A guide to constructing Residential House Roofs in St. Vincent & the Grenadines to sustain hurricane winds

東海大學

Master of Architecture II

Advance Architectural Design

Tunghai University

Taichung, Taiwan

By: *James Calton Campbelle*

Coordinator: *Kuowei Chiu*

Instructors: *Dr. Simon Shu*
Dr. Hao-Hsin Chiu

Research Project Advisor: *Mr. Lin Wei-Ping*

2019

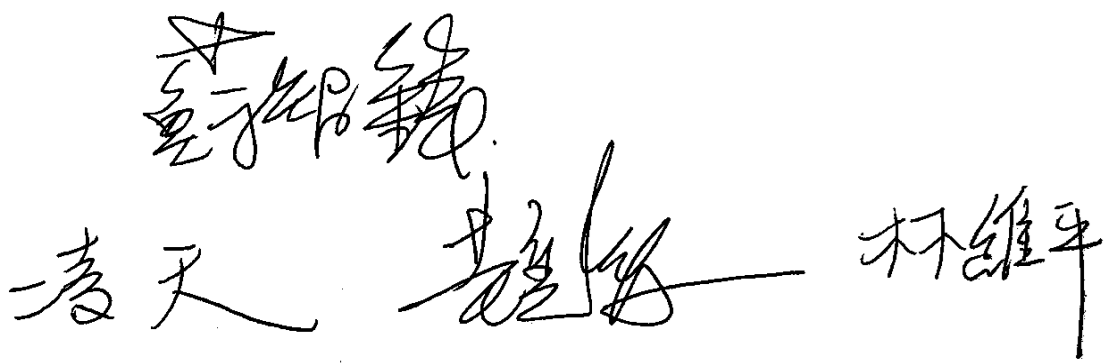
東海大學建築系碩士班
建築碩士學位論文

建構抗颶風屋頂構造系統參考指引研究
-以聖文森及格瑞那丁地區為例
A guide to constructing Residential House Roofs in St. Vincent & the Grenadines to sustain hurricane winds

研究生：甘傑士(Campbelle James Calton)

經審查及口試合格特此證明

論文考試委員會



指導教授：蘇智鋒 Shu, Chih-Feng

林維平 Lin, Wei-Ping

中　華　民　國　1　0　8　年　6　月

James Calton Campbelle

Email:

St. Vincent & the Grenadines
West Indies

2018 - 2019

ACKNOWLEDGEMENTS

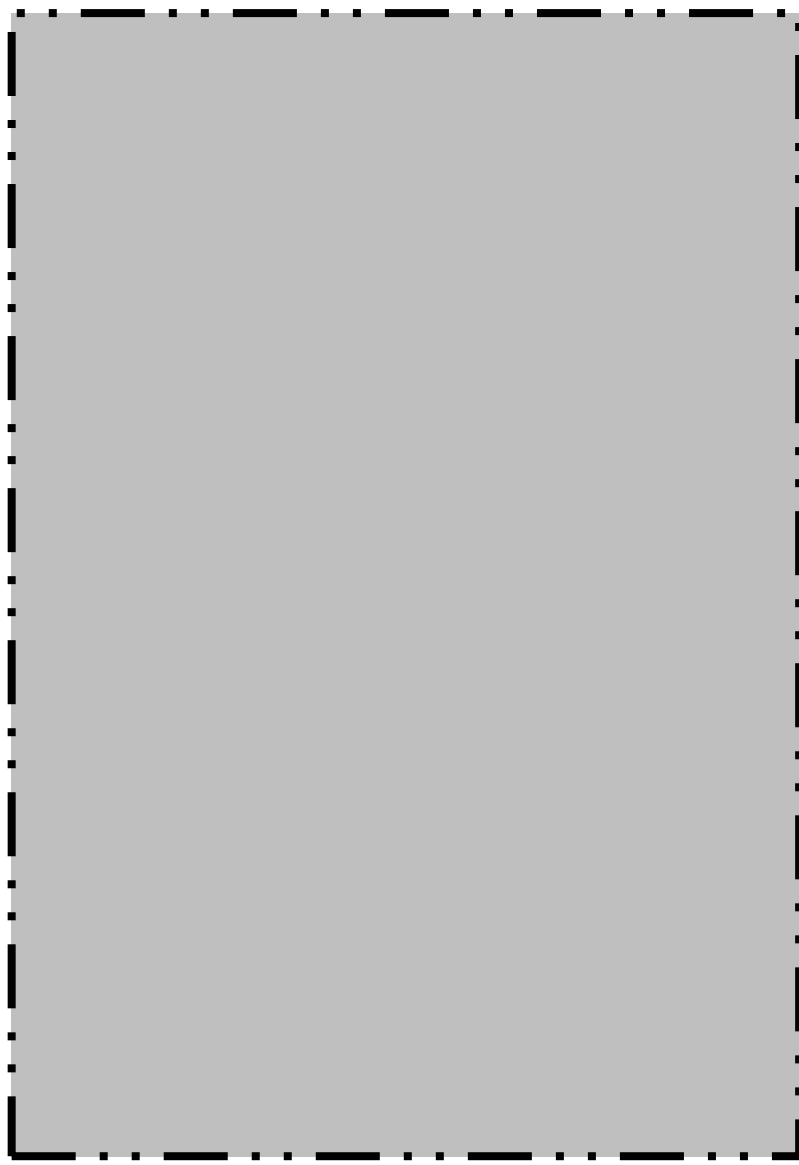
First and foremost, praises and thanks to the God, the Almighty, for his showers of blessings throughout this year of my studies.

The completion of this year would not be possible with out the love and support from a number of incredibly special people. First of all I would like to say a big thank you to the course coordinator Dr. Kuowei Chiu for his remarkable patience, not only for being the coordinator but also my instructor for some of my courses. Secondly, thanks to Dr. Simon Shu and Dr Hao-Hsin Chiu for helping me in the other courses needed to complete this phase in my studies and also my classes mates who were there for me along the way. Thirdly, my deep and sincere gratitude to Mr. Lin Wei Ping for extended discussions and valuable suggestions which have contributed greatly to the improvement of my thesis research project.

My mother, two brothers, sister and friends. Thank you all

Finally I would like to thank all of Tunghai University administrative staff who help and provide me with all the information I needed, especially Ms. Annie Chen and Ms Ziyi Lin from the International office.

CONTENT



Graduation Research Project

A guide to constructing Residential House Roofs in St. Vincent & the Grenadines to sustain hurricane winds

01

Project Location:

St. Vincent and the Grenadines

Directed by:

Shu, Chih-Feng

Lin, Wei-Ping

By:

James Campbelle

ABSTRACT

A guide to constructing Residential House Roofs in
St. Vincent & the Grenadines to sustain hurricane winds
by
James Calton Campbelle

Tunghai University, 2019
Taichung, Taiwan

The most vulnerable part of a house when a hurricane is approaching is the roof and it is the part that is easily and often get the most damage. When a house roof is damage by a hurricane, all of the other components of the house becomes expose to the strong winds of said hurricane. The goal of this research paper is to have a guide to constructing Roofing System for Residential Houses in St. Vincent & the Grenadines to sustain hurricane winds and will base on the St. Vincent and the Grenadines Building Code and Guidelines (SVGBCG).

RECOGNITION

First and foremost, praises and thanks to the God, the Almighty, for his showers of blessings throughout my research work to complete the research successfully.

I would like to say strongly thanks to Dr Simon Shu and also express my deep and sincere gratitude to Mr. Lin Wei Ping for extended discussions and valuable suggestions which have contributed greatly to the improvement of the research. He has taught me the methodology to carry out the research and to present the research works as clearly as possible. It was a great privilege and honor to work and study under his guidance. I am extremely grateful for what he has offered me.

Also would like to say thanks to Dr. Kuowei Chu for his friendship and empathy over this past year. His dynamism, vision, sincerity and motivation have deeply inspired me.

Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

RESEARCH LOCATION

Saint Vincent & the Grenadines

Saint Vincent and the Grenadines is a country in the Lesser Antilles island arc, in the southern portion of the Windward Islands, which lies in the West Indies at the southern end of the eastern border of the Caribbean Sea where the latter meets the Atlantic Ocean.
The sovereign state is also frequently known simply as **Saint Vincent**.

Its 389 km^2 (150 sq. mi.) territory consists of the main island of Saint Vincent and the northern two-thirds of the Grenadines, which are a chain of 32 smaller islands including Saint Vincent. Some of the smaller chain of islands which as known as the Grenadine Islands includes those that are inhabited: Bequia, Mustique, Union Island, Canouan, Palm Island, Mayreau, Young Island and those that are uninhabited: Tobago cays (Includes Petit Rameau, Petit Bateau, Baradal, Petit Tabac and Jamesby), Petit Saint Vincent, Baliceaux, Bettowia, Quatre, Petite Mustique, Savan and Petit Nevis. Most of Saint Vincent and the Grenadines lies within the Hurricane Alley.

RESEARCH LOCATION

Saint Vincent and the Grenadines

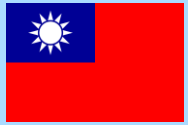
(32 Islands)

389 km^2 (150 sq. mi.)

St. Vincent & the Grenadines

Population
110 Thousand

Area: 389 km²



Taichung City (Taiwan)

Population
2.8 Million

Area: 2215 km²

INTRODUCTION

Introduction / Current Discourse

The Year of 2017 was called the year of hurricanes because within the time frame of two (2) months in August and September 2017, St. Vincent and the Grenadines as well as other Caribbean islands were badly affect by three (3) hurricanes named Irma, Harvey and Maria all of which were category 4 and 5 that carried wind speed from 210 and more kilometer per hour (KPH). Data gathered from local television and print media suggested that loss of roof is one of the main effects of the passage of hurricanes in St. Vincent and the Grenadines. Notably, and article obtained from the I-Witness News website informs that, in St. Vincent and the Grenadines the way in which most residential buildings were affected were by the loss of their roof. **A staggering 60% of the roof that were damage or completely removed, occurred when the hurricane exceeds Category 2.**

Hurricanes are ranked as the second most expensive of all-natural disasters world wide and represent over 40% of financial loses from its occurrence. **In the history of St. Vincent and the Grenadines, hurricanes are currently the costliest disaster**, and base on that history it also indicated that hurricanes winds is the major cause of damages to property. S.V.G is very small island located between the North Atlantic Ocean and the Caribbean Sea, its is very vulnerable to incoming hurricanes on a yearly basis during the hurricane season.

The aftermath of 3 hurricanes in 2017

Statement of Problem

St. Vincent and the Grenadines is geographical located in area that is susceptible to hurricanes between Category 1 to 5. As a consequence, during the passage of a hurricane many homes lose their roof due to the fact that the current roof design of **most residential houses are not able to withstand the winds of hurricanes that exceeds Category 2 status**.

Objective / Goal of Research

The objective / goal of research is to develop a hurricane roofing system that will be able to sustain the extreme wind power during a hurricane in accordance to the St. Vincent and the Grenadines building code and guidelines (SVGBCG).

Methodology

Firstly I studied the current reason that causes the roofs to fail during a hurricane, then I went through a series of case studies to figure out how this situation can be dealt with. After that I selected a site where the problem is being face. Then thirdly after accessing the information and analysis from the research, I will propose a guild and solution to help solve the current issue.

The collection of the for this research were obtain through one on one interviews with construction companies, architectural firms and local house owners as well as reading of articles from local media houses.

Research Questions

- What is the structural problem contributing to the loss of roof for residential houses in St. Vincent and the Grenadines when hurricane winds exceeds category two status?

- Which roofing designs or style and materials would be best suitable to withstand hurricane winds exceeding category 2 in St. Vincent and the Grenadines?

- To what extent will the integration of my research support residential houses from losing their roof through the passage of hurricanes in St. Vincent and the Grenadines?

Final Medium / Intervention Proposition

In order to meet the goal of this research , the following comprehensive development plan and procedure would be established.

- Determine a roofing system for residential houses that will be most effective against hurricane winds in St. Vincent and the Grenadines.
- Determine of a design or concept of a roofing system that will be in accordance to the St. Vincent and the Grenadines Building Code and Guidelines (SVGBCG).
- Propose a potential connection

RESEARCH

Design Requirements

The roof design in this research will be in accordance with the provisions of the St. Vincent and the Grenadines Building Code and Guidelines (SVGBCG). All Materials that will be use in this design, can be purchase locally.

The designs should have a shorter eave, with the ring beam rising to touch the covering of the roof, this will lessen the potential of wind to get up under the roof and lift it off and choice of finish materials.

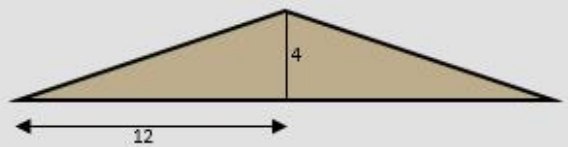
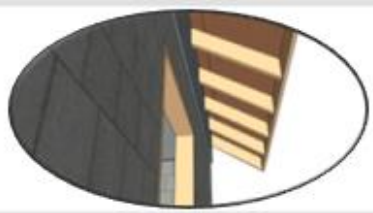
Conducted Interview

Interviews were conducted with three (3) construction companies, two (2) architectural design firms and house owners, some of the reasons given for the lost of house roofs during hurricanes are:

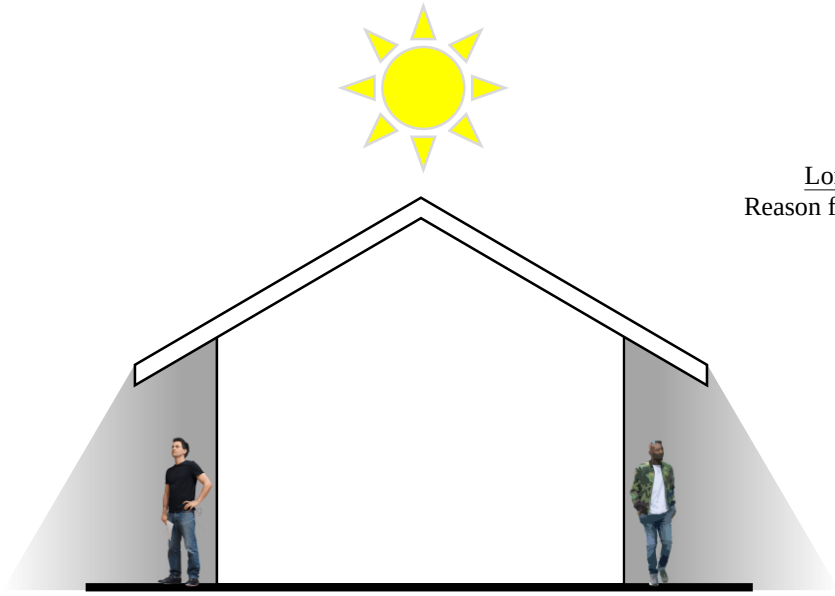
- Slope/Pitch (Low level roofs) - **20°or less**
- Long eaves - **More than 1ft 6 (45cm)**
- Inadequate Materials - **Rafters and batters far apart / not enough**
- Method used to attach galvanize to the roof frame - **Using nails instead of roofing screws**
- Joining of rafters to ring beam - **placing of rafter on top ring beam instead of inside with steel**

These are relatively cheaper to build.

Conducted Interview

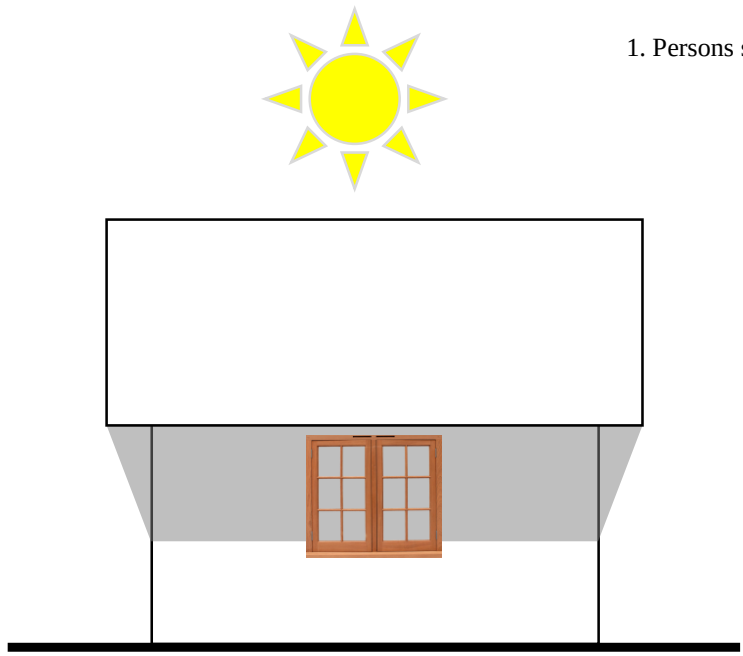
Issues	Figures	Given Reasons
Slope/Pitch (Low level roofs)		Less Materials
Long eaves		Shade from sun, capture of rain water
Inadequate Materials		Spacing between
Method used to attach galvanize to the roof frame		Widely use over the years
Joining of rafters to ring beam		Widely use over the years

Reasons for having long eaves

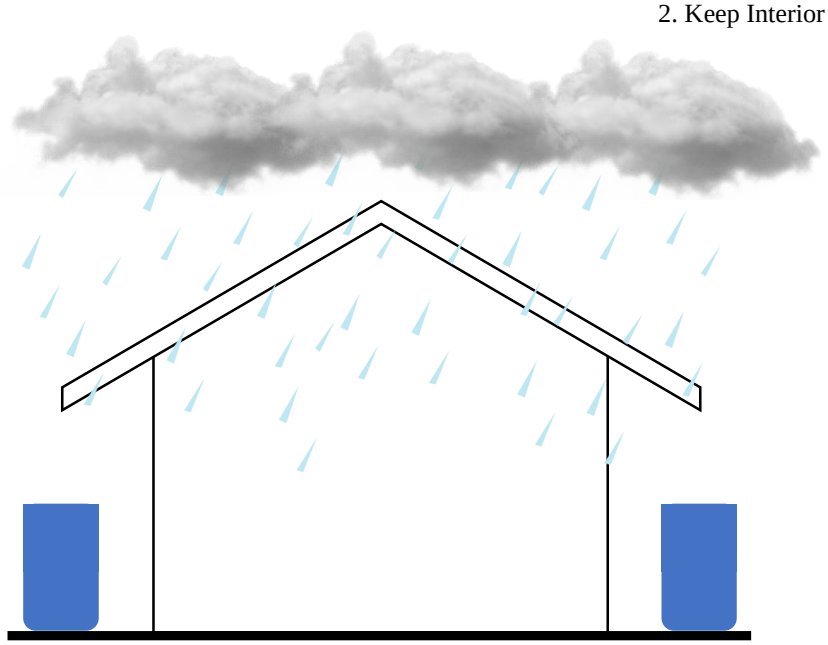


Long Eaves
Reason for Long Eaves

1. Persons shade from the sun

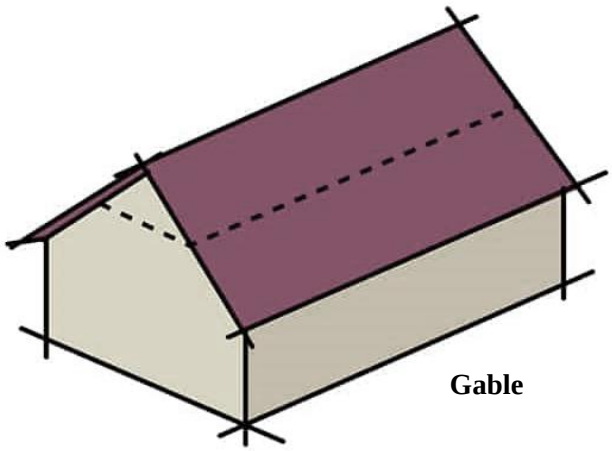


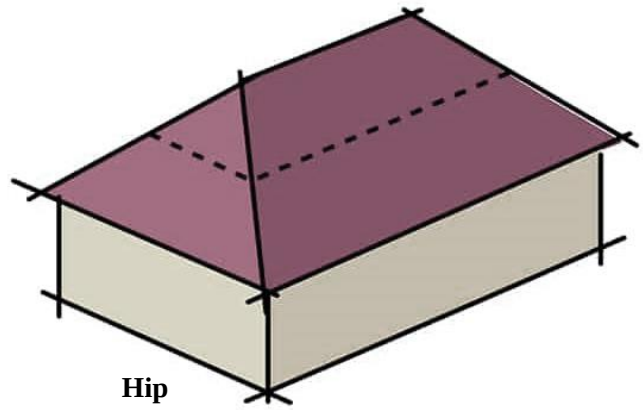
2. Keep Interior cool



3. Capture of Rain water

Conducted Interview





Survey questions about roof style

Which roof type last longer in a hurricane?
ANS: Hip

For the destroyed roofs, how many percentage were hip and how many percentage were gable?
ANS: Hip - 25%, Gable - 75%

For the destroyed roofs, how many percentage were high slope and how many percentage were low slope?
ANS: High - 33%, Low - 67%

During category were most roofs destroyed?
ANS: Category 3 (178 - 209 kph)

Florida’s Home Shapes And Roofs That Hold Up Best In Hurricanes

According to a researcher at New Jersey Institute of Technology (NJIT). **Civil engineer Rima Taher, PhD**, special lecturer in the New Jersey School of Architecture at NJIT. She spent two years examining the findings of research centers that have studied the best designs and construction materials and methods needed to withstand extreme wind events and hurricanes.

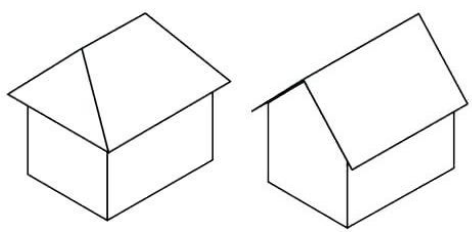
Wind researchers at the Center for Building Science and Technology (CSTB) in France, researched and tested reduced-scale home models at its wind tunnel facilities, and developed a prototype of a "cyclonic" or hurricane-resistant dwelling. Taher cooperated with the CSTB wind researchers, working on the structural aspect of the home's design.

That design eventually became an elevated structure of a square plan form on an open foundation. **The home had a hip roof and was equipped with a central shaft** with aerodynamic features designed to reduce wind forces during an extreme wind event. Wind tunnel tests at CSTB showed that such a home would be far more efficient under high winds and hurricane conditions than a typical structure. CSTB is working with a builder to construct a prototype of such a home on Réunion in the West Indian Ocean.

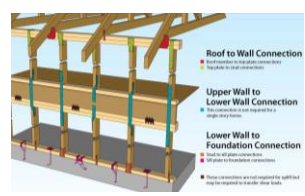
Article by
Dr. Rima Taher
New Jersey Institute of Technology

From this work and other studies Taher recommends the following construction considerations for homeowners in hurricane-prone regions.

- A home with a square floor plan (or better a hexagonal or octagonal plan) with a multiple-panel roof (4 or more panels) was found to have reduced wind loads.
- Roofs with multiple slopes such as a hip roof (4 slopes) perform better under wind forces than gable roofs (2 slopes). Gable roofs are generally more common because they are cheaper to build. A 30-degree roof slope has the best results than a 20-degree roof slope.
- Wind forces on a roof tend to be uplift forces. This explains why roofs are often blown off during an extreme wind event. Connecting roofs to walls matters. Stapled roofs were banned following Hurricane Andrew in Florida in 1993.
- Strong connections between the structure and its foundation and connections between walls are good. Structural failure is often progressive where the failure of one structural element triggers the failure of another, leading to a total collapse. Connections are generally vulnerable but can be inexpensively strengthened.
- Roof overhangs are subject to wind uplift forces which could trigger a roof failure. In the design of the hurricane-resistant home, the length of these overhangs should be limited to 50cm.
- The design of the cyclonic home includes simple systems to reduce the local wind stresses at the roof's lower edges such as a notched frieze or a horizontal grid to be installed at the level of the gutters along the perimeter of the home.
- An elevated structure on an open foundation reduces the risk of damage from flooding and storm-driven water.

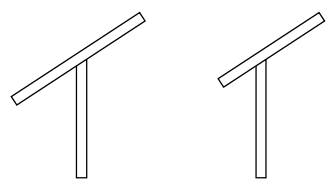


4 Panel vs 2 Panels



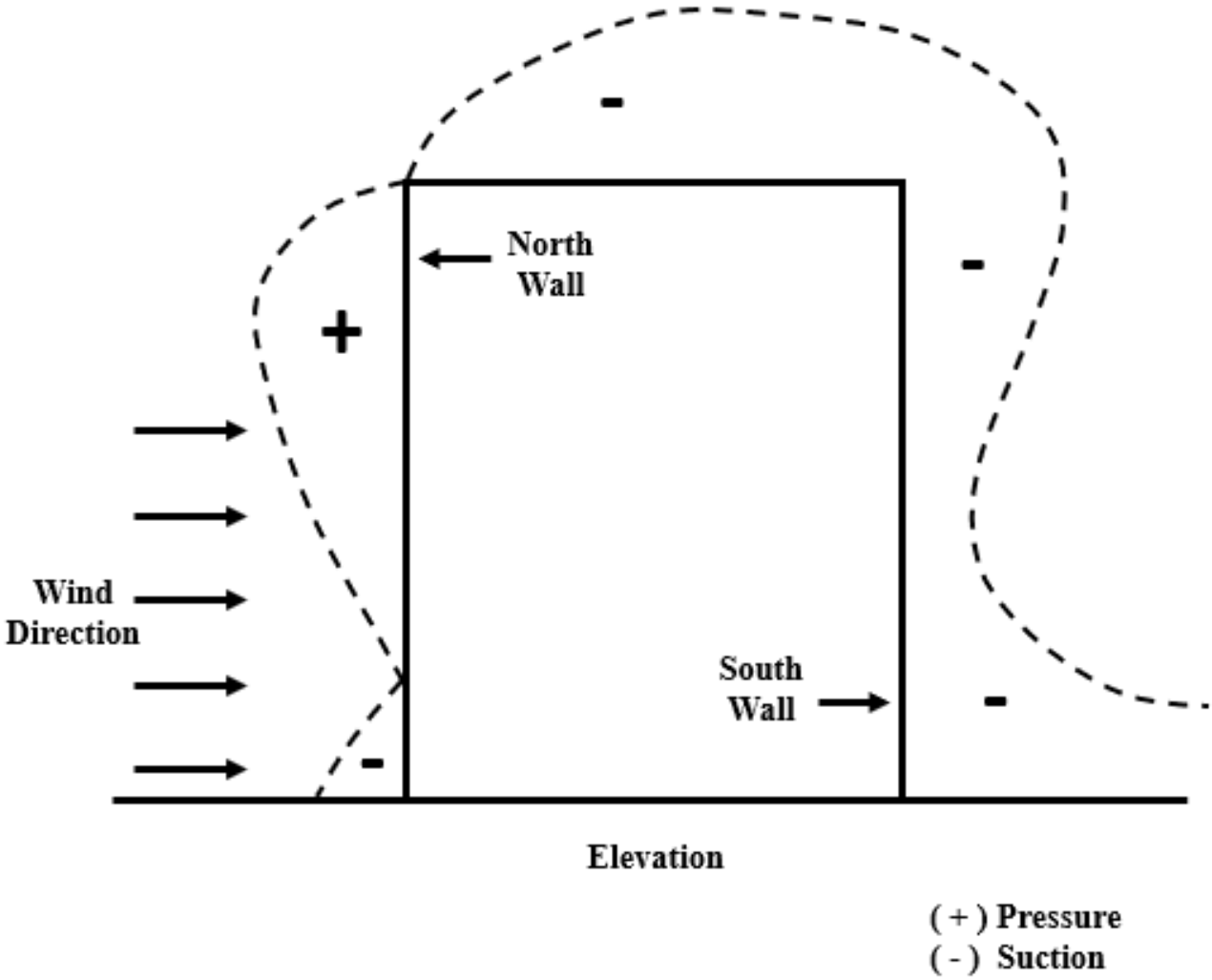
High Slope vs Low Slopes

Building Connection

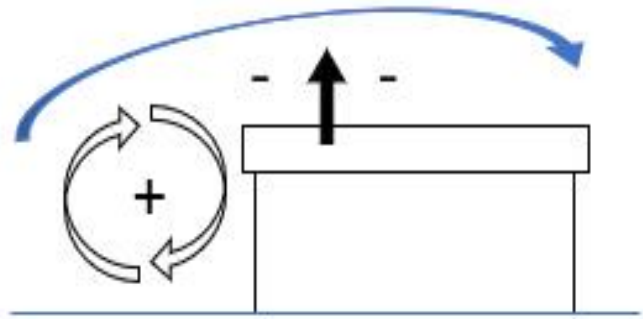


Long overhang vs Short overhang

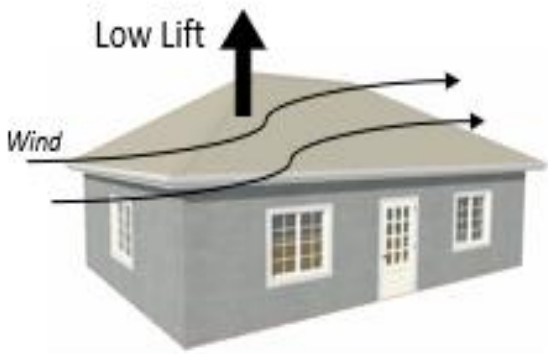
Wind Pressure

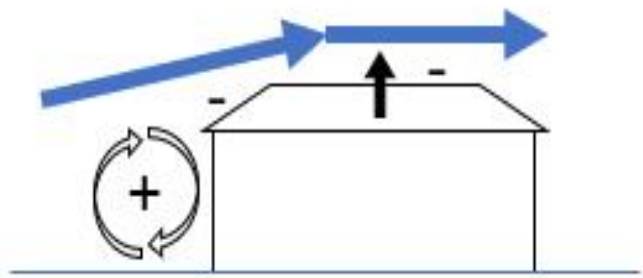


Wind Pressure

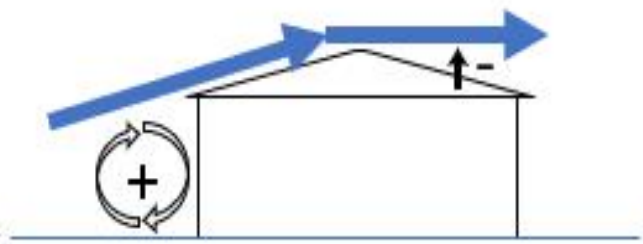


A. Gable roofs gets high uplift





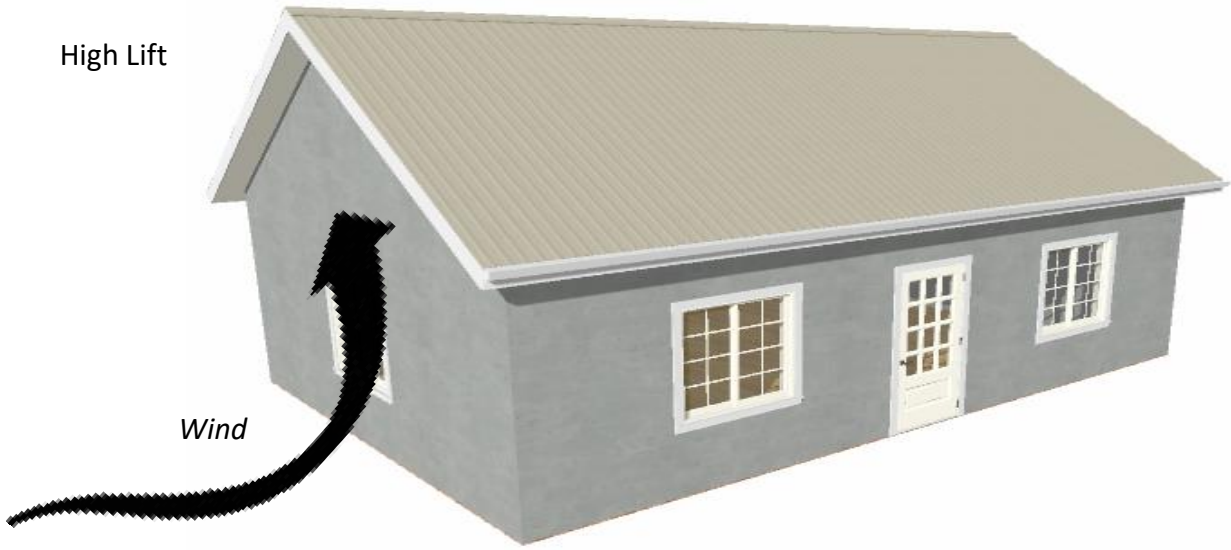
B. Hip roofs gets low uplift



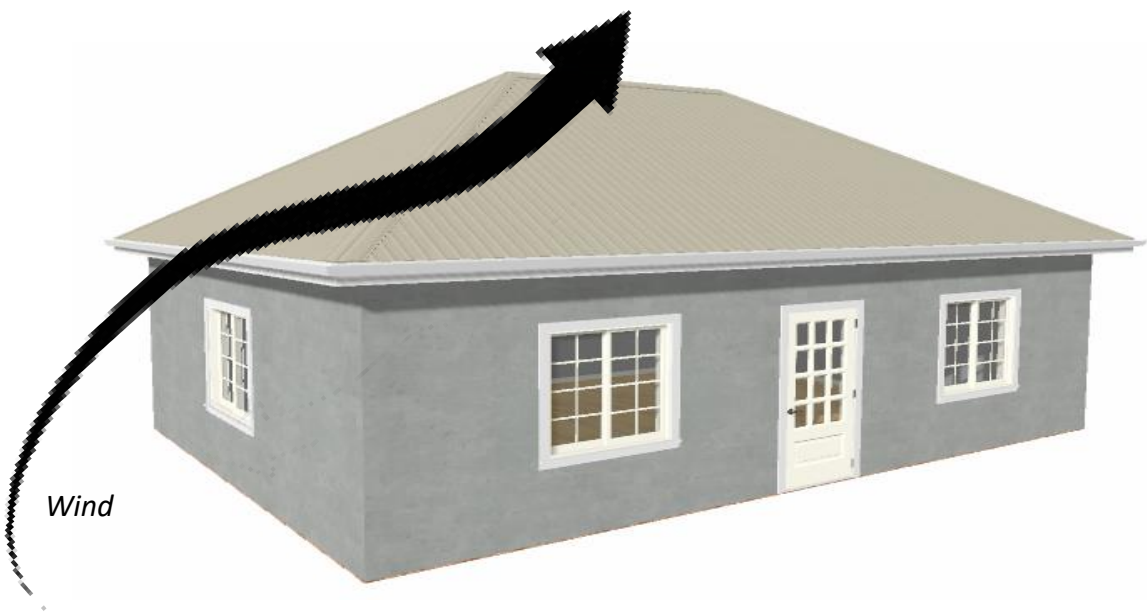
C. Pyramid roofs gets the lowest uplift

Wind Lift

High Lift



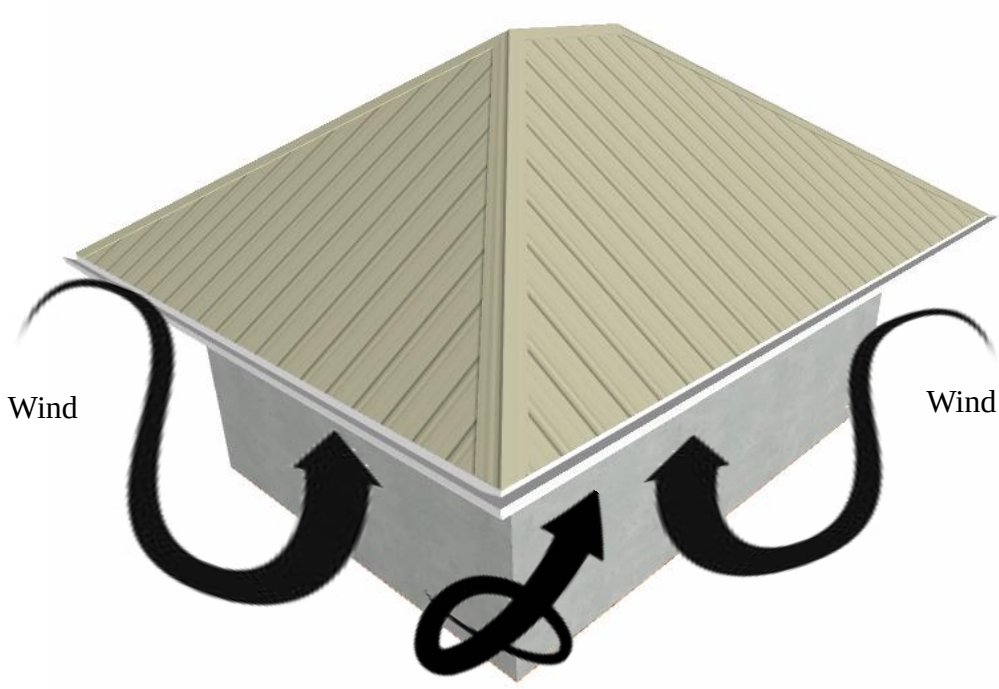
High Up lift of the wind, put a lot of pressure on the over hang of gable roofs



Slops around the Hip roofs create less/low up lift from the wind because there is not enough space to create a hook for the wind

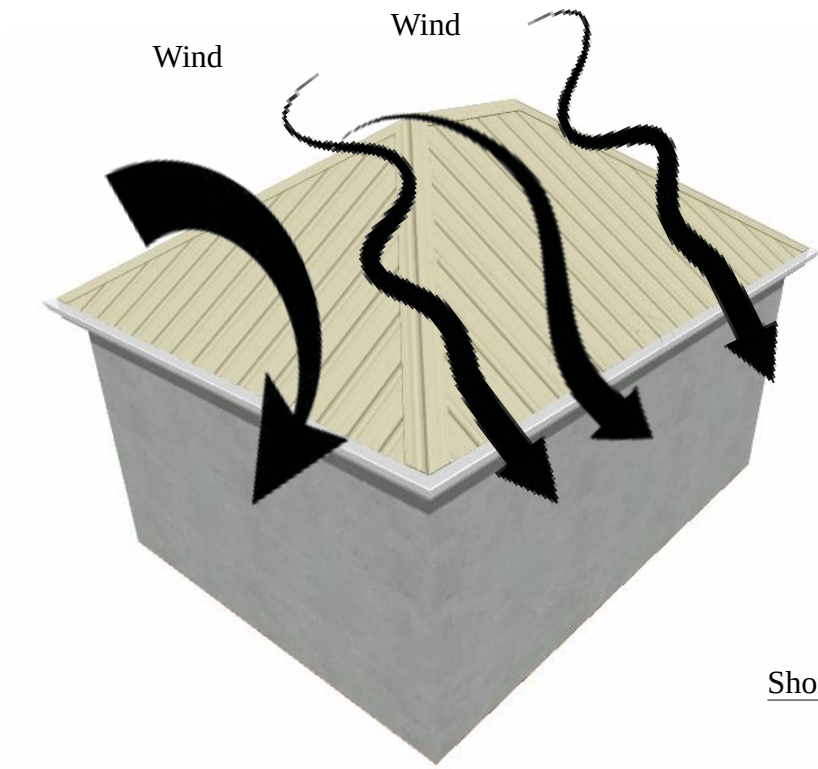
Wind Lift

Roof with long overhangs provides opportunity for the winds of the hurricane to flow up under the eave and grab the roof around the edges.



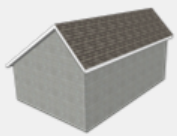
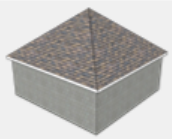
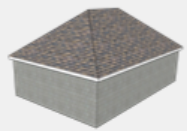
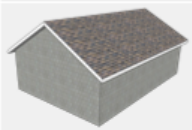
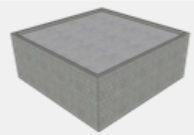
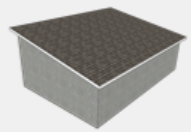
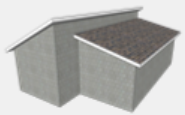
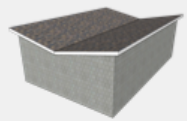
Long Eave vs Wind

Roof with short overhangs lessen the opportunity for the wind to get up under the eave and lift it off of the structure.

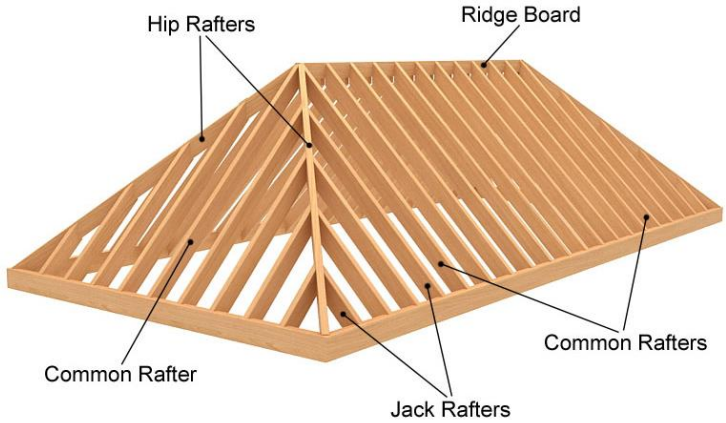


Short Eave vs Wind

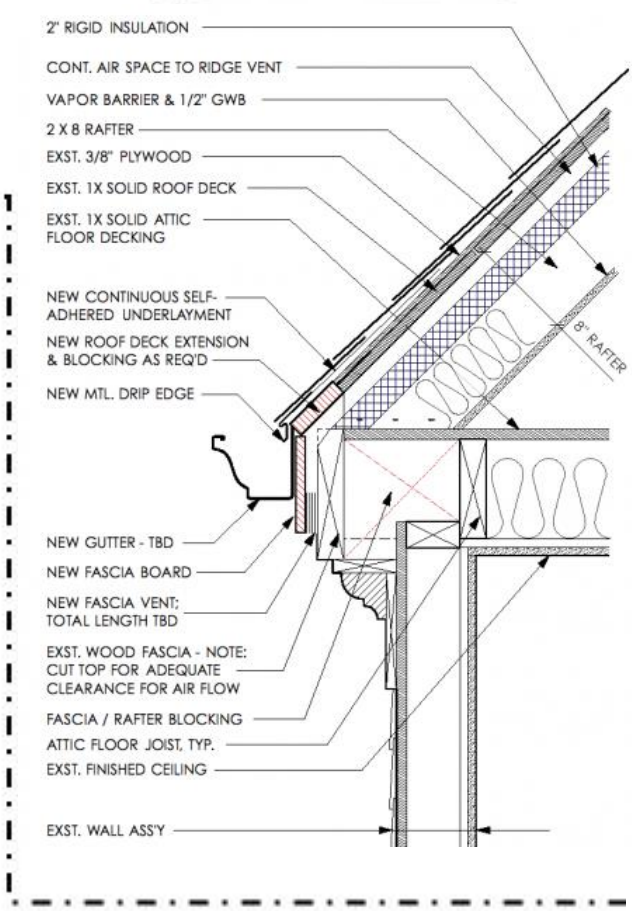
8 Global Roof Types

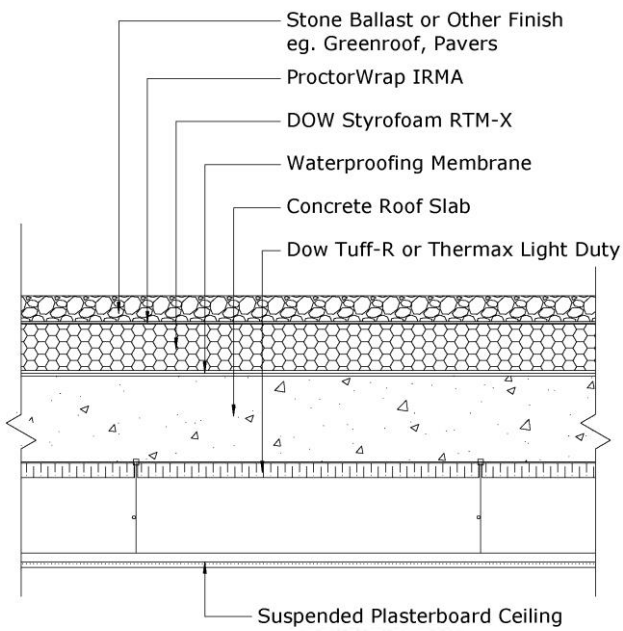
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8
Name	Salt Box	Pyramid	Hip	Gable	Flat	Shed	Skillion	Butterfly
Drawing								
Location	New England (Traditional)	United States	Globally	Globally	Globally	Globally	Australia	Greece
Pros	• Moderate to heavy rain • Easily maintain	• Improved resistance to winds • Eaves all sides	• Self bracing • Withstands most hurricanes • Water Runs of easily	• Cheap • Water runs of easily • Ventilation	• Usable space • Cheap • Resistant to winds • Moderate to heavy rain	• Affordable • Various materials • Water direction	• Water drainage • Easy to construct • Opportunity for solar • panel	• Collect water • Large windows
Cons	• Lose space • Additional roof materials	• Less space • Ventilation	• Additional roof materials • Ventilation	• Additional roof materials	• Water drainage • Heat	• Only for small house • Water flow	• Sensitive to high winds	• Costly • Water and snow damage

Roof Types Table

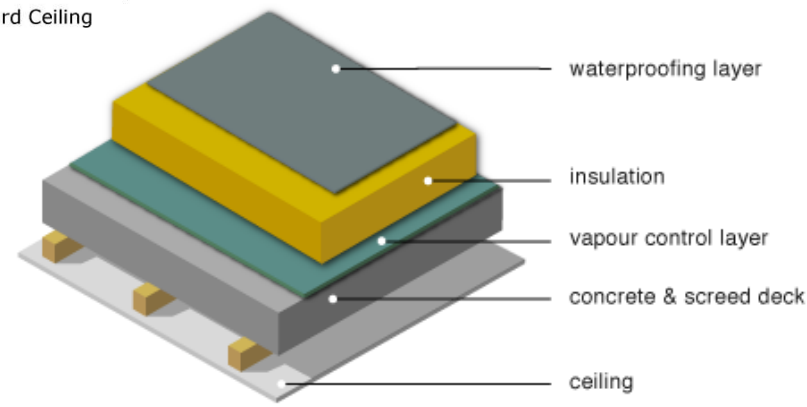


Hip and Pyramid Roof Details (Type 2 & 3)





Flat Roof Details (Type 5)



TNT Roofing

Wind speed comparison

Storm Classification	Wind Speed (kph)	Taiwan Typhoon	Roofs Compatibility
Tropical Depression	35 - 61		Any
Tropical Storm	62 - 117	Tropical Storm	Any
Hurricane - Category 1	118 - 152	Typhoon (Moderate Intensity)	Any
Hurricane - Category 2	153 - 177	Typhoon (Moderate Intensity)	Type 2,3,5,4,6
Hurricane - Category 3	178 - 209	Typhoon (Intense Intensity)	Type 2,3,4,5
Hurricane - Category 4	210 - 249	Typhoon (Intense Intensity)	Type 2,3,5
Hurricane - Category 5	> 250	Typhoon (Intense Intensity)	Type 2,3,5

Wind Speed Table

Traditional Roof Types Globally

Chinese Style

Image from chuan song me

Japanese and Korean Style

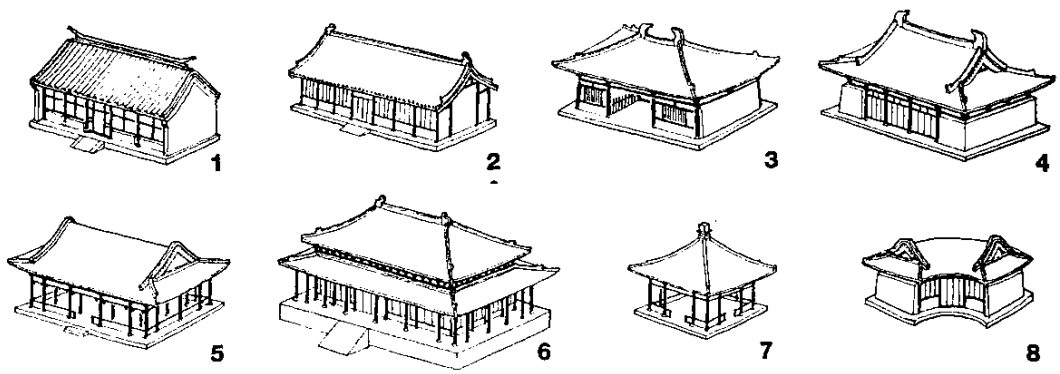


Image from chuan song me

Europe and American Style

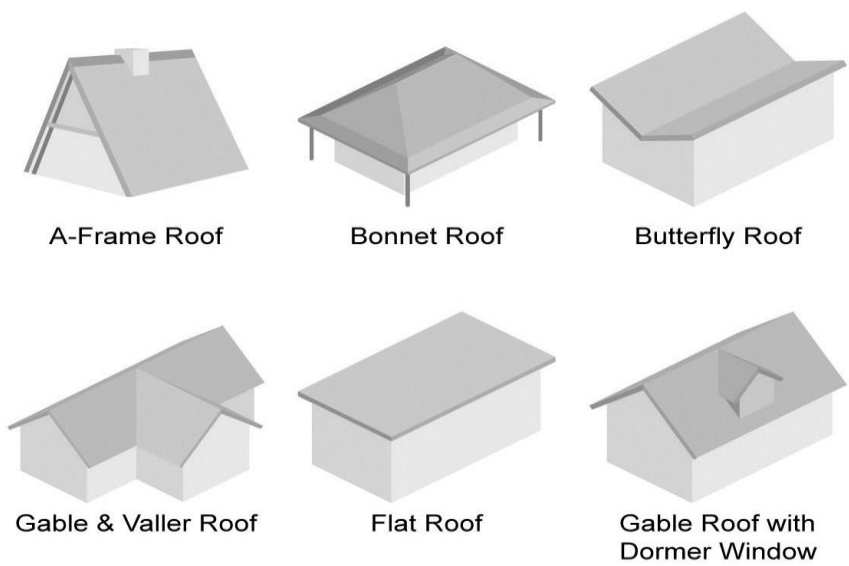
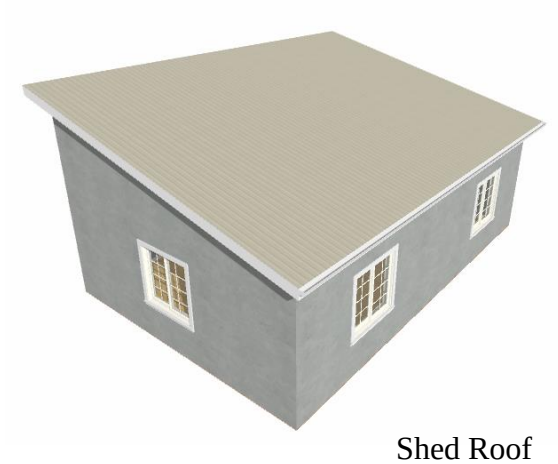


Image from dnbroofing

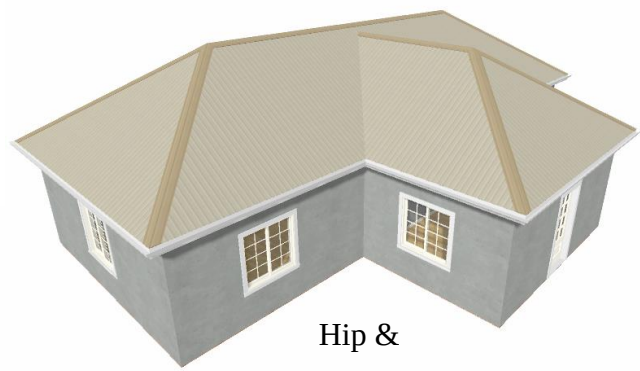
ROOFING TYPES, DESIGNS AND MATERIALS

Roof Types allowed by the SVGBCG



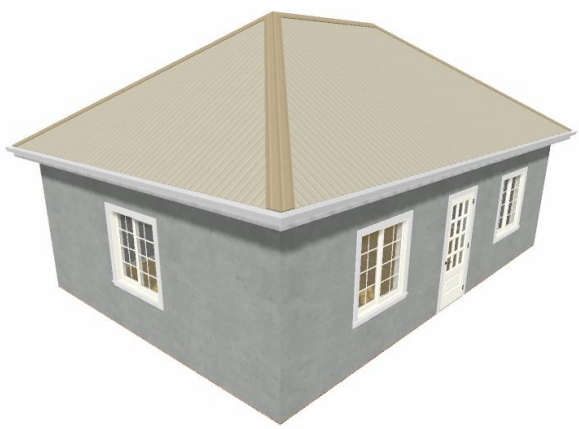
Shed Roof

Gable Roof



Hip &

Valley Roof



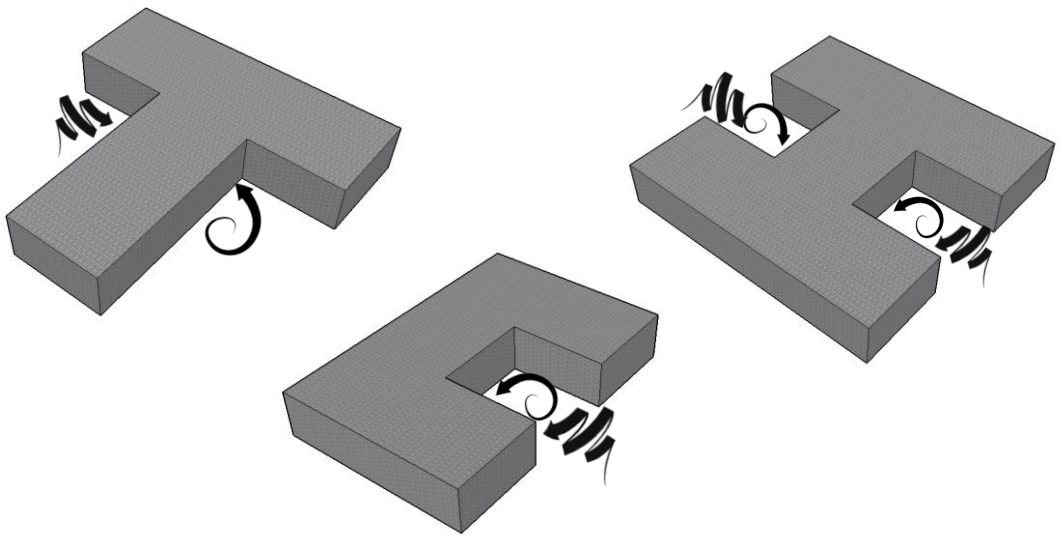
Hip Roof

Gable &

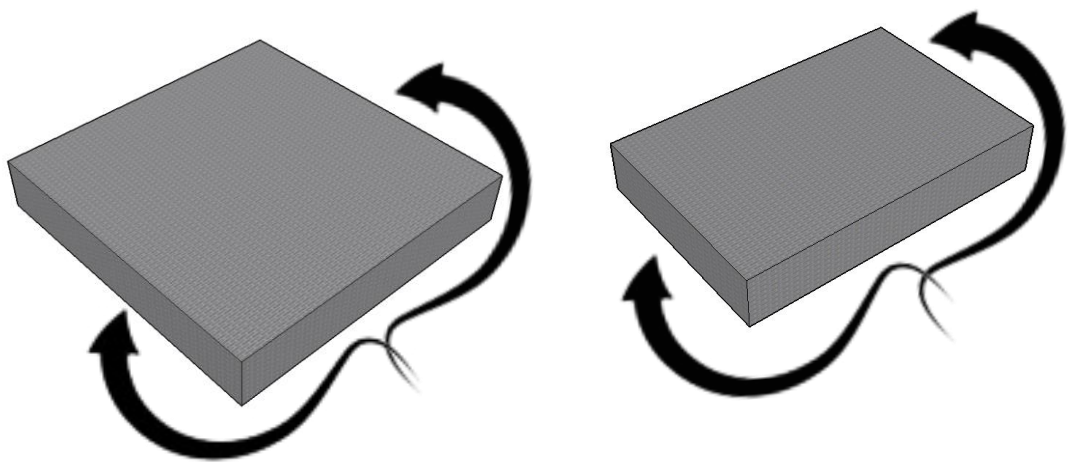
Valley Roof

Roof Types
Current Roof Types

Designs of building which easily looses its roof during a hurricane



Roofs on designs such as these are easily destroyed because the wind enter into the indented space, then the only direction the wind can go is up, which then leads to the lift of the roofs.



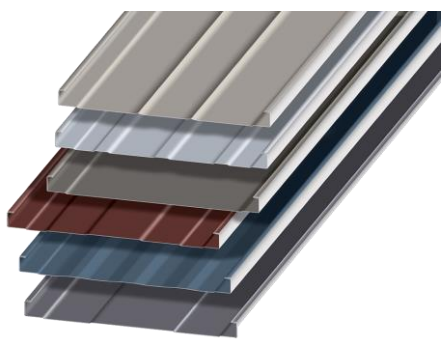
No space provided for hurricane winds to be trap

House Designs

Roofing Materials used Globally

Roofing Materials
Images from Valley View Roofing

Roofing Materials allowed by the SVGBCG



Metal Standing Seam

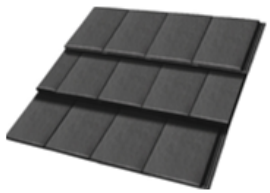
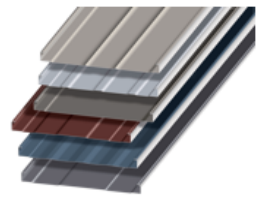
Clay Tile

Corrugated Sheet

Concrete Tile

Roofing Materials
Images from Harrington & Company

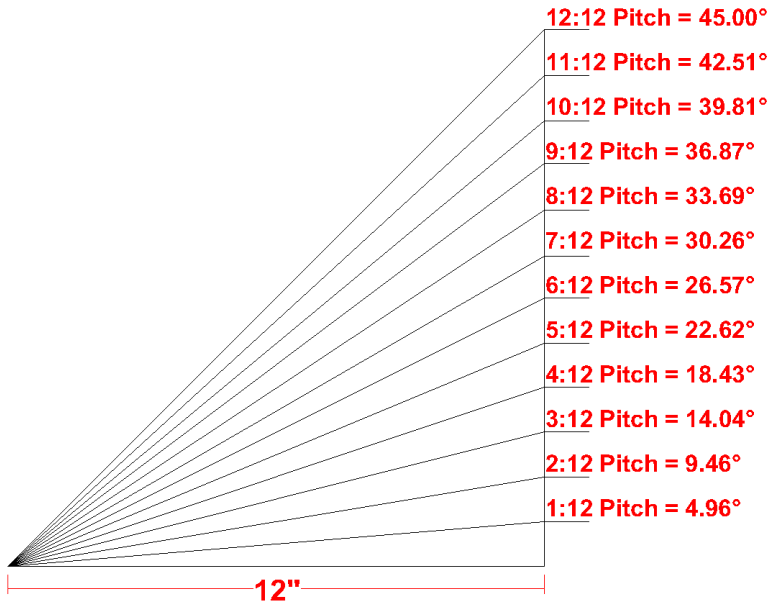
Roofing Materials Pros & Cons

	Concrete Tiles	Clay Tiles	Metal Standing Seam	Corrugated Sheet	Asphalt Shingles
Image					
Pros	• Do not corrode • Low rain noise • Easy to replace a tile in a run • Can collect rainwater from roof	• Do not corrode • Can collect rainwater from roof • Bold shape • Look great when new	• No joins needed • Lightweight • Able to be cut • Can be curved • Choice of color • Easy to install • Can collect rainwater	• No joins needed • Lightweight • Able to be cut • Can be curved • Choice of color • Easy to install • Can collect rainwater	• Distinctive look • Does not corrode • Possibility of overlaying
Cons	• Heavy • Minimum pitch • Not resistant to extreme winds • Can crack over time • High cost • Need increased structural supports	• Heavy • Expensive accessories • Crack easily • High cost • Not resistant to extreme winds	• Avoid contact with dissimilar metals • Need to remove entire roof to install new. • Warranty 25 years	• Avoid contact with dissimilar metals • Need to remove entire roof to install new. • Warranty 15 years	• Costly • Lose glue adhesion over time • Blow off in high winds • High maintenance

Roof Materials Table

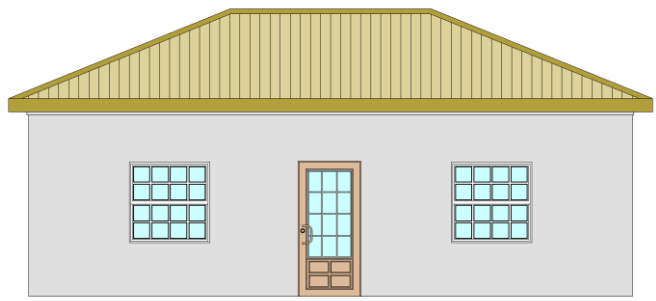
ROOFING SLOPES

Roofing Pitch used Globally

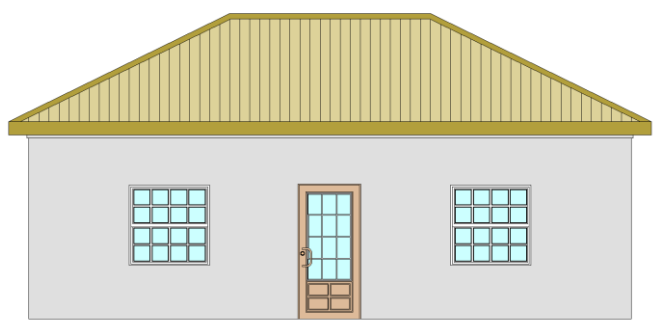


Roofing Pitch allowed by the SVGBCG

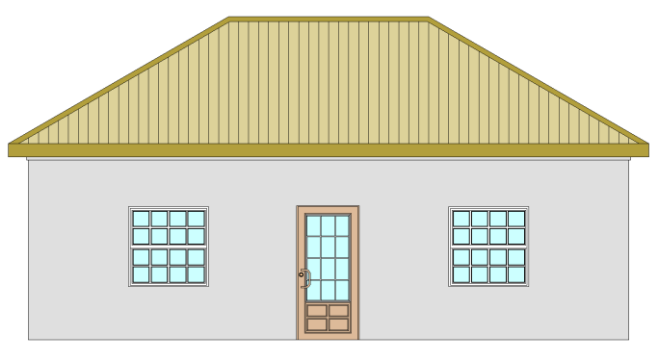
5 in 12
22.6°



6 in 12
26.5°



7 in 12
30.2°



Roof Slopes

“High Slope Roof” VS “Low Slope Roof”

High Slope Roof

Advantages:

- **Although walkability is lower with high pitched roofs, overall, they require less maintenance and upkeep.** This helps offset the slightly higher installation price tag of a high-pitched roof.
- **The greater height to width ratio of high pitch roofs allows water to drain easier**. This keeps moisture and tree rubbish, like branches, from collecting on your roof and causing damage.
- Along with being more aesthetically pleasing in residential areas, **higher pitched roofs mean more space for attic storage**, **a second story loft, or decorative gables.**

Disadvantages:

- **Due to a steeper grade of roof pitch, high pitch roofs are not as easy and safe to access** when maintenance/inspection is required. This can make maintenance costs a bit higher for high pitched roofs. A tradeoff for fewer maintenance calls, compared to their low pitch counterparts.
- **High pitch roofs require more shingles to fully cover the roofs’ surface.** This means that generally speaking, high pitch roofs are more expensive to install.
- **With more attic space comes more space to heat and cool.** This can mean it is difficult, and often times more expensive to keep your home at a comfortable temperature.

Low Slope Roof

Advantages:

- Since a low pitch roof doesn’t require as many shingles, more often than not, **a low pitch roof will end up being more cost-efficient during installation.**
- **The lower pitch of the roof means greater walkability.** Low pitch roofs are safer and easier to access when maintenance and/or repairs are needed.
- Especially for homes in the south, **a low pitch roof means a cooler interior.** There isn’t as much extra space to heat and cool with lower pitched roofs, so it easier to keep your home at a comfortable temperature.

Disadvantages:

- Due to the gradual low slope of this type of roof, **rainfall will not drain as effectively.** This may eventually cause leaks and other damage.
- Since the pitch of the roof is lower, it **can act as a catch-all for tree limbs and other debris.** Care must be given so that debris does not collect and thus cause damage.
- The ratio between width and height is much smaller with a low pitch roof. Therefore, **attic space can be at a premium with a low pitch roof.**

Roof Costing and Maintenance

Cost of Roofing

The steeper a roof is, the more expensive to build than the lower roof. It will require specialized equipment and it is riskier on the workers. Scaffolding is required when dealing with steeper roofs, adding to the cost.

The slope will also affect the amount of roofing materials used. Steeper roofs for example, require more shingles than flatter roofs. It takes much more time and expertise to construct.

Maintenance

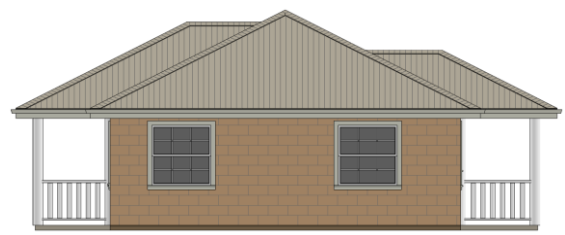
While steeper roofs are more expensive to install, they tend to be much cheaper to maintain and Repair. The steeper slope allows much better water drainage, leading to less damage over time. Flatter roofs on the other hand do not drain well and therefore and more prone to water damage.

Roofing Materials

The slope of the roof will also have an impact on the roofing material to be use.

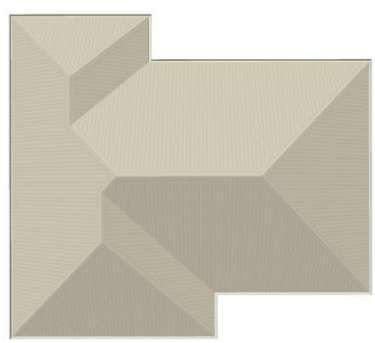
Flat or very lightly sloped roof cannot be roofed with shingles because the lack of pitch means the shingles do not drain water fast enough. This will easily lead to damage. Flat roofs require a roofing technique that is water proof. Gravel and tar become a better alternative for flat or nearly flat roofs.

Front Elevation
S - 1:150

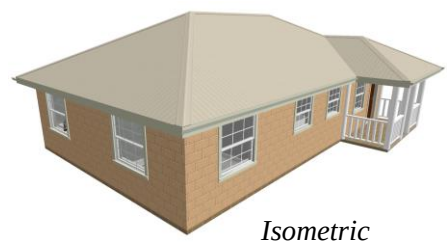


Right Elevation
S - 1:150

Isometric View



Roof



Isometric View

High Roof (30.2°)

Cost to Build

ROOFING MATERIALS			
Quantity	Description	Rate	Price
55	5/8” Groove ply	$ 125.00	$ 6,875.00
55	2” x 6” x 16’ dtyp	$ 54.00	$ 2,970.00
35	Galvanized Sheets (@ 16ft)	$ 152.00	$ 5,320.00
13	Ridging (@ 10ft)	$ 69.00	$ 897.00
35	1” x 4” 18’ R.T.P.P	$ 26.00	$ 910.00
10	1” x 10” x 18’ D.T.Y.P	$ 65.00	$ 650.00
3	2 x 6 x 20 dtyp	$ 120.00	$ 360.00
700	Screws	$ 0.45	$ 315.00
50	Nails (lbs)	$ 6.00	$ 300.00
		Total (xcd)	$ 18,597.00
		Total (ntd)	$ 216,409.00

Cost to Maintain or Repair

ROOFING MATERIALS			
Quantity	Description	Rate	Price
10	5/8” Groove ply	$ 125.00	$ 1,250.00
10	2” x 6” x 16’ dtyp	$ 54.00	$ 540.00
5	Galvanized Sheets (@ 16ft)	$ 152.00	$ 760.00
2	Ridging (@ 10ft)	$ 69.00	$ 138.00
5	1” x 4” 18’ R.T.P.P	$ 26.00	$ 130.00
2	1” x 10” x 18’ D.T.Y.P	$ 65.00	$ 130.00
1	2 x 6 x 20 dtyp	$ 120.00	$ 120.00
200	Screws	$ 0.45	$ 90.00
30	Nails (lbs)	$ 6.00	$ 180.00
		Total (xcd)	$ 3,338.00
		Total (ntd)	$ 38,844.00

TOTAL - $21,935 ($255,253 ntd)

Low Roof (22.6°)

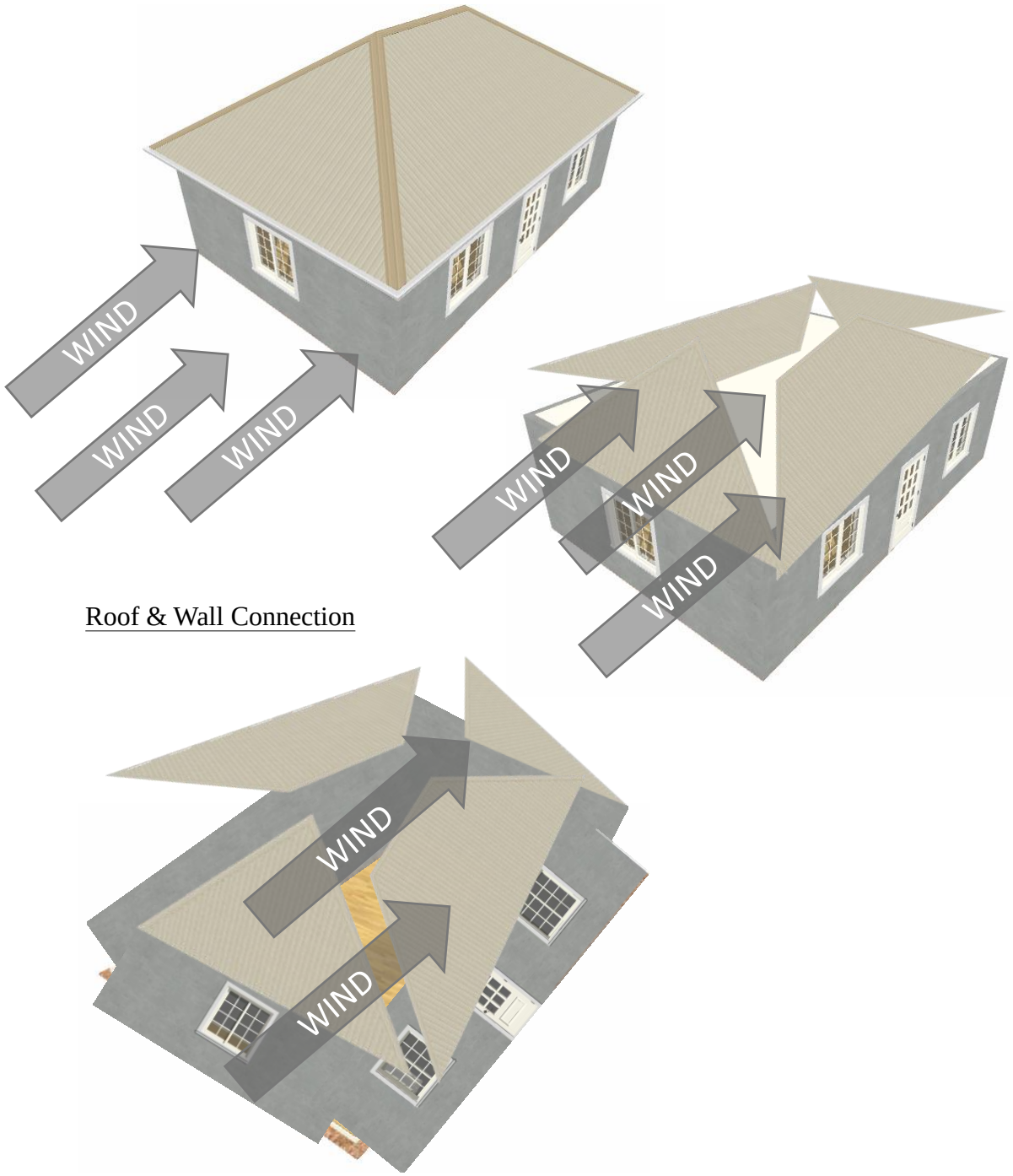
Cost to Build

ROOFING MATERIALS			
Quantity	Description	Rate	Price
50	5/8” Groove ply	$ 125.00	$ 6,250.00
52	2” x 6” x 14’ dtyp	$ 50.00	$ 2,600.00
30	Galvanized Sheets (@ 14ft)	$ 144.00	$ 4,320.00
10	Ridging (@ 10ft)	$ 69.00	$ 690.00
30	1” x 4” 16’ R.T.P.P	$ 21.00	$ 630.00
6	1” x 10” x 16’ D.T.Y.P	$ 60.00	$ 360.00
3	2 x 6 x 18 dtyp	$ 112.00	$ 336.00
500	Screws	$ 0.45	$ 225.00
45	Nails (lbs)	$ 6.00	$ 270.00
		Total (xcd)	$ 15,681.00
		Total (ntd)	$ 182,477.00

Cost to Maintain or Repair

ROOFING MATERIALS			
Quantity	Description	Rate	Price
25	5/8” Groove ply	$ 125.00	$ 3,125.00
25	2” x 6” x 14’ dtyp	$ 50.00	$ 1,250.00
15	Galvanized Sheets (@ 14ft)	$ 144.00	$ 2,160.00
5	Ridging (@ 10ft)	$ 69.00	$ 345.00
10	1” x 4” 16’ R.T.P.P	$ 21.00	$ 210.00
2	1” x 10” x 16’ D.T.Y.P	$ 60.00	$ 120.00
3	2 x 6 x 18 dtyp	$ 112.00	$ 336.00
400	Screws	$ 0.45	$ 180.00
30	Nails (lbs)	$ 6.00	$ 180.00
		Total (xcd)	$ 7,906.00
		Total (ntd)	$ 92,000.00

TOTAL - $23,587 ($274,477 ntd)



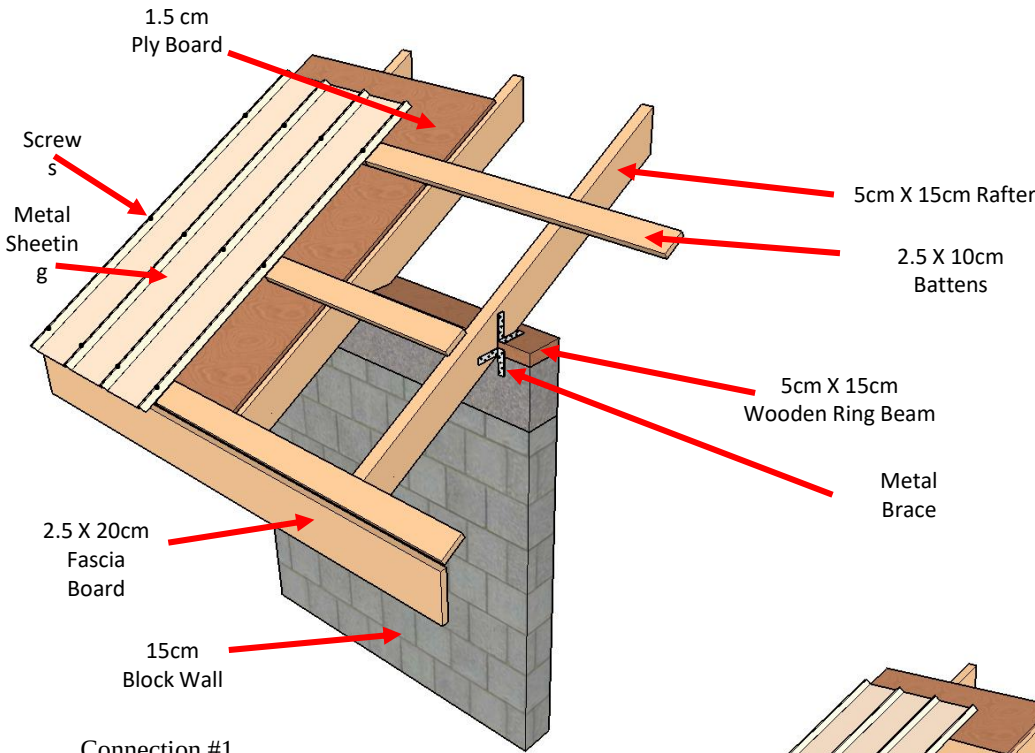
Roof & Wall Connection

Good Roof Connection

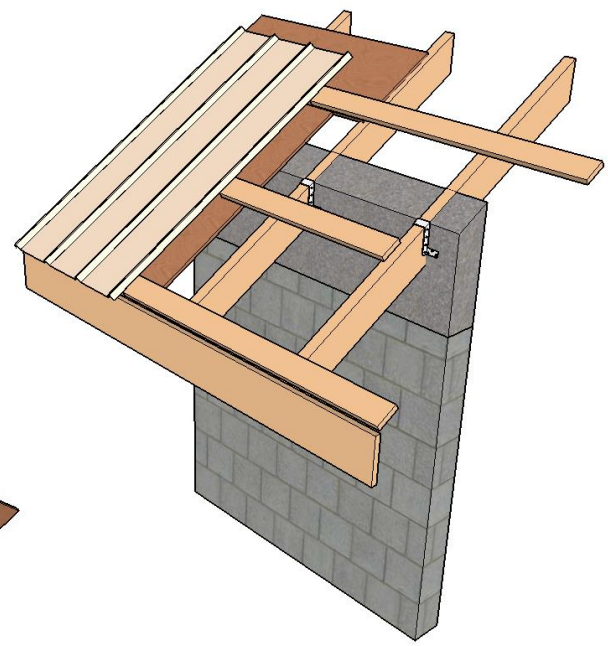
The connection between the roof and wall is a major point in designing and construction of a building. If the roof isn't connected properly to the walls, the roof can get rip off easily during a hurricane and that will cause weakness in the walls and also expose the interior of the building to severe damages, and in result of that, it can cause the building to collapse.

ROOFING CONNECTION

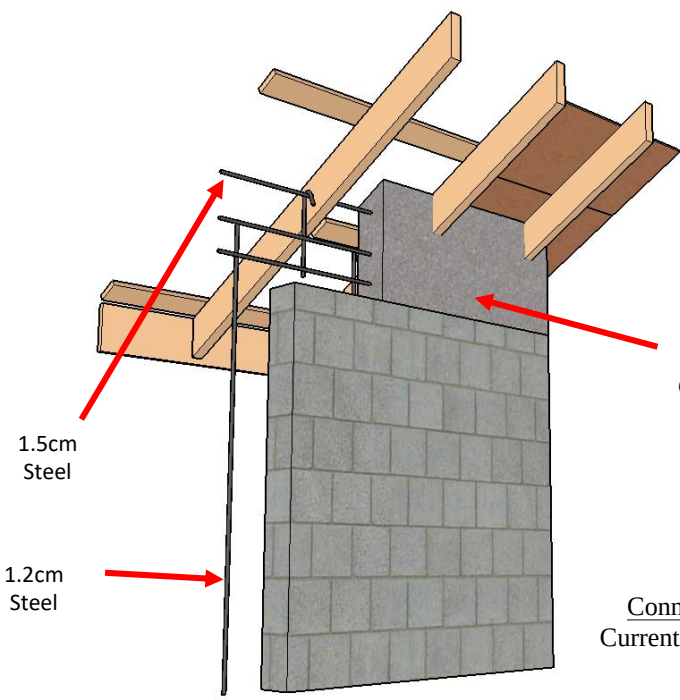
Past & Current Roofing Connection



Connection #1
Traditional Roofing
Connection

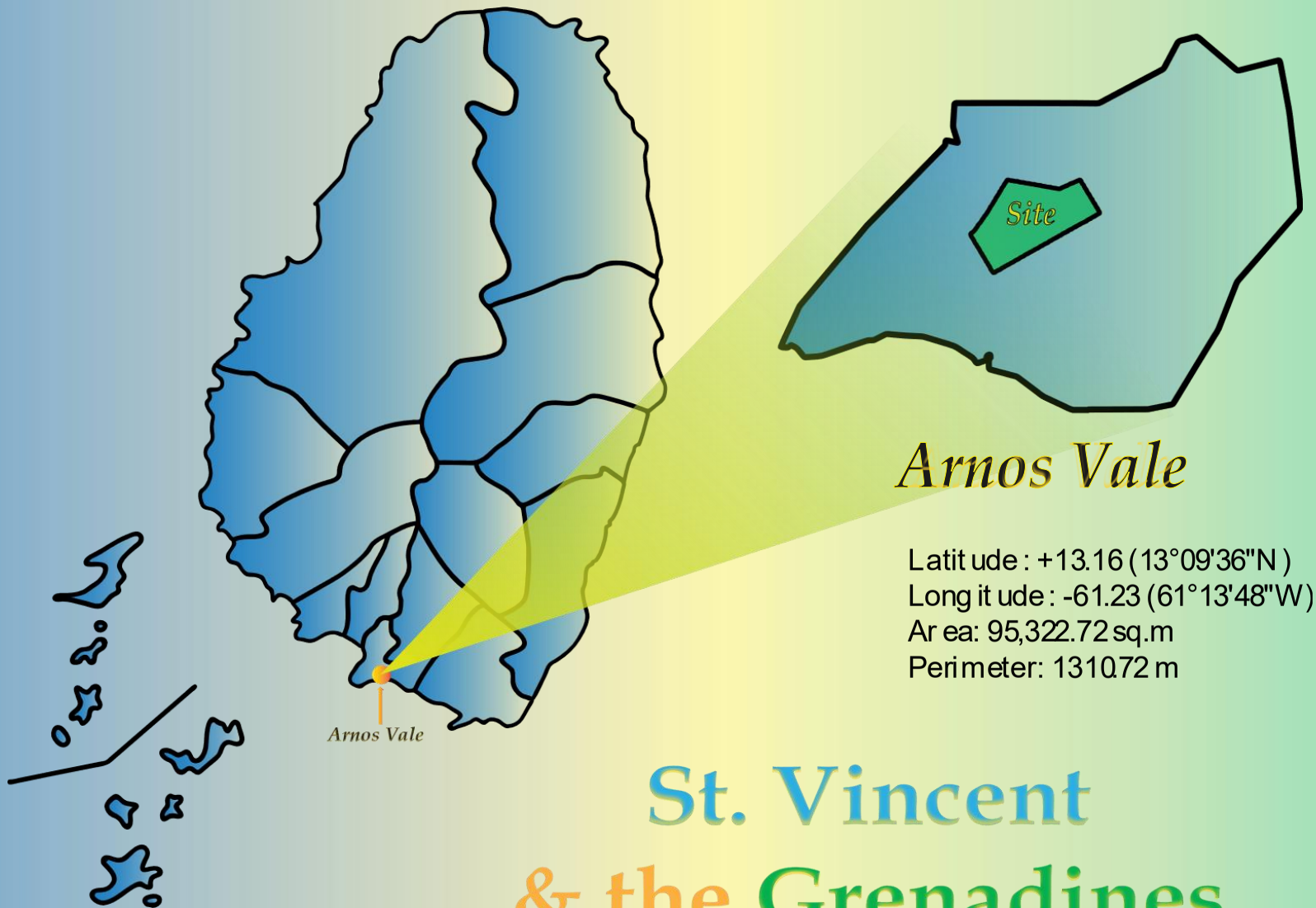


Connection #2
Past Connection



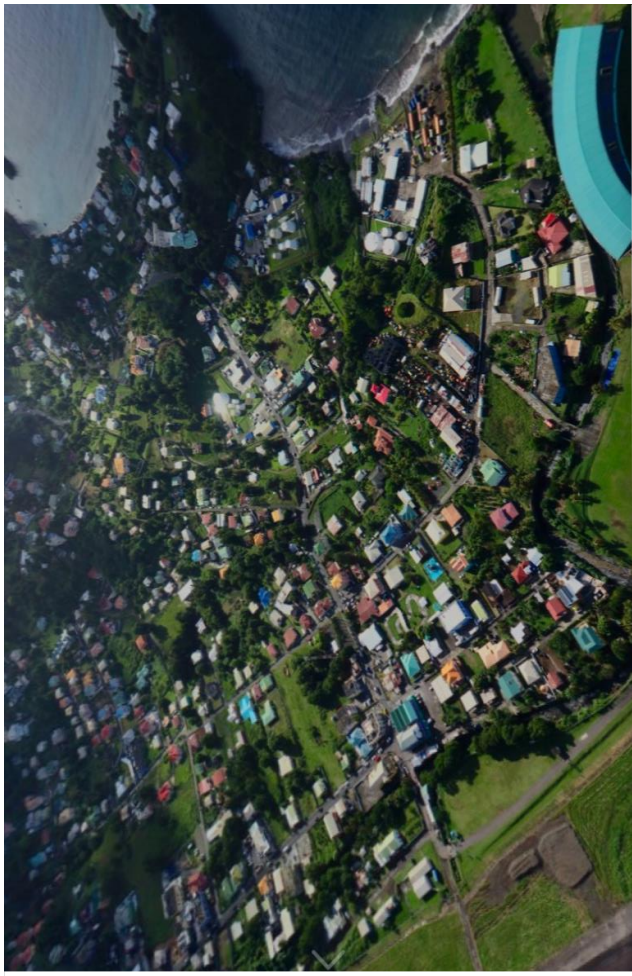
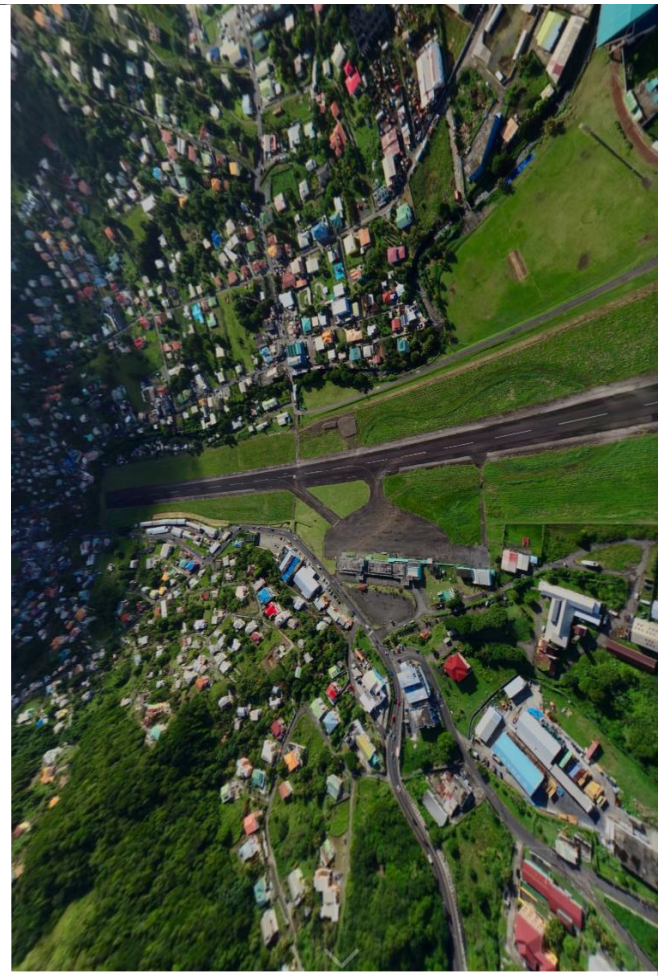
Connection #3
Current Connection

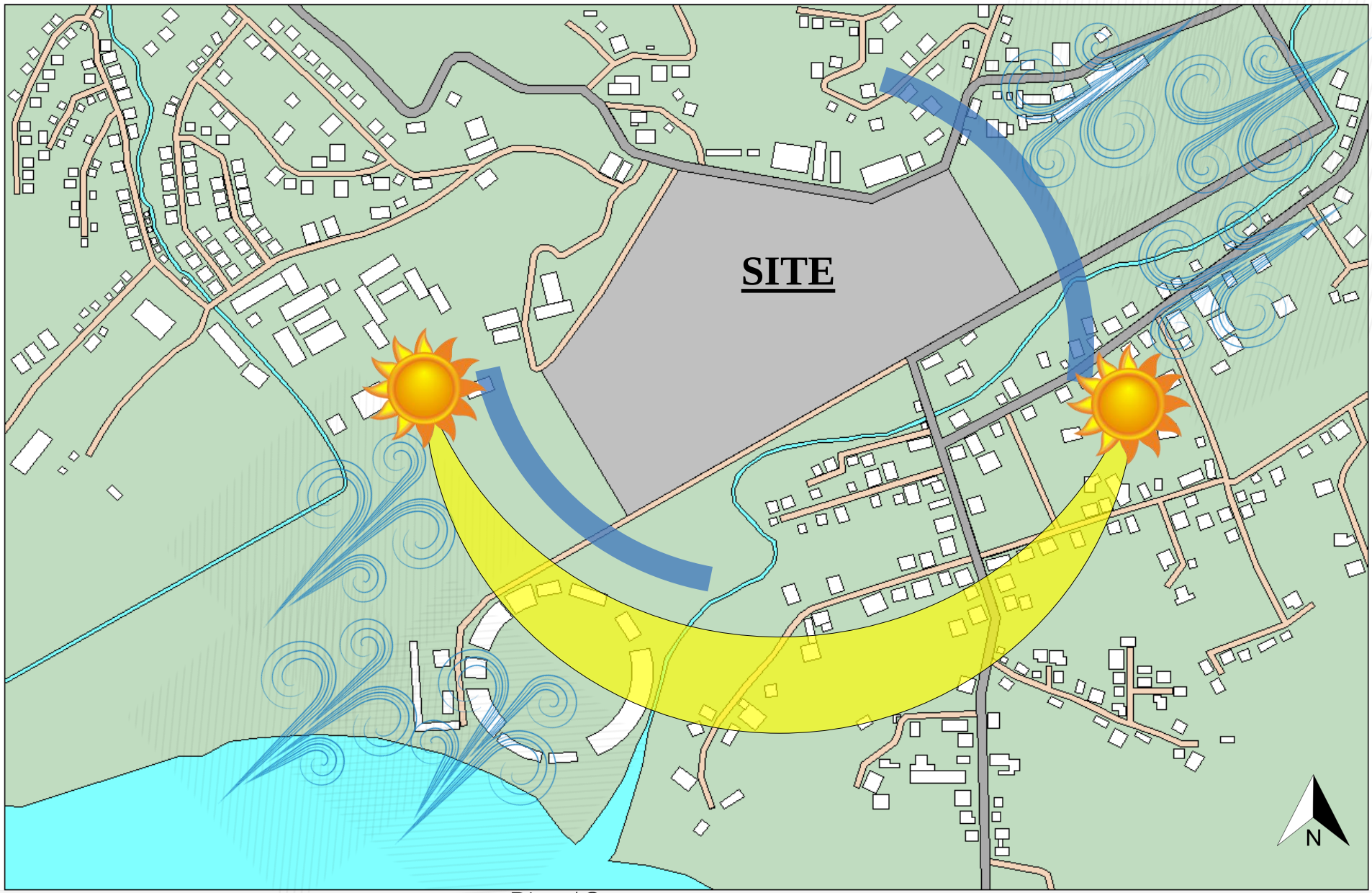
SITE



Latitude : +13.16 (13°09'36"N)
Longitude : -61.23 (61°13'48"W)
Area: 95,322.72 sq.m
Perimeter: 1310.72 m

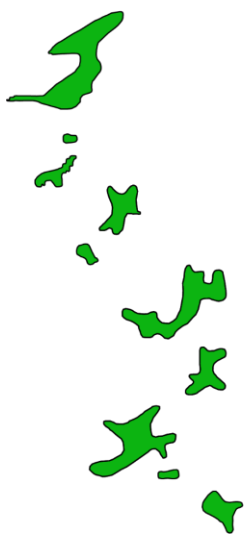
St. Vincent
& the Grenadines

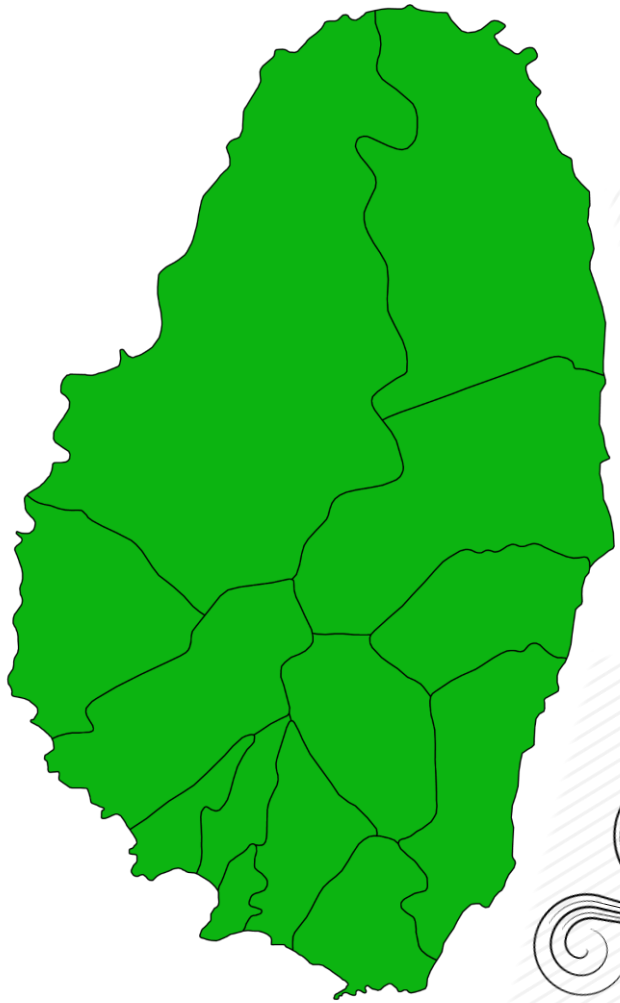




SITE
N
- Main Road
- Side Road
- River / Ocean
- Buildings
- Wind
S - 1:5000

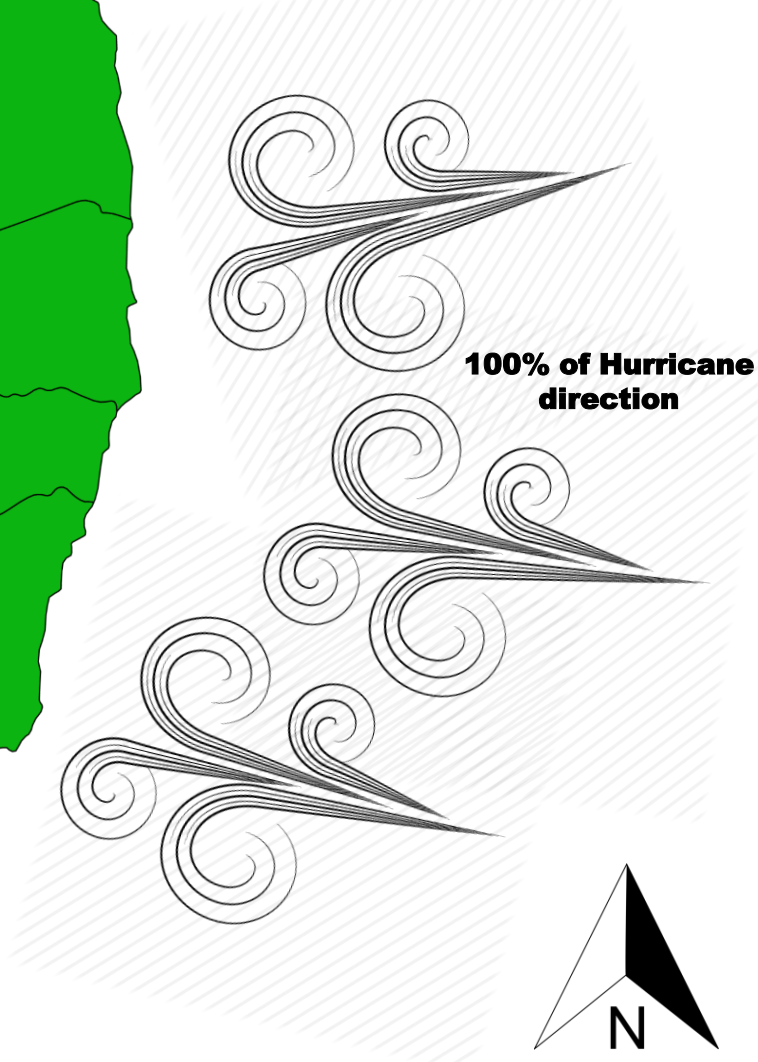
St. Vincent & the Grenadines

Caribbean Sea





Atlantic Ocean

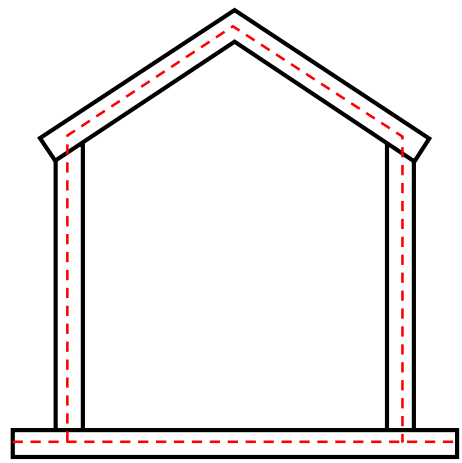


CONCLUSION

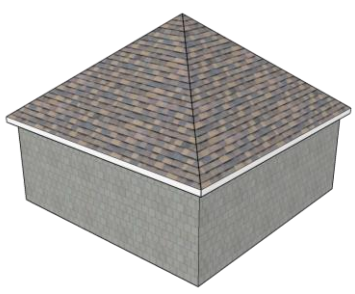
Summary

Base on the information gathered during this research, one possible solution is to integrate the structural system and the architectural elements into a **single building system** which will reduced the number of inter-component connections.

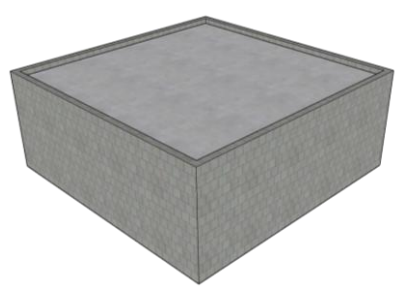
single building system



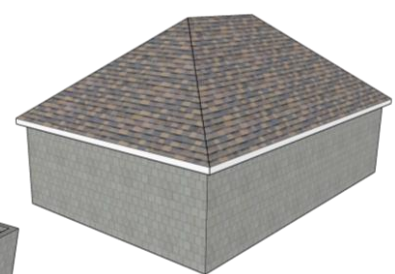
The roofing systems proposed are to promote hurricane resilience of buildings and the system is designed to satisfy SVGBCG requirements. The proposed system is not only improved structurally to resist extreme winds during hurricanes, it is also environmentally sustainable, durable and low maintenance. **All these attributes were achieved with an innovative combination of two or three existing roof designs or types, which are, pyramid, hip and flat roofing type**. The new roofing system is designed to withstand winds up to category 5 hurricanes.



Pyramid Roof



Flat Roof

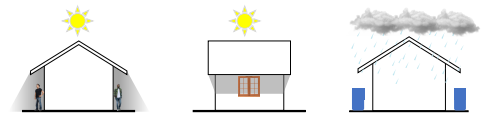


Hip Roof

Conclusions

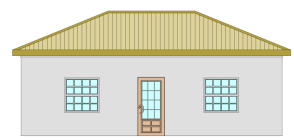
Issues noted during Research:

- Most home owners prefer long eaves for: 1. Shade, 2. Water drainage



- Roofs with long eaves are far easier to be lift off during a hurricane.

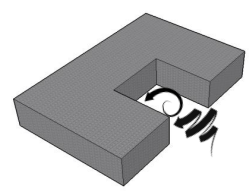
- More than 60% of damages houses had low sloped roofs.



- Insufficient materials are being use during construction.

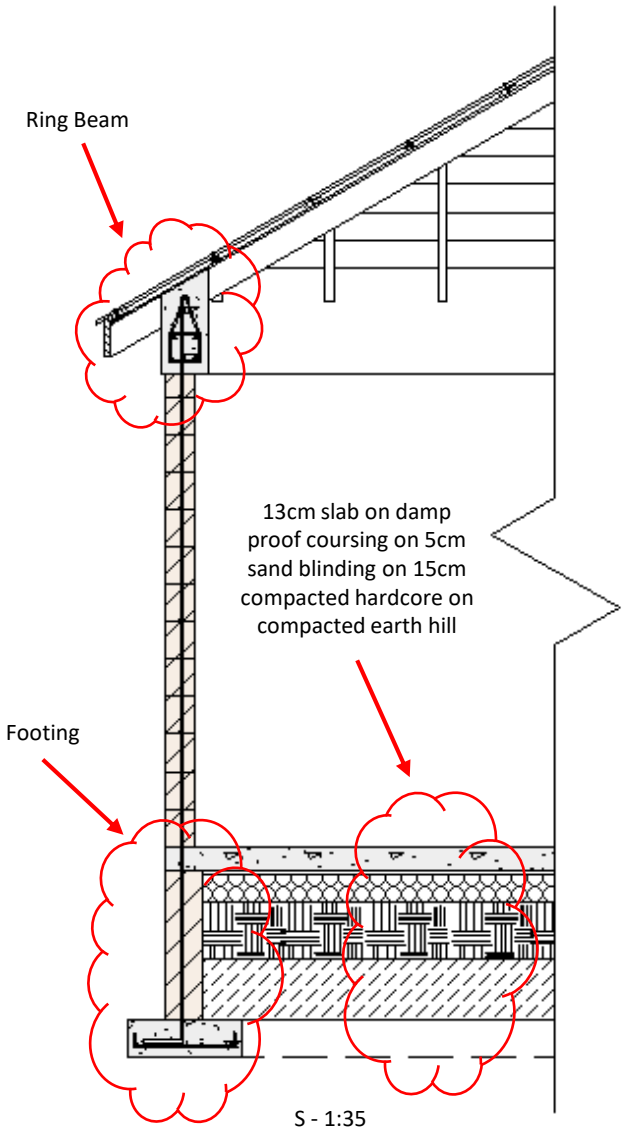
- Some roofing materials are not durable for strong hurricane winds.

- House designs with indented spaces creates potential for wind to circulate and lift.



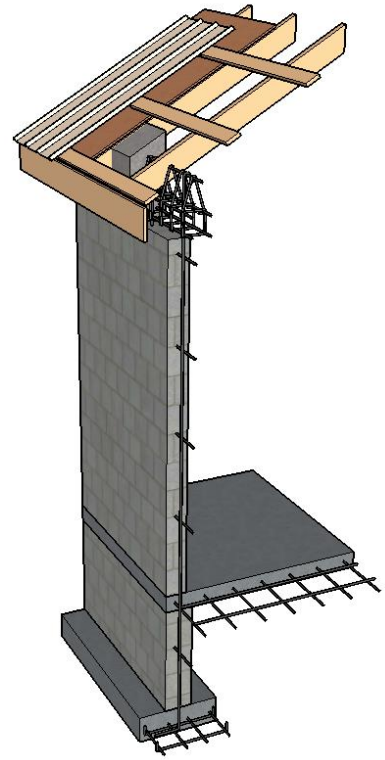
- Roof to walls need to have a stronger connection.

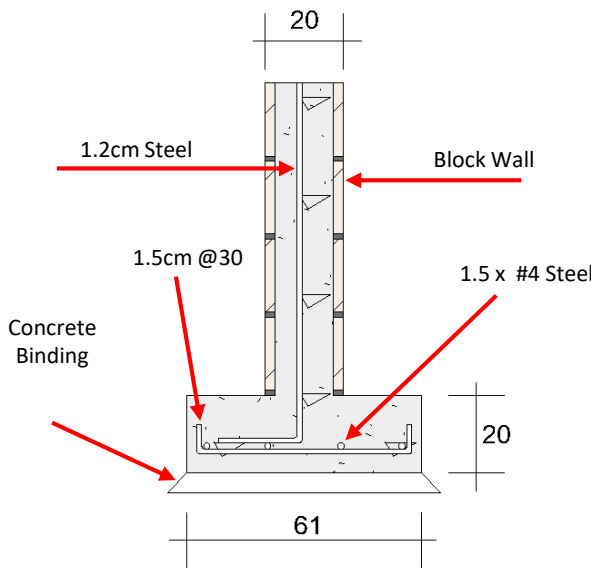
PROPOSAL



S - 1:35

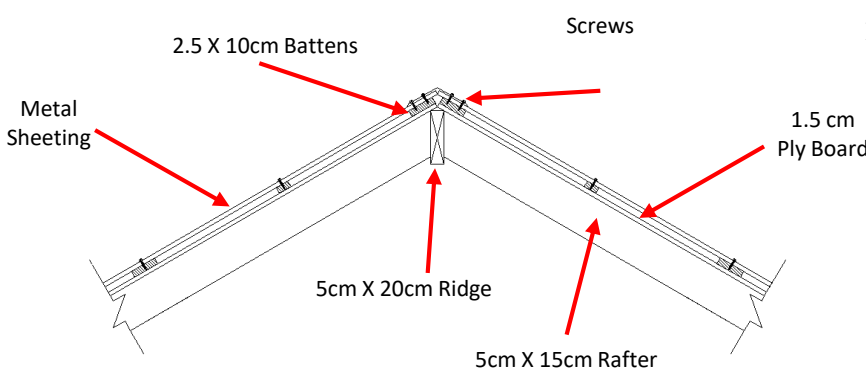
Section Detailing





Footing
Drawn by Author

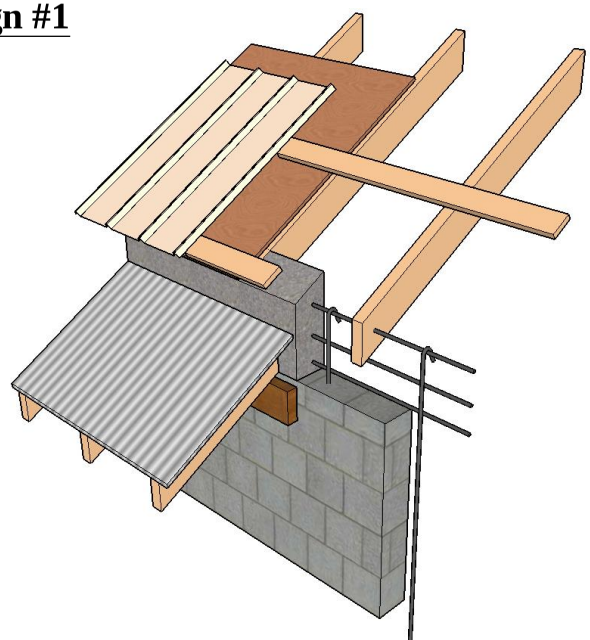
S - 1:20

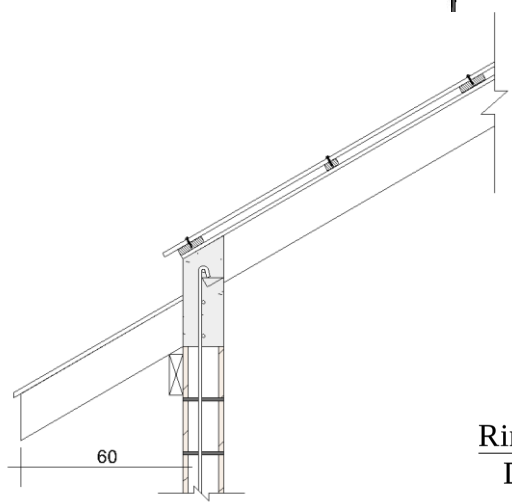


Ridge Joinery S - 1:25

Proposed Design #1

Roof Type
2 & 3



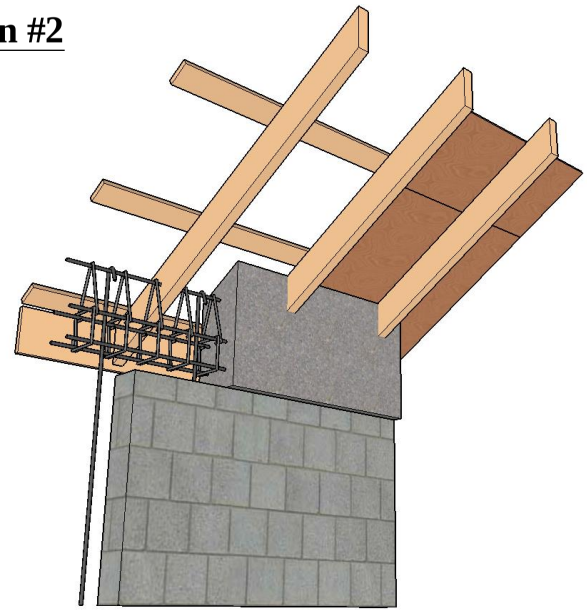


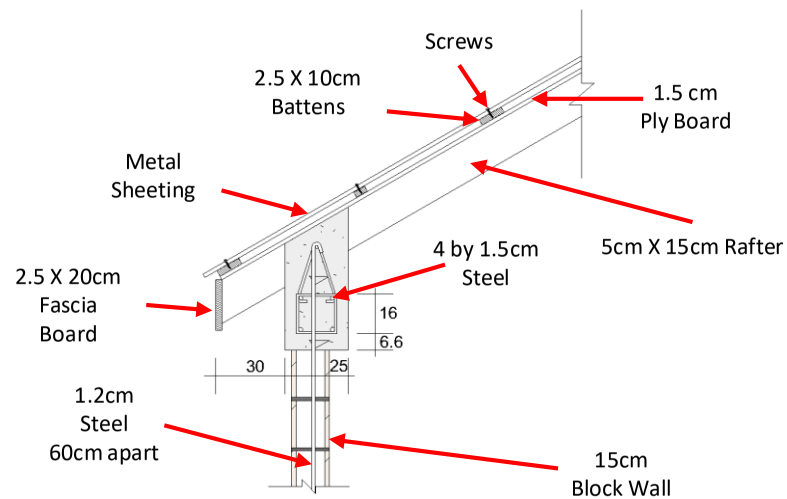
S - 1:25

Ring Beam Detailing
Drawn by Author

Proposed Design #2

Roof Type
2 & 3

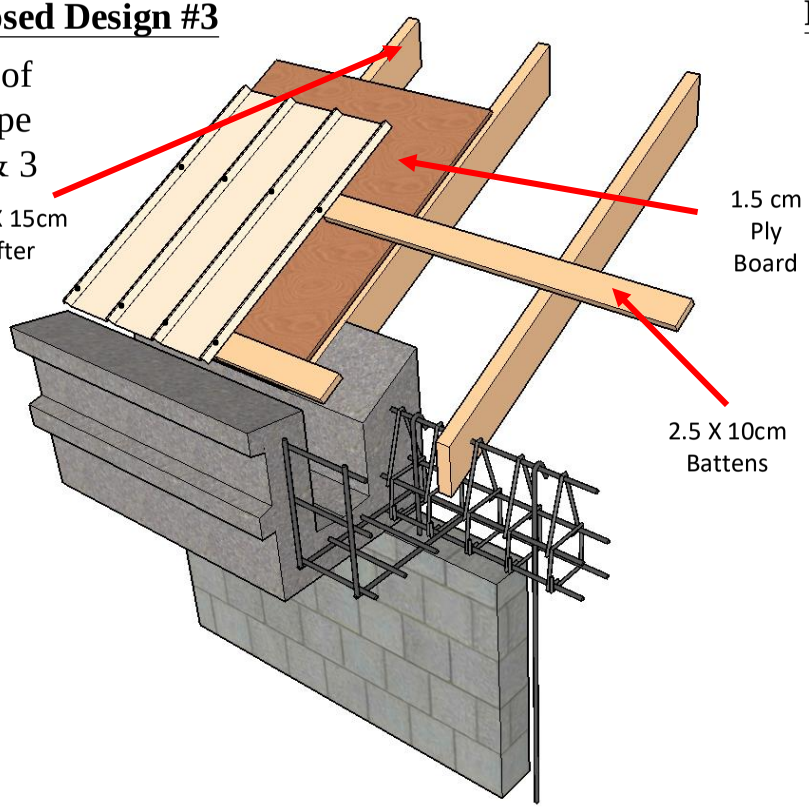


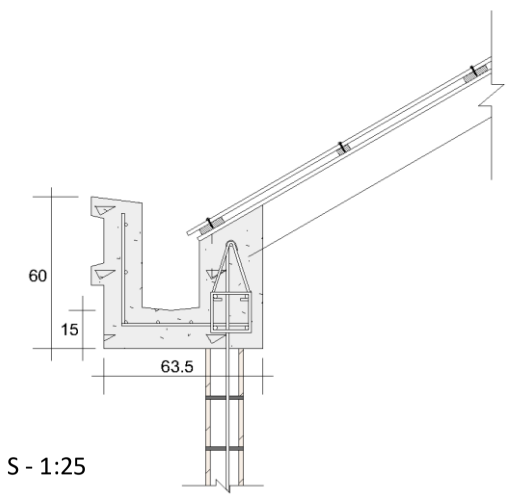


S - 1:25

Proposed Design #3

Roof Type 2 & 3



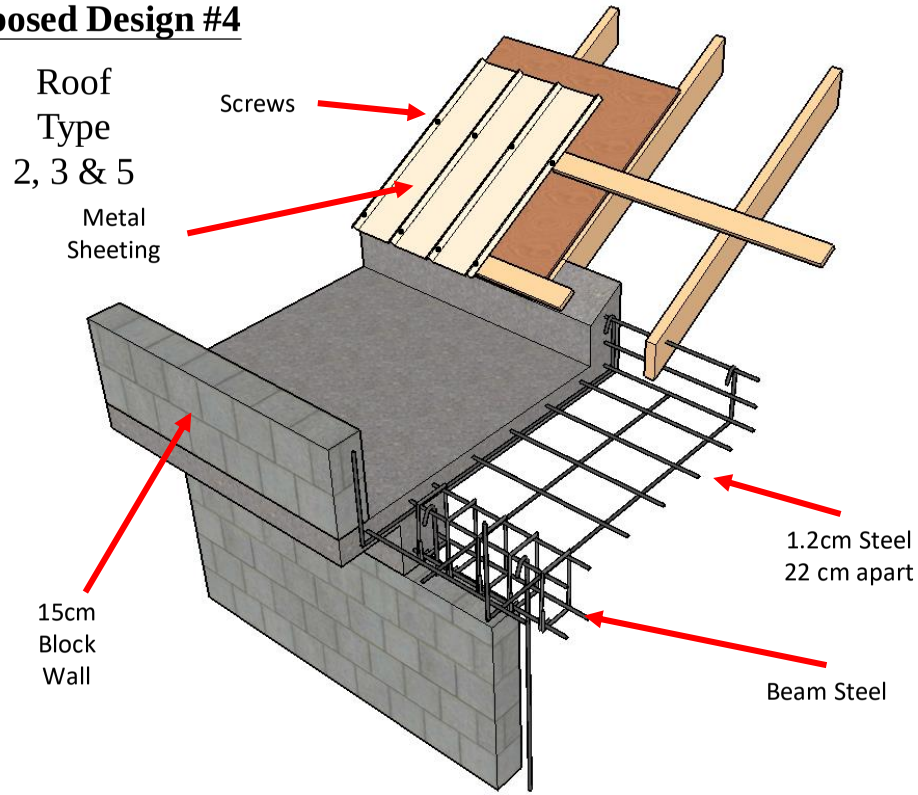


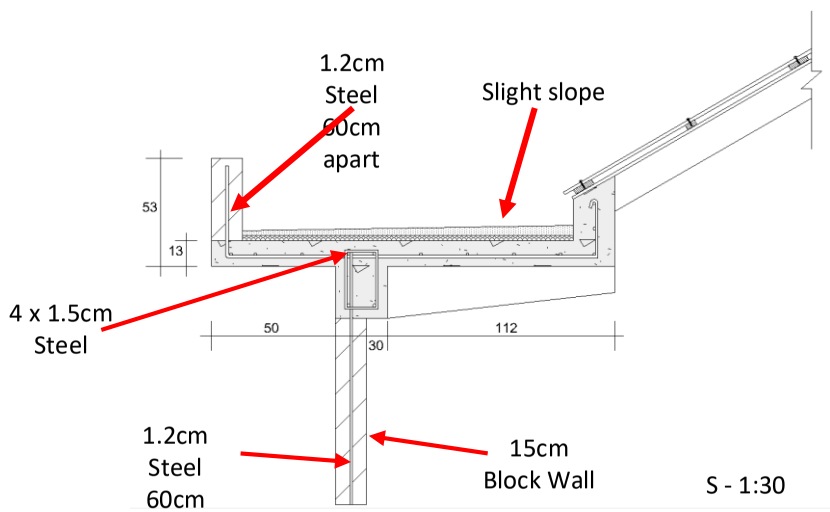
S - 1:25

Ring Beam Detailing
Drawn by Author

Proposed Design #4

Roof Type 2, 3 & 5

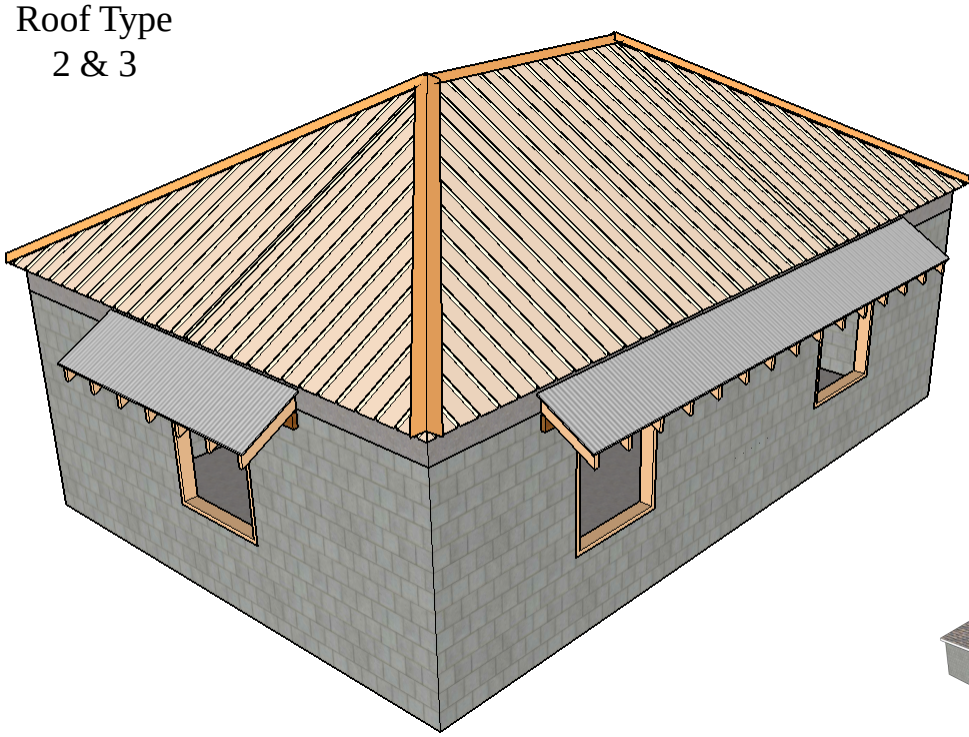


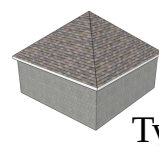


S - 1:30

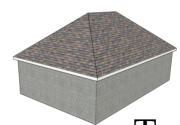
Proposed Design #1

Roof Type
2 & 3





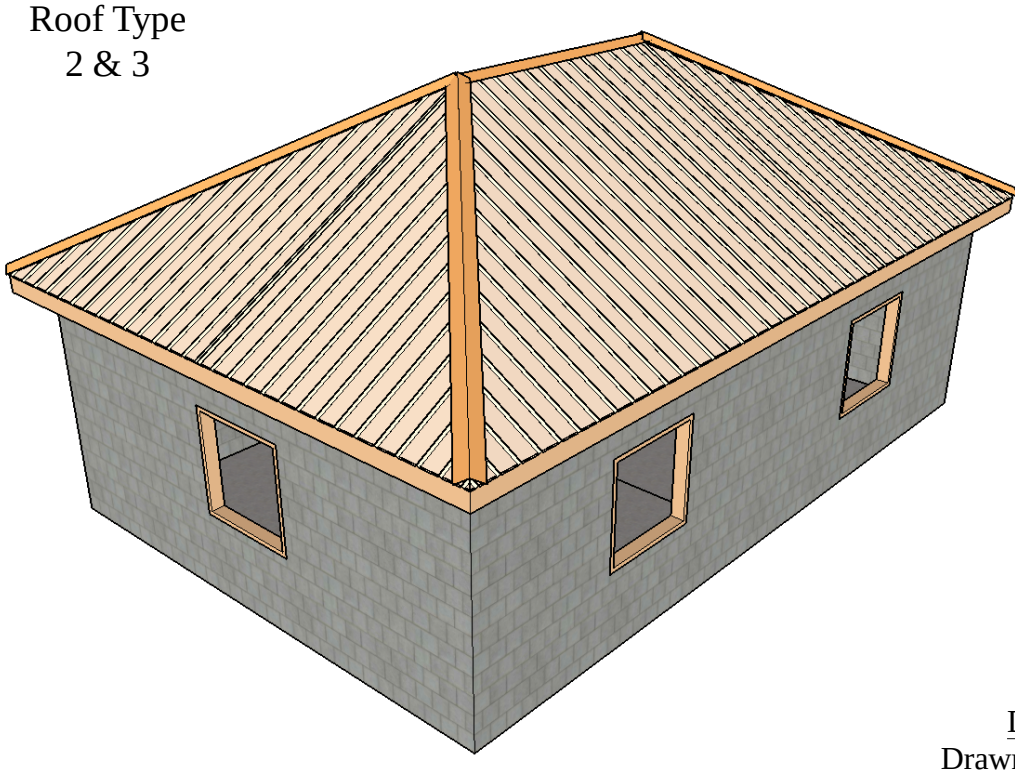
Type 2



Type 3

Proposed Design #2

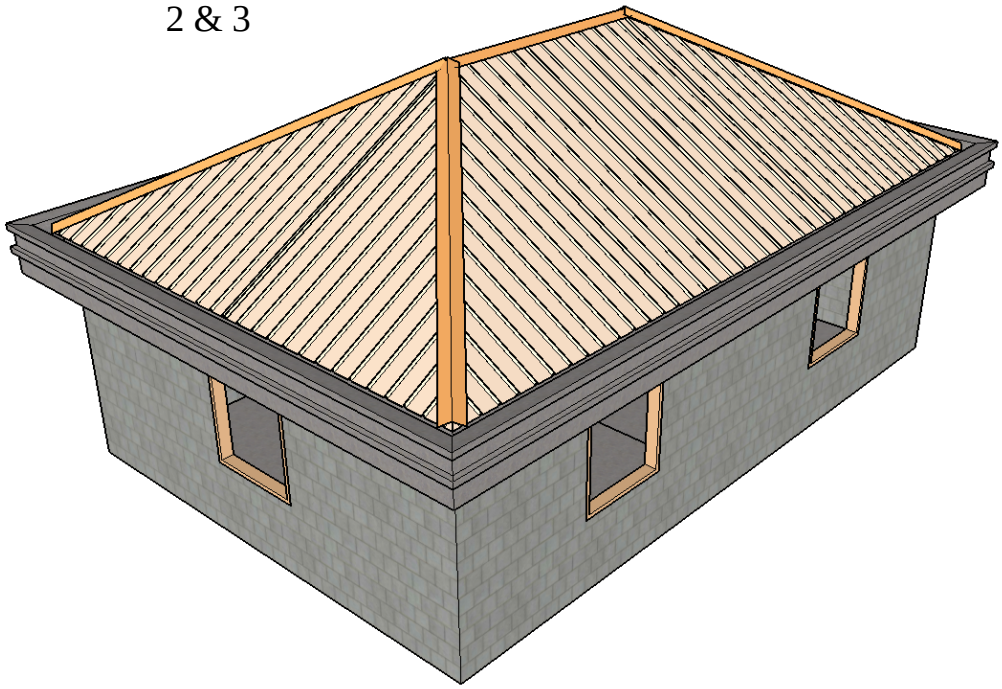
Roof Type
2 & 3

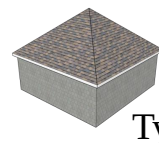


Design
Drawn by Author

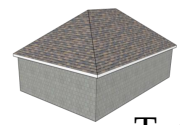
Proposed Design #3

Roof Type
2 & 3





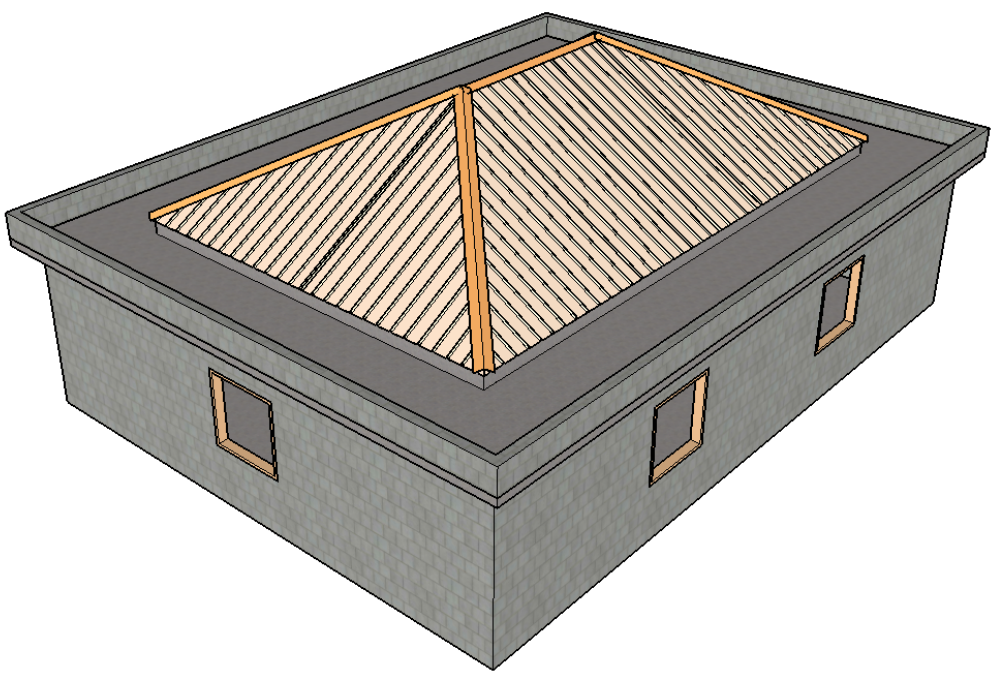
Type 2

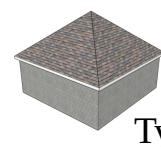


Type 3

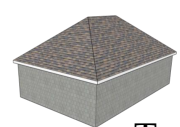
Proposed Design #4

Roof Type
2, 3 & 5

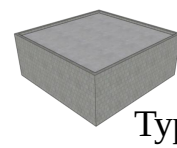




Type 2



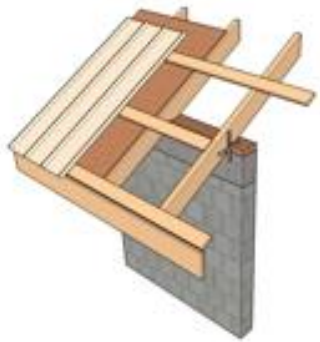
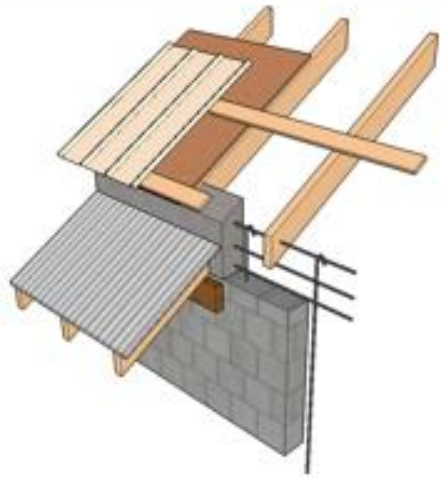
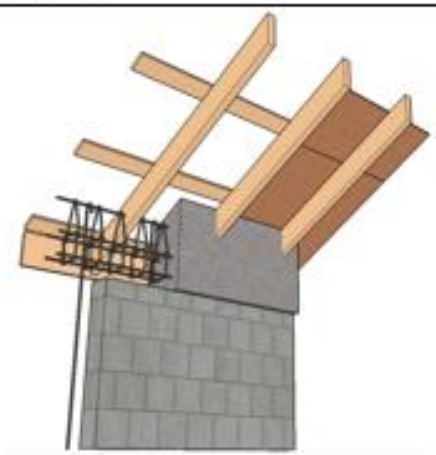
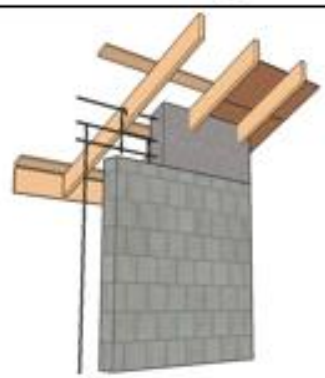
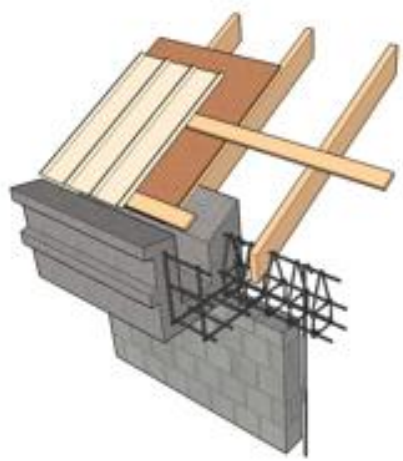
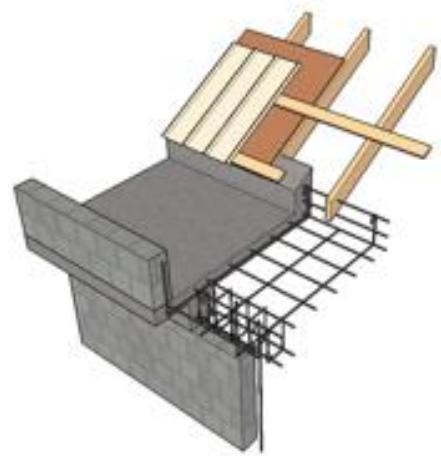
Type 3



Type 5

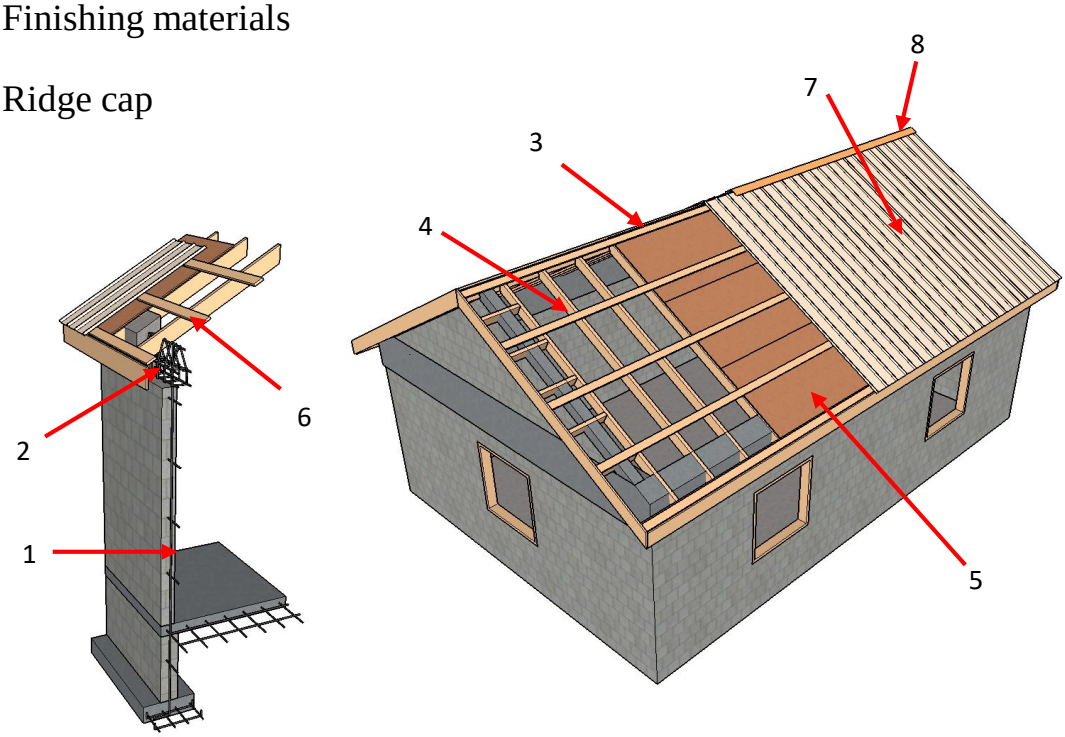
Design
Drawn by Author

Past & Current vs Proposed

Traditional & Current Designs	Proposed Designs	
Traditional Roofing Connection 	 Proposed Design #1	 Proposed Design #2
Past Connection 		
Current Connection 	 Proposed Design #3	 Proposed Design #4

Building Process of joinery.

1. During blocking process insert 1.2cm steel 60cm apart vertically between blocks, which will later be use to connect to the rafter steel.
2. Boxing of Ring beam with steel work inside (25cm x 25cm)
3. Ridge - 5cm x 20cm
4. Rafter - 5cm x 15cm (60cm apart on center)
5. Ply board - 1.5cm x 122cm x 244cm
6. Battens - 2.5cm x 10cm (60cm apart on center)
7. Finishing materials
8. Ridge cap



Place rafters on top of boxing prepared for casting of ring beam. Punch hole in each rafter, then insert ½" steel in punched hole. Tie 1.2cm steel to beam steel using 0.9cm stirrups.

Future Research

The first line of defense during a hurricane is the building exterior. The same concept used in this study can be implemented in creating an innovative building structure, which will include both the roof and walls. Therefore, a future research can be developed using this same concept, to create stronger walls to protect buildings from other natural disasters. Also, the proposed roofing system can be used in other countries that is facing the similar issues during a hurricane. Therefore, it would be good to develop this system, not only for roofing but also for the entire building frame structure.

REFERENCES

"Investors Clinic", accessed June 2019, http://www.investors-clinic.com/knowledge

"Chuan Song Me", accessed June 2019, http://www.chuansongme.com/roof

"Harrington & Company", accessed May 2019," http://www.harringtonco.com/roofing-supplies

"Ehssan Amir Sayyafi", accessed June 2019, http://www.researchgate.net/researchstudent

"Collis Roofing", accessed May 2019, http://www.Collisroofing.com/hurricaneseason

"PV Education", accessed April 2019, http://www.PVeducation.com/solar-concepts/

"Valley View Roofing", accessed June 2019, http://www.valleyviewroofing.net/what-are-inexpensive-roofing-materials/

"Doug White Architects", accessed May 2019, http://www.dwacaribbean.com/design-guidelines-for-hurricane-resistant-buildings/

"Mason Inc", accessed June 2019, http://www.masconinc.com/roofing/residential-roofing-options/asphalt-shingles/

"Roofing Key", accessed May 2019, http://www.roofingkey.com

"Miller Home Improvement", accessed April 2019,

http://www.millershomeimprovement.com/roofing-clinton-township-mi/repairs-of-all-kinds/

"DnB Roofing", accessed June 2019, http://www.dnbroofing.com/roofing-gallery/

"Roofing Compare", accessed June 2019, http://www.roofingcompare.com/materials/metal-roofing.html

"Ropa Roofing", accessed April 2019, http://wwww.Roparoofing.com/residential-roofing-denver-co/

"Home Logic", accessed June 2019, http://www.homelogic.co.uk/services/protective-walls

"Mas Mistral", accessed May 2019, http://www.mas-mistral.com/2019/05/22/common-types-of-commercial-epdm-roofing-damage/

"Carib Surf", accessed April 2019,

http://www.caribsurf.net/svg/mapssaintvincent.html

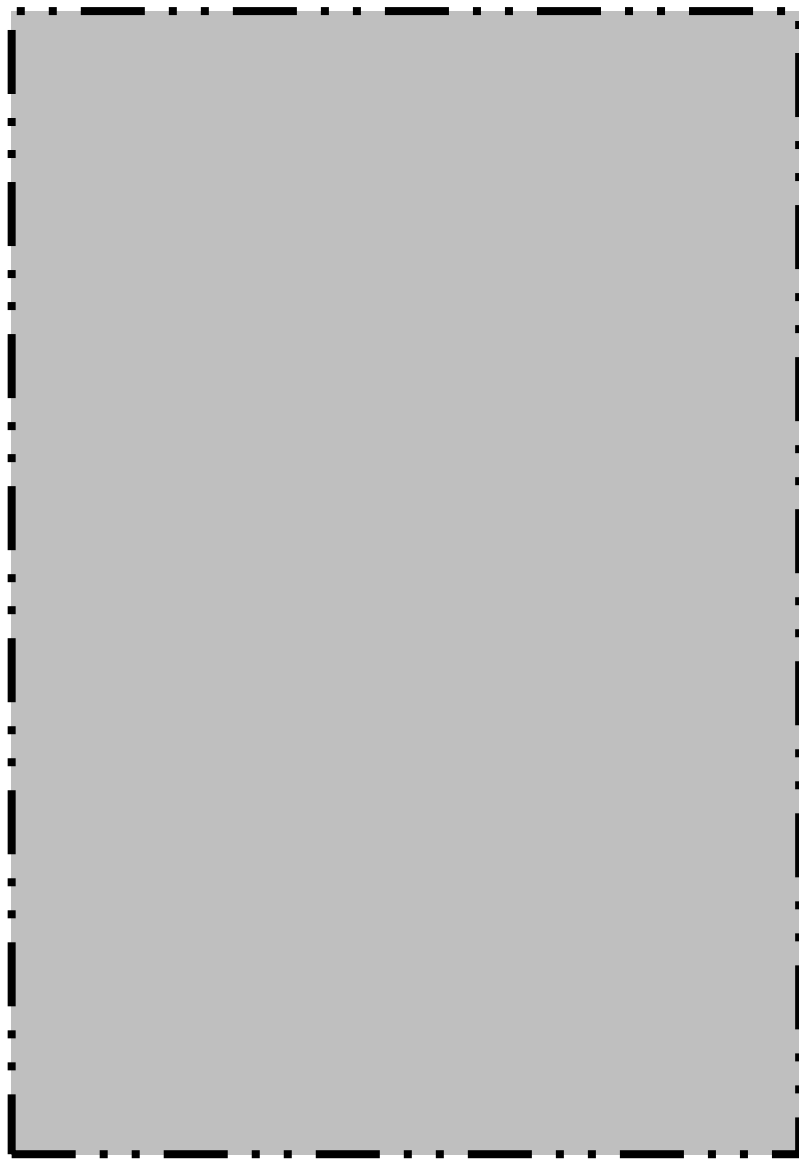
"Delaurier Roofing & Renovation", accessed June 2019, http://www.calldrr.com/metal-roofing/

"Gerard Roofs", accessed June 2019, http://www.gerardroofs.eu/en/products

Dr. Rima Taher
New Jersey Institute of Technology
Florida's Home Shapes And Roofs That Hold Up Best In Hurricanes

"TNT Roofing", accessed April 2019, http://www.tntcogroup.com/portfolio/

"HomeTech", accessed June 2019, http://www.hometechs.org/residential-and-commercial/



Experimental Design Studio

To analyze and critically apply determinations of Anthropocene responding to the alternative way of architecture, precinct and urban designs base on new knowledge in describing the momentous shift in Earth's operating systems and land use functions and urban spatial qualities.

02

Project Location:

Taichung Port

Directed by:

Kuowei Chiu

Group Members:

Zhaoyang

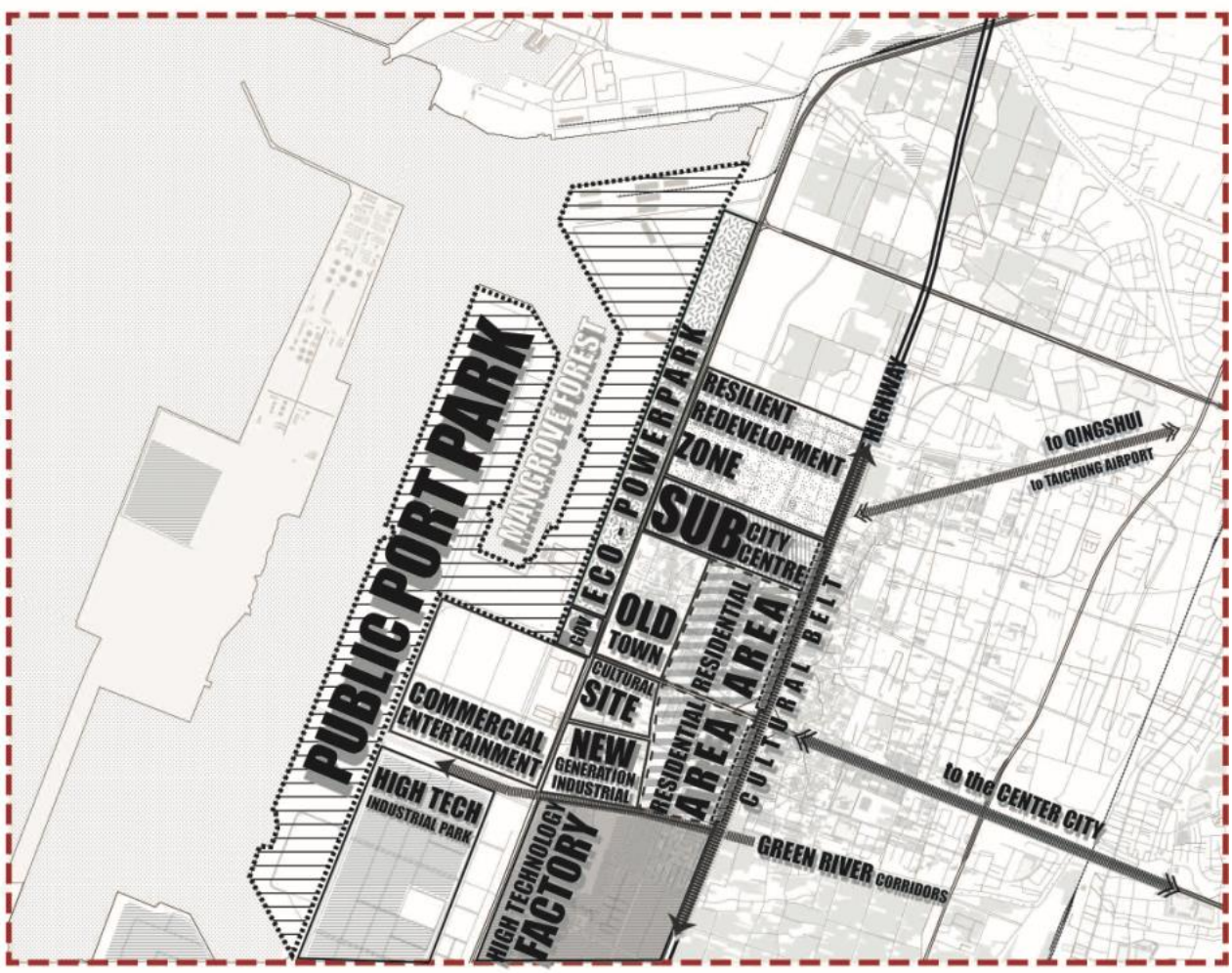
James Campbelle

Kezia Yemima Aprilia

Mingwei Cai

Hana Li

Wuqi is a small town that was developed from the year 1978 when the Taichung Port completed.
It has a special definition in the development process and is critically linked to the coastline railway and the West Coast port process.
In the future, it will develop into a coastal city, of the developing Taichung city.
In the process of 2050, how to deal with possible threats and opportunities? how to become a strategically positioned city? And how to deal with the relation between airport, Qingshui, Shalu, Longjing district and Wuqi area?



OLD WUQI STREET
Thousands of empty houses need to be preserved rather than to be demolished.

HIGH DENSITY DISTRICT
Only small amount of greening space in such a high dense areas especially in the Old town area.

SCHOOL DISTRICT OF THE EXISTED ORDER
Children's safety in going school should be prioritized in design of the hierarchy of the existing block's regeneration.

ORDERLY PLANED BLOCK
It's important to make it more human friendly pedestrian zone in the existed block.

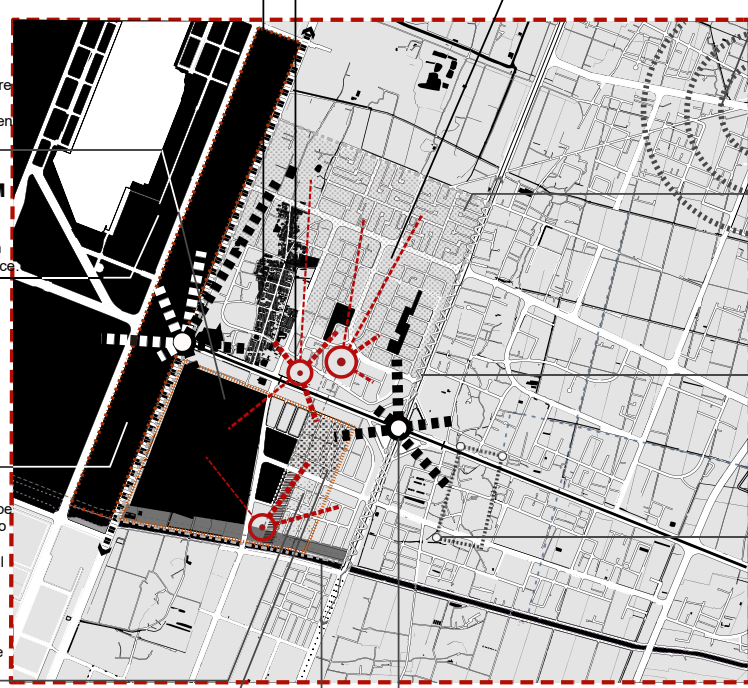
QINGSHUI DISTRICT
Because of the affection by the sub city center of Wuqi,as having the most population Qingshui district has to be connected very will with Wuqi & Taichung Port

LACK OF CONNECTION WITH TAICHUNG CITY
We don't have any reason coming this region even there is MRT. There isn't any commercial relations between Taichung.

TAICHUNG PORT TRANSFORM PUBLIC AREA
Opportunity to enhance the city's attraction by transform the port area into public space

STRIP GREEN SPACE
Taichung Port will transform into public space of Wuqi's planning but still facing the problem. (landuse/access)
The No.61 road cut the obstructs the Taichung Port and the site.

MIXED-USE BLOCK
The new pianning area will be a mixed-use block.So how to deal with the relationship between public & residencial in a good qulity.
Night market shows a traditional commercial axis parallel to the green blet constitute by garden and the baseball field.



Soil liquefaction AREA
This region had detected for soil liquid so its easy to be destroyed by earthquake or other natural disaster without structure reinforcement .

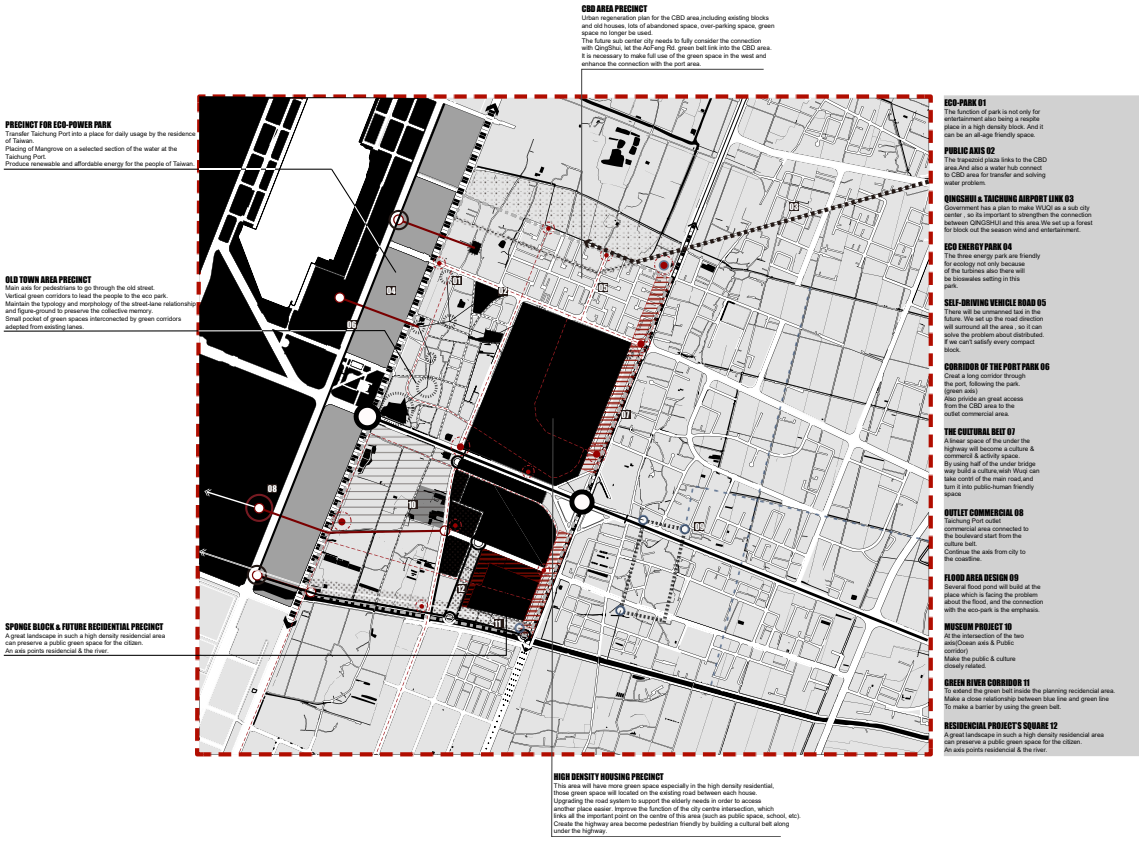
UNDER THE HIGHWAY LINEAR SPACE
Limitation growth of Wuqi is caused by the location of the highway which splits the area into 2 different sections.
Highway traffic causes different kinds of pollutions such as noise and air pollutions.

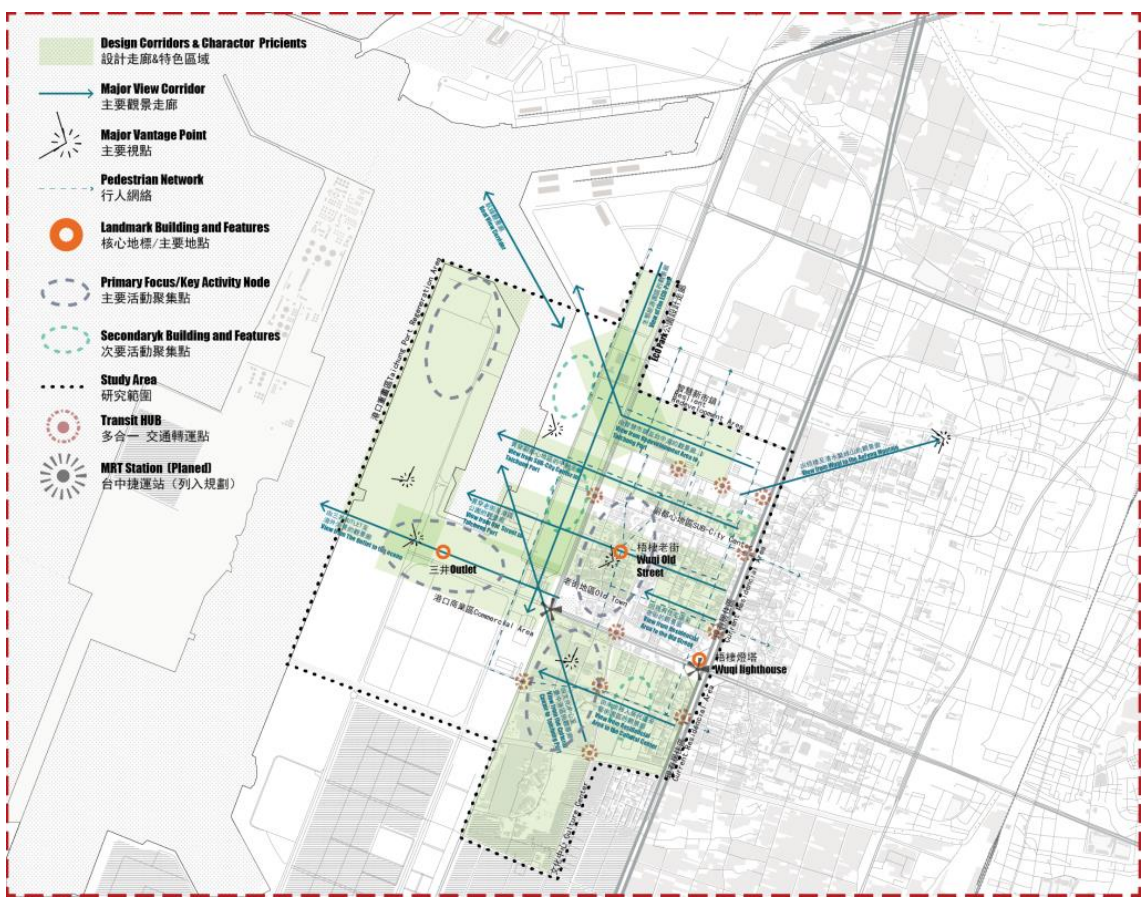
THE FLOODED AREA
The design of this city is not ready to face any sudden disasters.
There are few hidden flooded spots near the site. (450mm)
Consider about the existing grid of water system.

MRT STATION AREA
MRT station (not finish yet)should have good connection with other area,especially residencal, commercial,education, public space
Also the transportation of the inside blocks.

PLANED HIGH DENSITY RESIDENCIAL
The concept of new residential area to fulfill the housing needs as the response of the increasing population (immigrants data on 2032) has effects to the precincts area, such as, lack of green space in the future.

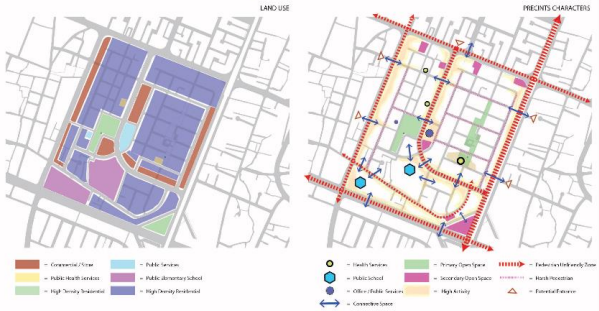
TRAIL ALONG THE RIVER PEDESTRIAN
Wuqi's Da Pai Shui river has lot of pollutants that make the water dirty and give off bad smells.

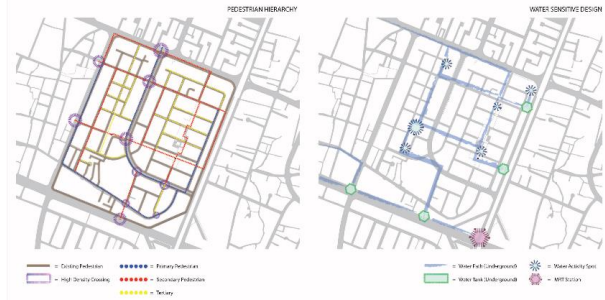

CBD AREA PRECINCT
Urban regeneration plan for the CBD area,including existing blocks and old houses, lots of abandoned space, over-parking space, green space no longer be used.
The future sub center city needs to fully consider the connection with QingShui, let the AiFeng Rd. green belt link into the CBD area.
It is necessary to make full use of the green space in the west and enhance the connection with the port area.
PRECINCT FOR ECO-POWER PARK
Transfer Taichung Port into a place for daily usage by the residence of Taiwan.
Placing of Mangrove on a selected section of the water at the Taichung Port.
Produce renewable and affordable energy for the people of Taiwan.
OLD TOWN AREA PRECINCT
Main axis for pedestrians to go through the old street.
Vertical green corridors to lead the people to the eco park.
Maintain the typology and morphology of the street-lane relationship and figure-ground to preserve the collective memory.
Small pocket of green spaces interconected by green corridors adapted from existing lanes.
SPONGE BLOCK & FUTURE RECIDENTIAL PRECINCT
A great landscape in such a high density residencial area can preserve a public green space for the citizen.
An axis points residencial & the river.
HIGH DENSITY HOUSING PRECINCT
This area will have more green space especially in the high density residential, those green space will located on the existing road between each house.
Upgrading the road system to support the elderly needs in order to access another place easier. Improve the function of the city centre intersection, which links all the important point on the centre of this area (such as public space, school, etc).
Create the highway area become pedestrian friendly by building a cultural belt along under the highway.
ECO-PARK 01
The function of park is not only for entertainment also being a respite place in a high density block. And it can be an all-age friendly space.
PUBLIC AXIS 02
The trapezoid plaza links to the CBD area.And also a water hub connect to CBD area for transfer and solving water problem.
QINGSHUI & TAICHUNG AIRPORT LINK 03
Government has a plan to make WUQI as a sub city center , so its important to strengthen the connection between QINGSHUI and this area.We set up a forest for block out the season wind and entertainment.
ECO ENERGY PARK 04
The three energy part are friendly for ecology not only because of the turbines also there will be bioswales setting in this park.
SELF-DRIVING VEHICLE ROAD 05
There will be unmanned taxi in the future. We set up the road direction will surround all the area , so it can solve the problem about distributed. if we can't satisfy every compact block.
CORRIDOR OF THE PORT PARK 06
Creat a long corridor through the port, following the park. (green axis)
Also privide an great access from the CBD area to the outlet commercial area.
THE CULTORAL BELT 07
A linear space of the under the highway will become a culture & commercil & activity space.
By using half of the under bridge way build a culture,wish Wuqi can take contr of the main road,and turn it into public-human friendly space.
OUTLET COMMERCIAL 08
Taichung Port outlet commercial area connected to the boulevard start from the culture belt.
Cordinue the axis from city to the coastline.
FLOOD AREA DESIGN 09
Several flood pond will build at the place which is facing the problem about the flood, and the connection with the eco-park is the emphasis.
MUSEUM PROJECT 10
At the intersection of the two axis(Ocean axis & Public corridor)
Make the public & culture closely related.
GREEN RIVER CORRIDOR 11
To extend the green belt inside the planning recidencial area.
Make a close relationship between blue line and green line
To make a barrier by using the green belt.
RESIDENCIAL PROJECT'S SQUARE 12
A great landscape in such a high density residencial area can preserve a public green space for the citizen.
An axis points residencial & the river.
08


Design Corridors & Charactor Pricients
設計走廊&特色區域
Major View Corridor
主要觀景走廊
Major Vantage Point
主要視點
Pedestrian Network
行人網絡
Landmark Building and Features
核心地標/主要地點
Primary Focus/Key Activity Node
主要活動聚集點
Secondaryk Building and Features
次要活動聚集點
Study Area
研究範圍
Transit HUB
多合一 交通轉運點
MRT Station (Planed)
台中捷運站（列入規劃）
三井Outlet
港口商業區Commercial Area
Wuqi Old Street
Wuqi lighthouse

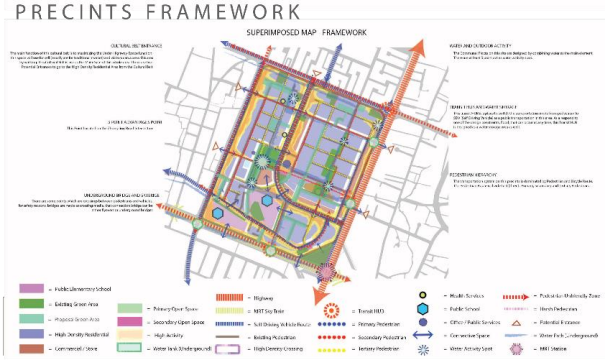
PRECINTS CONCEPTS

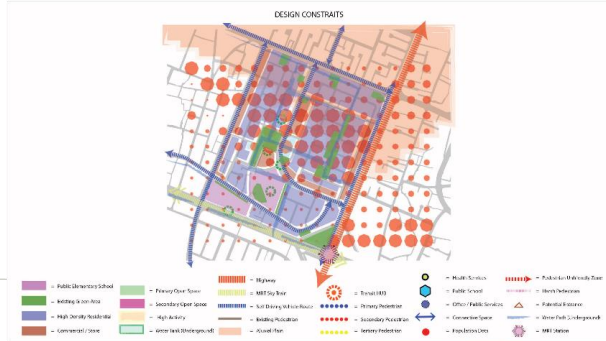
PRECINTS ANALYSIS

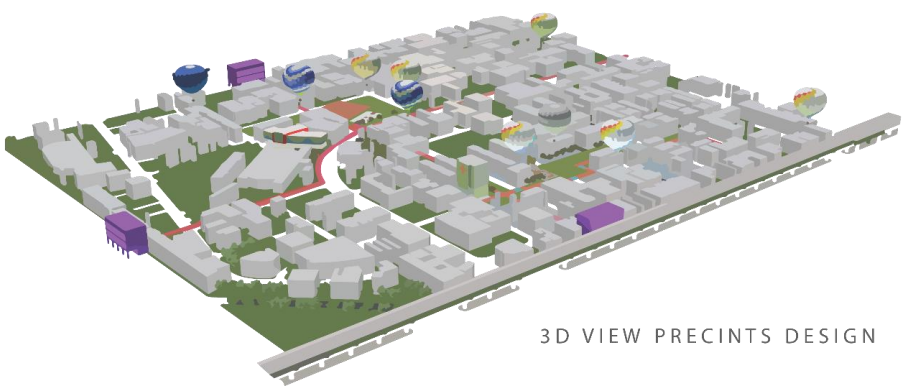




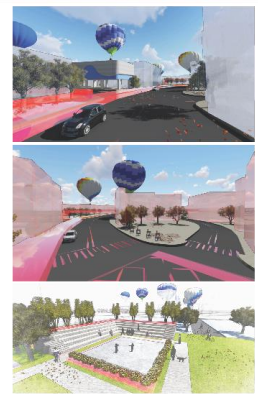
PRECINTS FRAMEWORK







3D VIEW PRECINTS DESIGN



PRECINTS SEQUENCE

City Overview

Google Images

Research Project

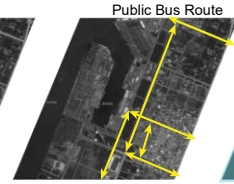
The base of this project is to develop Taichung's Wuqi District & the Port area for the year 2050 and beyond. The area that I choose to work on the development for is the Port area. The current use of this area is mostly for container storage.

Currently there is nothing interesting to do in this are for the residents of taichung, so my goal is to change that, and turn the are into a lively place that residents can enjoy on a daily basis.

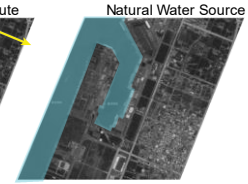
Research Site

Traffic Route

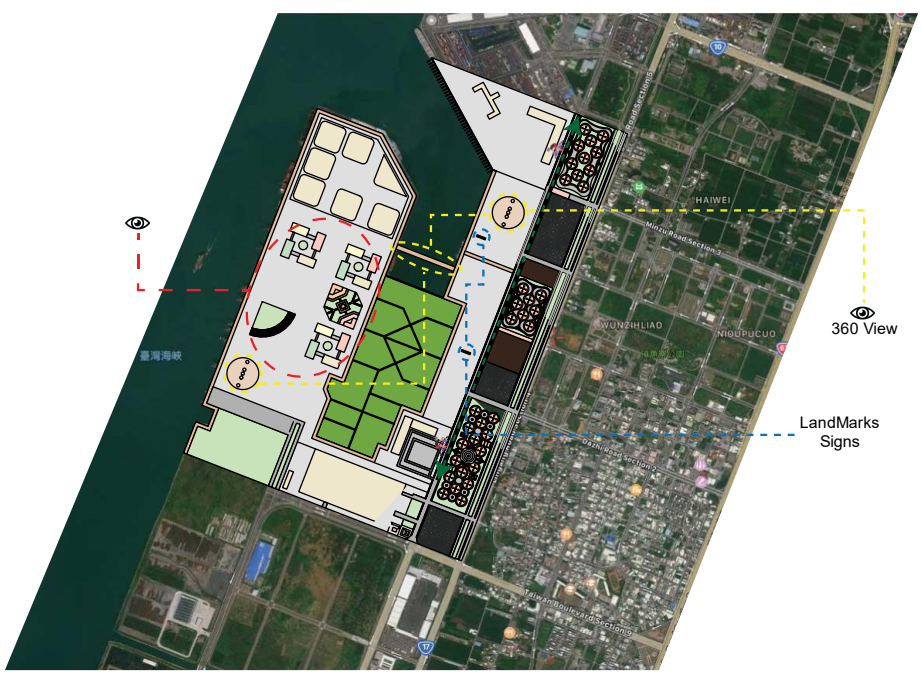
Public Bus Route



Natural Water Source

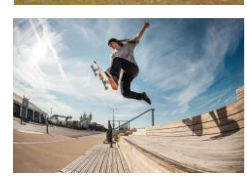


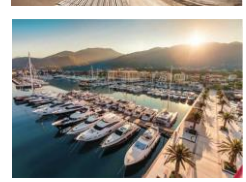
Area Overview



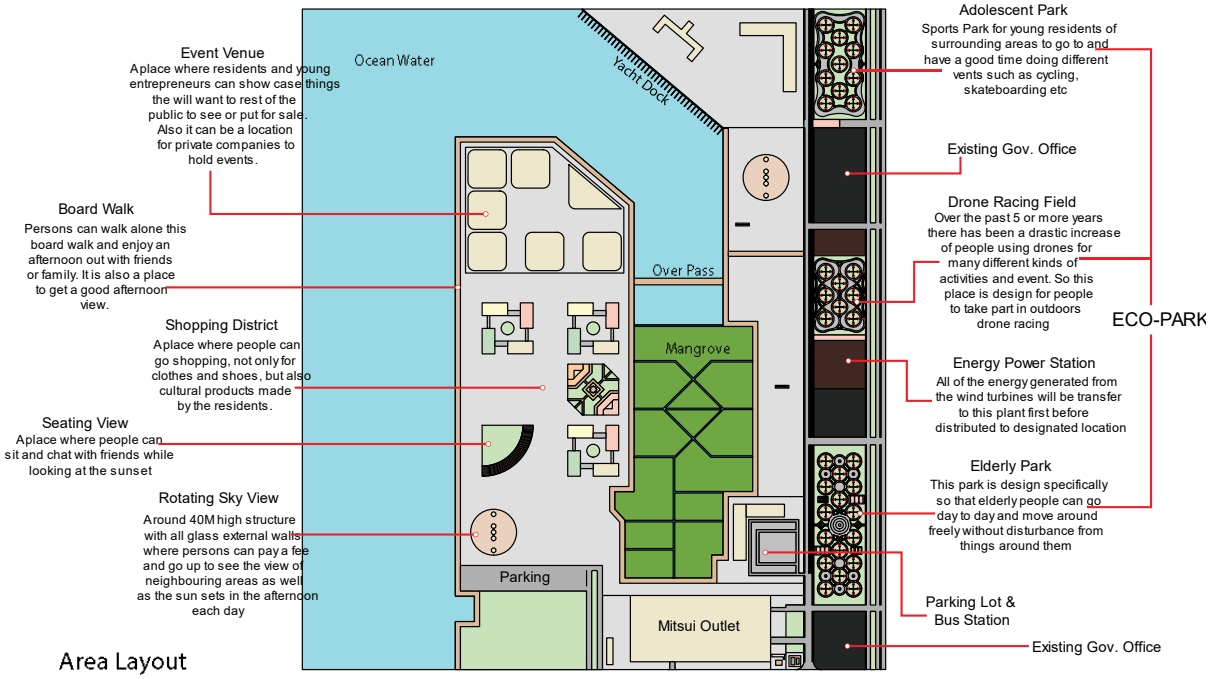
360 View

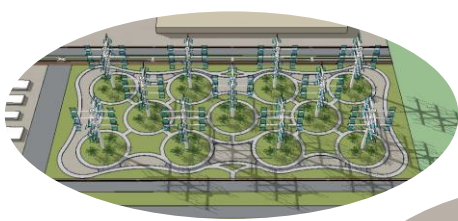
LandMarks
Signs

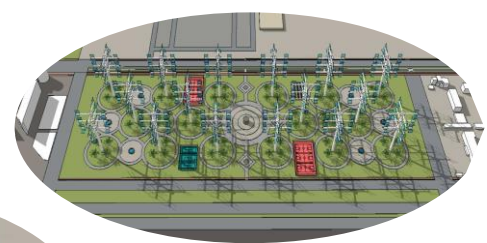


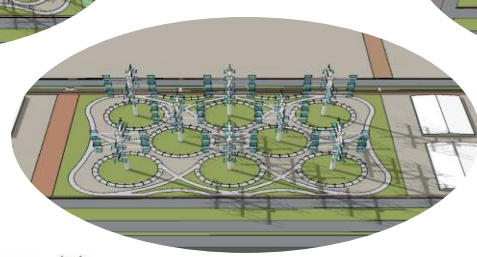


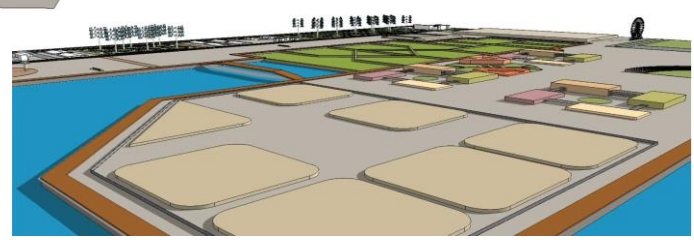
Explore

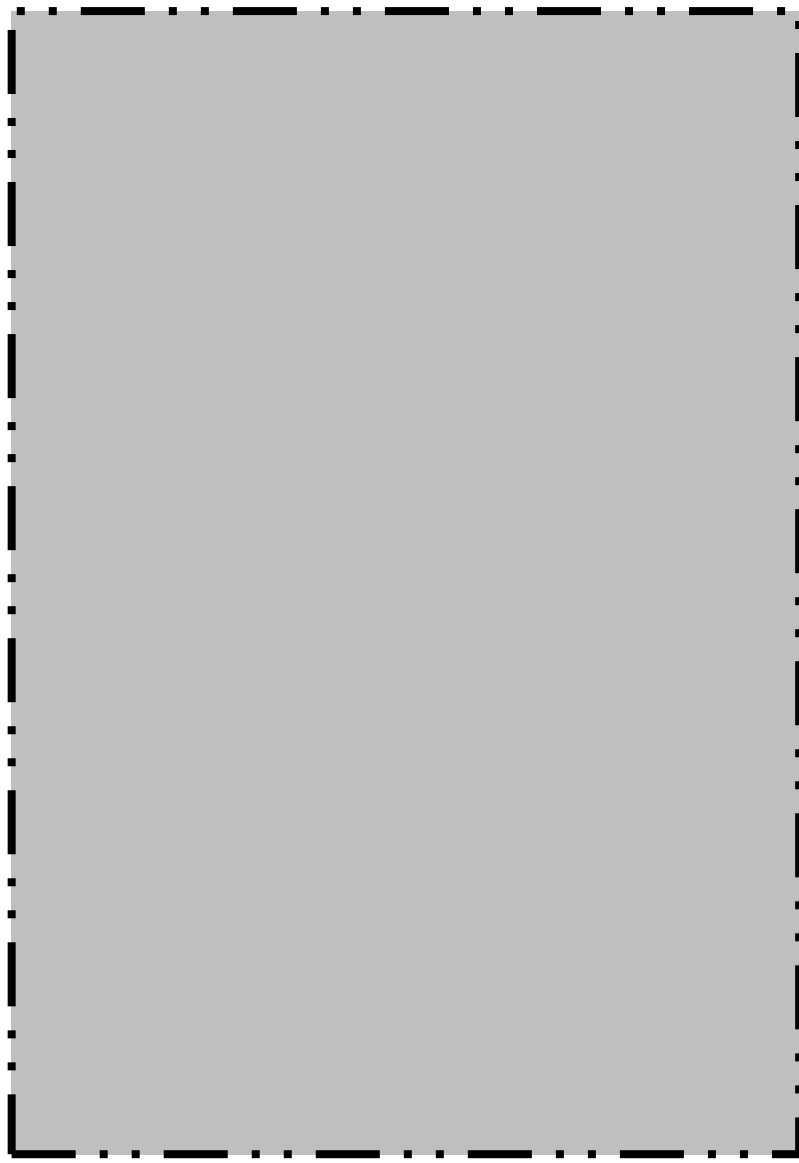

Event Venue
Aplace where residents and young entrepreneurs can show case things the will want to rest of the public to see or put for sale. Also it can be a location for private companies to hold events.
Ocean Water
Yacht Dock
Adolescent Park
Sports Park for young residents of surrounding areas to go to and have a good time doing different vents such as cycling, skateboarding etc
Existing Gov. Office
Board Walk
Persons can walk alone this board walk and enjoy an afternoon out with friends or family. It is also a place to get a good afternoon view.
Over Pass
Drone Racing Field
Over the past 5 or more years there has been a drastic increase of people using drones for many different kinds of activities and event. So this place is design for people to take part in outdoors drone racing
ECO-PARK
Shopping District
Aplace where people can go shopping, not only for clothes and shoes, but also cultural products made by the residents.
Mangrove
Energy Power Station
All of the energy generated from the wind turbines will be transfer to this plant first before distributed to designated location
Seating View
Aplace where people can sit and chat with friends while looking at the sunset
Elderly Park
This park is design specifically so that elderly people can go day to day and move around freely without disturbance from things around them
Rotating Sky View
Around 40M high structure with all glass external walls where persons can pay a fee and go up to see the view of neighbouring areas as well as the sun sets in the afternoon each day
Parking
Parking Lot & Bus Station
Mitsui Outlet
Existing Gov. Office
Area Layout











Biomimicry Challenge

Cross-disciplinary module is established to explore, discover, redefine and co-create for attempts to solve critical problems through design innovation for future environment in the epoch of Anthropocene. Biological intelligence will be scientifically analyzed and strategically translate into design actions of bio-intelligibility by the biomimicry approach.

03

Research Topic:

Plastic Pollution

Directed by:

Kuowei Chiu

Project Title:

The Micro-Plastic Filtration Device

Group Members:

James Campbelle

He Jhong-Xian

Chiu Yi-Ling

Meng Yan-Zhen

Cai Yi-Jun

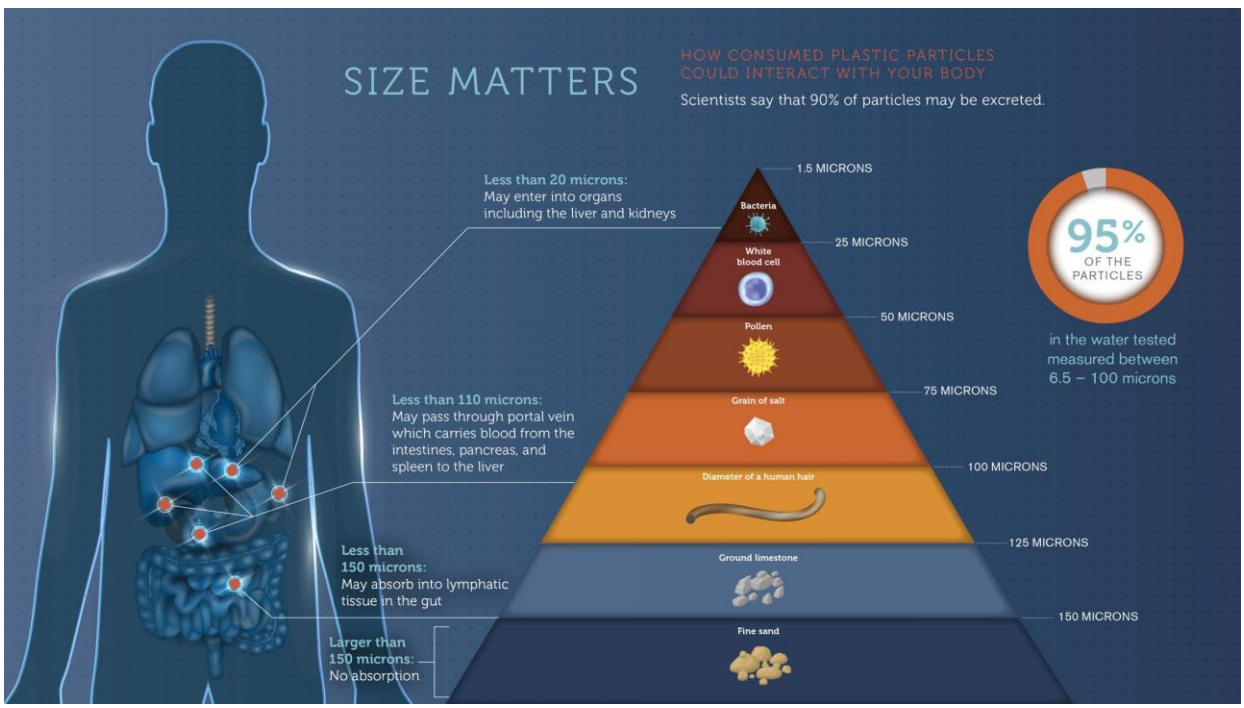

The Micro-Plastic Filtration Device

Base of research

Micro-Plastics

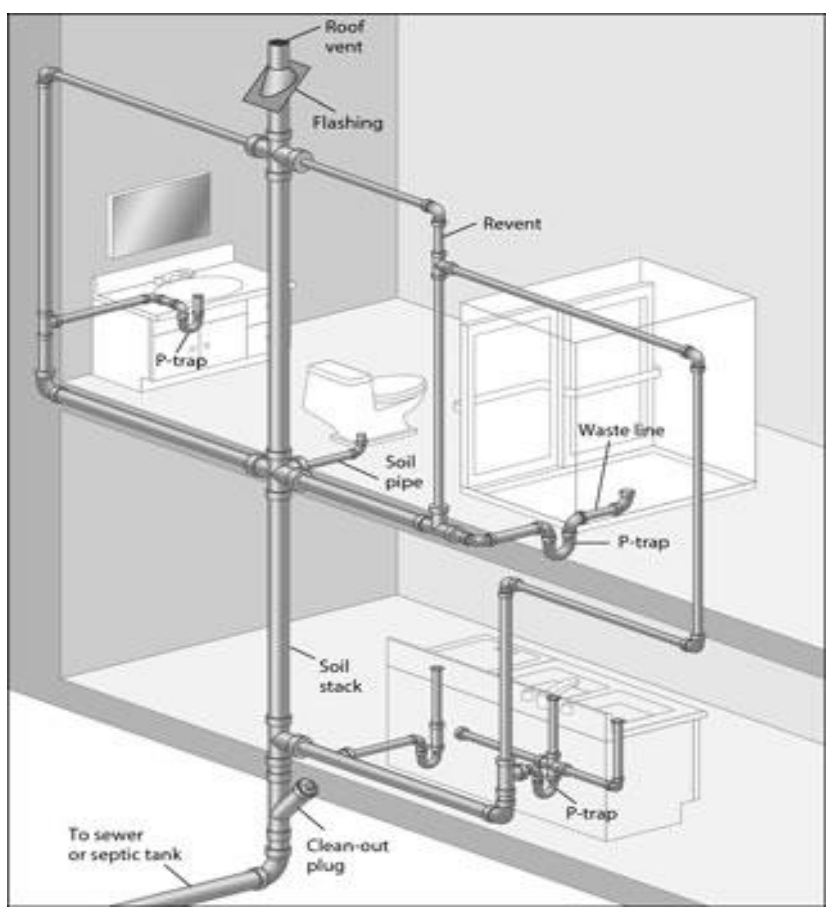
Plastic pollution, specifically microplastics, are becoming a major concern to marine life and freshwater environments. As we know Plastics are indigestible and non-biodegradable and once it is produced, it is not possible to get rid of it in any way. In the world today majority of the world's plastics either end up in the garbage, rivers, and then eventually end up in lakes and oceans. Microplastics exist everywhere especially on beaches and deeper waters. Micro-plastics are so tiny that it is often mistake for food by the marine animals. Once micro-plastics are consumed by marine animals, it then make its way to humans through ingestion or respiration. The best way to deal with this issue of micro-plastic is to control micro-plastic remains by properly handling it thorough treatment of wastewater.

Something that most people don't realize about micro-plastics is that, it is everywhere even though some of it we can't see with our naked eyes. A lot of which is coming from the household, from items that we use on a day to day basis. Sometimes we use these items several times in a single day and it gets flush down the wastewater drains without we even knowing and it makes it's way to the rivers and ocean.



Some Household Contributors of Microplastic

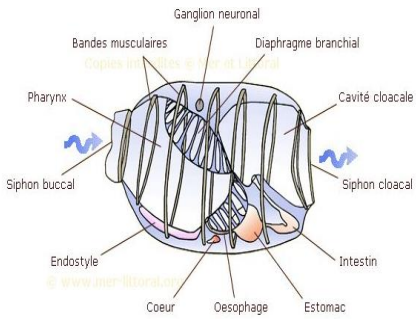
- Detergents and Disinfectants
- Toothpaste and Tooth Brush
- Clothing
- Tea bags
- Facial Scrubs
- Face Wash
- Wet Wipes



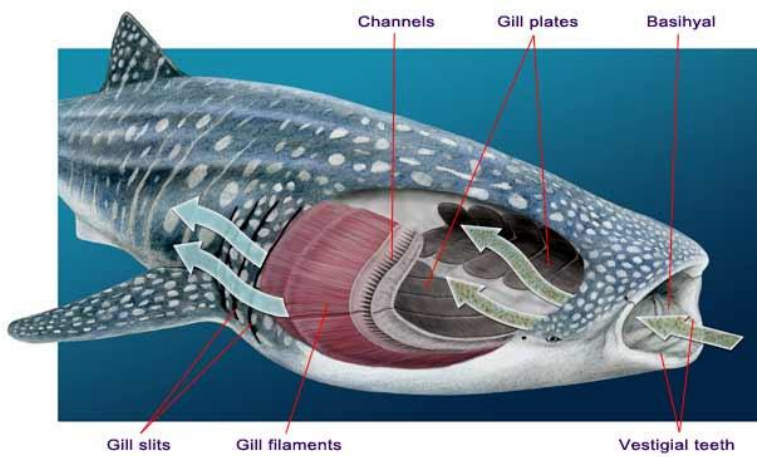
Nature's Inspiration (Peacock Worm)



Nature's Inspiration (Salps)

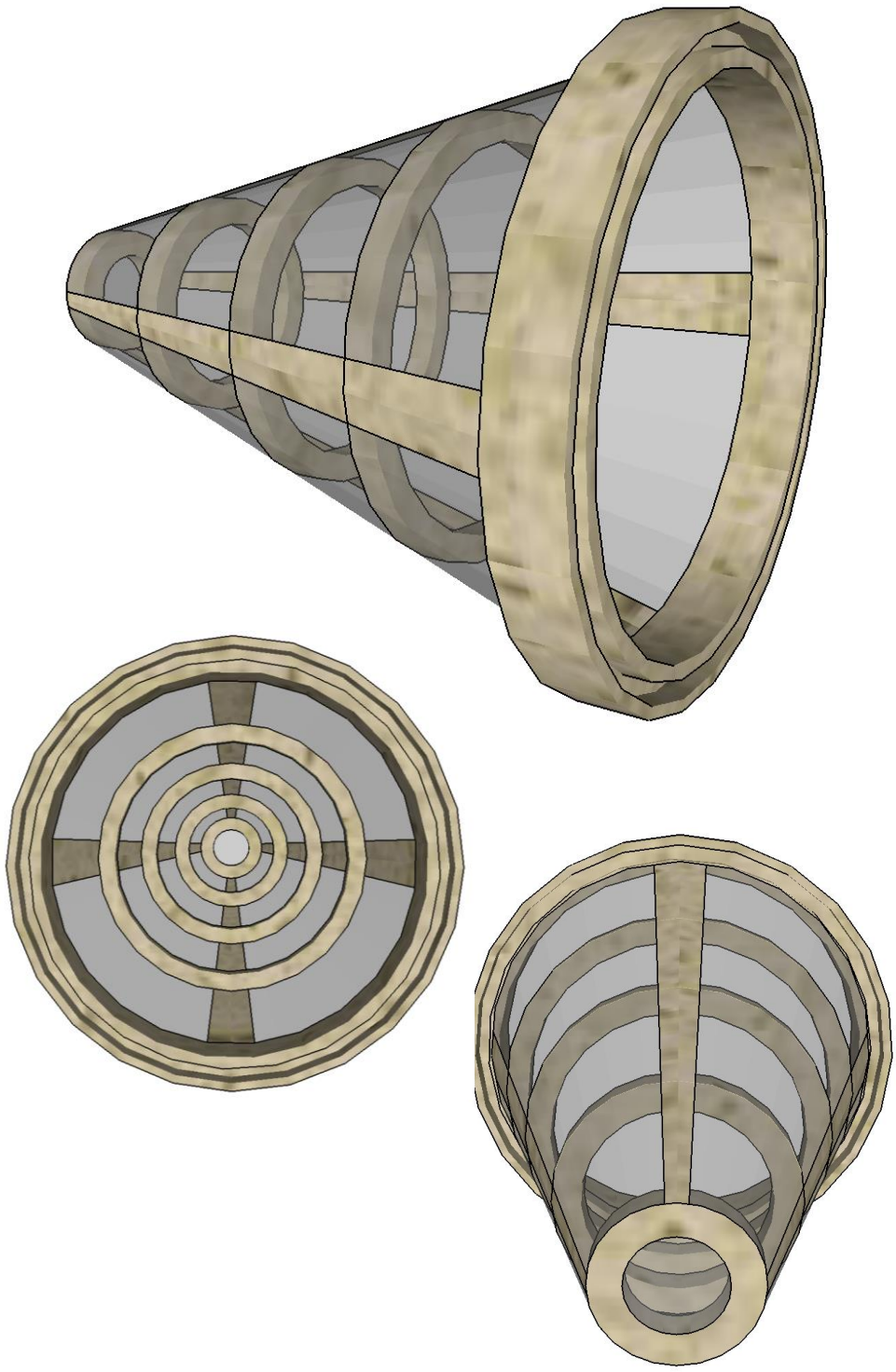



Nature's Inspiration (Basking Shark and Paddlefish)



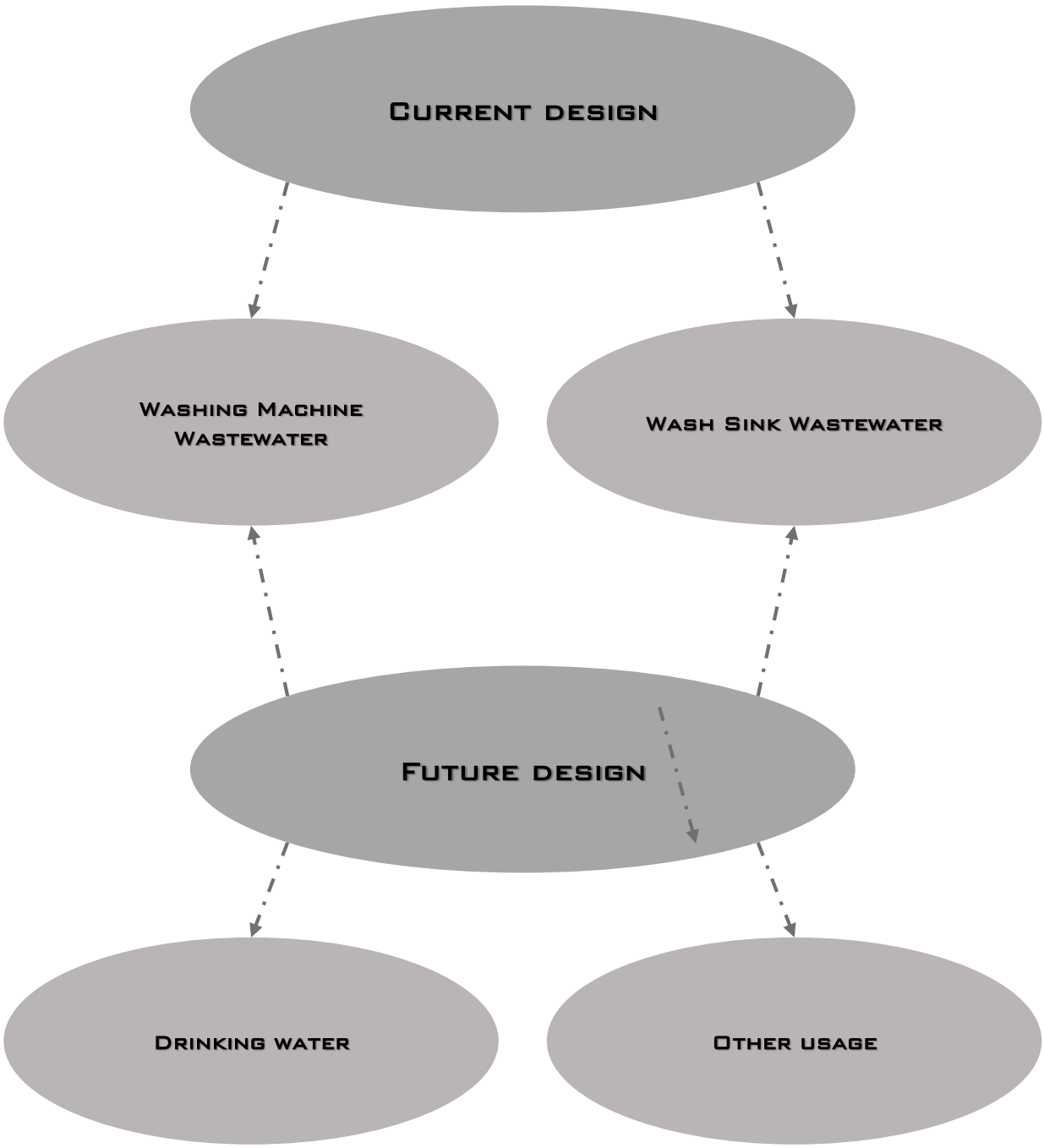

The Micro-Plastic Filtration Device

The team choose to design a filter for the household drains, more specifically for the Washing Machine Wastewater and Wash Sink Wastewater.



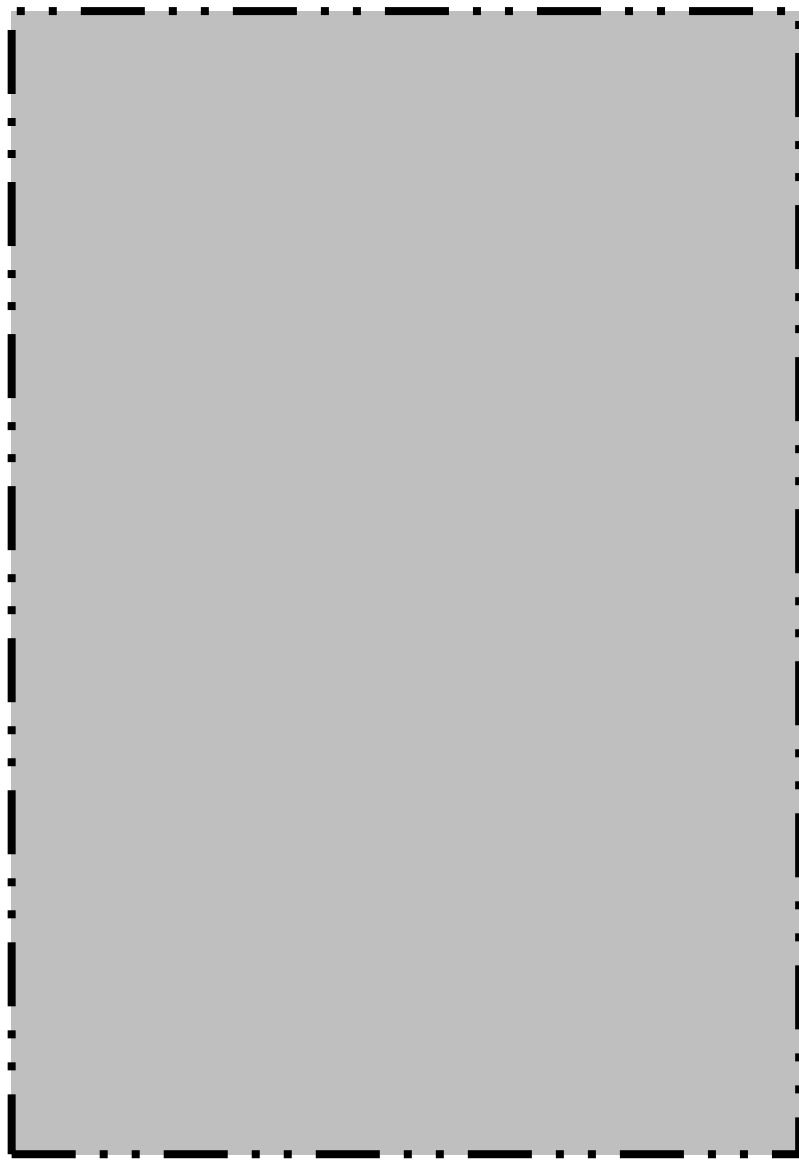
BIBLIOGRAPHY

Further Research



The Team

Our team is made up of 5 students, we are students at Tung-Hai University in Taichung City, Taiwan. We are from two different departments in the university. Our team is made up of Architecture and Life Science students. The advisor for our teams was Kuowei Eleazar-Godfrey Chiu. The Team Leader Name is James Campbelle, he is from St. Vincent and the Grenadines and currently living in Taiwan pursuing his Studies in Architecture. The other 4 member of the Team are Taiwanese.
During the course of this challenge we learn a lot about how damaging plastics are to the environment, animals and even human body and also how plastics plays a role in current situation we have at hand with climate change. Our research was base on microplastics and we found out that a big contributor of microplastic is household items. After our long research and brainstorming, we came up with the idea of designing a special kind of filter. This is how the “The Micro-Plastic Filtration Device” was born.



Research Seminar on Space Syntax

04

There are three major viewpoints in space syntax approach: immaterial and void spaces, scientific and quantification, phenomenology and social outcomes tendency. The training goal of this lecture is to facilitate the student's professional knowledge of parametric thinking to analyze social spatial issues and to strengthen student's professional ability to parametric making on spatial and form design through a combination of various parametric tools

Project Location:

Wuqi District & Taichung Port

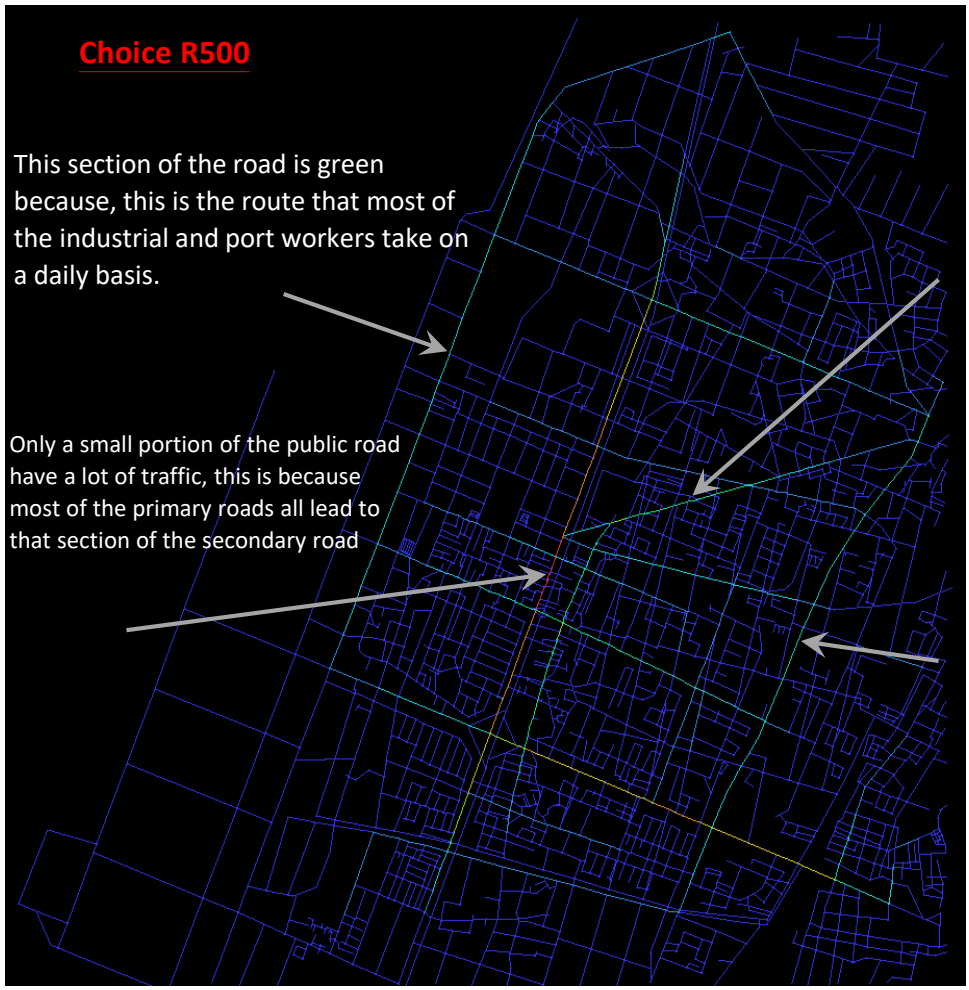
Directed by:

Simon Shu

Group Members:

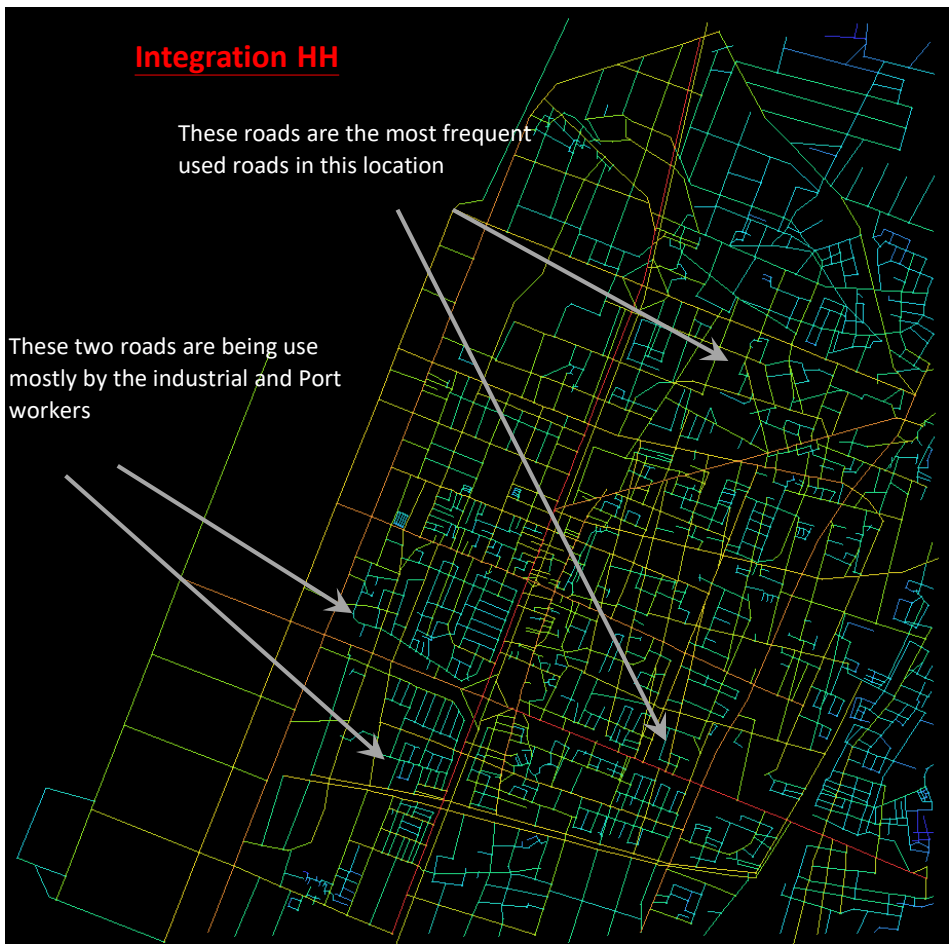
James Campbelle

Zhaoyang

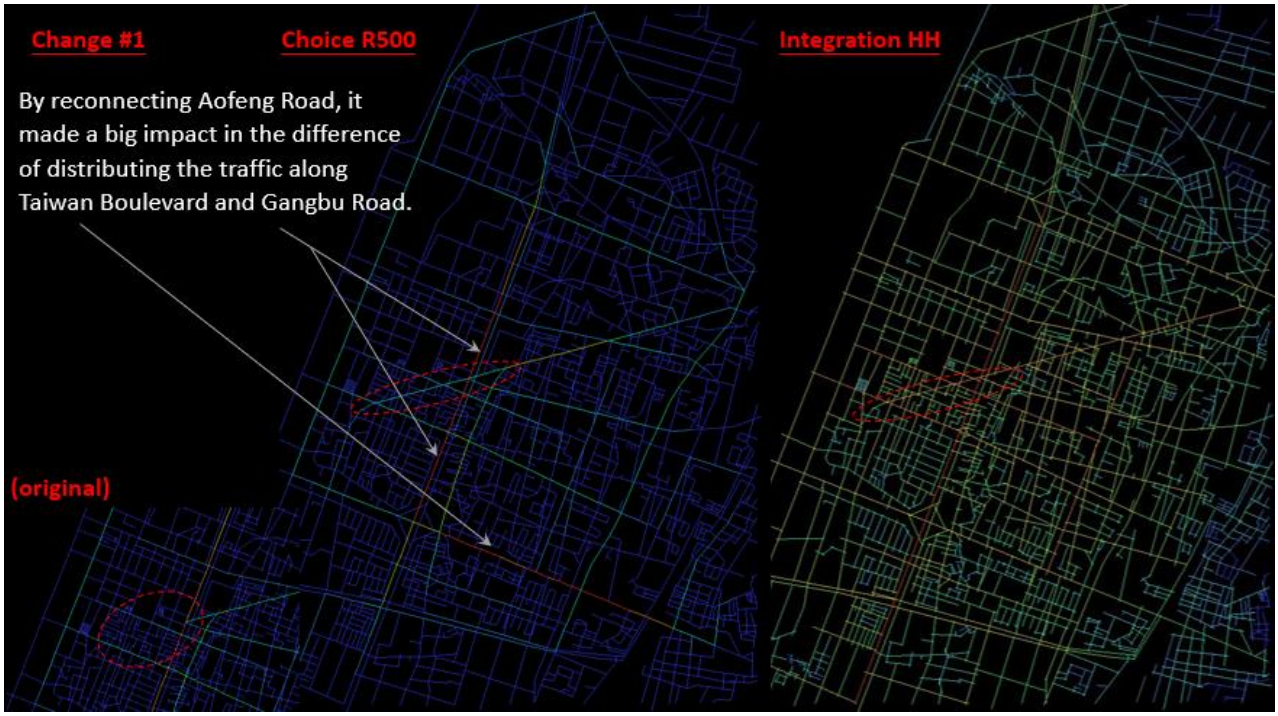


This road called Aofeng Rd. is green because, this road is use to connect Wuqi District and Taichung Port to Qingshui District and Taichung Airport

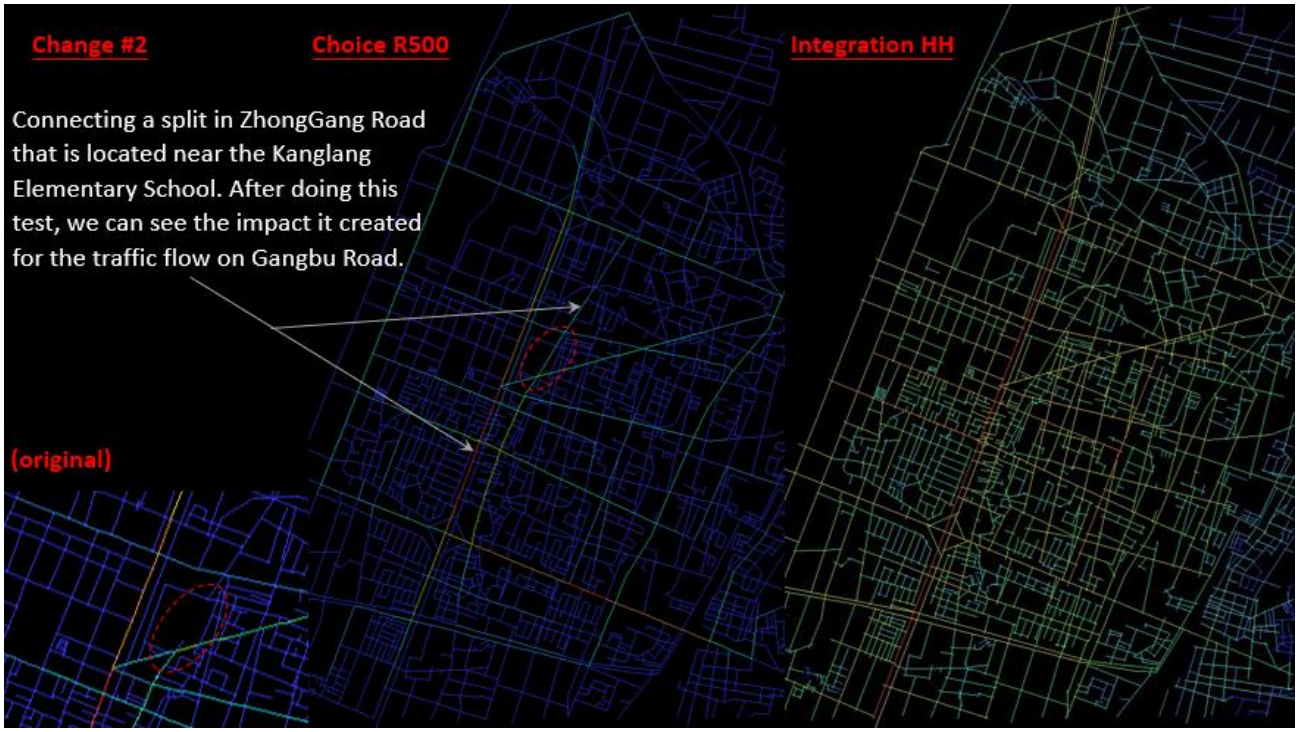
Zhongshan Rd. is green because this is the road that runs along side the Railway track in Wuqi District and Shalu District



The roads that are color yellow are the roads that is being use daily, mostly by the residents in this area.

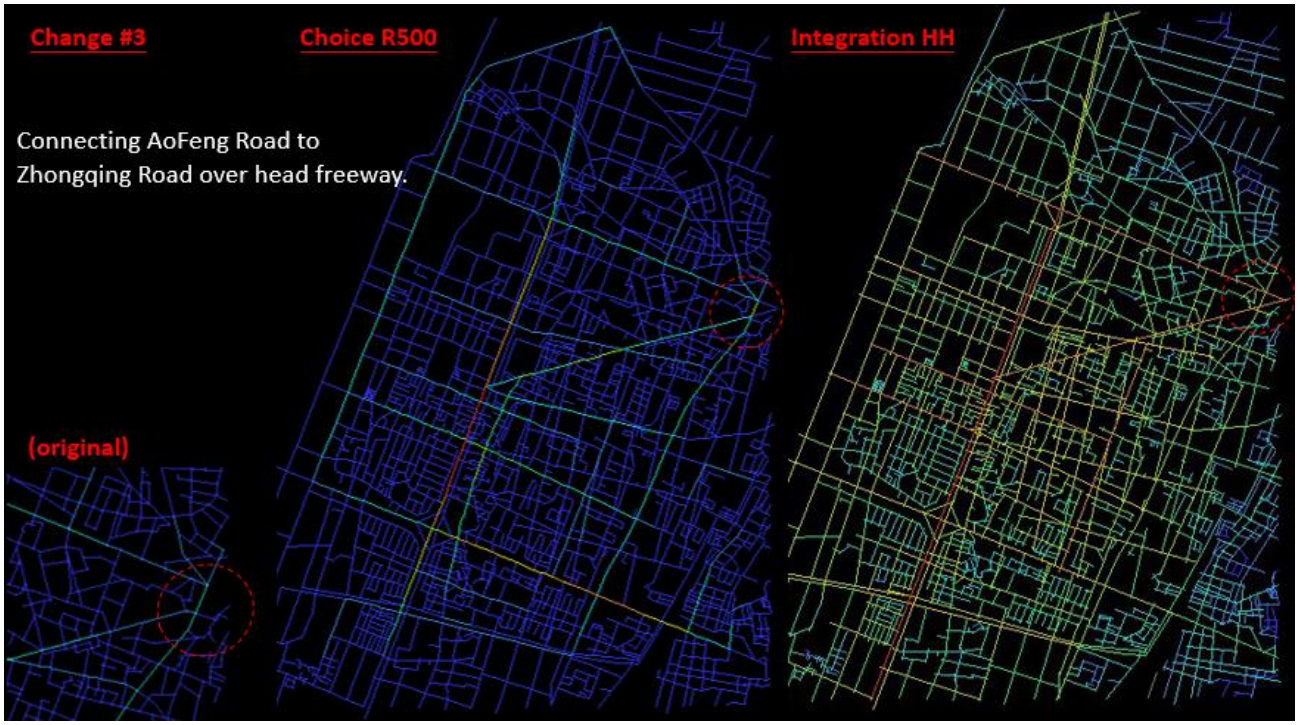

Change #1
Choice R500
Integration HH
By reconnecting Aofeng Road, it made a big impact in the difference of distributing the traffic along Taiwan Boulevard and Gangbu Road.
(original)


Change #1
Affected Areas



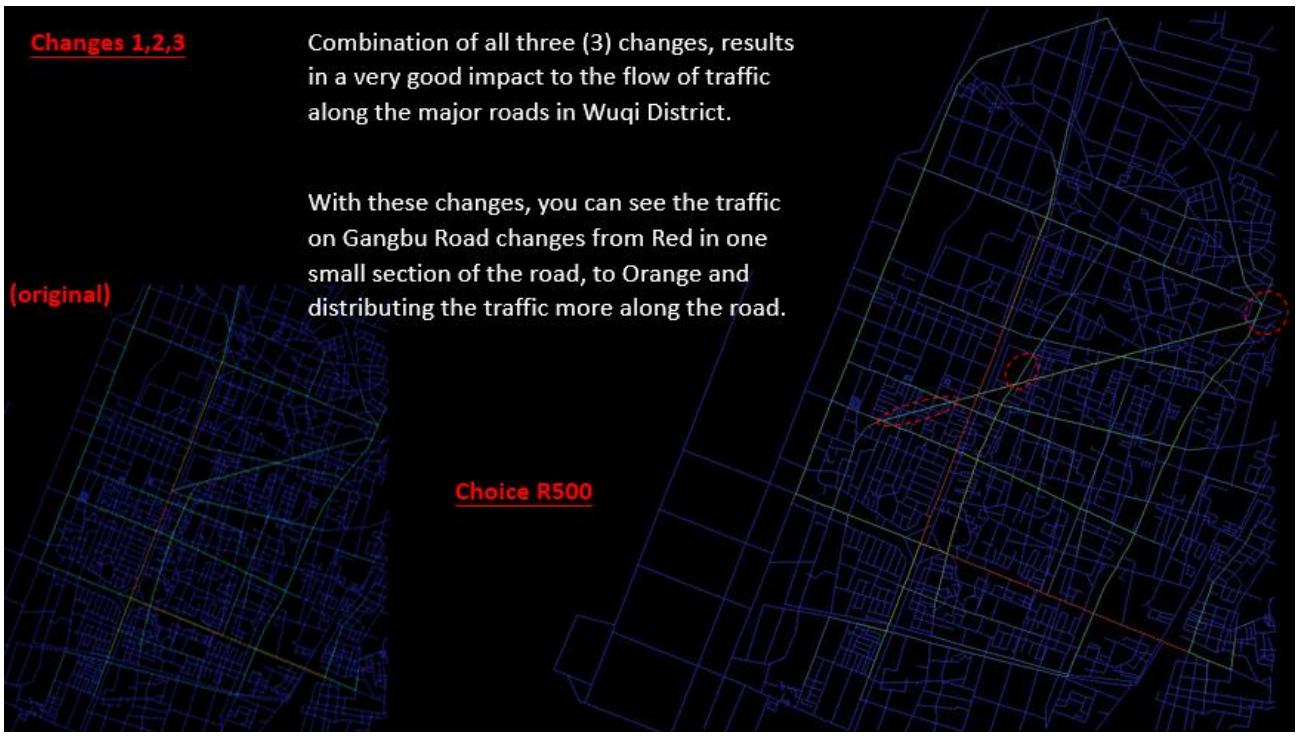
Change #2

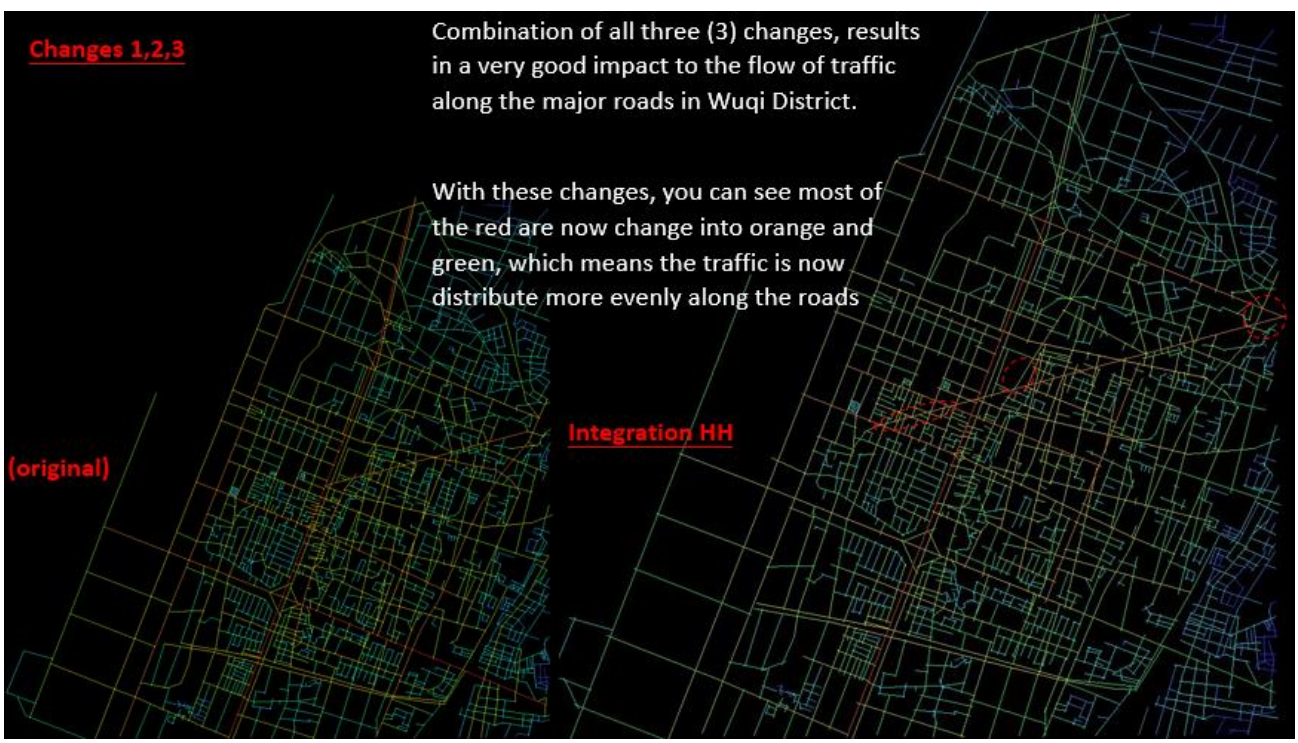
Affected Areas



Change #3

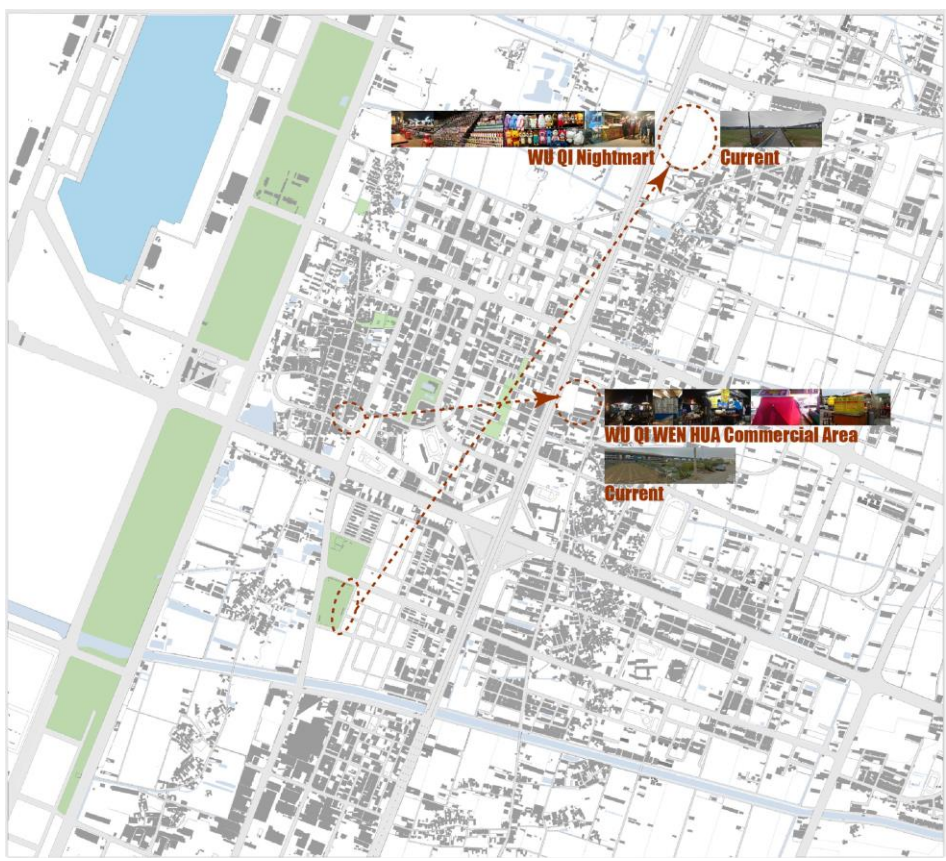
Affected Areas

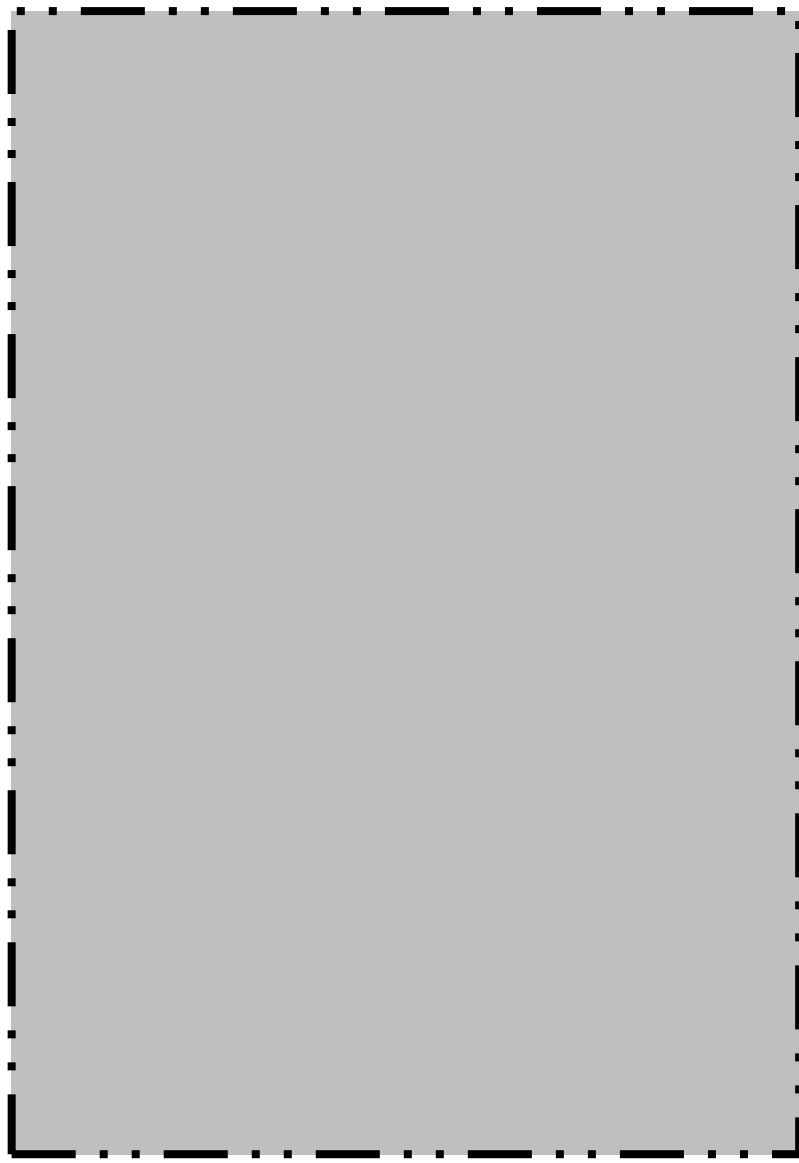

Changes 1,2,3
Combination of all three (3) changes, results in a very good impact to the flow of traffic along the major roads in Wuqi District.
With these changes, you can see the traffic on Gangbu Road changes from Red in one small section of the road, to Orange and distributing the traffic more along the road.
(original)
Choice R500


Changes 1,2,3
Combination of all three (3) changes, results in a very good impact to the flow of traffic along the major roads in Wuqi District.
With these changes, you can see most of the red are now change into orange and green, which means the traffic is now distribute more evenly along the roads
Integration HH
(original)

Two commercial Spaces located in our Site.

Proposed space for relocation of the Commercial Area





Parametric Design for Performative Architecture

05

This course is a combination of design workshops and seminars. Students will explore the potential of high-performance architecture by means of parametric design, digital fabrication, and material computation. As contemporary architects have been adopting the emerging digital technology in the process of crafting our physical environments, the techniques (know-how) and philosophy (know-why) toward more effective and efficient architecture become critical for young designers

Project Location:

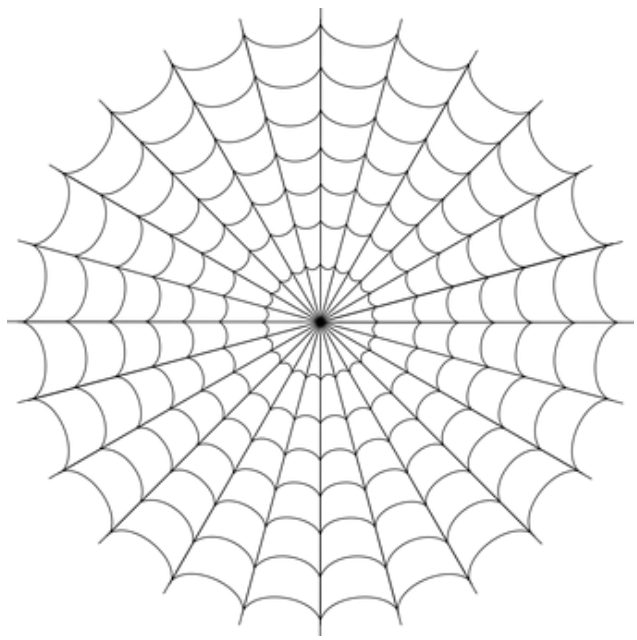
Unknown

Directed by:

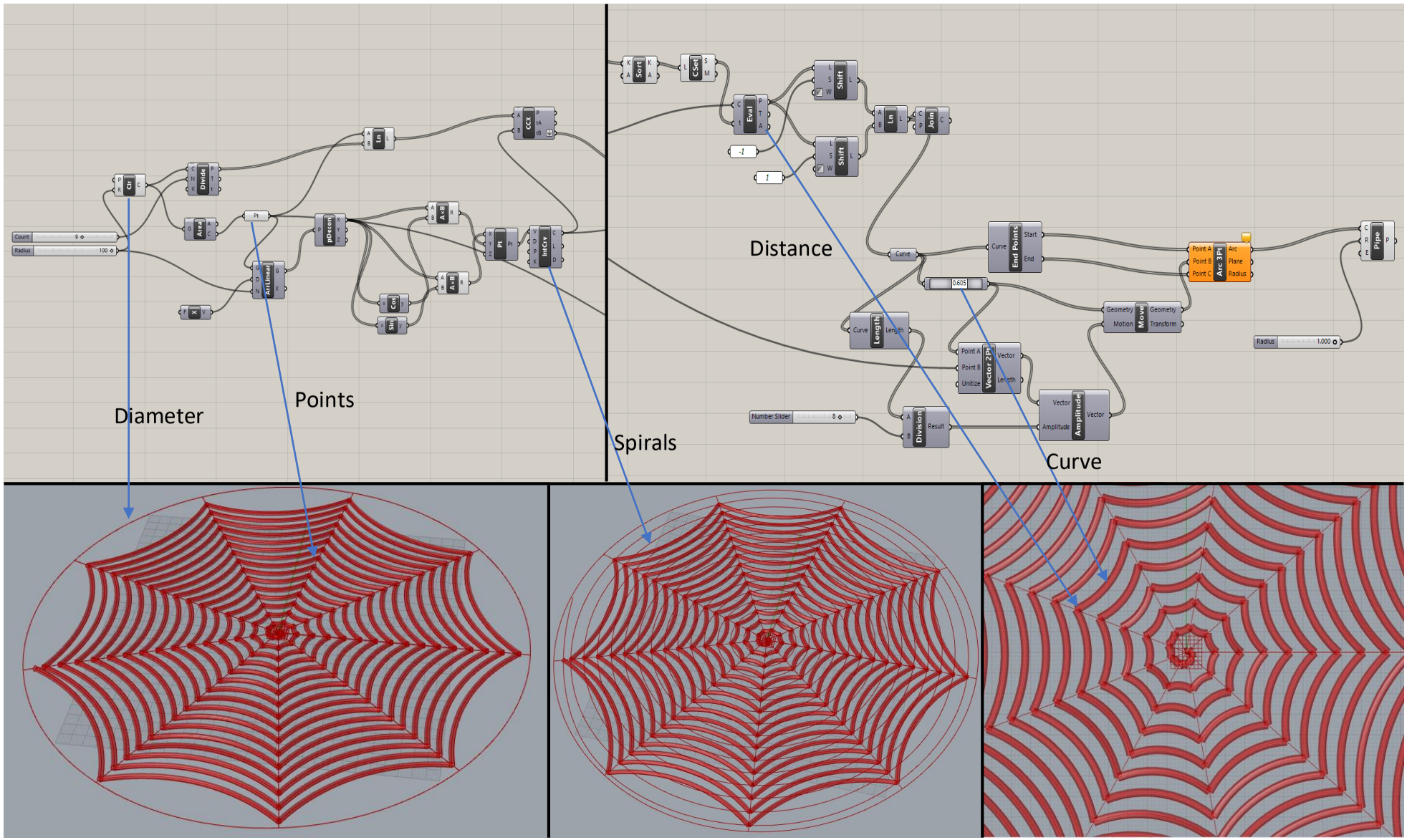
Hao-Hsiu Chiu

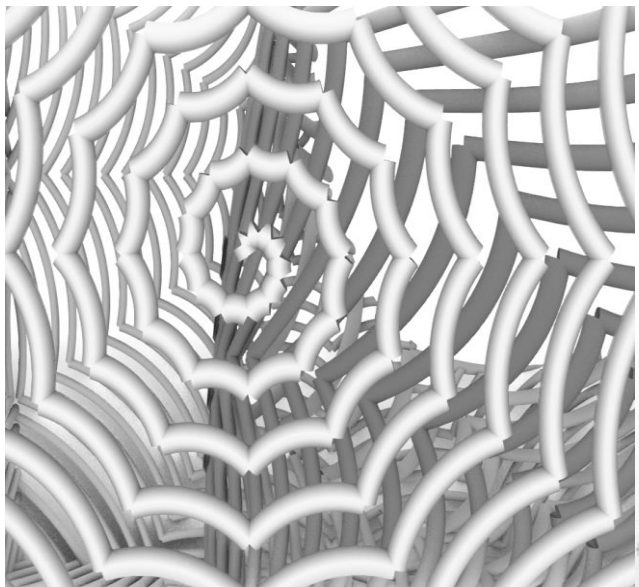
Group Members:

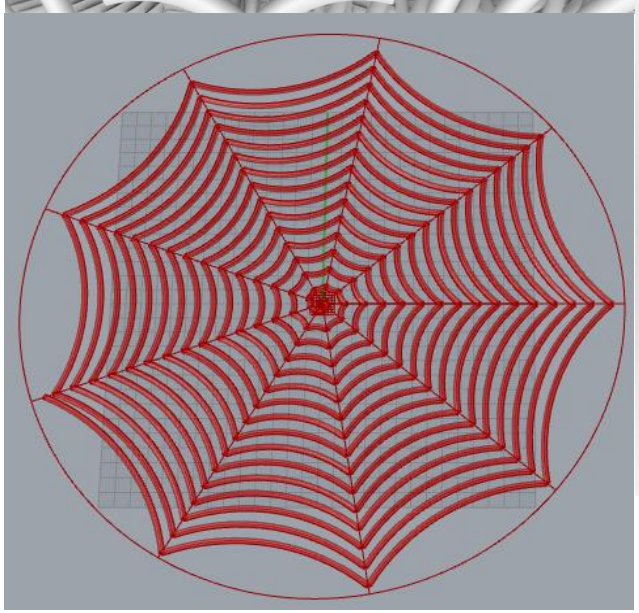
James Campbelle

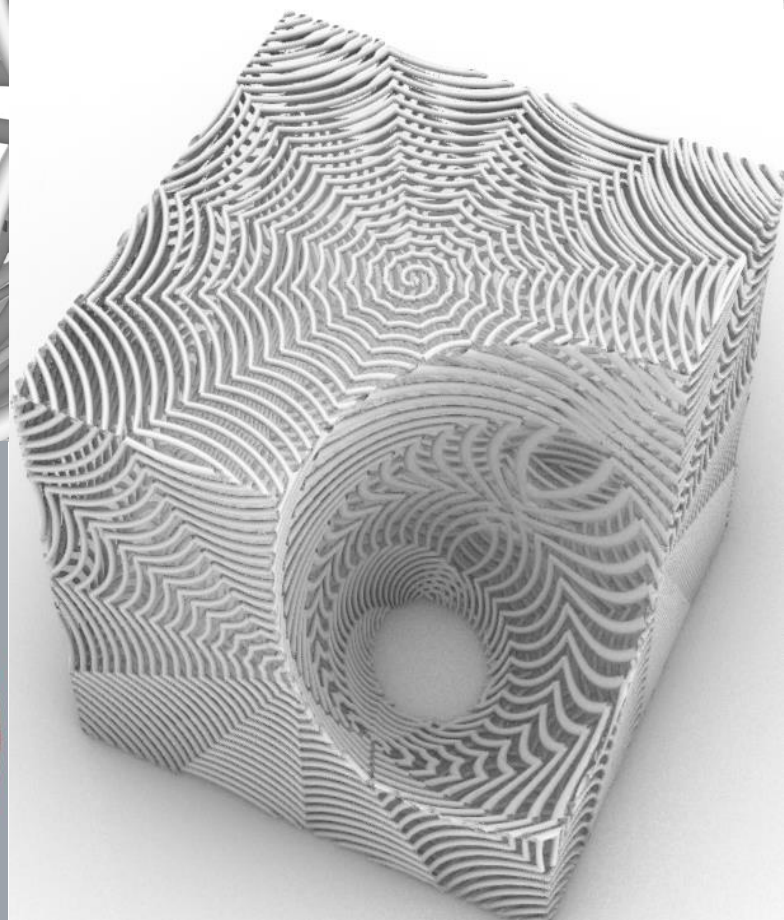


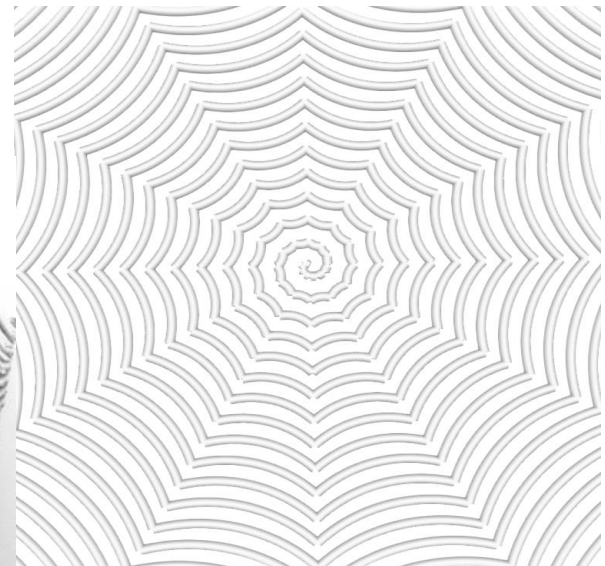
A **spider can** more easily repair a **web** rather than having to entirely rebuild it after every single impact from a bug, twig, or strong wind. For a **spider**, taking extra time to design a **web** means saving energy down the road.

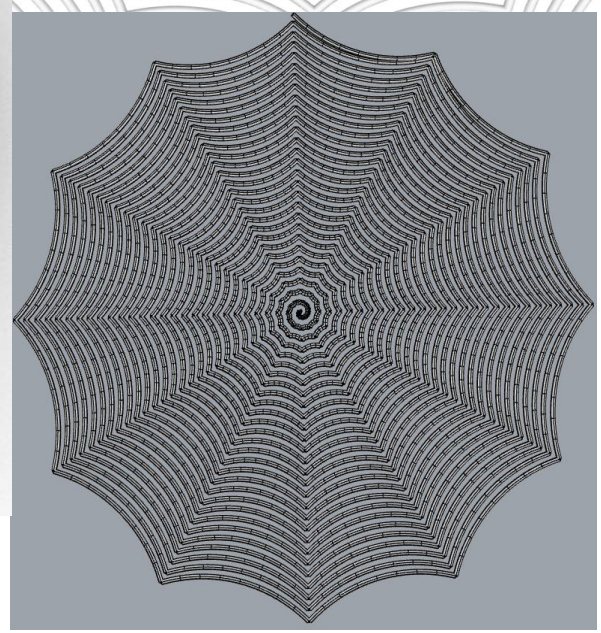

Diameter
Points
Spirals
Distance
Curve



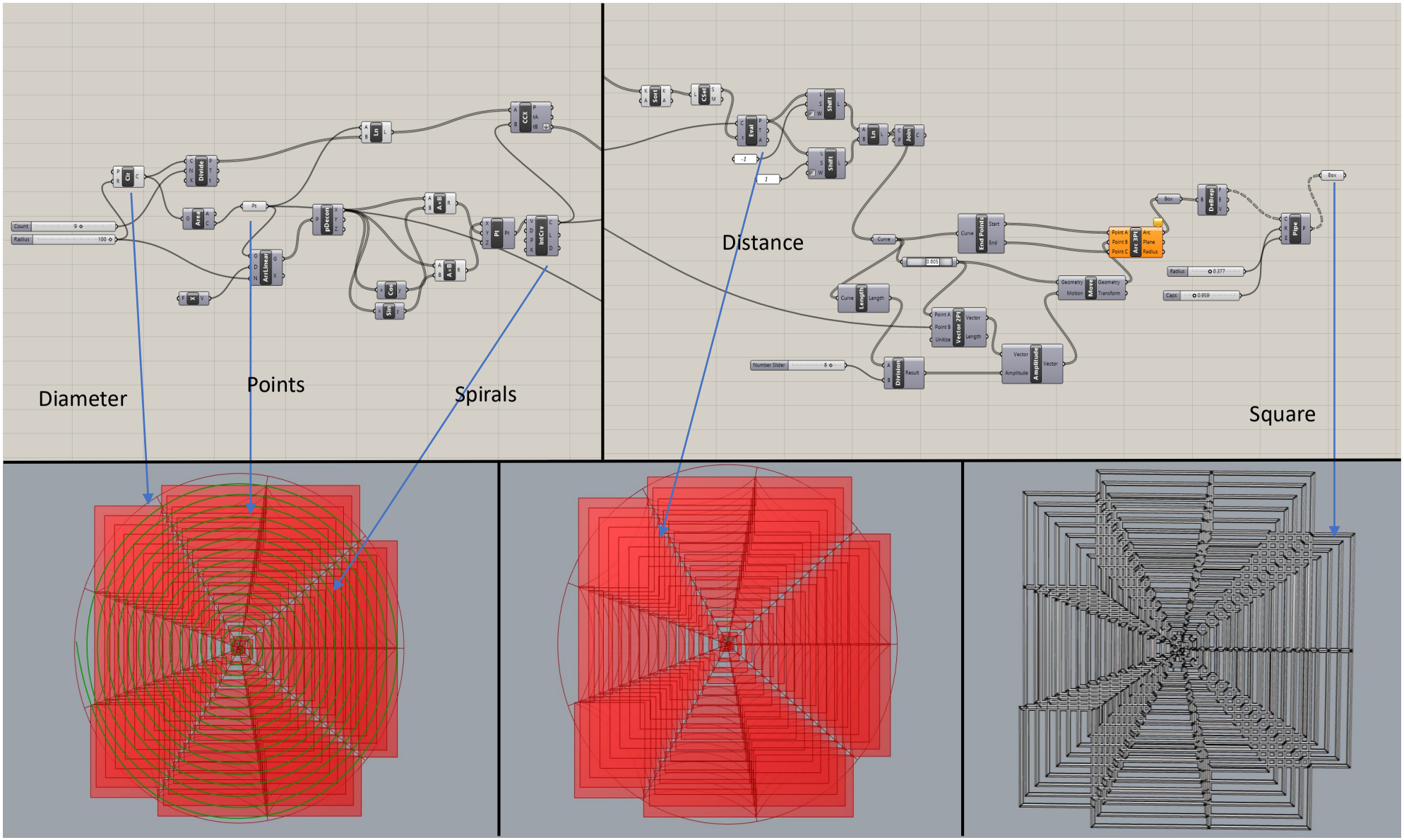


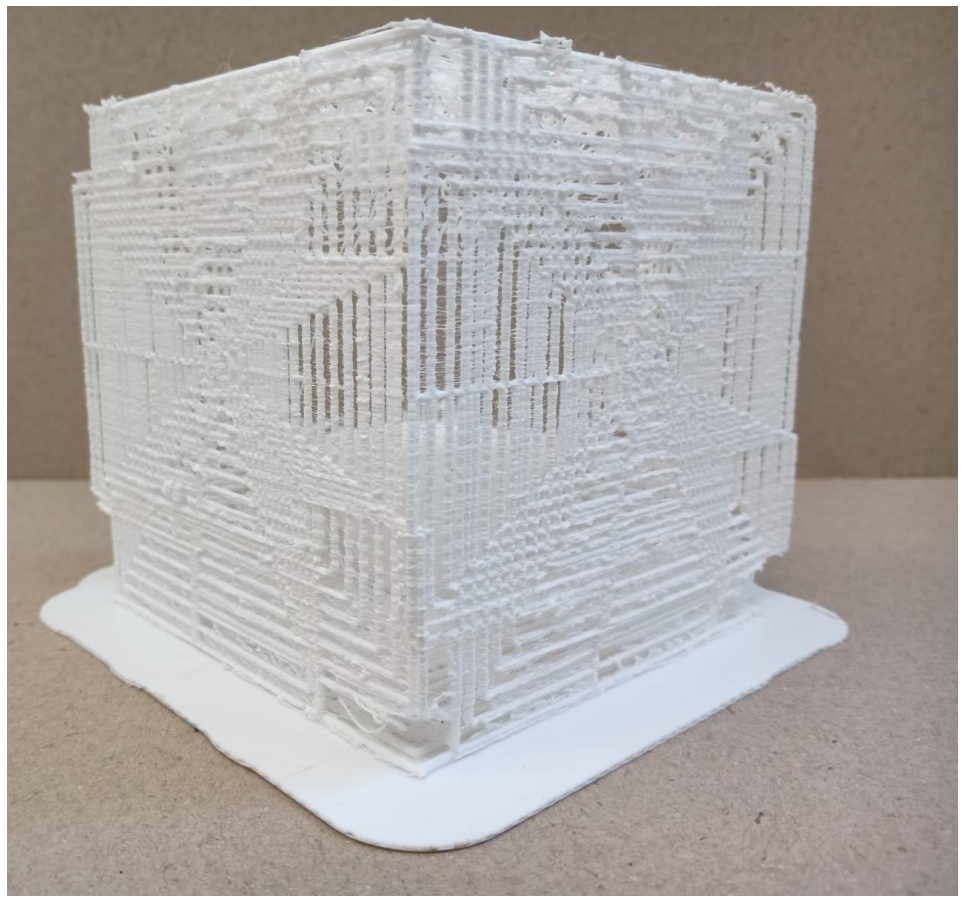




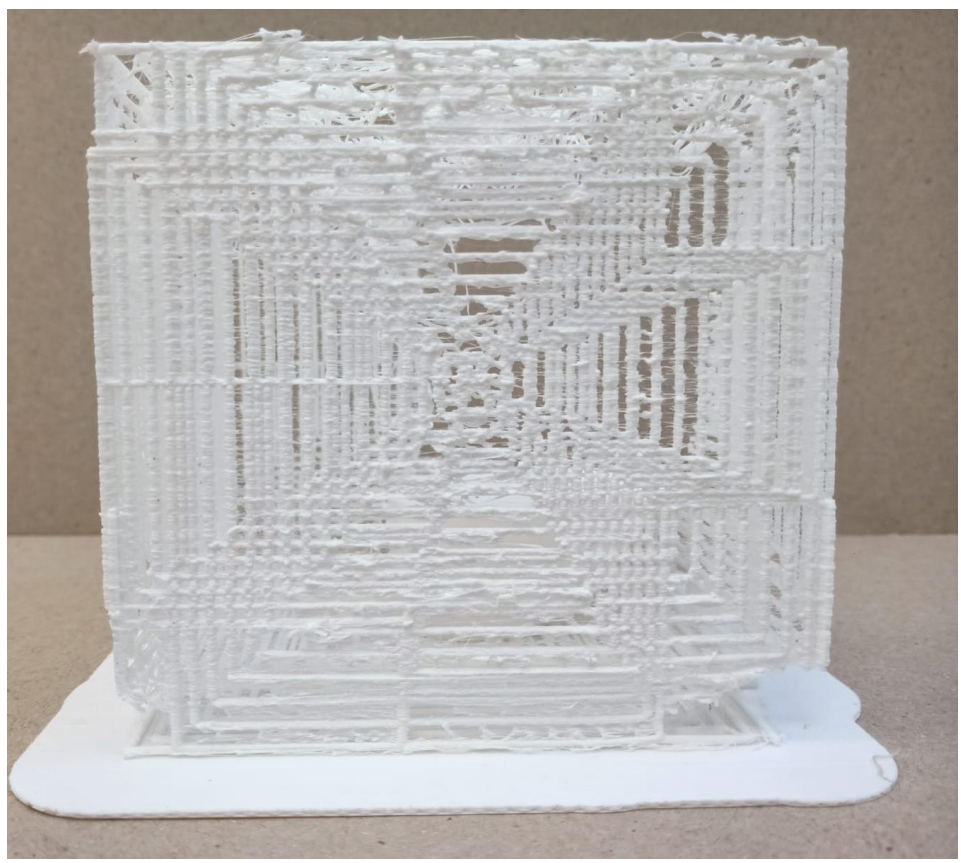


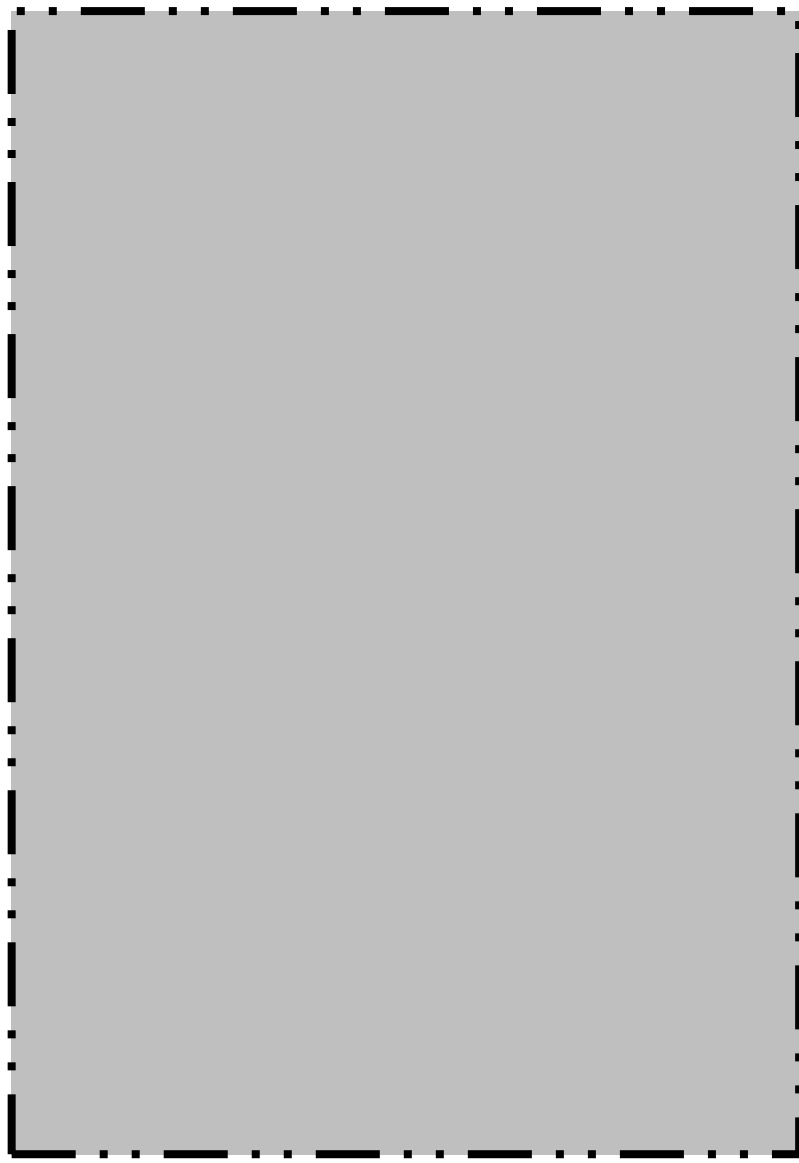
Geometric Rendering


Diameter
Points
Spirals
Distance
Square



3D Printed Model





Advanced Design Topics (1): Future Cities

International Design Competitions

06

Projects:

1. Beyond Bauhaus: Proto Typing The Future
2. Kaira Looro Architecture Competition

Directed by:

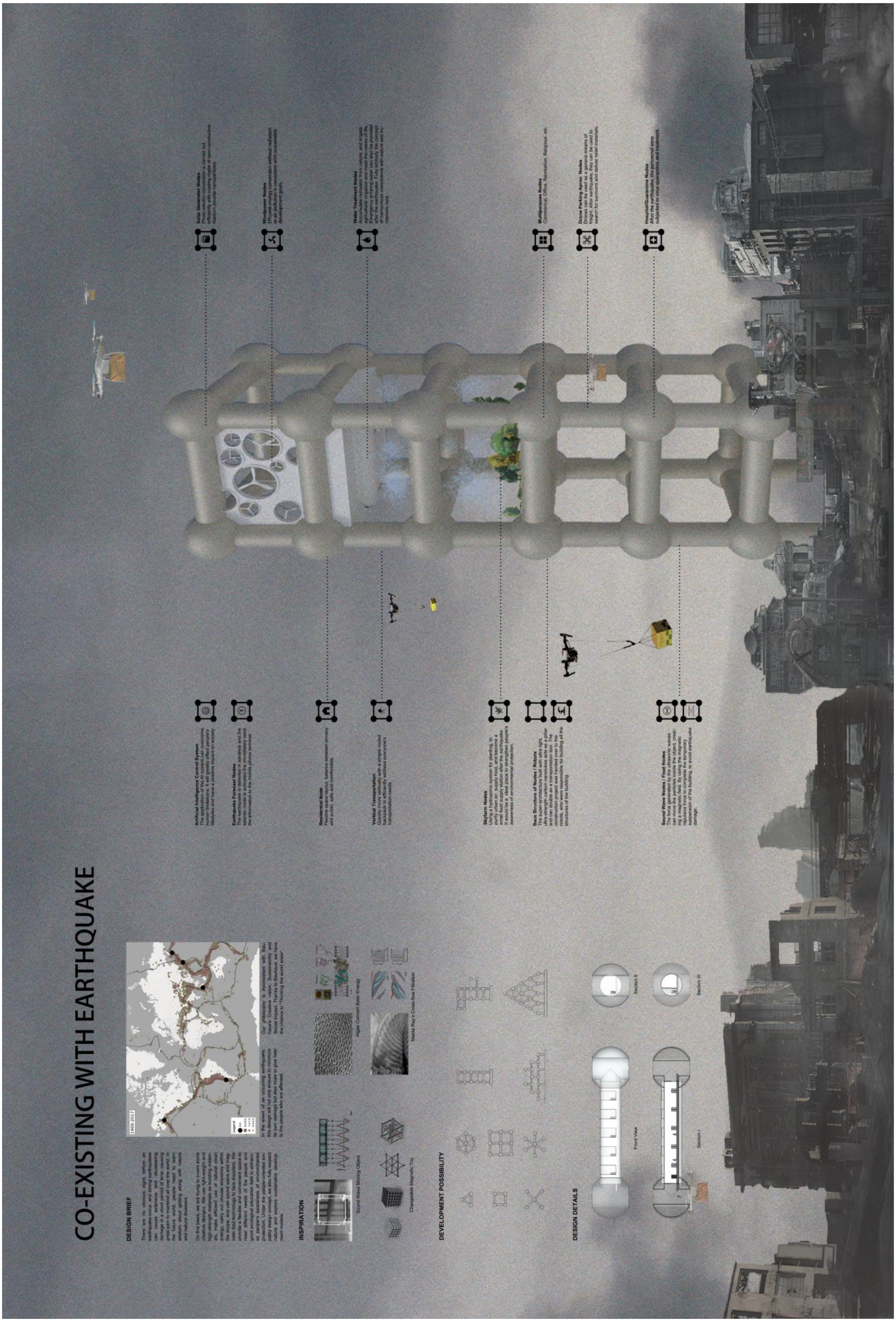
Kuowei Chiu

Group Members:

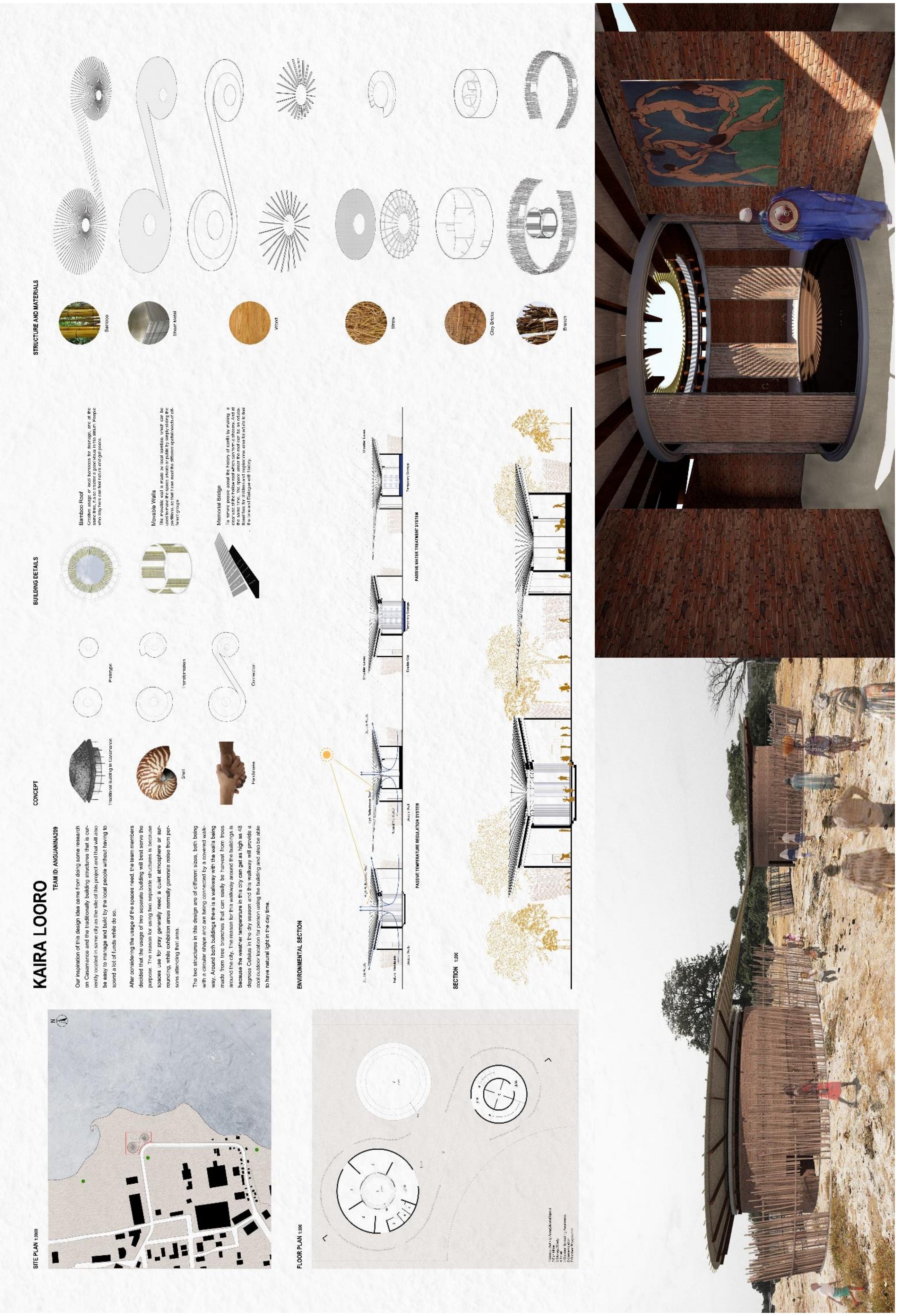
Guan Puyang

James Campbelle

Mingwei Cai



1. Beyond Bauhaus: Proto Typing The Future



2. Kaira Looro Architecture Competition

BIBLIOGRAPHY

"Investors Clinic", accessed June 2019, http://www.investors-clinic.com/knowledge

"Chuan Song Me", accessed June 2019, http://www.chuansongme.com/roof

"Harrington & Company", accessed May 2019," http://www.harringtonco.com/roofing-supplies

"Ehssan Amir Sayyafi", accessed June 2019, http://www.researchgate.net/researchstudent

"Collis Roofing", accessed May 2019, http://www.Collisroofing.com/hurricaneseason

"PV Education", accessed April 2019, http://www.PVeducation.com/solar-concepts/

"Valley View Roofing", accessed June 2019, http://www.valleyviewroofing.net/what-are-inexpensive-roofing-materials/

"Doug White Architects", accessed May 2019, http://www.dwacaribbean.com/design-guidelines-for-hurricane-resistant-buildings/

"Mason Inc", accessed June 2019, http://www.masconinc.com/roofing/residential-roofing-options/asphalt-shingles/

"Roofing Key", accessed May 2019, http://www.roofingkey.com

"Miller Home Improvement", accessed April 2019,

http://www.millershomeimprovement.com/roofing-clinton-township-mi/repairs-of-all-kinds/

"Earther Gizmodo", accessed December 2018, http://www.earther.gizmodo.com/design/

"Emagazine", accessed December 2018, http://www.emagazine.com/solar-incentives/

"Get Green Now", accessed November 2018, http://www.get-green-now.com/environment/

"DnB Roofing", accessed June 2019, http://www.dnbroofing.com/roofing-gallery/

"Roofing Compare", accessed June 2019, http://www.roofingcompare.com/materials/metal-roofing.html

"Ropa Roofing", accessed April 2019, http://wwww.Roparoofing.com/residential-roofing-denver-co/

"Home Logic", accessed June 2019, http://www.homelogic.co.uk/services/protective-walls

"Mas Mistral", accessed May 2019, http://www.mas-mistral.com/2019/05/22/common-types-of-commercial-epdm-roofing-damage/

"Carib Surf", accessed April 2019,

http://www.caribsurf.net/svg/mapssaintvincent.html

"Delaurier Roofing & Renovation", accessed June 2019, http://www.calldrr.com/metal-roofing/

"Gerard Roofs", accessed June 2019, http://www.gerardroofs.eu/en/products

Dr. Rima Taher
New Jersey Institute of Technology
Florida's Home Shapes And Roofs That Hold Up Best In Hurricanes

"TNT Roofing", accessed April 2019, http://www.tntcogroup.com/portfolio/

"HomeTech", accessed June 2019, http://www.hometechs.org/residential-and-commercial/

"Ask Nature", accessed November 2018, http://www.asknature.org/strategy/specialized-gills-filter-plankton/

"Arkive", accessed December 2018, http://www.arkive.com/year-round/witness-the-wild/

James Calton Campbelle
(St. Vincent & the Grenadines)