

## ***Experimental Analysis of Dynamic Behaviour of Lumped Mass System Using Shake Table***

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### ***Abstract***

*Experimental investigation plays an important role in studying the behavior of the structures during an earthquake. Usually, earthquakes are stimulated in laboratories using shake tables. Models of structures are mounted on shake tables and the response is measured using sensors. In this project, shake table is developed with the required machinery for actuators, controllers to impart different frequencies of vibration, methodology to mount the models as lumped mass systems, sensors to measure the response, software and data acquisition system for recording the data for future analysis and Interpretation.*

***Keywords-*** *Shake table, Arduino IDE, Arduino UNO Board, Ultrasonic sensor, Internet of Things (IoT)*

## **INTRODUCTION**

### **General**

In recent years, many earthquake disasters have occurred worldwide, and thousands of people were killed due to the collapse of buildings, the latest being in the Turkey-Syria region. These incidents highlight the value of studying how structures respond to vibrations in the event of an earthquake. The most effective instrument for engineers and scientists to simulate accurate seismic situations is a shake table. They create some effects that earthquakes do, hence they are used in many research projects. They make it possible to examine dynamically behaved civil engineering structures.

## SHAKE TABLE

It is an experimental setup that can stimulate earthquakes or any other dynamic loading applied to the test model or structures in a way that is both accurate and realistic. It provides an exact and clear result, in determining the response of the structure during an earthquake.

A shake table is usually composed of a rigid platform that holds the test structure to be examined. This platform is exciting with a dynamic motion. Since the structure is moving, the test is being conducted in real time while fully considering the structure's inertial effects and time-dependent material behavior.

## METHODOLOGY

The study includes an experimental approach to analyzing the behaviour of a model under seismic loading. A variation in stiffness and mass of the modeled structure will be initially established and the response of the same will be evaluated theoretically. The same will be validated with an experimental set up which includes a model resting on a shake table apparatus.

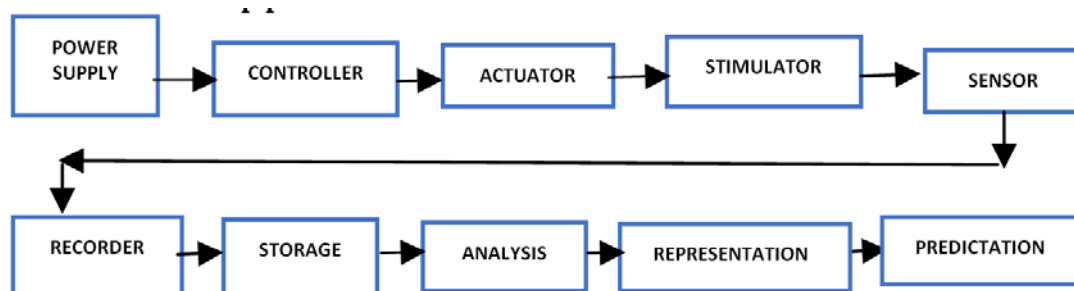


**Fig -1: Stages of Experiment**

A power supply's primary function is to transform electrical current from its source. It's capable of transforming 230V AC to 12V DC at 5A. It gives a consistent output of 12V and 5A to high torque orange TT55 12V 30RPM rectangular gearbox DC motor. This initiates the crankshaft mechanism which stimulates the vibration of the shake table in one direction. Ultrasonic HC-SR04 Sensors are placed to detect the deflection. The data is then stored and analyzed.

## VIBRATION MECHANISM

A crank is an arm that is joined at an angle to a spinning shaft and used to impart or receive a reciprocating motion to the shaft. It is employed to change reciprocating motion from circular

motion or the other way around. The end of a rod that connects to the crank rotates in a circle, whereas the other end is often only allowed to slide along a linear path. The structure vibrates as a result of the crank.

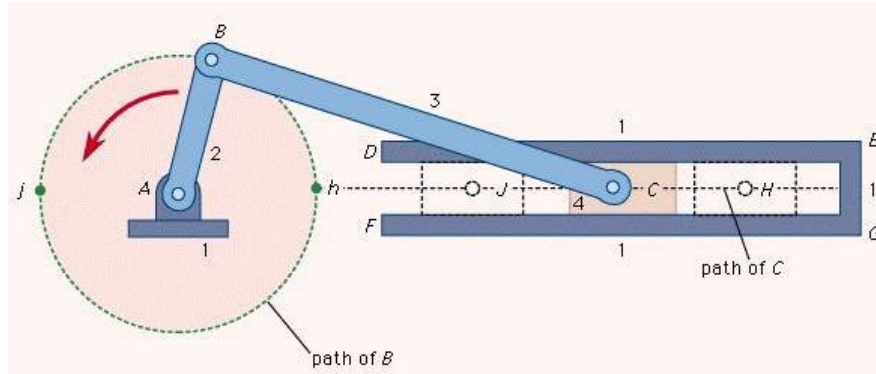


**Fig -2: Crankshaft Mechanism**

## WORKING OF SHAKE TABLE

The ratio of the pulley diameters governs speed. The two pulleys have an inverse relationship to one another. If the first pulley's diameter and RPMs are kept constant, changing the diameter causes a change in RPM.



**Fig -3: Speed Controller**

## REVIEW OF SELECTED LITERATURE

### Construction of Shake Table

**Construction and performance test of low-cost shake table T. Baran, A.K. Tanrikulu, C. Dundar, and A.H. Tanrikulu ((2011)**

Experimental work offers a different approach to analysis and pushes the boundaries of theoretical knowledge. Additionally, only experimental studies can verify the capabilities of these analytical models. Here the authors built the CUSHAKE shake table, at the Cukurova

University in Adana, Turkey, based on the aforementioned factors. CUSHAKE was built utilizing the most recent developments in computer, electronic, and electrical technologies. The table system is briefly described, along with its basic building blocks, in the first section of the text. In the second section of the study, several experimental works are used to determine the developed system's actual performance.

### **Experimental Analysis of Earthquake Shake Table A.N Swaminathen, P. Sankari (2017)**

This report presents an examination of seismic activity that has been scaled back for experimental purposes. Seismic analysis is conducted on a table composed of wood. The primary focus of this essay is on the most recent data, which is represented by a number of tests on various types of structures that may be completed using the earthquake simulator. To examine its behaviour and natural occurrence, a pre-built model is employed. The findings are recorded. The study is mostly based on the properties of steel, as well as the constructions such RC buildings and its constituent parts. The research work demonstrated the following: when a sine wave is operating at 1Hz, the accelerometer located on the shake table produces a waveform at 1Hz back into the computer. Additionally, it is more obvious in data files acquired from the lower third and second levels as there is less variance in the waveforms.

### **Experimental Study Using Earthquake Shake Table A.P. Kulkarni, M.K. Sawant, M.S. Shinde Patil (2017)**

In this paper when designing the shake table, the parameters of the earthquake created are taken into account. The type of payload is chosen according to the properties of the building, and the frequency should be chosen based on the magnitude of the earthquake. Throughout the analysis effort, several shake table applications and benefits are also investigated. Additionally, many base isolation material kinds are given.

Analyses of isolating materials are performed utilizing springs as the foundation. Dead loads on the first and third levels, Dead loads on floors two and four, loaded throughout all floors no two loads produce identical results, hence this experimental setup confirms the idea that dampers can be utilized in foundations to reduce frame deflection.

**Design of a Shake Table with Moderate Cost H. Damerji, S. Yadav, Y. Sieffert, L. Debove, F. Vieux-Champagne, Y. Malecot (2021)**

This paper describes the design and construction of a uniaxial shake table. The shake table's technical specifications, as well as an assessment of its effectiveness and validation, are offered. It is demonstrated that a functional shake table that can produce actual seismic activity for the evaluation of structural behavior may be constructed at a reasonable cost. Although computational techniques for structural dynamic analysis have been developed, earthquake engineering still heavily relies on practical testing findings to identify existing models and develop new approaches. Despite these benefits, a shaking table needs upkeep and a complicated control system, particularly when working with numerous actuators. Additionally, it is frequently used to test structures at lower scales because platform dimensions and the amount of supported payload have an impact on the dimension of the structure.

**MEASURING AMPLITUDE**

**Shaking Table Test of a steel-Concrete Composite High-Rise Building Xiang Ming Zhou & Guoqiang Li (2010)**

This study performed shaking table tests on a 1/20 scale model of a 25-story steel-concrete composite high-rise skyscraper made up of a steel frame (SF) and concrete tube (CT). With an increase in the acceleration amplitudes of the table input, the seismic behavior of the model was examined. MTS Systems Corporation produces a computer-controlled, electro-hydraulic-driven seismic simulator. The roof's acceleration was noticeably greater than any other story. The acceleration amplification coefficient (AAC), a key indicator of the impact of seismic activity on the height of the building, is described as the ratio of the peak acceleration at a particular level of the model to that of the base across the same direction. The impact of seismic activity over the height of the building would be clearly shown by an AAC plot based on the story number.

**Seismic Response of Embankment Slopes with Different Reinforcing Measures in Shaking Table Tests Yu-liang Lin, Wu-Ming Leng, Guo-Lin Yang, Liang Li, Jun-Sheng Yangm(2014)**

In this paper shaking table tests using three embankment slop algorithms were carried out to examine the seismic behavior of the embankment slopes using different strengthening

techniques. To study the change in model parameters, the horizontal acceleration response, and the dynamic earth pressure response of embankment slopes, earthquake motion, and white noise excitations were used. The seismic response of embankment slopes with various strengthening techniques was compared. The results indicate that the reinforced embankment slope has a higher natural frequency than the unreinforced embankment slope and is less responsive to seismic excitation. The embankment slope increases the responses to horizontal acceleration.

**Shaking Table Tests on Earthquake Response Characterization of a Complex Museum Isolated Structure in a High-Intensity Area Wenguang Lin, Chuan Qin, Yang Liu, Wenfu He, and Qiaorong Yang (2016)**

In this paper large base slab openings in the plan along with lengthy span trusses in elevation are increasingly taken into consideration in museum design due to the unique functional demands of the museum, including enormous space with story height for events, which presents problems to structural safety. Shaking table experiments of a 1/30 scale structure model with and without base isolated components have been performed under minor, moderate, and major earthquakes to investigate the seismic characteristics and confirm the isolation effect. The experimental results demonstrate that the dynamics of an isolated structure and the isolation effect are stable and that the superstructure's tale acceleration responses are lower than those of a fixed structure. Storey drifts of standalone structures are within acceptable bounds set forth under the Chinese design code, and bearing torsion responses are unremarkable.

**Shaking Table Model Test and Seismic Performance Analysis of a High-Rise RC Shear Wall Structure Shujin Li, Cai Wu, and Fan Kong (2019)**

In this paper through the examination of shaking table experiment data and the scaled model's observed cracking pattern, the dynamic properties, and responses of the model under various seismic intensities are examined. The shaking table model has been subjected to finite element analysis, and the results show good agreement with the experiment. To determine the extent of a structure's damage following exposure to various waves, an autoregressive approach is also offered. The results are consistent with both the test and the numerical simulation. The results of the shaking table model test, computational modeling, and damage detection show that the structure is well designed and suitable for operation.

## **INTERNET OF THINGS (IOT)**

### **Earthquake Early Warning System by IOT using Wireless Sensor Networks Alphonsa A., Ravi G. (2016)**

In this study, an IOT in WSN for an earthquake warning system is used. The earth's surface is where the sensors are positioned. Both compression P waves and transverse S waves radiate from the earth's epicenter during an earthquake. The sensors are distributed throughout the landscape, and the P wave, which travels the fastest, trips them. Early alert signals are transmitted as a result, notifying both automatic electronic systems and people to take precautions. The public will be notified sooner so that the harm won't start until the slower but more powerful S waves arrive. Many human lives will eventually be saved. When the sensors are interfaced with the software utilized in this case, LABVIEW, the three angle axes that comprise the sensor can be sensed and detected.

### **Development of a Low-Cost Single-Axis Shake Table Based on Arduino E. Damc & C. Sekerci (2018)**

In this paper, a substantial experimental setup is used to explore the behavior of structures. However, a popular research strategy in civil engineering uses scaled structural models to compare theoretical results with the dynamical behavior of structures. To simulate earthquakes, a table called SARSAR that includes an Arduino microcontroller board was created software programs utilizing an Arduino DUE board, the horizontal elements of the acceleration recordings from previous earthquakes are scaled and sent to the shake table. A data-gathering device that utilizes the Arduino MEGA board measures the table's response to provide proof.

### **Earthquake Damage Intensity Scaling System based on Raspberry Pi and Arduino Unadma Nyoman Crisnapati, Putu Desiana Wulaning, I Nyoman Rudy Hendrawan, Anak Agung Ketut Bagus Bandanagara (2018)**

In Indonesia, measuring earthquake damage levels is typically done through direct observation. However, the level of an earthquake's vibration could cause varying degrees of harm. As a result, a damage intensity scale system is crucial for assessing the severity of an earthquake's damage. As a result, we suggest in this study that a low-cost damage intensity scaling device be designed and developed using a microcontroller and a microcomputer. The goal is to track earthquake damage level and intensity data, disseminate accurate information,

and issue serious damage early warning. The MPU6050 accelerometer sensor with a potentiometer, which serves as a vibration detector, is used in this system's hardware architecture. To transmit sensor data to the user, this system uses the MQTT protocol and the Telegram API.

**Towards the Development of a Cost-effective Earthquake Monitoring System and Vibration Detector with SMS Notification Using IOT** Shaina Delia G. Tomaneng, Jubert Angelo P. Docdoc, Susanne A. Hierl, Patrick D. Cerna (2022)

The frequency of earthquakes is one of the most destructive ones. This study's main focus is on developing an earthquake detector using SMS messaging that can serve as an EEW system and has the added benefit of being inexpensive, making it more widely available to the general people. The earthquake detector and accompanying alert message system were built utilizing electronic parts utilizing an Arduino Mega 2560 and a Global System for Mobile Communications (GSM) module. Comparative investigation revealed that the values were as recorded. matched the data acquired from mobile applications with accelerometers. In conclusion, the study was shown to be functional in its capacity to identify low and high surface vibrations, demonstrating its effectiveness in identifying earthquake tremors and vibrations.

**CONCLUSION**

A Shake table that can shake at different frequencies driven by an assembly of motor, pulley, ram and wheels has to be developed. A methodology to measure parameter of oscillation using sensor should be formulated. Sensor is to be used to sense the displacement which captures and record analog reading using Arduino board and matching coding in Arduino IDE software. The sensors should be calibrated. Calibration verifies the precision and reproducibility of sensors. Experiments to find then period of oscillation for free vibration of simple and double pendulum has to be carried out. The period obtained in experiment using sensors has to be compared with Theoretically obtained results which should give same results. Experiments using shake table has to be carried out. The frequency of shake table using 30 rpm motor with and without reduction has to be determined from the experiment and has to be compared theoretically which should give the same result. Single degree of freedom system is to be analyzed.

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