It's 2017, 23rd of March, a normal day. Children at school, the shops are open, people are doing their jobs. Until it hit. In Queensland, cyclone Debbie ripped through the streets, collapsing buildings and homes whilst taking the lives of 14 people. But why did some buildings collapse and others didn't? It isn't luck, but actually the precautions built into buildings. These precautions, a damped pendulum among other methods, have been used in skyscrapers against strong wind and lateral swaying.

Although these techniques are successful, a variation of such a spring pendulum may be a strong candidate in efficiency due to the phenomena of internal resonance, which will be later explained. This investigation compared 2 devices: a traditional mass pendulum to the right, and a spring mass pendulum to the left. The aim of this investigation was to explore the physical characteristics and phenomena of each process to determine which was the most effective and reliable. The two devices were tested using a scale model building of the Eureka tower, to compare effectiveness and later discuss limitations and the reliability of each device.

This is just an example of the placement of a spring or a spring pendulum, or a regular pendulum, within a building. The pendulum works by absorbing the kinetic energy of the lateral movement of the building, transferring the energy to the kinetic energy within the pendulum. The energy goes back and forth between these modes and is distributed as such that the building decreases its swaying motion, similar to the pendulum. The spring pendulum distributes the kinetic energy of the building within its modes. Internal resonance, however, provides a third mode: spring oscillation, therefore with three modes the phenomenon suggests higher energy distribution and therefore less energy within the building and hence higher efficiency.

Originally a framework for simulation was considered, but Baker in 1973 suggested a scale model is more likely to identify relevant phenomena that would not otherwise be identified, although he presents the idea that a simulation would decrease error due to consistency on attributes of the building. This investigation focus was more towards the physical phenomena and the application of theory, therefore a scale model methodology was most appropriate in terms of material. Although Duncan in 1953 suggests that micro concrete is a viable material, Datin and Prevatt in 2013 provided evidence that wood for structural experiments with high applied horizontal loads, such as this investigation, is scalable where micro concretes are preferable to vertical load experiments. Hence the structure has been created from wood.

To create the lateral movement at resonant frequency a method of using an air blow was considered, though due to turbulence, which is the unpredictable flow of air at high velocity, consistency, and minimal error could not be insured for all trials. Considering the air blower was only to create a resonant frequency, Basal in 2006 suggests a mechanical solution can be a valid driving force, in addition to being more consistent. Hence a robot was created and connected to the base which produced lateral movement at the required frequency. The recordings of the motion were later analysed in tracker and analysis software to show the extent of swaying and transformation of energy.

Before I present my final data, it is important to know what a displacement time graph actually represents. Here time is on the y axis and displacement is on the x axis. Where the building sways to the right displacement is positive to the origin. As time passes the building oscillates around the zero. The centre point which is x is equal to zero meters decreasing in amplitude over time.

The graph presented here is the same, although time is shown on the x-axis and displacement is shown on the y. The overall building displacement summarizes the individual findings of each device control pendulum and spring pendulum come to a rest at 14.5 seconds, showing controlled friction within the building. Most importantly the amplitude of the peaks provides the effectiveness in reducing the building's displacement. The control in blue without precautionary devices perform the worst swaying the most.

Swinging the most. The traditional pendulum orange was less effective in comparison to this spring pendulum in grey that swayed less, although it's shown that the spring pendulum is more effective. This representation without more evidence doesn't justify this energy mode theory as an explanation for this improvement.

Here energy-time graphs show the distribution of energy within the buildings. The overall energy is shown to decrease in a negative exponential trend in blue, as energy is wasted in heat within the building. The overall energy trend was similar to the spring pendulum, and therefore showed the energy wasted to be exponential.

The spring pendulum graph shows three modes consistent with the earlier predictions, compared to the two modes presented in the traditional pendulum. The phenomena demonstrated in the numerical calculations by Wang li and Zhang in 2018 shows energy oscillates between three modes: building, spring, and pendulum, demonstrated within the results. Looking at the building's energy it's lower in the spring pendulum trials than the regular pendulum and is supported by the earlier displacement-time graphs.

To appeal to the reliability requirement in my research topic through literature and engineering journals, the following limitations for each device were identified. Limitations within the spring pendulum were the result of the properties of the springs. The mass attached can create long-term spring deformation, according to hooking in theory, and shows a reduction in effectiveness over time.

In addition, chaos theory presents the idea that the complexity of the spring to movement cannot be accurately- could not be predicted accurately if the swaying of the pendulum becomes too high it may be detrimental to the building, pushing its physical restrictions and may create internal damage. The pendulum however is a rod connected to a mass and is not subjected to the large limitation of deformation. Similarly, the pendulum does not appeal as heavily to chaos theory as the movement is restricted by the fixed path of the rod.

To improve this investigation could be achieved by constructing different replicas of the building, of different designs which could develop my investigation into a universal model / basis of the implementation of spring pendulums in buildings. This research could be investigated further through the use of simulations and gathering numerical values to analyse any discrepancies between the theoretical and experimental data points. This could help to more easily identify sources of error in the experiment and may possibly reveal any new physical phenomena not previously presented or found within this experiment.

Yep, sorry. The experiment successfully compared the two devices in terms of numerical effectiveness the pendulum was less effective than the spring pendulum as it had one less available mode for energy to be distributed across. Reliability was strong as a rod isn't subjected to the loud the same limitations as a spring. In terms of numerical effectiveness, the spring pendulum was more effective than the traditional pendulum, as it had one more available mode: spring oscillation, for energy to be distributed across.

Reliability was poor due to the unpredictable nature of motion as a result of chaos theory. In addition, hook in theory shows that a spring may deform in time due to a heavy mass. The next steps to further this investigation would be taken towards feasibility in terms of costs, when viewed in light of its effectiveness and long-term reliability further research with an appeal to the practicality of spring pendulums could be done to construct a literature review conducting interviews with experts from the construction industry, ultimately with the aim of enhancing and adapting existing structural precautionary technology to the changes and advancements of the modern age.

These next steps would appeal to the financial viability to help the device be considered in future implementation. Overall, this investigation expanded in the previous research conducted and hopes to bring light to the advantages of spring pendulums for further research towards future use. Thank you.

Thank you so much Zachary. Um, I don't have a physics brain at all but you did a wonderful job breaking that down, making it understandable. I also appreciated how relevant it was to the actual lives and experiences of people now. Looks like you did a lot of research and creation and thinking around this: what was the most difficult part of your research?

I think um yeah, I think I guess, so when I was doing the experiment due to covered um everyone was locked down and we had to do EI through zoom calls, and so accessing materials and um going to Bunnings to get materials, and I'm grabbing materials from my school, it was hard to do my experiment at home. It would have been a lot easier at school, so I feel like that was the most difficult part. Yeah it's an incredibly unique and unexpected challenge I'm sure. Thank you so much Zachary.

Thank you.

[Applause]

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