INCREASING TESTING ACCESSIBILITY WITH LATERAL TILTING TABLE TEST MACHINES

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Abstract

Lateral tilting table test machines utilize the self-weight of a specimen to apply a lateral load and help users better understand the seismic capacities of a material or construction. Many earthen construction methods, such as adobe and cob, are not common construction methods in the United States because of the difficulty with approvals and permitting. Although building codes for adobe and cob are included in the IBC, most recently in 2021, most state and local codes have not adopted the earthen construction parts of IBC. Based on the work of students at the University of San Francisco, this paper documents the creation of a manual for the construction and operation of a lateral tilting table testing machine which makes further research more accessible because of the low cost of the machine and the simplicity of the test.

Key Words: seismic testing, low-cost testing, education, research accessibility, earthen materials

Introduction

Earthen materials are low-carbon, locally sourced, affordable, healthy, and environmentally sustainable building options. Although earthen construction is common in much of the world, it is rarely used in the United States due to the exclusion of earthen materials from state and local building codes along with a general lack of exposure and understanding among the public and the industry. Greater research, especially on the seismic capacities of earthen materials, is needed in the United States for them to be included in state and local building codes and made more accessible.

Tilting table lateral test machines, also called "mesa inclinable", utilize gravity and the self-weight of a specimen to apply a lateral load and help users better understand the seismic capacities of a material or construction technique. While the use of these machines is relatively well documented in Central and South America, there is little research written in English [1]. Typical seismic testing machines in the United States are usually large frame structures that apply loads with hydraulic presses or use large shaking tables that simulate ground accelerations on a specimen. These high-tech machines cost millions of dollars to build, thousands of dollars to run, and require a lot of space, electronics, and energy.

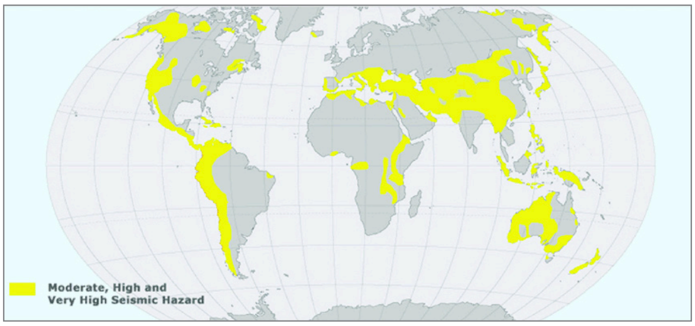

Figure 1. Moderate, high and very high seismic hazard zones of the world.
Photo: terracruda.com

Figure 2. UC Berkeley PEER Earthquake Shaking Table. Photo: UC Berkeley Pacific Earthquake Engineering Research Center

At least a third of the world's population live in earthen construction buildings, many of which are in earthquake prone regions. Damage to homes and their collapse are the leading cause for casualties during seismic events. Many of these homes are built without the involvement of engineers and architects and become greatly damaged during seismic events. The construction of seismic testing facilities is not often feasible in these locations because of the costs, maintenance, and need for skilled technicians. It is this lack of resources and accessibility to research that has prompted the greater development and documentation of tilting table lateral test machines in areas like Central and South America.

Manually operated lateral tilting table test machines are affordable to construct and operate, and the simplicity of the test makes it accessible for those who want to conduct research, but do not have access to a large research facility and funding. This paper describes the construction and operation of a manually operated lateral tilting table test machine in order to make research into the seismic capabilities of materials more accessible. This will add to the body of knowledge about these machines as well as facilitate the collection of data on natural building materials and techniques. This report builds on the work of previous University of San Francisco students who originally designed and constructed the test machine.

Concept of lateral tilting table test machines

The lateral tilting table test machine is a static test for lateral forces that uses gravity and the specimen's own weight (W) to apply a load on the specimen. As the specimen is tilted (Figure 3), the lateral force increases until the point of failure. The angle (θ) is recorded, and the lateral force (HF) is calculated with the equation $HF = \sin\theta \times W$. Examples of lateral tilting table test machines range in size from being able to test full-scale houses to small 1:8 scale [2, 3]. Some examples use a hydraulic system to tilt the specimen, while others have used bottle jacks or linear actuators [3, 4, 5, 6, 7, 8]. These can cost thousands of dollars and require a lot of space to use and store.

Designing and constructing the test machine

The manually operated lateral tilting table test machine was designed to be simple and low-cost. Its dimensions allow for the testing of many half-scale wall specimens. It requires no electricity to power, instead relying on a manually operated winch to tilt the table. Wood was used for the structure to make it easier to construct as wood shops are more common than metal working shops. It also helps to keep the cost down, the machine itself costs under $300 (Table 1). It can also be disassembled into four parts to make it easy to store, but is still easy to put together.

There are three components to the machine: the base, the frame, and the winch and sheave block system. The base is composed of 2 x 8 lumber to form the u-shaped base and 2 x 6 lumber to form the brackets. It sits on four caster wheels. The frame is made of 2 x 6 lumber for the posts and diagonal corner braces and 2 x 8 lumber for the top beam. Two square bend u-bolts and a load spreader plate hold the sheave block and hook to the frame. A horizontal member made of 2 x 6 lumber attaches the winch to the frame making it a "self-reacting" system. The machine can withstand a max load of one ton (2,000 lbs) [9].

Product	Quantity	Price	Total Price
Sheave Block w/ Hook (3")	1	$13.99	$13.99
Haul Master Hand Winch	1	$34.99	$34.99
Square Bend U-Bolt (5/8" Diameter x 2 5/16" Width x 7 3/4" Length)	2	$17.95 ea.	$35.90
Load Spreader Plate	1	$22.95	$22.95
Klein Tools Inclinometer	1	$29.97	$29.97
2 x 8 Douglas Fir	32 LF	$11.96 (per 8' board)	$47.84
2 x 6 Douglas Fir	49 LF	$9.36 (per 8' board)	$65.52
Caster Wheels	4 Wheels	$26.99 (4-pack)	$26.99
			$278.15

Table 1. Lateral tilting table test machine costs.

The design of the specimen table depends on the dimensions of the specimen and the type of material that is being tested. An example of a specimen table seen in Figure 7 uses Armor brand dog clamps and dog fences to keep the specimen from sliding off the specimen table. The dog clamps and

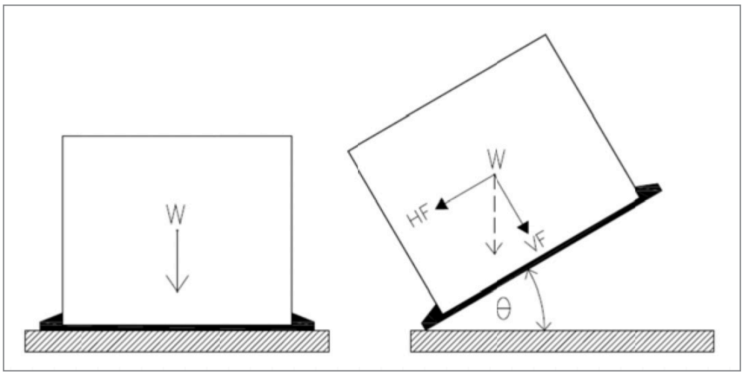

Figure 3. Loading diagram.
Photo: University of Technology Sydney

Figure 4. Hydraulic lateral tilting table test machine.
Photo: Universidad de El Salvador

Figure 5. Manually operated lateral tilting table test machine.

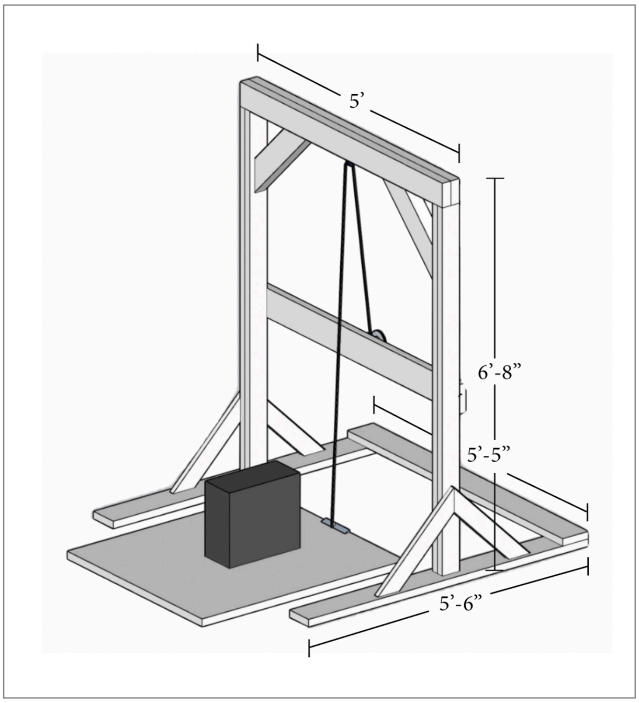

Figure 6. 3D model of the machine with dimensions.

Figure 7. Specimen table with clamps and dog fence to keep the specimen from sliding.

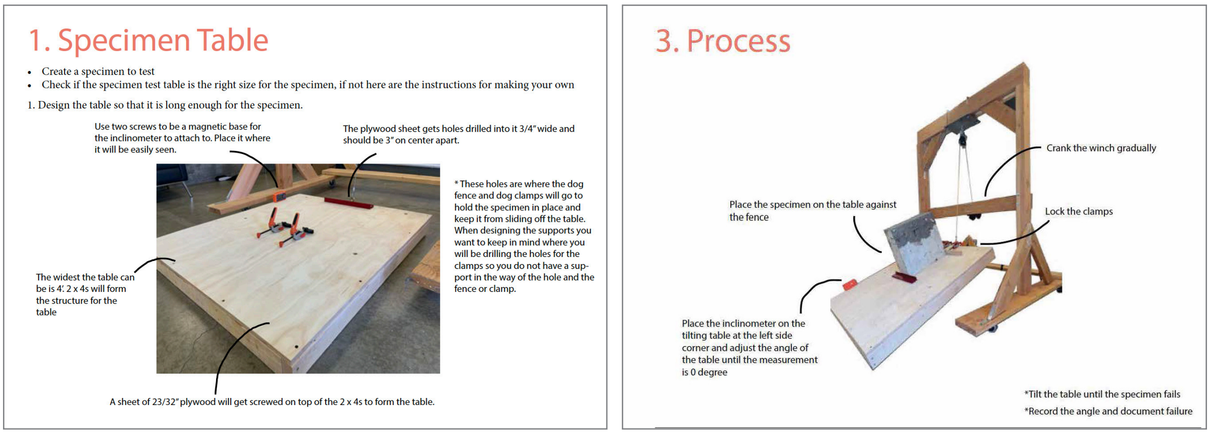

Figure 8. Pages from the Manually Operated Lateral Tilting Table Test Machine Manual.

dog fences slot into 3/4" holes drilled into the top of the specimen table and can fasten to the table. A simple u-bolt attached to the side of the specimen table allows for the sheave block hook to be attached to the specimen table to lift on side. Two screws can be added to the top of the specimen table for the inclinometer to magnetically attach to the table to calculate the angle.

The purpose of this paper is to serve as a starting point to the design and construction of a low cost manually operated lateral tilting table test machine. There may be some sliding in the specimen table as it is lifted which can possibly be remedied by adding a wooden bar connected to the machine base that keeps the specimen table from moving. Another option is to add a hinge to the wooden bar that is connected to the specimen table. In addition, certain specimen materials and dimensions, and conditions at different testing locations may require modifications to the design of the machine.

There is a long history of exclusivity in academia and research. The legacy of this exclusivity has been the erasure of earthen materials from our knowledge of building materials and limited access to research opportunities. This paper aims to remedy some of this exclusivity by making research more accessible through the simplicity and affordability of the manually operated lateral tilting table test machine. It allows for more localized contribution to the body of knowledge about non-conventional building materials and eases the determination of semi-quantitative comparisons between different solutions and techniques. Academic institutions that lack major resources can participate in research into earthen materials, broadening student exposure to them. And it empowers people, not only in the United States, but also in places where earthen construction is common, to contribute to the investigation of earthen materials.

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