Decreasing Seismic Acceleration Through Implementation of Base Isolation Systems in South America/Peru-Chile Trench

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Introduction

The converging action between the Nazca plate and South American plate in South America creates large and frequent earthquakes that inflict significant damage on South America's infrastructure. One solution to improving the resilience of buildings to earthquakes is by installing base isolators. Base isolation systems work by decoupling the building from its foundation and allowing the system to absorb the earthquake's acceleration, which drastically reduces building movement.

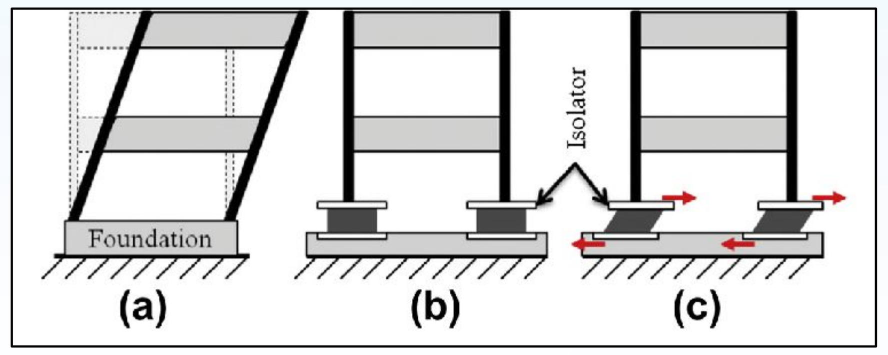


Figure 1: Standard Lead-Rubber Bearings

Figure 2: THK Cross Slider Bearings

Problem

The objective of this project was to discover what type of base isolation would provide the most cost effective and safe solution to lowering the acceleration in a given building.

Hypothesis

If a building is decoupled from its foundation and is able to move flexibly at multiple degrees of freedom, it will sustain less damage.

Materials

Marshmallow Model:

- Jet-Puffed Marshmallows (h=1.5")
- Popsicle Sticks (length= 1.25")
- Wooden Boards (6"x 10")
- Super Glue
- Fishing Line (9")

Metal Slider Model:

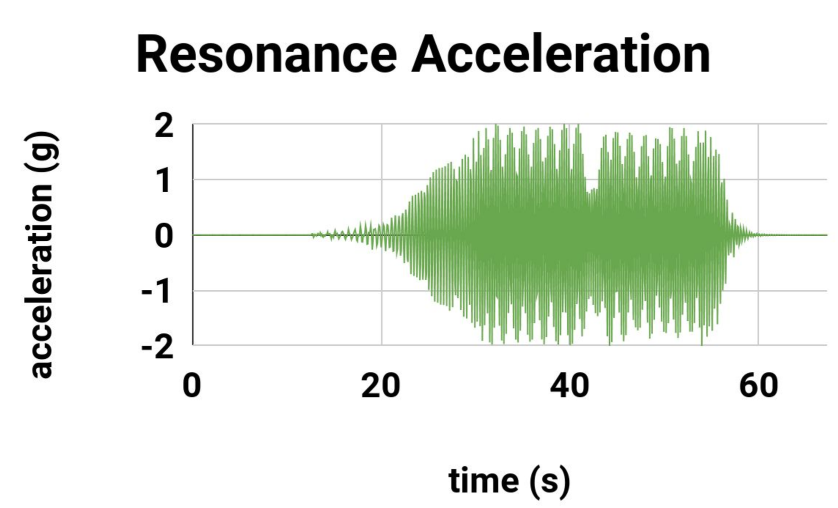
- Aluminum Sheets
- Hollow Aluminum Rods (r=0.355 mm)
- Solid Aluminum Rods (0.355 mm)
- Duct Tape
- Masking Tape
- Super Glue

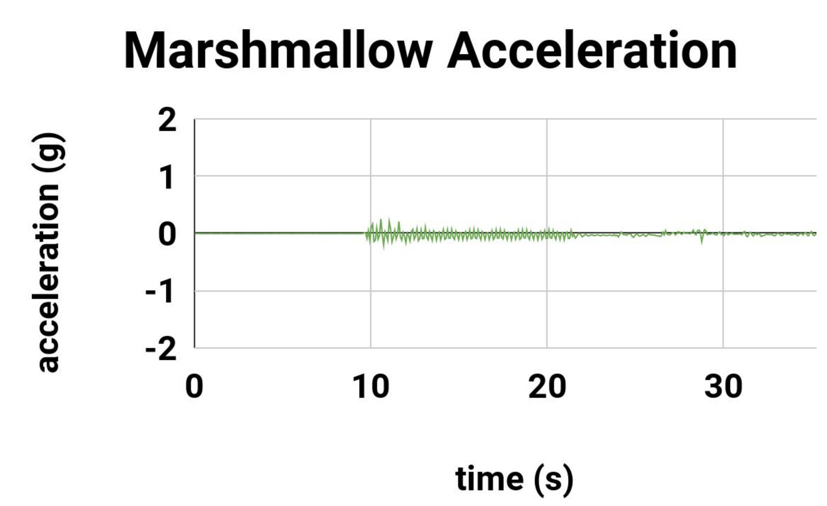
Procedures

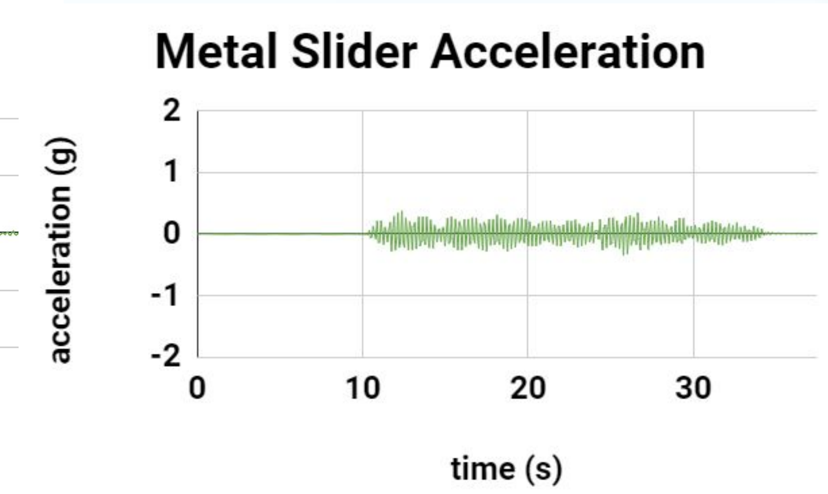
Begin by either creating the marshmallow or metal slider prototype and attach either one to wooden boards with super glue. Once the design is sandwiched between the wooden boards, attach the boards to the shake table with the building secured tightly on top. The building can then be tested at its natural frequency of 4.1 Hertz. Observe both the accelerometer data and any visual failures.

Abstract

The west coast of South America is one of the most seismically active regions in the world, illustrating the need to create structures that can withstand earthquakes. The purpose of this project was to understand the different types and effectiveness of base isolation systems, so they could be implemented in future buildings. In order to determine the most effective design, several base isolators were tested, each with varying degrees of freedom. After investigating ideal models of base isolators, two designs, Lead and Rubber Bearings (fig. 1) and THK Cross Linear Bearings (fig. 2) served as inspiration. The lead and rubber bearings were modelled using marshmallows (fig. 3) to serve as the flexible rubber along with short popsicle sticks around the cylindrical surface to add additional reinforcement. The tests were conducted by measuring the acceleration of a building when it was shaken at its natural frequency (4.1 Hertz). The data revealed that the acceleration of the building reduced drastically by 87.78% when the marshmallow system was applied and by 82.17% when the metal sliding system was applied. The design was successful in both giving the building flexibility in order to decrease the acceleration of the building through the marshmallow while restraining the overall movement of the marshmallow with popsicle sticks to ensure that it did not lose its shape completely. The metal design also worked because the base was able to slide with the earthquake without transferring that movement to the building. The metal slider could be enlarged and tested on an actual building. In reality, marshmallows would not be a practical solution in an actual building, but similar materials such as polyurethane rubber and steel as reinforcement are possibilities.







Natural Frequency of Building

87.78 % Decrease

82.17% Decrease

Final Marshmallow Design

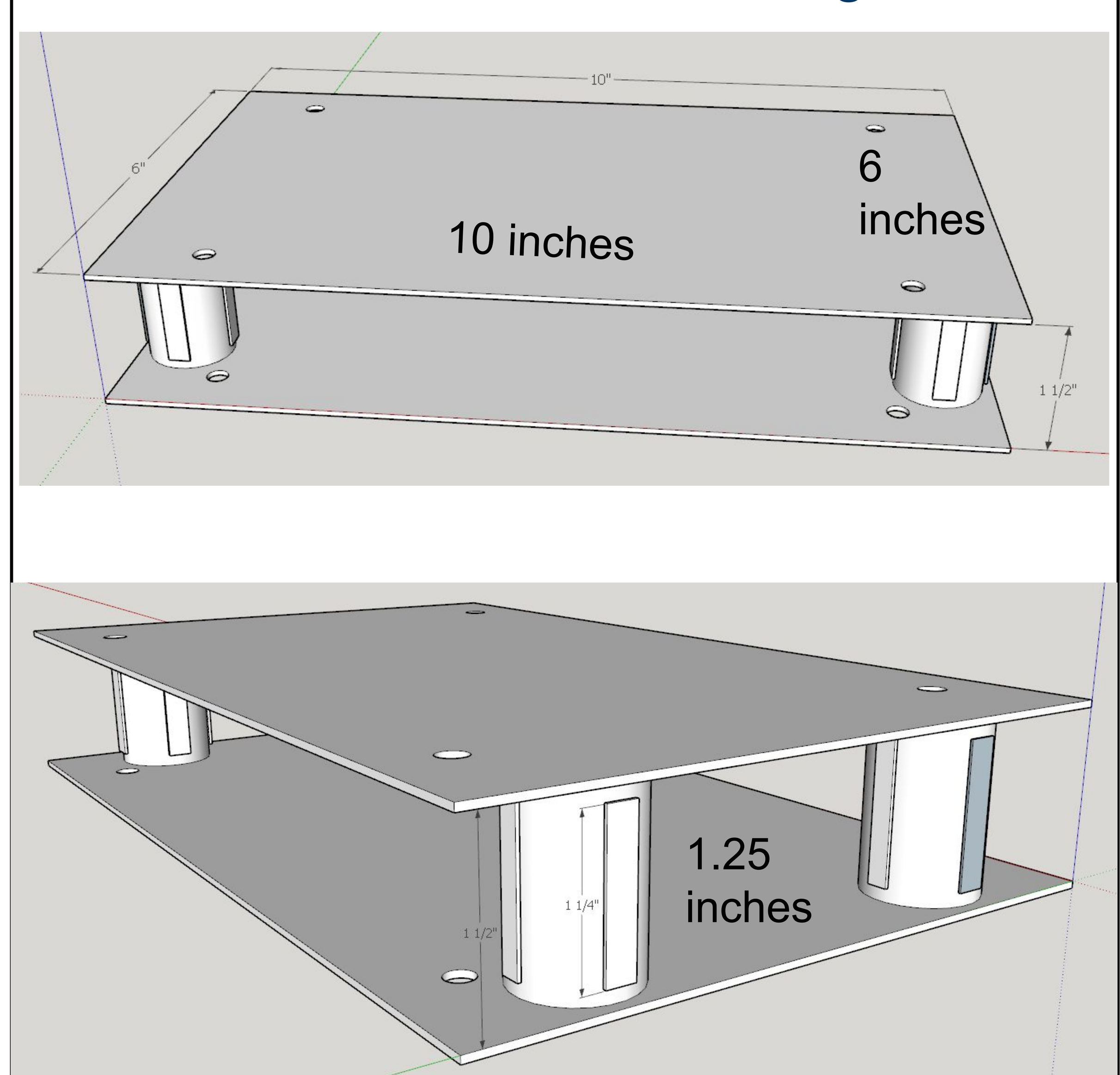


Figure 3: Marshmallow and Wood Bearing Prototype

Final Metal Slider Design

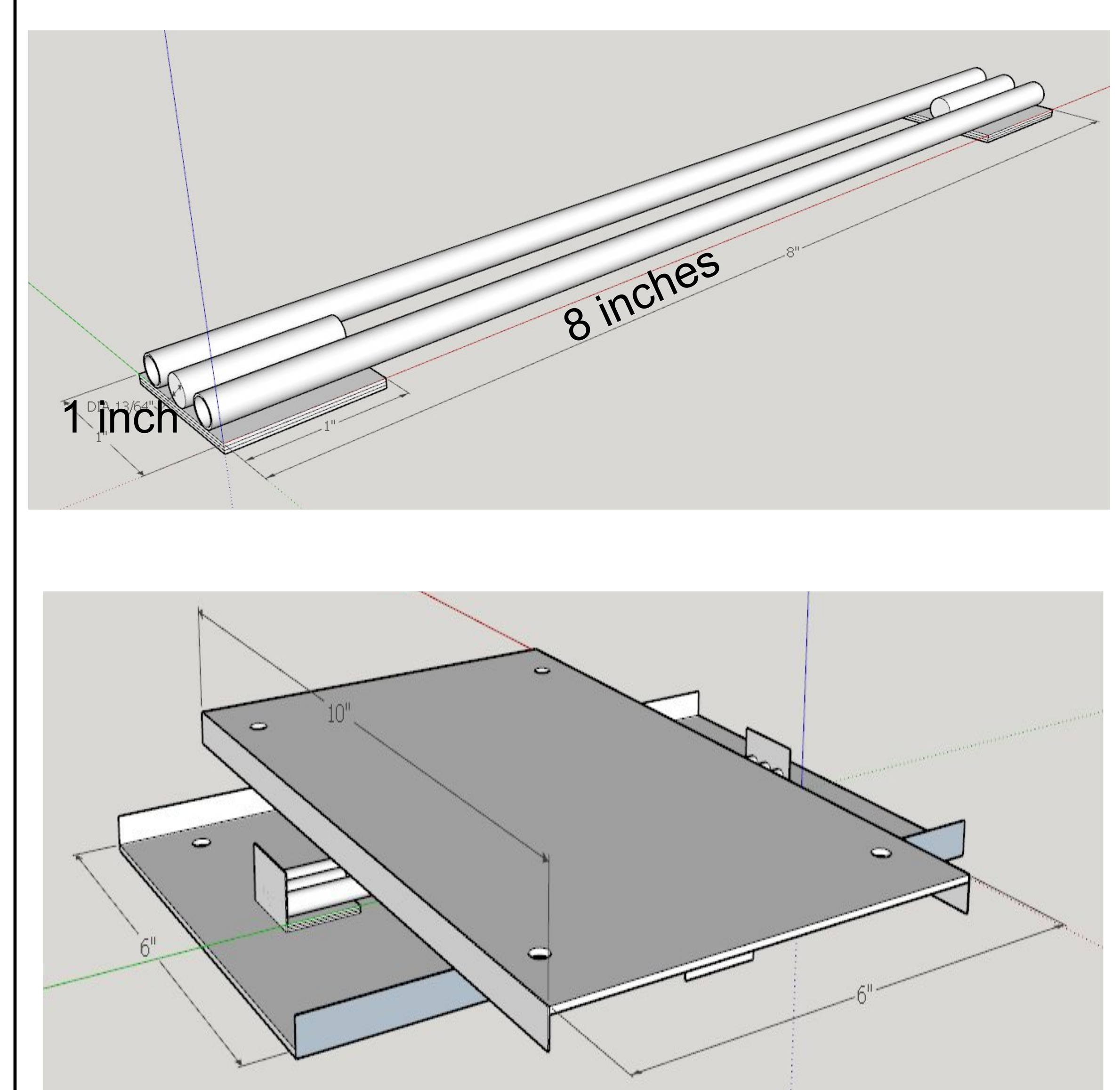


Figure 4: Metal Slider Prototype

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Results

Based on both our visual and numerical data, the acceleration of the building decreased dramatically when the base isolator systems were added. The marshmallow prototype proved to be more effective by reducing acceleration by 87.78% The metal slider was also successful in reducing 82.17% of the natural acceleration. Additionally, the building moved significantly less from a visual perspective. From this data, it can be concluded that both designs worked as expected.

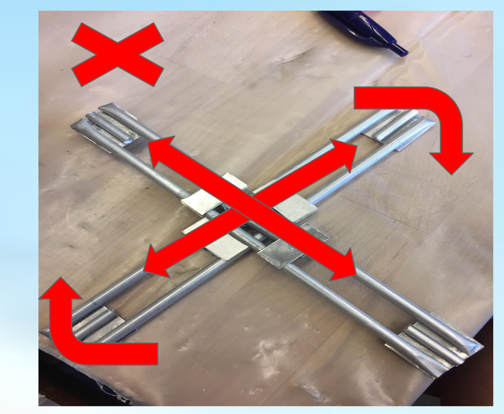

Figure 5: Metal Slider Movement

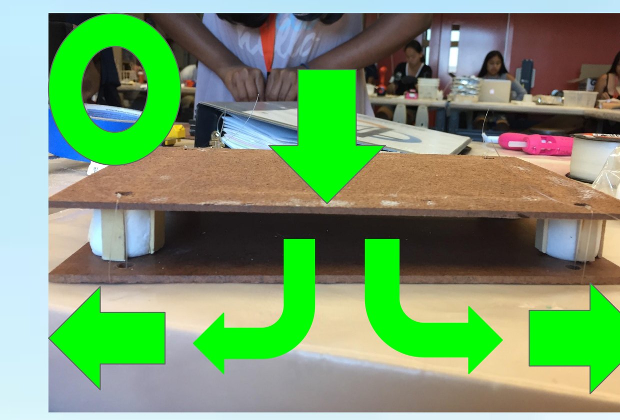

Figure 6: Marshmallow and Wood Bearing Movement

Discussion

The success from both the marshmallow and metal slider design was due to their abilities to both isolate and dampen. The marshmallow was flexible while the wood around its surface was strong. The balance allowed the system to bear the weight of the building and move during the earthquake (fig. 6), which is desirable in real buildings. The metal design worked by transferring the kinetic energy from the earthquake into the system itself. The metal would slide in two directions but it wooden base would keep the building stable.

Conclusion

It was concluded that base isolators can reduce acceleration and movement by a large degree (87.78%). The most effective base isolators consist of a flexible body that is strong enough to support the weight of a building, which was modelled by the marshmallow design. Base isolators are also very important in South America because the west coast lies directly upon a subduction zone, making it susceptible to long duration earthquakes. Adding base isolators would help this region reduce building damage significantly.

Future Study

During testing, the metal slider would occasionally twist in undesired directions (fig. 5) which would not be ideal for an actual building. Conducting more research to reduce twist on this design would be important for the future. Also, the marshmallow design is not a practical application for real buildings. Further testing could investigate materials with similar properties to marshmallows, like polyurethane, to see if they reduce acceleration in a similar way. Current base isolation systems are quite expensive so finding more cost effective systems would promote base isolators to be implemented in more buildings.