Performance Assessment of Meta Materials for Seismic Isolation

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INTRODUCTION

Seismic isolation is recognized as an effective technology to achieve high levels of protection against seismic forces. This is achieved by decoupling a building's superstructure from it's substructure, essentially isolating it from the shaking ground. Traditional seismic isolation systems are designed to saves lives while the building takes damage. This research proposes a new seismic isolation device that can both save lives and prevent building damage.

Applications of Seismic Isolation

Despite their effectiveness, currently used seismic isolators have practical, technical and economical limitations [3]. These limitations result in their application being restricted to critical structures only, like hospitals and bridges. Meta Material pads have been recently proposed as a solution to overcome these limitations and expand the use of this technology to small scale applications like residential homes and equipment (**Fig. 1**). This research focuses on the use of these isolation pads on server racks which provide vital services and are highly susceptible to the accelerations generated in an earthquake.

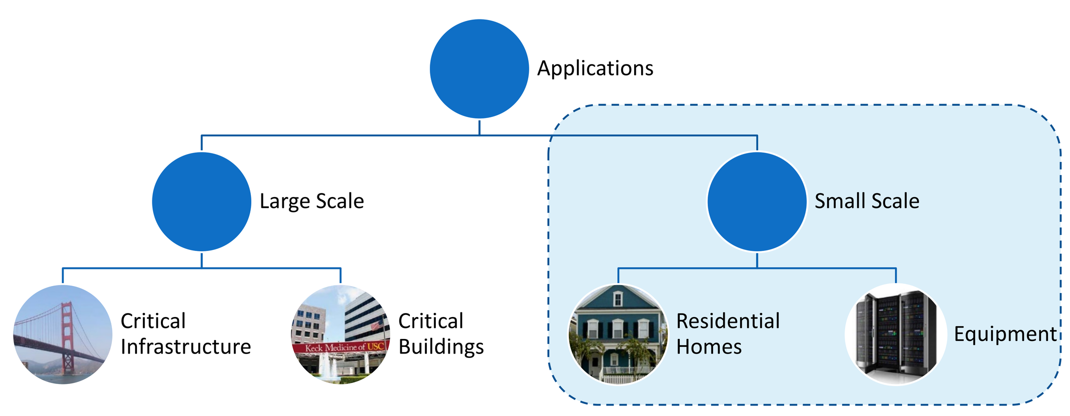


Fig. 1 – Large scale vs small scale application of seismic isolation systems.

Meta Materials

Meta Materials are engineered materials that exhibit properties and characteristics that do not exist naturally in nature. An architected material is a type of meta material that is designed with a specific pattern of microscopic voids, which give the material its out of the ordinary abilities [3]. For this application an architected material was designed to exhibit high strength vertically, with low stiffness laterally (**Fig. 2**). This will provide the strength to hold the object's weight, while allowing it to move horizontally in a seismic event.

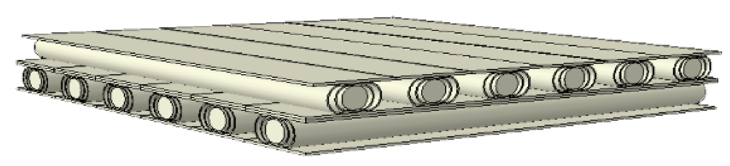


Fig. 2 – Meta Material pad for seismic isolation [2].

OBJECTIVE

Goal: Evaluate the performance of the meta material seismic isolation pad as a protection device for server racks.

Method: Lab testing is conducted to obtain acceleration data of a test mass isolated by the meta material pads. The lab data will be used in SAP 2000 and Excel to conduct a parametric analysis to calibrate a digital model of the isolation pads and a typological server rack. SAP 2000 is utilized to simulate several earthquakes on the isolated server rack and obtain bidirectional acceleration data. A SAP 2000 model of the same server rack without any isolation device will be subject to the same earthquakes and used for comparison.

Outcomes: The resulting acceleration values of the two different server racks will be compared to see if the isolation pads provide any reduction in acceleration. The performance of the meta material pads will be evaluated based on whether or not it provided any protection against seismic forces and resulting accelerations.

PHYSICAL/NUMERICAL TESTS

Lab Test
(**Fig. 3**)

- Acceleration Sensor
- Concrete Block (representative mass)
- 3 Isolation Pads
- Shake Table
- Subjected to 22 Earthquakes

Outcome: Block Acceleration in x and y Directions

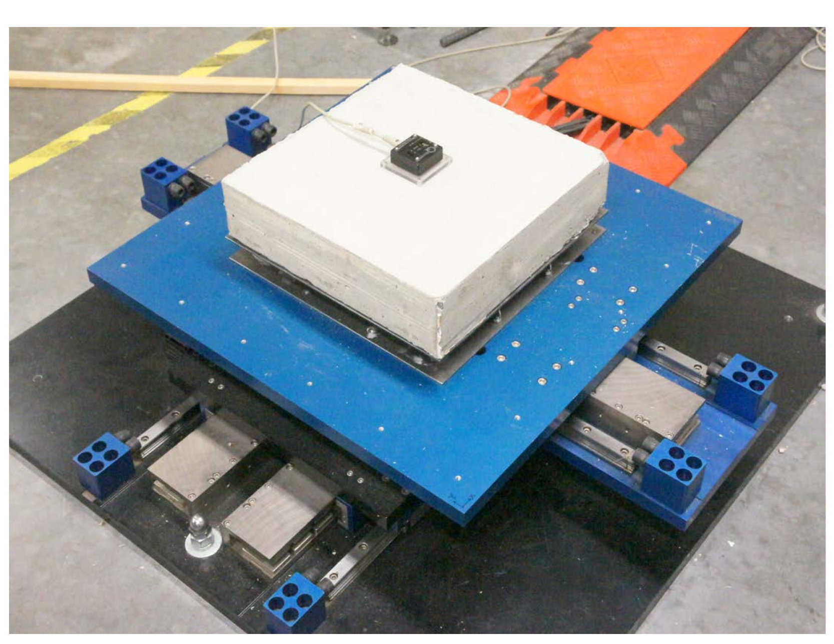
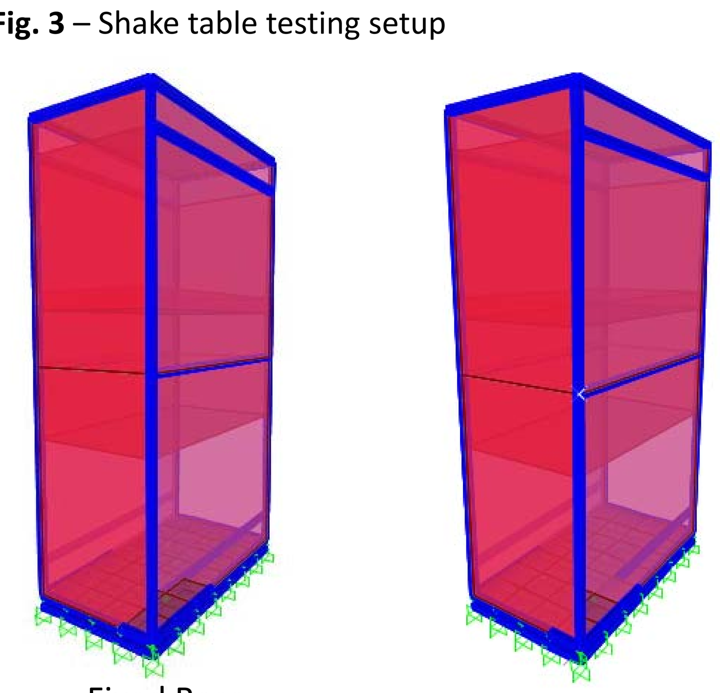


Fig. 3 – Shake table testing setup

SAP 2000 Numerical Model
(**Fig. 4**)

- Model of Typological Server Rack
- Simulation of 22 Earthquakes
- Calibrated Isolation Pad Element

Outcome: Server Rack Accelerations in x and y Directions

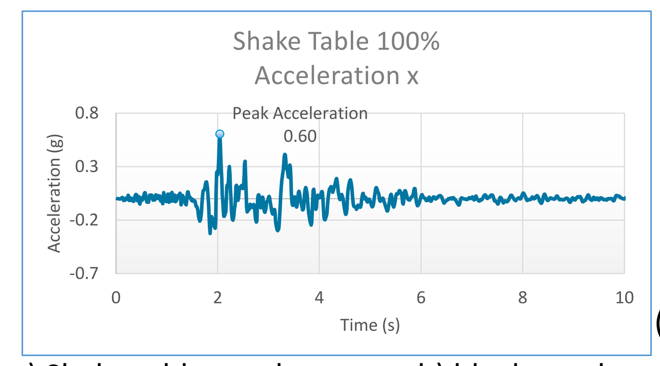


Fixed Base (Bolted Down) | Isolated Base

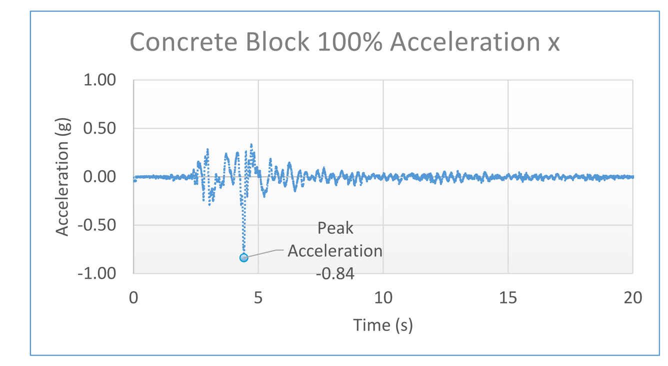
Fig. 3 – SAP 2000 server rack models

RESULTS

Lab Test Data Collection



(a)

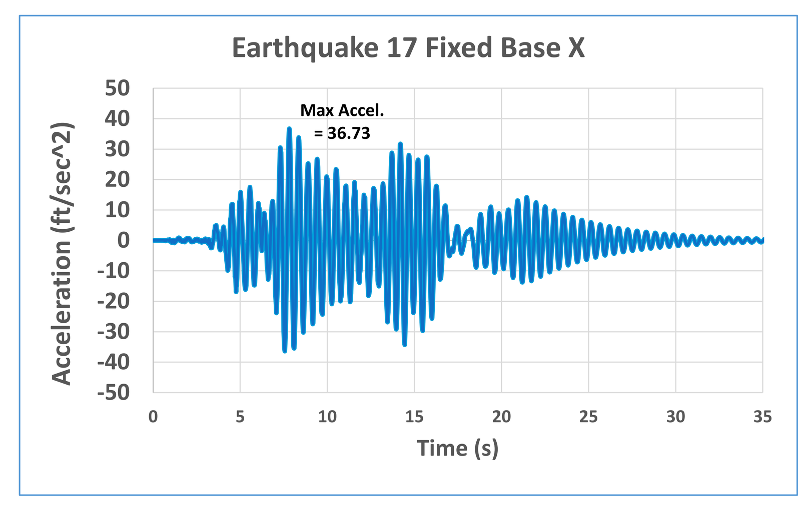


(b)

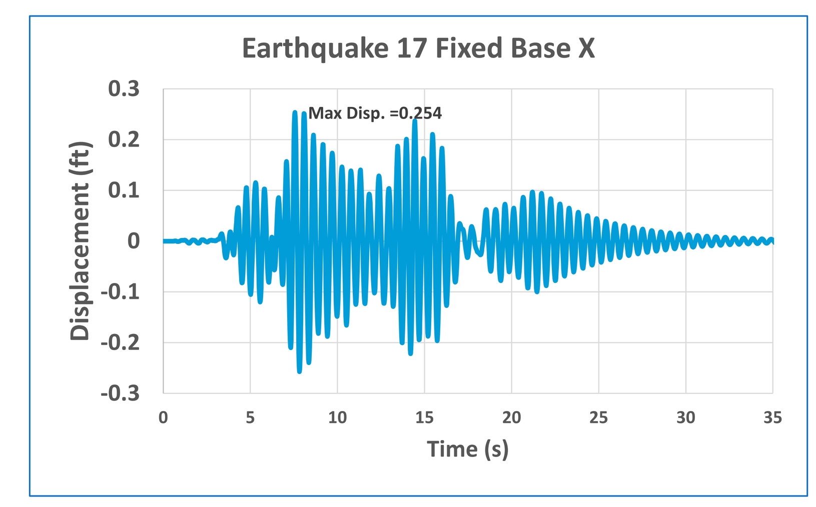
Fig. 5 – a) Shake table accelerogram, b) block accelerogram

For this lab test the peak acceleration of the Concrete Block (**Fig. 5b**) is observed to be higher than that of the Shake Table (**Fig. 5a**). Objects can experience accelerations up to 2.5 times larger than that of an earthquake, so this acceleration is still lower than normal and the isolation pads show some initial benefit.

Fixed Base Server Rack



(a)

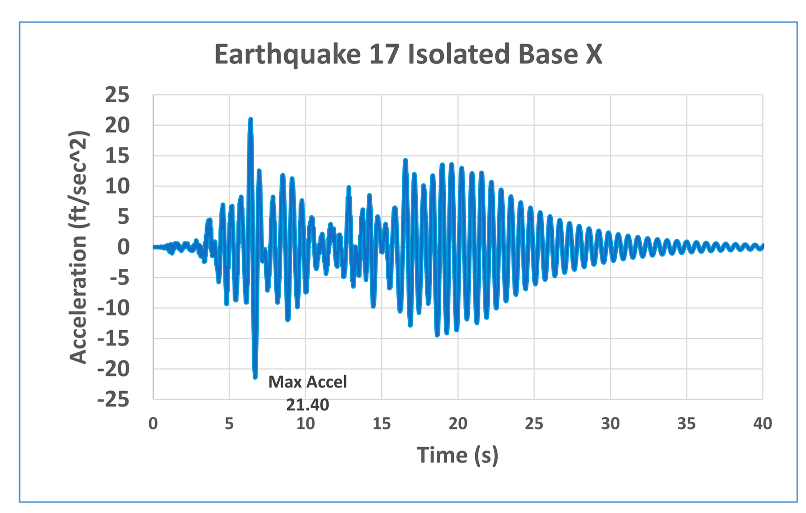


(b)

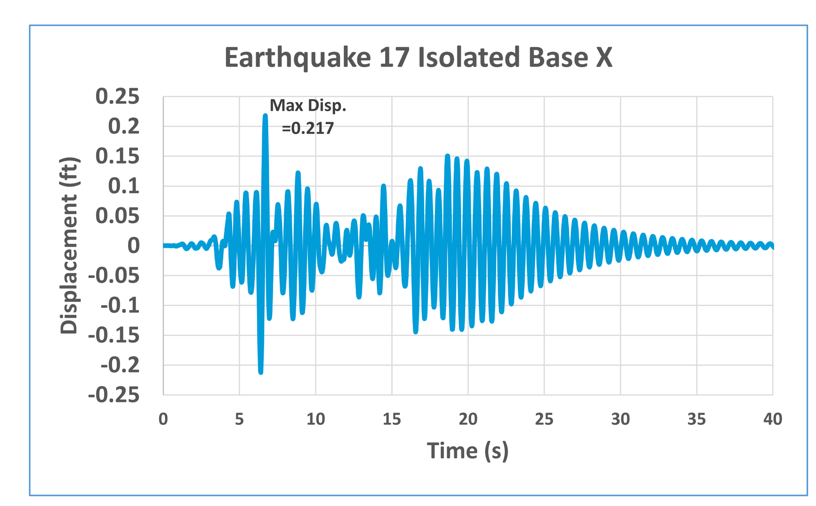
Fig. 6 – Fixed Base results: a) Server Rack accelerogram in x direction, b) Server rack displacement in x direction

The acceleration and displacement of the top of the Fixed Base server rack were obtained from SAP 2000 for 22 different earthquakes (**Fig. 6**). The results for earthquake #17 are shown here.

Isolated Base Server Rack



(a)

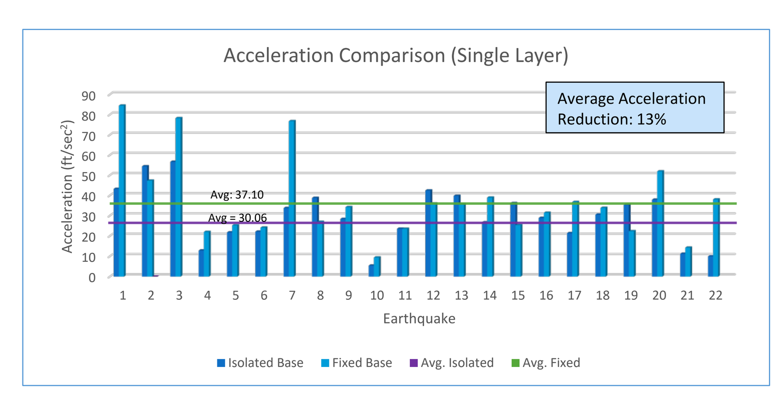


(b)

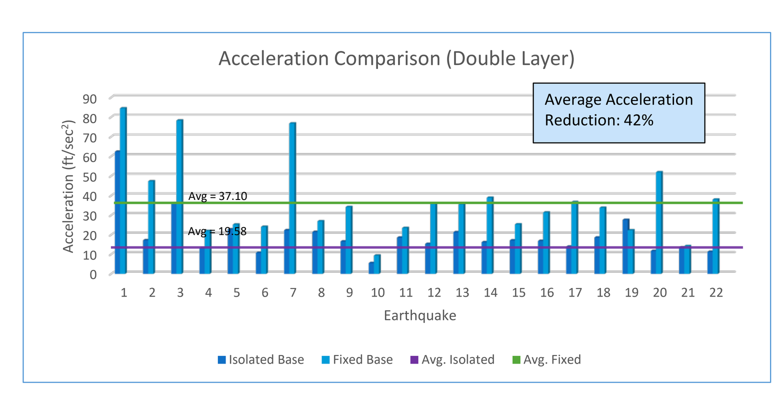
Fig. 7 – Isolated Base results: a) Server Rack accelerogram in x direction, b) Server rack displacement in x direction

The acceleration and displacement of the top of the Isolated Base server rack were obtained from SAP 2000 for 22 different earthquakes (**Fig. 7**). The results for earthquake #17 are shown here. It can be seen that the max acceleration of the Isolated Base is less than that of the Fixed Base but the displacement is not.

CONCLUSION



(a)



(b)

Fig. 8 – Acceleration Comparison: a. Single Isolation Pad Layer b. Double isolation pad layer

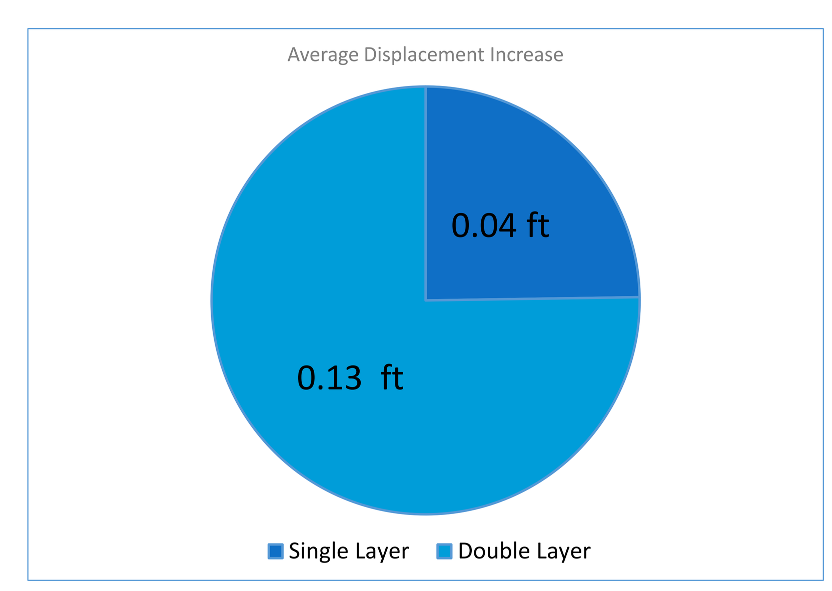


Fig. 9 – Average Displacement Comparison

Once the results from the Isolated Base model and the Fixed Base model were compared it can be seen that a **13% reduction** in acceleration occurred on average (**Fig. 8a**). Under this condition, the displacement of the server rack increased on average with the addition of the isolation pads, as expected. The average increase was **0.04ft**, which is relatively small and acceptable (**Fig. 9**). Additionally, this displacement occurs with rigid motion as apposed to the bending that takes place when the server rack is bolted down.

When an additional layer of isolation pads was added, essentially decreasing the stiffness in half, the performance increased. The decrease in acceleration was **42%** on average, much larger than with a single layer (**Fig. 8b**). The displacement increased to **0.13 ft**, which is acceptable under rigid motion (Fig. 9).

Based on this data the performance of the Meta Material seismic isolation pads was successful, they did decrease the accelerations generated during a seismic event. Additionally, the protection increased greatly when an additional layer of pads was introduced to the system. This demonstrates the scalability and effectiveness of the isolation pads under research.

References:

1. Bonessio, N., Lomiento, G., & Valdevit, L. (2017). A Cellular Periodic Material Design for Enhanced Seismic Protection of Low-Rise Buildings. In Proceedings of the 16th World Conference on Earthquake Engineering, Santiago, Chile.
2. Bonessio, N., Valdevit, L., & Lomiento, G. (2016). U.S. Patent No. WO2016201109A1. Washington, DC: U.S. Patent and Trademark Office.
3. Bonessio, N. (2017, July 10). SBIR Phase I: MetaMaterial for Seismic Energy Absorption. National Science Foundation, Award Number: 1721975.