Project Brief

Project Title: A new design for residential roofs resistant to hurricane force winds

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Background:

Natural disasters cause millions of dollars of damage due to structural failures every year. Some common disasters that affect buildings are earthquakes, hurricanes, and tornadoes. One of the main natural disasters to look at are hurricanes. This project focuses mostly on them because they are extremely costly in terms of damages. Of the top ten costliest natural disasters, seven were from hurricanes (He, 2017). Some examples of hurricane damages are hurricane Hugo causing $8 billion dollars in property damage in 1989 and hurricane Andrew causing $30 billion dollars in damage in 1992 (Gibbs, 2001). Hurricanes develop over warm water and are often found originating near the tropics. The lowest category for a hurricane is wind speeds over 74 miles per hour. The closer one gets to the eye of the hurricane, the more intense the rain and the wind speeds are. Structural faults from hurricanes include buildings being lifted off the ground due to weak foundations, connections in steel frames breaking loose, and concrete frames that cannot defend against strong winds. When major structural faults happen in the framing of a building, partial collapse or total collapse can happen, which severely increases the cost to repair the building. Component failures are less severe but happen more often. They most often occur in the roofs, windows and doors, and the walls (Gibbs, 2001). Most of these component failures often have the theme of having weak common points. Some simple ways of improving building design against hurricanes include having a symmetrical shape, changing windows and doors, and proper drainage for flooding. Hurricanes can be very damaging to buildings because of large structural damage, such as faults in the frame, and also in the small damages from component failures, which occur more frequently.

Hurricanes can be split up into four regions: a boundary layer, the region above the boundary layer, an updraft region, and the eye (Snaiki, 2018). The boundary layer is the part right outside of the eye of the hurricane, where wind speeds are at their highest. It also starts from ground level and rotates around the eye. The eye of the hurricane is where all of the winds rotate around, and since it is in the center, it has little to no wind or rain. It is often calm and not the focus of hurricane preventative structures. The region above the boundary layer is also not often looked at in terms of engineering since structures do not protrude into it, and thus are not affected. Generally, the boundary layer is most often looked at, since it can cause the most amount of damage.

Buildings are made up of many different structural components. The foundation is at the bottom of the building, and support the weight of the entire structure. There are different types of foundations, with some being deeper than others to support larger buildings. Surrounding the building is the ground environment, which is also a factor in building stability. Looser soil will cause the building to be structurally weaker than if the ground was stone. Another component of a building is its layout. Hollow floorplans cause for weaker interior structures, as opposed to floorplans with walls and support beams. Above the building is the roof. This is often the most vulnerable to damage from hurricanes, with more than 90% of roof covers being damaged in wind speeds of 80 meters per second or greater (Pita, 2012). Roofs can also be either horizontal slabs or slanted.

Problem statement:

Hurricane force winds cause major damage to parts of buildings every year, specifically roofs, resulting in billions of dollars in damages.

Engineering goals:

This project will develop a new design for roofs of buildings that is optimized to counter the effects of hurricanes and this will be accomplished by creating models and also test said models using low powered fans or adult-supervised leafblowers to compare them to current designs.

Project Definition:

The aim of this project is to research the effects of hurricane force winds, roof designs, and improve upon current roofs; success would mean creating models of roofs and simulating low force winds on the models to create a sturdier roof design.

Experimental Design/Research Plan Goals:

Major Parts of the Project (rough outline) will continue to evolve over time and should be updated frequently. Make sure the goals are SMART oriented.

- Have a list of the most common structural components and how they work / how they interact with each other
    - Use journal articles, research articles, engineering/mechanics textbooks to understand physics
- Decide which structural component to focus on
- Research characteristics of a hurricane and what about a hurricane to combat against
- Determine areas of improvement
- Come up with possible designs that could be improvements
    - Ideas might come from other structures
    - Possibly do calculations
- Build models and test them in a wind tunnel
    - Compare them with existing designs and compare data
    - Data will be: how much of the model is broken
    - Will change the wind speed

Timeline: (with action steps identified- sub-deadlines will continue to evolve):

Rough timeline of major phases. As these phases get established, specific tasks under these phases will be defined further.

Now - End of October break: Research on existing components, failures, and natural disasters

- 9/22 - 10/6: Mechanics and physics of material engineering and architecture
- 10/6 - 10/13: Common structural failures
- 10/13 - 10/21: Materials commonly used in buildings

October break - 3rd week in November: Running simulations, doing math and physics, calculating optimal designs

- 10/21 - 11/4: Coming up with optimal designs and comparing them to current designs
- 11/4 - 11/18: Build the models using materials and designs I came up with
- 11/18 - December fair: Testing all designs, taking measurements

December fair - End of Stem I: Going back to the beginning and go through another engineering cycle

- See if there was an improvement in my models
  - If there was, what went well?
  - If there wasn't, what could I do differently?

Background Knowledge Goals:

Date	**Topic**	**Completed Date**
9/22/19	Research on the mechanics and physics of material engineering and architecture	10/6/19
10/6/19	Research on common structural failures	10/13/19
10/13/19	Research on materials commonly used in buildings	10/21/19

Don't want to use	Why?
Holographic window monitor	This was my first STEM idea. This is too difficult and not feasible.
How does architecture affect people	This is more of a social experiment and not related to STEM.

What to use to develop further?	Why?	Assumptions making with ideas?	How can these assumptions be challenged?

Roof designs to counter natural disasters	Roof in dangerous areas are prone to damage	The main cause of structural damage during natural disasters is the natural disaster itself and not other factors	The main cause of damage is through disasters
More efficient designs	Some buildings are too inefficient in designs and waste material and money	Lots of resources are being lost in the design of buildings	On a large scale, improving building material or design by even 1% would make a large difference

Budget:

Research: $0
Experts: $0
3-d printing: $0
Various building materials: ~$50
Testing contraptions: $0

Works cited:
Gibbs, T. (2001, January). Hurricanes and their Effects on Buildings and Structures in the Caribbean. Retrieved October 22, 2019, from https://www.oas.org/pgdm/document/BITC/papers/gibbs/gibbs_01.htm.

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