Chapter 16
Design and Construction of a Low-Cost Portable Seismic Shaking Table

Eliú Pineda and A. Ortiz

Abstract Studying structural behavior under seismic events is fundamental to civil engineering and risk management. However, access to seismic simulation equipment is limited in many institutions due to its high cost. This work presents a breakthrough in developing a low-cost, portable seismic table for earthquake simulation, making it accessible to research and teaching laboratories. The platform is based on a microcontroller and a stepper motor, enabling the reproduction of real seismic signals. A motion control system, optimized using a sinusoidal function, ensures simulation accuracy through digital signal processing. The seismic table features a preloaded earthquake library, enabling the playback of historical records without requiring an external connection. This significantly facilitates its use in educational and experimental settings, as users can immediately select and execute various seismic scenarios. Furthermore, the system incorporates the Internet of Things (IoT) through wireless connectivity, allowing for remote management of the seismic table via a web browser. The developed seismic table represents a significant advancement in the democratization of research in earthquake engineering, offering a cost-effective solution with digital connectivity, the ability to reproduce preloaded earthquakes, and unprecedented portability.

Keywords Low-Cost · Shaking Table · Engineering Education

Introduction

Seismic event simulation is a key tool in the teaching and research of civil engineering, particularly when integrated with the experimental response of structures. However, the high cost of simulation equipment limits its implementation in educational institutions, particularly in regions with restricted resources. This has motivated the development of accessible solutions that democratize access to technological tools. This work presents the development of a low-cost portable seismic table with IoT connectivity (called P-Shaker). Its design focuses on portability, ease of use, and the ability to simulate real seismic records, making it an ideal tool for teaching structural dynamics and applied research in educational contexts.

System Design

The P-Shaker seismic table consists of a fixed base and a mobile platform displaced by a leadscrew-nut system coupled to a stepper motor. The platform's linear movement is generated by the rotation of the leadscrew, which is directly coupled to the stepper motor, allowing precise displacement control through the sequential activation of coils and microstepping (Hughes and Drury, 2019).

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Kristin B. Zimmerman, PhD (eds.), *Dynamics of Civil Structures, 2026, Vol. 2*, Conference Proceedings of the Society for Experimental Mechanics Series, https://doi.org/10.1007/97887-438-1441-2_16

Fig. 1 Design and execution of the P-Shaker in PLA

The control system is composed of a microcontroller (Espressif Systems, 2016) that coordinates the execution of simulations, processes signals, and hosts a web interface for remote control and monitoring. From this interface, accessible from any device connected to the local Wi-Fi network, users can select different types of simulations, configure parameters, and run experiments wirelessly.

The P-Shaker is designed to reproduce three main types of signals:

- Frequency sweep: allows for exploring the structural response to variations in excitation frequency, which helps identify natural vibration frequencies through resonance. (Figure 2)
- Sinusoidal control: the user can manually adjust frequency, amplitude, and acceleration to generate personalized oscillatory movements.
- Preloaded earthquake reproduction: The system has a library of real historical earthquakes obtained from the IRIS database. These signals are pre-processed in Python using numerical integration and smoothing techniques to avoid unwanted mechanical vibrations. The result is stored as .json files, containing the motor's target positions, which ensures trajectory fidelity and movement precision. (Figure 2)

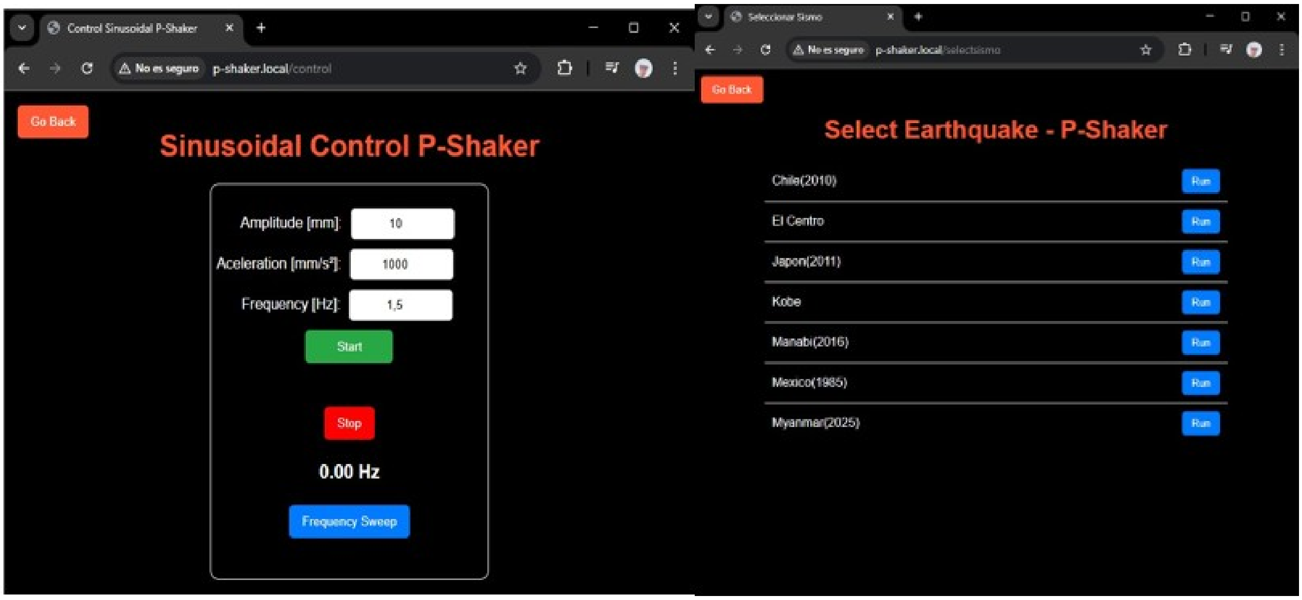

Fig. 2 Web access to the frequency sweep and sinusoidal control (left) and the preloaded earthquake reproduction dashboard of the P-Shaker (right)

Results and Discussion

Experimental simulation

To validate the table's dynamic behavior, simulations were conducted using both synthetic and real seismic signals. The system was capable of executing a sinusoidal function with frequencies ranging from 0.5 Hz to 10 Hz, demonstrating stability throughout its operational range. The input frequency was compared with the one obtained using FFT on the Android accelerometer app (Plaincode, s.f.). The maximum amplitude reached was 60 mm, with good linearity in displacement as shown in Figure 3.

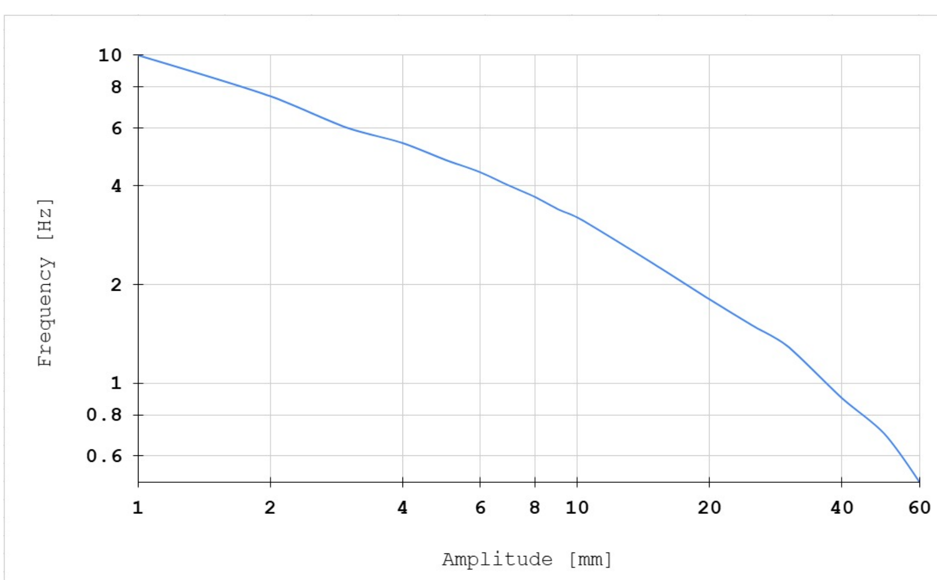

Fig. 3 Frequency response as a function of the maximum reached amplitude of the sinusoidal function

Records obtained from IRIS (NSF, 2013), such as the Myanmar earthquake (2025), were tested. The trajectories were reproduced satisfactorily, especially at the dominant frequencies.

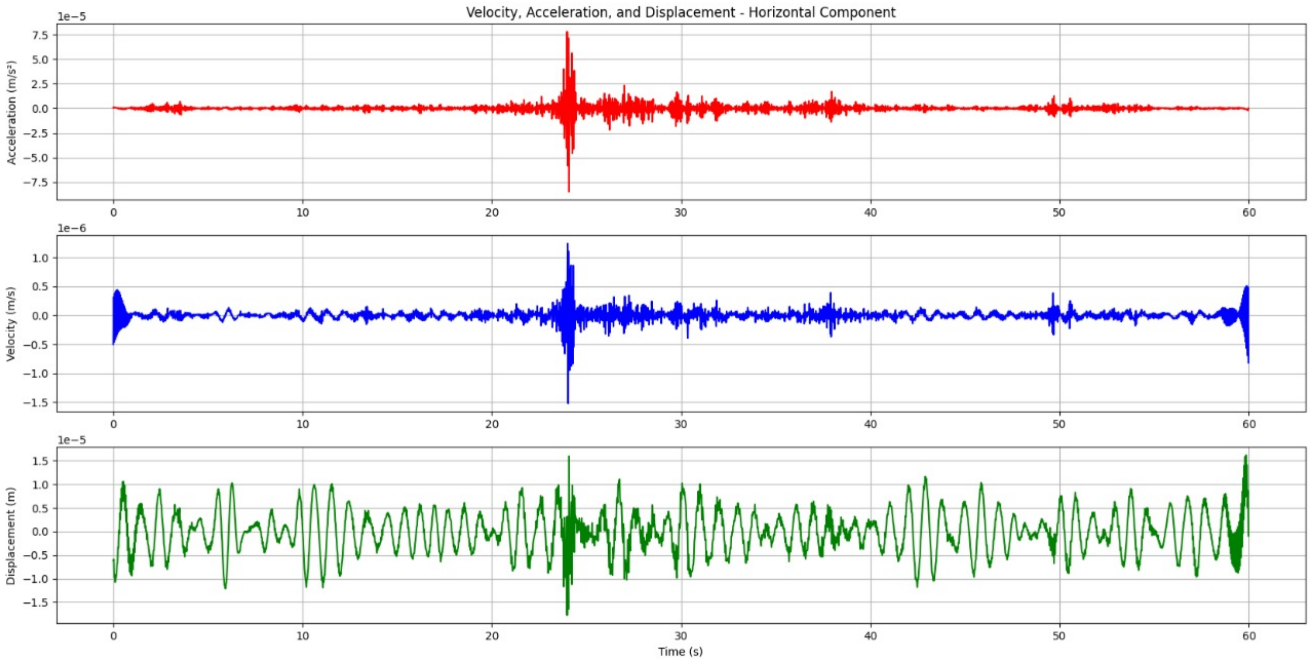

Fig. 4 Connection to IRIS, download of Myanmar information, and conversion to a format read by P-Shaker

Educational and research applications

The P-Shaker is currently on the market and has been used in university laboratory sessions to visualize structural responses in scale models. Engineering students were able to interact directly with the system, configuring parameters and observing

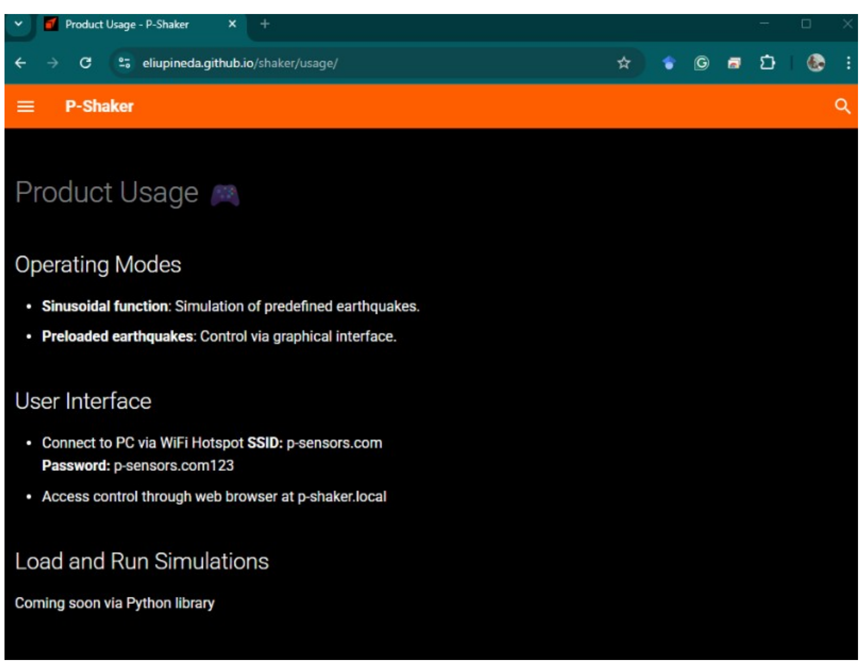

Fig. 5 P-Shaker documentation (P-Shaker, 2025) for education

phenomena such as resonance. Its use is also projected for research on structural reinforcement and active control tests in reduced structures, venturing into simulation areas studied in (Chopra, et al., 2017). The seismic table's website can be consulted here: https://eliupineda.github.io/shaker/.

Conclusions and Future Work

The development of the P-Shaker seismic table represents a significant step forward towards democratizing access to structural simulation tools in educational and research settings. Its low-cost design, portability, and remote connectivity make its implementation possible in university laboratories, technical schools, and training centers with limited resources. The experimental results have shown that the P-Shaker is capable of accurately reproducing different types of signals, ranging from sinusoidal functions to real earthquakes, which enables the study of phenomena such as resonance, damping, and the dynamic response of scaled structures. Further improvement of its fidelity is expected. Furthermore, the use of a web interface facilitates interactive learning and enables multiple users to operate the system without requiring programming or electronic expertise.

Future lines of work include extension to two degrees of freedom (X-Y), which will allow for simulating two-dimensional trajectories and torsional phenomena in structures; Implementation of closed-loop control with sensor feedback, which will improve the system's precision against external disturbances; Integration of real-time data visualization for immediate analysis of the performed tests; and the publication of the project as open source, promoting academic collaboration, continuous improvement, and the possibility of being replicated by other institutions.

Furthermore, the development of educational guides and laboratory manuals is planned to enable teachers and students to implement experimental practices using the seismic table in courses on structural dynamics, earthquake engineering, or seismic-resistant design. This educational vision, combined with accessible technology and connectivity, makes the P-Shaker a versatile and high-impact tool in training engineers who are better prepared for the challenges of seismic risk.

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