake table has two axis as the x axis and the y axis, each of which is driven by a DC motor.

Figure 5. Final design of structure portable shake table system.

TABLE 1.
SPECIFICATIONS OF PORTABLE SHAKE TABLE SYSTEM

Specifications of System Design	Value of Specification
Shaking direction	Double axis horizontal motion
Dimension of shake table	640mm × 550mm
Thickness of shake table	25mm
Operating Load	100kg
Factor of safety	1.5
Design Load	150kg
Peak displacement	±270mm
Operating Voltage	0V – 24V (with decreasing available amplitudes)

Figure 6. Building dummy with wooden pole.

Table 1 shows the specification of the shaking table designed in this research. The table joints may travel up to 270 mm. This table was designed to be operated properly for up to 100kg of load. The experiments conducted in this research use the dummy building with wooden pole (Fig. 6) and iron ruler pole (Fig. 7).

Figure 7. Building dummy with iron ruler pole.

Figure 8. Displacement simulation using wooden pole dummy building.

The only problem with wooden pole dummy building is that the displacement of every floor of the building is hardly observable.

Figure 8 shows the simulation scenario of the shaking table using wooden pole dummy building. As predicted earlier that the displacement of every floor's movement could not be recorded since the poles were quite indestructible, especially with normal speed of vibration conducted in the experiments.

Figure 9 shows the simulation scenario of the shaking table using iron ruler pole dummy building. The ruler is thin so it can be bent easily even with small vibration produced by the movement of the table's joint. But unfortunately the ruler can only bent in one axis. So when the experiments conducted, the displacement can only be observed in one direction. In further development, the ruler may be replaced with multidirectional material, so when the experiments run, we can observe the attitude of the building more realistic.

Figure 9. Displacement simulation using iron ruler pole dummy building.

B. Design of Human Machine Interface (HMI)

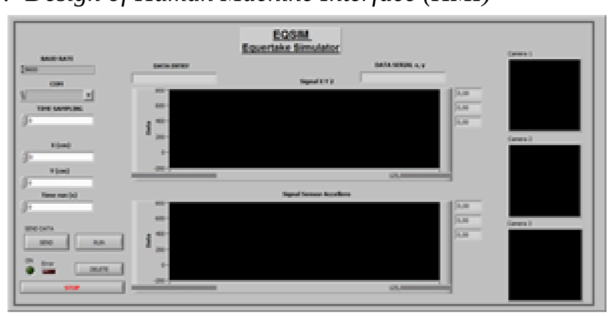

Figure 10. Design of Human Machine Interface (HMI) for portable shake table system.

VI. CONCLUSION

This paper presents the development of a space-saving portable shake table. The mechanism of table movement and the effectiveness of table movements are regulated by the HMI on the Personal Computer. In the proposed Portable shake table system, the table displacement reference for each actuator is generated on the basis of input from the user via the HMI that is passed on by the microcontroller. DC motor actuator movement is controlled by motor driver. This paper proposes a portable shake table mechanism as a laboratory scale prototype. This portable shake table is shaken horizontally based on two X and Y axes.

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