

# Dormitory

Northeast USA



## Thesis Proposal



Rendering Courtesy of WTW Architects

Cadell G. Calkins

Structural Option

Faculty Advisor: Dr. Richard A. Behr  
December 12, 2011

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## Executive Summary

The Dormitory, a four story tall dormitory in the Northeast United States with a walk-out basement is constructed mostly out of wood framing. Primarily, the Dormitory consists of an open web wood floor truss system supported by 2x6 wood stud walls. For lateral support, the primary system consists of either oriented strand board (OSB) or gypsum wall board (GWB) on wood studs.

As global warming continues to become a larger issue for the world, soon it will be a concern for a structural engineer in the form of increased wind and weather loads. It is this author's proposal to investigate these increasing wind and weather loads in a design process by theoretically moving the Dormitory to a location near the State College of Florida, Manatee-Sarasota facility. Upon this move, higher wind loads will need to be designed for as well as hurricane winds and impact loadings.

To begin the new design, proper loads will need to be determined according to the Florida Building Code 2010, and ASCE 7-10, where applicable according to the code. After loads are determined, it is proposed that two main systems be designed for comparison. First, in the wings, an OSB shear wall system similar to originally designed will be considered. Second, a steel braced frame system will be considered for both the wings and the core. Both situations will implement the original gravity system of wood studs. To continue the investigation and address the problem of termites in a moist environment, a full redesign in steel will be implemented. This redesign includes the use of a Vulcraft Ecospan Composite Floor System in conjunction with wide flange steel beams, girders, and columns as the gravity system. Lastly, a braced frame lateral resistance system will be designed and a new foundation will be designed for Florida's sandy soil.

In addition, two breadths are proposed as part of this thesis. The first breadth is a façade design breadth concentrating on impact resistance due to debris in a hurricane or tornado. A second breadth of electrical concentration will involve a photovoltaic system design for emergency backup power and to partially remove the building from the electrical grid.

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## Building Introduction

Located in a rural Northeast United States university campus, Dormitory consists of two buildings, Building A and Building B, to be built simultaneously. These new buildings, to be built where tennis courts and a parking lot once sat, will house suite style dorm rooms in each wing with a study lounge and gathering space in the central glass core. The two buildings are nearly identical except mirrored about a North-South axis. For design analysis, only Building A will be considered. However, both buildings will be considered for sitework and cost.

Building A is a 4 story building primarily consisting of a wood frame structure sitting atop a concrete masonry foundation. For lateral load analysis, the building is considered to be a 5 story building due to the walkout basement / ground floor.

To adhere to the architecture of the surrounding university, the majority of the façade of Building A consists of face brick with a base of ground face concrete masonry units. To complement the brick and masonry units, precast window heads and sills can be seen at each suite window and maroon and gray metal panels can be seen throughout the building as well. In the central core, glass storefront walls can be seen complementing the façade of the brick wings. Traditional to the brick wings, a hip roof with asphalt shingles was used and sticking with the modern feel of the glass storefront walls, a flat roof was utilized over the central core.



Figure 1: Rendering Courtesy of WTW Architects

## Structural Overview

Dormitory Building A rests on rammed aggregate piers at a depth of about 30 feet. Above this, the basement rests on spread footings and a slab on grade. The primary structural system for the gravity loads in the ground floor consists of concrete masonry units and from the first floor and above, the structural system for gravity loads is wood columns and walls. For lateral loads, oriented strand board and gypsum wall board provide the support needed for the wings, while concrete masonry units provide the support for the central core.

An Occupancy Class of II was used for all Importance Factors per IBC 2009. Occupancy Class II was used because the occupancy load of the building is under 5000 and it does not fall into the other categories.

## Foundation

Empire Geo-Services, Inc. performed the subsurface exploration of the site. This included 8 test borings for Building A completed by SJB Services, Inc. (affiliated drilling company of Empire). The findings concluded that the first 0.5 feet below the surface was either asphalt or topsoil. Below this, fill soils were found to a depth of 2 feet in some bores and at least 22 feet in others. By use of a Standard Penetration Test, it was found that the fill soils were probably installed in an uncontrolled manner. At depths between 8.4 feet and 61.5 feet, the top of bedrock is believed to exist. Per Empire's findings and recommendations, with the given fill conditions, a slab on grade and spread foundations were not a viable option and they suggested using micro-piles or drilled piers. In addition, Empire also found that groundwater conditions do not appear to be within 15 feet of the surface.

To counter the poor soil fill conditions, rammed aggregate piers, as designed by Geopier, were installed by GeoConstructors. The piers utilized a 2 foot diameter drilled hole and the hole was compacted using 2 foot lifts of well graded crushed rock. Placed on a semi-regular grid of 10

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feet, the piers were drilled between 8 feet and 50 feet deep depending on bedrock and soil conditions and most were around 30 feet deep. This type of pier also compacted the surrounding soil resulting in a better structure for a slab on grade.

Below the surface, 12 inch reinforced concrete masonry units were utilized on spread footings with 8 inch concrete masonry units above the surface up to beneath the Second Floor. On the sides where soil was to be held back, 12 inch Ivany blocks grout solid on spread footings were utilized below the surface and 8 inch Ivany blocks grout solid were used above the Ground Floor up to the First Floor with 8 inch concrete masonry units to continue up to the Second Floor. A detail of the Ivany block wall can be seen in Figure 2 below. The floor of the Ground Floor was a 4 inch concrete slab over drainage course. The floor of the First Floor consisted of a 2 inch concrete cover over 8 inch hollow core precast concrete planks. This floor was utilized to provide a 2 hour fire rating between the Ground Floor and the First Floor.

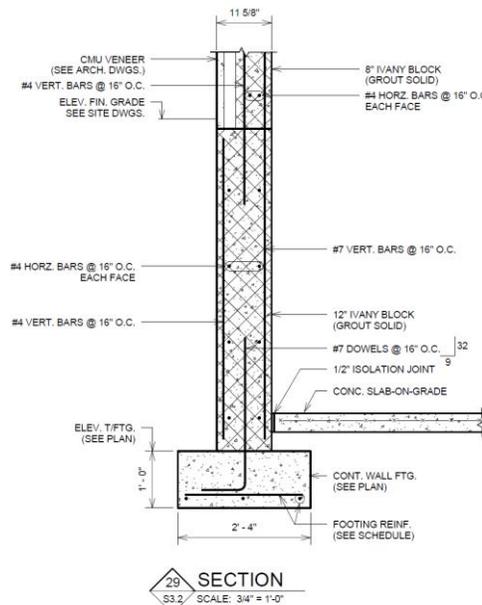


Figure 2: Typical Ivany Block Wall  
Courtesy of WTW Architects  
(Page S3.2)

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## Floor Construction

Considering the First Floor as part of the foundation, the Second through Fourth Floors are nearly identical. Each suite rests on 18 inch deep wood floor trusses spaced at 19.2 inches on center. On top of the trusses consists of  $\frac{3}{4}$  in. of Gypcrete on top of  $\frac{1}{4}$  in. sound mat all resting on  $\frac{3}{4}$  in. plywood sheathing. The corridors follow a similar structure, except that instead of trusses, the sheathing is supported by 2x10 Spruce-Pine-Fir or Douglas Fir wood joists at 16 inches on center resting on the corridor walls.

Within the central core, the floor structure consists of 1.75 in. x 9.25 in. laminated veneer lumber wood joists at 16 in. on center topped with  $\frac{3}{4}$  in. Gypcrete on top of  $\frac{3}{4}$  in. plywood. For sound, 3.5 in. batt insulation is placed between the joists and the joists rest on W10x22 beams which in turn rest on W10x45 girders.

A typical partial floor plan can be seen below in Figure 3 with the central core outlined with a dash line.

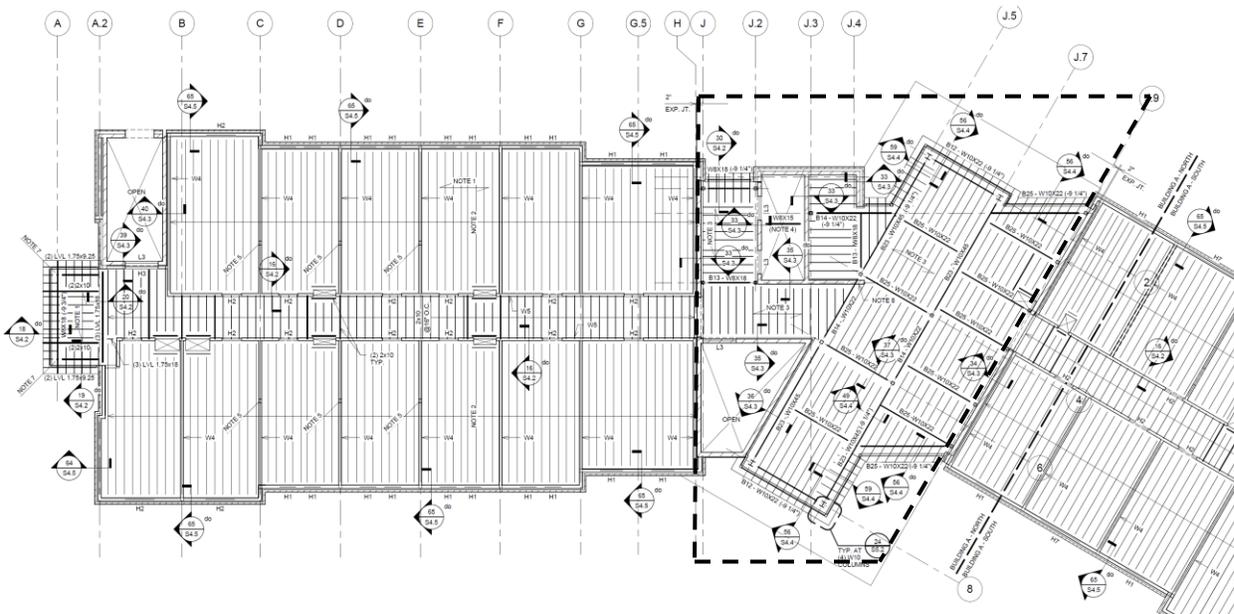


Figure 3: Typical South Wing Floor Plan Courtesy of WTW Architects (Page S1.3A)

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## Lateral Systems

In regard to handling lateral forces, Building A is basically three separate buildings; South Wing, Central Core, North Wing.

In the North-South direction, the wings use shear walls that go from the first floor up to the roof. These shear walls consist of the exterior walls and the corridor walls. The exterior walls use  $\frac{1}{2}$  in. oriented strand board and  $\frac{5}{8}$  in. gypsum wall board per wall to resist the lateral forces, while the corridor walls use  $\frac{3}{4}$  in. oriented strand board and two layers of  $\frac{5}{8}$  in. gypsum wall board per wall. In comparison, the corridor walls take more direct shear while the exterior walls help with torsional shear.

In the East-West direction, the wings use similar shear walls as the North-South direction for the exterior walls. For the interior walls, the walls that separate the suites, the lateral forces are taken up by utilizing three layers of  $\frac{5}{8}$  in. gypsum wall board per wall. This creates a fairly even distribution of lateral forces throughout the building.

For the Central Core, the lateral forces in each direction are taken by concrete masonry unit walls that surround the stairs and elevators and that line the walls where the core connects to the wings.

In all cases, wind loads will be applied to the brick or metal panel or glass façade and directed to the floor diaphragms above and below the exterior walls by the flexure of the exterior stud walls. The floor diaphragms transfer the load to the shear walls as described above, which continue down to concrete planks. The planks are assumed to be a rigid diaphragm that transfers the shear to soil it sits on top of.

For seismic loadings, the mass of each section is concentric with the center of rigidity. The seismic loads start at the center of mass in each diaphragm at each floor level and this load is then transferred to the shear walls as described above for wind.

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## Materials Used

Materials listed in the tables below come from page S2.1, General Notes and Typical Details, of the structural drawings.

**Table 1 – Concrete Specifications**

Concrete	$f'_c$ (psi)	Max Water Cement Ratio	Weight	Max Aggregate Size
Foundations	3000	0.50	Normal	1 ½ in.
Interior Slabs	4000	0.45	Normal	¾ in.
Exterior Slabs	4000	0.40	Normal	¾ in.

**Table 2 – Mortar and Grout Specifications**

Mortar and Grout	Use	$f'_c$ (psi)	Standard
Mortar	Above Grade	2100	ASTM C270, Type S
Mortar	Below Grade	2900	ASTM C270, Type M
Mortar	Ivany Block	2900	ASTM C270, Type M
Grout	All Masonry	3000	ASTM C476
Leveling Grout	Concrete	5000	CE-CRD-C621

**Table 3 – Masonry Specifications**

Masonry	$f'_m$ (psi)	Standard
Hollow Units	1500	ASTM C90, Type N-1
Solid Units	1500	ASTM C145, Type N-1
Ivany Block	3000	ASTM C270, Type M

**Table 4 – Steel Specifications**

Steel	Standard	Grade
Wide Flange Shapes	ASTM A992	50
Other shapes, plates, bars	ASTM A36	Typical
Steel HSS Shapes	ASTM A500	B
Steel Pipes	ASTM A53, Type E	B
Bolts	ASTM A325, Type N, ¾ in. dia.	N/A
Anchor Rods	ASTM F1554, ¾ in. dia.	36
Deformed Reinforcing Bars	ASTM A615	60
Welded Wire Fabric	ASTM A185	N/A
E70 Welding Electrode	AWS D1.1	N/A

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**Table 5 – Wood Minimum Specifications**

<b>Wood Minimums</b>	<b>Grade</b>	<b>Fb (psi)</b>	<b>Fv (psi)</b>	<b>Fc (psi)</b>	<b>Ft (psi)</b>	<b>E (psi)</b>
Spruce-Pine-Fir	#2	875	135	1150	450	1,400,000
Douglas Fir	#2	875	135	1150	450	1,400,000

**Table 6 – Wood Sheathing Specifications**

<b>Wood Sheathing</b>	<b>APA Rated</b>	<b>Span Rating</b>	<b>Exposure</b>
Floor	Yes	40/20	1
Roof	Yes	32/16	1
Wall	Yes	N/A	1

## Design Codes and Standards

According to Sheets S2.1 and LS0-1, the Dormitory was designed according to:

- Pennsylvania Uniform Construction Code
  - (2009 International Building Code and other adopted ICC codes)
  - (American Society of Civil Engineers, ASCE 7-05)
- Building Code Requirements for Reinforced Concrete (ACI 318-08)
- Building Code Requirements for Masonry Structures (ACI 530-08)
- National Design Specification for Wood Construction 2005 (NDS-05)
- American Institute of Steel Construction (13<sup>th</sup> Edition – 2005)
- Design Specifications for Metal Plate Connected Wood Trusses (TPI-85)

The same codes will be used for thesis with the following changes:

- ASCE 7-10 will be used in lieu of ASCE 7-05
- AISC 14<sup>th</sup> Edition will be used in lieu of AISC 13<sup>th</sup> Edition

These changes in code were made because these are the newest editions of the codes.

## Problem Statement

In this day and age, many problems face a structural engineer, including but not limited to earthquakes, terrorism, snow and other loads. One problem area that is not an apparent concern are the effects of global warming structurally. It is well known that global warming is a concern in the building industry, thus buildings are becoming more efficient and greener. However, global warming has the potential to become a design consideration for a structural engineer.

According to the National Wildlife Federation website, the maximum hurricane wind speeds are expected to increase 2 to 13 percent within this century. (Global Warming is Affecting Weather) As a hurricane is often the maximum wind event that a building is designed for, it is logical to assume that the maximum wind event will also increase 2 to 13 percent.

In regards to the Dormitory, which was originally designed for a wind speed of 90 mph (ASCE 7-05) or 115 mph (ASCE 7-10), at a maximum this speed would increase to 102 mph or 130 mph, respectively, due to global warming. In able to better understand this increased wind load on a wood structure, the author of this proposal has created a scenario in which the State College of Florida, Manatee-Sarasota, (SCF) would like to build their first on-campus housing and really liked the design of the Dormitory. In this area, the design wind speed is 150 mph.

Planned to be a potential haven for students during hurricanes or tornadoes caused by hurricanes, SCF has required that the Dormitory be capable of withstanding wind pressures due to hurricanes and tornadoes, and debris impacts on the façade. In addition, they also require that a foundation that will support the Dormitory on sandy soil in both dry and flooding situations.

# Proposed Solution

To meet the SCF's design requirements, the Dormitory's lateral system will need to be redesigned and a new foundation will also need to be designed. For the lateral system, it is foreseen that using a mostly gypsum wall board based system, like in the original Dormitory will be inadequate. In this case, it is best that two systems be considered for the wings:

- Oriented strand board (OSB) shear walls
- Steel braced frame shear walls

In addition, the lateral system in the core will also need to be redesigned and it is proposed to be two steel braced frame walls in the East-West direction and three steel braced frame walls in the North-South direction.

To counteract the moist conditions in a termite prone area, the Dormitory will also be completely redesigned as a steel building. This will amount to a redesign of the floor in steel joists and deck with a gravity system composed of mostly wide flange shapes. Furthermore, the lateral system will be designed using braced frames where applicable and moment frames elsewhere.

In regards to the foundation, it is proposed that spread footings, similar to what is in place, be redesigned for Florida's sandy soil. To accomplish this, this author is currently in the process of obtaining a geotechnical report for the area.

## Breadth Topics

### Breadth 1: Façade Design – Impact Resistance

As part of the SCF requirements, a façade designed to resist impacts and the large pressures seen during a hurricane is required. This will include specifying windows and detailing the installation of the windows. Also, the brick façade will also be properly designed and detailed for impact and pressure resistance.

### Breadth 2: Electrical – Solar Panel Design

As this proposal started with a discussion on global warming, it is imperative that global warming be considered for a breadth topic. To consider global warming, it is this author's desire to design a solar panel system that can partially take the Dormitory off of the grid. To match the SCF's desire to make this a haven for students during a storm, the solar panel system will also double as a backup system should the Dormitory lose power. For this, a proper battery system will need to be implemented to power the essential systems of the Dormitory.

### MAE Material Incorporation

The information gained in AE 534, Steel Connections, will be utilized to design a typical braced frame connection in both the core and the wings. In addition, information learned in AE 537, Building Performance Failures and Forensic Techniques, and AE 542, Building Enclosures, will be used to properly design and detail the façade for impact and pressure resistance. Lastly, skills gained in AE 597A, Computer Modeling, will be utilized to model the steel braced frame shear walls in able to ensure the drift is within the prescribed limits.

## Methods

In accordance with the Florida Building Code 2010, and ASCE 7-10, where mentioned in the code, the wind loads on the Dormitory will first be calculated using Chapter 28 of ASCE 7-10 (MWFRS Envelope Procedure). Following the load determination, the lateral load resisting system will be redesigned for the wings utilizing an oriented strand board system in accordance with NDS-05 and also steel braced frames according to the AISC 14<sup>th</sup> edition. Similarly, the lateral load resisting system in the core will also be redesigned as steel braced frames according to ASIC 14<sup>th</sup> edition.

After the investigation into keeping the Dormitory as close to originally designed as possible, a complete redesign in steel will be completed. To start, the Vulcraft Ecospan Composite Floor System will be researched before specifying the most economical solution for the building. Once complete, a typical bay in the wings at each level will be designed for gravity loads as well as each level in the core according to AISC 14<sup>th</sup> edition. Using structural design software, probably RAM Structural System, these designs will be joined and an analysis ran to determine the adequacy of the system and to further optimize the system.

To continue the steel design, the lateral load system in the wings will be designed next. This includes a braced frame design of the exterior walls in the N-S direction and the walls of the center hallway for N-S lateral loads in accordance with AISC 14<sup>th</sup> edition. In addition, the walls running in the E-W direction, or perpendicular to the hallway, will be designed as a braced frame in accordance with AISC 14<sup>th</sup> edition for E-W lateral loads. Both designs will be combined in structural design software and analyzed for the adequacy of the system. Similarly, the same procedure will be examined for the central core.

Lastly, a new foundation will be designed in accordance with ACI 318-08. This will include a typical concrete strip footing for the wings and a typical concrete spread footing for the core. In both situations, uplift and overturning will be considered in the foundation design as well as soil and load conditions in dry and flooding situations.

## Tasks and Tools

### Structural Depth: Wind Study in Hurricane Prone Region

#### Task 1: Determine lateral loads

- Research Florida Building Code 2010 and ASCE 7-10 to determine:
  - Wind loads, including winds in hurricane-prone regions
  - Seismic loads
  - Impact loads
- Compute the loads for the two wings and the core in the North-South and East-West directions

#### Task 2: Redesign the lateral load resisting system in the wings

- Utilizing oriented strand board
  - Use NDS-05 to determine member sizes and connections.
- Using steel braced frames
  - Use AISC 14<sup>th</sup> edition to determine member sizes and connections.

#### Task 3: Redesign the lateral load resisting system in the core

- Using steel braced frames
  - Use AISC 14<sup>th</sup> edition to determine member sizes and connections.

#### Task 4: Design gravity system utilizing steel

- Design the floor system using Vulcraft Ecospan Composite Floor System for required loads, serviceability, and depth requirements.
- Design the beams, girders, and columns using AISC 14<sup>th</sup> edition for required loads, serviceability, and depth requirements.
- Use structural design software to optimize layout.

#### Task 5: Design lateral load resisting system in the wings using steel

- Where applicable, use information gained in previous tasks to expedite the design.
- Design a typical braced / moment frame in the wings in the N-S direction according to AISC 14<sup>th</sup> edition.
- Design a typical braced / moment frame in the wings in the E-W direction according to AISC 14<sup>th</sup> edition.

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- Using structural design software, combine all the frames together and run an analysis to determine drift and further optimize design.

Task 6: Design lateral load resisting system in the core using steel

- Where applicable, use information gained in previous tasks to expedite the design.
- Design a typical braced /moment frame in the wings in the N-S direction according to AISC 14<sup>th</sup> edition.
- Design a typical braced / moment frame in the wings in the E-W direction according to AISC 14<sup>th</sup> edition.
- Using structural design software, combine all the frames together and run an analysis to determine drift and further optimize design.

Task 7: Foundation design

- Design a typical strip footing for the wings according to ACI 318-08.
- Design a typical spread footing for the core according to ACI 318-08

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## Breadth Topic 1: Façade Design – Impact Resistance

Task 1: Participate in AE 542, Building Enclosures

- Use information from class in determining proper façade design.

Task 2: Research impact resistant design

- Use sources recommended by faculty
- Florida Building Code 2010
- Reputable websites and articles

Task 3: Draw and detail the façade

## Breadth Topic 2: Electrical – Solar Panel Design

Task 1: Research photovoltaic systems and determine sunlight data

- Faculty recommended sources
- Reputable websites
- Library resources

Task 2: Determine any standards applicable to photovoltaic design

- Reputable websites
- Library resources
- Faculty advice

Task 3: Determine use

- Calculate the load requirements of essential equipment
- Research the length of a worst case Florida power outage

Task 4: Design system

- Determine required number and size of panels
- Calculate minimum number of batteries needed for emergency use
- Draw a wiring diagram

Task 5: Structural Check

- Check to make sure the photovoltaic panels way less than the roof live load / snow load allowances.

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## Schedule

The Dormitory Cadell Calkins - Structural Option		Proposed Spring 2012 Schedule Faculty Advisor: Dr. Richard A. Behr Submitted: December 12, 2011			
Task	Start	End	Milestone	Notes	
Determine Lateral Loads	Jan. 8 - Jan. 14	Jan. 15 - Jan. 21	January 27 Milestone 1		
Redesign Lateral System in Wings	Jan. 15 - Jan. 21	Jan. 22 - Jan. 28	January 27 Milestone 1		
Design Gravity System with Steel	Jan. 29 - Feb. 4	Feb. 5 - Feb. 11	February 13 Milestone 2		
Design Lateral System in Wings with Steel	Feb. 12 - Feb. 18	Feb. 19 - Feb. 25	February 13 Milestone 2		
Design Lateral System in Core with Steel	Feb. 19 - Feb. 25	Feb. 26 - Mar. 3	March 2 Milestone 3		
Design Lateral System in Core with Steel	Feb. 26 - Mar. 3	Mar. 4 - Mar. 10	March 2 Milestone 3		
Foundation Design	Mar. 11 - Mar. 17	Mar. 18 - Mar. 24	March 26 Milestone 4		
Depth Write-Up	Mar. 11 - Mar. 17	Mar. 18 - Mar. 24	March 26 Milestone 4		
Draw and Detail Façade	Mar. 25 - Mar. 31	Apr. 1 - Apr. 7	April 8 - April 14		
Façade Breadth Write-Up	Mar. 25 - Mar. 31	Apr. 1 - Apr. 7	April 8 - April 14		
Final Reports Due April 4, 2012	Apr. 1 - Apr. 7	Apr. 8 - April 14	April 15 - April 21		
Final Report Organizing and Editing	Apr. 15 - April 21	Apr. 22 - Apr. 28	April 29 - May 5		
Final Presentation Creating and Preparing	Apr. 15 - April 21	Apr. 22 - Apr. 28	April 29 - May 5		
ABET Evaluation and CPDP Finalization	Apr. 15 - April 21	Apr. 22 - Apr. 28	April 29 - May 5		
Senior Banquet / Final Jury on April 27, 2012	Apr. 22 - Apr. 28	Apr. 29 - May 5	May 6 - May 12		

**Key**

Structural Depth: Wind Study in Hurricane Prone Region
Breadth 1: Façade Design - Impact Resistance
Breadth 2: Electrical - Solar Panel Design

**Milestones**

- Redesign the lateral system in the core as a braced frame and in the wings with both braced frames and oriented strand board shear walls.
- Design gravity system in steel.
- Lateral System designed in steel and electrical (solar panel design) breadth completed.
- Foundation designed and depth complete with the façade designed and the façade (impact resistance) breadth completed.

## Conclusion

The structural depth for this thesis will begin with proper load determination according to the Florida Building Code 2010, and ASCE 7-10, where applicable according to the code. After loads are determined, two main systems will be designed for comparison. First, in the wings, an OSB shear wall system similar to originally designed will be carefully designed. Second, a steel braced frame system will be designed for both the wings and the core. Both situations will implement the original gravity system of wood studs. To continue the investigation, a full redesign in steel will be implemented. This redesign includes the use of a Vulcraft Ecospan Composite Floor System in conjunction with steel beams, girders, and columns as the gravity system. Lastly, a braced frame lateral resistance system will be designed and a new foundation will be designed for Florida's sandy soil.

The first breadth for this thesis will consist of a façade design breadth concentrating on impact resistance due to debris in a hurricane or tornado. A second breadth of electrical concentration will involve a photovoltaic system design for emergency backup power and to partially remove the building from the electrical grid.

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## References

"Global Warming Is Affecting Weather." (No Year). *National Wildlife Federation*. Web. 12 Dec. 2011. <<http://www.nwf.org/Global-Warming/What-is-Global-Warming/Global-Warming-is-Causing-Extreme-Weather.aspx>>.