Hurricane Communities

Katie Masters
Hurricane Communities: 
An Analysis of Florida Housing

Request for Approval of Thesis Research 
Project Book Presented to:

Professor Bronne Dytoc

and to the 
Faculty of the Department of Architecture
College of Architecture and Construction Management

by

Katie Masters

In partial fulfillment of the requirements for the Degree

Bachelor of Architecture

Kennesaw State University
Marietta, Georgia

Spring 2018
Kennesaw State University
Department of Architecture
Collage of Architecture and Construction Management

Request for Approval of Project Book

Katie Masters
Hurricane Communities

Katie Masters _________________________________   Date____________

Approved By:
Primary Advisor: Bronne Dytoc _________________________________   Date____________
Thesis Coordinator: Liz Martin _________________________________   Date____________
Department Chair: Tony Rizzuto _________________________________   Date____________

The Author Would Like to Acknowledge
Bronne Dytoc
Josh Blount
The Authors Parents
CHAPTER 01

OVERVIEW

1.1 HYPOTHESIS
1.2 THE PROBLEM

CHAPTER 02

REASONING AND RESEARCH

2.1 RELEVANCE OF HYPOTHESIS: CASE STUDY OF HOUSE DAMAGES
2.2 HISTORICAL ANALYSIS OF THE FLORIDA BUILDING CODES
2.3 PRINCIPLES OF THE HOUSE AND HURRICANE'S EFFECTS ON THE HOUSE PRINCIPLES
2.3.1 FORCES
2.3.2 SHAPE
2.3.3 CONSERVATION
2.3.4 MATERIALS
2.3.5 JOINTS

CHAPTER 03

PRECEDENTS

3.1 CALAÉARTH
3.2 TSUNAMI HOUSE
3.3 DELTEC HOUSES
3.4 COBE HOUSE
3.5 MODERN SCHOOL
3.6 THE DOMINO HOUSE
3.7 THE UMBRELLA HOUSE
3.8 DELTA HOUSE
3.9 SEA SIDE COMMUNITY

CHAPTER 04

SITE AND PROGRAM ANALYSIS

4.1 SITE CONTEXT
4.1.1 GEOGRAPHICAL, NATURAL AND HISTORICAL PATTERNS
4.1.2 PHYSICAL AND SOCIO-SPATIAL PATTERNS
4.1.3 EXISTING SITE CONDITIONS

CHAPTER 05

ARCHITECTURAL DESIGN SOLUTION

5.1 DESIGN SOLUTION
5.2 OVERVIEW OF THE PROJECT
5.3 FINAL SITE DESIGN PROCESS
5.4 CONTEXTUAL ANALYSIS
5.5 HOUSING PATTERNS
5.6 RESIDENTIAL AREA
5.7 HOUSE DESIGN AND ANALYSIS
5.8 MODEL DOCUMENTATION

CHAPTER 06

REFLECTIONS AND CONCLUSIONS

6.1 REFLECTIONS AND CONCLUSIONS
6.2 BIBLIOGRAPHY
6.3 BIBLIOGRAPHY LIST OF FIGURES
Parts of the United States deal with natural disasters every year, one of the most devastating of these natural disasters and one that is very costly to recover from is the hurricane. These storms leave paths of destruction and heartache. The aftermath and repairs are long and tedious often lasting years or decades. These storms may foster migration to less hurricane prone areas.

We have recently experienced these disasters when hurricanes Irma and Marie struck the state of Florida in 2017. We know that the population of the areas hit by these storms is still working through the repair of homes, loss of utilities and challenges of rebuilding their lives. The strain of this recovery takes an enormous emotional toll.

What should we do, knowing that these hurricanes are certain to recur, to typical houses that were not constructed to survive these storms? Can we design better forms and use better construction that harmonizes with the forces of the hurricane rather than trying to resist them? In many coastal regions, not all the housing is destroyed and replaced following a disaster, so the homes now in these neighborhoods is a mixture of older non-storm and upgraded more hurricane resistant structures. While many upgrades were made to the building codes, particularly after Hurricane Andrew in 1992, even the newer houses are not fully hurricane resistant. There has not been a holistic design solution to develop neighborhoods capable of withstanding a storm. At best, the solutions have been individual house modifications that have led to lessen the debris generated when whole houses come apart in the driving wind. What is needed is a well designed coastal architecture that harmonizes with hurricanes through better form and structure.

This thesis aims to reexamine how we can as architects can design more effectively at the residential scale through investigation of site, lateral forces, form and structure. The intent is to minimize the physical and emotional damage that is left behind by hurricanes so that the next time an area is struck, we can be better prepared through more thoughtful design.
1.2 THE PROBLEM

Hurricanes are tropical cyclones, which are rapidly rotating storms characterized by a low-pressure center, a closed low-level atmospheric circulation, strong winds, and a spiral arrangement of thunderstorms that produce heavy rains. The hurricanes range from category one to category five, the most devastating. Category one storms have winds speeds between 74 and 95 miles per hour. Category five winds are in excess of 155 miles per hour. These storms cause damage due to the high winds followed by flooding. Storms category three and above can result in major structural damage, particularly from flying debris and roof damage exposing the interior of the house to flooding.

Examining data from the parts of the United States with the most frequent hurricanes, the state of Florida is a frequently affected area and the only state with a risk area that covers the entire state. It is a rare year that Florida is not hit by at least one major hurricane as can be seen in figure 1.8. Florida is a high risk area that extends into the ocean with no barrier protection, a flat topography and high working class population density near the coast that tends to live in single family homes. The flat topography results in a high flood risk associated with the storms as shown in figure 1.10.

Data for the state of Florida as seen in figures 1.8 shows that the major population centers of Miami and Dade County are historically in the path of many hurricanes (including a category five, Andrew), have a high population with many neighborhoods including homes built under the old building standards.

The figures (1.9, 1.10, 1.11, 1.12) are useful in this thesis because they show that Florida is the state most affected by the devastation hurricanes bring to the USA. Figure 1.9 shows the hurricane and tropical storm risk and frequency by county. Figure 1.10 shows the reoccurring flood risk in the US according to county. Figure 1.11 shows how much the hurricanes have cost each state on the south-east coast. Figure 1.12 shows which places in the USA are most at risk for natural disasters. Collectively the diagrams provide solid evidence that Florida is the most appropriate site to study for this thesis over any other state.
Readings
The readings that I looked for were based on five things: Housing damage, emotional damage, cost in repairs, what was missed and potential improvements. The readings looked at Hurricane Andrew, which caused the most damage to Miami-Dade county and to the rest of Florida.

I reviewed two articles and two books on hurricanes and what was learned and observed from each one. The articles were:


The two books that I read were:

2. Building After Katrina: Visions for the Gulf Coast.

2.1 RELEVANCE OF HYPOTHESIS: CASE STUDIES OF HOUSE DAMAGES

For the working class communities that are the focus of this thesis, the housing damage from a major hurricane can be massive. From a 1993 survey of the South Miami Heights, Florida neighborhood following Hurricane Andrew, "The community has been largely destroyed, with 70% of the homes reporting severe damage, and a median estimated repair cost of $40,000-$50,000 (median value home value in 1990 was $46,500)." (Ref 1)

The conclusions of the FEMA Building Performance Assessment Team (BPAT) following Category 5 Hurricane Andrew in 1992 effectively summarize the damage. "The breaching of the building envelope by failure of openings (e.g., doors and windows) due to debris impact was a significant factor in the damage to many buildings. This allowed an uncontrolled buildup of internal air pressure that resulted in further deterioration of the building’s integrity. Failure of manufactured homes and other metal (clad) buildings permitted significant debris. Numerous accessory structures such as light metal porch and poll enclosures, carports, and sheds, were destroyed by the wind and further added to the damage."

The loss of roof material and roof sheathing and the failure of windows and doors exposed interiors of buildings to further damage from the wind and rain. The result was significant damage to buildings interiors and contents that rendered many buildings unhabitable.

Field observations concluded that the loss of roof cladding was the most pervasive type of damage to buildings in southern Dade County. To varying degrees, all of the different roof types observed suffered damage due to the failure of the method of attachment and/or material, inadequate design, inadequate workmanship, and mis application of materials.

Much of the damage to residential structures also resulted from inadequate design, substandard workmanship, and misapplication of various building materials. Inadequate design for load transfer was found to be a major cause of the observed structural failure of buildings. In adequately designed buildings, the load transfer path is clearly defined. Proper connections between critical components allow for the safe transfer of loads that is required for structural stability. (Ref 4, p 2) Additionally: "The wood-frame gable ends of roof structures were found to be especially failure prone. Wood-frame gable ends are effectively a vertical continuation of windward/leeward wall systems and require bracing from within the roof structure for lateral force resistance. A lack of adequately defined load transfer path for the gable ends was evident." (Ref 5, p 17)

The BPAT for the Category 3 Hurricane Georges in Puerto Rico in 1998 described much of the same damage modes, noting: "A large number of residential buildings in Puerto Rico experienced structural damage from the high winds of Hurricane Georges. This can be attributed to a lack of continuous load transfer path from the roof structure to the foundation." (Ref 1, p 17)

References

1) Lasing Effects of Hurricane Andrew on a Working-Class Community: Nicole Dash; Betty Lee Moses; Jonathan Mandrich; and Lisa Cunningham; Natural Hazards Review: American Society of Civil Engineer (ASCE) February 2007
4) Building After Katrina: Visions for the Gulf Coast.

HOUSING DAMAGES
EMOTIONAL DAMAGES

For the working class neighborhood, the predominant feelings after Hurricane Andrew are abandonment and hopelessness. From a long-term study of the effects of Hurricane Andrew on a working-class community, residents of the South Miami Heights, Florida neighborhood following Hurricane Andrew report, “It was five weeks before the military discovered their situation, and longer than that before they received any local or state assistance. Even the usual nongovernmental agencies were absent.” (Ref 1, p 14) This is reflective of the more recent experiences of hurricane Katrina in New Orleans and hurricanes that hit in Puerto Rico.

“The overall findings are that hurricanes impact the financial resources, work, family and community life of the residents in many different ways. As before or after the hurricane, people divide their lives as before or after Andrew. “Nothing was the same after that. We mark time in partially destroyed houses… Getting anything accomplished in a largely destroyed community with many businesses and other institutions gone was time consuming and frustrating…” (Ref 1, p 15)

As could be expected, the strain took an emotional toll on individuals and families. In the 10 year follow-up survey, “90% reported major or moderate long-term effects on their emotional functioning.” (Ref 1, p 14) Many of the respondents had lived in damaged homes for an average of 25 months before repairs were completed. Even more significantly, one-quarter reported that their homes were still not repaired. In addition to this extreme delay, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services. Many felt they were in hopeless situations and things would never get back to normal.” (Ref 1, p 14)

The long-term (10 years later) follow-up survey conducted with the same respondents as the initial one-year survey tells an even more emotionally devastating story. “About two-thirds had lived in damaged homes for some time… Many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

In the 10 year follow-up survey, “90% reported major or moderate long-term effects on their emotional functioning.” (Ref 1, p 14) Many of the respondents had lived in damaged homes for an average of 25 months before repairs were completed. Even more significantly, one-quarter reported that their homes were still not repaired. In addition to this extreme delay, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

RESOURCES TO REPAIR

The long-term (10 years later) follow-up survey after Hurricane Andrew showed, the majority of those affected lived in damaged homes for over two years. Some homes were not fully repaired, even after 10 years and over half had problems relating to their homeowners insurance. Repairs were incomplete or poorly done, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation.” (Ref 1, p 15)

In many of the smaller companies were overwhelmed by the number of claims filed, particularly among minority residents who were less likely to have insurance than white owners. Analyzing the extent of the failure, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

While Florida building codes have been extensively upgraded, many areas are not insured adequately” (Ref 1, p 20) Following Hurricane Andrew, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

WHY WAS THIS THE CASE? Where were the resources to repair what was missed? Potential improvements:

POTENTIAL IMPROVEMENTS

The South and East Coasts of the United States will continue to experience hurricanes, with a high potential that category 4-5 storms will increase in frequency. Based on the inadequate insurance coverage noted by the IRAF for both hurricanes Georges and Andrew (Ref 3), the governments at all levels will need to increase their efforts to improve insurance standards and policies. Improvements could include:

- Improvements in construction quality and standards
- Improved inspection and qualification standards for building contractors
- Improved training and qualifications for building inspectors
- Improved insurance standards to mitigate under insurance and insurance
- Neighborhood based reinsurance planning services

WHAT WAS MISSED

Repairs were done under older and no building codes, either by contractors who were in some cases fraudulent or by the residents themselves. “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

Additional potential improvements:

- Improving insurance standards to mitigate under insurance and insurance
- Neighborhood based reinsurance planning services

RESOURCES TO REPAIR

The long-term (10 years later) follow-up survey after Hurricane Andrew showed, the majority of those affected lived in damaged homes for over two years. Some homes were not fully repaired, even after 10 years and over half had problems relating to their homeowners insurance. Repairs were incomplete or poorly done, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation.” (Ref 1, p 15)

In many of the smaller companies were overwhelmed by the number of claims filed, particularly among minority residents who were less likely to have insurance than white owners. Analyzing the extent of the failure, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

While Florida building codes have been extensively upgraded, many areas are not insured adequately” (Ref 1, p 20) Following Hurricane Andrew, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

WHAT WAS MISSED

Repairs were done under older and no building codes, either by contractors who were in some cases fraudulent or by the residents themselves. “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

Additional potential improvements:

- Improving insurance standards to mitigate under insurance and insurance
- Neighborhood based reinsurance planning services

RESOURCES TO REPAIR

The long-term (10 years later) follow-up survey after Hurricane Andrew showed, the majority of those affected lived in damaged homes for over two years. Some homes were not fully repaired, even after 10 years and over half had problems relating to their homeowners insurance. Repairs were incomplete or poorly done, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation.” (Ref 1, p 15)

In many of the smaller companies were overwhelmed by the number of claims filed, particularly among minority residents who were less likely to have insurance than white owners. Analyzing the extent of the failure, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)

While Florida building codes have been extensively upgraded, many areas are not insured adequately” (Ref 1, p 20) Following Hurricane Andrew, “...many small insurance companies were unable to handle the losses, resulting in homeowners receiving inadequate compensation. Further, this community appeared to be a magnet for fraudulent contractors and repair services... Many felt they were in a hopeless situation and things would never get back to normal.” (Ref 1, p 14)
Building codes in 1970’s became more popular. In 1974 Florida law required local adoption, amendment and enforcement of State selected model codes (State Minimum Building Code). The Problem was that codes operated locally, the South Florida Codes (Dade and Broward counties) and Standard Codes (everywhere else).

- Coastal and bight area systems were damaged by construction practices.
- Rapid development of coastal land increased risks to construction practices they were based on. However, they are developed empirically and were appropriate to the construction practices.
- New law requiring Licensing/Certification of Local Government Building Code Enforcement Officials and Building Official Training was passed.
- Building code system and non-indigenous construction of the 1970’s boom. But what happened was the code failed. The state of Florida responded to Andrew by a move to building code system and non-indigenous construction of the 1970’s boom. But what happened was the code failed. The state of Florida responded to Andrew by a move to engineered design using ASCE 7-1988 requirements, which made new building products and materials wind testing standards. Creating the First Wind Engineering Based Design requirements.

2.2 HISTORICAL ANALYSIS OF THE FLORIDA BUILDING CODES

1940’s-50’s

Hurricanes and coastal environmental concerns led to the hurricane protection issue called “Coastal Building Code”.

1960’s

In 1970 building codes were a local option and many didn’t make specific building codes. However we could start to see more counties adopting the building code since 1940’s it were almost non-existent.

1970’s-80’s

In 1960’s-70’s-80’s the state mandate for local adoption and enforcement of the State Minimum Building Code, the first Florida Building Code, the first State mandated code, the Florida Building Code pre-existing codes.

2000-2017

Lessons from 2001 Florida Building Code Improvements:

- Improved requirements for wood framing wall interfaces
- Allow unvented attics under certain conditions
- Improved requirements for roof tie attachment
- Improved roof drainage requirements to reduce wind speed
- Require improving roof deck nailing when reroofing
- Adopt wind engineering code and wind testing standards
- Eliminate partially enclosed design option
- Labeling of windows, garage doors and shutters for wind pressure are required
- Higher wind designed buildings in South Florida and most coastal areas
- Windborne debris protection of windows in all coastal areas
- Windborne debris protection of windows and attics
- Product approval system ensuring products comply with codes
- Improved window performance labeling requirements to improve performance
- Windborne debris protection of windows in all coastal areas
- Product approval system ensuring products comply with codes
- Improved window performance labeling requirements to improve performance
- Windborne debris protection of windows in all coastal areas
- Product approval system ensuring products comply with codes
- Improved window performance labeling requirements to improve performance
- Windborne debris protection of windows in all coastal areas
- Product approval system ensuring products comply with codes
- Improved window performance labeling requirements to improve performance
- Windborne debris protection of windows in all coastal areas
- Product approval system ensuring products comply with codes
Figure 2.1 above shows typical failure modes of a house as the severity of the hurricane increases from one to five. In category one, the roof and openings remain intact and flooding does not enter the home. Some damage is visible in category 2 and in category 3, the integrity of the roof and openings is lost, allowing water inside the structure. Rain soaks the interior from above and once the flood waters enter the structure, the damage proceeds upward floor by floor until the destruction is complete. Any technique to improve survivability must be focused on these failure modes. If the openings and roof remain intact, the structure has a reasonable chance of survival.

From the codes discussed above we can identify certain techniques that help houses be more hurricane resistant. There are five main factors that can be defined to help protect or improve already existing houses. The forces acting on the structure determine what techniques are most affective. The techniques include but are not limited to: conservation, shape, material and joints.

Forces are a strength or energy as an attribute of physical action or movement. The main forces that are seen in hurricanes as shown in Figure 2.2 are:

- Compression
- Tension
- Bending
- Shearing
- Torsion

The other figures 2.3-2.5 show how each force reacts with the structure in both elevation and plan. As shown above, the movement of wind against, across or through the structure is the primary agent for inducing forces against the structure. Bending, shearing, compressive...
2.3.2 SHAPE

Shapes are the external form or appearance characteristic of a house. The source material allowed me to examine the roof shape, the overall building shape which led to the diagrams above describing what is and what is not a good design for the shape of a residential house to withstand the hurricane winds. In general, minimizing the surface area that is normal to the wind flow, this minimizes the forces the wind can apply in the structure.

Examining Figure 2.6, at the top, the circle presents the smallest cross sectional wind flow regardless of the direction of the wind, making it the best design. The pentagon approximates the circle; but still presents substantial flat surfaces in five directions and the square presents large flat faces, making it the worst choice. The figures at the bottom in Figure 2.4 have closed corners that do not allow an outlet for wind. Wind that gets "trapped in the corner" allowing forces to build up causing damage to the house.

Figure 2.7: The wind pushes against the gable, forcing it inward, while wind flows freely over the hip roof.

Figure 2.8: The overhangs apply lift forces that take the roof off which allows water in the home causing issues.

Figure 2.9: Illustrates the important principle of continuous connection between roof and foundation. The top images line does not extend all the way up making for a poor design while the bottom image have the continual lines.

2.3.3 CONSERVATION

Conservation is defined as the action of preserving something. In the case of the house, the main conservations that are useful in Florida are:

- Lifting the house to move it above the flood (figure 2.13)
- Puncturing the foundation of the house to allow water to flow under the house. (figure 2.14)
- Making barricades to hold the water back from the house which could be done in a small way with a wall or on a bigger scale by using hills or mountains by redesigning the lay of the land. (figures 2.15 & 2.10)
- Lastly, a break away method could be used where the main part of the house is built with concrete and the rest is allowed to break away and be easily replaced (figure 2.11)

All of these conservation techniques limit the extent of flooding, even after the failure of the openings or roof. The final summation of the house means, but does not mean that the house is fully protected from the hurricane. Recovery of the structure would be easier than without the conservation if the structure could be left attached to its foundation by the use of conservation.
Materials are the matter from which a thing is or can be made. All materials have characteristic bending, compressive and tensile strengths.

In figure 2.16, each material makes up part of the houses in Florida. The concrete and metal on the far left are the most resistant to wind and water, followed by the brick. The lap siding exterior below the brick is the least resistant exterior covering and the wood and gypsum wall board on the bottom are generally the least resistant interior materials. Gypsum dry wall is generally destroyed in even minor flooding. This is why it is important to maintain the outside materials so it will protect the weaker interior materials.

By mixing certain stronger materials with the weaker materials, such as bracing the wood with metal strapping, the structural integrity from the lateral forces being applied to the house during a hurricane can be resisted or allowed to bend more freely. Florida has started to adopt this technique since 2000 and however they have failed to try mixing other materials together to see if any other combination could be useful to the effort of strengthening the house.

Joints are the point at which parts of an artificial structure are joined. The strength of these joints determines the amount of compressive, bending, torsion and shear forces a structure can withstand without joint failure.

As can be seen in figure 2.17, roof detachment would require joint failures at the roof attachment points that can be countered by metal strapping or plates reinforcing the joints. Corner and floor to wall joints also present opportunities for failure.

Figure 2.18 shows the variations in corner joints from simple butt joints to stronger notched joints. Butt joints tend to be weak because the pieces are only relying on nails and metal strapping to hold the two pieces in place.

Whereas the lap joint is more secure because the actual material holding each other together in the extra support such as the nails and strapping are put on. The idea of the lap joint as show latter in the book in the Pagoda precedents demonstrates how strong and useful the lap joint can be in keeping houses stable against strong lateral forces.

Figure 2.19 shows the use of diagonal bracing to counter the lateral racking forces due to wind.
3.8 PRECEDENTS ANALYSIS
3.1 Calearth Houses

The Calearth houses were developed by Nader Khalil. The houses have been erected in various different sites. The house’s structure is not meant to be a permanent structure, but the structure can be converted into one if desired. The materials used to build this house were locally found as well as inexpensive ones.

The form of the house is a rounded dome that employs the timeless forms of arches, domes and vaults to create single and double-curvature shell structures that are both strong and aesthetically pleasing. The form of the structure is aerodynamic because of its round shape which makes the house resistant against hurricane winds up to 180 mph winds.

The materials that are used are: sand bags, PVC pipes, clay/concrete, barbed wire and earth. The house’s structure has additions of barbed wire in the walls. The wire helps the compression of the structure which allows the house to be earthquake resistant. While these load-bearing or compression forms refer to the ancient mud-brick architecture of the Middle East, the use of barbed wire as a tensile element alludes to the portable tensile structures of nomadic cultures. The result is an extremely safe structure.

Sand bags are used in the walls as well to resist flood waters from penetrating the house. The earth is then placed over the wire and sand bags to provide insulation and fireproofing to the house.

From: http://www.earthbagbuilding.com/projects/sandbagshelters.htm
The rounded form of the CalEarth house provides few corners or flat surfaces for wind to apply force to the structure. The four exterior semi-circles provide protection to the central dome.

**Conservation**
The principle conservation feature of the CalEarth house is the soil berm around the bottom of the structure. This drains water away and anchors the structure more firmly to the ground.

**Forces**
The principle forces on the structure are the downward compression due to the weight of the structure, firmly fanged in place. Wind flows over and around the domed shape without a significant flat surface to apply force against. The only vulnerability to forces due to wind and water are the openings for the entrance way which expose a section of the inner dome wall.

**Material**
The sand or soil bags are the same basic material as used in the sandbags used to build temporary levees to combat flooding. Combined with the connecting barbed wire and PVC piping, the materials are simple and not subject to generating debris or collapsing due to the wind or flooding. This makes the structure very survivable.

**Joints**
The sand or soil bags are overlapped and anchored together with barbwire to create a joint system between the bags that will not slide. Separation is unlikely due to the shear weight of the bags. The bags are used to form main columns that are incline and extend from the top to the bottom of the structure, providing lateral stability.

**Site**
The site is used to bunker the house. This provides direction of water falling on the domes away from the house. In addition, the lower areas between houses provide a means of channelling water away from the community.

### 3.1 CalEarth House Analysis

<table>
<thead>
<tr>
<th>Sand Bags</th>
<th>Clay / Concrete</th>
<th>PVC Pipe / Barbed Wire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunkered</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Main columns are barb wired from bottom to top

| بالرغم من أن النمط المُروّج للمنزل CalEarth يوفر بعض الزوايا والповكلاط من الأسطح للهواء لم يٌمكنه تحمل القوة على المبنى. الأربعة نصف الدوائر الخارجية تقدم حماية للدôme المركز.

**الحفاظ**
الособة الأساسية للحماية في منزل CalEarth هو الفخمه الحالية بالقرب من قاعدة المبنى. هذا ينيرّ مياه النزول ويجعل المبنى أكثر ثباتًا على الأرض.

**التأثير**
التأثير الأساسي على المبنى هو القوة الشاذة الناتجة عن وزن المبنى، والذي يثبت في مكانه بشكل ثابت. يغمر الرياح المدمج من حولي الشكل الدوائي دون سطح كبير يتيح للهواء تحمل القوة. الوحيد الذي يمكن أن يهدد هذا هو الأضراس من خلال الأبواب التي تفتح على الطريقة التي يقبع فيها قسم من الدôme الداخلي.

**المادة**
الكربس أو القماش يُقدَّم أيضًا كمواد أساسية في الصندوقين المستخدمين لإنشاء جدران كندية لحماية النزول. المصنوع من مواد سهلة الاستخدام مثل الفخمه الجص و PVC، فإن المواد بسيطة وتشهد عدم إنتاج أشياء أو انهيار بسبب الرياح أو النزول. هذا يجعل المبنى قيد الرعاية إذاً.

**النقطة**
الموقع يستخدم للنور بالمنزل. هذا يوفر مسارًا للعوم التي تقع على الدومات بعيدًا عن المبنى. بالإضافة إلى ذلك، المناطق المنخفضة بين المنازل تقدم طريقة لنور السقوط مياه النزول بعيدًا عن المجتمع.

| بالرغم من أن النمط المُروّج للمنزل CalEarth يوفر بعض الزوايا والповكلاط من الأسطح للهواء لم يٌمكنه تحمل القوة على المبنى. الأربعة نصف الدوائر الخارجية تقدم حماية للدôme المركز.

**الحفاظ**
الособة الأساسية للحماية في منزل CalEarth هو الفخمه الحالية بالقرب من قاعدة المبنى. هذا ينيرّ مياه النزول ويجعل المبنى أكثر ثباتًا على الأرض.

**التأثير**
التأثير الأساسي على المبنى هو القوة الشاذة الناتجة عن وزن المبنى، والذي يثبت في مكانه بشكل ثابت. يغمر الرياح المدمج من حولي الشكل الدوائي دون سطح كبير يتيح للهواء تحمل القوة. الوحيد الذي يمكن أن يهدد هذا هو الأضراس من خلال الأبواب التي تفتح على الطريقة التي يقبع فيها قسم من الدôme الداخلي.

**المادة**
الكربس أو القماش يُقدَّم أيضًا كمواد أساسية في الصندوقين المستخدمين لإنشاء جدران كندية لحماية النزول. المصنوع من مواد سهلة الاستخدام مثل الفخمه الجص و PVC، فإن المواد بسيطة وتشهد عدم إنتاج أشياء أو انهيار بسبب الرياح أو النزول. هذا يجعل المبنى قيد الرعاية إذاً.

**النقطة**
الموقع يستخدم للنور بالمنزل. هذا يوفر مسارًا للعوم التي تقع على الدومات بعيدًا عن المبنى. بالإضافة إلى ذلك، المناطق المنخفضة بين المنازل تقدم طريقة لنور السقوط مياه النزول بعيدًا عن المجتمع.
The Tsunami house was built by Designs Northwest Architects, with the head designer Dan Nelson and Tom Rochon. The house is located in the United States. The house is laid out and uses materials that allow water to pass through the house.

The main level had to be located 5' above grade so it was able to withstand high velocity wave action. Above ground sand filters help with erosion control. The foundations had to be designed on pilings capable to withstand high velocity tsunamis. Concrete columns and steel frame are left exposed because they can withstand the water and lateral forces. Lower level walls made of glass and wood are designed to break away in a strong storm surge. Overhead doors on the lower level open to allow water flow through the building. The exterior siding is a mixture of composite and galvanized standing seam panels and aluminum window. The lower level was meant to be a flood room which is why it’s built to the standards as previously discussed.

The main level is located 9 ft. above grade. This level houses the main amenities of the house such as kitchen, living room, bedroom and bathroom. This design allows water to come up 9 ft. with minimal damage to the house but keeps the main components and belongings safe on the second level.
The form of Tsunami Houses is specifically designed to survive a wave. There is little or no consideration for the effects of wind in the shape of the house.

The principle conservation feature of the Tsunami house is elevation of the structure above grade. The addition of offshore breakwaters also are installed to mitigate the wave.

If the storm surge or wave passes beneath the house and the first level flood room functions as designed, the principle forces acting on it are winds blowing directly from the ocean. Tsunami houses contain a large flat area of glazed openings. In response to higher category hurricane force winds, roof failure is very probable.

The concrete pylons and steel frame will ensure the basic structure survives after the breakaway siding and other materials are washed away.

The alignment and continuity of the main columns added to the insertion of the steel frame should provide sufficient strength against flooding or wind for the structure.

The site is meant to be ocean front with only the elevation to protect the building. Site provides little to the survivability in a hurricane, but should provide some protection from flooding in a smaller tsunami.

**Form**

The form of Tsunami Houses is specifically designed to survive a wave. There is little or no consideration for the effects of wind in the shape of the house.

**Conservation**

The principle conservation feature of the Tsunami house is elevation of the structure above grade. The addition of offshore breakwaters also are installed to mitigate the wave.

**Forces**

If the storm surge or wave passes beneath the house and the first level flood room functions as designed, the principle forces acting on it are winds blowing directly from the ocean. Tsunami houses contain a large flat area of glazed openings. In response to higher category hurricane force winds, roof failure is very probable.

**Material**

The concrete pylons and steel frame will ensure the basic structure survives after the breakaway siding and other materials are washed away.

**Joints**

The alignment and continuity of the main columns added to the insertion of the steel frame should provide sufficient strength against flooding or wind for the structure.

**Site**

The site is meant to be ocean front with only the elevation to protect the building. Site provides little to the survivability in a hurricane, but should provide some protection from flooding in a smaller tsunami.
Deltec homes are located in various places but all of them have the same characteristics. The structure is round thus wind can’t build-up enough pressure on any side to cause a structural failure. Energy from the wind is dispersed instead of building up in a single area and trying to push through. Its optimum roof pitch is 6/12 for wind deflection and to reduced lift. Radial floor & roof trusses work like spokes of a wheel to hold the house in place.

The materials that are used to construct the house include: machine rated 2400 psi framing lumber that is used in trusses and walls are twice as strong as typical framing material. Five Ply 5/8” plywood sheathing is used instead of OSB on exterior walls. The roof and floor strengthen the home and prevents flying debris from penetrating the structure, in combination with its pinwheel design. Reinforced windows with impact glass prevent wind and water from entering the home causing water damage.

The type of connections used throughout the house are oversized truss hangers that keep roof system anchored to the walls. Walls also have multiple construction ties to the floor system for structural stability and to transfer shear forces. There are continuous metal strapping go from roof trusses to the foundation to help maintain structural stability.
3.2.3 DELTEC HOUSES ANALYSIS

**FORM**

The form of Deltec Houses is geared to surviving high winds. As discussed in section 3.2.3, the house is octagonal, approximating a circle presenting small areas normal to the wind flow. In addition, its hip roof allows wind to flow easily over the top. Reducing the size of the overhangs would help roof survivability.

**CONSERVATION**

The principle conservation features of the house are elevation of the structure allowing water to pass beneath and the use of underbrush to dampen wind forces.

**FORCES**

The overall shape channels wind around the structure minimizing the lateral forces. However, the octagonal shape as opposed to a round shape provides a normal face to the wind. The structure must be strong enough to withstand that force. Some lifting force is imparted due to the overhangs, but they are a small percent of the roof area.

The house uses higher-than-normal strength wood framing, plywood, impact glass and other premium materials throughout, limiting the possibility of debris induced damage. The wooden columns that support the house are round and limiting wind and water forces on their surfaces.

The house uses oversized metal connectors for framing, large columns that extend from the foundation to the roof, and extensive metal sheathing that also extends from roof to foundation.

**SITE**

The site is not specifically altered for the house.

- The underbrush helps absorb some of the lateral wind forces brought by the hurricanes.
- Wood round column
- Wood shingles
- Metal/Wood roof
- Metal/shear connections to hold house to base
- Main columns are in line and extend from foundation to base
The core house is a design concept developed by the Q4 group. The site that they used was Joplin, MO. The house was designed so that the main components would break away. The house was designed based off the idea of a safe room with a hardened exterior structure in a portion of the house. The house is built for natural disasters such as earthquakes, tornadoes and hurricanes.

The project features a 600 square foot indestructible concrete core that has spacious daylight rooms wrapped around it. The home’s core, which is sealed off with heavy-duty tornado doors, houses Murphy beds, a kitchen, bathroom and access to backup systems. The walls of the Safe House are constructed of filled and anchored carbon-neutral concrete masonry units. The outside of the house is built with various cheap materials. They designed it this way because they expected the outside of the house to be a protective barrier for the inside core. The outside is meant to be rebuilt while the main and expensive components of the house remain intact with in the core.

The core design allows for a very flexible design strategy allowing for many different arrangements and varieties of houses built to withstand high winds.
In a sense, the shape of Core houses is irrelevant. The intent is that the exterior blows or is washed away leaving only the indestructible core, functioning as lifeboat for the inhabitants.

Conservation is not a factor for these houses. The force of the storm is meant to tear away the exterior of the house, leaving essentially a square concrete box. Forces will concentrate on one face of the box due to wind; however, the overall strength of the unit should make these forces irrelevant. This design will become a wind borne debris generator for its neighbors, possibly resulting in zoning restrictions.

The house uses disposable exterior material. The concrete survival core is essentially impervious. The concrete core units are anchored to each other and in place. The remainder of the structure uses non-survivable joints by design.

The site is not specifically altered for this house.
The earthquake school was designed by Vin Varavarn Architects. It is located in Chiang Rai, Thailand and was built in 2015. The school sits on a sloped site and is held up by pillars. The building was designed to withstand the shaking of the earthquakes that are frequent in the region. Most of the selected building materials were lightweight to reduce horizontal momentum caused by the weight of the building during an earthquake. Most material was lightweight steel but there were bamboo and timber as well. Some materials were clad in a combination of fiber cement and bamboo. The roof was made of resin panels inserted into bamboo and metal roof frame members. The structure touches the ground on one end and is raised up by steel stilts on the other. The structure was designed in such a way to convey safety and reduce finishing costs. The diagrams show their design process and how they looked at the forces and loads that needed to be considered in the project based on the earthquakes in the surrounding area.
The Earthquake School’s shape was chosen for earthquake survival. It is not optimized for the flooding or wind of hurricanes. Its partial elevation on posts would provide some protection against flooding.

The location on an elevated slope is the only conservation feature of this structure.

The force of winds coming from the sides would be minimized to some degree by the sloped sides that would channel wind over and beneath the structure. Winds parallel to the long axis of the building would impart significant forces to the facing end, but it is narrow compared to the building as a whole and there is a significant gap under the building to channel the wind.

The low mass of the lightweight steel frame is ideal for earthquakes, but may work against the building in hurricanes. The resin panels and bamboo components of the roof covering may not survive well if the openings to the building are compromised.

Diagonal bracing appears to be well employed in the building structure. The main columns are linear and extend from the top to the foundation of the structure.

The site slope allows for space below the structure for wind flow. No other site accommodations were made.

**Form**

The Earthquake School’s shape was chosen for earthquake survival. It is not optimized for the flooding or wind of hurricanes. Its partial elevation on posts would provide some protection against flooding.

**Conservation**

The location on an elevated slope is the only conservation feature of this structure.

**Forces**

The force of winds coming from the sides would be minimized to some degree by the sloped sides that would channel wind over and beneath the structure. Winds parallel to the long axis of the building would impart significant forces to the facing end, but it is narrow compared to the building as a whole and there is a significant gap under the building to channel the wind.

**Material**

The low mass of the lightweight steel frame is ideal for earthquakes, but may work against the building in hurricanes. The resin panels and bamboo components of the roof covering may not survive well if the openings to the building are compromised.

**Joints**

Diagonal bracing appears to be well employed in the building structure. The main columns are linear and extend from the top to the foundation of the structure.

**Site**

The site slope allows for space below the structure for wind flow. No other site accommodations were made.

---

**Figure 3.20**
3.6 THE DOMINO STRUCTURE

The Domino structure was designed by Le Corbusier. It is a theoretical project and can be assembled anywhere. It was designed in 1914-15. The structure was based on the architectural order found in classical architecture. The structure was designed so that columns moved to the inside and there which would allow an open adaptable interior space.

The frame is meant to allow freedom within creating an open floor plan and eliminating load bearing walls and elaborate supporting beams for the ceiling. The concept was designed during the war and came about because buildings were being destroyed faster than they could be rebuilt. Thus, the domino house was built so that the exterior could be completely destroyed and the main frame would stay in place allowing for an easy transition to the next rebuild.
The Umbrella house was designed by Paul Rudolph in 1953. The house is a one story 3 bed, 3 bath house located in Sarasota, Florida.

The Umbrella House is unique due to its second roof. The intent was to have a second roof that could be replaced easily if flying debris damaged the roof during hurricanes. Also, during normal living conditions the house is well ventilated through large windows that allow breezes from the ocean to move through the house.

The house is built out of a steel frame with a wood corrugated roof, glass and concrete. The steel roof however was originally made of wood and provided a sun shade for the back yard. However a hurricane took the roof, thus the new one was put on. Thus the roof is an important detail to this house because it protects the main structure from flying debris and in the case the roof is blown away it is a relatively cheap renewable resource that can be easily replaced.
The Delta Shelter was designed by Olson Kundig. It was a 1,000 sqm house built in 2005. The house is located in Mazama, United States. The house is an easy maintenance with large panels that can be replaced. The doors are hand operated by a large wheel and pulley system in the inside of the house. The interior is made of plywood which keeps the cost of the house down. The columns and exterior panels are made of steel which supports the main structure and frame of the house.

The Delta House is a steel house that has operable panels that act like a shell in bad weather, however in good weather the protective shell can be slid back to enjoy the outside. Also, due to the lifted floor plan the house can withstand up to 10 feet of snow or 10 feet of water. This was a desirable precedent because it offered a solution to the storm and on everyday use comfortability design.
3.9 SEA SIDE COMMUNITY

Sea Side community is located in Walton county Florida. It was built in 1979 by Andres Dunany and Elizabeth Plater-Zyberk. The community is on the panhandle of Florida. It is an urban planning project that sits on the coast. The community is a mixed use and contained densities greater than conventional suburban development. The plan was able to have minimal zoning issues because there were no zoning ordinances at the time. The inhabitants were vacationers and people who lived there for months at a time. There are strict limitations on the external aesthetics of the house.
Post-Tsunami Sustainable Reconstruction Plan of Constitucion

is a project located in Constitucion, Chile. It was purposed and built in 2010. The design principle behind the site was to create low cost housing for local people that was able to be easily rebuilt and protected the houses from tsunamis caused by the local, reoccurring earthquakes.

The site was hit by a 8.8 earthquake that cause a massive tsunami that destroyed most of the houses in the area and almost 500 people died from debris and flood waters. Elements design team was given three months to come up with a design to improve the durability of the town for future tsunamis. They designed a forest in between the city and the sea that wouldn’t try to resist the energy of nature, but dissipate it by introducing friction. When the waves hit Constitución, they were 12 meters tall; a forested island to the north of the city dissipated their energy and, by the time they reached the city center, they were only 6 meters tall. Our idea was therefore to protect the city by redeveloping the riverfront with trees. The design for the houses was an idea that part of the houses would be built keeping cost down and the rest would be developed over time. They were also designed in groups so that one house could rely on the other if another storm was to hit.

This alternative was the most challenging politically and socially, because it required the city to expropriate private land. However, it was validated by the people and government. The forest would be able to damper flooding, slowing it down before it hit the buildings.

To pay the historical debt of public space (before the tsunami struck, there were only 2.2 sqm of public space per person, with riverfront land that would increase to 4.4), and to provide democratic access to the river (the plots around the river were privately owned at that time).
The two images above show how Florida is broken up into districts such as: Northeast, Central East, South East, Central West, Big Bend and Panhandle. The state is broken down into independent counties. This is important to note because before hurricane Andrew the counties had individual building codes, whereas after hurricane Andrew they had district building codes and now they have state wide building codes. This is also important to determine which parts of Florida have been most affected by hurricanes in the up coming data figures.

Figure 4.1 shows the topography of Florida with the light pink showing the lowest point and the purple and white at the top showing the higher points. The graph is broken up into 10 feet increments. This graph is useful in the design hypothesis because it shows where water is mostly to come on land first during a hurricane. It also shows where natural barriers like hills or mountains, which Florida contains very minimal of both, leave Florida very vulnerable for high hurricane waters which if the house is not raised or the roof is not well attached water damages could be the third worst part of the storm, where fling debris and wind strength are the first two big issues for housing during hurricanes.

What the hurricane data shows are the parts of the USA that have been hit the most. In the past 25 years Florida has been the most affected with the worst hit in 1992 when Andrew came through the South Florida. This is the reason South Florida was selected as a study site for improved, hurricane resistant housing. Andrew through the thesis is studied and examined because of the high winds and devastation it brought to the houses of south Florida.

The figure 4.3 show all the hurricanes that have hit Florida and the ones that have had the most devastation.
Figure 4.4 shows the number of times each county in Florida has been hit by hurricanes. This is important to determine which county would be best for conducting a study on the related hypothesis topic. The red represents places that have been hit the worst and as seen in the color scale on the picture moving towards blue represents places that have not been hit at all. Figure 4.5 shows the risk factor of being hit by a hurricane in a year glance for the counties of Florida. The red is a very high risk factor and as we move to green that is a very low risk factor for counties hit by hurricanes.

Figure 4.6 shows the parts of Florida that has high, blue, to low, pink, wind-borne debris. The west part to be for wind-borne debris in Florida’s south Florida. Figure 4.7 shows extreme wind threat and potential places that are impacted by high winds. The purple represents extreme winds and the gray is the lowest or no wind threat.

Figure 4.8 shows potential storm surge threats to the lower Florida regions. The threat for storm surges tends to stay towards the base of the Florida peninsula and dies down as it gets closer to the center of the state. Figure 4.9 shows expected rainfall for hurricane Irma as it goes over Florida. As we can see by the image the southeast coast of Florida is getting the most rain fall from Irma.

Figure 4.10 shows the destruction path of hurricane Irma, which just happened last year, 2017. This data is important to the design hypothesis because it gives the study a more up-to-date analysis on which counties in Florida were impacted by hurricanes last year and what we can expect for next year.

Figure 4.11 shows the evacuation plan for Dade County during a hurricane. The red zone is the people that are evacuated first and goes up to the purple people were they are the last people to evacuate if the hurricane gets that bad. The blue line is the main evacuation route whereas the black smaller lines are ways to get to the main route if people are located more inland. What this graph provides for the design hypothesis is that I need to look towards the lower part of Miami for a site to examine.

Figure 4.12 is an article that shows where the eye of Hurricane Andrew hit when it passed through Florida. In figure 4.13 we can start to see the more recent hurricane that hit Florida, and with minimal reports as of now I was able to gather what the wind and air pressure speed was, giving a more updated information on the recent hurricanes. All of the information from the images put together allows me to hone in on a specific county where the hurricanes hit the worst. The data collected indicates that Cutler Bay has been effected most by hurricanes.
4.1.2 PHYSICAL AND SOCIO-SPATIAL PATTERNS

The Florida in figure 4.15 shows housing density per square km. The dark blue areas are places with high housing density whereas the light blue is where there are no houses. From this diagram I was able to determine which counties would be best for a study looking at residential houses. This graph helps with the design hypothesis because it points out which counties would be better suited for the design study. The design study focuses on high populated middle class residential housing that is in harm's way of hurricanes.

Figure 4.15

Figure 4.16 very similarly to figure 4.17 looks at housing and assisted and public housing. However what this graph offers that the other one does not is the median monthly owner housing cost in neighborhoods. The colors go from green to red with green representing lower monthly costs or lower income neighborhoods and red representing the higher monthly cost or higher income neighborhoods. Figure 4.16 is important to the design hypothesis because it focuses on the range of people and their income which helps show places where there are poor and rich and the in-between. Since the design hypothesis focuses on the in-between, I will be focusing more on the range of yellow and orange.
4.1.3 EXISTING SITE CONDITIONS

Now that I had a site, I looked at specific statistics of the area that would be important to the upcoming re-design of houses. I looked at cost, housing units, owner ship, number of rooms/baths, floor plan layout, year built of houses and housing shape. Each category is represented above by a blue icon and the breakdown of each are represented in a blue box. What this data adds to the design hypothesis is the program in which the design hypothesis will be applied.

HOUSING DENSITY PER SQ. MILE: 998.83
AVERAGE NUMBER OF ROOMS: 3.3
AVERAGE HOME VALUE: 203,300
AVERAGE MONTHLY RENT: 1,112
MOST HOUSES BUILT WERE IN: 1976

The type of housing found in Florida refers to the number of units, how large each unit is and overall density of the houses. It also shows the average appearance and construction of the houses. Data was identified that houses in Florida are typically of wood frame construction with a stucco outer shell and a tile roof. It was determined that most of the housing units are single detached homes and the rest consist of mostly apartments and town homes. This is important because it, along with the program, shows the need for newly designed detached housing units in the state of Florida.

Year built and home value are important because they tell us that the houses built in Florida are mostly from 1980 and earlier which means they were built to the old building code standards which were significantly inadequate from a hurricane survivability perspective. They could fail in any upcoming hurricane season. A time or a systematic upgrade plan for middle class working neighborhoods, so that people can transition into a more reliable suitable house that is better built to survive hurricanes if theirs is lost.

Program as shown above is important to the design hypothesis because it tells us what most houses are like in the area, what most people are expecting to see and what most people need to accommodate their living/family needs. What program shows is that the majority of houses will need to be re-designed and most shapes are square or rectangular which from our previous studies we know that is not the best design for a hurricane proof house. What this data also shows are the importance of the houses remaining standing after a hurricane because most of the houses are occupied and half of them are still owned by the same family.
4.2.1 SITE RELATIONSHIP AND USAGE PATTERNS

Figure 4.18 represents the selected area of study based on the data presented above. I chose three sites around the area to study and analyze. The site location that was selected is in Miami Dade County Florida. It is called Cutler Bay. The three sites selected were chosen because each represents a repeating grid for neighborhoods in Florida. Each site has different natural and layout features that would affect houses during a hurricane.
For site 1, as seen here and on p76, wind is flowing smoothly around the main outside of the neighborhood and through the center. But we start to see wind being trapped in the smaller more compact pockets. However, the wind outside is stronger flowing around straight through the center of the neighborhood before it's been dissipated by the surrounding houses.

For site 2, as seen here and on p76, the wind is stronger on the top right corner of the neighborhood, where there is a jut out. This happens because the wind has been allowed to build up and then peak at this point. But unlike the first site, we see wind that moves through the center has been slowed and is not as strong as well as broken up.

For Site 3, as seen here and on p76, the stronger wind forces are all on the outside and the wind is broken up as it gets closer to the center of the neighborhood, similarly to site 2.
The images that are represented on page 76 show figure ground. Which is the relating to or denoting the perception of images by the distinction of objects from a background from which they appear to stand out, especially in contexts where this distinction is ambiguous. What these images show is the relationship between houses, site and streets. Relative to shape:

- Rectangle Housing
- Square Housing
- One Jut-Out
- Two-More Jut-One

The images that are represented on page 77 show different shapes of the houses, whether they are rectangular or square shape. What this shows is if the houses in the neighborhood are more adaptive to hurricanes or not and if you refer back to pages 26-31 to the principles, we can see that the shape is important because the wind impacts square and pocket shapes worse than rectangular shapes. What these diagrams allow us to see is how well the neighborhood is designed to withstand a hurricane.

Wind builds up speed as it wraps around corners. The diagrams above show wind of a category 5 hurricane, 157 mph, and how it builds up and decreases speed as it moves throughout the different shapes of the buildings.

4.2.2 FIGURE GROUND RELATIONSHIP AND USAGE PATTERNS: HOUSING SHAPE
The images that are represented on pages 78-79 are what happening if we look at the houses in clusters vs. individually. What this study does is look at the neighborhood from a different perspective. The cluster introduces the idea of a large canopy covering several houses for wind protection. The concept of the study is using each individual house as an extension of the next.

### CLUSTERING

<table>
<thead>
<tr>
<th>SITE 2</th>
<th>SITE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORGANIC</td>
<td>ORGANIC</td>
</tr>
<tr>
<td>GOOD</td>
<td>GOOD</td>
</tr>
<tr>
<td>LINER</td>
<td>LINER</td>
</tr>
<tr>
<td>MODERATE</td>
<td>MODERATE</td>
</tr>
<tr>
<td>MIXED</td>
<td>MIXED</td>
</tr>
<tr>
<td>BAD</td>
<td>BAD</td>
</tr>
</tbody>
</table>

### WIND (FT/Sec)

| 150-250 | 150-250 |
| GOOD | GOOD |
| 250-450 | 250-450 |
| MODERATE | MODERATE |
| 450-OVER | 450-OVER |
| BAD | BAD |

#### 4.2.2 FIGURE GROUND RELATIONSHIP AND USAGE PATTERNS: HOUSING CLUSTERS

- Housing Cluster

- Figure Ground relationship and usage patterns: Housing clusters
The images that are represented on pages 80-81 show where water is and the density of trees surrounding houses in the neighborhood. The reason these diagrams are important is because they show what type of protection the neighborhood has due to vegetation. The trees help soften the forces of the hurricane winds. However, what we have to be careful of is with lots of trees around, the ones that are knocked over in a storm pose a potential threat to the houses from immediate impact and flying debris.
ANALYSIS ON THE NEIGHBORHOOD

I looked at neighborhoods around my site to determine how the plan, nature and shape of the houses reacted and allowed wind to flow through different layouts of neighborhoods around the site. Site one is above my site and is a mixture between a grid layout and an organic layout. Site two is a totally organic plan creating different sized clusters. Site three was excluded because it was extraneous information but still held representation value. Both sites had moderate vegetation, houses with one protrusion or less and allowed the wind to flow more around the larger site than through it, which builds up the wind on the outside of the site.

EXPECTED DEPTH OF FLOODING

4.2.3 SITE PLAN: PHYSICAL CHARACTER ANALYSIS: FLOOD ANALYSES
4.2.4 CONTEXTUAL ANALYSIS

BUILDING TYPE

The figure to the left highlights public and private spaces. The figure also shows what surrounds the site and what is near it. The hospital, church, and school are good places to start a community. However, the site is lacking a necessity store such as a grocery store or convenience store.

BUILDING HEIGHTS & COST

The figure to the left highlights how tall each building is, which influences the heights of the new building. The design intent calls for buildings that are no more than 3 stories tall. The diagram also highlights the price range the homes should stay within, which is between $200,000 and $300,000.

STREETS & VEGETATION

The figure to the left highlights major roads that influence the entry into the site and the connections to other neighborhoods. The lighter portions of the site represent tree density and how protected the site is by natural influence. From this diagram, there will need to be more natural elements incorporated in the site for optimal protection of the buildings.
4.2.5 HOUSING PATTERNS


Vegetation Study

The two house that are found within the sites studied in chapter 4.1.5 are used as a study of how vegetation and house relate. Since the vegetation is lacking around most houses there is a need for more vegetation. The reason vegetation is important is because it creates a second/third skin of protection for the house as well as help with heat for ventilation around the house.

In house one the longer house builds up more wind spirals behind it. However when turned 90 degrees there is a better reaction. But the corners still have the highest wind speed. The more square house creates smaller wind spirals behind it. But in the other diagrams the wind is highest at the corners.

Figure 4.20

Figure 4.21
### 4.2.6 Housing Patterns

#### Site 2 Clustering

<table>
<thead>
<tr>
<th>Rectangle</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 3 Clustering

<table>
<thead>
<tr>
<th>Square</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 2 Materials

<table>
<thead>
<tr>
<th>Shingle Roof</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 3 Materials

<table>
<thead>
<tr>
<th>Metal Roof</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 2 Position

<table>
<thead>
<tr>
<th>Lifted 15' or more</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 3 Position

<table>
<thead>
<tr>
<th>Lifted 6' or more</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 2 Wind

<table>
<thead>
<tr>
<th>150-250</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 3 Wind

<table>
<thead>
<tr>
<th>250-450</th>
<th>Good</th>
<th>Moderate</th>
<th>Bad</th>
</tr>
</thead>
</table>

#### Site 2 Public

<table>
<thead>
<tr>
<th>Site 2</th>
<th>Site 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>Public</td>
</tr>
<tr>
<td>Private</td>
<td>Private</td>
</tr>
</tbody>
</table>
The design intent for the site is to create a space where the community can go for refuge during a hurricane. However, when there is no potential threat, the space can be used to have and entertain the community. Since the site is triangular and the hypotenuse is on the main road, I want to maintain the edge between the inside of the site and the main busy road. I will do this by placing the shops on the long edge and placing the houses more towards the backside of the site will not favor the pedestrians, but will maintain the pedestrian walk. The community space provides an area that people can feel comfortable in and interact with one another through activities. This currently does not exist on the site. The space should be geared towards the pedestrian and not the vehicle in case of a hurricane. During the storm, it can provide shelter; after the storm, a rallying and recovery coordination point. The lack of resources within the vicinity is important because during a hurricane it is difficult or impossible to drive to acquire food or other necessities. Thus, grocery stores, hardware stores and pharmacies should be added to the existing site.
Pros
- The line is kept between the street and the site which protects the pedestrian from the main street. There is an organic flow of the neighborhood, allowing people to meander. Lastly, the water feature in the center allows an open green space that acts as a community center creating a visual guide through the site and keeps movement flowing. It also acts as a floodplain during a hurricane.

Cons
- The issue with this layout is that it is very structured and straight lined which makes the site monotonous to walk through. A parking lot takes up a lot of the green space. The grid creates lots of unused spaces in the site because it cannot connect the rest of the existing streets and site very well.

The design option above addresses the design intent by adding multiple levels to the site, added vegetation and creating a transition from shops to residential spaces. The line down the center separates program.
OFFSET

The design option above addresses the design intent by adding multiple levels to the site, added vegetation and creating a transition from shops to residential spaces. It has a center path that radiates out separating the program up into sections.

Pros

- There is a central area for the community to gather for events and in refuge after a storm.
- The program has a better transition from one area to the next.
- There is a better integration between an organic flow of shopping and the gridded patterns of the existing site.

Cons

- The shopping area is filled with rows and rows of straight lines that become monotonous to walk through.
- The line that runs through the site tries to connect the surrounding neighborhoods with a walking path, however, it fails to do so and is more of a separation between programs.

RADIATING

The design option above addresses the design intent by adding multiple levels to the site, added vegetation and creating a transition from shops to residential spaces. It has a center path that radiates out separating the program up into sections.

Pros

- There is a central area for the community to gather for events and in refuge after a storm. The program has a better transition from one area to the next.
- There is a better integration between an organic flow of shopping and the gridded patterns of the existing site.

Cons

- There are similar cons with that of the first concept. There is a harsh separation between the residential and the shopping areas. It still contains a monotonous shopping area. The large water feature takes up space that could be used for other programs.
The site has inadequate vegetation. Little vegetation is bad because it leaves the house exposed to wind and debris. The need for more natural vegetation is desirable.

### PROTECTION / SUN SHADES
Places within the community should be allowed to be customizable for the inhabitants. This allows for the community to start to build more organic and personalized spaces. The structural frame will remain the same but the exterior will be flexible.

### MATERIALS
The materials used in the original houses are installed poorly and are not the best choice. A slab foundation is also not the best design choice for Florida.

---

### 4.3.3 BUILDING SCALE

**CONCEPT STATEMENT**

The design intent for the house is similar to the Domino house and the Tsunami house. The structure is based on the Domino concrete open column plan. This allows the house to be almost fully customizable. However, there are certain criteria that the house must meet to be buildable. One of these criteria is the design intent of the bottom floor to be used as a flood room based on the Tsunami house. This feature will be used in all houses to keep high waters away from the important electrical components.

The built community should be allowed to be customizable for the inhabitants. This allows for the community to start to build more organic and personalized spaces. The structural frame will remain the same but the exterior will be flexible.

---

**BUILDING PROGRAM**

- **Not Enough Vegetation**
- **PROTECTION / SUN SHADES**
- **MATERIALS**
4.3.4 Explorations that Help Inform House Design

The roof is best as a hip roof. There are three basic materials a roof can be made. The materials are laid out so that the best option of roof material is on the top and the worst is at the bottom. The order was determined by its ability to be installed with ease, how well it deals with uplift and the ease of access and making it.

The layout for a house plan in the hurricane consist of three basic shapes rectangles, circles and types of hexagon, pentagons, octagonal, etc. shapes. There are three basic materials a roof can be made. The materials are laid out so that the best option of roof materials is on the top and the worst is at the bottom. The order was determined by how the material dealt with uplift, how water reactive it was, how easy it was to install and how cheap it was to reinstall if damaged.

The structure of the house was a major component but the rules found in chapter 1 showed that if a structure can extend from top to bottom with no interruptions it will be the most stable. There are three basic materials a roof can be made. The materials are laid out so that the best option of roof materials is on the top and the worst is at the bottom. The order was determined by how structurally sound the material was, how well it reacted with water and how costly it was to use.

- Asphalt shingles
- Metal Roof
- Tile Roofing

- Brick
- Stucco
- Wood Plank Siding

- Concrete
- Metal
- Wood
4.3.5 EXPLORATION FOR HOUSE DESIGN OPTIONS

- Original Issues
- Vegetation to Increase
- Structure
- Vegetation
- Southern Red Cedar
- Bamboo
- Slab Structure
- Oak Trees
- Cabbage Palm
- Roof Material and Overhang

Different Ways of Thinking About the Roof Extensions
- Option 1: Slanted Roof
- Details of Components
- Roll Up Door
- Details of Components
- Option 2: Extend Existing Roof
- Details of Components
- Sliding Door
- Details of Components
- Option 3: Gable Roof Extended
- Details of Components
- Folding Panels
- Details of Components
- Option 4: Creates Points like a Plane to Slice Through the Wind
- Details of Components
- Rolling Panels
- Details of Components

Open and Closing Methods
- Folding Panels
- Details of Components
- Sliding Door
- Details of Components
- Roll Up Door
- Details of Components

Exploration for House Design Options
- Open and Closing Methods
- Folding Panels
- Details of Components
- Sliding Door
- Details of Components
- Roll Up Door
- Details of Components

Figure 4.22
Figure 4.23
Figure 4.24

Details of Components
Details of Components
Details of Components
Details of Components
Details of Components
Details of Components
5.1 DESIGN SOLUTION
Designing a hurricane community in Cutler Bay, Florida that improves survival of house structures and minimizes emotional damage.

Hurricanes disrupt many people's lives and recovering is a long and tedious process. Materials are poorly installed and wind picks up the roof allowing water damage in the house. There is no community space. Vegetation is lacking. There are no necessary resources in the vicinity.

There is a better way to protect and design communities for hurricanes, through simple layout and design additions.

5.2 OVERVIEW OF THE PROJECT

- Change roof conditions, raise lower levels and add flood rooms. Full roof structure supports into the structure.
- Add vegetation to the site. Create a more organic and open flow for wind between and around buildings.
- There is a better way to protect and design communities for hurricanes, through simple layout and design additions.

WHY IS THIS TOPIC IMPORTANT

Hurricanes disrupt many people’s lives and recovering is a long and tedious process.

ISSUES OF CURRENT CONDITION

Materials are poorly installed and wind picks up the roof allowing water damage in the house. There is no community space. Vegetation is lacking. There are no necessary resources in the vicinity.

SOLUTION PRECEDENTS

- Change roof conditions, raise lower levels and add flood rooms. Full roof structure supports into the structure.
- Add vegetation to the site. Create a more organic and open flow for wind between and around buildings.

DESIGN

CONCLUSION
The design of the site features an organic shopping and refuge area to face the hurricanes at the front. The back of the site where the boundaries meet the existing neighborhood blend the rest of the site with the preexisting neighborhood. Since the area lacked a place for people to congregate, go during a storm, and buy groceries and essential items during and emergency needs, the new organic shopping and refuge area would provide all the missing needs, especially during a storm, along with new houses that could withstand hurricane winds and water.

The reason I kept with the existing grid is because it helps in transitioning the newer more adaptive houses into the existing neighborhoods and help encourage rebuilds or remodels to the older houses around the area.

5.3 Final Site Design Process
5.4 COMMUNITY CENTER

PLAN

SECTION

PERSPECTIVE
5.6 RESIDENTIAL AREA

PLAN

SECTION

PERSPECTIVE

SUGGESTED CAR
5.8 MODEL DOCUMENTATION
6.1 REFLECTIONS AND CONCLUSION

THE GOOD: POSITIVE REMARKS AND SUCCESSES

The thesis was successful in its design to protect the house and had a good start in understanding what it means to be resilient and harmonious for two colliding concerns, the existing grid and organic flow. The thought of a hurricane is that it brings damaging high winds and water that make aftermath costly and stressful. The concept behind the thesis was to find a way to create a condition for envelop and buildings to deal with hurricanes as a fact of life and a part of this community just as much as a regular day or any other weather condition. The thesis was successful in creating a condition that is sustainable and built for the long term.

The thought of a hurricane is that it brings damaging high winds and water that make aftermath costly and stressful. The concept behind the thesis was to find a way to create a condition for envelop and buildings to deal with hurricanes as a fact of life and a part of this community just as much as a regular day or any other weather condition. The thesis was successful in creating a condition that is sustainable and built for the long term.

The design to create flood rooms and plains throughout the site to deal with the extreme flooding during the storm and house cars or parks was a good way to use a space for more than one condition and was very successful. Lastly creating multiple levels and extending the roof was a simple move that made a huge impact on the pre and post-storm environment because it gave the structure more support when needed and provided a place to put sun shades to help against Florida’s high temperatures when there is no threat.

THE BAD: FEEDBACK AND CRITIQUES

I consider this thesis project to have been somewhat successful. Elements that could have been more thought out and improved included affordability, ground conditions, a more detailed designed shopping area and community center. The biggest challenge when designing for a storm beforehand is that the structures either needs to be added to or the materials used need to be of a higher quality and this can be expensive, making it undesirable for mid-class families to invest in such items as a house. Thus, it was difficult to create a structure that was affordable and protected. The transition to the main part of the house being on the second level and the bottom of the house left open or meant for a garage or flood room made the ground condition difficult to figure out transitioning from house to sheet level because many people won’t naturally go on the ground level except for walking and going to their cars. This left the option open to the public on how to address right under their house by creating rooms to inhabit on the ground floor that could be flooded and replaced easily. The created options for people to dwell in could expand into the design of the house, community center and shops or could be expanded into the design of the house. The design of the house, community center and shops were all intended to read the same language. With the colliding grids of the site and the desire for the shops to be more organic than the grid pattern of the houses the need to mix the two was the design decision, however it would have been better if the organic started at the front of the site and expanded/grew to the surrounding site. This was difficult though because of the number of people who would not naturally be on the ground level except for walking and going to their cars. Thus, I left the option open to the public on how to address right under their house by creating rooms to inhabit on the ground floor that could be flooded and replaced easily. The created options for people to dwell in could expand into the design of the house, community center and shops or could be expanded into the design of the house. The design of the house, community center and shops were all intended to read the same language. With the colliding grids of the site and the desire for the shops to be more organic than the grid pattern of the houses the need to mix the two was the design decision, however it would have been better if the organic started at the front of the site and expanded/grew to the surrounding site. This was difficult though because of the number of displaced people. Also, it would have been better if there was more detail in the design of the shops and community center to adapt like the house did to hurricane winds and water, however working on two scales urban and small building scale was already a large scope of research to address. Lastly more testing of the community and house with a wind tunnel would have beneficial to the thesis to better inform if the project was a full success or not.

THE CONCLUSION: WHAT WAS LEARNED

Throughout the thesis there were many things tested, learned and discovered. Trying to create an urban space that was on a triangular site with colliding desires, between the grid and the organic flow, was difficult but there were benefits to both and benefits to mixing the two. I learned that working with purely venice is a hurricane is difficult because the vessel is constantly spinning in different ways every time and the issue of water is always present. However, there is a way to achieve house protection and a working post-hurricane community for both wind and water issues. I learned a lot about how the Floridas codes have tried to address and upgrade the current building codes to improve the protection of people and things. I learned a lot about the impacts on people’s emotional states and how to create a place for people to live and survive in Florida. I also learned a lot about the effects of hurricanes, the response for communities in the after math of the storms and how architecture can help achieve a symbiotic relationship between the storm and the community.
Chapter 01

Figure 1.1

Figure 1.2

Figure 1.3

From: https://www.nbcnews.com/business/10-states-most-natural-disasters-41038195

Figure 1.4

Figure 1.5


Figure 1.6

http://news.psu.edu/story/299772/2014/01/10/research/owner-occupied-homes-pay-quantifiable-benefits-neighborhoods

Figure 1.7


Figure 1.8

Figure 1.9

Figure 1.10

Figure 1.11

Figure 1.12


Chapter 02

Figure 2.1

https://www.marketwatch.com/story/irma-is-now-a-category-3-hurricane-and-it-could-strengthen-over-the-weekend-2017-09-01

Figure 2.2

Retrieved from https://steemit.com/education/@ghostgtr/how-stuff-works-structures

Figure 2.3

https://www.wbdg.org/resources/wind-safety-building-envelope


Figure 2.4


Figure 2.5

http://www.grook.net/forum/civil-engineering/construction/types-of-loads-structure

Figure 2.6

Figure 2.7

Figure 2.8

Figure 2.9

http://uap-ea.blogspot.com/2015/05/guidelines-for-disaster-resilient.html

Figure 2.10

https://www.oas.org/dsd/publications/Unit/oea66e/ch12.htm

Figure 2.11

Figure 2.12

Figure 2.13

http://uap-ea.blogspot.com/2015/05/guidelines-for-disaster-resilient.html

Figure 2.14


Figure 2.15


Figure 2.16


Figure 2.17

Figure 2.18

Figure 2.19

http://uap-ea.blogspot.com/2015/05/guidelines-for-disaster-resilient.html

Chapter 03

Figure 3.1

Figure 3.2

Figure 3.3

From:http://www.earthbagbuilding.com/project/sandbagshelters.htm

Figure 3.4

Figure 3.5

Figure 3.6

Figure 3.7

Figure 3.8


Figure 3.9

Figure 3.10

Figure 3.11

Figure 3.12

http://www.ecobuildingpulse.com/projects/deltics-hurricane-proof-homes

https://www.vrbo.com/996942

Figure 3.13

Figure 3.14

Figure 3.15

Figure 3.16


6.3 BIBLIOGRAPHY
LIST OF FIGURES
Chapter 05

Figure 5.1 Google.com
Figure 5.2 Google.com
Figure 5.3 Googl.com
Figure 5.4 Designs Northwest Architect. (2014, January 08), Tsunami House/ Designs Northwest Architect, Retrieved From https://www.archdaily.com/.../tsunami-house-de-
signs-northwest-architect